# PERIYAR INSTITUTE OF DISTANCE EDUCATION (PRIDE)

# PERIYAR UNIVERSITY

**SALEM - 636 011.**

**B.Sc. BOTANY**

**SECOND YEAR**

**PAPER – IV : ANATOMY AND EMBRYOLOGY OF ANGIOSPERMS**

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**PAPER – IV : ANATOMY AND EMBRYOLOGY OF ANGIOSPERMS**

**BLOCK : 1**

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| **BLOCK** | INTRODUCTION |
| **UNIT - I** | MERISTEMS, SIMPLE PERMANENT TISSUES |
| **UNIT - II** | COMPLEX TISSUES, STOMATAL TYPES |
| **UNIT - III** | PRIMARY AND SECONDARY STRUCTURE - DICOTS, MONOCOTS |
| **UNIT - IV** | MALE AND FEMALE GAMETOPHYTE |
| **UNIT - V** | POLLINATION, FERTILIZATION AND EMBRYO DEVELOPMENT |

**B.Sc. BOTANY**

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**PAPER – IV : ANATOMY AND EMBRYOLOGY OF ANGIOSPERMS**

**Anatomy**

**UNIT - I**

Meristems: Classification, distribution, structure, function.

Theories: Tunica - Corpus and quiescent centre.

Simple permanent tissues: Parenchyma, Collenchyma, Sclerenchyma, (fibres and sclereids), Transfer cells.

**UNIT - II**

Complex tissue: Xylem-tracheids, vessels, xylem fibres and xylem parenchyma. Secondary xylem, Annual rings, Heart wood and sap wood.

Phloem: Sieve elements, companion cells, phloem fibres and phloem parenchyma. Secondary phloem: Laticifers.

Stomatal Types: Ranunculaceous, cruciferous, caryophyllaceous, rubiaceous and graminaceous.

**UNIT - III**

Primary and secondary structure of dicot stem. Anomalous secondary growth in stems of Boerhaavia and Nyctanthes. Primary and Secondary structure of dicot root. Primary structure of monocot stem and root. Structure of Dicot and Monocot leaf. Nodal anatomy - Uni, tri and multilacunar node.

**Embryology of Angiosperms**

**UNIT - IV**

Structure and development of anther. Structure of Pollen grain. Development of male gametophyte.

Types of ovules. Nucellus. Development of female gametophyte: Monosporic (Polygonum), Bisporic (Allium) and Tetrasporic (Peperomia).

**UNIT - V**

A brief account on pollination and fertilization.

Endosperm: Nuclear, Cellular, Helobial and Ruminate.

Development of Embryo in Dicot (Capsella - bursa - paustoris).

Development of Embryo in monocot (Najas). Polyembryony.

## BLOCK PLAN (CONTENT)

# BLOCK INTRODUCTION

We are in the block of course - Anatomy and embryology of angiosperms. In this block we will discuss about meristems, simple permanent tissues, complex tissues, stomatal types, Primary, Secondary structure, male and female gametophyte, Pollination, Fertilization and embryo development.

Plant anatomy is the study of internal structure of plant organs. Embryology of angiosperms is the branch of biology which deals with the study of development of zygote into embryo.

In the first unit we are going to discuss about the meristematic tissues and simple permanent tissues.

In the second unit of this block you are going to explore about complex tissues such as xylem, phloem and stomatal types.

In the third unit we are going to learn about the Primary and Secondary structure of dicot and monocot stem, root and leaf.

In the fourth unit you will get the clear explanation about male and female gametophyte.

In the fifth unit you will acquire the knowledge on the area of fertilization, endosperm, development of embryo and polyembryony.

**UNIT - I MERISTEMS, SIMPLE PERMANENT TISSUES**

# PLANT ANATOMY

## UNIT - I

## MERISTEMS, SIMPLE PERMANENT TISSUES

**1:0 INTRODUCTION**:

The study of internal structure of plant organs is called plant anatomy (ana = as under; temnein = to cut)".

