UNIT 1

TISSUES

Structure

1.1 INTRODUCTION

All living organisms are made up of basic units known as cells. The individual cells are grouped to form tissues which perform a specific function. The cells have distinctive shapes, wall characteristics and show specific physiological properties. Depending upon the organization of cells, tissues have been categorized into different types. In this unit you will study about different types of tissues found in plants. Some cells develop specialized structures, some carry out limited functions while the others carry out multiple functions. Cells mainly participate in growth, cell division and differentiation. The detailed information about function of various tissues with emphasis on their role in plant growth will be provided to you in this unit.

Objectives

After studying this unit you whould be able to :

- describe different type of tissues;
- differentiate between simple and complex tissues;
- define meristematic tissues; and
- describe the role of different tissues.

1.2 TYPES OF TISSUES

Plant body comprises of several types of tissues, now you are going to study about different types of tissues. Fahn defined tissues as 'complex of cells of common origin'. Tissue comprise of group of cells which may possess a common structure or may perform a common function.

Tissues are classified basically into two types :

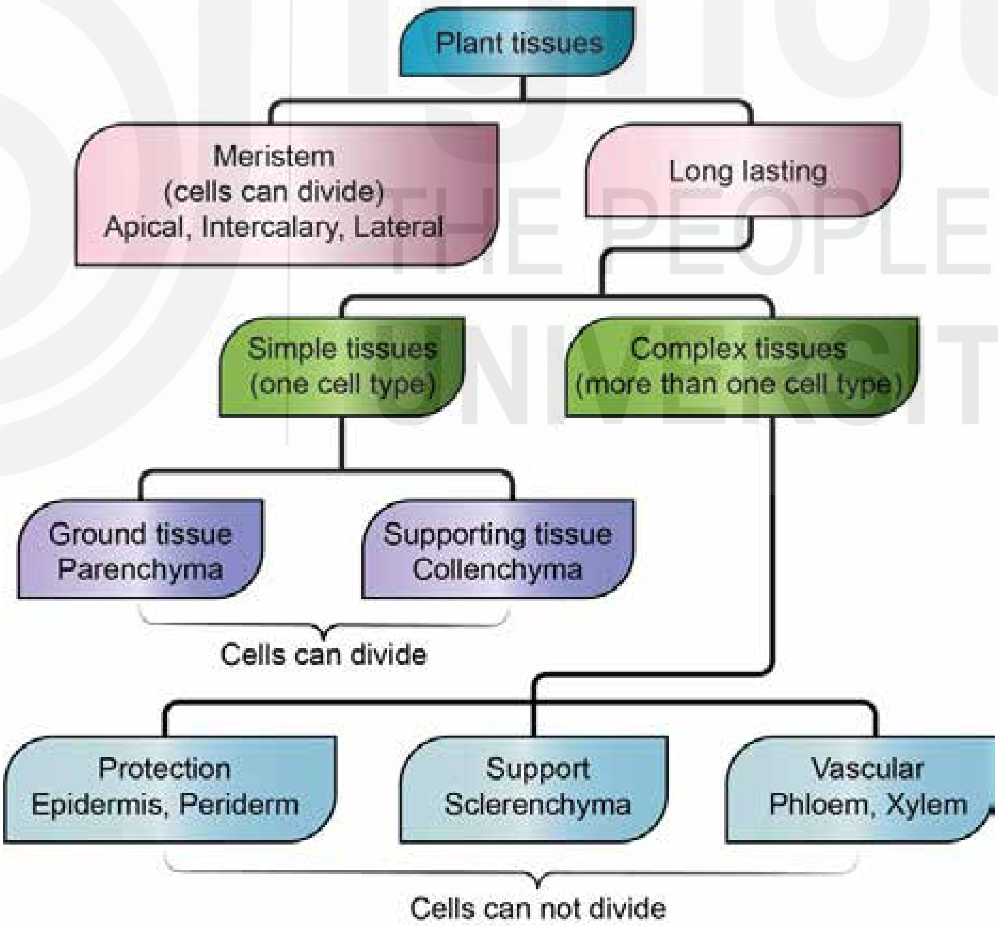
- Simple
- Complex

Simple tissues-The tissues which consist of similar type of cells are referred as simple tissues. They appear to be homogeneous. These include parenchyma, collenchyma and sclerenchyma.

Complex tissues- The tissues which consist of more than one type of cells are referred as complex tissues. These include xylem and phloem.

Based on the stage of development of the plant body, the tissues are also classified into two types :

1) Meristematic tissue; and 2) Permanent tissue



1) **Meristematic tissue or meristems** : The cell(s) of this tissue are generally young and immature, and possess the potential to show continuous division. These tissues show the ability to divide and self perpetuate throughout the plant life. A meristem may consist of one or more group of cells and these cells are defined as meristematic cells

(meristem- like). Thus we can say that a cell or group of cells that are meristematic constitute a meristem. You will study about meristems in unit 2 of this course.

2) **Permanent tissue** : These cells are derived from a meristem. The cells of this tissue cannot divide as they lose the capacity to divide. The cells of this tissue possess living or dead cells which may be thick or thin walled but have well developed organelles. These cells are also known as mature tissue.

1.3 SIMPLE TISSUES

Simple tissues mainly consist of parenchyma, collenchyma and sclerenchyma.

