

Block

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SECONDARY GROWTH AND ADAPTIVE FEATURES

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BBYCT-135: PLANT ANATOMY AND EMBRYOLOGY

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BLOCK 2 : SECONDARY GROWTH AND ADAPTIVE FEATURES

Anatomical studies disclose the complex process of growth and development in plants. This branch of plants provides information regarding various meristematic tissues present in plants. The meristematic tissues play a major role in the development of plant organs. The activity of root and stem meristems results in the formation of the primary body of the plants. The primary growth continues and finally leads to secondary growth which is responsible for an increase in height and girth of plants. In addition, various adaptive features are developed and protective systems are also found in plants.

The block contains three units .In unit 6 the secondary growth of roots and stems have been given in detail. In addition, the activity of vascular cambium that cuts xylem on inner side and phloem on outer side and cork cambium that forms the protective tissue in the plant has also been specified.

As you know that defense mechanism is a very important part of plant. Since the animal kingdom is wholly or partially dependent on plants and plants fixed to the ground, they need to maneuver when attacked.

Unit 7 describes various special organs present in plants to protect themselves from attacks of animals. In this unit we have described the structure of epidermis, various cells present in the outer layer along with their role in plant protection. The structure and function of various protective features such as trichomes, cuticle and epidermis has been included in the unit.

Unit 8 deals with various adaptations shown in plant body .As you know plants are immobile yet they possess certain characteristics that help them to survive in different types of habitats. The features which make plants to adapt different types of environments are known as adaptations. These include changes in structural, morphological and anatomical characteristics. Various types of adaptations in hydrophytes and xerophytes have been described in this unit. In addition, specific adaptive features found in mangroves have also been highlighted.

Objectives

After studying this block, you should be able to :

- explain secondary growth in stems and in roots and describe the structure and give function of vascular cambia, cork cambium, lenticels;
- appreciate the woody anatomy and climate studies (Dendroclimatology);
- list various types of unusual secondary growth in stems and roots;
- describe various protective features found in plants and recognize various specialised cells present in the epidermis;
- illustrate the structure and distinguish the function of cuticle; and know the importance of trichomes in plants; and
- know other prominent adaptive features in plants, describe and differentiate various adaptations in xerophytes, hydrophytes and in mangrove plants.

UNIT 6

SECONDARY GROWTH|

Structure

6.1	Introduction	Economic Value of Secondary Phloem
	Objectives	
6.2	Secondary Growth in Typical Dicotyledonous Stem	6.7 Secondary Growth in Monocot Stem
6.3	Vascular Cambium	6.8 Periderm
	Structure of Vascular Cambium	Structure
	Types of Cambium	Phellem
	Structure of Protoplast and Cell Growth	Phelloderm
	Ray Initiation	Origin and Development of Periderm
6.4	Cambium Activity	Bark
	Formation of Annual Rings	Commercial Cork
6.5	Secondary Xylem	6.9 Distribution of Lenticels
	Basic Structure of Secondary Xylem	Development and Structure of Lenticels
	Wood Parenchyma	6.10 Cambial Variants
	Heart Wood and Sapwood	In Stems
	Porous and Nonporous Wood	In Roots
	Economic importance of Wood and its Characteristics	6.11 Summary
		6.12 Terminal Questions
6.6	Secondary Phloem	6.13 Answers

6.1 INTRODUCTION

You have studied that among seed bearing plants, herbaceous annuals attain a limited height and do not need to increase in girth. Primary growth is often sufficient to meet their structure needs. However, in woody perennials that reach enormous height and produce large canopies, increase in girth is necessary to support the weight of the shoot. Secondary growth, derived from secondary or lateral meristems results in increase in diameter of stems and

roots. In the present unit we will describe the structure of vascular cambium, explain its functioning and role it plays in forming the woody tissues.

The ability of woody plants to undergo secondary growth and produce wood has many consequences. Woody plants when grow in girth which also contain conducting tissues gives plant greater capacity to move water and minerals upward and carbohydrates downward thus number of leaves and roots that the plant can support increases as does the photosynthetic capacity.

Vascular cambium is a bifacial meristem, which adds to the girth of stem and root. Vascular cambium varies greatly in its activities during different seasons, in different plants and on different parts. The active meristematic tissues i.e., fascicular cambium regions lies between primary xylem and phloem. Interfascicular cambium arises from parenchyma cells between vascular cambia. The fascicular and interfascicular cambium joins to form ring which in turn give rise to cambial ring. The cells of the cambium differentiate to form the secondary tissues.

Objectives

After studying this unit you would be able to :

- ❖ explain the phenomenon of secondary growth in plants;
- ❖ describe the structure and give function of each of the following vascular cambia, cork cambium, lenticels;
- ❖ identify the secondary growth of monocotyledonous and dicotyledonous stems;
- ❖ distinguish between types of wood, its annual rings, sapwood, heartwood and bark;
- ❖ appreciate the woody anatomy and climate studies (Dendroclimatology);
- ❖ explain the commercial uses of cork and different wood; and
- ❖ list various types of unusual secondary growth in stems and roots.

6.2 SECONDARY GROWTH IN TYPICAL DICOTYLEDONOUS STEM

You have already read in block 1 that the primary plant body in itself is structurally and functionally complete, for example the majority of monocotyledons and pteridophytes. In gymnosperms and most dicotyledons primary growth is followed by secondary growth. In stem, the secondary growth in thickness in diameter is confined both intrastelar, i.e, within the stele and extrastelar regions. The cells that form secondary tissues are produced by lateral meristems. The lateral meristems grow and join to make a circular ring known as the vascular cambium which lays down cells that become the secondary vascular tissues. In the stem, cells which are situated between the primary xylem and primary phloem in the vascular bundles become

meristematic and form part of the vascular cambium. Additional cells between the vascular bundles also become meristematic. Hence the vascular cambium can be seen in a cross section of the stem as a continuous ring of tissue, with the xylem and pith on the inside and phloem, cortex, and epidermis on the outer side of interfascicular cambium/cambium ring (Fig. 6.1).

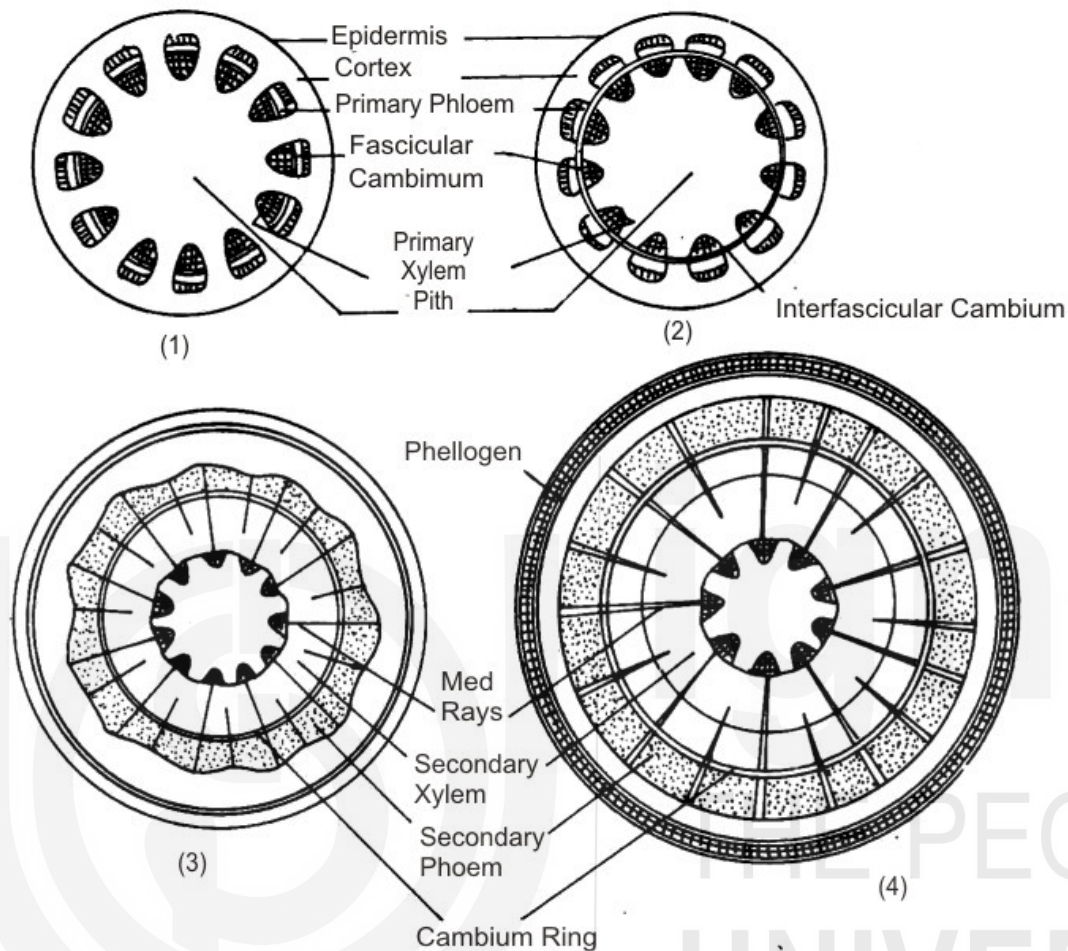


Fig. 6.1: Diagrammatic representation of secondary growth in a dicot stem upto two year (stages (1-4) in T.S.).

The vascular cambium usually, if not always, has a dual origin within the primary tissues; from provascular strands, and from the "ground" meristem tissues between those strands. These two modes of origin are termed **intrafascicular** (within fascicles) and **interfascicular** (between fascicles). The term "provascular tissue" will be used in the text. We should know what this means. Provascular tissue is the precursor of all vascular tissues and "Procambium" is that part of the provascular tissue that is the precursor of the vascular cambium (which may also produce some metaxylem). The transitional stages between procambium and cambium are denoted as **metacambium**.

Both procambium and then metacambium differentiate acropetally within the provascular bundles. Most of the divisions in this layer are periclinal, producing metaxylem and metaphloem. The cells between the metaxylem and metaphloem eventually begin to function as cambial initials. Cambial initials consists of two morphological types of cells-axially short, blocky, ray cells and long, slender fusiform cells. Procambium at first consists of short cells from which longer cells may arise in two ways :

- 1) Different cell lengths result from locally different rates of transverse and/or pseudotransverse cell divisions during growth. Thus the shorter cells become ray initials and the longer become fusiform initials
- 2) All procambial cells first become quite elongated. Then some of them by nonrandom transverse and/or pseudotransverse divisions are secondarily transformed into sets of axially short ray initials. As soon as a circle of vascular cambium is completed, its cells divide to produce new cells.

Those cells formed inside the ring of cambium differentiate into secondary xylem or wood, about which you would study in the later part of this unit. Most of the cells of secondary xylem have very thick walls. As the cambium produces new wood, the stem increases in diameter, the phloem peripheral to the vascular cambium becomes stretched. In the mean time cells produced just outside the vascular cambium become differentiated into secondary phloem, and participate in the transport of organic substances. As more secondary xylem is formed, the first formed secondary phloem is destroyed and replaced by the newly formed secondary phloem (Fig. 6.2).

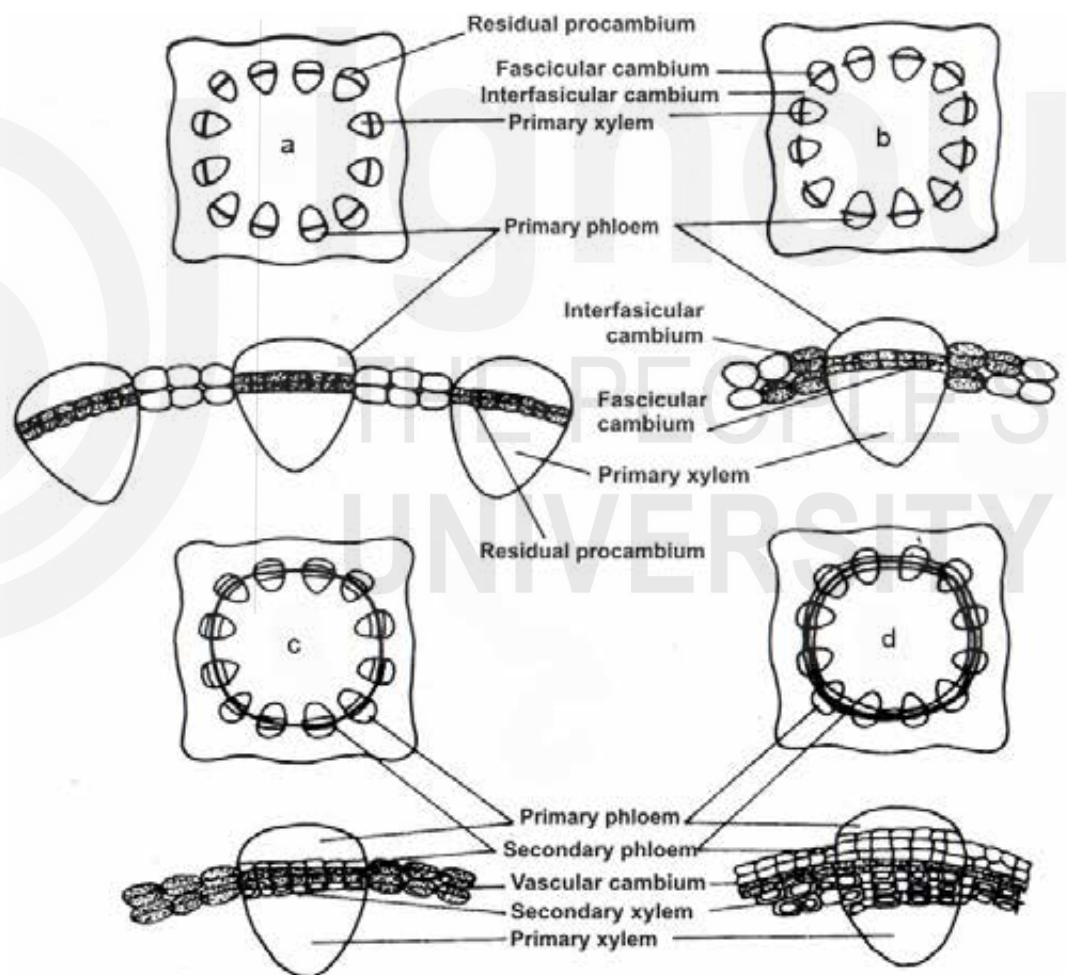


Fig. 6.2: Formation of complete vascular cambium. a) After completion of primary growth some meristematic cells remain between primary xylem and primary phloem; b) The residual procambium becomes reactivated to form fascicular cambium and some parenchyma cells of pith become meristematic to form the interfascicular cambium; c) Formation of complete cylinder of vascular cambium; d) Cylinders of secondary phloem and secondary xylem have been formed by vascular cambium.

With the addition of secondary tissues, the stem grows thicker with secondary xylem and phloem, the peripheral primary tissues, cortex and epidermis

become compressed and destroyed. The epidermis is replaced by a new protective layer of secondary tissue. Simultaneously another lateral meristem called phellogen (formerly termed **cork cambium**), is differentiated. It divides and produces new cell towards the outside. These cells become suberised i.e., impregnated with a waterproof waxy material and die, giving rise to a protective layer of cork. Secondary growth in roots is similar to that in the stem. The main roots of a tree are large and woody and provide anchorage to the plant. The tasks of absorbing water and minerals are performed by younger roots at the far ends of the root system. A detailed account of the structure and description of secondary tissues and secondary growth will be dealt later in the unit.

SAQ 1

- Define secondary growth.
- Name the region in a dicot stem where secondary growth occurs.

6.3 VASCULAR CAMBIUM

In certain plants, including monocotyledons, all the cells of the procambium undergo differentiation into primary vascular tissues. In almost all the dicotyledons and gymnosperms, a portion of the procambium remains meristematic even after the completion of primary growth and develops into the cambium of the secondary body.

The cambium that arises within the bundles of primary vascular tissue of the stem is called **fascicular** cambium, because it originates within the bundles or larger segments of the primary vascular system. Commonly the bands of fascicular cambium become interconnected by additional bands of meristem, the **interfascicular** cambium, which originates from interfascicular parenchyma. A completely formed cambium of the stem has the shape of hollow cylinder, extending through the nodes and internodes. If the axis is branched, the main axis of the cambium is continuous with that of the branches, and it may extend some distance into the leaves.

In gymnosperm initials 600-8700µm long was reported. Fusiform initials sometimes become very long in old trunks of *Sequoia sempervirens* e.g. they reach a maximum length of 8700 µm. (Bailey, 1923).

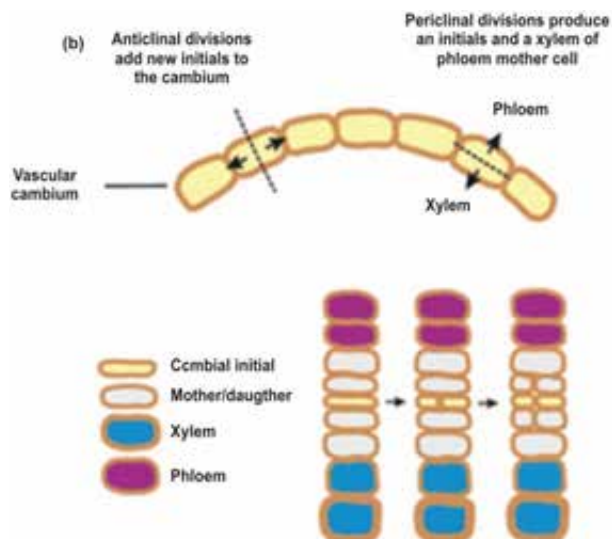


Fig .6.3: Division in Vascular cambium.

The procambium and cambium may be looked upon as two developmental stages of the same meristem; they intergrade with regard to their morphological and physiological characteristics. The typical features of cambium of a woody dicotyledons and gymnosperms is segregation of its initials into fusiform and ray initials, the occurrence of apical growth, and the precise method of division in a tangential plane during the formation of xylem and phloem (Fig. 6.3).

The origin of the **interfascicular** cambium in the more or less vacuolated interfascicular parenchyma results from a resumption of meristematic activity by a potentially meristematic tissue. Usually, no cytological changes are noticeable in connection with the return to meristematic activity. In most of the dicotyledons and gymnosperms the cambial cylinder develops between the axillary xylem and phloem, a position that is retained throughout the life of the plant. It is from this point that the cambium produces the secondary xylem centripetally and secondary phloem centrifugally (Fig.6.4). Now we will study about the structure of vascular cambium.

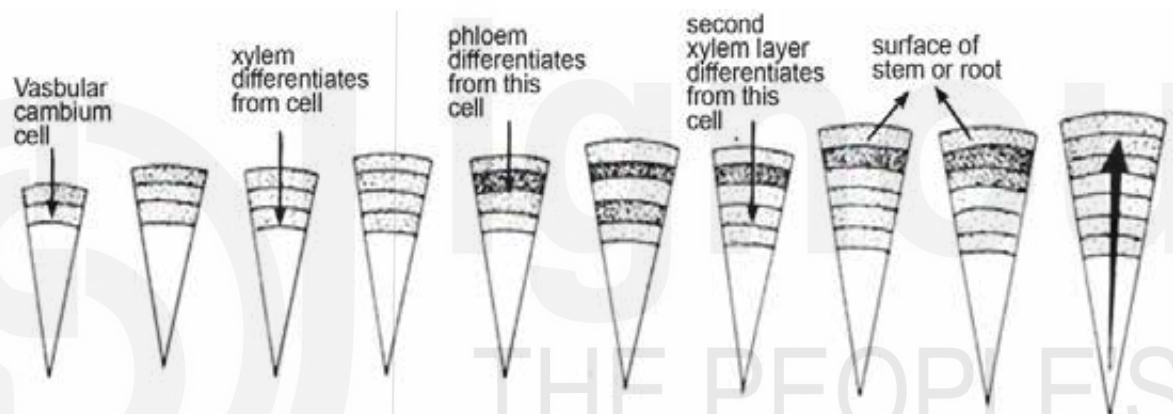


Fig. 6.4: Cambial initials and its derivatives; and Production of new xylem and new phloem each year. Vascular cambium is shifted away from the centre of the plant.

6.3.1 Structure of the Vascular Cambium

Active cambial cells are richly cytoplasmic and not wholly undifferentiated and different in shape from embryonic ground meristematic and apical meristem. These cells have pitted thin walls while radial walls are thicker than the tangential walls. The cambial cells possess numerous cytoplasmic connections. The cytoplasm of the cells is rich in ribosomes, dictyosomes and endoplasmic reticulum.

The differentiation of the cambial derivatives into xylem and phloem removes cells from the cambial zone but zone itself does not get removed (Fig. 6.5). If the rate of radial growth and periclinal division are balanced by the rate of cell loss through differentiation, the cambial zone thickness remains constant.

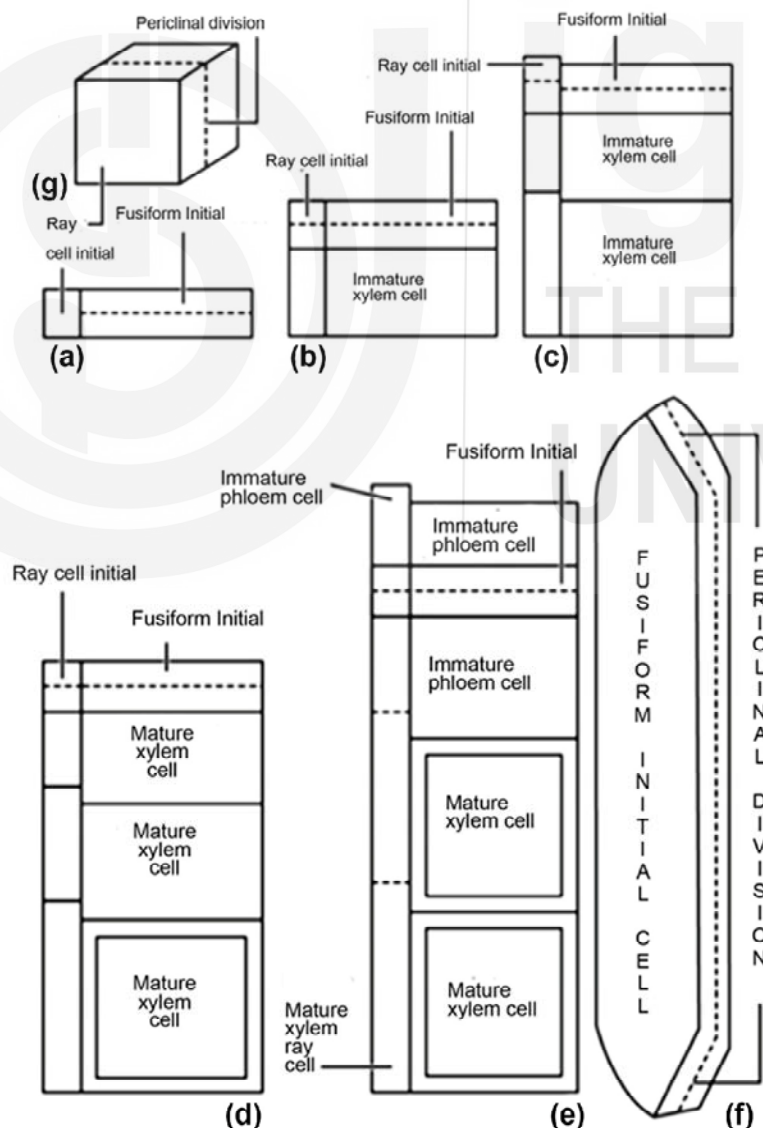
The new cell becomes larger than the cell from which it is derived. The formation of the cell plate is peculiar during the longitudinal division in these cells.

This meristem, in the anatomical sense of the term usually includes two histologically distinct kinds of cells: i) Fusiform Initials, ii) Ray Initials.

i) Fusiform Initials

These are typically axially elongated cells with tapered ends. The mean length of fusiform cells varies, among taxa and within an individual plant. It tends to increase with the age of the plant. These cells are shaped somewhat like flat shoe laces (Fig. 6.5). It would be easy to assume that they have about 8 faces but a study of *Pinus sylvestris* has shown that 8 sides are minimum; they can often have up to 32 faces with an average of 18; they have 14 contact faces with other such cells. The fusiform initials undergo periclinal division. The dividing fusiform cells show no phragmoplast function which appears at the end of the mitosis. It directs the cell plate expansion laterally. Fusiform cell length is greater in angiosperms. These cells are shorter when present in storied cambia. Fusiform initials differentiate to form secondary xylem and secondary phloem.

The periclinal divisions of the fusiform initials result in radially oriented file of cells. The cells differentiate to form secondary xylem towards the centre of the axis and form secondary phloem towards the periphery. Few derivatives of the fusiform initials remain undifferentiated and retain the feature of meristematic cells. These cells form the cambial zone.



The proportion of ray initials in the cambium is variable. In conifers they are arranged as vertical, uniseriate groups that produce vertical, uniseriate rays.

Fig.6.5: Schematic drawing: cambial initial cells (a-e) produces secondary xylem and secondary phloem. f) Fusiform initials can be seen in three dimensional views.

ii) Ray Initials

They are smaller than fusiform initials and are nearly isodiametric (equal dimensions, small sides) or only about two or three times as tall as wide. Let us study how the ray initials are formed in cambium (Fig. 6.5):

- i) A single cell may be cut off along the side of a fusiform initial (lateral division),
- ii) A single cell may be cut off the end of fusiform initials,
- iii) A declining fusiform initials may be reduced to a single ray initials, and
- iv) The last part or whole fusiform initial

Sometimes the fusiform initials can be converted to ray initials in gymnosperms and dicots. In contrast in dicots ray initials can elongate and convert themselves into fusiform initials this conversion prevents rays from becoming too massive and creating large islands of weak parenchyma in wood. The ray initials can also be broken by intrusive growth of a fusiform initial from the periphery of the group into the mass of ray initials.

The ratio of fusiform initials to ray initials is high in dicots. In most of the species 90% of the cambium is reported to consist of fusiform initials. The ability of a fusiform initial to form ray initial is important because multiplicative divisions produce a common wall that is not in contact with the ray. A second division produces an entire cell with no ray contacts. New ray cells need to be produced to maintain proper horizontal conduction through wood, bark and cambial zone. Rays in woody dicots are mainly multiseriate while gymnosperms show the presence of uniseriate rays.

Ray initials are smaller than the fusiform initials they are shorter and isodiametric. The ray cells appear quadrilateral and smaller in length in the tangential section of the stem. They usually appear lens shaped group of ray initials. Dicots generally have both uniseriate and multiseriate group of ray initials.

It is interesting to note that the vascular cambium remains dormant during stress. As it enters dormancy, it stops cell division. Some of the xylem and phloem mother cells become quiescent and get partially differentiated. After the stress gets over they start differentiating and quickly form the new tissues. The cambial initials resume cell division in spring and the mitosis starts in the cambial cells. This is triggered by the basipetal movement of the auxin. In tropics the cambial activity of the trees continues throughout the year.

SAQ 2

Fill in the blanks with appropriate word(s).

- a) Vascular cambium is composed of and
 - b) Vascular cambium remains dormant during
 - c) Ray cell contains duct.
 - d) Ray initials are..... than the fusiform initials.
 - e) behaves as a permanent meristem.
-

6.3.2 Types of Cambium

On the basis of the arrangement of the fusiform cells as seen in tangential section, cambium is divided into:

i) Storied or Stratified Cambium

The groups of ray initials may become taller either by the loss of fusiform initials located between two groups of ray initials, allowing them to fuse; or a fusiform initials can by transverse division, convert itself into a row of ray initials. All the structural elements which extend radially are produced by the ray initials (Fig. 6.6 a). In this type the fusiform cells are arranged in tiers, or stories, That is, the ends of large tangential groups of cells are aligned at the same levels of axis. If you view them tangentially the ends of cells in axially adjacent stories generally overlap only slightly making a zigzag pattern.

ii) Non-storied or Nonstratified Cambium

In this type of cambium the ends of cambial fusiform cells typically overlap much more extensively and in a seemingly random manner. In nonstoried cambia there is no lateral alignment. In vesselless dicotyledons the fusiform initials may reach a maximum length of 6200 μm . Thus nonstoried initials are longer. They are also of more common occurrence (Fig. 6.6 b).

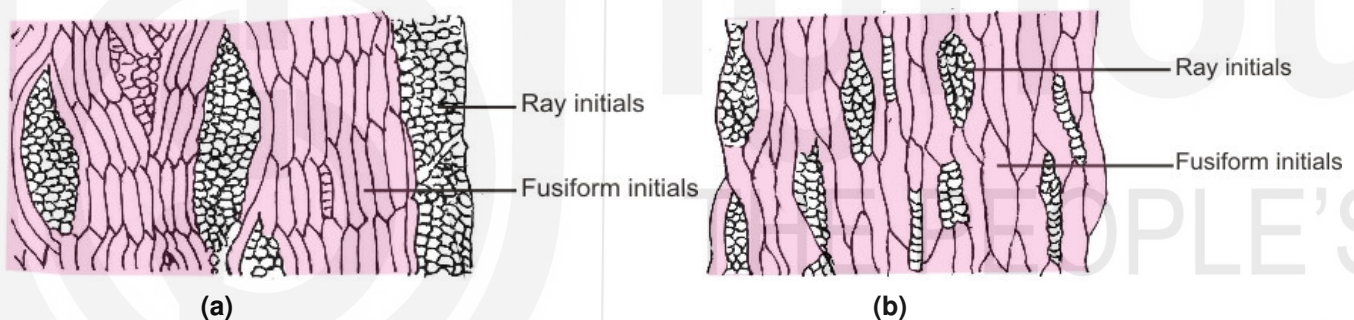


Fig. 6.6: L.S. views of fusiform initials and ray initials a) Storied cambium; b) Non-storied cambium.

6.3.3 Structure of Protoplast and Cell Growth

Active cambial cells are richly cytoplasmic and are not wholly undifferentiated. They are obviously different in shape from embryonic ground meristem and apical meristem cells. They also differ cytologically from the other meristematic cells. They are more highly vacuolated, have large mitochondria and often have more highly differentiated plastids. In a cambial fusiform cell, the nucleus is quite elongated whereas in a ray cell it is usually more nearly spherically. Active fusiform cells commonly have one or two large vacuoles transverse by many slender cytoplasmic strands, and small vacuoles in the peripheral cytoplasm.

The cambium initials form phloem and xylem by tangential division. These vascular tissues are laid down in two opposite directions, the xylem cells towards the interior of axis and the phloem cells towards its periphery (also see Fig. 6.3). The consistent tangential orientation of the planes of division during the formation of vascular tissues determines the arrangement of cambial derivatives in radial rows. Such radial seriation may persist in the developing xylem and phloem or it may be disturbed through various kinds of growth readjustments during the differentiation of these tissues.

The thickness of xylem cylinder increases by secondary growth, and the cambial cylinder also enlarges in circumference. Although active cambial cells undergo repeated periclinal divisions and radial growth, the width of cambial zone does not increase indefinitely. Conversely, although differentiation of cambium derivatives into xylem and phloem continually removes cells from the cambial zone, the zone itself does not disappear. If the rates of radial growth and periclinal division are just balanced by the rate of cell loss through differentiation, the cambial zone thickness remains constant. However, the balance is often imprecise, and cambial zone thickness tends to vary during the active season. The rate of production of cambial derivatives depends on the number of cells in the cambial zone and on the duration of the cell cycle.

Addition of new fusiform initials is brought about by longitudinal anticlinal divisions of the existing initials in the storied cambium while in nonstoried cambium, the fusiform initials undergo oblique, pseudotransverse anticlinal divisions, followed by intrusive growth, and each of the new cells becomes as long as or even longer than the cell from which it was derived (Fig.6.7).