The plant body consists of a number of organs i.e., Root, stem, leaf and flower.Each organ is made up of a number of tissues. Each tissue consists of many cells of one kind. The tissue units are called tissue systems. The plant body of a vascular plant is basically composed of three systems namely.

1. The dermal system
2. Vascular system
3. The fundamental system

The tissue systems of primary body are derived from the apical meristems. The partly differentiated tissues can be classified as Protoderm, Procambium and ground meristem.

**1:1 TYPES OF TISSUE**:

Plant tissues are classified on the basis of the ability or inability to divide in to meristematic tissues and permanent tissue respeatively.

The different types of tissues can be categorised as follows.

**MERISTEMATIC TISSUES**:

The term meristematic is derived from the Greek word Meristos which means divisible.

**TISSUES**

Meristematic Tissues (Cells can divide)

Permanent Tissues (Cells cannot divide)

Primary Meristems

Secondary Meristems (Phellogen)

1. Apical Meristem
2. Intercalary Meristem
3. Lateral Meristem

Simple Permanent tissue

Complex Permanent tissue

Parenchyma

Collenchyma

Sclerenchyma

Xylem (Wood)

Phloem (Bast)

Meristems are a group of cells with the potential to divide. The term meristem was introduced by Nageli in 1858 to designate dividing cells. The term meristem is applied to regions of more or less continuous cell and tissue initiation. The cells of meristem differ from those of mature tissues in that commonly they have abundant cytoplasm with vacuoles, nuclei and no intercellular spaces.

In plants continuous nature of growth is due to the ability of meristematic tissues present in permanently embryonic state in different parts like stem tips, root tips and other zones.

## 1:2 CYTOLOGICAL FEATURES OF MERISTEMS:

1. The cells have no inter cellular spaces.
2. The cells have dense cytoplasm.
3. The cell walls are very thin and flexible.
4. Plastids are absent, however proplastids may present.
5. Ergastic substances are absent.
6. The neighbouring cells of meristem are interconnected by cytoplasmic strands (Plasmodesmata).

## 1:3 CLASSIFICATION:

Meristems are variously classified on the basis of the following criteria.

1. Classification on the basis of origin.
2. Classification on the basis of location in the plant body.
3. Classification on the basis of planes of cell division.
4. Meristem based on function.

### 1. CLASSIFICATION ON THE BASIS OF ORIGIN:

Based upon this criteria meristems are classified into

(a) Primary meristems.

(b) Secondary meristems.

Perimary meristems are present as such from the time of embryo formation till the death of the plant. These meristems are responsible for the primary growth of the plant body. Some of these meristems like intrafascicular cambium also contributes to secondary growth as in dicot stems. The primary meristems develop from embryonic meristems called promeristem.

Secondary meristems develop from permanent tissues by the process of dedifferentiation. During this process cells which usually do not divide develop the ability to divide. These meristems are exemplified by interfascicular cambium and cork cambium. It is formed from mature cells like cortical, epidermal or phloem cells.

### 2. CLASSIFICATION ON THE BASIS OF LOCATION IN THE PLANT BODY:

On the basis of location in the plant body the following types of meristems are recognized.

(a) Apical meristems.

(b) Intercalary meristems.

(c) Lateral meristems.

**Apical** meristems which are located at the growing apices of the main stem, main roots and their branches. The apical meristems are responsible for growth in length of the plant organs. Initiation of growth is maintained by **apical cells**.

**Apical Cells** among vascular plants, solitary apical cells occur in most of the ferns. In other vascular plants group of apical and sub apical cells constitute the initiating body.

**Intercalary** meristems are found at the base of the leaves of many monocots, many grasses. The basal part of the internodes of the stem has intercalary meristems. The apical and intercalary meristems are mainly responsible for the vertical growth of the plant organs. These meristems are merely portions of apical meristems that have become separated from the apex during development by permanent tissues.