1.3.1 Parenchyma

It consists of least specialised and least differentiated cells. They are primarily isodiametric and possess a primary cell wall but may exhibit variety of shapes and forms. They are thin walled living cells and may be capable of regaining the capacity to divide (Fig. 1.1). They are compactly arranged or separated by abundant of intercellular spaces. Parenchyma can have diverse origins. They originate either from an apical meristem or from lateral meristems. They are regarded as the basic ground tissue from which all specialised cells might have developed. The cells occur as scattered diffused elements or homogenous mass. They are generally polyhedral but sometimes morphological variations stellate and armed forms also occur. A typical parenchyma cell is 14 sided. These cells are physiologically very active and participate in various metabolic activities such as synthesis, storage, transport of metabolites, wound healing, repair and regeneration. It is the most common type of tissue and present in all many parts of the plants such as pith and cortex regions of the stems, roots, fleshy tissues of fruits and seeds, photosynthetic leaves and rays of secondary xylem and phloem as well as the axial secondary xylem and secondary phloem. When parenchyma are fully turgid they provide considerable stiffness to stems.

Parenchyma present in different regions arises in different ways. Parenchyma present within the primary plant body differentiates from the ground meristem, procambium and protoderm, while that present in the secondary body, originates from the activity of both vascular and cork cambium.

Parenchyma that contains chloroplast participates actively in the photosynthesis and are known as chlorenchyma. The thin cell wall of these cells allows light and carbon dioxide to pass through to reach chloroplast. Some parenchyma cells can secrete nectar, mucilage resins and oils. These cells contain large amount of dictyosomes and endoplasmic reticulum. They assist in the transfer or transport of large quantities of sugar and minerals.

1.3.2 Collenchyma

It is a supporting tissue composed of more or less elongated living cells with unevenly thickened, non-lignified primary walls. It is in regions of primary growth in stems and leaves. The three most characteristic morphological features of collenchyma are axially elongated cells; cell wall thickenings; and living protoplasts.

It consists of elongated cells having a primary cell wall. The cells are axially elongated (up to 2mm long).The cell wall is unevenly/irregularly thickened and rich in pectin. The cell wall is thick at the corners (Fig.1.1). The cell walls of collenchyma are rich in cellulose and pectin. The cell walls possess high tensile strength with high water content. The cells are living at maturity. They give mechanical support principally for the primary organs such as young stems, hypocotyls, pedicels, peduncles etc. The walls of the collenchyma's exhibit plasticity. The cells get deformed under pressure or stress but retain their shape after the stress is relieved.

They are mostly found at the periphery of stem, leaves and floral parts. The collenchyma cells are present as a layer under the epidermis or as bands next to vascular bundles. On the basis of deposition of primary cell wall thickenings, the collenchyma have been categorized as **angular** collenchyma in which the corners are thickened, **tangential** collenchyma in which the inner and outer tangential walls are thickened, **annular** collenchyma in which the walls are uniformly thickened and **lacunar** collenchyma in which the primary cell wall thickenings are present at the places where the cell wall is in direct contact with the intercellular spaces.

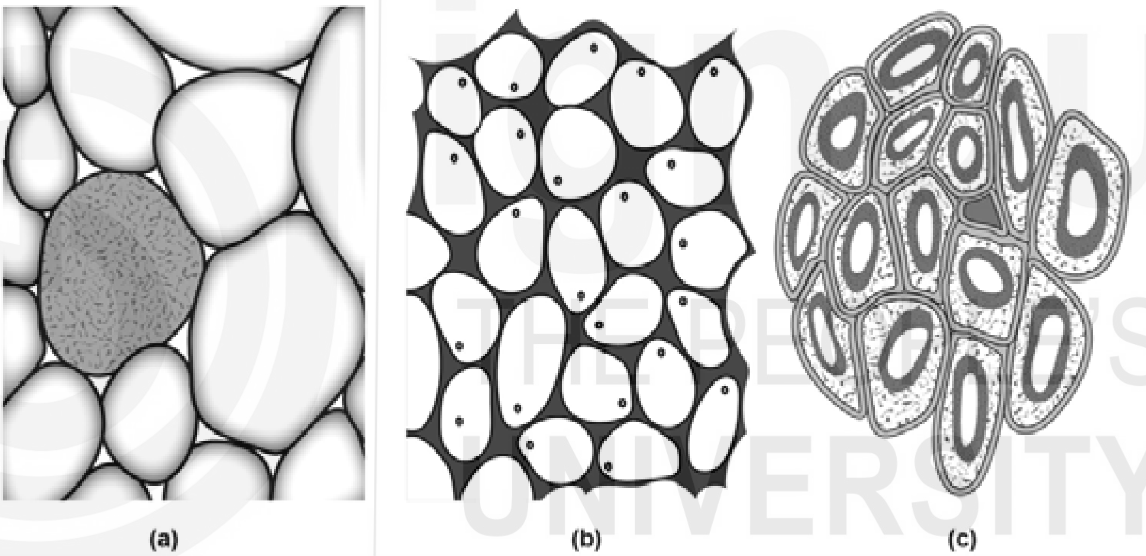


Fig. 1.1: Diagrammatic representations of cells a) Parenchyma; b) Collenchyma; c) Sclerenchyma.

1.3.3 Sclerenchyma

It consists of cells having thick, lignified secondary cell walls. They do not retain a living protoplast at maturity. The walls of the cells are elastic i.e. return to their original shape after the pressure or tension is released. The cell wall shows specialized structures called pits. Sclerenchyma prevents the protoplast from expanding. These cells play a protective or supportive function throughout the plant body. Sclerenchyma cells arise within the primary body after differentiation of protoderm, ground meristem, procambium or from fusiform initials of vascular cambium in a secondary plant body.

These cells are classified into two types - **fibers** and **sclereids**.

Fibers

Fibers are narrow, elongated sclerenchyma cells with tapering ends. The secondary wall of the fibers is generally thick. They form major component of xylem tissue. They are lignified and non-living, hence incapable of further growth and division. Most of them are non living but sometimes they can be living particularly those found in the wood of dicotyledons. The mature fiber is thick and almost or entirely occluded. They are also found in various parts of the plant. They are mainly found in primary plant parts such as pericycle, hypodermis, bundle sheaths, pith etc. They function in mechanical support in various organs.