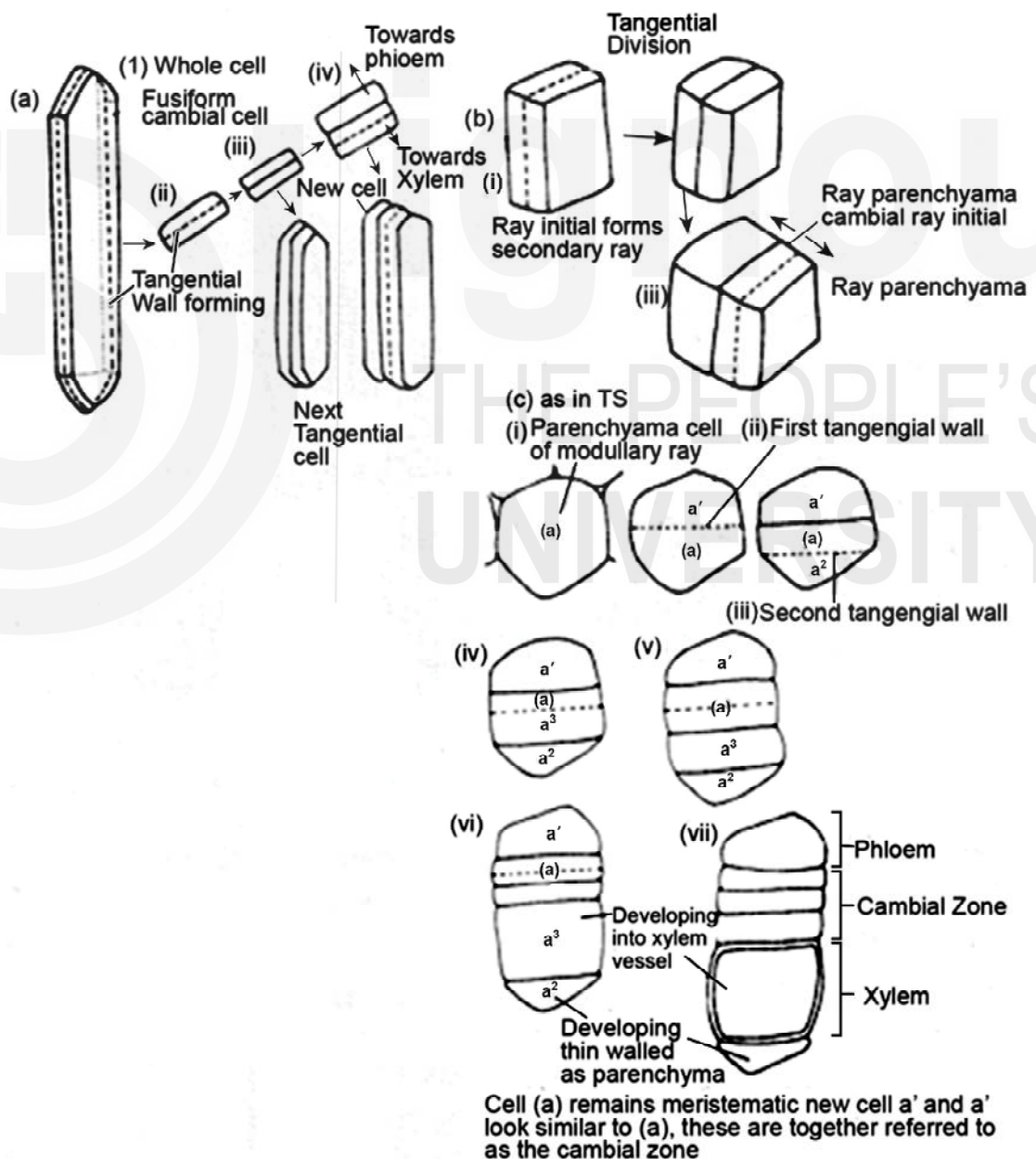


Fig. 6.7: Cambial development. a) Fusiform cambial initial; b) Ray initial; c) Ray initial as in T.S.

Because of the excessive length of the fusiform initials, the formation of the cell plate during the process of longitudinal division is peculiar to these cells. The cell plate begins to form between the two nuclei and it spreads slowly. The plate takes a long time to reach the end walls.

6.3.4 Ray Initiation

With the enlargement of the cambial cylinder new ray initials develop and single fusiform initials are continuously lost from the cambium and are replaced by new ones (Fig 6.8). You have studied how ray initials are formed in section 6.3.1 of this unit.

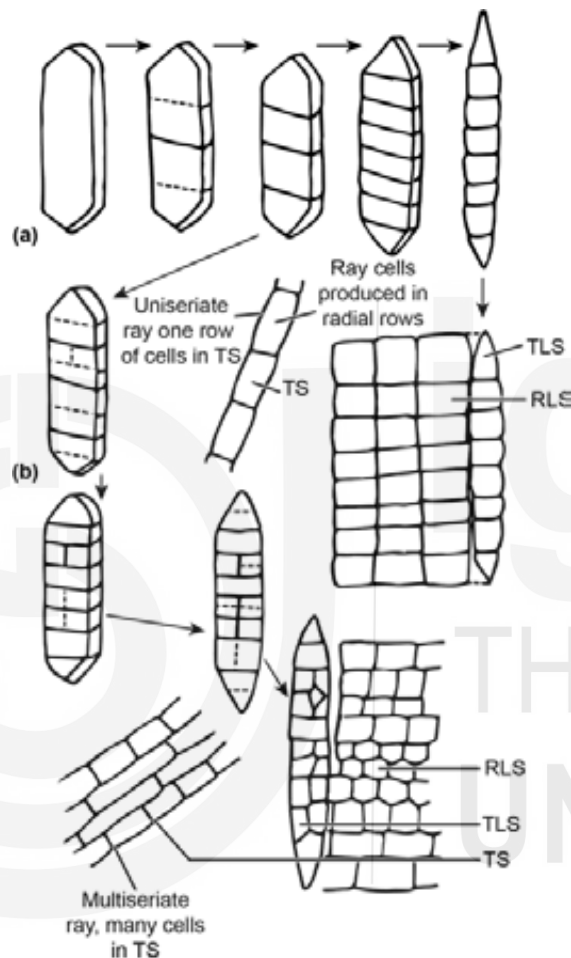


Fig. 6.8: Origin of a secondary ray. a) Division of fusiform cambial initial to uniseriate; b) Multiseriate ray.

SAQ 3

- Name the two cambia which join and form a cylinder of cambium.
- Describe the types of cells found in the vascular cambium.
- Differentiate between storied and non storied cambium.

6.4 CAMBIAL ACTIVITY

The radial growth is directly correlated with the rate of cambial activity. The variation in the number of cell across the cambial zone seems to express the balance between the rate of cell division and the rate of differentiation of the

derivatives. However, at the time of cambial activity cell divisions are faster than cell differentiation. This results in a wide cambial zone. But as soon as demarcation begins, a balance is established and the width of the zone remains more or less constant. When the rate of division becomes less and the rate of differentiation is faster the cambial zone becomes narrower. The vascular cambium shows variation in the period and intensity of activity. These variations result from internal and external factors.

6.4.1 Formation of Annual Rings

The secondary xylem in perennial axis commonly consists of concentric layers, each one of which represents a seasonal growth. If you see a cross section of the axis, these layers appear as rings, and the terms annual ring and growth ring or growth layer are applied to each layer.

An annual ring or growth ring of xylem is a layer of secondary xylem formed in one growing season over the entire plant and is, therefore, an extensive tubular structure having the general form of the axis of the plant. It is open at ends where meristems occur. There are some plants in which cambium are active during the entire life. These plants commonly occur in the tropical regions where seasons are not markedly different. However, not all tropical trees exhibit a continuous cambial activity. In warm temperate climates, the percentage of ringless trees is still lower.

In geographical regions where there are clear cut seasons, cambium shows decreased activity with the onset of autumn, and it enters a dormant state during winter. This may last till the beginning of the following spring. In spring the cambial activity is resumed and becomes highest during summer. Thus periodical activity of cambium results in the formation of ring wood. The wood thus formed in spring is called **spring wood** or **earlywood** and that formed in autumn is called **autumn wood** or **latewood**.

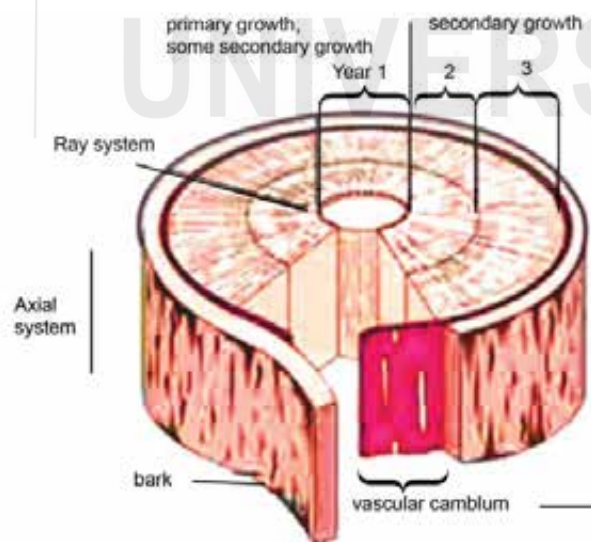


Fig. 6.9: T.S. of dicotyledonous stem showing annual rings.

It is noted that each annual ring corresponds to one year's growth hence the age of plant can be determined roughly by counting the total number of annual rings in a log (trunk) as seen in a transverse section (Fig. 6.9). Tree ring analysis is also known as **Dendrochronology**. By analysing the tree rings, a great deal can be learned about past climatic conditions. This study is known as **Dendroclimatology** (See box 6.1).

BOX 6.1: TREE RING ANALYSIS - A WAY TO TELL THE LIFE HISTORY OF A TREE.

Every year a new growth ring is added to trunk of the tree. In spring growth is fast and wood is light in colour and in summer the wood is darker. By counting the dark rings you can tell the age of tree. In addition other useful information can be obtained by analysing tree rings as well. For example, the size of each ring varies depending on environmental conditions, including precipitation and temperature.

Sometimes the variation in tree rings can be due to a single environmental factor. Then similar patterns appear in the rings of many tree species in a large geographical area. For example, if a certain year is drought year then in that particular year much smaller wood layer's will be produced. Sometimes locusts may have eaten the leaves just after they have appeared. This will result in a marked decrease in photosynthesis, causing low wood production. This will also result in two annual rings being very close each other because very little growth will take place.

To study the sequence of rings, in trees that have lived for several thousand years, first a master chronology of complete records of sample of rings dating back as far as possible is developed. Then by matching the rings one can know the exact age of the living tree or trees (Fig.6.10).

A great deal can also be studied from tree rings about the past climatic conditions. For several years A.E. Douglass, Harlod C. Fritts and others associated with the Laboratory of Tree Ring Research of the University of Arizona Phoenix, USA studied ring widths in trees from various sites. They found that a very significant statistical relationship exists between the growth of trees and climatic condition. With the help of computers and statistical analysis they developed techniques that take into account of climate and other environmental variables. They were able to reconstruct relatively precise histories of climatic changes and fluctuations dating back thousands of years. Presently by ring analysis data are gathered to determine climates of prehistoric times.

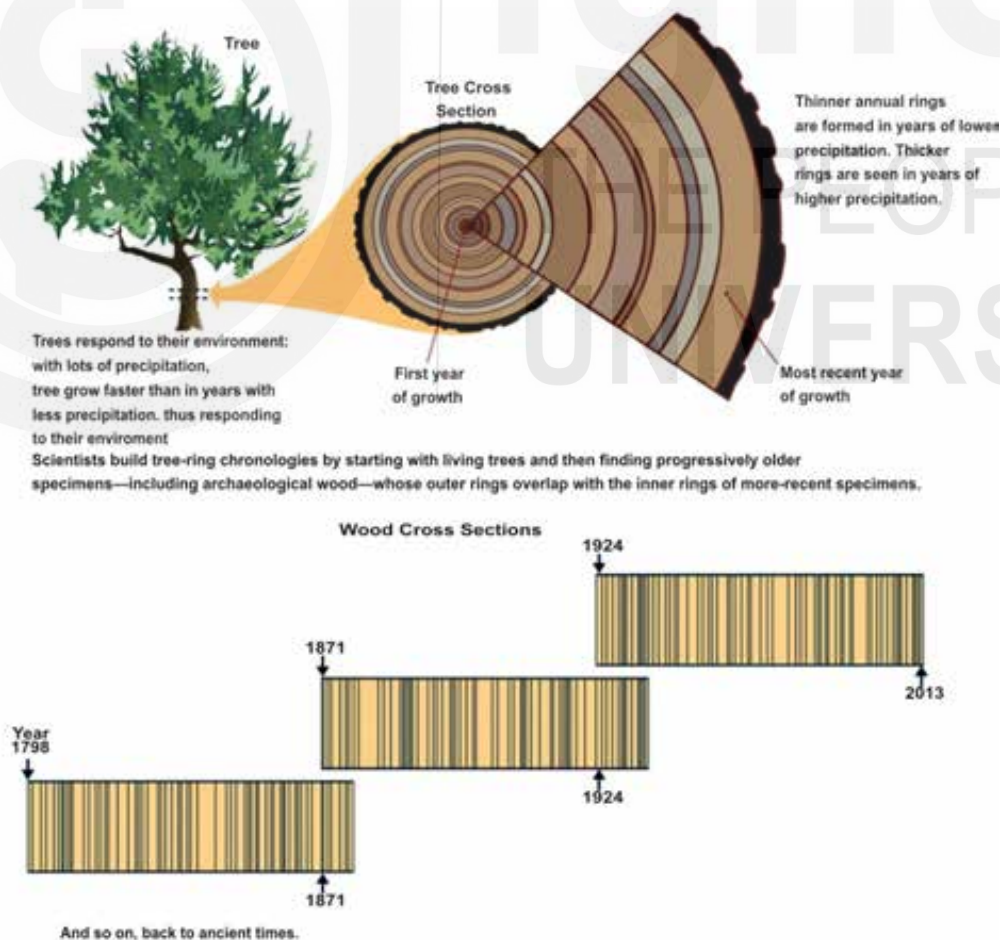


Fig. 6.10: Tree ring dating: A master chronology is developed using progressively older pieces of wood from the same geographical area. The age of the sample can be accurately determined by matching the rings of a wood sample of unknown age to the master chronology.

To determine the age of living old tree you do not have to cut it down, to examine the rings. A simple instrument known as increment borer is used. The increment borer is primarily made up of a rigid metal cylinder. It is driven in the stem of a tree and a core of wood is removed. The hole is then treated with a disinfectant and covered up without harm to the tree. The rings are examined counted from the core and then analysed (Fig.6.10).

SAQ 4

Which of the following statements are true or false. Write T for true and F for false.

- a) All tropical trees exhibit a continuous cambial activity. []
- b) Regions with warm climate have a low per cent of ringless trees. []
- c) It is possible to calculate the approximate age of a tree by counting the total number of rings in one log of wood. []

6.5 SECONDARY XYLEM

The products of the cambium formed towards the centre of the stem and root constitute secondary xylem. Secondary xylem is composed of tracheids, vessel members, and different types of fibers, parenchyma cells, xylem ray cells and sometimes secretory cells (Fig.6.11).

The occurrence and the arrangement of these elements vary in different group of plants. The quantitative differences in the number of cells and the size of the elements that exist between the species of a single genus make it possible to identify individual species on the basis of secondary xylem alone.

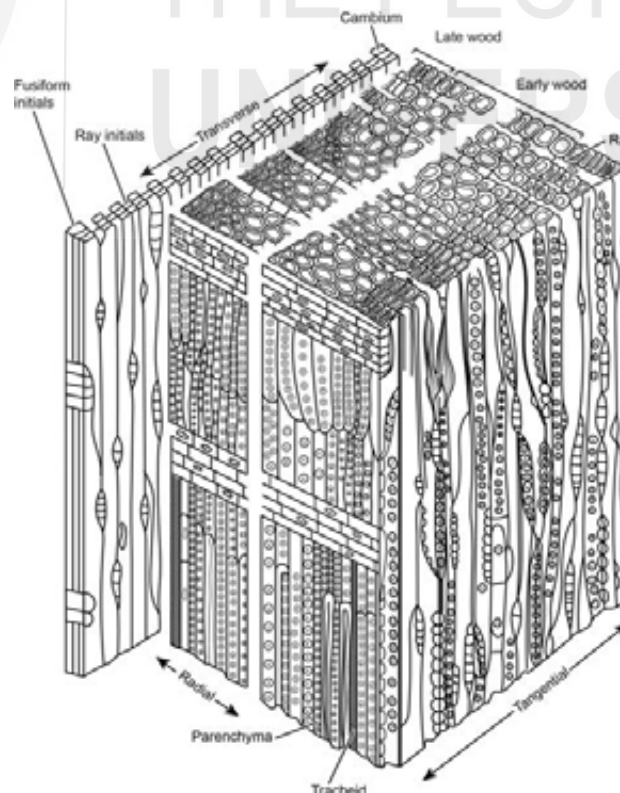


Fig. 6.11: Structure of secondary xylem in three dimensional diagram of a cube of *Pinus*.

6.5.1 Basic Structure of Secondary Xylem

Secondary xylem is characterised by the existence of two systems of elements which differ in the orientation of their longitudinal axis. One system is horizontal and other is vertical. The horizontal system is made up of xylem rays (see Fig. 6.11) and the vertical or axial system consists of tracheary elements, fibres and wood parenchyma. The living cells of the rays and of the vertical system are usually interconnected and a continuous system of living cells is formed, which in turn is connected with the living cells of the pith, phloem and cortex.

6.5.2 Wood Parenchyma

Two types of parenchyma are found in secondary xylem: The axial parenchyma and the ray parenchyma. The relatively short, special cambial initials give rise to ray parenchyma, whereas fusiform initials from axial parenchyma. The axial parenchyma cells may be as long as the fusiform initials or much shorter. It is more common to find shorter parenchyma cells (Fig. 6.12).

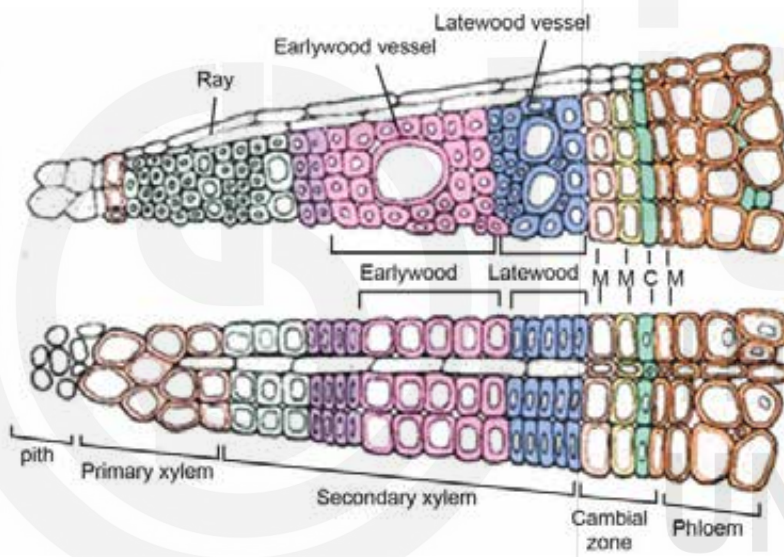


Fig. 6.12: Early and late wood vessels.

The ray parenchyma may be of different kinds, the most common forms are:

- i) in those which longest axis of the cell is radial,
- ii) in which it is vertical.

The number of xylem rays increases with the expansion of stem girth. The length, width and height of each ray can be measured by cross sections and tangential sections respectively, when the ray is one cell wide it is called **uniseriate ray**; when two cells wide it is **biseriate** and when more than two cells wide, it is **multiseriate**.

All the cells of ray parenchyma may have primary wall or only secondary walls are found. The secondary walls may develop pitpairs that are to be simple, half bordered, and sometimes even bordered. These secondary cell walls are commonly characterised by the presence of depressions or cavities varying in size, depth and structure. Such cavities are termed as pits. The parenchyma cells of the xylem serve to store reserve food materials such as starch and

The color distinction between sapwood and heartwood may be sharp as noted in *Pinus roxburghii*, *Dalbergia sisso*, *Albizia lebbek* or gradual (*Shorea robusta*, *Adina cordifolia*). No color distinction has been noted in species such as *Abies pindrow*, *Picea smithiana*.

fats. Tannin, crystals, silica bodies and other substances are also deposited in these cells (Fig. 6.13 a). The ray parenchyma is the main route of radial symplasmic transport between xylem and phloem.

In several plants wood parenchyma cells form protuberances which penetrate into the vessels through the pits after they become inactive, or later injured. These outgrowths are termed **tylosis** (- singular: tylose) (Fig. 6.13 b). The nucleus and part of cytoplasm of the parenchyma cells may enter the tylosis. Tylosis may also divide. Although the formation of tylosis is considered a natural phenomenon, in many species it has been reported to result from mechanical injury or diseases.

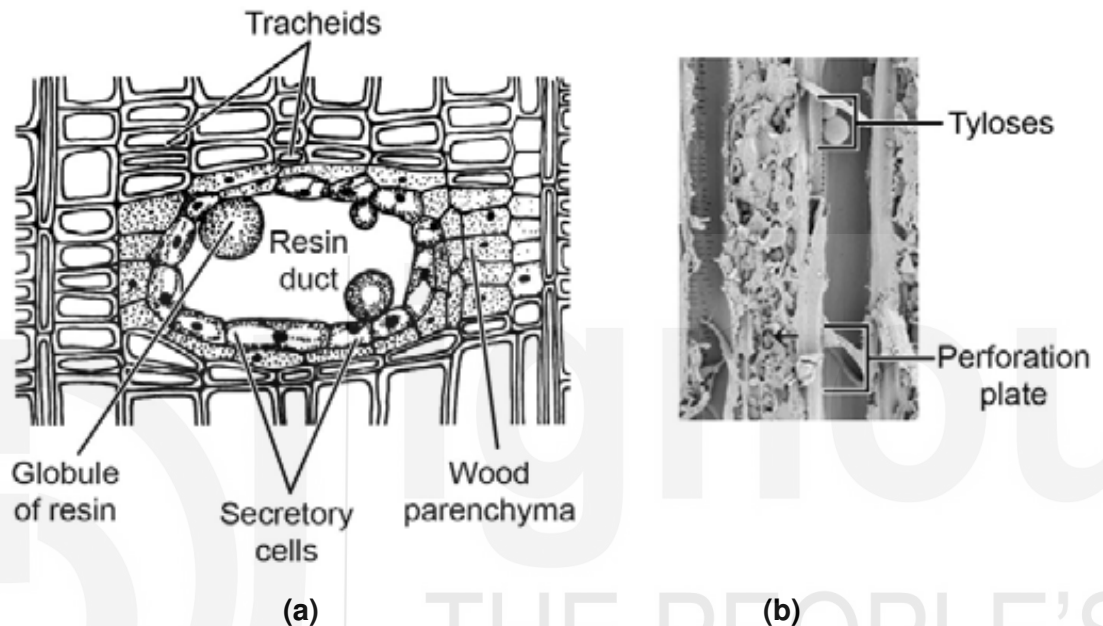


Fig. 6.13 (a-b): Tylosis in wood.

6.5.3 Heartwood and Sapwood

In some plants heartwood contains important pigments such as hematoxylin (*Hematotoxylon campechianum*), brazilin (*Cesalpinia sappan*) and santalin (*Pterocarpus santalinus*).

The outer part of the secondary xylem contains living cells and at least one or two outermost rings participate in the conduction of water. The outer part of secondary xylem with living parenchyma is named as **Sapwood** or **alburnum** (Fig. 6.14).

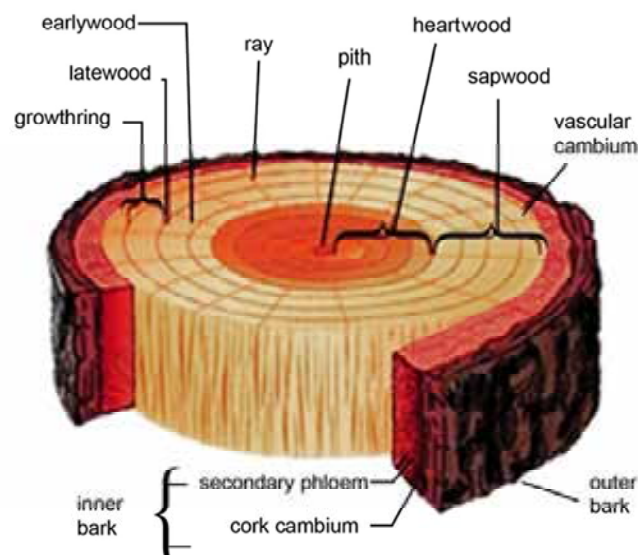


Fig. 6.14: Heartwood and sapwood in Cross Section of a tree.

In nearly all the trees the central portion of the xylem consists of dead parenchyma which ceases to conduct water. This is called **heartwood** or **duramen**. The events that occur in the formation of heart wood include disintegration of protoplast, loss of cell sap and hydrolysis of reserve material stored and formation of tylosis. In such species in which the tylosis are formed the inner portion of the cell is totally blocked by the tylosis. Oil, gums, resins, tanins, aromatic compounds and coloured substances which develop in the cells are accumulated in the heartwood. The amount of heartwood and sapwood varies in different species. These differences are also influenced by genetic and environmental conditions.

Heartwood may sometimes develop as the result of pathological conditions

In the timber trade wood of dicotyledons is known as hardwood and that of gymnosperm as softwood. These terms do not accurately express the degree of hardness, as in both groups wood with both hard and soft structure can be noted. However, there is an important difference in the wood of dicotyledons and gymnosperms. The former have vessels and the latter lack them. If we see the histological structure of the wood of dicotyledons and that of gymnosperms there are fundamental differences.

6.5.4 Porous and non-porous wood

The wood is categorised on the basis of presence or absence of vessels. The woody dicots that possess vessels in xylem are known as **porous wood** or **hard wood** while the wood of gymnosperms that lack vessels is called **non-porous** or **soft wood**.

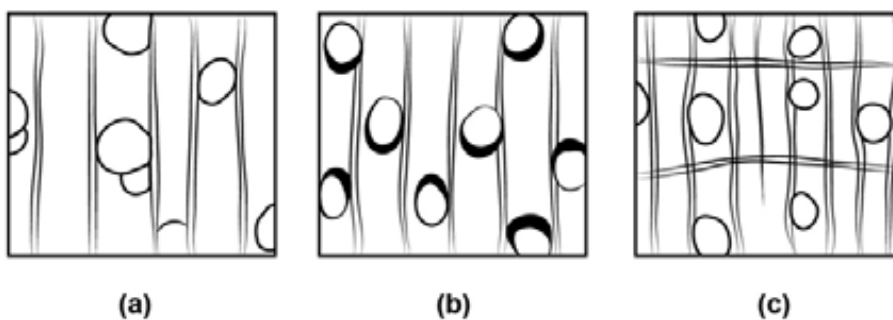
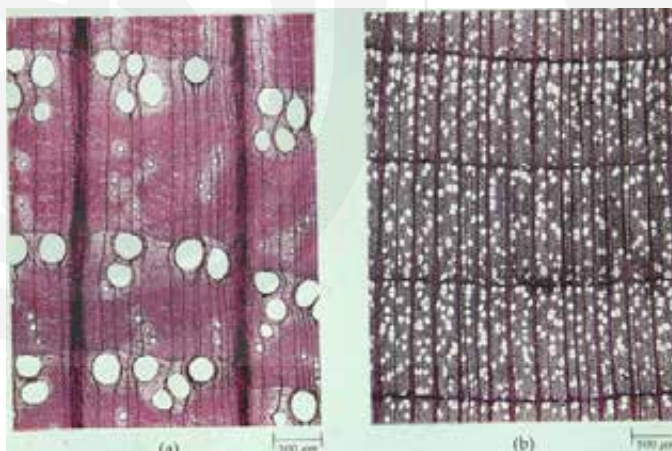


Fig 6.15 (a to c): Ring porous and diffuse porous wood.

For example wood of *Pinus* is non-porous wood while *Cedrus* is referred as soft wood. The hard wood looks more complex than the soft wood. In a transverse section, the vessels appear in the form of circular or oval pores in the hard wood. The arrangement of the pores varies for species and has been

considered a diagnostic feature of timber. On the basis of distribution of pores within the growth ring, the wood can be classified as **ring-porous** and **diffuse porous wood** (Fig. 6.15). In ring porous wood, the pores of the early wood are larger than those of late wood and arranged in the form of conspicuous ring. In diffuse porous wood, the pores of the early and late wood do not show any size difference in the pores and pores are uniformly distributed throughout the growth ring.

6.5.5 Economic Importance of Wood and its Characteristics

Wood has much importance in day to day life in form of furniture, paper gum, resin and several other industrial purposes. We will discuss some of the properties of wood by which wood quality is judged.

- i) **Weight** : The wood may be either light or heavy. Differences in weight are due to variations in the proportions of wall substance and of lumen space, when the lumen is small the wood is dense and heavy. The abundance of slender, thick walled fibres make wood heavy. Extremely light woods such as *Ochroma* sp. is also found. The majority of well known commercially important wood range from 0.35 to 0.65 in specific gravity. Balsa wood (*Ochroma lagopus*) and sola (*Acshynomene* sp.) have abundant of parenchyma and very few fibres.

Light woods have limited economic importance. Balsa (*Ochroma* sp.) with a specific gravity of 0.12 to 0.35, is used extensively in insulation, as material for modelling (by architects) and for life rafts. The heavy woods are used in construction of wagons, carts, railway sleepers and furniture etc.

If a large proportion of the wood is made up of fibers or fiber tracheids, it tends to be strong. Thus the dense and heavy woods are of greater strength. Strong woods are used for building, structural works and furniture etc.

- ii) **Durability** : The ability of wood to withstand decay by the action of fungi and bacteria is largely dependent upon the chemical nature of the wood and is referred as its durability. The presence of tylosis and other natural constituents of wood such as tannin, resin and oils largely determine the durability of wood. Both light and heavy woods can be durable. The durable woods are used for ship building, boats, masts, ships, carts, bodies of railway compartments, railway wagons, in construction, bridges, and railway sleepers.

Some other important uses of Wood

Teak, sisham and rose wood are used as decorative timbers for panelling furniture, cabinet, boxes, for carving idols, inlay works and various aspects of art etc.

- i) **Pines** : They are chiefly used for doors, windows, pattern making in cabinets, boxes and matches. In India *P. roxburghii* is used for building houses, packing cases, matches, music instruments, railway sleepers etc.

- ii) **Sandal Wood** : Sandal wood is smooth and tends itself to exquisite used for carving as well as for extraction of the oil. The sandalwood oil is fragrant and finds its use in perfumes, cosmetics, soaps, and incense sticks etc.

SAQ 5

- List the two types of systems and various cells found in secondary xylem.
- How do uniseriate, biseriate and multiseriate rays differ from one another?
- Distinguish between hardwood and softwood.
- What structural features give strength to wood?
- List as many independent uses of wood as you can think.

6.6 SECONDARY PHLOEM

In the secondary phloem there are also two systems- the vertical and horizontal products from those cambial initials as in the case of xylem. Though these two tissues secondary xylem and secondary phloem differ in ontogeny and structure at maturity. The important components of the vertical system are sieve elements, phloem parenchyma and phloem fibers (Fig.6.16).

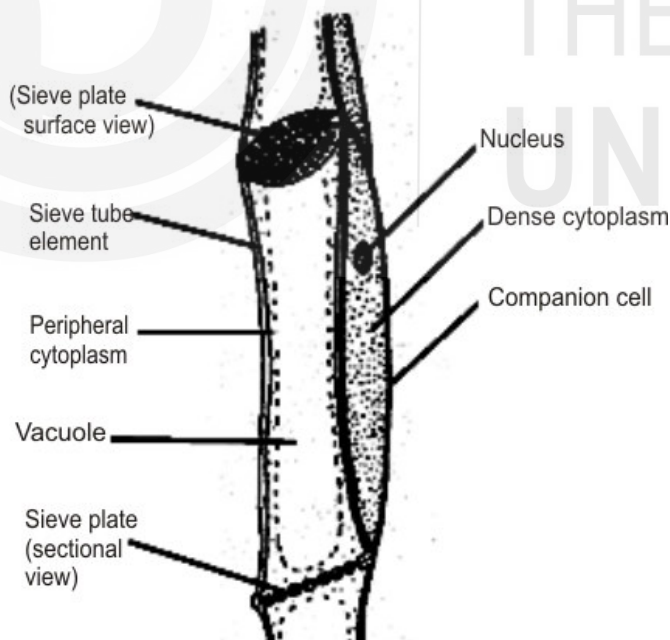


Fig 6.16: Basic structure of phloem.

The horizontal system consists axial and ray phloem which is made up of parenchymal cells. As in the xylem, the arrangement of the tissue in phloem is primarily determined by the nature of cambium i.e. whether it is storied or not. Secondly it depends upon the extent of elongation of various elements of vertical system during the differentiation of the cells.

In several species of dicotyledonous trees, growth rings can be observed in the secondary phloem but they are less distinct than in secondary xylem. This is because cells which are produced at the beginning of the season are extended radially while in the end of the season they are flattened. After some growth the arrangement of growth ring becomes obscured due to the obliteration of the sieve elements. The primary reason is also because of absence of lignin that is why they cannot be used as an indication of the age of secondary phloem.

As you have already studied, that the ray initials in the cambium produce cells towards both xylem and phloem. Thus xylem and phloem rays are continuous. In the vicinity of the cambium the xylem and phloem rays are equal in size but in many plants the mature outer portions of phloem rays are wider. The widening of the phloem ray may be accomplished solely by the lateral expansion of the existing cells or as is more common by an increase in the number of cells on the periphery by radial divisions.

In the dicotyledons the functional secondary phloem is restricted generally to the produced in the last growing season. In some cases when the cambium starts producing new phloem, almost all the previously produced sieve tubes cease to function. However, in *Tilia* sp. the sieve tubes are active for several years including winter.

6.6.1 Economic Value of Secondary Phloem

The secondary phloem may be quite rich in secretory tissues because of its role of protecting the plant. The phloem may contain well developed duct systems in some species. It is the system of lactifers in the bark of *Hevea* that is tapped to obtain rubber and the resin canals of the bark of conifers that are harvested for pine resin which is further distilled to make turpentine and resins.

Bast Fibers: These are sclerenchyma fibers associated with the phloem of certain stems of plants. They are rather easy to separate from underlying woody tissues. They arise with primary tissues from the apical meristem or with secondary tissues produced by the lateral meristem, the cambium. Important sources of bast fibres are flax, jute, sunnhemp etc.

SAQ 6

Write T in front of true statement and F for false statement in the bracket provided.