**Lateral** meristems are composed of initials that divide mainly in one plane and increase the diameter of an organ. The vascular cambium and cork cambium commonly seen in dicots are examples of lateral meristems. These meristems bring about secondary growth.

3. **CLASSIFICATION ON THE BASIS OF PLANE OF CELL DIVISION**:

On the basis of plane of division, Rib, Plate and mass meristems have been distinguished as "growth forms" of meristems.

In **Rib** meristem the cells divide at right angles to the longitudinal axis of the plant body. Such a pattern of cell division results in the formation of long rows of cells.

In **Plate** meristem the cells mainly divide at right angles to the length of the plant body. The meristem has parallel layers of cells and is seen in the leaf tissue.

In **Mass** meristem, the cells divide in numerous planes to form a massive three dimensional structure of the plant.

4. **MERISTEM BASED ON FUNCTION**:

This type of meristems was proposed by Haberlandt. He suggested that the primary meristem at the apex of the stem and root is distinguished in to three tissues such as

(a) Protoderm.

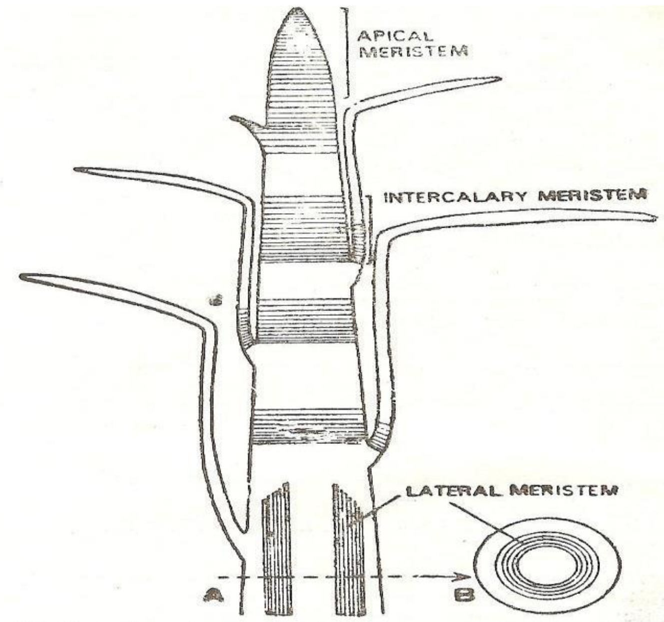
(b) Procamibum.

(c) Ground meristem.

The **Protoderm** is the outer most tissue which develops into epidermis. The **Procambium** develops in to primary vascular tissues. The **ground** meristem develops in to ground tissues and pith. In **Physiological anatomy** a classification of meristems based mainly on functional significance. (Figure - 1).

**Figure - 1**

**POSITION OF MERISTEM**




Position of meristems. A, longitudinal view; B, cross-section.

**1:4 MERISTEM BASED THEORIES**:

**TUNICA - CORPUS AND QUIESCENT CENTRE**:

Several theories dealing with the methods of origin of the patterns formed by the zonation and their histological and morphological significance have been proposed.

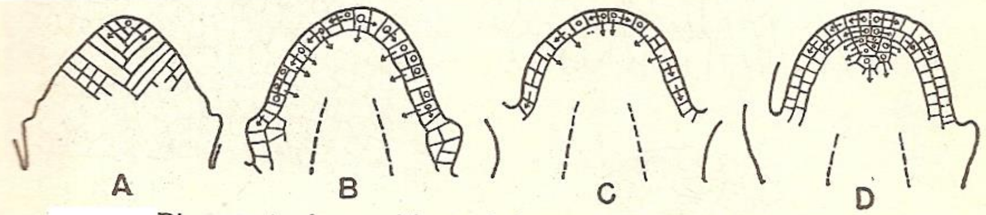
1. Tunica - Corpus theory.
2. Quiescent centre.