On the basis of their position in plants, fibers are classified as **phloem fibers** (phloem) and **wood fibers** (xylem). The plants also show the occurrence of **xylary and extraxylary** fibers. Extraxylary fibers are those which are positioned in the cortex or phloem and are referred as bast fibers, while **xylary fibers** are those which are occurring in the wood and originating from the vascular cambium (Fig.1.2). In many plants, the extraxylary fibers are very long. The longest fiber has been noted in ramie (*Boehmeria nivea*) which is about 550 mm in length. Bast fibers are economically important because they possess high tensile strength and are used for making ropes and other items. They can be septate (having septum or cross walls) or aseptate (septum is absent). Fibers of some taxa show formation of thick, lignified secondary wall while the others depict the thin partition or septa of secondary wall across the cell lumen. These are referred as **septate** fibers. In some plants, fibers remain active at maturity and carry out metabolism. These living cells store starch or calcium oxalate. Wood fibers show transition during the evolutionary process from tracheid like elements with bordered pits to slender wood fibers without pit borders.

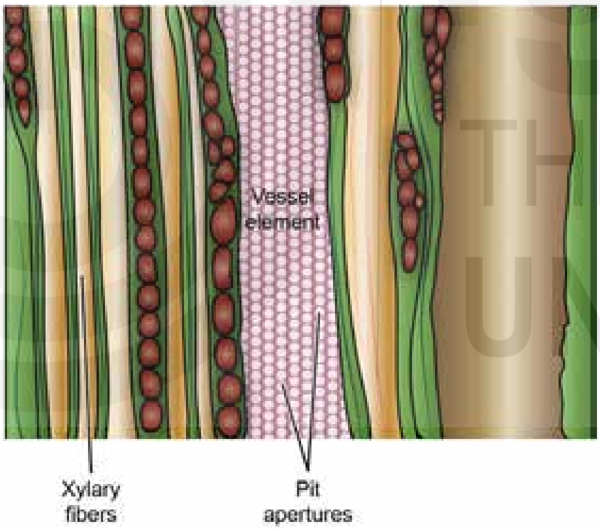


Fig. 1.2: Structure of xylary fibers.

Sclereids

They are reduced/small, isodiametric (cuboidal) irregular shaped sclerenchyma cells. They have thick lignified cell walls having conspicuous concentric laminations interrupted by pitting. They are non-living at maturity and found to be present in various plant tissues such as the periderm, cortex, pith, xylem, phloem, leaves and fruits. They mainly originate in the vicinity of the midrib or both in the midrib and leaf margins. They can be of different shapes such as spherical, oval or cylindrical. They are known to function in mechanical support and protection such as minimizing or deterring herbivory.

Sclereids can be classified into different types- **astrosclereids**, branched sclereids, **brachysclereids** (stone cells), short roughly isodiameteric cells that resemble parenchyma, **fliform** sclereids, elongated and slender cells resembling fibers, **macrosclereids** elongated cells showing uneven deposition of secondary walls, **osteosclereids** (bone shaped) the cells having columnar middle and enlargement at ends and **trichoscelereids**, branched with hair like branches extending into intercellular spaces (Fig.1.3).

On the basis of their occurrence, sclereids have been classified as **diffuse** sclereids which are dispersed in the leaf mesophyll, **terminal** sclereids which are confined to the end of small veins and **mixed** pattern containing both terminal and diffuse sclereids and **epidermal** sclereids. Many plant families possess more than one type of sclereids. Sclereids of varied shapes and sizes have noted in families such as Theaceae, Proteaceae. In some species, crystals are also present in the walls of the sclereids and these are referred as crystalliferous sclereids. This type of sclereids has been found in *Araucaria, Nymphaea, Nuphar, Schisandra, Welwitschia* etc.

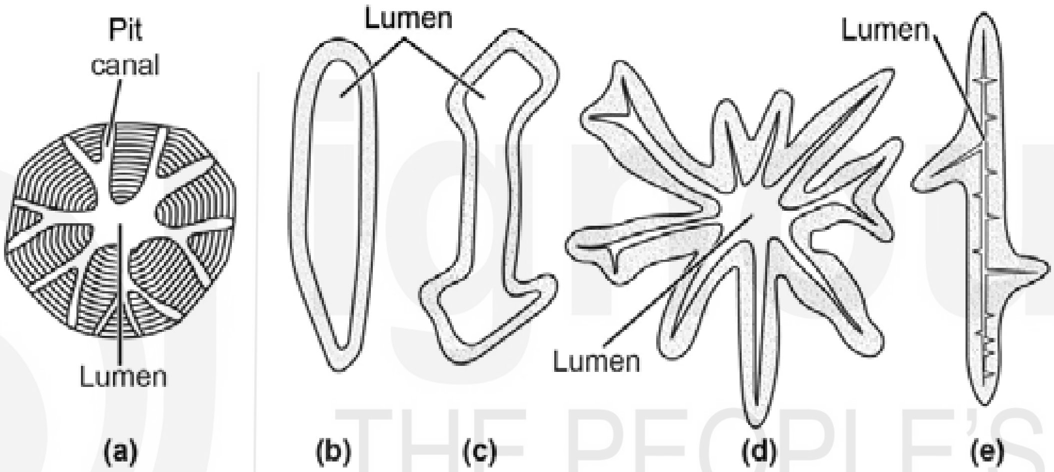


Fig. 1.3: Structure of various type of sclereids a) Stone cell; b) Macrosclereid; c) Osteosclereid; d) Astrosclereid; and e) Filiform sclereid.