- a) In phloem there are two systems the vertical and horizontal. []
- b) We can judge the precise age of tree by counting the number of rings of phloem. []
- c) In several dicotyledonous species we can see more distinct ring in secondary phloem than in secondary xylem. []

6.7 SECONDARY GROWTH IN MONOCOT STEM

Normally in a monocot stem, no secondary growth takes place, as the vascular bundles are closed i.e. cambium is absent. But in some herbaceous

and treelike woody monocotyledons plants belonging to families Liliaceae, Agavaceae etc., the increase in thickness is through secondary cambium (Fig 6.17) (which is entirely a secondary meristem).

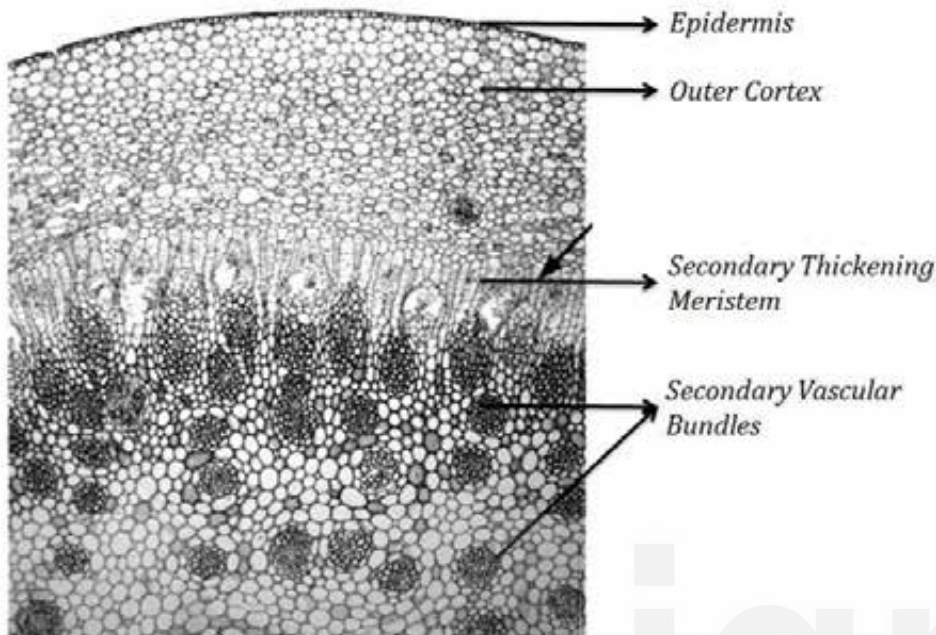


Fig. 6.17: Portion of *Dracaena* stem showing secondary growth.

At the time of secondary growth some of the innermost parenchymatous cell becomes meristematic; the cells divide tangentially forming a band of secondary cambium, a few layers in thickness. The secondary cambium is made up of rectangular fusiform cells. They do not produce secondary phloem or xylem outside and inside respectively as in dicotyledonous stems and roots. Instead, the secondary cambium cuts off secondary tissues on the inner side first and then a small amount of new tissues on the outside. These newly formed inner secondary tissues directly differentiate into oval shaped collateral vascular bundles and radially arranged parenchyma cells called conjunctive tissue. Thus the vascular bundles remains embedded in the conjunctive tissue.

In a monocot stem a periderm is absent but some storied cork cells, forming a protective tissue with suberisation (*Dracaena*) are present.

6.8 PERIDERM

Before dealing with **periderm** formation we must know what periderm is? The term periderm is collectively given to the protective tissues **phellem** and **phelloderm** and the meristem that lies between them and gives rise to them. This meristem, the **phellogen**, similar to vascular cambium is a uniseriate layer of initial.

Cells of phellogen by periclinal divisions give off derivatives from their adaxial and abaxial faces. A phellogen produces phelloderm adaxially and phellem abaxially (Fig. 6.18). Phellem, a major constituent of periderm, is generally suberised and inhibits translocation of water and solutes to tissue abaxial to it, as a result, these tissues senesce and die. The cork tissue forms a protective layer of the tree after the epidermis dies and is shed. Cork is

generally formed in the stem and root of dicotyledons which have a continuous and pronounced secondary thickening. Cork is not formed in leaves with the exception scales of winter buds of certain plants. Cork is an important part of secondary tissue which is termed periderm (Fig. 6.18). Periderm is usually divided into three parts :

- i) The phellogen- cork cambium
- ii) The phellem-cork which is produced centrifugally by the phellogen.
- iii) The phelloderm-a parenchymatous tissue in some species, and produced centripetally by the phellogen.

6.8.1 Structure

Phellogen is a lateral meristem consisting of a single layer of initial cells. The cells are uniform, rectangular in cross section with their shorter axis in the radial direction. In a TLS they appear as regular polygons. The protoplasts of phellogen cells contain vacuoles of various sizes and may contain chloroplasts and tannins. Phellogen has no intercellular spaces except in the regions of lenticels.

The phellogen has distinct periods of activity and nonactivity. The activity period may or may not coincide with that of the cambium. However, in some plants two periods of phellogen activity have been noticed in a single annual period of cambial activity.

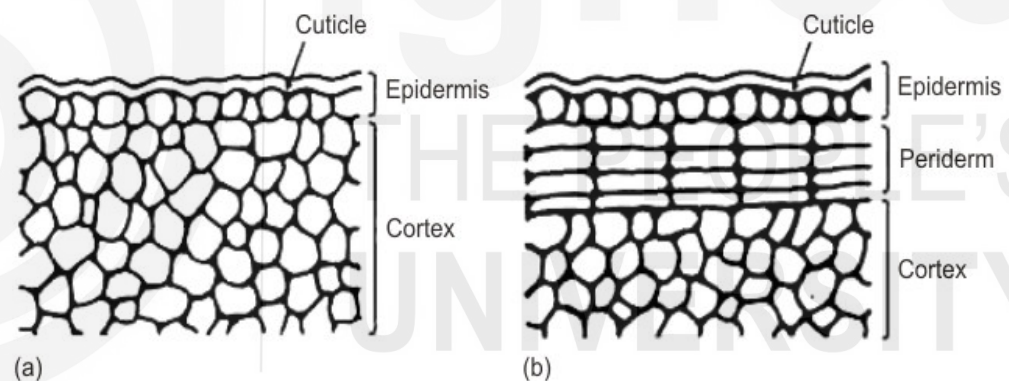


Fig 6.18 (a-b): Formation of Periderm.

6.8.2 Phellem

Phellem or cork arises from the abaxial derivatives of phellogen. The cells of phellem or cork are usually polygonal and radially flattened and divide tangentially in a cross section. Cells are devoid of intercellular spaces except in lenticular region. The cells of phellem divide tangentially. Cork cells are dead. They may contain crystal containing cell, they may be sclerieds, or even nonsuberised. In certain species the cork cell's primary walls are suberised and contain a thick suberin layer interior to the primary wall called the suberin lamella. This substance suberin is highly impervious to gases, water and resist the action of acid. This phenomenon of impregnation of walls with suberin is known as suberisation.

6.8.3 Phelloderm

The phelloderm cells are living cells with nonsuberised walls. They are similar to the parenchyma cells of the cortex but, if the phelloderm is multiseriate, they

are usually arranged in radial rows. In some plants cells of the phelloderm have chloroplasts and are photosynthetic.

6.8.4 Origin and Development of Periderm

The phellogen may differentiate in a living epidermal (Fig.6.19), collenchyma or a parenchyma cell. Just before the onset of meristematic activity the cell loses the central vacuoles, the volume of cytoplasm increases and it undergoes a periclinal division. Following the first periclinal division, two similar cells are formed, of which the inner ceases to divide further. The outer divides periclinally. The outer cell differentiate into the cork cell and the inner constitutes the phellogen initial and continues to divide.

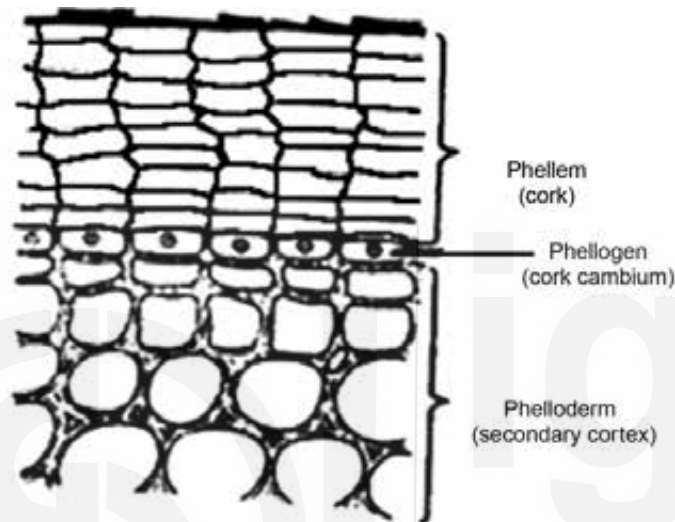


Fig. 6.19: Fully developed periderm.

The initials of phellogen cells occasionally undergo anticlinal divisions, to keep pace with the increase in the circumference of the cork cylinder. The number of phellem layers is usually greater than the number of phelloderm layers. If the first formed periderm remains on the axial organ for many years, the other layers of cork show cracks and are shed off. Thus the thickness of cork on a plant remains constant.

6.8.5 Bark

The first formed periderm may be replaced by newer periderm. When such replacement takes place, the last periderm is always produced inner to the earlier (last formed) one.

This later produced periderm may have its origin in cortex, primary phloem or even in secondary phloem. Generally, two types of formation of subsequent periderms may be distinguished :

- i) Plants where first formed periderm is developed in inner tissue, the later formed periderm usually form an entire cylinder similar to the first formed periderm. Such plants produce **ring bark**.
- ii) Plants in which the first formed periderm originates in epidermis or outer layers of cortex, the later periderms develop in the form of scales or shells. The concave side of these scales is directed outwards. Such plants produce **scaly bark**.

Rhytidome : Whenever a new periderm is formed inner to the one already present, the tissues exterior to it become cut off from the inner tissues. The nutrition and water supply to them is cut off and such cells eventually die. A hard outer crust develops out of such tissues. This crust increase in thickness due to the additional cork tissue is being produced from beneath. All such cork layer together with cortical/phloem tissues exterior to the inner most phellogen are termed as **rhytidome** (outer bark) (Fig. 6.20).

All tissues exterior to the vascular cambium are included in the term **bark**. The living part of the bark inside the rhytidome is often referred to as **inner bark**.

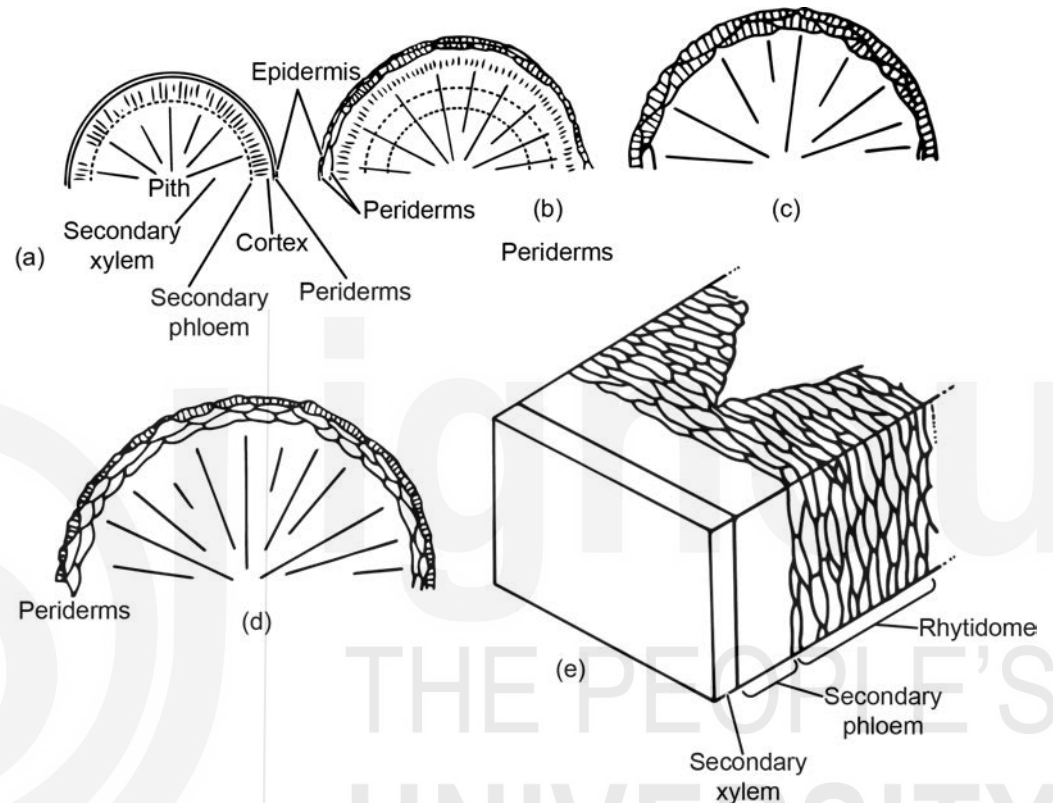


Fig. 6.20: Formation of periderm and rhytidome following the secondary activity in a stem.

6.8.6 Commercial Cork

The two types of cells of cork may found in one species e.g. *Arbutus* and *Betula*, where they occur in alternating layers in *Betula* this feature causes an interesting feature and cork is peeled off like sheets of papers.

The source of commercial cork is *Quercus suber* which occur naturally in the countries boarding the Mediterranean sea. In this species phellogen arises in the epidermis. It may remain on the plant for an indefinite period of time. For commercial purpose the first formed periderm is removed when the tree is about 20 years old and about 40 cm in diameter. The exposed cells of the phelloderm and cortex dry out and die, and a new phellogen is formed a few millimeters within the cortex. The subsequent phellogen produces cork more rapidly and in about 6 years a sufficient thickness to be of commercial value. The stripped cork shows a rough outer surface and a smooth inner surface.

The cork is valuable because it is impervious to gases and liquid, nonreactive and has strength, elasticity and lightness. It is used for insulation, sound proofing and in the manufacture of sports goods. Cork is unparallel as a material for making stoppers for wine and Champagne bottles.

You may like to know why commercial cork is to be cut in a particular plane. Cork is several centimeters thick and the lenticels remain active for a long time

and result in the formation of cylinders of complementary tissue which extend from the phellogen to the surface of the phellem. This complementary tissue forms the patches of dark brown crumbling tissue found in commercial cork. Because of the radial orientation of the tissues, bottle corks to be in a direction parallel to the surface of the trunk. This way the cylindrical lenticels extend transversely through them. Sheets of cork from the tree are rarely more than 3 cm. thick. Cork with a diameter greater than that cannot be obtained by cutting in the usual manner. Large corks are usually cut from sheets of ground and compressed cork or from "multiple sheets" composed of layers cemented together. These kinds of cork are of low quality.

SAQ 7

Complete the sentences from section A with those given in section B.

Section A

- a) Periderm is usually divided into
- b) In some plants phellogen has
- c) Histologically phellogen
- d) Cork

Section B

- i. consists only one type of initial cells
- ii. three parts
 - a) Phellogen
 - b) Phellem
 - c) Phelloderm
- iii. is impermeable to water gases and can withstand the action of acid
- iv. alternating periods of activity and inactivity

6.9 DISTRIBUTION OF LENTICELS

You must also know about lenticels. These are restricted area of relatively loosely arranged cells; in the periderm. Lenticel protrudes above the periderm because of their larger size and loose arrangement of numerous cells. There is continuity of intercellular spaces of lenticels with tissue in the axial organs.

Lenticels are highly differentiated lens shaped areas of periderm. They are usually found on stem and roots and appear on young branches or other organs as rough dark patches. Due to many intercellular spaces, lenticels have a loose structure. Mostly scattered over the entire surface of stem (Fig. 6.21). If we examine lenticel it usually looks like a convex lens both internally and externally.

6.9.1 Development and Structure of Lenticels

Lenticels originate from localized regions in the phellogen that become continuous with the nonlenticular phellogen. Lenticular phellogen has more intercellular spaces and produces derivatives at a higher state than do nonlenticular phellogen. The first formed lenticels generally appear below a

Only a few plants e.g. *Philadelphus*, *Anabasis Haloxylon*, *Campsis radicans*, *Vitis* and some other species many of which are climbers do not possess lenticels

stoma or group of stomata. Cells below the stomata begin to divide in different directions and the chlorophyll in them disappear so that a loose colourless tissue is formed. The cells that are derived from the divisions become more and more periclinal until the phellogen of the lenticels is formed (Fig. 6.21 a). The cells which are derived from the divisions of the substomatal cells, as well as those produced towards the exterior by the phellogen of the lenticels are termed complementary cells. After division the number of cells increases and masses of complementary cells are pushed out and rise above the surface of the organ (Fig. 6.21 b).

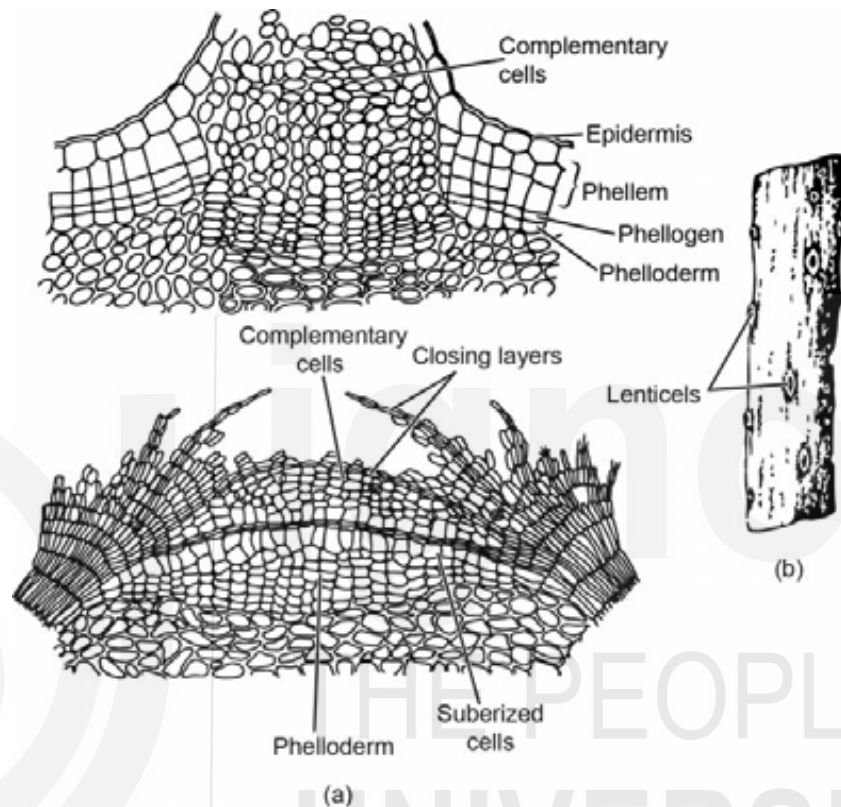


Fig. 6.21: a) Well formed Lenticel in L.S.; b) Lenticels on stem.

In the temperate regions lenticels become closed by the end of autumn season by a closing layer. Whereas in some plants lenticels are formed relatively early in the life of the plant and are shed together with the bark, in others they may remain active for several years.

SAQ 8

Define the following in two or three sentences:

Lenticels and Complementary cells.

6.10 CAMBIAL VARIANTS

In this unit you have studied the function of vascular cambium and cork cambium in dicotyledonous and monocotyledonous stems accounting for development of secondary tissues. Cambium shows variation in its activity giving rise to conditions which are rather typical. Various terms such as

cambial variants, anomalous or aberrant secondary growth has been used to describe these instances (Fig. 6.22). As the variants are of quite regular occurrence in certain plants, anatomists have discouraged the use of the term anomalous secondary growth. Instead cambial variant has been recommended for usage.

In normal conditions, in most of the dicot stems the vascular bundles are arranged in a ring whereas in monocots they are scattered in the ground tissue. The division of lateral meristem i.e. vascular cambium increases the thickness of the stem. The division of the cambium results in formation of secondary xylem towards inner side and secondary phloem towards outer side or periphery. The cambium remains functional/ active throughout the life of the plant and hence is referred as normal secondary growth. This occurs in most of the dicot stems. In some dicots and monocots the structures appear different from normal. Cambium shows variation in its activity. The terms used to describe such condition is referred as cambial variants, anomalous (less common) growth or aberrant secondary growth has been used to describe this.

The anomalies may be present in the primary structure of the stem i.e. cortical bundles, medullary bundles, and xylem are described as primary anomalous structures. Some structures also develop during secondary growth such as included phloem, accessory cambial strips. They are referred as secondary anomalous structures.

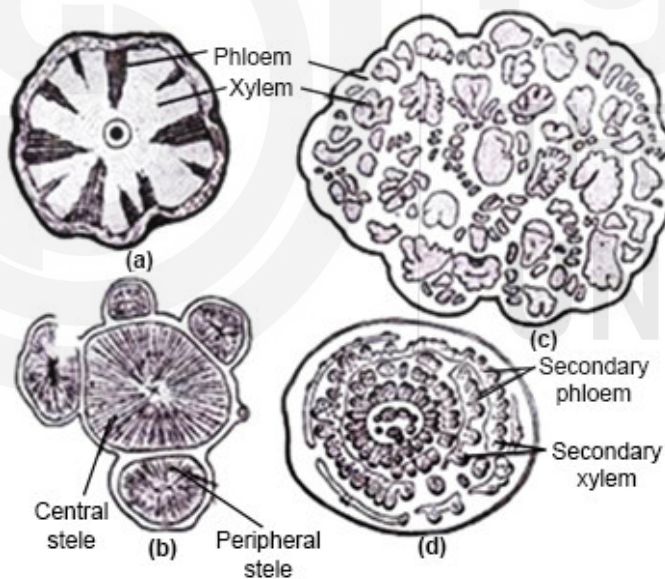


Fig. 6.22: Cambial Variants a) *Bignonia*; b) *Serjania*; c) *Bauhinia*; d) *Boerhaavia*.

6.10.1 In Stems

First we will study about the cambial variants found in stem.

- I. **The cambium is persistent and normal in position. Its products show unusual arrangement and proportion.**
 - a) In ***Bignonia*** (Fig.6.23) and some other members of the Bignoniaceae family the cambium produces secondary xylem and secondary phloem in different amounts. Thus in some part of the plant the amount of xylem

is much greater than phloem while in the other, phloem is much more abundant than xylem. This feature results a characteristically ridged and furrowed xylem cylinder. Phloem can be identified by the presence of wedges. There, as usually, four such wedges symmetrically arranged and corresponding in position to the larger primary vascular bundles.

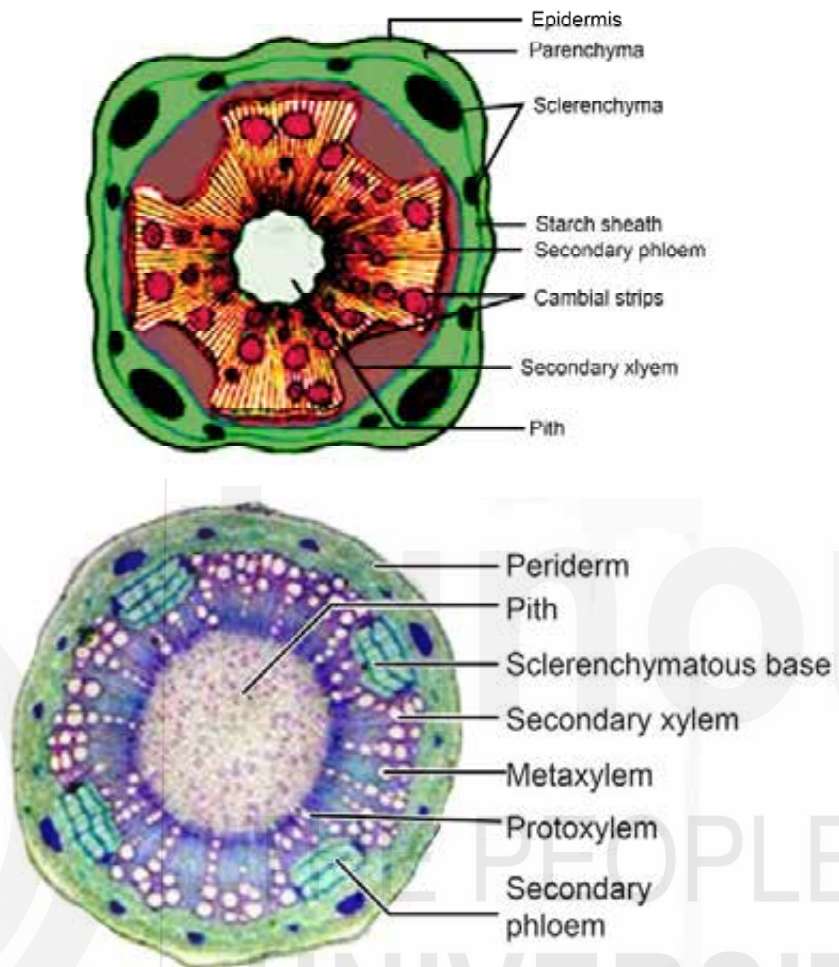


Fig 6.23: T.S. of Stem of *Bignonia* Showing anomalous secondary growth.

- b) In some climbing species of genus *Vitis* (grapes) *Clematis*, *Aristolochia* (Fig. 6.24) *Tinospora* etc. a complete ring of cambium is formed. The fascicular cambium functions normally but the interfascicular cambium produces only ray like parenchyma cells. As a result, broad and long medullary rays and fluted vascular cylinders are formed.

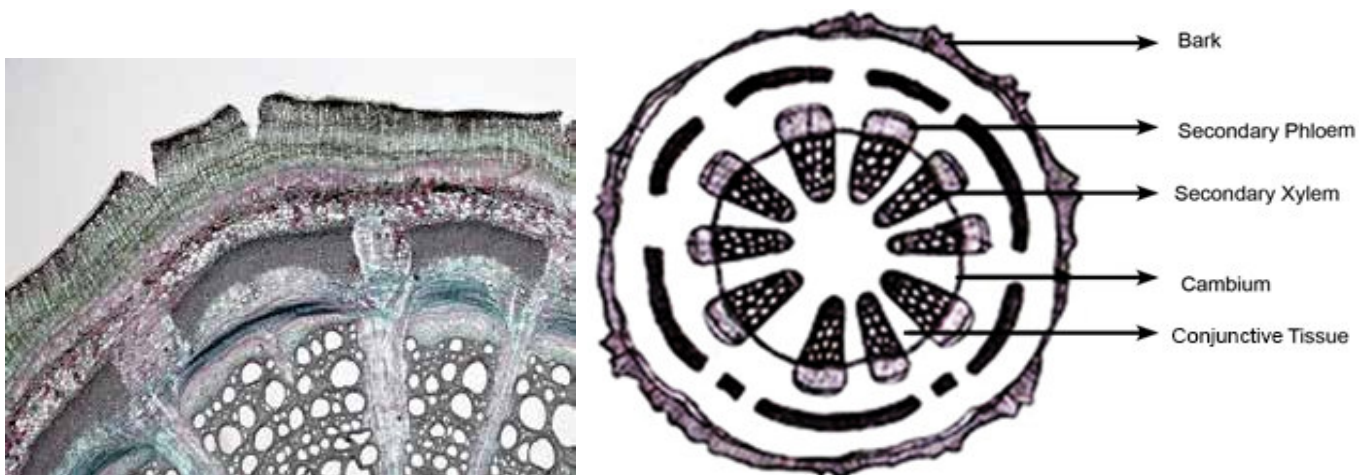


Fig 6.24: T.S. of stem of *Aristolochia*.

II. The Cambium is abnormal in position but normal in activities

This situation is noted in some climbing species of *Serjania* (Fig 6.25). During development, the cylinder of primary vascular bundles become notched at certain points, so that groups of bundles are formed. Thus bundles become constricted to form the cylinder. They may be cut off even at the procambial stage. These groups of bundles function as independent cylinders and give rise to separate cambia, each of which functions normally and independently. Thus the stem appears as if it is made up of several discrete woody cylinders, each of which has its own periderm. Sometimes the woody cylinder is only lobed.

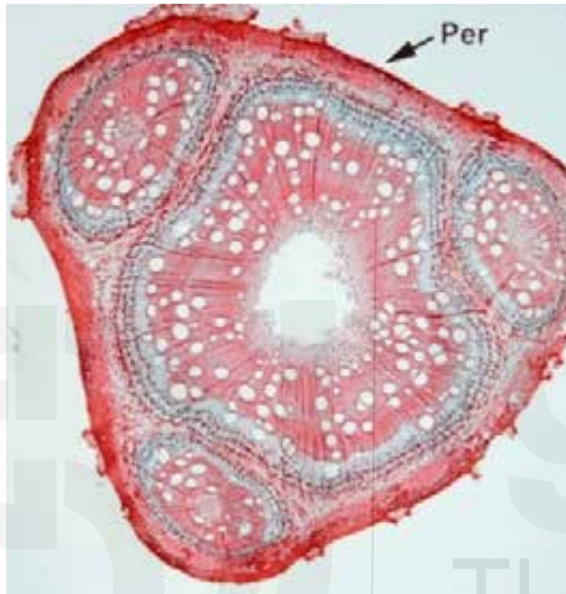


Fig 6.25 : T.S. of stem of *Serjania*

III. Anomaly due to the formation of accessory cambium and its activity

- a) In some species of *Chenopodium* and members of the Amaranthaceae, the anomalous secondary growth results from accessory cambia. A hollow cylinder of vascular tissue or a ring of irregularly arranged bundles. The bundles are of secondary nature but their cambial activity soon ceases. Just outside the bundles a new secondary cambium arises in the pericycle. In some species the cambium forms tissues centripetally, consisting of bundles embedded in nonvascular tissue. The bundles formed in this way may be arranged irregularly or in definite concentric rings.
- b) In *Tecoma* sp. secondary xylem and phloem are produced in the beginning by the activity of a normal cambium ring. At later stage an accessory secondary cambium arises in two arcs on the inner side of the normal wood or towards the pith. This accessory cambium cuts off xylem and phloem in an inverse order i.e. xylem towards the periphery and phloem on the inside. This newly formed phloem is intraxylary phloem and is secondary in origin. And the secondary xylem merges gradually with the previously formed secondary xylem (Fig. 6.26).

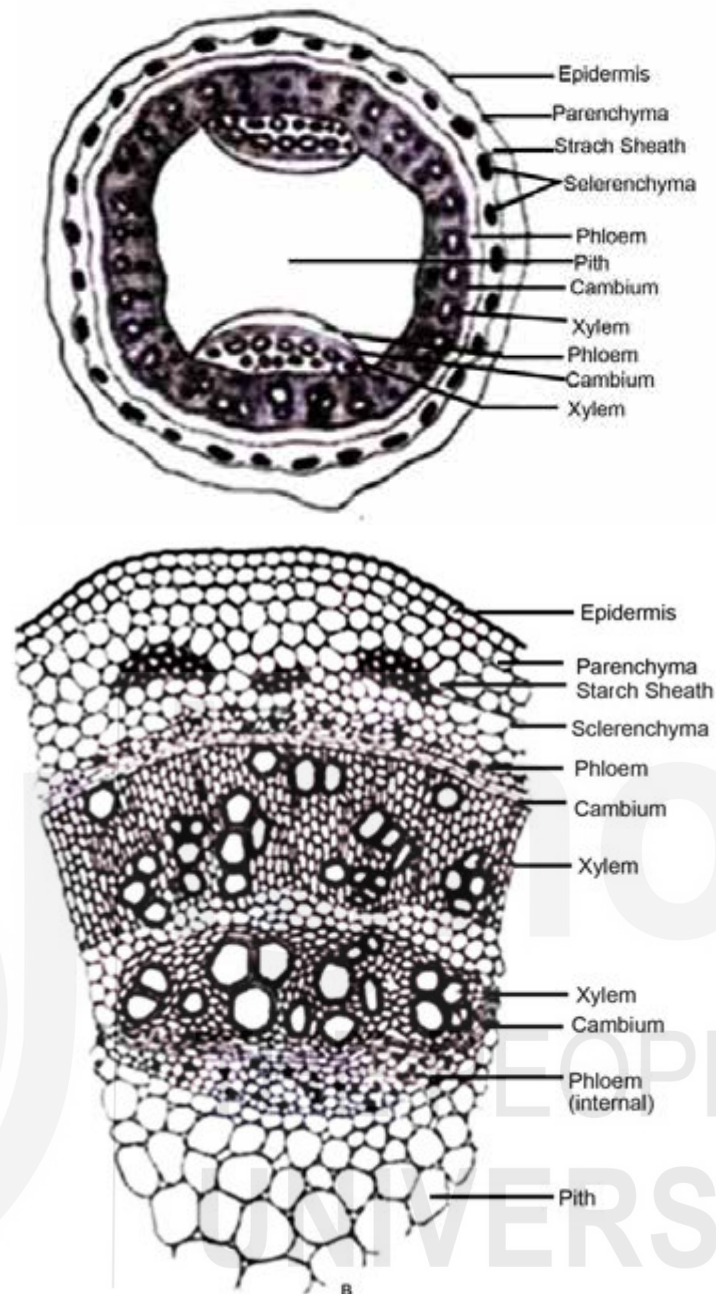


Fig.6.26: T. S. of stem of *Tecoma* diagrammatic and cellular.