**1.Tunica - Corpus** theory was proposed by **Schmidt** in 1924. According to this theory, there are two zones of tissues in the apical meristems - the tunica consisting of one or more peripheral layers of cells and the corpus a mass of cells enclosed by the tunica. The layers of the **tunica** show predominantly anticlinal divisions, that is they are undergoing surface growth. In the corpus the cells are large, with arrangement and plane of cells division irregular.(Figure -2, 3).

The number of initials is few to several or many.  Rarely in small, very slender apices.  The determination of initials as self maintaining and persistent cells is often impossible because they differ from daughter cells.

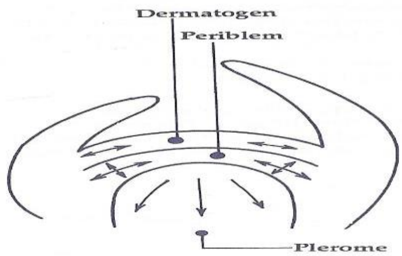
**Figure - 2**

**SHOOT APEX WITH TUNICA - CORPUS**

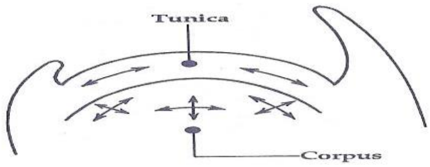



Diagrams to show position and planes of division of stem-apex initials. *A*. initial solitary, with oblique anticlinal divisions only; *B*, initials many, superficial, with their divisions and those of the dermatogen both anticlinal and periclinal; *C*, initials several, superficial, with their divisions both anticlinal and periclinal and those of the dermatogen largely anticlinal; *D*, initials in three tiers, the two outer, with divisions anticlinal only, forming a two-layered tunica and the innermost, with divisions in all planes, forming a corpus. (Initials indicated by outlined nuclei.)

**Figure - 3**




Shoot apex with the three histogens.
(Arrows indicate main directions of growth)




Shoot apex with tunica and corpus.

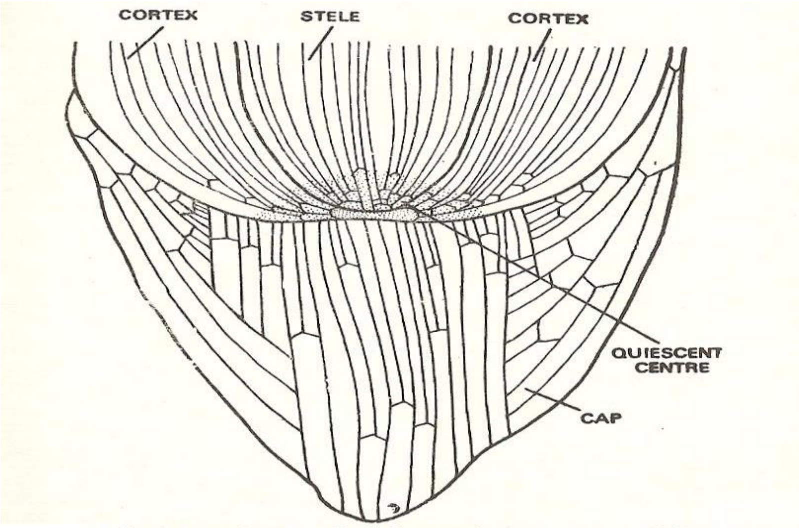
**2. QUIESCENT CENTRE**:

The **Korper-kappe** theory was proposed by **Schuepp** in 1917. According to this theory the root changes in diameter during growth, at various points it forms a double file a s a result of cell division, and it leads to formation of T-shaped structure.  The zones of the root, delimited by the planes of cell division, were called Korper (body) and Kappe (Cap) respectively.  The study of cell lineages that there is a central region of cells which divide rarely or not at all, example ***Zea mays***.  This inactive region of cells is known as **Quiescent Centre**.( Figure - 4).