SAQ 1

Differentiate between meristematic tissues and permanent tissues?

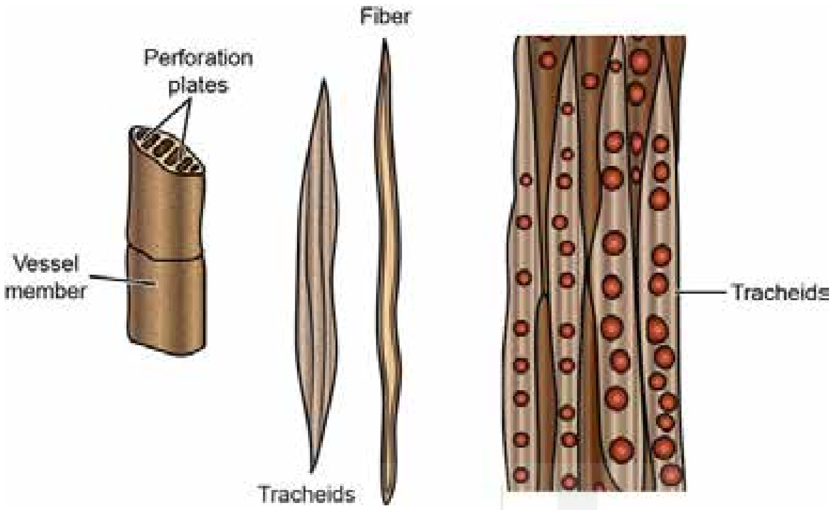
1.4 COMPLEX TISSUES

These mainly consist of xylem and phloem. Both are composed of different cell types which possess specialized structure and perform specific function. We will study about them in detail.

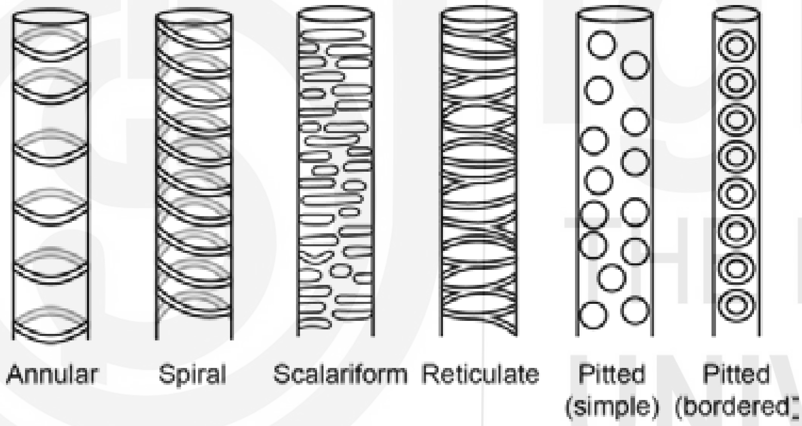
1.4.1 Xylem

It consist of two conductive tissues namely tracheids, vessel elements along with parenchyma and xylem fibers (Fig. 1.4 a). Tracheids and vessels are also referred as conducting tissues or tracheary elements. Tracheary elements consist of elongated cells with rigid and pitted secondary walls. They lack protoplasmic contents at maturity. Vessel elements join end to end to form a continuous tube like structure. They assist in function to conduct water and essential nutrient elements from roots to other parts of the plants.

Trachieds are the major water conducting elements found in vascular plants. They are elongated structures which are imperforate i.e. allow movement of water and mineral nutrients between adjacent cells through pit pores. Water passes from cell to cell through series of pit membranes of bordered pit pairs present along the overlapping and tapered end walls of two adjacent cells.



(a)



(b)

Fig.1.4: Structure of a) tracheids, Vessels and fibers; b) secondary wall thickenings in tracheary elements.

Each vessel possesses a stack of vessel elements. Each vessel element has one perforation on each end. The vessels members are attached end to end to form a continuous tube like structure. Vessels are perforate structures i.e. movement of water and mineral nutrients occurs through one or more continuous holes between adjacent cells. The contact area of two adjacent plates is called as **perforation plate**. The plate can be simple or compound. A simple perforation plate is an area of end wall that exhibits large, single, circular or elliptical openings that leave a narrow rim of primary wall remaining. A scalariform perforation plate is a plate consisting of elongated parallel openings i.e. several pores (pit pores with primary cell walls) separated by one or more branched or unbranched bars. These are found in many families such as Betulaceae, Magnoliaceae, Hydrangeaceae and Theaceae. Vessel members differ considerably in their length, width and degree of perforation. Vessels absorb water from parenchyma, tracheids or other vessels and pass on. The pits help in the transfer of water on lateral sides. The wall thickenings noted in the tracheids are also found in the vessels.

During development of trachery elements, mature parenchyma cells stop dividing. The cell with primary cell wall starts elongating, become narrow and develops certain thickenings which are referred as secondary walls. The pattern of wall deposition permits the differential expansion or elongation essential for morphogenesis. The secondary wall is impermeable to water and develop certain thickenings which occur as rings, reticulate, helical or scalariform (Fig 1.4 b).

1.4.2 Phloem

Phloem is a conducting tissue composed of specialised cells called sieve elements, parenchyma and sclerenchyma. Sieve elements consist of two cells- **sieve cells** and **sieve tubes**. Sieve tube in turn is made up of a number of cells each termed as sieve tube member or sieve tube element. They consist of sieve pores which are aggregated to form sieve areas.