IV. Anomaly due to the formation of interxylary (included) phloem as a result of aberrant activity and position of cambium

Secondary phloem patches are sometimes embedded in secondary xylem in the form of strands. Those extra patches of secondary phloem present inside the secondary xylem are known as **interxylary** or **included phloem**.

- a) In certain plants there are strands of secondary phloem within the secondary xylem, e.g., in *Avicennia*, *Thunbergia*, *Bougainvillea*, *Salvadora* (Fig. 6.27) and in the families of Amaranthaceae and Chenopodiaceae. In these plants cambium differentiates outside the primary vascular bundles, in the pericycle or in the inner cortical layers. Later a series of vascular cambia arise successively outward, each of which cambium produces xylem toward the inside and phloem towards the outside until a new cambium develops from parenchyma cells on the outside of the phloem.

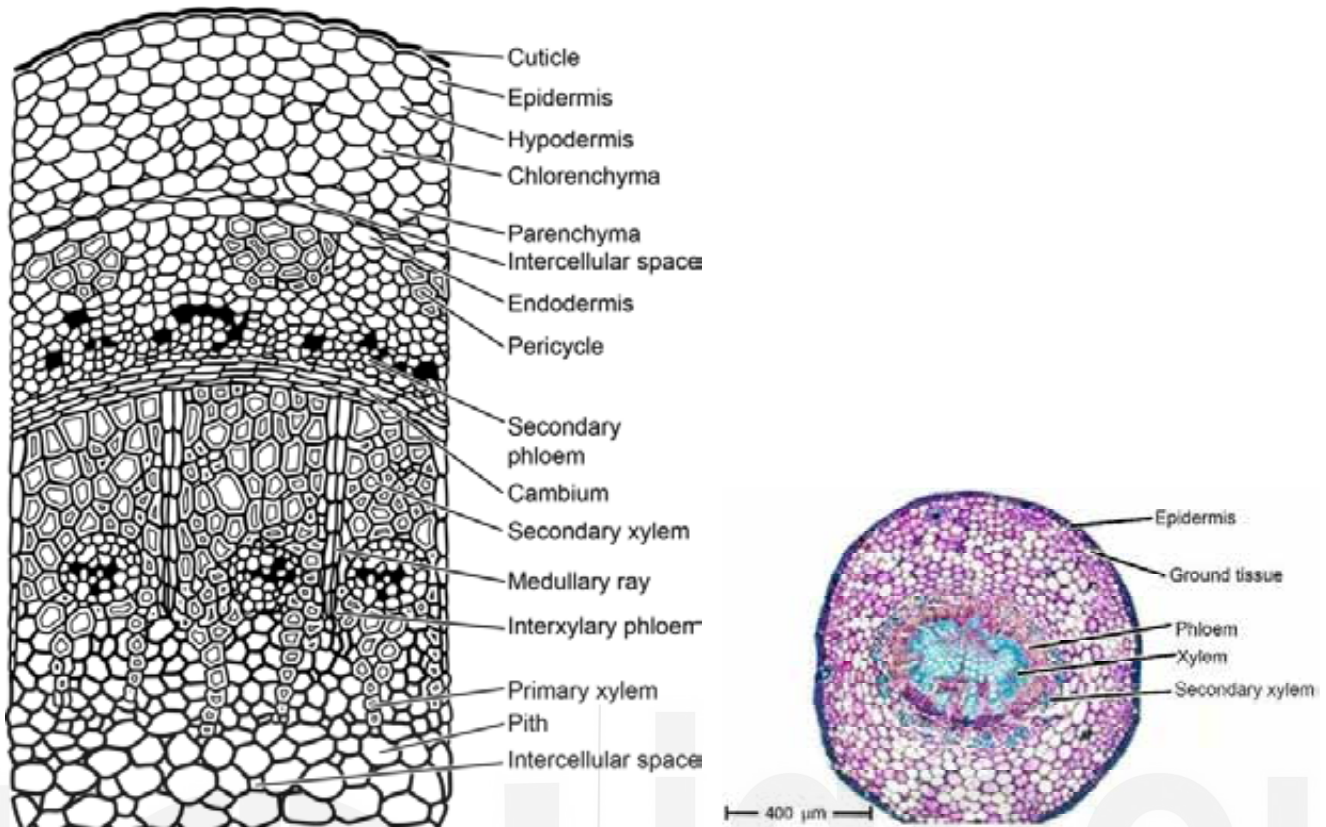


Fig 6.27: T.S. of *Salvadora* stem diagrammatic and a portion of stem (cellular).

- b) In Chenopodiaceae the successive cambia can be seen in the form of long or short arches. They produce irregularly or spirally arranged phloem strands (Fig.6.28) frequently the additional cambia in this family form more or less entire rings.

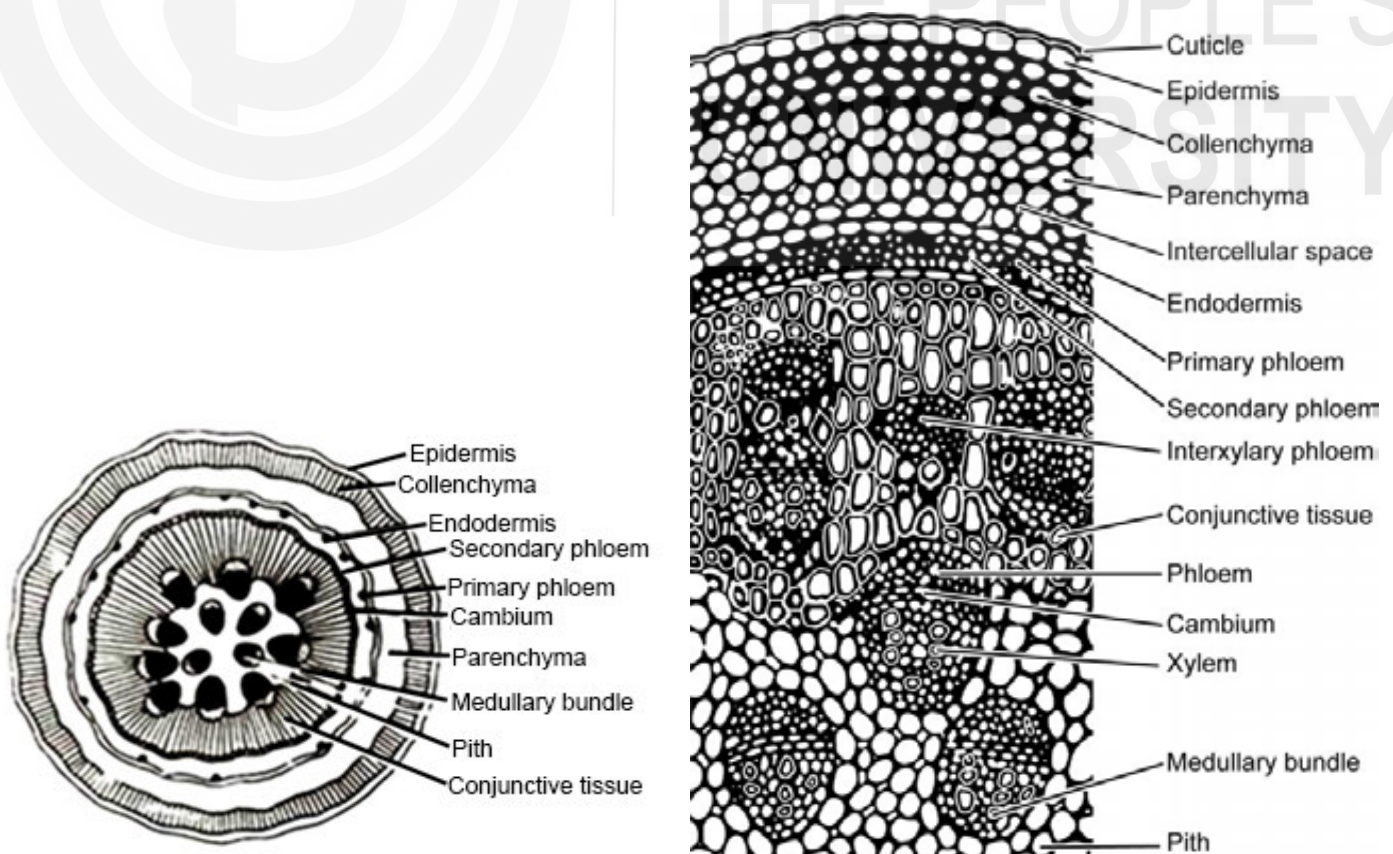


Fig 6.28: Diagrammatic representation stem and a portion of the stem (cellular) of *Chenopodium*.

6.10.2 In Roots

Cambial variants are also found in the roots of some plants, especially those that serve a storage function :

- a) In the beet roots *Beta vulgaris* first the cambium ring develops near the primary xylem patches which in turn produces secondary xylem towards inside and secondary phloem toward the outside. Soon its activity ceases and then from the cells of pericycle and phloem a secondary cambium ring is formed. This is followed by the formation of several concentric cambia. All the cambial layers continue to function and produce a large amount of storage parenchyma and strands of xylem and phloem. Although cambia are in continuous rings they produce separate bundles which are surrounded by conjunctive tissue. The bundles are separated from one another by wide radial panels of parenchyma formed due to the activity of newly formed cambium. Thus alternate bands of proliferated pericycle and vascular bundles are formed which can be seen as dark coloured and light coloured rings respectively. The bundles are themselves largely parenchymatous with a few lignified elements in xylem (Fig.6.29).

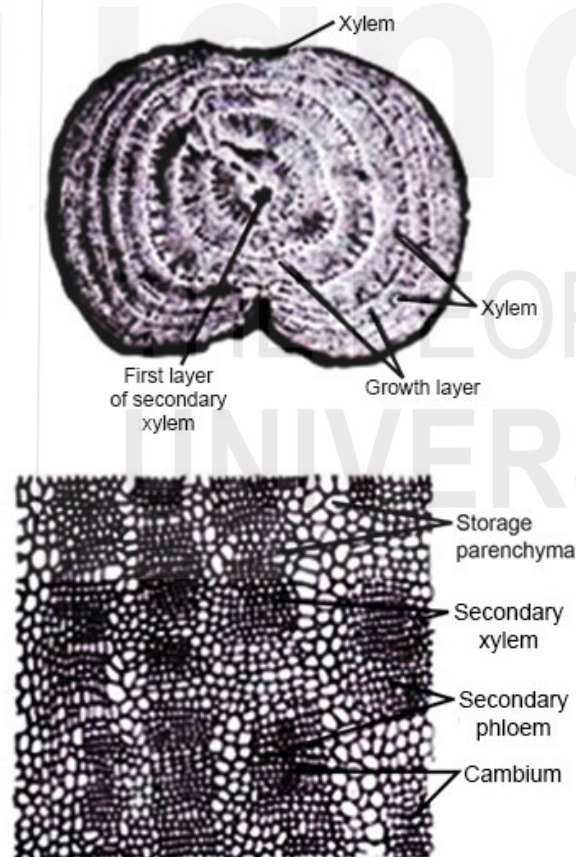


Fig 6.29: T.S. of root of sugar beet.

- b) In the sweet potato root of *Ipomoea batatas* (Fig. 6.30) (Convolvulaceae) the secondary growth is unique. The xylem, has an abundant amount of parenchyma. Secondary cambia develop in the parenchyma around the individual vessels or vessel groups. The cambia produce tracheary elements towards the vessels and sieve tubes away from the vessels; A considerable amount of storage parenchyma is produced in both the directions. Thus the phloem appears to be a portion of root that originally differentiated as xylem.

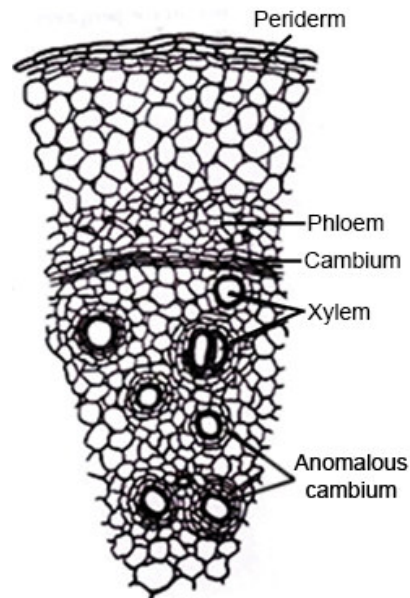


Fig 6.30: T. S. of root of sweet potato.

SAQ 9

List various types of cambial variants and describe any one variant from root and one from stem along with labeled diagram.

6.11 SUMMARY

- In general the plants having only primary growth are limited in size and longevity. Secondary growth helps the perennial gymnosperms and dicotyledons to increase the diameter and support the height and growth size.
- After the procambium strand become differentiated into primary vascular tissue, active meristematic regions lie between primary xylem and primary phloem from which continued, addition of fresh tissues is possible. These meristematic cells constitute the fascicular cambium.
- An interfascicular cambium arises from ray parenchyma cells between vascular cambia.
- The fascicular and interfascicular cambium joins together and forms a complete cylinder of vascular cambium. The divisions in cambium are longitudinal, so that the stem now increases only in girth.
- In many plants, phellogen differentiates near the surface of the stem. This gives rise to phellem and phelloderm. Cork cells have suberin in their wall, which makes cell impervious to gas and liquids. Lenticels in the bark facilitate gas exchange.
- Cork cambium may originate in successively deeper tissues: epidermis, cortex and phloem.
- Woody dicotyledons have most of their secondary tissues arranged in concentric layers. The most conspicuous tissue is wood (secondary xylem). The early wood usually has relatively large vessel elements, while late wood has smaller vessels and/or a predominance of tracheids.

- Generally an annual ring comprises one year's growth of xylem. The age of a tree and other aspects of its ecological history can be determined by studying histological details of the annual rings. Older wood ceases to function and is gradually accumulated in the centre to form the heartwood or dead core which becomes plugged with tylosis. The younger, more peripherally located or living wood is called sap wood. The scientist have shown that only one or two recently formed annual rings or wood are actually involved in the ascent of sap.
- Some monocots such as *Agave* and *Dracaena* have true secondary growth, with a type of cambium that produces secondary vascular bundles and parenchyma.
- Certain dicotyledonous stem have cambial variants that contribute to unusual secondary growth. Cambial variants may arise from the following situations/conditions: i) The cambium is persistent and normal in position. Its products show unusual arrangement and proportions. ii) The cambium is abnormal in position but normal in activities. iii) Formation of accessory cambium and its activity. iv) The formation of interxylary phloem because of abnormal activity and position of cambium.
- Cambial variants are also noted in some roots such as *Ipomoea batatas*, *Beta vulgaris* etc.

6.12 TERMINAL QUESTIONS

- 1) What is secondary thickening (growth)? Explain the mode of secondary growth in dicotyledons and monocotyledons. List the similarities and differences in their secondary structures.
- 2) If a nail is driven into the trunk of a tree say at breast height, will it remain at the same distance from the ground and move up or down in the course of the next 6 years. Explain your answer.
- 3) What is periderm? Explain how it divides and the tissue it produces.
- 4) What are tylosis? How are they formed?
- 5) How is cork formed? Explain the structure, properties and uses of commercial cork.
- 6) What are lenticels? How they are formed? What are their functions?
- 7) List various types of cambial variants. Describe the structural anomaly arising as a result of formation of accessory cambium and its activity provide suitable diagram?
- 8) Explain how dark coloured and light coloured rings are formed in the beet roots.
- 9) Explain briefly the main features of unusual secondary growth in roots.

6.13 ANSWERS

Self-Assessment Questions

1.
 - a) Secondary growth is growth in diameter due to addition of new tissues due to activities of lateral meristems.
 - b) Secondary growth occurs both in intrastelar and extrastelar regions.
2.
 - a) ray initials, fusiform initials
 - b) stress
 - c) resin
 - d) smaller
 - e) cambium
3.
 - a) Fascicular cambium and interfascicular cambium.
 - b) Vascular cambium consist two types of cell: Fusiform initials and ray Initials The fusiform Initials: are elongated cell with tapering ends. They are found in tracheary elements, fibres, xylem and phloem parenchyma and sieve elements. Ray Initials: are much smaller than fusiform initials and are almost isodiametric. They have intense vacuolation, the cell wall possess primary pit fields with plasmodesmata. The radial walls are thicker than the tangential wall.
 - c) See section 6.3.2
4.
 - a) False b) True c) True.
5.
 - a) Secondary xylem can be classified in two systems: i) One system is horizontal and ii) Other is vertical.

The horizontal system is made up of xylem rays and the vertical consists of tracheary elements, fibres and wood parenchyma. The living cells of rays are usually interconnected and a continuous system of living cells is formed
 - b)
 - i) Uniseriate Ray; when the ray is one cell wide it is called uniseriate ray.
 - ii) Biseriate Ray: When two cell wide the ray is called biseriate rays. On stem they are longitudinally or horizontally arranged but most of the time they are scattered all over the entire surface. Usually it looks like a convex lens both internally and externally.
 - iii) Multi seriate: When it is more than two cells wide.
 - c) In timber trade wood of dicotyledonous is known as hardwood and the wood of gymnosperms as soft wood. But these words do not express the degree of hardness. But histologically the dicotyledonous woods have vessels while gymnospermous wood lack them.

- d) The large part of the wood is made up of fibers or fiber tracheids and they give strength to wood. These woods are dense and heavy.
- e) Woods have several uses which are listed below:
 - i) building material for houses in windows, doors, cabinets, boxes, furniture.
 - ii) Building boats, ships, masts.
 - iii) Bodies of automobiles, railway wagons, railway sleepers, bridges.
 - iv) Electric poles.
 - v) Various aspects of art are also made up of wood.
 - vi) Wood is a good material for carving idols, inlay work.
 - vii) Packing cases, matches.
 - viii) Several music instruments.
 - ix) Cosmetics, soaps, perfumes and incense sticks are made from oil derived from woods.
- 6. a) True; b) False; c) False.
- 7. a) ii; b) iv; c) i; d) iii.
- 8. **Lenticels:** Restricted areas of relatively loosely arranged cells, in the periderm. They protrude above the periderm because of their loose arrangement, larger size of the numerous component cells. Lenticels usually found on young branches of stem and roots. They are involved in exchange of gases between internal tissues and the atmosphere through periderm.
Complementary Cells: The cells which are derived from the divisions of the substomatal cells as well as those produced towards the exterior by the phellogen of the lenticels. As the division progresses, masses of complementary cells are pushed out and rise above the surface of an organ.
- 9. List the types of cambial variants from section 6.10 and give an example from subsection 6.10.1 and one example from 6.10.2 along with diagrams.

TERMINAL QUESTIONS

1. In the dicotyledons the stem generally increases in girth due to the activity of the vascular cambium. The growth is known as secondary growth or secondary thickening. Also see section 6.2 and Fig.6.1.
2. Stem increases in height due to the activity of shoot apical meristem. So if a nail is driven in trunk. It will always remain at the same height above the ground. The nail may eventually become embedded as the stem increases in girth and you can see the differences between the activities of the apical meristem and of the vascular cambium.

3. Refer to section 6.8 and Subsection 6.8.1 and 6.8.2.
4. The outer part of the secondary xylem with living parenchyma is named sapwood. In nearly all the trees the central portion consists of dead parenchyma which ceases to conduct water. This is known as heartwood. Heartwood is formed after disintegration of the protoplast, loss of cell sap, hydrolysis of stored reserve materials and formation of tyloses. Tyloses totally block the cell. Oils, gum, resins, tannins are accumulated in the heartwood making it extremely durable. Thus heartwood is preferred to sapwood for making furniture
5. Cork is an important part of secondary tissue which is termed as periderm. It is divided into three parts. i) The phellogen cork cambium. ii) The phellem-parenchymatous tissues in some species, produced by the phellogen. iii) The phelloderm-parenchymatous tissues in some species, produced by the phellogen.

Phellogen abaxially cuts off derivatives as phellem. The phellem or cork cells are usually polygonal, and radially flattened. The cells are arranged in compact radial rows which are devoid of intercellular spaces. Cork cells are dead. Some cells are hollow and thin walled, and somewhat radially rounded; some others are thick walled and radially flattened. The later type of cells may be often filled with dark resiniferous or tanniniferous substance. Most of the commercial cork comes from *Quercus suber*. In this species phellogen arises in the epidermis. The first formed periderm is removed when tree is about 20 years old and 40 cm in diameter. A new phellogen differentiates a few millimeters within the cortex. This cambium divides rapidly and in about 10 years it forms sufficiently thick cork for commercial uses.

Cork is of commercial value because it is impervious to gases and liquids and has strength, elasticity and lightness and also see Subsection 6.8.2.

6. Refer to Section 6.9 and Fig. 6.21.
7. Refer to section 6.10. Sometime unusual secondary growth occurs due to the formation of accessory cambia and their activity. There are two types of vascular tissues i) a hollow cylinder; or ii) irregularly arranged bundles. Their cambial activity ceases and outside a bundle in the pericycle a new secondary cambium arises. The cambium forms tissues centripetally, consisting of bundles embedded in nonvascular tissue. The bundles may be arranged in concentric rings or irregularly.
8. In the beet roots first formed cambium activity ceases very soon. Then there is formation of several concentric cambia. All the cambial layers continue to function and produce a large amount of storage parenchyma and strands of xylem and phloem. Though the cambia are continuous they produce separate bundles which are surrounded by conjunctive tissue. Bundles are also separated from one another by radial panels of parenchyma. Thus alternate bands of proliferated pericycle and vascular bundles are formed which is seen as dark coloured and light coloured rings respectively Fig. 6.29.
9. Refer to Subsection 6.10.2, Fig. 6.29 and Fig. 6.30.

Acknowledgements for Figures

- Fig 6.17** : <https://i.pinimg.com/736x/81/59/19/8159195fc8da6d027ff09578e8ad27d8.jpg>
- Fig 6.25** : https://lh3.googleusercontent.com/proxy/W7Cel0pOZO4lf_http://virtualplant.ru.ac.za/Main/ANATOMY/serjania-stem1.jpg
- Fig. 6.27** : <https://encrypted-tbn0.gstatic.com/images?q=tbn%3AANd9GcRCPOylvfY3-jJxjNpuxurToj3pBxPUvOVieQ&usqp=CAU>



UNIT 7

PROTECTIVE FEATURES IN PRIMARY ORGANS OF PLANTS

Structure

7.1	Introduction	7.5	Role of Epidermis in Plants
	Objectives		Root epidermis or Rhizodermis
7.2	Protective features	7.6	Trichomes
7.3	Epidermis		Types of Trichomes
	Development of Epidermis		Functions of Trichomes
	Types of Epidermal Cells	7.7	Cuticle
	Guard Cells and Stomata	7.8	Summary
7.4	Specialised Epidermal Cells	7.9	Terminal Questions
	Cystoliths	7.10	Answers
	Silica and Cork Cells		
	Bulliform Cells		
	Root Hairs		
	Multiple Epidermis		

7.1 INTRODUCTION

In earlier unit 1 you have studied about the various tissues in plants. The role of various meristems has also been discussed in regard to growth of root and shoot in plants. In this unit you will be studying about epidermis which forms the outermost layer of the primary plant body. It is derived from the protoderm layer in plants. Epidermis forms the interface between the plant and its environment, hence acts as the first line of defense in plants. As you know that defense mechanism is very important part of plant, animal kingdom wholly or partially depended on plant kingdom and fixed to the ground as they have to manoeuvre when attacked. For this reason plants have been provided with special organs to protect themselves from such attacks. In the present unit we will describes the structure of epidermis, various cells present in the layer along with their role in plant protection.

Objectives

After studying this unit you would be able to :

- ❖ demonstrate the structure and explain the function of epidermis;
- ❖ recognize various specialised cells present in the epidermis;
- ❖ illustrate the structure and distinguish the function of cuticle; and
- ❖ know the importance of trichomes in plants.

7.2 PROTECTIVE FEATURES

Protective systems mainly include dermal tissues such as epidermis and rhizodermis. Epidermis protects the soft tissues of plants and regulates interaction of plant with the surroundings. This layer defends or guards the plants against pathogens and other harmful agents. Epidermis consist of a single layer of cells covering the shoot, leaves, flowers, fruits, and seeds. It secretes cuticle which prevents loss of water. Cuticle acts as a barrier and regulates the entry of substances but permits the exchange of gases. Other structures present in the epidermal region include root hairs, trichomes, stomata etc. Root hairs are the extensions of root epidermal cells. They increase the surface area of the root and contribute in the absorption of water and minerals. Rhizodermis covers all underground plant parts of the plants. Cells of the rhizodermis secrete mucilage.

7.3 EPIDERMIS

Epidermis (epi-upon; derma –skin) is the outermost layer of cells present in the primary organs of the plants. It comprises of mature, uniseriate surface layer of the plant body. The epidermal tissue system is derived from the dermatogens of the apical meristem. Hence the precursors of epidermal cells are protodermal. In root outer covering called rhizodermis is present.

The epidermal cells are variable in shape and retain active protoplast. Pavement cells are the most common cells of the plant's epidermis. These cells are unspecialized and generally have an irregular wavy shape. High turgor pressure maintains shape to the cell and formation of intercellular spaces along the edges of the cell. Epidermal cells are characterized by anticlinal divisions. When the cell division takes place perpendicular to the surface of the organ, it is called as anticlinal division. In most plants, the anticlinal walls of leaf epidermal cells have many curves and turns (Fig. 7.1). The curved wavy cell walls provide hydraulic support to leaves during expansion. Hydraulically stiffened epidermal cells provide mechanical support. In conifers the epidermal cells become thick walled and die. These dead layers of cells provide help in protection. Epidermis consists of a variety of cell types including guard cells, subsidiary cells and trichomes.

Epidermis prevents the excessive loss of water but allows gaseous exchange with the external environment. Cuticle forms the major component of epidermis. The epidermal cells produce structures like hairs (glandular or non-glandular), trichomes, scales or papillae. These structures protect epidermal

cells from injuries or damage. Hairs are composed of dead air-filled cells. Trichomes consist of one or more layer of cells formed from meristemoid tissue that arises from epidermal cell. Trichomes reduce the thermal load on living tissue during periods of harsh conditions of insolation and reducing transpiration. In some taxa, the dense trichome layers protect the plant against desiccating (dry) winds. The plants belonging to families Poaceae, Cyperaceae, Palmaceae accumulate grains or nodules of silica in the epidermal cell walls and this decreases their palatability to herbivores.

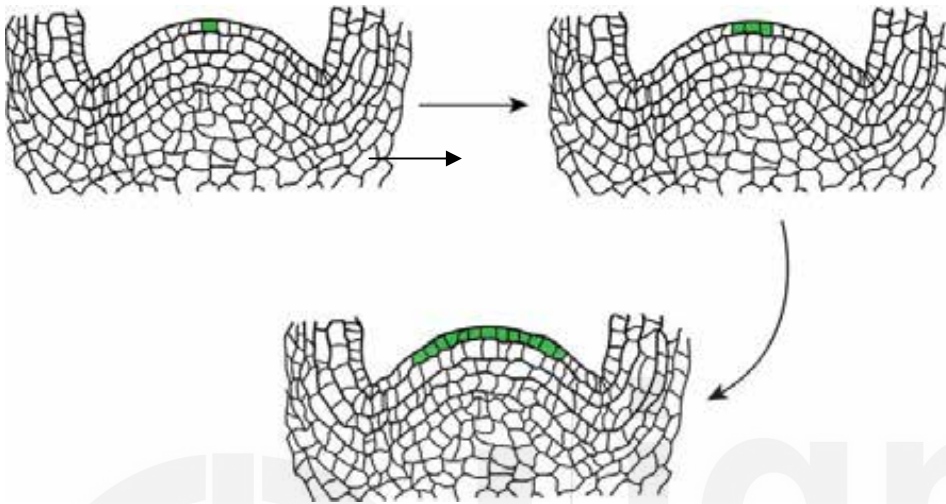


Fig 7.1: Anticlinal division in epidermal cells.

7.3.1 Development of Epidermis

A single layer of epidermal cells is present in the shoot. The layer is derived from the outermost layer of the tunica. The cells are small, isodiametric and characterised by anticlinal cell divisions. Anticlinal cell division is the plane of division perpendicular to the surface of the organ. The cells show the formation of cuticle, stomatal guard cells, stomata, trichomes and other cell types.

The pavement cells are frequently found in the epidermal layers of all the plant organs. These are morphologically unspecialised cells. Pavement cells in the dicot species undergo multiple rounds of endoreduplication and simultaneously increase in cell volume by almost two times of magnitude compared to their protodermal precursors. In dicot leaves pavement cells are usually shaped like the interlocking pieces of a jigsaw puzzle. Pavement cells undergo morphogenesis which is discontinuous and includes phases of initiation and expansion. The pavement cells increase in size, remain highly vacuolated without any increase in the thickness of the cell wall. The thick external cell walls obstruct expansion perpendicular to the leaf surface. The cell size increases preferentially within the plane of the epidermis (Fig.7.2). Pavement cell expansion occurs in a sinusoidal pattern generating highly interdigitated cells which form mechanically stabilized tissue. Adjacent pavement cells initiate protrusions that are offset from one another.

Occurrence of anticlinal (perpendicular to the leaf surface) microtubule bundles (AMBs) and the presence of cell indentations form a local concave shape. The pattern of deposition of cellulose microfibrils at the plasma membrane is dictated by cortical microtubules. Cortical microtubules

coordinate the growth of orthogonal cell walls. These cells show different degrees of morphological specialization. Expansion of the opposing lobes generates air spaces between cells that facilitate efficient gas exchange between the plant and the environment. Pavement function in protecting the underneath tissue layers and ensure the morphogenesis of specialised cells.

Box 7.1: Molecular studies on gene of *Arabidopsis thaliana* meristem Layer.

Molecular studies have shown that a number of genes help in differentiation of epidermal cells. A gene *Arabidopsis thaliana* Meristem Layer 1 (*ATML1*) helps in the formation of epidermal cells. It is expressed in the outermost cell layer. It also possesses the ability to differentiate other cells into epidermis. Overexpression of gene activates the expression of genes that induce epidermis-related traits such as the formation of stomatal guard cells and trichome-like cells.

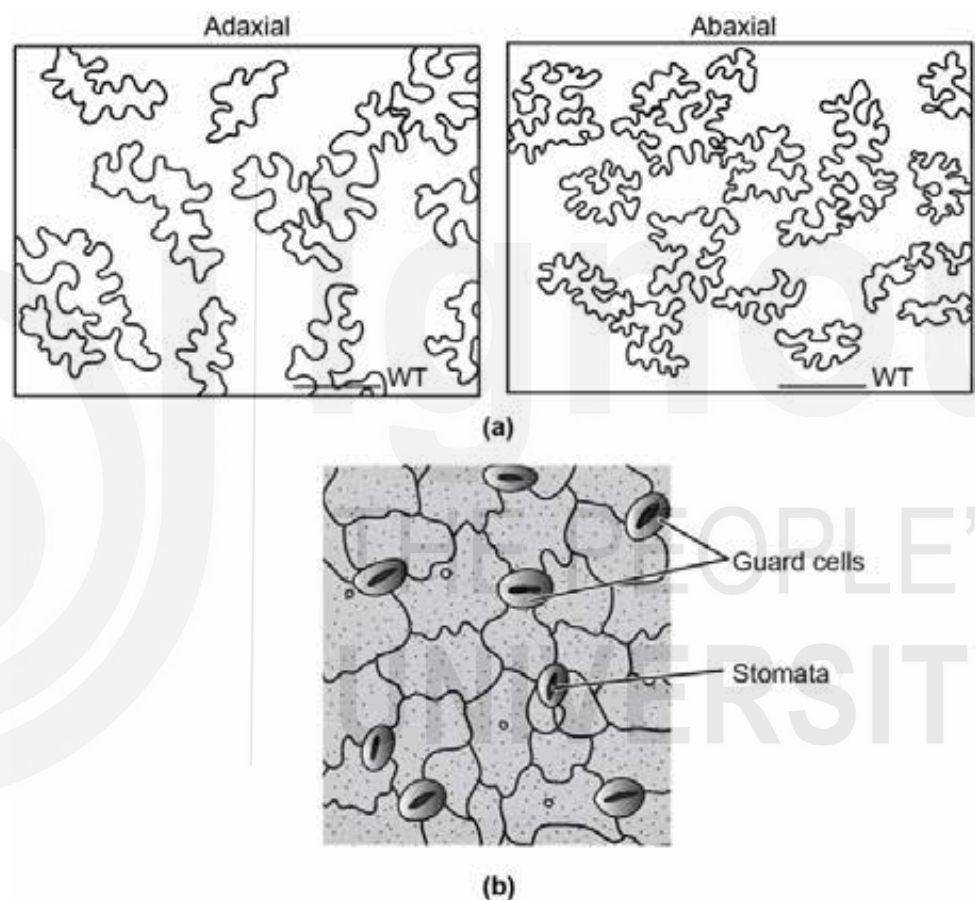


Fig.7.2: a) pavement cells in epidermis (abaxial and adaxial surface); and b) view of the epidermal region showing stomata.

7.3.2 Types of Epidermal Cells

Epidermal cells lie in between the specialised cells, numerous and occupy a greater proportion of the plant body. Various cells are found in the epidermal tissue include stomata, trichomes, guard cells, subsidiary cells, hairs and some specialised cells such as lithocyst, cystoliths, bulliform cells. They are mostly tubular and possess all the cell organelles along with plastids. The plastids occur as proplastids or leucoplasts. Epidermal cells become papillate or mucilaginous in appearance. The outer most protective layer made up of cutin is referred as cuticle.