Sieve tube members have both sieve areas and sieve plates. Sieve tube members contain elongate cells having thin primary cell walls. These are metabolically active. Pore of the sieve area is lined with a substance called **callose**, a polysaccharide. The sieve elements are also aligned end to end to form a structure called sieve tube. They function to transfer dissolved sugars and organic metabolites to various parts of the plant. **Sieve tube members** are elongate cells whose walls bear differentiated regions occupied by numerous narrow sieve pores filled with protoplasmic connecting strands that link them to adjacent sieve elements. The end wall of the sieve tube element is termed as **sieve plate** (Fig.1.5). The sieve plate is composed of one or more sieve areas with large sieve pores. The protoplasts of two functional sieve elements are interconnected by means of continuous cytoplasmic bridges similar to plasmodesmata. During maturation of sieve tube elements, the plasmodesmata penetrate the enlarged and open sieve plate pores to form continuous system of protoplasm between contiguous sieve tube elements. Sieve plates consist of one or more sieve areas at the end junction of two sieve tube members. A sieve plate composed of single sieve area is a **simple sieve plate** while the end wall containing two or more sieve areas is a **compound sieve plate**. A simple sieve plate is correlated with transversely oriented end walls and compound sieve plates are usually located in various inclined end walls. A unique feature of the sieve tube elements found in dicots and some monocots is the presence of proteinaceous substances called **phloem protein bodies (P protein).**

Sieve cells may possess one or more sieve areas on its lateral walls. Sieve cells are found confined to gymnosperms and lower vascular plants. They are slender, elongated cells with tapering ends. They possess sieve pores on lateral walls (Fig.1.5). They lack P protein which is found in sieve tubes of angiosperms. These cells possess a complex network of endoplasmic reticulum that is continuous from cell to cell through sieve area pores. These cells are associated with albuminous cells (Strasburger cells). Albuminous cells are not derived from the same mother cell as the associated sieve cell.

Both sieve cells and sieve tube members have parenchyma physically associated with them. The phloem parenchyma cells function primarily as long lived storage cells. Both of these cells help to load and unload sugars into the cavity of sieve cells or sieve tube members. The parenchyma cells associated with sieve cells are referred as albuminuous cells, while those attached with sieve tube members are called as companion cells. The companion cells are small, densely cytoplasmic cells that are ontogenetically derived by unequal division of same initial as the sieve tube element. They communicate with the sieve tube element by means of plasmodesmata pore connection across the common walls. These cells possess a large nucleus at maturity and are rich in organelles such as mitochondria, plastids and endoplasmic reticulum. Companion cells supply the energy to the sieve tube element to drive translocation (Fig. 1.5 a).

Sieve cells are found in primitive i.e. non-flowering vascular plants, while sieve tube members are found only in angiosperms i.e. flowering vascular plants.

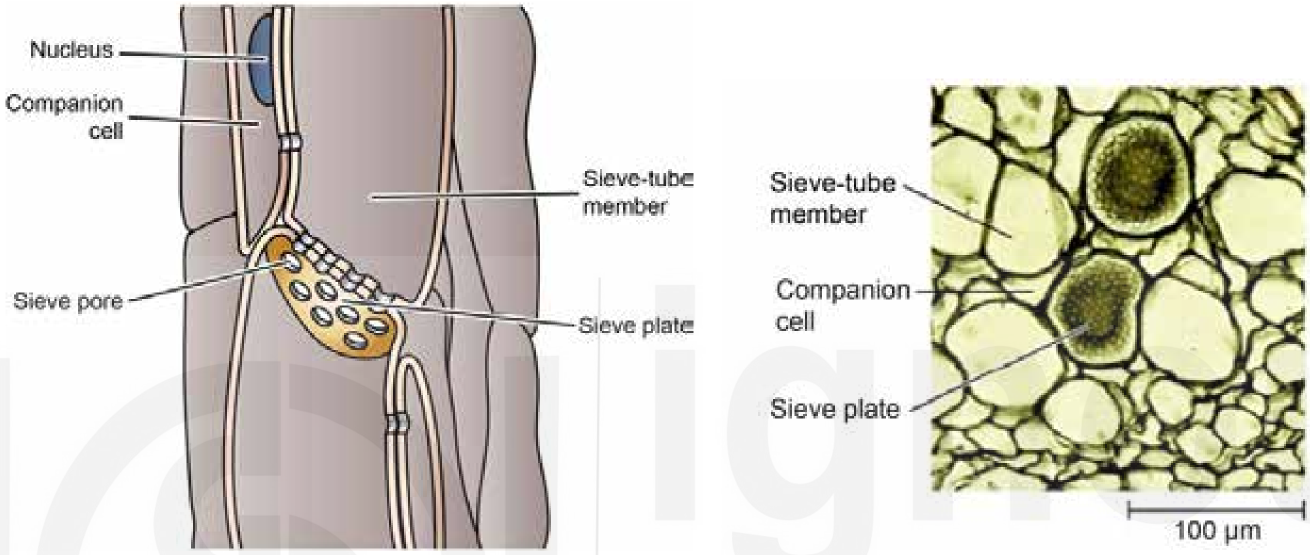


Fig.1.5: a) Longitudinal view; and b) Transverse view of the phloem structure.

SAQ 2

a) Fill in the blank(s) with appropriate word(s) :

i) The cells having thick lignified walls as referred as……………… .

ii) Cells associated with the sieve tube elements are called as …….. .

iii) ………………….. are the main conducting tissues in plants.

iv) The sieve tube elements found in dicots and some monocots show the presence of proteinaceous substances known as …………. .

v) Long narrow sclerenchyma cells with tapering ends are referred as ……………..… .

vi) Each vessel element has one ……………………. on each end.

vii) Tracheids generally show …………………… thickenings.

viii) In phloem, both sieve cells and sieve tube members have ……………… physically associated with them.

ix) Pore of the sieve area is lined with a substance called ………… .

x) The sieve plate is composed of one or more …………. with large sieve pores.

b) Write the functions of :

   i) chlorenchyma

   ii) tracheids

   iii) fibers

   iv) sclereids

c) Answer in one word.

   i) A simple tissue having undifferentiated isodiametric cells.

   ii) A simple tissue having cells with thick, lignified cell walls.

   iii) Long narrow cells with tapering ends which function in mechanical support in various organs.

   iv) The parenchyma cells associated with sieve cells.

   v) Tissues in which the cells divide indefinitely or remain in the active phase throughout the life of the plant.

   vi) Perforate structures that allow movement of water and mineral nutrients.

   vii) A sieve plate composed of single sieve area.

   viii) Sieve cells are mostly found in these plants.

   ix) A unique proteinaceous substances found in sieve tube elements of dicots and some monocots.

   x) Small/reduced, isodiametric (cuboidal) irregular shaped sclerenchyma cells having thick lignified cell walls.

1.5 MERISTEMATIC TISSUES

Meristematic tissues are composed of a group of undifferentiated self-renewing cells which give rise to most of the plant structures. The meristematic cells help in the growth of the plants. In meristematic tissues or meristems, the cells divide indefinitely or remain in the active phase throughout the life of the plant. Meristematic tissues are found near the tips of roots and stems, buds and nodes of stems. The cells of the meristematic tissues are small in size, immature and possess the power of continuous division. Meristematic cells have the ability to enlarge, stretch and differentiate into other types of cells as they mature. The meristematic cells can be oval or rounded or polygonal in shape. They have a large nucleus and lots of vacuoles. They are so minute to be discernible under a compound microscope. Intercellular space between cells is absent.

When a meristematic cell divides in two, the new cell that remains in the meristem is called an 'initial' and the other is called the 'derivative'. As new cells are added by repeated mitotic divisions of the initial cells, the derivatives are pushed farther away from the zone of active division. They stretch, enlarge and differentiate into other types of tissues as they mature. Meristematic cells are generally small and cuboidal with large nuclei, small vacuoles, and thin walls.

The main characteristics of cells of meristematic tissues :

i) It consist of living, thin cellulose walled cells.

ii) The cells contain dense protoplasm and conspicuous nuclei.

iii) The cells are spherical, oval or polygonal in shape.

iv) Vacuoles are few and small in size.

Meristems are of two types depending upon their location in the plant body. Namely shoot apical meristem and root apical meristem. The shoot apical meristem (SAM) (Fig.1.6) gives rise to organs like the stem, leaves and flowers, while the root apical meristem (RAM) provides the meristematic cells for the future root growth. The cells of the shoot and root apical meristems divide rapidly and are considered to be indeterminate, which means that they do not possess any defined end fate.

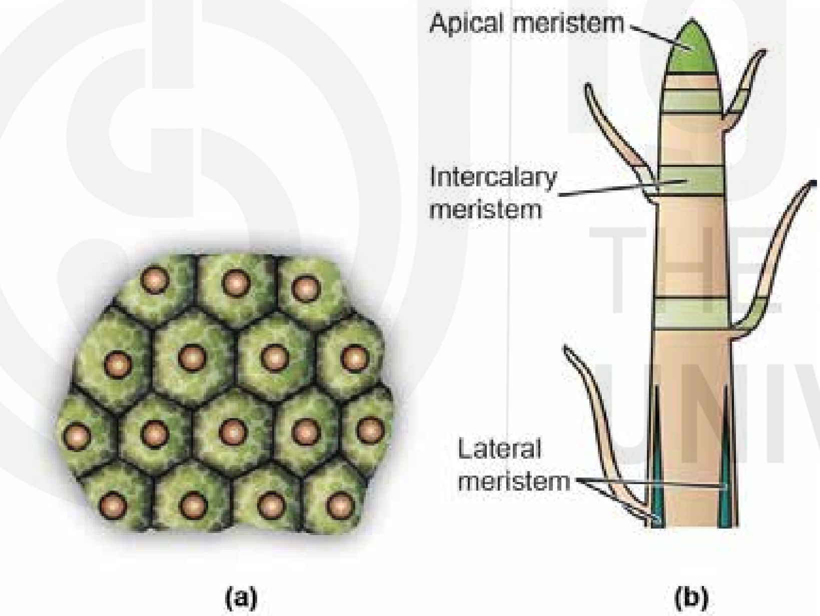


Fig.1.6: a) Structure of meristematic cells; b) location of various meristems.