Uniseriate trichomes develop from the smaller of cells produced by unequal division which you will study in coming sections of this unit. The small

trichoblast begin to grow outward only after the underlying region of the root pushed forward through soil. The cytoplasm gets localized at the tip region with high concentration of dictyosomes.

7.3.3 Guard Cells and Stomata

Epidermis contains certain holes/pores which allow the gaseous exchange to take place which are called as **stoma** (mouth). Stomata are found on all green parts of the plant especially stem and leaves. In leaves they are more abundant on the abaxial surface while the upper adaxial surface has few or none of them. The adaxial surface of leaves typically have about 100 stomata per mm² but in deciduous plants the number can be about ten times high. In submerged water plants, the adaxial surface shows the presence of stomata. Stomata are generally not present on the fibers or sclerenchyma cells.

Stomata include a pore called stoma surrounded by specialised cell called guard cells (Fig. 7.3). The guard cells open or close the stomatal pore by changing turgor pressure, hence regulating the rate of transpiration and gaseous exchange between atmosphere and the air spaces. Increase in the internal pressure allows the pectin rich guard cells to expand in the direction along the longitudinal axis. This results in opening of the pore. The pore, guard cells and subsidiary cells collectively form the **stomatal complex**. The subsidiary cells store large amount of water and ions. The plasmodesmata are not present between the guard cells, subsidiary cells and the epidermal cells.

Several plants show unusual distribution of stomata. In *Saxifraga*, the stomata occur only near the leaf tip, while in other plants they occur near the leaf margin. In *Daphne* they occur only near the midrib. The stomata show a characteristic alignment which varies with the plant. In monocots and conifers, the stomata are aligned in the linear way i.e. parallel along the axis of leaf. In some plants, the stomata are clustered in group and in others the guard cells of the neighbouring stomata are not in contact with each other.

The guard cells present in the plants can be of different shapes. Dumb bell shaped guard cells occur in the grass family and Cyperaceae (sedges), while crescent shaped cells are reported in most of the plants (Fig. 7.3). The dumb bell shape results from the elongated guard cells having thin walls at the end but thick wall in the middle. As the cells absorb water, the ends swell but the middle portion remains narrow. The mid regions are pushed apart by the enlarged ends thus opening the stomatal pore. When the guard cells lose water, the ends shrink, the middle region moves together and the pore is closed. The dumbbell shaped is present only when the guard cells are turgid. In other type of guard cells, the cell walls are asymmetrically thickened. The wall adjacent to the pore is thicker than the opposite wall. The changes in shape result from changes in pressure and volume that occur as the water is absorbed from or released to the surrounding. The cells adjacent to guard cells are distinct in shape, size or cell contents and are termed as **subsidiary cells**. The movement of water between guard cells and adjacent cells is controlled by changes in water potential as potassium ions get transported between two cells. In dicots, a small triangular cell continues to undergo variable number of precise divisions to form the guard cells.

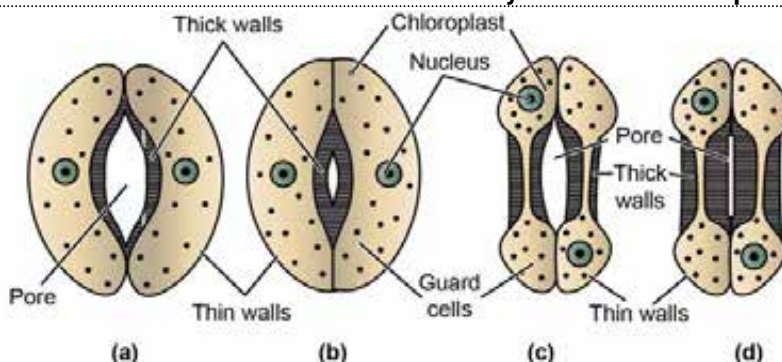


Fig. 7.3: Stomata of Dicotyledonous plants a) open; b) closed and Monocotyledonous plants; c) open; d) closed.

Development of Stomata

Stomatal development has been well characterized in *Arabidopsis*. The ontogeny of stomata shows difference in the development pattern according to the taxon. In most of the species, the development of stomata starts with an initial asymmetric division of protodermal precursor cell which forms two daughter cells. The stomatal lineage is initiated by the division of an undifferentiated post-embryonic epidermal cell which gives rise to two unequally sized daughter cells. The daughter cells are unequal in size and fate. The smaller cell is the stomatal initial or **meristemoid** (Fig. 7.4). Meristemoid usually divide asymmetrically many a times. Each asymmetric division produces a meristemoid and a larger sister cell. The latter can divide or become a pavement cell, the generic type of cell in the epidermis. The meristemoid mother cells (MMCs) are derived from a subset of protodermal cells. MMCs undergo asymmetric divisions to produce small, often triangular-shaped, meristemoids and larger sister SLGCs (stomatal lineage ground cells). Meristemoids carry out additional asymmetric divisions termed amplifying divisions which regenerate the meristemoid and create another SLGC. Meristemoids divide few times and differentiate into a guard mother cells (GMCs) which are recognized by their distinctive rounded morphology. The guard mother cells get connected to the surrounding cells through plasmodesmata. The plasmodesmata disappear when two guard cells are formed after the division of guard mother cell. GMC divides symmetrically producing the two guard cells of a stoma. GMC undergo a single symmetric division and cell fate transition to form a pair of GCs. The SLGCs may differentiate into pavement cells (interdigitated cells that provide the waterproof covering of plant leaves). Amplifying asymmetric divisions in the meristemoid produce sister cells which differentiate into an oval-shaped guard mother cell. Meristemoids and SLGCs continue divisions and this lineage is responsible for generating epidermal cells in the leaves. The meristemoid acts as a stomatal precursor while the latter produces the two cells of the stoma. Spacing divisions take place in cells next to a stoma or precursor. Output estimates suggest that most of the epidermal cells in a leaf are generated by the stomatal lineage. The number of stomata produced depends on the frequency of the different types of asymmetric divisions. If no larger daughter cells divide then only one stoma will be produced per lineage even if there are many amplifying divisions. Stomata are produced by a dedicated and specialised cell lineage including various stomatal lineage cell types such as meristemoids, MMCs, GMCs, SLGCs, GCs.

In monocots the smaller of the daughter cell becomes guard mother cell and undergoes subsequent equal division to form a pair of guard cells.

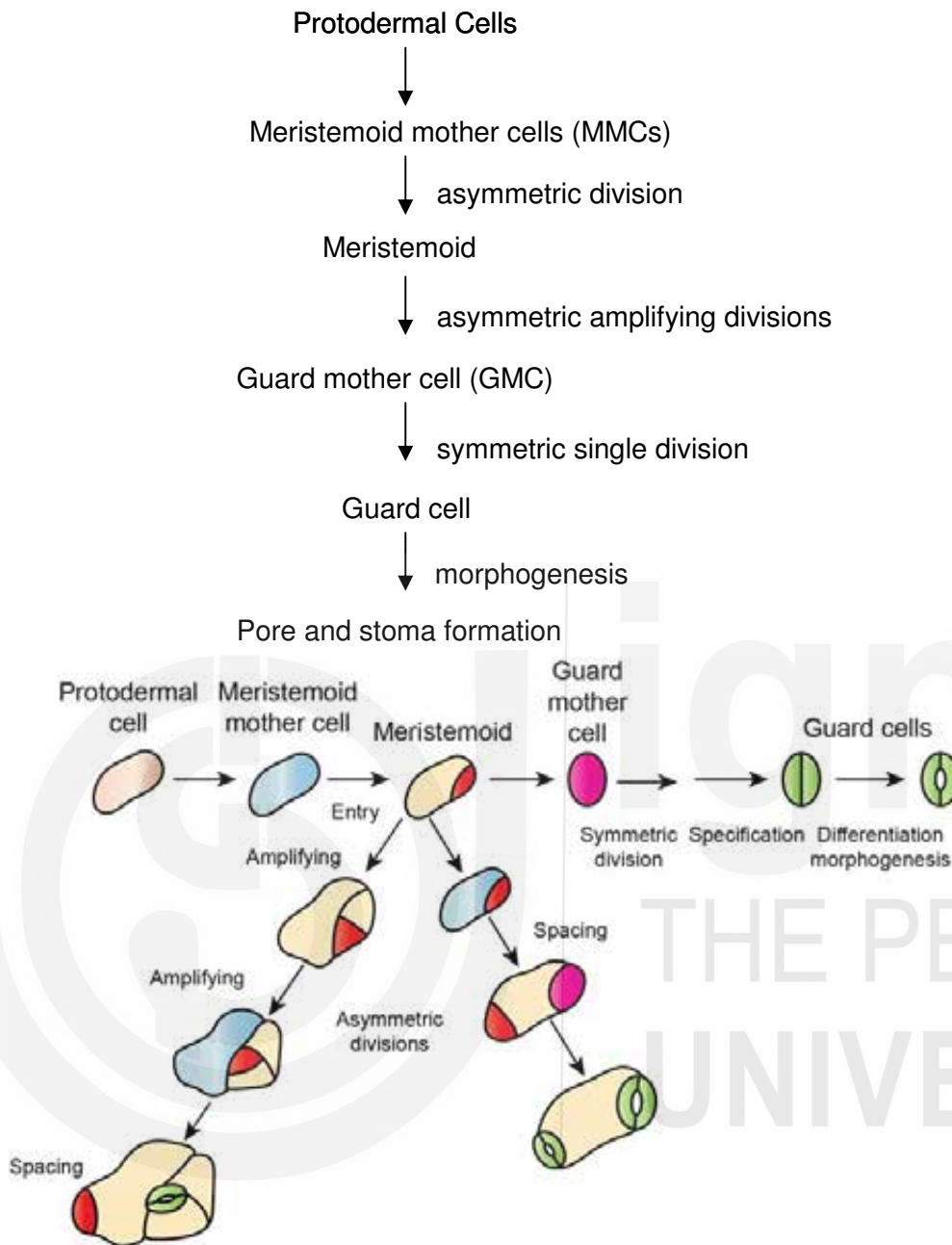


Fig.7.4: Diagram showing stomatal development in *Arabidopsis thaliana*.

On the basis of origin of subsidiary cells, and arrangement of stomata and epidermal cells, the angiosperms stomata can be categorized into different types (see Unit 5).

Stomatal Frequency and Stomatal Index

The number of stomata present on the upper (adaxial) and lower (abaxial) leaf surface show variation. In most of the plant species, high number of stomata is present on the lower surface of the leaf to facilitate exchange of gases. The number of stomata present per unit area of a leaf is called as **stomatal frequency (stomatal density)**. It varies among species (Table 1). Several environmental and genetical factors affect stomatal frequency. These include availability of water, concentration of carbon dioxide, temperature and light intensity. Plants growing in wet soil with high humidity show low stomatal

frequency in comparison to those growing in dry soil with low humidity. The plants growing in water stress conditions generally show high stomatal frequency. The stomatal frequency decreases with decline in light intensity. The plants growing in full sunlight show high stomatal frequency. The degree of ploidy also affects stomatal frequency. Polyploid plants have less stomatal frequency and larger stomata. Stomatal frequency also varies according to position of leaves. High frequency has been found in leaves growing on the top. The decline in stomatal frequency has been noted in plants in response to increase in carbon dioxide concentration. An inverse relationship has been noted between atmospheric CO₂ concentration and stomatal density. Gas exchange gets affected by the abundance of stomata on the leaf surface. The change in stomatal density affects the gas exchange capacity.

Salisbury (1927) proposed the term '**stomatal index**' for the ratio of number of stomata to that of epidermal cells. It is also referred as the proportion of stomata relative to the total epidermal cell number (stomatal index). It is defined as the percentage of number of stomata to the total number of epidermal cells. It can be calculated by using the following equation: $SI = S \times 100 / E + S$, where E is the number of epidermal cells and S is the number of stomata.

Both stomatal index and frequency varies among species. Stomatal density and stomatal index act as indicator of CO₂.

Table 1: Variation in the stomatal index noted in several plant species.

Plant species	Stomatal index
<i>Acacia arabica</i>	20
<i>Albezia lebbek</i>	4.25
<i>Mangifera indica</i>	7
<i>Pongamia glabra</i>	5.17
<i>Syzygium cumini</i>	47.05
<i>Mangolia grandiflora</i>	1.92
<i>Ficus glomerata</i>	10.95
<i>Cassia fistula</i>	9.09
<i>Azadirachta indica</i>	5.26
<i>Murraya paniculata</i>	7.92
<i>Ficus religiosa</i>	45.45

SAQ 1

- a) State whether the statements are true or false.
 - i) Unspecialised epidermal cells are referred as pavement cells. []
 - ii) The number of stomata present on the upper (adaxial) and lower (abaxial) leaf surface are the same. []
 - iii) According to Salisbury Stomatal index is the ratio of number of stomata to that of epidermal cells. []

- iv) The smaller cell which acts as the stomatal initial is called meristemoid. []
- v) Dumb bell shaped guard cells have been found in most dicot plants. []
- b) Fill in the blanks with the appropriate word.
- i) present in the epidermis help in the exchange of gases.
- ii) The guard cells in monocots are shaped.
- iii) Pore in stomata surrounded by specialized cell called
- iv) Pores which allow the gaseous exchange to take place are called
- v) Frequently occurring epidermal cells that have a shape like the interlocking pieces of a jigsaw puzzle are called..... .
- vi) The epidermis of the shoot is derived from layer of tunica.
- vii) Stomatal initial is also called as

7.4 SPECIALISED EPIDERMAL CELLS

Certain families possess some specialised types of epidermal cells which show some uncommon and characteristic features.

7.4.1 Cystoliths

Large epidermal cells which possess a large crystal of calcium carbonate are known as **cystolith**. The cells are complex, stalked and irregularly arranged. These cells protrude into the underlying tissues (Figure 7.5). A papilla of the wall material grows into the cell lumen and then becomes a nucleation site for the calcium carbonate. This often appears pear-shaped in leaf of *Ficus* (Indian rubber). In some cystoliths, the deposition of pectin and silica help in the stabilisation of the calcium deposit. These are the characteristic to the family Acanthaceae, Cucurbitaceae, Moraceae, Urticaceae and Cannabinaceae etc. Usually a single cystolith is present in cell but in some families such as Boraginaceae, group of cystoliths are also found.

Wheat straw contains about 72% silica, rice straw contains about 52% and *Equisetum* about 71%.

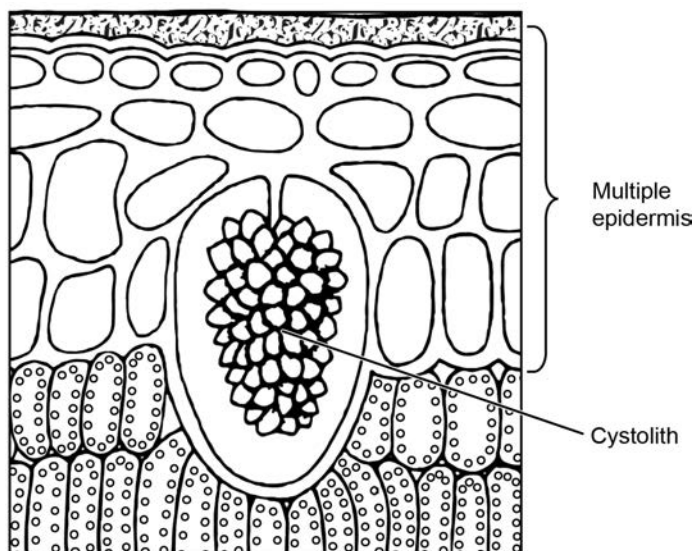


Fig. 7.5: Structure of a cystolith as seen in the epidermal cells of *Ficus elastica*.

Some other types of crystals are also found in plants such as raphides, conglomerate and octahedral and other forms.

Raphides are needle-like crystals occurring singly or in bundles. These are found in plants singly or in bundles. They are commonly found in *Eichhornia*, *Impatiens*, *Pistia* and aroids such as *Colocasia*, *Alocasia*, *Amorphophallus* etc. They are frequently shut enclosed by a cell wall which prevented from coming in contact with protoplasm of the cell.

Conglomerate crystals or sphaero-crystals are clusters of crystals which radiates from a common centre and thus have a more or less star shaped appearance. They are found in *Pistia*, *Colocasia* etc. On the dry scales of onion you can also see octahedral crystals.

7.4.2 Silica and Cork Cells

The epidermis in the grass species contain long and short cells grouped together as pairs. The long cells of the epidermis are like ordinary cells but short cells are modified into silica or cork cells. The silica cells contain silica bodies which can be of various shapes such as round, elliptic, dumb bell. They have taxonomic importance because they are found in few families particularly in monocots. Some the plant families which show the presence of silica cells include Poaceae, Arecaceae, Zingiberaceae, Cyperaceae, Bromeliaceae and Orchidaceae.

The cork cell is non-living and the cell walls are composed of a waxy substance which is highly impermeable to gases and water (Fig. 7.6). The cork cell may be filled with air or may contain traces of lignin, tannins, or fatty acids and may vary in thickness depending upon the species of woody plant. The cork cells have walls encrusted with suberin and their lumen is filled with ergastic substances. The cells are generally arranged in radial rows and are closely packed together. The cork cells are also restricted to some families Equisetaceae, Poaceae, Cyperaceae, Zingiberaceae, Commelinaceae, Urticaceae, Ulmaceae, Cannabaceae, and Fabaceae.

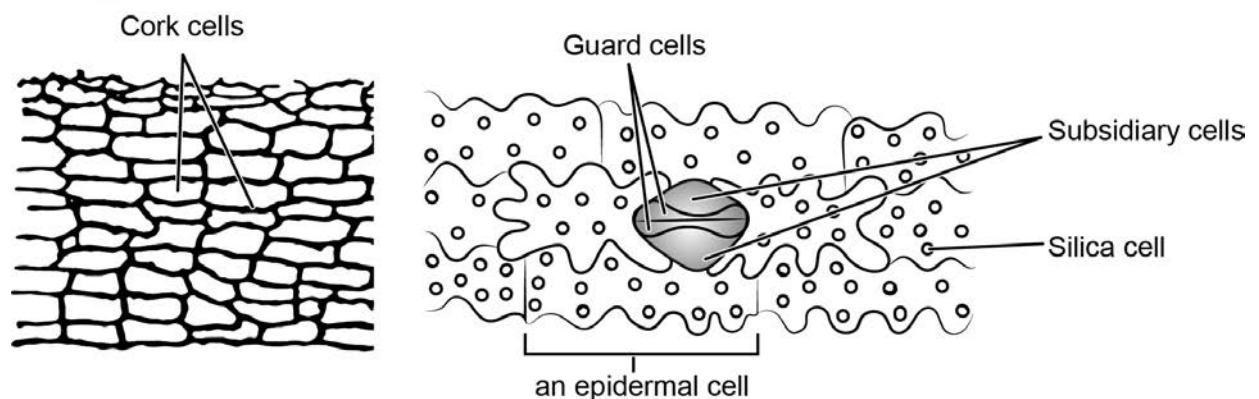


Fig.7.6: Structure of cork cells and silica cells found in the epidermis.

7.4.3 Bulliform Cells

The epidermis of many monocots especially grasses and sedge contains specialized type of cell called bulliform cell. These are large thin walled highly vacuolated epidermal cells arranged in long bands parallel to the length of the

leaf (Fig. 7.7). If these cells are turgid and swollen, the leaf is open and flat. In contrast when they lose water, they become flaccid, the leaf folds minimising the exposed surface area. The primary function of the bulliform cell is the opening of the leaf as it expands from the bud. They function in rolling of leaves in dry, unfavorable conditions and reopening again under conditions when there is no water stress.

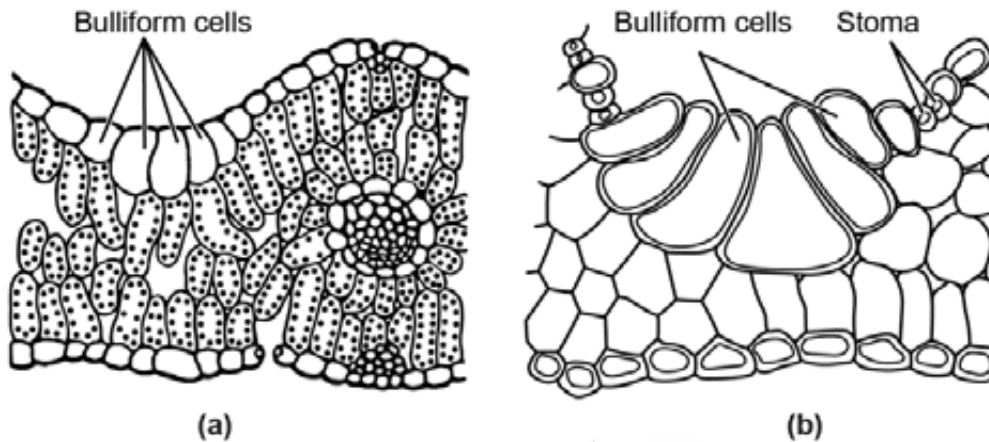


Fig. 7.7: Bulliform cells as seen in *Triticum aestivum*.

7.4.4 Root Hairs

Hairs are specialized epidermal cells present all over the surfaces of plant organs such as roots, stems, leaves, floral parts, seeds (*Gossypium*) and stamens (*Tradescantia*). They can be unicellular or multicellular. In roots of most monocot and dicot plants, they are present at a short distance behind the root tip. In some plants, root epidermal cells grow out to produce hair but in other plants, cells undergo an unequal division and the short dense cytoplasmic cell or the **trichoblast** grows out as the root hair. Trichoblast develops into unicellular root hairs (Fig. 7.8). They can be 70 to 1500 μm long with the diameter ranging from 5 to 17 μm .

They provide high area for absorption of water and nutrients. They remain alive for some time and die after several days of their formation. They get removed from the surface but if remain attached their walls become thick, lignified and suberised.

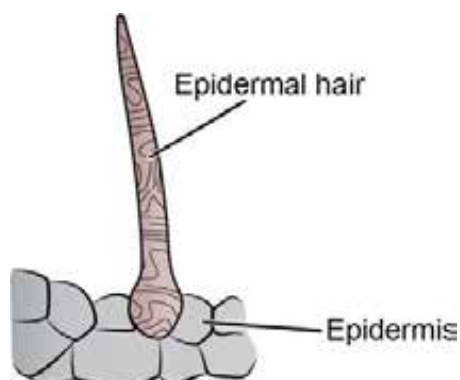


Fig. 7.8: Epidermal region showing the presence of hair.

7.4.5 Multiple Epidermis

In some species, the epidermis is tough, resistant dermal system having many layers of thick walled cells. In some species such as *Piper*, *Ficus elastica* and

Peperomia, epidermal cells store water and the dermal system consists of thin walled cells. In some plants, the epidermal cells are derived from the outermost layers of the tunica which undergo periclinal divisions. This produces a structure with multiple layers of epidermis. All the layers have the same developmental origin. In multiple epidermis, the outermost layer is like uniseriate epidermis containing guard cells, cuticle and waxes (Figure 7.9).

A hypodermis plays a mechanical role in plants. They can be collenchymatous or sclerenchymatous. The presence of hypodermis is common in plants but the occurrence of multiple epidermis is rare. They have been noted in *Chenopodiaceae*, *Moraceae* and *Piperaceae*.

The entire surface is covered with multiple epidermis except at extreme tip region called velamen. The cells in this region are large, thick walled and dead at maturity. Velamen is capable of absorbing and storing water and minerals. The root cortex absorbs water from the velamen.

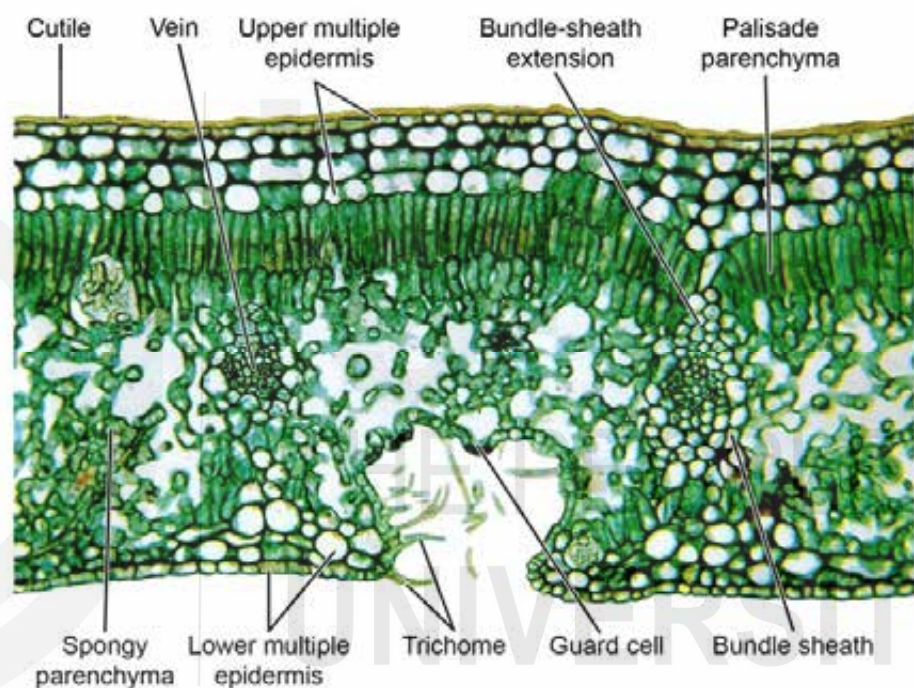


Fig.7.9: Multiple epidermis in xerophytic plant.

SAQ 2

a) Match the following.

Column A	Column B
i) Bulliform cells	a. Dicot plants
ii) Cystolith	b. Non-living and impermeable to gases, water
iii) Crescent shaped guard cells	c. Root hair
iv) Cork cells	d. Number of stomata present per unit area
v) Trichoblast	e. Calcium carbonate crystal
vi) Stomatal frequency	f. Grasses and other monocots

b) Fill in the blanks with the appropriate word.

- i) Large epidermal cells that protrude into the underlying tissues and contain a large crystal of calcium carbonate called as
- ii) provide high area for absorption of water and nutrients.
- iii) is capable of absorbing and storing water and minerals in root cortex.
- iv) The cells that contain silica bodies of various shapes such as round, elliptic, dumb bell are called.....
- v) Monocots especially grasses and sedge contains specialized type large thin walled epidermal cells called
- vi) cell is non-living with cell walls are composed of a waxy substance which is highly impermeable to gases and water.

c) Complete the following sentences.

- i) The epidermis is derived from layer.
- ii) The pore, guard cells and subsidiary cells collectively form the
- iii) Meristemoid mother cells (MMCs) undergo asymmetric divisions to produce
- iv) Guard mother cell (GMC) divides symmetrically to produce meristemoids and
- v) Lithocysts are made up of mineral deposit of
- vi) Cuticle is composed of
- vii) The cell grows into root hair.

d) State whether the statements are true or false.

- i) Epidermis prevents the excessive loss of water but allows gaseous exchange with the external environment. []
- ii) The plants belonging to families Cruciferae, Compositae and Leguminosae accumulate silica grains in the epidermal cell walls. []
- iii) Epidermal cells show periclinal cell division. []
- iv) The stomatal lineage is initiated by the division of an undifferentiated post-embryonic epidermal cell. []
- v) Cystolith generally contains crystal of ammonium oxalate. []

7.5 ROLE OF EPIDERMIS IN PLANTS

Epidermis forms a boundary between the plant and the external environment. Its primary function is protection of the internal tissues against mechanical injury, excessive cold or heat potential pathogens and against the leaching effect of rain.

Protective roles of epidermis- The cuticle present on the epidermal surface provides protection to the plant. It controls the loss of water and also provides an efficient barrier against plant pathogens. The cuticle is waxy in nature and acts as a water-repellent. The cuticle and hairs protect the plant against intense illumination and excessive radiation of heat. Surface wax acts as a moisture barrier and also protects the plant from intense sunlight and wind. It also prevents the excessive evaporation of water from the internal tissues.

Pavement cells form the largest interface with the environment via the cuticle and ensure the protection of the aerial parts of the plant. Specialised and non-specialised epidermal cells provide protection to plant for defense against biotic and abiotic stress. Epidermal cells are tightly linked to each other and provide mechanical strength and protection to the plant. The glandular hairs present in some plants tend to secrete lipophilic substances that prevent animals from consuming the leaves of the plant.

Functional roles - The stomata present on the epidermis helps in the exchange of gases and regulate the movement of water in and out of the plant. Hence the epidermal layer plays a role in process of photosynthesis and transpiration. The cells maintain the moisture by regulating the opening and closing of stomata. The hairs present on the epidermis of roots secrete metabolic compounds and absorbs water and mineral nutrients. Stomata participate together with the cuticle in the regulation of leaf transpiration.

In some of the plants (such as apples and sorghum) the unicellular hairs can secrete mucilaginous droplets which help in maintenance of moisture and ensure that the plant does not dry out. This helps the plant to survive for longer duration. This substance also prevents excessive loss of water from the leaves thus maintaining the moisture content.

7.5.1 Root Epidermis or Rhizodermis

The outermost layer of cells of the root is rhizodermis. This layer is derived from the outermost layer of the tunica. Both root and shoot epidermis develops from two distinct meristems having origin in different parts of the embryo. The precursor of rhizodermal cells are overlaid by other cells. The deep seated rhizodermal cells constitute root protoderm. The root apical initial cells are generally deep seated. Rhizodermal cells possess thin walls, lack cuticle and covered by a layer of mucilage. Rhizodermis contains no stomata, and is not covered by cuticle. Its unique feature is the presence of root hairs. Root hair is the outgrowth of a single rhizodermal cell. They occur in high frequency in the adsorptive zone of the root. Root hair derives from a trichoblast as a result of an unequal division. It contains a large vacuole; the root epidermis does not possess guard cells. The lack of cuticle helps in the transfer of water from the soil to the interior of the plant. After the disintegration of rhizodermis the outer

cortical layer may be converted into an ephemeral protective tissue called exodermis. The layer shows deposition of suberin and related substances within the cells. Exodermis shows suberization and lignification. The layer protects the roots against dessication. The inner layer called endodermis is lignified and suberized (Fig 7.10). The surface of young root is protected by rhizodermis, exodermis and suberized endodermis. Rhizodermis plays an important role in nutrient uptake by the plant roots. It contains no stomata, and is not covered by cuticle.

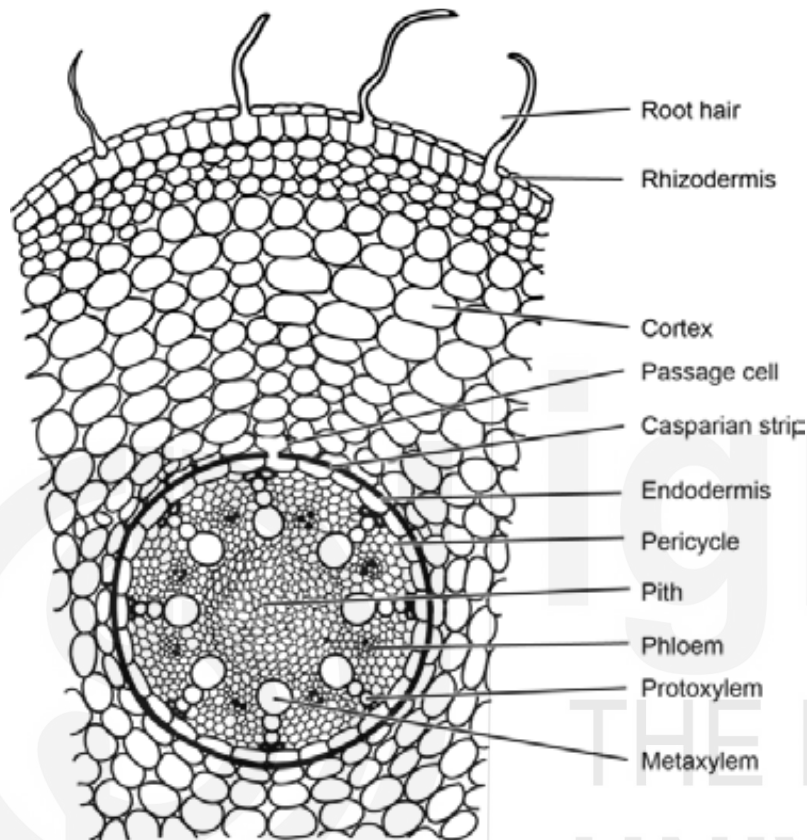


Fig. 7.10: Diagrammatic representation of the rhizodermal region.

7.6 TRICHOMES

Trichomes include the structure projecting out of the plane of epidermis. They are present mainly on the leaves and stem of plants. They arise from the asymmetric division within a single protodermal mother cell. The first division of mother cell is symmetric. More than one initial is involved in the formation of trichome. At maturity, the cells lose protoplast but remain long. The development and differentiation of trichomes is regulated by several factors including phytohormones particularly cytokinins, jasmonic acid and salicylic acid. This has been noted in *Arabidopsis*. They play a very protective role in plants.

7.6.1 Types of Trichomes

They are of two types of Trichomes -Non glandular and Glandular or secretory.

Non-glandular trichomes- These are unicellular. They consist of single cell that project above the surrounding surface. They along with cuticle and waxes

protect the plant from excessive sunlight. Their wall becomes refractile and scatters light. They also provide protection against insects and pests because they can tangle the feet or impale the insect. If small part of the outer wall projects, they are called warts or papillae. Cotton fibers have been considered as long unicellular trichomes of the seed coat. Trichomes can be multicellular. These trichomes can be uniseriate i.e. consist of one row of cells or multiseriate i.e. consist of several row of cells. These can be long or short, branched or unbranched. Stellate (star-shaped) hairs and candelabriform hairs look like complete tree. In some plants they are present as disc shaped or shield shaped structures having a stalk (Fig. 7.11). They are referred as peltate hairs. If the stalk is short, they are called as scales or squamiform scales. The peltate hairs are complex and critically important for taxonomy. They help in the identification of the genus.

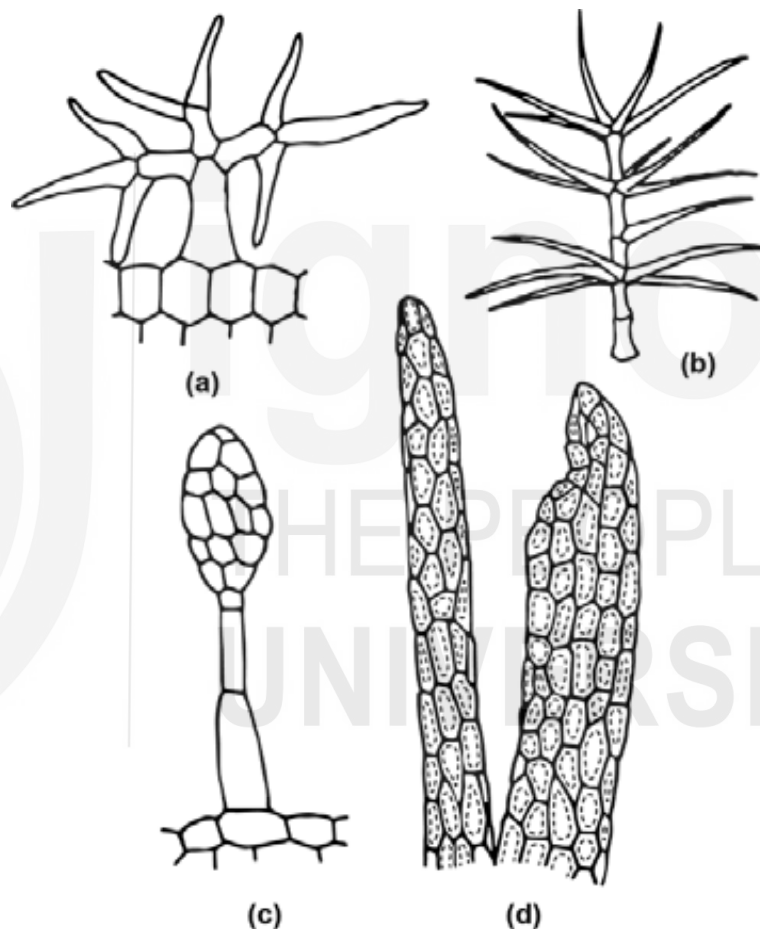


Fig. 7.11: Diverse forms of non-glandular trichomes. a-b) Single-celled trichome; c-d) Multi-shaped trichomes.

Glandular trichomes-These are also structurally similar to that of non-glandular trichomes but are secretory in nature. They have a glandular head elevated by a stalk or neck (Figs. 7.11 and 7.12). They are attached to epidermis by foot cell or basal cell. They are covered by cuticle. They secrete water, salt, adhesives, nectar, mucilage, terpenes etc. The secretory products accumulate below the cuticle and get lifted up from the cellulosic portion of the wall (Fig.7.12). The products can also be released by the tearing of the cuticle. If the trichome is long, the stalk may contain vascular tissue with trachery elements (Fig. 7.13). The plasmodesmata present in the stalk cell facilitate the flow of material to the head.

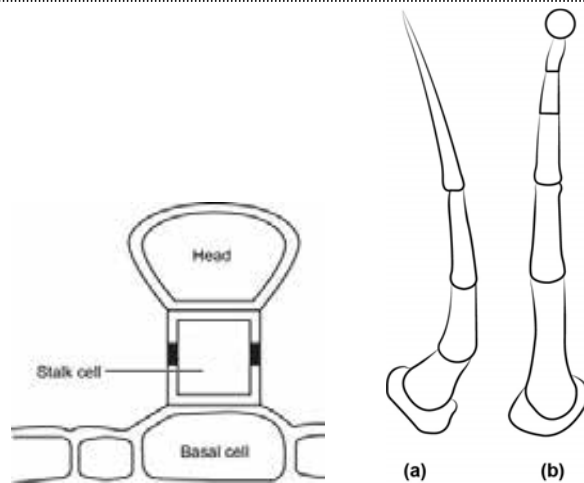


Fig.7.12: Diagrammatic representation of a glandular trichome showing its various parts and Epidermal region showing the presence of trichomes. Diagrammatic representation of a) non-glandular; and b) glandular trichome.

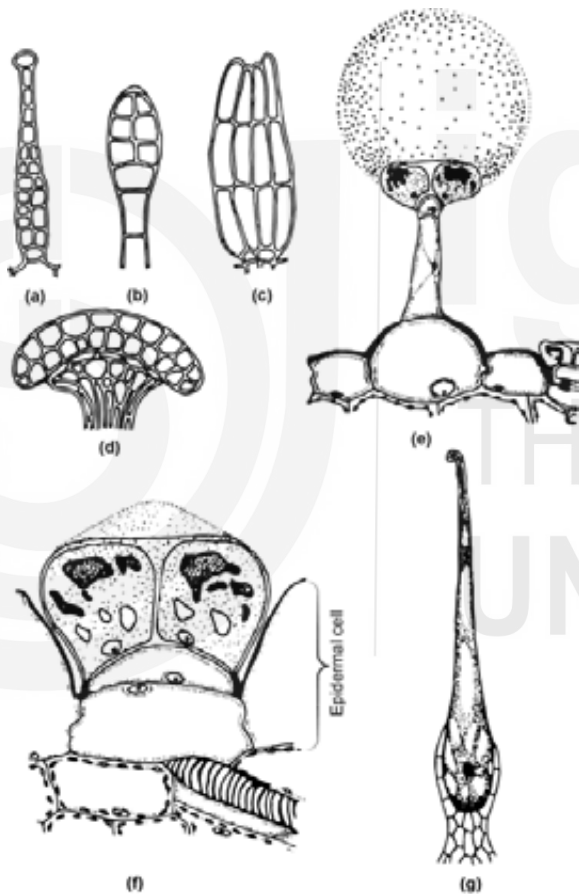


Fig 7.13 a-g): A few forms of secretory trichomes. In a-d and f) note the casparian thickenings; e) a trichome showing head and an stock; g) this glandular trichome is also known as stinging hair and is found in *Urtica*. The single-celled needle-like trichome is surrounded by epidermal cells arranged in a cup-like manner. The tip of the gland readily breaks even on slight touch. The broken portion is very sharp and penetrates the skin and injects its poisonous irritating cell contents containing largely histamines and acctyl choline. (Redrawn from Fahn, 1977).

7.6.2 Functions of Trichomes

Different types of trichomes perform different functions in plants. Some of the known functions of trichomes include:

Protection: Trichomes protect plants from animals and extreme environmental conditions. The trichomes present on the leaf surface acts the first line of defense against biological pests and herbivores. This is done with the help of sharp and stiff hairs (some cucurbits), a dense coating of hair (as in *Gnaphalium*), stinging hairs (as in nettles). Some plants such as *Tragia cannabina* develop stinging hairs which protect the plant from herbivores. When an animal comes in contact with the hair, they break off and penetrate the body of the animal causing irritations.

Glandular trichomes found in *Cannabis* plants secrete a bitter substance and produce a strong aroma that prevents some animals from eating it. The trichomes act as resin glands that produce various oils that protect the plant by acting as deterrents. These substances also provide protection to the plant from extreme conditions and fungal growth.

The non-glandular trichomes form a thick and dense surface covering around the leaves which protects leaves and plants from harsh environmental conditions and pathogens. Apart from these, these trichomes secrete mucilage that traps insects when they come in contact with the plant leaves.

Absorption of Water and Moisture- Non-glandular trichomes found in the roots of the plant support the absorption of water and other minerals. These trichomes exist as tubular structures that grow outwards to absorb water and minerals from the soil.

Other functions of trichomes: These function includes elimination of excess toxic substances and salts (as reported in plants as *Atriplex*), Ephemeral trichomes provide protection to developing buds, waxes protect plants from extreme heat and sunlight while the essential oils from plants such as *Cymbopogon* act as insect repellent. Recently trichome from *Cannabis* (marijuana) has been found to contain a mind altering substance. These chemicals have proven medicinally beneficial to patients. Trichomes develop on the plant with the initiation of its growth and develop fully with its flowering.

Box 7.2: Special Trichomes in *Cannabis*.

In the *Cannabis* plant three types of trichomes have been noted. These include:

- Bulbous trichomes - These trichomes appear as small pointed structures on the surface of the plant. They are small in size and secrete resins.
- Capitate-sessile – These trichomes are bigger in size and develop before the plant starts flowering. They are flattened and contain cannabinoids.
- Capitate stalked trichomes - These are the largest than the other two types and are formed during flowering. They are largely involved in the synthesis of cannabinoids and terpenoid synthesis.

7.7 CUTICLE

The waxy layer covering the outer walls of the cells of aerial organs is referred as cuticle. It is multilayered and covers outer wall of epidermal cells. It is rich in waxes and cutin. The thickness of this layer is usually 1 µm to 15 µm. The layer is impervious to liquid and gases.

The cuticle can be primary or secondary. The primary cuticle is formed when the epidermal cells are in process of expansion while the secondary cuticle forms when the cells have achieved their full size.

The layer of cuticle is made up of a compound called cutin. Cutin is the hydrophobic material deposited on the outer wall of epidermal cells. It is a complex, high molecular weight lipid polyester. It is formed as a result of polymerization of certain fatty acids. It is high molecular weight lipid polyester of long chain substituted aliphatic acids. Cutin contains fatty acids that are 16 carbon (C_{16}) long, some have fatty acids which are 17 carbon (C_{17}) long and those having equal amount of both 16 and 17 carbon long fatty acids. Fatty acids get hydroxylated, esterified and linked to complex polymer to form cutin. The cutin of gymnosperms lack C_{17} monomers. It is synthesized in epidermal cells under the control of specific localized enzymes. The soluble precursors of the cutin pass through plasmalemma into the wall and through channels in the wall. After passing through the cuticle they condense or polymerize into solid form.

The fatty acids are produced by the epidermal protoplasts, apparently the endoplasmic reticulum. The fatty acids migrate outward and begin to polymerize. The cutin forms the matrix surrounding the cellulose microfibrils. The mixture of cutin and wall material forms the cuticular layer. The pure cutin layers forms the cuticle. The process of deposition of cutin in the wall to form cuticular layer is called cutinization. The deposition of pure cutin on the outside of the wall to form cuticle is called cuticularization. In the process the cutin becomes oxidized and polymerized. The cutin layer gets separated from the cellulose wall by a layer of pectin which is rich in pectic substances. In angiosperms, various types of cutin have been noted.

Cuticle is separated from and attached to underlying epidermal cells by a layer which is proteinaceous in nature. Beneath this layer is present cuticular layer which consist of outer lamellae of epidermal cell walls incrustated with cutin. The cuticular layer lacks cellulose but possess pectin and polysaccharides. The cuticle contains embedded wax crystals or bodies and its surface is covered by an epicuticular layer of crystalline or amorphous wax.

Cuticle helps in the retention of the water. Many of the properties of the epidermis such as water proof nature and water retention is because of the cuticle. Because of its shiny and reflective nature, it is capable of deflecting excess solar radiation. It also reflects ultraviolet light thereby protecting the DNA from mutagenic effects of sunlight. Cutin is non-digestable and metabolizable, hence it acts as an excellent protection against fungi and bacteria. These organisms do not possess enzymes capable of digesting it. Though cutin is deposited on the outer wall of epidermal cells, in some plants it may be deposited on the anticlinal and even the periclinal walls in lesser amounts.

Besides cutin, the epidermal cells also show the presence of lignin, silica, waxes or mixture of other materials.

Wax- It is a universal adjunct to the outer wall of epidermal cells. It is a heterogeneous polymer formed from the interaction of long chain fatty acids,

aliphatic alcohols and alkanes in the presence of oxygen. Waxes are formed when fatty acids are elongated and modified. Cuticular wax consists of aliphatic constituents that get readily solubilised by lyophilic solvents. The constituents are based on even numbered carbon chains C_{12} to C_{32} and odd numbered chains from C_{17} to C_{33} . Cyclic compounds including triterpenoids also form major constituent of the waxes. The pectin content of the cuticle in the wall decreases outwardly but forms a continuous layer with middle lamella of the anticlinal walls. The surface of the highly specialised cuticle of stigmatic surfaces of the angiosperm flowers tend to be high in pectin and other carbohydrates. These substances function in pollen recognition and compatibility. Epicuticular waxes are insoluble in water and get weathered away by wind. These are generally found in young leaves.

Epicuticular waxes synthesized in the epidermal cells pass through epidermal cell membrane, cell wall and cuticle to reach the surface. Epicuticular wax decomposition occurs either by diffusion of wax through cuticle or by passage through small pore. Waxes are deposited within the cuticle either intracuticularly or epicuticularly as a thin film or layer on the surface of leaves or other structures. The epicuticular waxes give glaucous appearance to the organ surface. Waxes mainly consist of solid lipophilic substances secreted by nonspecialised epidermal cells. Most waxes get deposited as thin films or crust. Epicuticular wax gets deposited as tubules, platelets, rods, filaments and ribbons. Aggregation of wax on the leaf surface creates hydrophobicity that repels water. Surface wax restricts loss of water through transpiration and in addition avoids entry of air pollutants into leaves and other parts of plants. Two types of waxes have been identified as epicuticular waxes on the surface of the cuticle and intercuticular wax occurs as particles within matrix. The intracuticular waxes are composed of short chain (C_{17}) monomers. Waxes are effective against insects and pests because they can block the insect mouth parts and stick to the claws of the insect feet.

The epicuticular waxes restrict the transcuticular movement of water. The cutin and wax layers being highly hydrophobic control water loss and water soluble materials through the epidermis. Thickness and surface texture of waxy layers influence their effectiveness as barriers to water loss. Xerophytes possess thick cuticles and heavy waxy layers to control loss of water.

SAQ 3

- a) Answer in one word.
- i) Epidermal region present in the roots.
 - ii) The waxy layer covering the outer walls of the cells of epidermis.
 - iii) The outer wall of epidermal cells is covered with heterogeneous polymer formed from long chain fatty acids.
 - iv) The epidermal layer that lacks cellulose but possess pectin and polysaccharides.

- b) State whether the statements are true or false.
- i) Trichomes arise from the symmetric division within a single protodermal mother cell. []
 - ii) Rhizodermis plays an important role in nutrient uptake by the plant roots. []
 - iii) Non-glandular trichomes form a thick and dense surface covering around the leaves which protects leaves and plants from harsh environmental conditions and pathogens. []
 - iv) Cutin is the hydrophilic material deposited on the outer wall of epidermal cells. []
 - v) Cutin is a complex, high molecular weight lipid polyester formed as a result of polymerization of fatty acids. []
- c) How are trichomes important from the taxonomic point of view in plants?
-

7.8 SUMMARY

- The dermal tissues namely rhizodermis and epidermis are present in the plant body. Epidermis forms the protective layer in plants. This layer defends or guards the plants against mechanical damage, pathogens and other harmful agents. In roots outer layer called rhizodermis is reported. This layer regulates the loss of water, movement of substances and exchange of gases.
- Epidermis mainly consists of ordinary epidermal cells, stomatal guard cells, accessory cells and trichomes. Certain specialized cells are also present in the epidermis. The large epidermal cells that protrude into the underlying tissues and contain a large crystal of calcium carbonate and form the complex crystal which is called a cystolith. Silica and cork cells are found in the epidermis of monocots especially grass species. The epidermis of many monocots contains specialised large thin walled epidermal cells called bulliform cells. These are arranged in long bands parallel to the length of the leaf. They assist in the opening of the leaf.
- Trichomes are the structures projecting out of epidermal plane. They play a protective role in plants. They are of two types - glandular (secretory) and non-glandular. The glandular trichomes have a glandular head elevated by a stalk or neck. They are attached to epidermis by foot cell or basal cell. They are covered by cuticle and secrete water, salt, adhesives, nectar, mucilage, terpenes etc. Non-glandular trichomes are unicellular. They provide protection against sunlight, insects and pests. Trichomes can be multicellular, uniseriate, multiseriate, long, short, branched or unbranched.
- Cuticle is the layer covering the epidermis and provides the protection to the epidermis. It is rich in waxes and cutin. The layer is made up of cutin which is a hydrophobic material. It is a complex, high molecular weight lipid polyester that results from the polymerization of certain fatty acids. The cuticle protects the plant from excessive sunlight and helps in the retention of the water.

7.9 TERMINAL QUESTIONS

1. Epidermis performs various functions in plants. Justify the statement.
2. Differentiate between :
 - a) Glandular and Non-glandular trichomes
 - b) Paracytic and Dicytic type of stomata
 - c) Stomatal frequency and Stomatal index
3. Describe the composition of cuticle layer found in epidermis.
4. How are bulliform cells different from silica cells?
5. Trichomes play an important role in defense of plants. Explain the statement.

7.10 ANSWERS

Self-Assessment Questions

1.
 - a) i) True; ii) False; iii) True; iv) True; iv) False
 - b)
 - i) Stomata
 - ii) Dumb bell shaped
 - iii) Guard cells
 - iv) Stoma
 - v) Pavement cells
 - vi) Outermost
 - vii) Meristemoid
2.
 - a)
 - i) Bulliform cells - Grasses and other monocots
 - ii) Cystolith - Calcium carbonate crystal
 - iii) Crescent shaped guard cells - Dicot plants
 - iv) Cork cells - Non-living and impermeable to gases, water
 - v) Trichoblast - Root hair
 - vi) Stomatal frequency - Number of stomata present per unit area
 - b)
 - i) Cystoliths
 - ii) Root hairs
 - iii) Velamen
 - iv) Silica cells
 - v) Bulliform cells
 - vi) Cork cells

- c) i) the outermost layer of the tunica
 ii) stomatal complex
 iii) small, often triangular-shaped, meristemoids and larger sister stomatal lineage ground cells (SLGCs)
 iv) two guard cells of a stoma.
 v) calcium carbonate
 vi) 16 and 17 carbon long fatty acids
 vii) Trichoblast
- d) i) True; ii) False; iii) False; iv) True; v) False
3. a) i) Rhizodermis ii) Cuticle
 iii) Wax iv) Cuticle
- b) i) False; ii) True; iii) True; iv) False; v) True
- c) The trichomes present on the epidermal surface of plants show variations in structure. They may be present as unicellular or multicellular structures, uniseriate (consist of one row of cells) or multiseriate, long or short, branched or unbranched. In some cases they may have wall projections called as warts or papillae. In some plants they are present as disc shaped or shield shaped structures having a stalk. They are referred as peltate hairs. If the stalk is short, they are called as scales or squamiform scales. The type and structure of trichome is characteristic of each family, hence can be used as important tools in taxonomy. They help in the identification of the genus.

Terminal Questions

1. The major functions of epidermis are :
- It controls the movement of water in and out of the plant.
 - It allows the exchange of gases
 - It protects the plant against harmful effect of solar radiation.
 - It acts the first line of defense against biological pests.
 - It also provides defense against non biological agents such as wind and water.
 - It also maintains the moisture absorption by the cells that regulate the opening and closing of leaves.
2. a) Non-glandular trichomes - These consist of a single cell that project above the surrounding surface. They protect the plant from excessive sunlight. They also provide protection against insects and pests. These trichomes can be uniseriate, multiseriate, long, short, branched or unbranched.

Glandular trichomes-These are also structurally similar to non-glandular trichomes but are secretory in nature. They have a glandular head elevated by a stalk or neck. They are attached to epidermis by foot cell or basal cell. They are covered by cuticle. They secrete water, salt, adhesives, nectar, mucilage, terpenes etc. The secretory products accumulate below the cuticle and get lifted up from the cellulosic portion of the wall.

- b) Paracytic type - In this type, each guard cell is accompanied by one or more subsidiary cells that are aligned parallel with it. These occur in the families Convolvulaceae, Leguminosae and Rubiaceae.

Diacytic type (Caryophyllaceous type) - There are two large subsidiary cells that completely surround the guard cells and are aligned perpendicular to them. These are found in the families of Acanthaceae and Caryophyllaceae.

- c) The number of stomata present per unit area of a leaf is called as **stomatal frequency (stomatal density)**. Several environmental and genetical factors affect stomatal frequency.

The ratio of number of stomata to that of epidermal cells is referred as **Stomatal index**. It is also represented by the proportion of stomata relative to the total epidermal cell number.

3. Cuticle covers outer wall of epidermal cells. It is made up of waxes and cutin. The cuticle proper contains embedded wax crystals or bodies and its surface is covered by an epicuticular layer of crystalline or amorphous wax. Beneath this layer is present cuticular layer which consist of outer lamellae of epidermal cell walls incrustated with cutin. The cuticular layer lacks cellulose but possess pectin and polysaccharides. Cutin is the hydrophobic material deposited on the outer wall of epidermal cells. It is a complex, high molecular weight lipid polyester that results from the polymerization of certain fatty acids. It helps in the retention of the water. The continuous secretion leads to build up of cutin layer on the surface of outer wall. The cuticle is responsible for giving epidermis many of the properties such as water proof nature and water retention. Because of its shiny and reflective nature, it is capable of deflecting excess solar radiation. Cuticular wax consists of aliphatic constituents and cyclic compounds including triterpenoids which also form major constituent of the waxes. Epicuticular waxes are insoluble in water and get weathered away by wind. Both cutin and wax layers being highly hydrophobic control water loss and water soluble materials through the epidermis.
4. Refer to Section 7.4.
5. Refer to Section 7.6.

Acknowledgements for Figures

Fig 7.9 : <https://i.pinimg.com/originals/0f/0b/7f/0f0b7f260cdf52502596a9ad09b8570e.jpg>

UNIT 8

ADAPTIVE FEATURES IN PLANTS

Structure

8.1	Introduction	8.5	Adaptation in other plants
	Objectives		Alpine Plants
8.2	Adaptation		Epiphytes
8.3	Adaptations in Hydrophytes		Insectivorous Plants
	Morphological Adaptations		Halophytes
	Anatomical Adaptations	8.6	Summary
8.4	Adaptations in Xerophytes	8.7	Terminal Questions
	Morphological Adaptations	8.8	Answers
	Adaptations in Leaves		
	Anatomical Adaptations		
	Other Adaptations		

8.1 INTRODUCTION

In the previous units you have studied various aspects related to development of plants and protective features of plants, now you will study about adaptive features of plants. As you all know that plants grow in different habitats. They possess certain characteristics that help them to survive in different types of habitats. The features which make plants to adapt different types of environments are known as adaptations. These include changes in structural, morphological and anatomical characteristics. The modifications help the plant species grow and survive in a particular environment. The present unit discusses about the various adaptations seen in plants growing in water bodies (hydric) and dry/arid land (xeric) habitat such plants are called hydrophytes and xerophytes respectively. A special type of adaptations such as those prominent in mangroves have also been included in this unit.

Objectives

After studying this unit you would be able to :

- ❖ describe and differentiate types of adaptations in hydrophytes;

- ❖ describe different types of adaptations in xerophytes;
- ❖ specific adaptive features found in mangroves; and
- ❖ know other prominent adaptive features in plants.

8.2 ADAPTATION

Any plant is able to survive and reproduce in any environment because of certain adaptations. Adaptation is defined as any modification in structure of an organism that promotes its survival in a particular habitat. This mainly includes morphological modifications, histological changes in cells and tissues and physiological specialisations. These changes are heritable and result from the evolutionary change. Such adaptations ensure the survival of plants under conditions of intense sun, shade, cold, heat, wind, humidity, dry and wet conditions. The adaptation to a particular habitat or environmental condition influences the conduction of food, water and rate of transpiration. Adaptations are also supposed to protect plants from insect /pathogen attacks, grazing and allow abscission or dormancy of organs under unfavorable conditions. example - formation of spines in cacti and roses protect the plant from being eaten by grazing animals.

The plants growing in areas having abundant soil, water, humidity are termed as **mesophytes** and are found in the temperate areas. Some other species are found growing in the regions with good water supply and humid conditions, these plants are known as **hydrophytes**. They grow on the surface of water or submerged at various depths. These plants do not need to conserve water, hence possess features that enhance absorption of light, and provide efficient exchange of gases between plant and the surroundings. In some regions there is scarcity of water, the plants which grow in these conditions are known as **xerophytes**. These plants inhabit regions such as deserts, semi deserts, topical shrub and savannah communities and other dry places. The plants growing in xerophytic conditions possess xeromorphic features which enable them to survive such harsh conditions and possess an ability to conserve water. The adaptations in these plants are primarily related to storage and transport of water, and prevention of water loss. You have already studied in details about these plants in unit 4 of ecology course

Besides the changes in the structural features, some plants have also shown the alterations in the production of compounds such as essential oils, resins, alkaloids and many other such chemical compounds.

8.3 ADAPTATIONS IN HYDROPHYTES

Hydrophytes are the plants that float on the surface of water or live completely or partly submerged in water. In completely submerged plants the leaves or flowers project out of the water. Hydrophytes are of three different types of namely free-floating, submerged and emergent. In hydrophytes most of the adaptation are because of high water content and deficient supply of oxygen. These adaptations includes :

- i) Reduction in protective tissue;
- ii) Reduction in supportive or mechanical tissue;
- iii) Reduction in absorbing tissue; and
- iv) Development of air chambers.

Hydrophytes can be of different types- free-floating, submerged and emergent.

8.3.1 Morphological Adaptations

Free-floating plants

In free floating plants or amphibious plants leaves are flat and contain air spaces that give the buoyancy to the plant. Because of this feature the leaves float on the surface of water. The leaves have a thin layer of epidermis because the plants do not need to conserve water to maintain water balance within the plant. The leaves trap sunlight to carry out photosynthesis. In some species such as *Trapa*, *Pistia* and *Hydrocharis*, leaf petiole or the base forms a bladder-like swelling (Figure 8.1). In *Eichhornia*, the whole petiole may be swollen into a bulbous spongy float. These flat surfaces mainly consist of spongy parenchyma and help in floating of plant.

Roots are poorly formed or absent. In many species, adventitious roots are present which are shorter and less branched e.g. *Salvinia*, *Eichhornia* and *Pistia*.

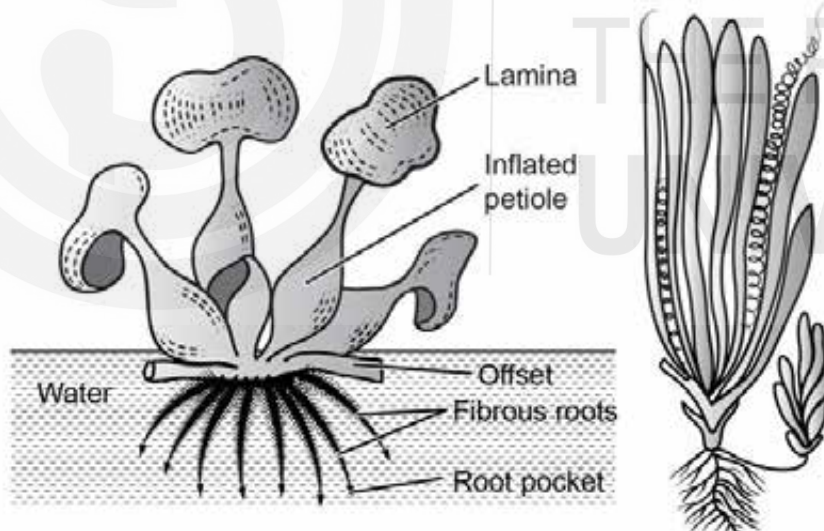


Fig. 8.1: Plant structure in free floating hydrophytes such as *Eichhornia* and *Vallisneria*.

Submerged plants

In these types of plants roots are thin, poorly developed and short. This is because they are not required to absorb large amounts of water. The roots are found embedded in the soil. Example- *Nymphaea*, *Nelumbo*. Root hairs are absent in most species.

Stem is long slender and flexible in submerged plants, e.g., *Hydrilla*, *Potamogeton*. The tough and woody-rhizomes have been found in *Cyperus*,

Scirpus, *Typha* etc. A well developed rhizome has been noted in rooted plants with free floating leaves in *Nymphaea*, *Nelumbo*, and *Pontederia*. Leaves in completely submerged plants are thin, long and ribbon like or finely dissected. e.g. *Vallisneria* (Fig. 8.1) and *Potamogeton*. In partly submerged plants, leaves are wide/broad, floating on the surface of water which increases the surface area for absorption of sunlight required for photosynthesis and evaporation. The petioles or the leaf-bases remain slender and elongated. The bifurcations in the leaf increase the surface area for the absorption of nutrients, exchange of gases such as carbon dioxide. The linear and the finely divided leaves have a higher surface area/volume ratio and offer less resistance to water currents. Mechanical tissues such as angular collenchyma found along the margins of finely divided or ribbon-shaped leaves help in resisting tearing stress.

Heterophylly is the phenomenon commonly noted in submerged hydrophytes (Fig. 8.2). The different forms of leaves are produced on the same plant. Entire, rounded or slightly lobed floating aerial leaves are found along with linear, ribbon-shaped or finely dissected submerged leaves. e.g. *Sagittaria sagittifolia*, *Limnophila heterophylla* and *Ranunculus* sp.

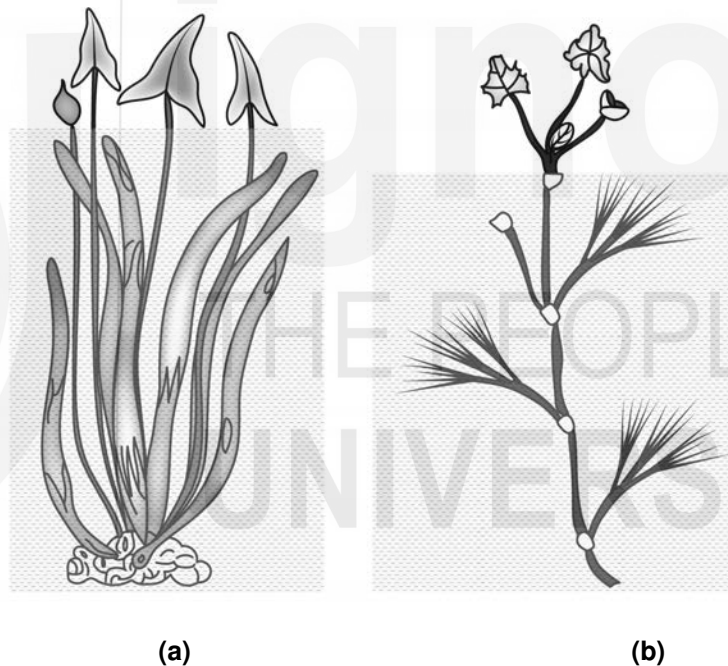


Fig.8.2: Heterophylly as seen in a) *Sagittaria*; and b) *Ranunculus*.

Emergent plants

Plants which are well rooted with stiff stem standing above the water surface are called emergent plants. Their stems, flowers, and leaves rising above the water (Fig. 8.3). Their roots grow in the mud or soil underwater and leaves or spikes grow through the surface up into the air. They can be small with two inches in height to as big as 6 feet. They get their nutrients exclusively from the soil. These plants grow in shallow areas and are usually found along the banks of ponds or lakes or shallow marshy areas. Example cattails. In these vascular hydrophytes, a significant proportion of biomass is represented by the underground parts i.e. rhizome, roots, bases of the aerial shoots. In *Typha* more than 50% of the biomass can be accounted by the roots. They can grow from tubers or from roots.



Fig. 8.3: Structure of emergent plant *Typha latifolia*.

8.3.2 Anatomical Adaptations

In free floating plants, roots develop chloroplasts in their epidermal and cortical cells which trap light and contribute in photosynthetic activity. Root hairs are absent. Stem is slender or thick, short and spongy for example *Eichhornia*. The stem has little or no lignin tissues. The hollow stem provides buoyancy to the plant and provides space for storage of gases such as carbon dioxide and oxygen. The vascular tissue like xylem is very poorly differentiated because there is no requirement for water transport. Water can directly enter the leaves and stem via osmosis. The cells of leaf and stem possess intercellular air spaces called lacunae or **aerenchyma**.