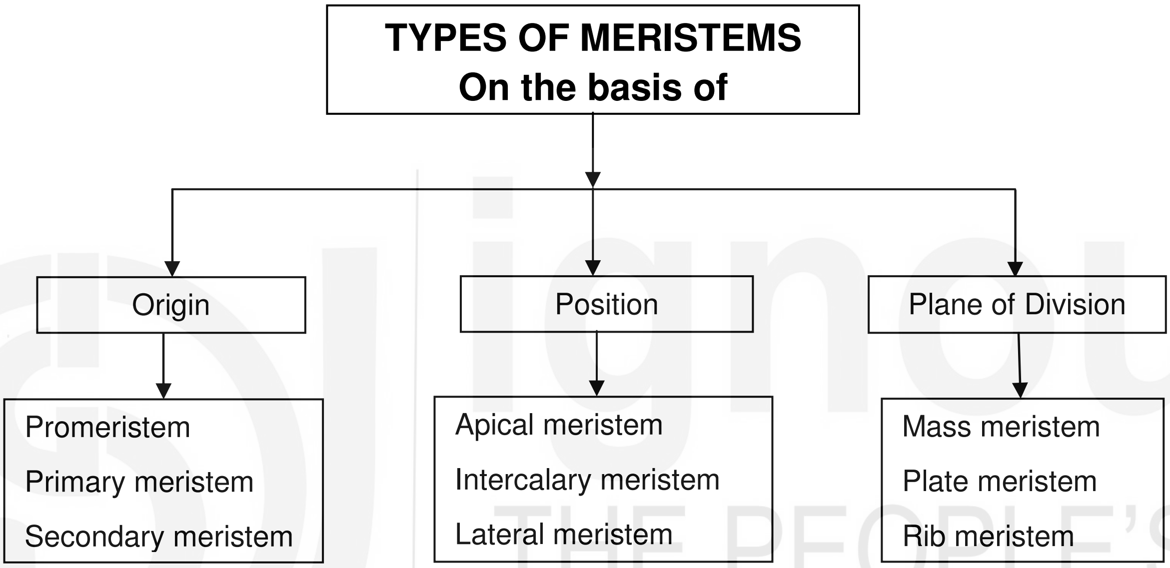
1.5.1 Properties of Meristems

Meristems contain a population of cells with characteristics of **stem cells**. The cells divide continuously to replenish meristem and provide cells that will differentiate into plant organs and tissues. The plant meristems have the capacity to differentiate as any cell type. Vegetative meristems are **indeterminate** i.e., they can grow indefinitely. Some plants normally produce a relatively fixed number of nodes, if the meristem is removed and then allowed to reform in culture, they will produce normal number of nodes. Thus node number is a property of the whole plant and not inherent to the meristem. Vegetative meristems are highly **regulative**. If portions are surgically removed, the remainder will reorganize into a functioning meristem.

The activity of vegetative meristems is **repetitive**, often described as meristic (mer meaning unit as in polymer). The meristem produces modular units consisting of a lateral organ (leaf), axillary bud, node and subtending internode. Each unit is called a **phytomer**. Thus primary shoot growth involves the repetitive addition of stem segments and associated leaves to the end of the shoot. You will study about meristem in the coming unit but here we will like you to be introduced to important expressions used in describing meristem.

1.5.2 Types of Meristems

The meristems have been classified into different types on the basis of origin, development, position, plane of division and function in the plant body.



a) On the basis of origin and development of initiating cells, meristems have been classified into three types :

i) **Promeristem or priomordial meristem -** A group of young meristematic cells of a growing organ. It is the early embryonic meristem from which other advanced meristems are derived. In a plant, it occupies a small area at the tip of stem and root. It further divides to form primary meristem. It is made up of thin walled isodiametric cells.

ii) **Primary meristem -** These are derived from promeristem. Hence they can be referred as derivatives of promeristem. It forms fundamental parts of the plant. They are present below the promeristem at shoot and root apices. These cells divide and form permanent tissues. These include apices of roots, shoots and primordial of leaves or other appendages.

iii) **Secondary meristem -** It is derived from primary permanent tissues which have the capacity of division. This meristem appears after a certain stage of development of plant organ. It develops from mature tissues which have already differentiated. It is lateral in position. Example- cork cambium, cambium of roots and inter fascicular cambium of stem.

b) On the basis of their position in the plant body, meristems have been classified into three types :

i) **Apical meristem** - These are located in the growing points such as apices of primary stem and root.

ii) **Lateral meristem** - These are located and arranged parallel to the sides of the organs. They divide periclinally or radially. They help in increasing the diameter of stem or root. Example- vascular cambium, cork cambium.

iii) **Intercalary meristem** - the meristem lies between the regions of permanent tissues. It is considered as part of the primary meristem. It is present at the base of the leaves in monocotyledons and internodal region of grasses.

c) Meristems can also be divided into different types on the basis of plane of division. The plane of division determines the growth pattern in plants.

i) **Rib or file meristem** - In this meristem the plane of division is restricted to right angles to the longitudinal axis of the cell. This means that the cells divide anticlinally and result in formation of long rows or file of cells. This meristem gives rise to cortex and pith of stem and root.

ii) **Plate meristem** - It consist of parallel layer of cells which divide anticlinally and it brings intercalary growth. This meristem occurs in leaves and increases its surface area.

iii) **Mass meristem** - In this type of meristem, the cell division occurs in all planes resulting in the formation of massive plant body or organ. This meristem is involved in the development of embryo or endosperm.

d) Meristem can also be divided into different types on the basis of function. The primary meristem of root and shoot apex have been classified into different types on the basis of their function.

i) **Protoderm -** The outermost meristematic layer of the growing regions. It develops into outer dermal tissues including epidermis.

ii) **Procambium -** It is composed of narrow, elongated, parenchymatous cells. The cells are densely cytoplasmic and contain large nucleus, proplastids and possess meristematic activity. They develop into primary vascular tissue. The peripheral derivatives of procambium are primary phloem and the inner derivatives are primary xylem. The portion of procambium that remains in between primary phloem and xylem differentiates into cambium.

iii) **Ground meristem -** It is precursor of ground tissue and consists of large thin walled cells. The cells develop into hypodermis, cortex, pericycle and pith. This meristem is considered as the precursor of fundamental or ground tissue system.

The cells of these zones are produced by divisions in the apical meristem. The tissues in each of these zones differentiate into distinct tissues which mature and compose the primary body of a plant.

SAQ 3

a) Enlist some characteristics of meristematic tissues.

b) Classify meristems into different types on the basis of their position in the plant body.

c) Name the following :

   i) The outermost meristematic layer that develops into epidermis.

   ii) The meristematic layer that develops into primary vascular tissue.

   iii) The layer of the meristematic tissue that develops into hypodermis, cortex, pericycle and pith.