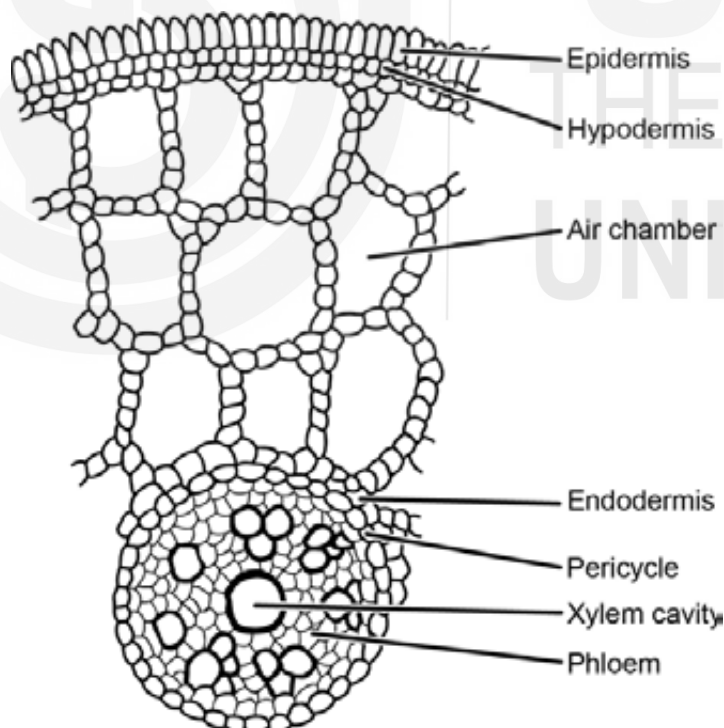


Fig. 8.4: T.S. of *Hydrilla* stem showing presence of aerenchyma.

These are small air pockets and assist in the exchange of gases such as oxygen and carbon dioxide (Fig. 8.4). The air spaces also help in maintaining buoyancy in the cell. The plants retrieve gases via diffusion and dissolution in water. Exchange of gases takes place through diffusion. The gases diffuse from the leaves into aerenchyma of the stem. The gaseous exchange allows the plant to float and survive in the aquatic environments.

The epidermal cells possess chloroplast which increases absorption of light and the photosynthetic potential. Cuticle and stomata are poorly formed or absent. Thick waxy cuticle if present around/on the stomata facilitates transpiration and protects stomata. Stomata are mostly absent or if present are non-functional. Stomata are found mostly on the upper side of the leaf in submerged species and remain open because there is no need to conserve water as the water is available abundantly.

Hairs present on the leaves protect the leaf surface from getting wet. Accumulation of mucilage on the aerial organs protects them from getting too wet. Mucilage also prevents rapid diffusion of water through the cell wall.

Vascular system (xylem or phloem tissues) of stem and roots is not well developed. This is because that the plants are constantly surrounded by water. They can absorb the water through their leaves and stems by osmosis, hence do not require xylem and phloem for the transport of water. Vascular tissues are reduced but present consist of few vascular elements/bundles towards the periphery. Hence the supporting and conducting tissues are poorly developed.

The secondary growth which correlates with the increasing thickness of stems and roots is completely absent.

8.4 ADAPTATIONS IN XEROPHYTES

Plants growing in dry habitats are referred as xerophytes. These plants have certain morphological and physiological features that enable them to survive in dry habitats. Xerophytes have been categorized into three types:

- **Drought escaping species** – Species with a compressed growth cycle. i.e., they complete their vegetative and reproductive growth within short period of time.
- **Drought evading species**- The plants species which possess the means to reduce water loss. These include specialised structures or features such as extensive root system.
- **Drought enduring species**- The plants which can survive even in the conditions of reduced water uptake or availability. These plants show rolling of leaves, loss of leaves or changes in leaf angle.

8.4.1 Morphological Adaptations

The leaf blades, pinnae and pinnules of xerophytic plants are smaller in size and more compact. The flora is microphyllous. Presence of microphyllous leaves reduce the rate of transpiration. If the leaves are microphyllous, they are present in more numbers. Due to microphyly, the smaller leaf blade leads to less heating of leaf surface when exposed to strong intensity of light. In plants such as *Ephedra*, the reduction in the size of the leaf blades is such that only vestigial part is visible. In plant species in which leaf blades are lost, the photosynthetic function is taken over by the expanded petioles (phyllodes) or stems or both. In some plants, the leaf petiole become flattened and widened so that it looks just like a leaf and perform the function of leaf. It is called a phyllode. They develop the ability to photosynthesize and function as foliage. Examples include *Acacia auriculiformis*, *Acacia mangium*, *Parkinsonia aculeata* etc.

The plants possess long tap root system that penetrates deep into the soil. The extensive root system also helps the soil in retaining water. The production of extensive root system increases the absorptive capacity of the plant but reduces the exposure of the plant to the atmosphere. Many desert plants develop adventitious roots which are deep and capable of absorbing even the little amount of available water present in the moist subsoil.

Succulents are plants in which organs become smaller and fleshy due to accumulation of water. The bulk of the plant body is composed of water storing tissues. Water stored in these tissues is used during the period of water scarcity. In cacti, leaves are reduced to spines but stem gets modified into fleshy and spongy structures (Fig. 8.5). Leaf succulents include species such as *Sedum*, *Aloe*, *Mesembryanthemum*, *Kleinia* and several members of family *Chenopodiaceae*.

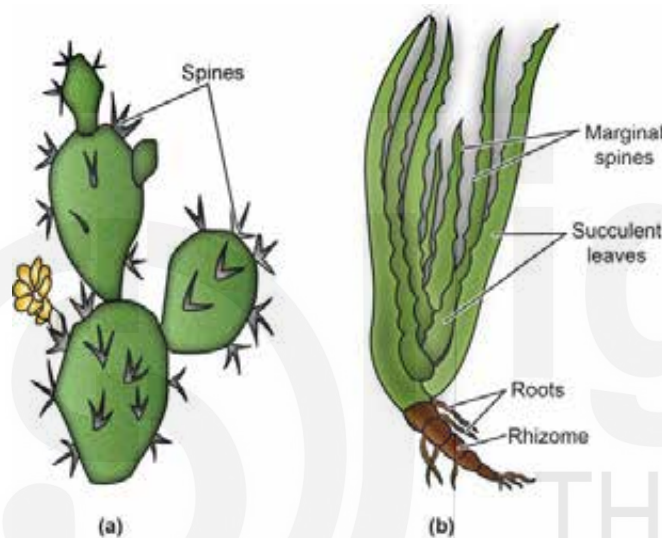


Fig. 8.5: Structural features of xerophytes such as *Opuntia* and *Aloe*.

In some xerophytes, the undersurfaces of the leaves are covered with thick mats of hairs. These hairs protect the stomatal guard cells and check the transpiration. The xerophytes having hairy covering on the leaves and stems are known as trichophyllous and the condition is referred as trichophylly e.g. *Zizyphus*, *Calotropis*, *Banksia* and *Nerium*, etc.

In many xerophytic grasses the leaves roll under dry conditions. In these grasses, the stomata are present on the ventral surface of the leaf. The air enclosed by the rolled leaf soon becomes saturated with water for example- *Ammophila*, *Erica* and *Spartina*.

The leaves of some xerophytes contain enlarged epidermal cells that occur in longitudinal rows. These cells store water. These cells are called as bulliform cells. You have studied the structure of these cells in unit 7 sub-section 7.4. In conditions of water loss they lose their turgidity, constrict upon themselves and causing the leaf lamina to fold inwards edge to edge. The entire upper leaf surface forms a barrier to prevent water loss.

8.4.2 Adaptations in Leaves

Some major changes in anatomical features of xerophytes include reduction in size of the leaf, increase in thickness of outer walls of epidermis, increase in

thickness of cuticle, increase in density of trichomes, reduction in stomatal pore area, increase in cell wall lignifications, increase in succulence and accumulation of mucilage. The formation of thin, linear leaves noted in members of family Ericaceae is referred as **ericoid**. The leaves of some dicots show broad lamina and become increasingly leathery. The leaves show increase in cutinisation and lignification and hence are known as **sclerophyllous** or coriaceous. The leaf is thick and possesses lignified cell walls and cutinised epidermal cell walls. The leaf show extensive development of palisade parenchyma in the mesophyll region.

Xerophytic plants having succulent leaves show storage of water and show the presence of mucilagenous substances. The storage cells are large, thin walled and colorless. The plants show Crassulacean acid metabolism (CAM) which promotes photosynthesis in hot arid environments. The stomata open in the evening and close during the day as a means to conserve water. There is no carbon dioxide fixation during the time of high radiance. In some plants, the body structure and function vary according to the availability of water. These plants are referred as **poikilohydric** plants. The cells, tissues and organs of these plants remain viable following the periods of dehydration and are called as **resurrection** plants. The leaves of these plants shrink in size and curl. This is because of the leaf epidermis become wrinkled and the shrinkage is associated with the contractibility of the xylem elements. In cases of extreme dryness, loss of chlorophyll in the cells has also been seen.

8.4.3 Anatomical Adaptations

In xerophytic plants, more number of stomata is found towards the midrib in comparison to margins. In the leaves of xerophytes the cells are small in size with small vacuoles. Cells having a larger proportion of protoplasm and consequently smaller vacuole are least distressed by loss of water and are also protected against injury. The protoplast of these cells protected against injury by the extraordinarily firm nature of the cell vacuoles which resist desiccation.

In many xerophytes, the epidermis is multilayered, heavily cutinized and waxy to provide greater resistance to desiccation under extreme dry conditions. The closure of stomata is coupled with cutinization of the epidermal cells. Plants of this type are referred as sclerophylls (hard leaved). The thick cuticle prevents the breakage and consequent damage to the leaves. Heavily cutinized leaf surface reflects much of the sun's rays, thereby reducing transpiration through reduced heat absorption.

Xerophytes show a greater density of epidermal hairs on one or both surfaces of the leaves. Hairs increase the rate of cuticular transpiration but reduce the transpiration by reflection of large proportion of incident light. They act as a mechanical barrier to keep the air currents away from the stomatal surface.

The presence of sunken stomata (Fig.8.6) i.e., presence of stomata in cavities below the level of epidermal surface has been noted commonly in the xerophytes. The compactly packed palisade cells have been found located beneath the upper and lower epidermis. They help in reducing water loss via transpiration.

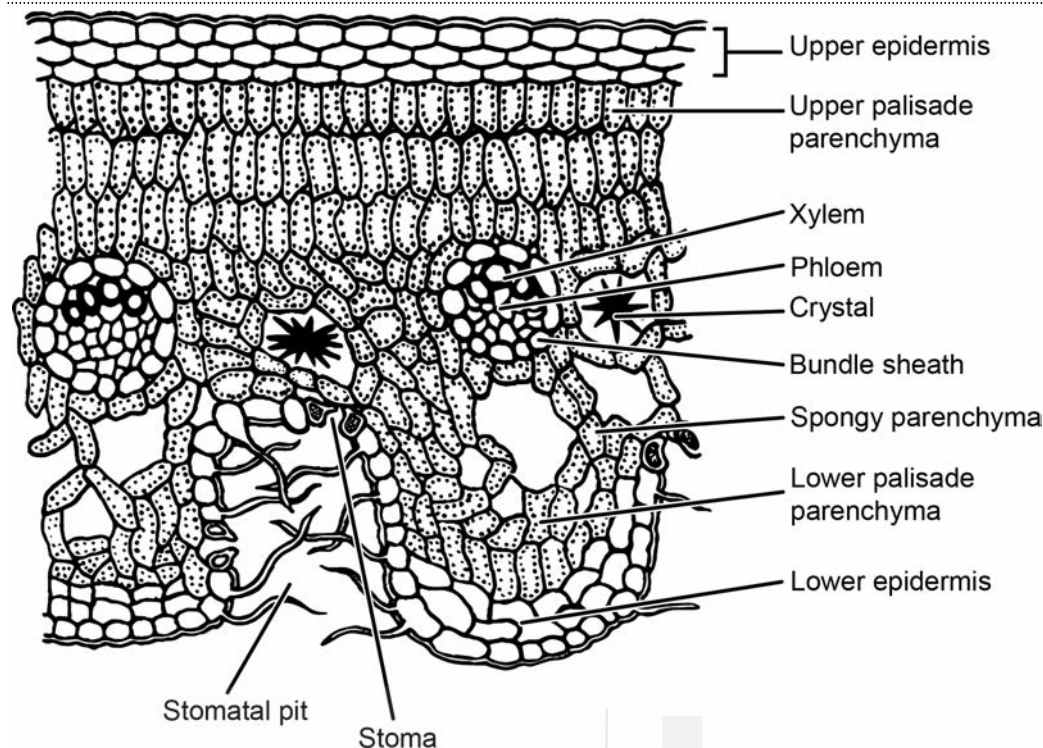


Fig. 8.6: The section of xerophytic leaf showing the presence of sunken stomata.

The reproductive structures such as buds, spores, zygotes and seeds generally lack vacuoles which help them to survive through drought condition.

8.4.4 Other Adaptations

Xerophytes possess the potential to withstand considerable dehydration up to 50% of their dry weight. These plants tolerate protoplasmic desiccation by changing the colloidal chemical state of the protoplasm. The cells possess high osmotic pressure and a very high water-potential (100-150 atm). This is because of high solute content of the soil. The cell walls exhibit little or no elasticity. Rigid and inelastic cell-wall structure prevents cellular collapse under water-stress conditions and influences the water-holding capacity of the cell. This feature enables plants to adapt themselves to drought conditions and provide resistance to water loss through transpiration. The stomata are also closed during the day.

The leaf-shedding noted in some xerophytes provides a means of enduring transpiration. Xerophytes possess the capacity to change the position and form of leaves so that the amount of light received per unit area generally becomes less. The leaflets of many plants fold upwards in such a manner that only approximately half the leaf-surface is exposed to air. The leaves of some plants roll or fold lengthwise along the longitudinal furrows in their upper surface. This happens due to changes in turgor movements caused by loss of water in enlarged colorless cells known as bulliform cells (motor cells) (Fig. 8.7). This phenomenon has been observed in species of family Ericaceae. In certain erect and shrubby xerophytic plants, the leaf blades are permanently oriented in a vertical position.

The light green color of xerophytic plants reflect light rays to prevent more light being absorbed and converted into heat, raising the temperature of the leaf

thus promoting rapid transpiration. In extreme water-deficient conditions, the photosynthetic efficiency is considerably reduced. Xerophytes have more intense assimilation rate than other plants for their palisade cells and chloroplasts are better developed and also can only function part-time because of the restriction of their activity during periods of water-deficit. The cell metabolism changes in conditions of desiccation.

The thickened cell walls, formation of protective coverings might be due to accelerated conversion of polysaccharides into their anhydrous forms. In xerophytes conducting vessels are well developed and the heavily thickened vessels are more numerous, larger in diameter and longer. The lignification of the vessels has been noted in xerophytes. Annual growth rings are more pronounced in these plants. Lignified bast fibres and sclerenchyma have also been found to be present abundantly in xerophytes.

The gelatinous coating on the cell walls of the blue-green algae helps in maintaining hydration in cells

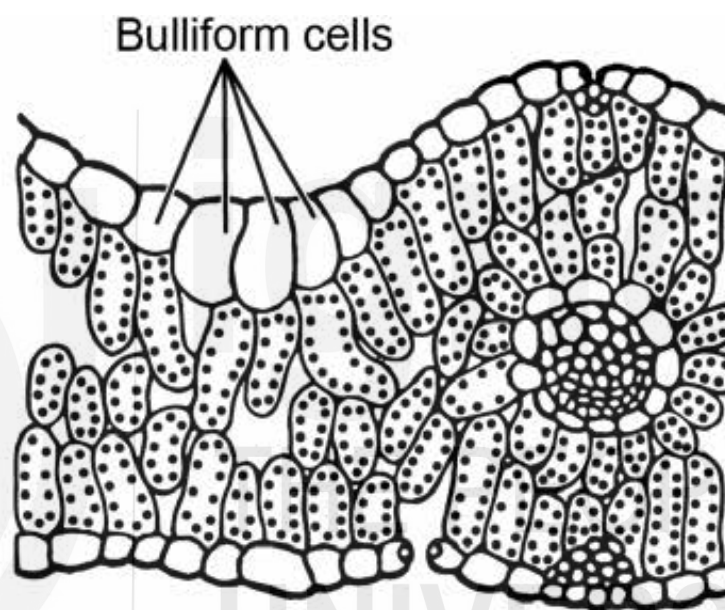


Fig. 8.7: Presence of Bulliform cells in the epidermal region of xerophytes.

SAQ 1

- a) Fill in the blanks with appropriate words.
 - i) Cells of hydrophytes possess air spaces called
 - ii) Air spaces present in the leaves of hydrophytes provide
 - iii) Occurrence of more than one type of leaf in plants is referred as
 - iv) Plants in which organs becomes smaller and fleshy due to storage of water are called as
 - v) The leaves in xerophytes are reduced to
 - vi) The features which enable them to survive such harsh conditions such as scarcity of water are

- b) State whether the statements are true or false.
- i) The whole petiole may be swollen into a bulbous spongy float in *Eichhornia*. []
 - ii) The plants growing in conditions of water scarcity are called as mesophytes. []
 - iii) The hollow stem of submerged hydrophytes provides buoyancy to the plant. []
 - iv) Hydrophytes possess a well developed vasculature. []
 - v) The secondary growth which accounts for increase in thickness of stems and roots is completely absent in hydrophytes. []
- c) With the help of an example, explain what is heterophylly?
- d) Fill in the blanks.
- i) The plants species which possess the means to reduce water loss are called as
 - ii) The root system in xerophytes is
 - iii) The cells in xerophytes possess high and
 - iv) The rolling of leaves in xerophytes occurs due to changes in turgor movements in enlarged colorless cells known as
 - v) When the stomata are present in cavities on the level below the epidermal surface. The condition is referred as
 - vi) The plants that show the presence of storage of water and mucilaginous substances are called as
 - vii) In resurrection plants, the cells, tissues and organs remain viable following the periods of
 - viii) In most xerophytic plants, more number of stomata are found towards region of the leaf in comparison to margins.
- e) Define the following.
- i) adaptation
 - ii) mesophytes
 - iii) resurrection plants
 - iv) aerenchyma
- f) Enlist the major morphological differences noted in xerophytes and hydrophytes.

8.5 ADAPTATIONS IN OTHER PLANTS

The plants growing at different altitudes and different climatic conditions show modifications in the external/ physical features that help them to survive and reproduce in harsh conditions. These adaptations in the form of changes in the

body or modification in its structure help plant to survive in that habitat. Adaptation in plants can be physiological which include change in body processes. Plants also show variety of reproductive adaptations to ensure their propagation or survival of seed.

8.5.1 Alpine Plants

The plants that grow at high elevation (high altitudes) are called as alpine plants. Different types of plant species and taxon that grow in alpine areas include perennial grasses, sedges, forbs, cushion plants, mosses, and lichens. These plants grow in alpine climate and are well adapted to the harsh conditions such as low temperatures, dryness, ultraviolet radiation, and a short growing season. These plants are exposed to high intensity light and strong winds. Alpine plants possess a particular architecture such as rosettes or tussocks. This morphology helps the plant to survive the microclimate as low amount of light and UV radiation are absorbed by leaf tissue, an increase in moisture content of leaves prevent drying out. The acquisition of this type of morphology represents a first avoidance response. The alpine plants are resistant to photoinhibition and many protection mechanisms play a role in this. These plants show presence of well-developed roots that store carbohydrates during the winter which are used during the spring time for developing new shoots.

They show certain specialized structures such as presence of dense hairs on leaves. The hairs reduce the absorption of light during high temperature, drought conditions. They also reduce the diffusion of gases across the leaf and air interface and also reduce the predation by insects and herbivores. Other adaptive features include presence of thick cuticle and thickened epidermal cells. The compact mesophyll cells with multiple palisade layers are also found throughout the leaf surface. To avoid exposure to low temperatures, the plants growing in the area show increase in the amount of solutes in their tissues via depression in freezing point or super cooling methods.

Many herbaceous flowering plants that grow on alpine areas include species such as mountain daisy (*Celmisia*), spaniard (*Aciphylla*), *Anisotome*, buttercup (*Ranunculus glacialis*), *Ourisia*, eyebright (*Euphrasia*), and gentian (*Gentianella*). Shrubs are associated with the grasses growing in alpine zone include snow tōtara (*Podocarpus nivalis*), *Coprosma* species, *Gaultheria*, *Archeria*, *Leucopogon* and *Dracophyllum* (Fig.8.8).



Fig. 8.8: Image of a) *Gentianella campestris*; and b) *Ranunculus glacialis*.

8.5.2 Epiphytes

The plants which grow on another plant or object using them as their physical support are called as epiphytes. They are also called as **air plant** because they are not anchored in the soil. Epiphytes are found on branches, leaves, trunk and other surfaces of plants and have no attachment to the ground (Fig. 8.9). Most epiphytes are found in moist tropical areas especially the rainforests and possess an ability to grow above ground level. This provides access to sunlight in forests. Epiphytes obtain water from rain that gets absorbed by roots or water vapour in the air. Many of them possess specialized leaves that take in moisture. Minerals are obtained directly from rain but some nutrients are absorbed from the debris that is present on the supporting plants. They get nutrients available from leaf and other organic debris of the tree canopy. This type of biological interaction is known as **commensalism**. In this type of mutual relationship, one of the species gets benefited and the other species is neither benefited nor harmed.

Majority of epiphytic plants are angiosperms. They also include many species of orchids, tillandsias, and members of the family Bromeliaceae (the bromeliads). Mosses, ferns and liverworts are common epiphytes found in both tropical and temperate regions. Most epiphytes have feathery or dust like seeds which get dispersed through wind. Animal and bird dispersal is noted in the species have edible fruits with seeds.

Epiphytes show certain adaptations. To overcome shortage of water and nutrients at the canopy of the forest, epiphytes capture the nutrients and water present in the air or from the debris of trees and rain. Their epiphytic habit helps them to get light and air rich in moisture. **Ball moss** found in the coastal desert of Mexico gets moisture from fog. Epiphytes have aerial roots which anchor the plant to the surface they grow. In epiphytic plants, roots are specialised to perform other functions too. Example- Some of the **orchids** have **photosynthetic roots** which also help in the absorption of moisture.



Fig 8.9: Image of *Dendrobium* plant attached to the branch of a tree.

In a parasitic epiphyte, **mistletoe**, roots are modified to penetrate the host plant and absorb water. In **Strangler fig**, roots become too long and reach the ground anchoring the plant in the soil. They compete with the host tree for light and other resources. **Orchids** conserve water in their thick stems. They make fleshy and edible fruits, seeds get dispersed by animals and birds. The leaf surface is covered with trichomes which facilitate the movement/absorption of

water and minerals into the shoot. The roots of the plants possess a special covering called velamen.

Dendrobium is an epiphytic and lithophytic orchids belonging to the family Orchidaceae. These herbs bear cylindrical roots usually arising from the base of a pseudobulb. The pseudobulbs are hard, cylindrical or cone-shaped and more or less covered with the bases of the leaves. Bromeliads are short-stemmed epiphytes that live in trees or on cacti. The flowers are often borne in long spikes.

8.5.3 Insectivorous Plants

Some plants have developed extraordinary adaptations for capturing animals as a diet supplement. These are called insectivorous plants. These include around 370 species of flowering plants belonging to 12 genera. Examples- *Nepenthes*, *Sarracenia* (pitcher plants), *Darlingtonia* (Cobra plant), *Dionaea* (Venus flytrap), *Drosera* (Sundew) and *Utricularia* (bladderwort). These carnivorous plants are capable of normal photosynthesis and absorption of minerals from the soil. These plants are adapted to soil with very little nutrients (impoverished soils) hence they capture insects primarily as an alternative source for nitrogen, phosphorous, potassium and other minerals.

The Venus flytrap, *Dionaea muscipula* (Fig 8.10) is a small terrestrial plant well adapted to catch insect prey. The plant has rosettes of six to eight leaves bearing traps 1-3 cm long. Trap is formed at the end of the leaf. The leaf stalk forms a hinge and the remainder of the leaf tissue forms two lobes. Edges of the lobes are equipped with a number of long spines. On each lobe stiff hairs are located. These are about 1.5 mm long and serve to trigger off the closing of the leaf. An insect when brushes against one of the hairs, an electric charge are created but trap remains open. The hinge is activated only when a second hair movement increases the potential charge to a fixed discharge level. The electric discharge, then activates the hinge and moves across the leaf as fast as nerve impulse. Once triggered, the trap closes very quickly within one fifth of a second. The leaves of this plants close when insects touch the tiny hairs inside the leaf surface. The fly gets trapped. The plant secretes digestive juice that digests the fly for the plant. If no prey is caught, the trap opens within an hour. The leaves are brightly coloured due to anthocyanin pigment which in turn attract insects to the plant.

Bladderworts (*Utricularia* spp.) is another common insectivorous plant. The genus has approximately 180 species. It belongs to the family Lentibulariaceae. It consists mostly of free floating water plants with submerged leaves. The leaves are modified into bladder-shaped structures with a diameter of 0.3 to 5 mm. The bladder acts like a one-way door. The sensitive hairs are located at the edge of the trapdoor. When stimulated they cause the valve to move due to a sudden inrush of water, pulling in the aquatic organism, and then the door swings into the closed position. Digestive enzymes are secreted by the surrounding tissue and prey gets digested within several days. If prey is not captured, the trap resets within 30 minutes.

Sundew, *Drosera*, use sticky mucilage to snare insects. The blade of leaf is circular in some spp., elongated in others and is set with curious tentacles (Fig. 8.11 a). These are emergences containing vascular bundles and ending

in swollen reddish heads which secrete a sticky glistening fluid. Flies and other insects mistake it for honey and get trapped. The tentacles are exceedingly sensitive to continued pressure even by the lightest bodies; the result is to cause inward and downward movements of the head of the tentacle, finally placing the fly upon the blade of the leaf. At the same time the stimulus passes to the surrounding tentacles, causing them also to bend downward to the same point. The insect is smothered and now glandular heads of the tentacles secrete ferment which acts upon the prey and digestive enzyme digest the prey.

Pitcher plants (*Nepenthes* spp., *Sarracenia* spp.) (Fig. 8.11 b) capture their prey by means of modified, cup-shaped leaves or 'pitchers' which contain digestive fluid. Insects are induced to land inside the pitcher. Pitchers are often brightly coloured and attract insects. Leaves are modified into vases of various shapes and sizes; with or without umbrella like flaps over the mouth. Some pitchers are formed at the terminal portion of a leaf. Plants release distinct odour to attract insects. There are nectar secreting glands at the rim of the pitcher. Seduced insects fall into the fluid at the bottom and small slippery walls downwardly projected hairs prevent further passage. Eventually they die and are digested by the plants with the help of digestive enzymes and bacteria.

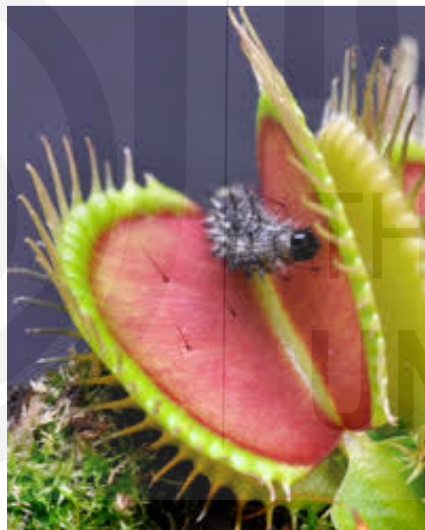


Fig 8.10: Venus flytrap.

Nepenthes khasiana is the only species found in India (Meghalaya) which is also endemic. Its pitcher measures upto 12 cms.



(a)



(b)

Fig. 8.11: Images showing a) Sundew; and b) Pitcher plants.

8.5.4 Halophytes

The plants which grow in extreme saline conditions are known as halophytes. Halophytic plants are the flora of saline environments. Vascular halophytes inhabit near-shore shallows and estuaries, land within the tidal zone, coastal salt marshes, inland salt lakes and saline desserts. Halophytes possess the ability to tolerate high levels of salt while high concentrations of Na^+ and Cl^- present in the water produce detrimental effects on the growth of normal plants.

Morphological adaptations

Halophytic species show diversity of structural adaptations. The leaves of most halophytes are thick, entire, succulent, small-sized and often glossy in appearance. Some species are aphyllous. The succulent leaves show presence of colorless storage cells which possess the capacity for salt accumulation.

The vegetative and generative organs of hyperhalophytes such as *Halocnemum strobilaceum*, *Salicornia europaea* and euhalophytes such as *Suaeda arcuata*, *S. microsperma*, and *S. prostrata* show certain modifications. These include development of shallow normal roots in addition to stilt or prop roots that develop from the aerial branches of stem for efficient anchorage in muddy or loose sandy soil. These roots grow downward and enter the deep and tough strata of the soil. In *Rhizophora mucronata*, the stilt roots may be strong and extensively developed (Fig. 8.12). Buttresses root, which is an adventitious root, arises from the basal parts of tree trunks. These root buttresses provide sufficient support to the plants.

Development of special type of negatively geotropic roots called **pneumatophores** or breathing roots. These are also called as respiratory or knee roots. These develop from the underground roots and project in the air well above the surface of mud and water. They appear as peg-like structures. The tips of these roots may be pointed. They possess numerous lenticels or pneumathodes on their surface and prominent aerenchyma enclosing large air cavities. The gaseous exchange takes place in these roots through the lenticels. The air enters through small openings (lenticels) followed by their passage to soft spongy tissue and then roots beneath the mud. Aerenchyma tissue helps in the exchange of gases. The pneumatophores provide structural support and allow oxygen transfer to the roots that are present below ground in the anaerobic soils. Aerenchyma helps in the conduction of air down to the subterranean or submerged roots.

Stems in halophytes develop succulence. Succulence is induced only after the accumulation of free ions in an organ increases above a critical level. Succulence has been directly correlated with salt tolerance of plants and the degree of their development can serve as an indicator of the ability of plants to survive in highly saline habitats e.g. *Salicornia herbacea* and *Suaeda maritima*.

Fruits and seeds of halophytes are generally light in weight. Fruit walls have a number of air chambers and the fruits, seeds, and seedlings float on the surface of water for long time and get dispersed to distant places by water current. The stiff bractiolar bristles of the inflorescence help in the movement of the inflorescence. When the seeds mature the globular and hairy

inflorescence becomes bodily detached from the creeping plant and trails on the sandy substratum dropping its seeds at places. Finally the inflorescence with rest of fruits becomes buried in the mud. Fruits are not sclerified. The pericarp is parenchymatous. The testa has two layers of cells. The presence of tannins and melanins in the testa and fat in the embryo, prevent salt penetration. Halophytes or mangrove plants growing in the tidal marshes show 'vivipary'. It is the germination of seeds while the fruits are still attached to mother plants for example *Rhizophora*, *Aegiceras*, *Avicennia*, *Cassula*, and *Ranansatia vivipara*.

In *Rhizophora* plants, (Fig. 8.12) when the embryo reaches advanced stage of development the massive club-shaped hypocotyl and terminal radicle pointing downwardly emerge out of the fruit. When the hypocotyl attains a length of several centimeters (about 50-80 cm), the seedling falls vertically down. Thus, the radicle and a part of hypocotyl become fixed in the mud and the remaining upper part of hypocotyl along with other embryonal parts, such as plumule and cotyledons remains above the surface of mud or water. The radicle develops a tuft of roots within a few hours while the plumule starts growing rapidly. On reaching shallow areas, the radicle becomes fixed in the soft mud and the plant starts growing rapidly. The viviparous germination is a significant adaptation in these plants to avoid the retarding effects of salinity on seed germination.



Fig 8.12: *Rhizophora* plants growing in their natural habitat.

Box 8.1: Halophytes and Salinity.

According to Stocker (1833), the critical level of salinity for plants is 0.5% of the dry weight. The halophytes with upper tolerance limits for salts are the **euhalophytes**.

Plants cope with the salinity in various ways. Some of them avoid salinity, some evade salinity or resist it, and a few others tolerate salinity. Halophytes are able to achieve exclusion of Na^+ and Cl^- at high external salt concentrations. The degree of exclusion ranges from 80 to 88.6 % of the external Na^+ . Halophytes reduce the concentration of ions present in solution by excreting it outside with the help of salt glands. In this way, they regulate the ions entering the xylem stream. Some of them compartmentalize ions within vacuoles. This process involves role of ion transporters located at the tonoplast (vacuolar membrane) particularly vacuolar Na^+/H^+ exchangers (NHX). In salt tolerant plants, the protoplasm functions normally and endures a high salt concentration without apparent damage.

Anatomical adaptations

The succulent leaves show increased mesophyll area, thick cuticle and wax deposition on epidermis. Most halophytes possess special surface glands and hairs to remove NaCl from the underlying mesophyll cells followed by active secretion out of leaf surface. The salt glands are generally formed on the upper surface of the leaf. The gland consists of two to four highly vacuolated basal cells, a cutinised stalk and eight terminal cells covered with a thin perforated cuticle that separated from the cell wall. All gland cells are connected via plasmodesmata. The salt is deposited in the subcuticular cavity followed by its movement to leaf surface through cuticular pores. Chlorenchyma cells with large vacuoles are often found associated with different forms of salt secreting glands.

Some species also possess salt hairs on the surface. These hairs are composed of an enlarged terminal bladder cell that contains a large salt accumulating and salt storing central vacuole. The bladder is attached to the leaf epidermis by a stalk cell through which the salt is actively transported. The salt containing cells burst and the salt is deposited on the epidermal surface. The salt present on the surface provides reflective coating that shades the leaf from direct sunlight and also decreases the palatability of the plant to herbivores.

Stems and leaves surfaces of coastal halophytes are densely covered with trichomes. Leaves of submerged marine halophytes are thin and have very poorly developed vascular system and frequently green epidermis. Euhalophytes have small cylindrical leaves with Kranz (*Suaeda arcuata*, *S. microsperma*) and non-Kranz structure (*S. prostrata*, *Hymenolobus*, *Spergularia*). The main adaptation is the succulence by which moisture is preserved at the expense of abundant water-bearing cells with thin walls. The structure of stems and roots is anomalous, polycambialous and sclerenchymatous. These provide protection to lateral meristems.

Stems in the succulent plants possess thin-walled water storing parenchyma cells in them. Mucilage cells may be found in abundance. Cortex is fleshy, several cells thick and in old stems it may become lacunar. Salinity causes extensive lignification of stele. The leaves and stems of coastal halophytes are covered with various types of simple and branched trichomes. The trichomes exert a protective function in plants by maintaining water status and affecting temperature of the leaves.

The plants show presence of thick cuticle on the aerial parts of the plant body. The epidermis of halophytes is characterized by a cover of waxy layers in addition to thick cuticle. Leaves may be dorsiventral or isobilateral. Epidermal cells are thin-walled (Fig. 8.13). Epidermal cells of various mangrove species contain large quantities of tannins and oil droplets. The palisade consists of several layers of narrow cells with intercalated tannin and oil cells. Leaves of many species of mangrove are dotted with local cork formation "cork warts".

The root systems show reduced cortex with aerenchyma but wide casparian strips. These anatomical characteristics are the basis for their physiological adaptation to high saline condition. The stilt roots of mangrove plants show

Mangrove flora along the coast of America and Gulf of Mexico to Florida consists of red mangrove (*Rhizophora mangle* (family- Rhizophoraceae) and the black mangroves (*Avicennia nitida*, *A. marina*) (Acanthaceae). Mangroves in Southeast Asia mainly consist of species *Sonneratia* (Lythraceae) and nipa palm (*Nypa fruticans* (family- Arecaceae).

normal features with periderm on the surface, aerenchymatous cortex containing sclereids, normal endodermis, secretory pericycle, radially arranged xylem and phloem and extensively developed pith. The cortex is spongy and consists of extensively developed aerenchyma enclosing large air chambers.

Other features characteristic to halophytes include presence of large cells and small intercellular spaces, high elasticity of the cell walls, extensive development of water storing tissues, small and fewer stomata, low chlorophyll content, thick walled and heavily cutinized epidermis in succulent leaves and stem.

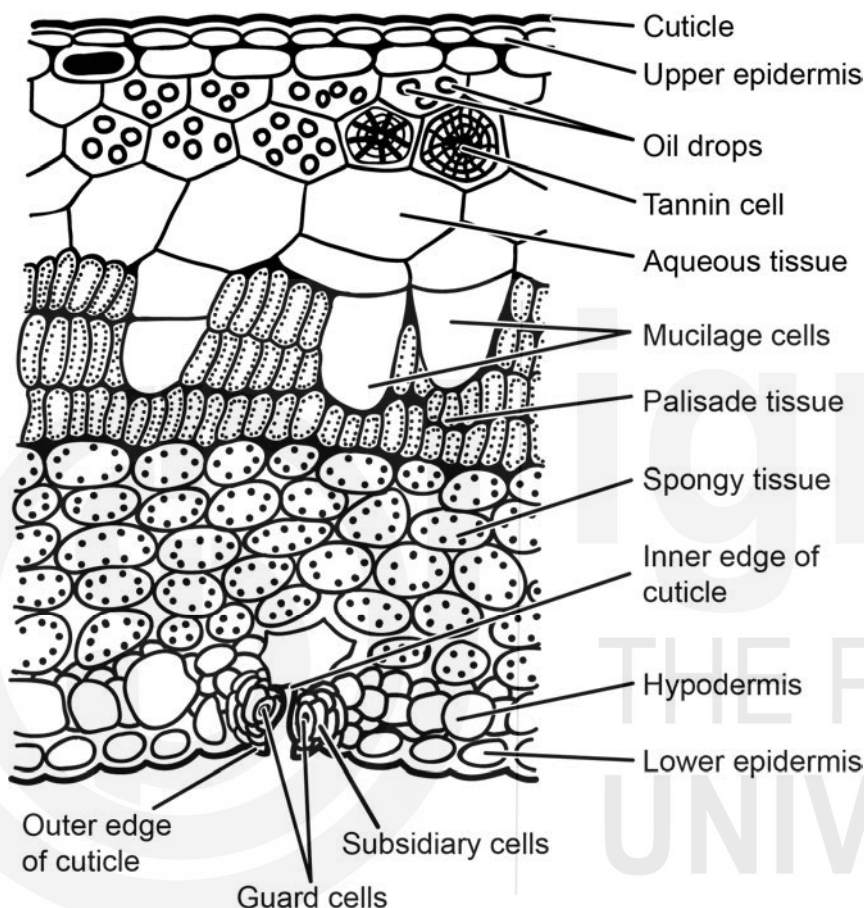


Fig. 8.13 : V.S. of *Rhizophora* leaf.

Mangroves

Mangroves are unique ecosystems found near tropical and subtropical bodies of water throughout the world. **Mangroves** include certain shrubs and trees that grow in dense thick forests along tidal estuaries, salt marshes and muddy coasts. The trees and shrubs found in this region belong to families Rhizophoraceae, Acanthaceae, Lythraceae, Combretaceae and Arecaceae. Sundarbans are the largest coastal ecosystems of the world located between India and Bangladesh. They have widest range of mangrove species.

The mangroves grow generally up to 8 m (30 feet) in height. The leaves are generally 5 to 15 cm long, opposite, oval or elliptic. They have leathery surfaces and are borne on short stems. The surfaces are thick and leathery, preventing excess water loss through transpiration. The roots have developed the ability to breathe above ground. The roots are stilt-like in appearance. The prop roots or exposed supporting roots arise from the lower trunk of some mangrove species facilitate exchange of gases.

Mangroves possess unique leaf anatomical features which help them to adapt in highly saline environment and grow in oxygen-deficient soil. Large amounts of water storage tissues present in the hypodermal or mesophyll tissue of the leaves helps in adapting mangroves to stressful habitat. Erect aerial roots arising from lower roots facilitate gaseous exchange in mangrove species. Example- *Avicennia marina*. **Pneumatophores** are characteristic of many species (Figure 8.14). They project above the ground. The trunks and branches of plants produce adventitious roots. The roots bend down at some distance from the parent stem and give rise to new plants. Example- *Bruguiera gymnorhiza*, *Kandelia obovata*. Mangroves restrict the opening of their stomata to limit the loss of water through leaves. This enables it to survive in a saline environment.

The mangroves develop special leaves which turn down to reduce exposure to the sunlight. The turning of leaves reduces the exposure to sunlight. This prevents water loss due to transpiration. The phenomenon is referred as phototaxis. The waxy coating on the upper layer of the leaf prevents water loss and extreme exposure to the sunlight. Mangroves show the capacity to accumulate salt in selected parts of the plant such as leaves. The leaves of the salt tolerant mangrove species such as *Avicenna germinans* show the presence of large, tightly packed multiple rows of specialized hypodermal cells that play a role in salt accumulation and storage.

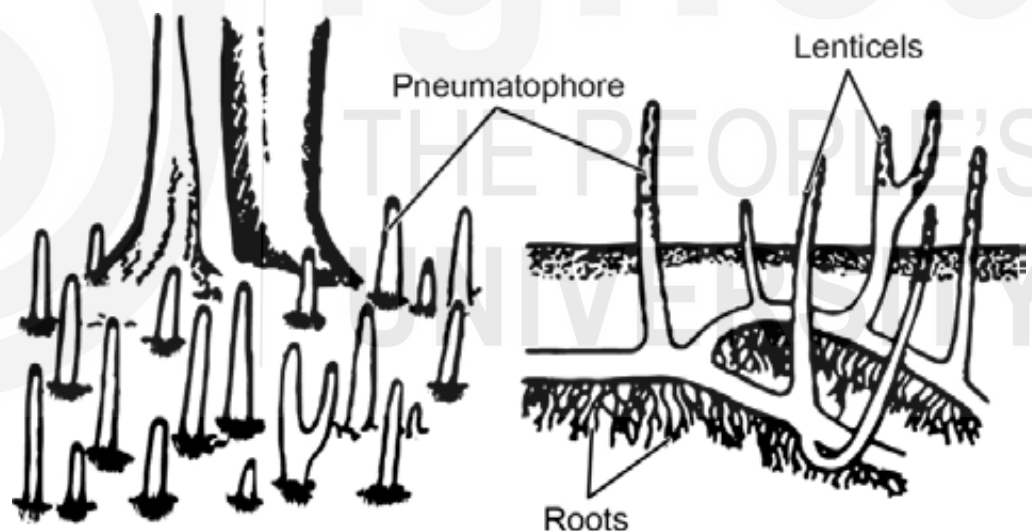


Fig. 8.14: The mangroves showing the presence of pneumatophores and aerial roots.

Mangroves can regulate ion homeostasis under salt stress by salt secretion, ultrafiltration and ion sequestration. Grey Mangrove can also tolerate the storage of large amounts of salt in their leaves. These species possess salt secreting glands in their leaves. In these species large amounts of salt are stored in their leaves and the leaves are discarded when the salt content is too high. Salt glands present in the leaves concentrate and remove the absorbed salts to regulate the salt concentration inside the mangroves. The process is called as excretion. The presence of glandular and non-glandular hairs on the abaxial and/or adaxial leaf surfaces in some taxa also assist in secretion of salt from these plants e.g. *Aegiceras corniculatum*. In some mangroves, roots

have structures to exclude the salt. When the root tissues get exposed to salt water, the concentration of salt in the vessels of the root is lower than the concentration of salt in the water surrounding the plant. This concentration gradient drives salt ions across the plant tissue's membranes into its cells. A red mangrove possesses impermeable roots which acts as an ultra-filtration mechanism and exclude sodium salts (about 80%-87%) from the plant. These plants store salt in cell vacuoles.

Many mangrove species such as *Avicennia* have fruits that are buoyant and thus can be carried away by the water to another location where they can grow. The seeds of mangroves are also buoyant and get dispersed through water. The 'seed coat' is thick and hairy and traps air. This makes the seed 'buoyant'. Plants possess viviparous seeds i.e. seeds germinate to produce new plantlets when they are still attached to the parent tree. The mature tree provides it with the nutrients and water for survival. Once the seedlings mature, they drop from the parent plant and float on the water below. The seedlings get attached to soil after rooting. This kind of viviparous reproduction allows rapid growth and establishment of mangrove seedlings once they come into contact with the substratum e.g. *Bruguiera gymnorhiza*. The seedling grows either within the fruit or out through the fruit to form a propagule (a ready-to-go seedling) which can produce its own food via photosynthesis. Once mature, it will drop into the water. Propagules can survive desiccation and remain dormant for over a year before arriving in a suitable environment. Once a propagule is ready to root, its density changes so that the elongated fruit now floats vertically rather than horizontally whereby it is more likely to lodge in the mud and root.

Mangroves are ecologically and economically very important. They are important to the coastal ecosystems they inhabit. They serve as a buffer between marine and terrestrial communities and protect shorelines from damaging winds, waves, and floods. Mangroves improve water quality by filtering pollutants and trapping sediments from the land and reduce coastal erosion. Mangroves possess ability to prevent erosion of coastal areas. The complex root systems of these forests protect shorelines from being eroded over time by waves. They collect sediment as it flows downstream and into the ocean. This action helps protect coral reefs and other underwater ecosystems from being covered and destroyed by sedimentary deposits. Ecologically, they provide habitat to many of the terrestrial organisms. The species of coastal, offshore fish and shellfish rely exclusively on mangroves for their breeding, spawning and hatching. Because of their high salt tolerance, mangroves are often among the first species to colonize mud and sandbanks flooded by seawater. Mangrove habitats also provide protection to different fish and marine animal species, making them important in sustaining environmental biodiversity and as fisheries for human use. An increase in coastal development and altered land use has led to a decline in global populations.

SAQ 2

- a) What is vivipary? Explain.
- b) Enlist the ecological importance of mangroves.

- c) Choose the correct option.
- i) The plants growing in areas having abundant soil, water, humidity are termed as
 - a) Halophytes b) hydrophytes
 - c) xerophytes d) mesophytes
 - ii) The plants growing in saline conditions are called as
 - a) halophytes b) hydrophytes
 - c) xerophytes d) mesophytes
 - iii) The plants which can survive even in the conditions of reduced water uptake or availability are called as
 - a) Drought escaping species
 - b) Drought enduring species
 - c) Drought evading species.
 - d) Drought averting species
 - iv) The root system is very well developed in
 - a) halophytes b) hydrophytes
 - c) xerophytes d) mesophytes
 - v) These plants show the presence of 'sunken stomata'
 - a) xerophytes b) hydrophytes
 - c) halophytes d) mesophytes
 - vi) Pneumatophores or breathing roots are found in
 - a) xerophytes b) hydrophytes
 - c) halophytes d) mesophytes
- d) State whether these statements are true or false.
- i) The seeds of mangroves are buoyant and get dispersed through water. []
 - ii) Viviparous reproduction allows rapid growth and establishment of mangrove seedlings. []
 - iii) The plants which grow in extreme saline conditions are known as xerophytes. []
 - iv) The type of biological interaction shown by epiphytes is called **commensalism**. []
 - v) Epiphytes capture the nutrients and water present in the soil through roots. []
 - vi) Insectivorous plants are generally found in impoverished soils. []

- | | |
|---|-----|
| vii) <i>Ranunculus</i> is an example of insectivorous plant. | [] |
| viii) <i>Avicenna</i> shows the presence of large specialized hypodermal cells that play a role in salt accumulation and storage. | [] |
| ix) The pneumatophores or lenticels present in halophytes help in photosynthesis. | [] |
| x) Many mangroves show viviparous type of reproduction. | [] |
-

8.6 SUMMARY

In this unit you have studied that :

- Plants have developed special features through the process of evolution which has helped them to survive in different situations. These features make a particular plant species well adapted to its habitat. These are called as adaptations and these can be structural or physiological.
- The leaves of hydrophytes are flat, thin containing air spaces called aerenchyma that give the buoyancy to the plant and help them to float on the surface of water. The aerenchyma present in the leaves and stem of hydrophytes help in the gaseous exchange.
- In hydrophytes roots are poorly developed and the stem is thin and slender. The leaves exhibit heterophylly, i.e., show presence of two or more distinct types of leaves on a single plant. The leaves differ markedly in shape and anatomical organisation.
- Xerophytes bear leaves which have thick waxy coating. They also show features such as folding of leaves, reduction in leaf size and development of spines. The reduction in leaf area prevents transpiration. These features help the plants to reduce absorption of sunlight, help them to escape and adapt to dry conditions. The presence of dense, hairy leaf covering helps them in tolerating extreme heat and dry conditions. In other species, leaves become succulent and store water. The deep and extensive root system in xerophytes helps in the absorption of water and nutrients.
- Halophytes grow in saline environment and develop special type of negatively geotropic roots, called pneumatophores or breathing roots. They possess numerous lenticels or pneumathodes on their surface and prominent aerenchyma enclosing large air cavities internally. Stems in halophytes develop succulence. The leaves of most halophytes are thick, entire, succulent, small-sized and often glossy in appearance. They also show viviparous mode of reproduction.
- Mangroves possess distinct morphological characters and anatomical features which help them to adapt in highly saline environment and grow in oxygen-deficient soil. The mangroves possess roots with stilt-like appearance. These roots have the ability to breathe above ground and obtain oxygen from the surrounding air. The respiratory roots called pneumatophores project above the ground. The aerenchyma present in them helps in the exchange of gases.

- The fruits of mangroves are buoyant and get dispersed through water. Plants show the presence of viviparous seeds. Once the seedlings mature, they drop from the parent plant and float on the water below. The seedlings attach to soil and root. This increases the survival rate of the mangroves in the unstable substratum and the intertidal environment.

8.7 TERMINAL QUESTIONS

1. What are succulents? Describe their characteristic features.
2. What are the different types of adaptations noted in leaves of xerophytes?
3. What type of stomata is found in xerophytes?
4. What are pneumatophores? What is their function?
5. How do mangroves remove salt?

8.8 ANSWERS

Self-Assessment Questions

1. a) i) Aerenchyma
ii) Buoyancy
iii) heterophylly
iv) Succulents
v) Spines
vi) xeromorphic
b) i) True; ii) False; iii) True; iv) False; v) True
c) In submerged aquatic plants the different type of leaves are produced on the same plant. The phenomenon is referred as heterophylly. In many submerged species entire, rounded or slightly lobed floating aerial leaves are found along with linear, ribbon-shaped or finely dissected submerged leaves. Example- *Sagittaria sagittifolia*, *Limnophila heterophylla*.
d) i) Drought evading species
ii) extensive
iii) osmotic pressure, water-potential
iv) bulliform cells
v) sunken stomata
vi) Succulents
vii) dehydration
viii) midrib

- e) i) Any modification in structure of an organism that promotes its survival in a particular habitat is called as **adaptation**.
- ii) The plants growing in areas having abundant soil, water, humidity are termed as **mesophytes**.
- iii) The plants in which cells, tissues and organs remain viable following the periods of dehydration are called as **resurrection** plants.
- iv) The parenchyma cells of hydrophytes which possess intercellular air spaces called lacunae are called **aerenchyma**. The air spaces help in the exchange of gases and maintaining buoyancy in the cell.

f)

Xerophytes	Hydrophytes
The leaf blades are smaller in size and more compact. Microphyllous leaves reduce the rate of transpiration.	In free floating plants, petioles of leaves are swollen into a bulbous spongy float. In submerged plants leaves are thin, long and ribbon like or finely dissected.
In some plant species, the leaf petiole become flattened and widened so that it looks just like a leaf and perform the function of leaf. This is called phyllode.	The petioles or the leaf-bases remain slender and elongated.
The plants possess long tap root system that penetrates deep into the soil. It helps in retaining water.	The roots are thin, poorly developed and short.
In some plants known as succulents, organs become smaller and fleshy due to accumulation of water.	Succulents are not present.
The leaves are covered with dense hairs. which check transpiration.	Hairs are absent.

2. a) Mangroves plants possess viviparous seeds i.e. seeds germinate to produce new plantlets when they are still attached to the parent tree. The mature tree to which the seeds are attached provides it with the nutrients and water for survival. Once the seedlings mature, they drop from the parent plant and float on the water below. The seedlings are able to survive in the water until they attach to soil and take root. This kind of viviparous reproduction allows rapid growth and establishment of mangrove seedlings once they come into contact with the substratum. It increases the survival rate of the mangroves in the unstable substratum and the intertidal environment. Example- *Bruguiera gymnorhiza*.

- b) Mangroves are ecologically and economically very important. They are important to the coastal ecosystems they inhabit. They serve as a buffer between marine and terrestrial communities.
- i) They protect shorelines from damaging winds, waves, and floods. Mangroves improve water quality by filtering pollutants and trapping sediments from the land, and they reduce coastal erosion. The complex root systems of these forests protect shorelines from being eroded over time by waves.
 - ii) They collect sediment as it flows downstream and into the ocean. This action helps protect coral reefs and other underwater ecosystems from being covered and destroyed by sedimentary deposits.
 - iii) They provide habitat to many of the terrestrial organisms. The species of coastal, offshore fish and shellfish rely exclusively on mangroves for their breeding, spawning and hatching.
 - iv) Mangroves are among the first species to colonize mud and sandbanks flooded by seawater because of their high salt tolerance.
 - v) Mangrove habitats also provide protection to different fish and marine animal species, making them important in sustaining environmental biodiversity and as fisheries for human use.
- c) i) d) mesophytes
 ii) a) halophytes
 iii) b) Drought enduring species
 iv) c) xerophytes
 v) a) xerophytes
 vi) c) halophytes
- d) i) True; ii) True; iii) False; iv) True; v) False
 vi) True; vii) False; viii) True; ix) False; x) True

Terminal Questions

1. Succulents are plants in which organs become smaller and fleshy due to active accumulation of water. The bulk of the plant body is composed of water storing tissues. Water stored in these tissues is used during conditions of water scarcity. In cacti stem gets modified into fleshy and spongy structures. Leaf succulents include species such as *Sedum*, *Aloe*, *Mesembryanthemum*, *Kleinia* and several members of family *Chenopodiaceae*.
2. Refer to Section 8.4.

3. In xerophytes the stomata is present in cavities below the level of epidermal surface. These are referred as sunken stomata. They help in reducing water loss via transpiration.
4. The respiratory or knee roots called pneumatophores are characteristic of mangrove species. These roots project above the ground. The air enters through small openings called lenticels followed by their passage to soft spongy tissue and then roots beneath the mud. These roots contain aerenchyma tissue which helps in the exchange of gases. The small holes present in the pneumatophores provide structural support and allow oxygen transfer to the roots that are present below ground in the anaerobic soils.
5. Mangroves regulate ion homeostasis under salt stress by salt secretion, ultrafiltration and ion sequestration. They possess salt secreting glands in their leaves. Salt glands present in the leaves concentrate and remove the absorbed salts to regulate the salt concentration inside the mangroves. The process is called as excretion. The presence of glandular and non-glandular hairs on the abaxial and/or adaxial leaf surfaces in some taxa also assist in secretion of salt from these plants. Chlorenchyma cells with large vacuoles are often found associated with different forms of salt secreting glands. In some mangroves, roots have structures to exclude the salt. A red mangrove possesses impermeable roots which acts as an ultra-filtration mechanism and exclude sodium salts (about 80%-87%) from the plant. These plants store salt in cell vacuoles.

Acknowledgements

Fig 8.10 : <https://encrypted-tbn0.gstatic.com/images>

GLOSSARY

Abaxial	: Lower surface of leaf or surface away from axis.
Adaxial	: Upper surface of a leaf or surface towards the axis.
Acropetal	: Growth, development or movement upwards from the base or point of attachment.
Actinocytic	: A stoma with a number of elongated subsidiary cells radiating laterally.
Adventitious root	: Roots that arise from any organ other than the radicle of the embryo.
Amphicribal	: Concentrically structured vascular bundle with phloem completely surrounding xylem.
Amphistomatous	: A leaf possessing stomata both of its surface.
Amphivasal	: Concentrically structured vascular bundle with xylem completely surrounding phloem.
Amplifying	: Increase number of something.
Anchorage	: Covering or holding something from outside.
Anomalous	: Something which is not normal or unexpected.
Anomocytic	: A stoma without any subsidiary cells or with no distinct subsidiary cell(s).
Anisocytic	: A stoma with three subsidiary cells of unequal dimensions.
Annular	: Round in shape.
Anticlinal	: Opposite to the surface.
Aphyllous	: Plant bearing no leaves or devoid of foliage.
Apotracheal	: Axial wood parenchyma not associated with vessels.
Autumn wood	: Conspicuous in ring porous wood characterized by vessels of smaller diameter.
Axial system of wood	: Xylem elements of wood derived from the fusiform initials of vascular cambium.
Bark	: A non-technical term used for all the tissues outside the vascular cambium.
Basipetal	: Produced in order so that movement or development occurs from the apex downwards so that the youngest are at the base.
Bicollateral	: A vascular bundle in which phloem is present on two sides of the xylem.

Bifacial	: A leaf where palisade parenchyma is present only on the adaxial side, and spongy parenchyma on the abaxial side. Also, called dorsiventral.
Boundary axial parenchyma	: Axial parenchyma in a wood formed primarily at the beginning or end of the growth ring.
Bulb	: A modified stem axis with much reduced stem (disc) and fleshy scale leaves growing from it.
Bundle Sheath	: A ring of cells around a vascular bundle morphologically distinct from mesophyll cells.
Buttress roots	: Buttress roots are large wide aerial roots emerging from all sides of a shallowly rooted tree in tropical forests. They prevent tree from falling and also help in gathering more nutrients.
Casparian strip	: Waxy band encircling some endodermal cells along their radial and transverse walls.
Cauline	: Referring to the stem axis in a shoot system.
Centripetally	: Moving towards center.
Cladophyll	: Flattened or swollen, chlorophyllous stem that serves as photosynthetic organ. The leaves are reduced as spines or small scales. Also, termed as phylloclade.
Collateral	: A vascular bundle construction with phloem on the outer side of the xylem.
Concentric	: Having a common center.
Columella	: Cells in the central region of a root cap; characterized by their orderly arrangement and containing many amyloplasts.
Conspicuous	: Clearly noticeable.
Cortex	: Region of primary tissue in the plant axis located between the epidermis and vascular tissue. Predominantly parenchymatous.
Decumbent	A stem axis growing or drooping downward.
Demarcated	: Separate or distinguish from.
Dessication	: State of intense dryness.
Diacytic	: A stoma with two subsidiary cells placed perpendicular to the longer axis of stomatal aperture.
Diarch	: A structural condition in a primary root having primary xylem with two protoxylem poles.

Discernible	: Thing that is noticeable or apparent.
Distal	: Away from the apical end.
Dorsiventral	: A thing having two surfaces differing from each other in appearance or structure.
Early wood	: Conspicuous in ring porous wood characterized by vessels of larger diameter. Also, termed early or spring wood growing.
Epidermis	: Outermost layer of cells on the primary plant body. Rarely multilayered.
Endarch	: Primary vascular tissue strand that differentiate radially and centrifugally. The oldest elements are closest to the centre of the axis.
Endodermis	: A layer of cells without intercellular spaces and forming the inner most zone of cortex, separating cortex from vascular tissue.
Endogenous	: Produced within from deep seated cells.
Endoreduplication	: A process in which cell duplicates its genetic material without division or replication of a nuclear genome in the absence of cell division.
Epistomatous	: A leaf where stomata are restricted to adaxial surface only.
Euhalophytes	: Plant growing in saline or alkaline soil habitats with upper tolerance limits for salts.
Exarch	: Primary vascular tissue stored that differentiate radially and centripetally. The oldest elements are nearest to epidermis (farthest from the axis of the organ).
Flaccid	: A structure lacking strength.
Foliage leaf	: A mature photosynthetic leaf.
Furrow	: A depression or groove.
Graminaceous stomata	: Stomata of <i>Poaceae</i> , where guard cells are dumb-bell shaped.
Haplocheilic	: Development of a stoma where none of the subsidiary cells has a common origin with any of the guard cells.
Heart wood	: Inner layers of wood in a growing tree that have ceased to contain living cells. Generally darker than the peripheral layers of wood darker than the peripheral layers of wood.

Histology	: Branch of science that deals with structural details.
Hydraulic	: A function that occurs under pressure of liquid.
Hydrophobic	: Substances that repel water or do not mix in water
Hyperhalophytes	: Plants showing high salt accumulation or tolerance potential.
Hypostomatous	: A leaf where stomata are restricted to abaxial surface only.
Impregnated	: Filled with something.
Inherent	: An essential or inbuilt part of something.
Intercalated	: Insert something between layers.
Internode	: The region of a stem axis that lies between two contiguous, adjacent nodes.
Lacunar	: Having an unfilled space
Lamina	: A thin layer or plate.
Late wood	: Same as autumn wood.
Lateral root	: The root that arise endogenously from the axis of a primary root.
Lenticels	: Separated portion of a periderm, consisting of loosely arranged cells, serving for gaseous exchange through otherwise impermeable periderm. Various shaped, often lenticular.
Lipophilic	: Substance that dissolves in lipid or fat.
Lumen	: Inside space of a tubular structure.
Megaphyll	: Same as foliage leaf.
Mesogenous	: When all the subsidiary cells of a stoma has common origin with the guard cells.
Mesoperigenous	: When at least one of the subsidiary cells of a stoma has common origin with the guard cells.
Mesophyll	: Chlorophyllous cells present in between two surfaces of a leaf.
Metabolites	: Substances released as by-product of a metabolic process.
Metaxylem	: Later-formed primary xylem.
Metaphloem	: Later-formed primary phloem.
Microphyll	: A leaf of smaller size, generally without any mid-vein.

Morphogenesis	: The process of formation of some structure or shape.
Multiseriate ray	: Wood ray two or more cells wide as viewed in tangential section.
Node	: Region of stem from which a leaf, leaves or branches arise.
Obscured	: Unclear, undistinct.
Occluded	: Blocked by something.
Ontogeny	: The study that deals with origin and development of organism.
Orthotropic	: An erect stem axis.
Paracytic	: A stoma with 2 or more subsidiary cells present in plane parallel to the axis of the stomatal pore.
Paratracheal axial parenchyma	: Axial wood parenchyma associated with or in contact with the vessels or vascular tracheids.
Pavement cells	: Cells found in the outmost epidermal layer of plants.
Perforation	: A hole or gap.
Periclinal	: Parallel to the surface.
Periderm	: Outer protective layers produced by the phellogen that replace epidermis may become multilayered.
Perigenous	: Development of a stoma where none of the subsidiary cells has common origin with any of the guard cell.
peripheral	: Situated on the edge or corner.
Petiolar	: Plant in which leaf is attached to stem by stalk.
Phragmoplast	: Cytoplasmic structure that forms at the equator of the spindle after the chromosomes have divided.
Plagiotropic	A stem axis showing horizontal growth.
Polyarch	: Structural condition in a root having xylem with many protoxylem groups.
Polymerize	: Combining to form structure built up from a large number of similar units bonded together.
Polyploid	: Receiving or getting multiple copies of each chromosome.
Precursor	: Something that existed before another thing.
Prickle	: Epidermal/peripheral cells of an organ with pointed ends and stiff texture, and without any vasculature; easily separable from surface.

Primary phloem	: Phloem of the primary plant body; it is differentiated below or behind the apical meristem.
Primary root	: The root axis that arises from the activity of RAM.
Primary tissue	: Tissues differentiating from the derivatives of RAM and SAM and their derivatives.
Proplastids	: A small, colourless organelle that gives rise to a plastid such as chloroplast, chromoplast and leucoplast.
Protuberance	: A structure that bulges out.
Pro-vascular tissue	: Procambium. Derived from RAM, forming the core of primary axis, that differentiates into vascular tissue. The cells are tightly packed and lie parallel to the axis of the root.
Proximal	: Near the point of attachment.
Pseudotransverse	: Seems to be situated or extending across something.
Radial system of wood	: The cells/tissues of wood that arise from the ray initials of the vascular cambium. The cells lie perpendicular to the long axis of the plant.
Reniform	: Kidney or bean shaped referred to the shapes of guard cells.
Ring bark	: The periderm that usually form an entire cylinder around the axis.
Rhizome	: Under ground, dorsiventral stem or branches growing horizontally under the surface of the soil. They possess nodes and internodes; brown scaly leaves at nodes; and possess both axillary and apical buds.
Rhytidome	: Technical term for outer bark. Phellem and tissues isolated by it, often enclosing pockets of cortical or phloem tissues.
Root apex	: Distal-most region of any primary root axis.
Root apical meristem	: Primary meristem cell(s) that occupy subterminal region of a root apex. Responsible for formation of all the tissues of the primary axis of the root.
Root cap	: Collection of cells that covers and protects the RAM and that assists the movement of the root.
Sap wood	: Portion of wood in the living tree that contains living cells and reserve materials.
Scaly bark	: The later formed periderm that develop in the form of scales or shells. The concave side of these scales is directed outwards.

Secondary meristem	: Lateral meristems (vascular cambium and phellogen) that arise later on an axis. Responsible for increase in girth of the organ.
Secondary tissue	: Tissue derived from the activity of a lateral meristem/vascular cambium/phellogen.
Secondary root	: A root or a region of a root that comprises of tissues that are derived from the activity of secondary meristem.
Secondary phloem	: Phloem produced by vascular cambium.
Secondary xylem	: Xylem or wood produced by vascular cambium.
Self perpetuate	: Capable of renewing oneself.
Senescence	: Process of deterioration with age.
Seriation	: Sorting objects according to their characteristics such as size, color, shape, or type.
Shoot apical meristem	: Distal end of the axis of shoot systems that possesses the meristem and contributes to both the axial and laterals of a shoot.
Spine	: Lateral, scalariferous, stiff, pointed extensions of the surface layers with distinct vasculature.
Spring wood	: Same as early wood.
Starch sheath	: Innermost cortical cell layer in a stem that possesses abundant starch grains.
Stipule	: Lateral outgrowths from the petiole of a leaf.
Stoma	: A pair of guard cells with a stomatal aperture between them. (Plural = stomata).
Subsidiary cells	: Specialized cells two or more in number surrounding a pair of guard cells, with or without common origin with them.
Sucker	: Underground runner which soon grows up and forms a daughter plant after striking roots.
Sympodial	: Formation of an axis from successive secondary axis
Syndetocheilic	: Development of stomata where at least one of the subsidiary cells has common origin with that of guard cells.
Tangential	: A plane that touches a curve or curved surface at a point.
Taxonomy	: Science of classifying something.

Tendrill	: Slender, flexible modification of a leaf or a leaflet, a petiole or a scale leaf to support the organ.
Tetrarch	: Structural condition in a primary root having primary xylem with four protoxylem poles.
Tetracytic	: A stoma with four subsidiary cells of which two are lateral and two are polar regions.
Thorn	: Same as spine.
Triarch	: Structural condition in a primary root having primary xylem with three protoxylem poles.
Translocation	: Movement of something from one place to another
Tuber	: Any fleshy part of the plant which store food.
Uniseriate ray	: Wood ray that is one cell wide as viewed in tangential section.
Vasculature	: Vascular system of plant.
Vivipairy	: A condition in which seed germinates or embryo grows before they detach from the parent i.e. fruit is attached to the mother plant.

FURTHER READING

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