1.6 SUMMARY

- A group of cells of a common origin are termed as tissue. These cells may be similar in structure or may perform similar function. Depending upon the organization of cells, tissues can be of different types.
- The tissues which consist of one type of cells are simple tissues. These include parenchyma, collenchyma and sclerenchyma.
- The tissues which consist of more than one type of cells are complex tissues. These include xylem and phloem.
- Meristematic tissues or meristems are tissues in which the cells remain young and divide actively throughout the life of the plant.
- On the basis of their position in the plant body, meristems have been classified into three types, apical, lateral and intercalary.
- Apical meristem is located at opposite ends of the plant axis in the tips of roots and shoots. Cell divisions and subsequent cellular enlargement in these areas lengthen the above and below ground parts of the plant. The meristems also influence the shapes of the mature plants since the patterns for subsequent growth are laid down in the meristems. These are found at the apices or growing points of root and shoot and bring about increase in length.
- In lateral meristem, cells are arranged parallel to the sides of origin and normally divide periclinally or radially and give rise to secondary

permanent tissues. These increase the thickness of the plant part. The lateral meristems are present on the lateral side of the stem and root of a plant. These meristems help in increasing the thickness of the plants.

- Intercalary meristem lie between the region of permanent tissues and are considered as a part of primary meristem which has become detached due to formation of intermediate permanent tissues. It is found either at the base of leaf e.g. *Pinus* or at the base of internodes e.g. grasses.

1.7 TERMINAL QUESTIONS

1) Why are xylem and phloem considered as complex tissues?

2) Differentiate between

   a) primary and secondary meristem.

   b) companion cell and albuminous cell.

3) How is apical meristem different from intercalary meristem?

4) With the help of well developed diagrams explain the different components of the water and food conducting tissue in plants.

1.8 ANSWERS

Self-Assessment Questions

1. **Meristematic tissue or meristems :** The cells of this tissue are generally young and immature, with the power of continuous division. These tissues have the ability to divide actively throughout the life of the plant.

   Permanent tissue : The cells of this tissue cannot divide. They have lost the capacity to divide. The cells of this tissue possess living or dead cells which may be thick or thin walled but have well developed organelles.

2. a) i) Sclerenchyma

   ii) Companion cells

   iii) Tracheids and vessels

   iv) Phloem protein bodies (P protein)

   v) Fibers

   vi) Perforation

   vii) Wall

   viii) Parenchyma

ix) Callose

x) Sieve areas

b) i) These parenchyma cells contain chloroplast and are actively involved in photosynthesis.

ii) Trachieds are the elongated structures which conduct water and mineral nutrients in vascular plants. They allow movement of water and minerals between adjacent cells through pit pores.

iii) Fibers provide mechanical support to the plant.

iv) Sclereids are known to function in mechanical support, protection such as minimizing or deterring herbivory.

c) i) Parenchyma

ii) Sclerenchyma

iii) Fibers

iv) Albuminuous cells

v) Meristematic tissues or meristems

vi) Vessels

vii) Simple sieve plate

viii) Gymnosperms and lower vascular plants

ix) Phloem protein bodies (P protein)

x) Sclereids

3. a) Meristematic cells are generally small and cuboidal with large nuclei, small vacuoles, and thin walls. The main characteristics of cells of meristematic tissues are:

i) It consist of living, thin cellulose walled cells

ii) The cells contain dense protoplasm and conspicuous nuclei

iii) The cells are spherical, oval or polygonal in shape

iv) Vacuoles are few and small in size

b) On the basis of their position in the plant body, meristems have been classified into three types

i) **Apical meristem -** These are located in the growing points such as apices of stem, root.

ii) **Lateral meristem -** These are located and arranged parallel to the sides of the organs. They divide periclinally or radially. They help in increasing the diameter of stem or root. Example- vascular cambium, cork cambium.

iii) **Intercalary meristem -** This meristem lies between the regions of permanent tissues. It is considered as part of the primary meristem. It is present at the base of the leaves in monocotyledons and intermodal region of grasses.

c) i) Protoderm

ii) Procambium

iii) Ground meristem

Terminal Questions

1. Xylem is composed of more than one type of tissue namely tracheids and vessels. Tracheids consist of elongated cells joined end to end to form a continuous tube like structure. They assist in function to conduct water and essential nutrient elements from roots to other parts of the plants. Vessels are perforate structures attached end to end to form a continuous tube like structure and allow movement of water and mineral nutrients between adjacent cells.

   Phloem is composed of specialised cells called sieve elements. Sieve elements consist of sieve cells and sieve tube members. The sieve elements are also aligned end to end to form a structure called sieve tube. They function in transfer of dissolved sugars to various parts of the plant. The parenchyma is also associated with them.

   Since both xylem and phloem are composed of more than one type of tissues, they are called as complex tissues.

2. a) **Primary meristem -** These are derived from promeristem. Hence they are also referred as derivatives of promeristem. It forms fundamental parts of the plant. They are present below the promeristem at shoot and root apices. These cells divide and form permanent tissues. These include apices of roots, shoots and primordial of leaves or other appendages.

   Secondary meristem - It is derived from primary permanent tissues which have the capacity of division. This meristem appears after a certain stage of development of plant organ. It develops from mature tissues which have already differentiated. It is lateral in position. Example- Cork-cambium, cambium of roots and inter fascicular cambium of stem. It develops during the time of injury or wounds.

   b) These cells are associated with sieve cells are referred as albuminous cells (Strasburger cells). Albuminous cells are not derived from the same mother cell as the associated sieve cell.

   The cells attached with sieve tube members are called as companion cells. The cells are small, densely cytoplasmic cells and derived by unequal division of same initial as the sieve tube element.

3. Apical meristems are located in the growing points such as apices of primary stem and root while lateral meristem are located and arranged parallel to the sides of the organs.

4. Refer to Section 1.4 and draw diagrams.