The cells on the periphery of this hemispherical or cup shaped regim are meristematic and may be regarded as the constituents of the promeristem.  In the year 1956, **Clowes** able to demonstrate that, the cytoplasm had the lower content of RNA and the cells did not actively synthesize DNA. The cells of quiescent centre also have fewer Mitochondria, little Endoplasmic reticulum and small nucleoli. The main function of this region is synthesis of **hormones**.

**Figure - 4**

**ROOT APEX**




Root apex. Pattern of cell lineages in the root apex of *Zea mays*. The cortex, vascular cylinder or stele, root cap and quiescent centre are indicated.

**SELF ASSESSMENT QUESTIONS - I**

**ANSWER THE FOLLOWING QUESTIONS**

1. The term meristem was introduced by ___________
2. Types of meristem.
3. Meristem based theories - Examples.

**1:5 II. SIMPLE PERMANENT TISSUES**:

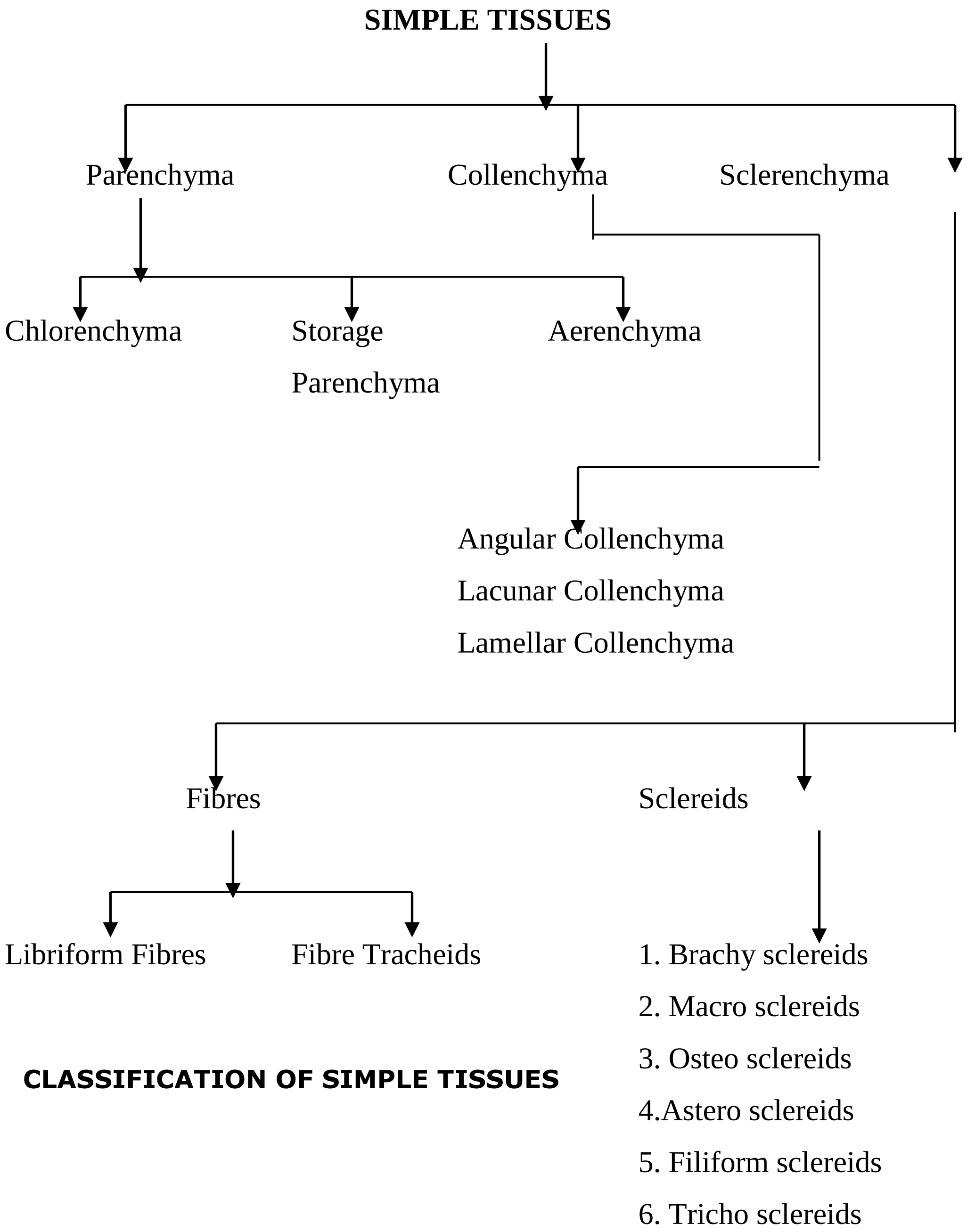
Simple permanent tissues have only one type of cell and the cells generally do not divide. The common types of simple permanent tissues are:

a. Parenchyma

b. Collencyhyma

c. Sclerenchyma

d. Transfer cells




**CLASSIFICATION OF SIMPLE TISSUES**

1. **PARENCHYMA**:

Parenchyma is a living and physiologically active tissue. The parenchyma cells of epidermis have cutinised cell walls. They are protective in function.

The parenchyma tissues mainly modifies into

i. Chlorenchyma

ii. Storage parenchyma

iii. Aerenchyma

CHLORENCHYMA is found in different organs like stems and in all the photosynthetic leaves. It is also called assimilatory parenchyma since it functions in food manufacture by photosynthesis.

**STORAGE PARENCHYMA**:

Parenchyma cells that store waste products like tannins, gums, resins, oils, calcium oxalate crystals etc.

**AERENCHYMA**:

It is a type of parenchyma where the tissue has very large intercellular spaces which stores air. In hydrophytes the stored air also helps in reducing the specific gravity which helps the plant to float.(Figure - 5)

**Figure - 5**

**TYPES OF PARENCHYMA**

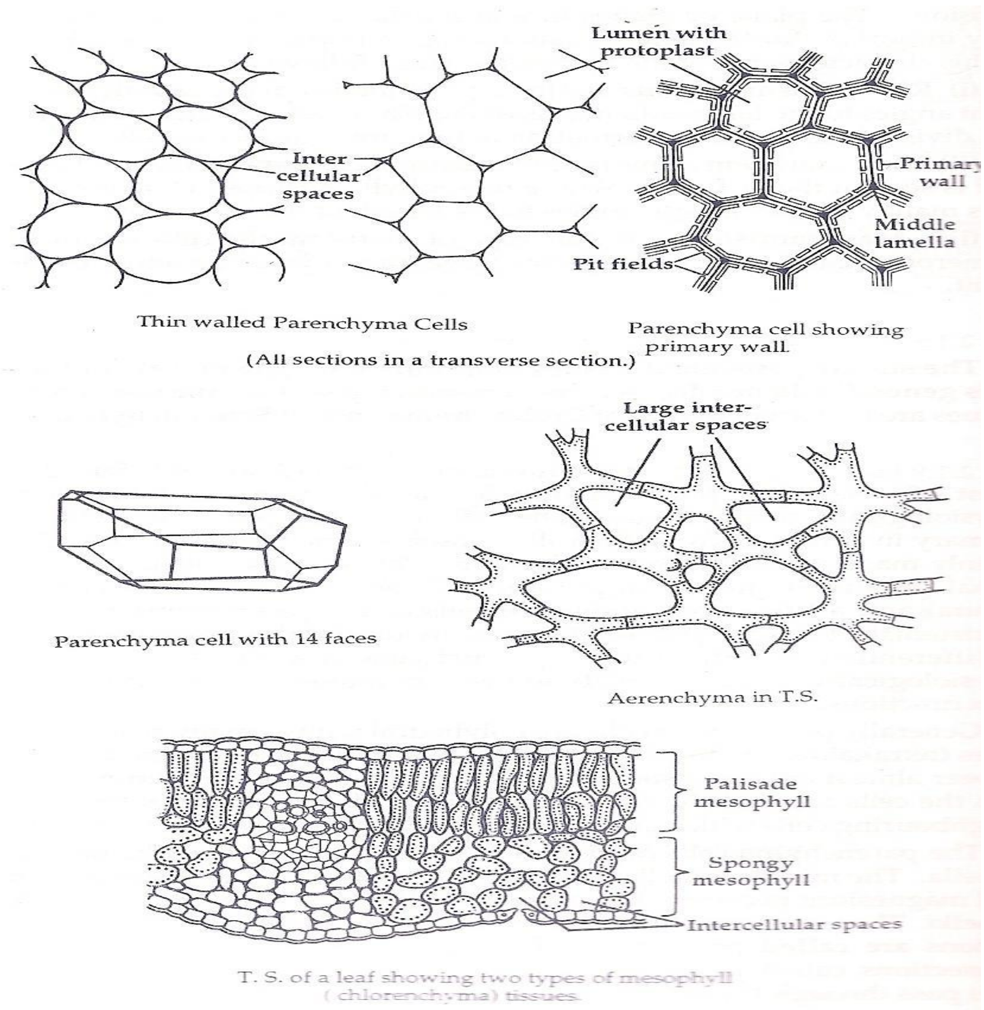
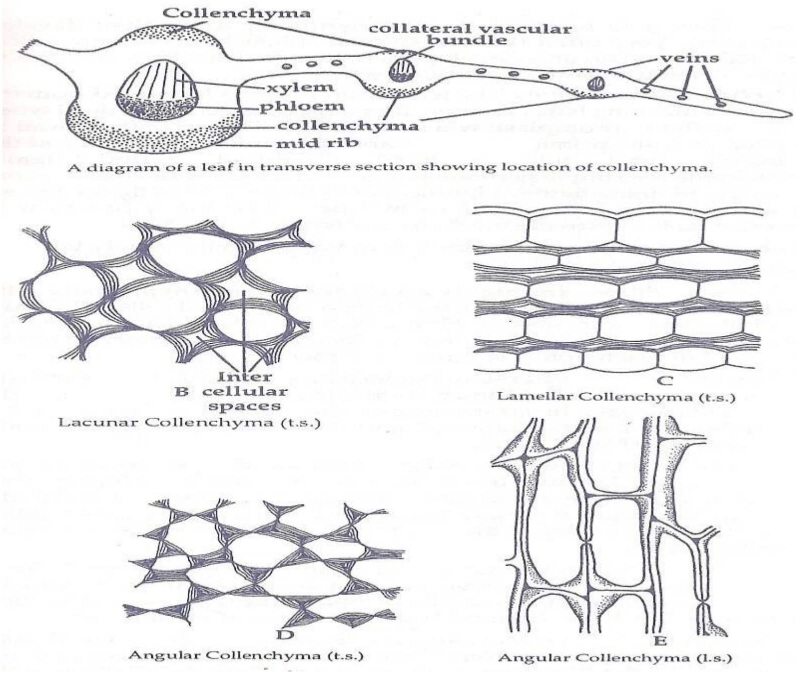


**Figure - 6**




**COLLENCHYMA**:

Collenchyma is a living simple, mechanical tissue occurring in young stems, petiole, leaf margins etc. The position of collenchyma gives mechanical strength to the leaf lamina. The collenchyma cells are longer than parenchyma cells. (Figure - 6)

On the basis of thickening of the cell wall at the corners, collenchyma is divided into three types,

i. Angular collenchyma

ii. Lacunar Collenchyma

iii. Lamellar Collenchyma

**ANGULAR TYPE**, the thickenings are confined only at the corners of cells. Intercellular spaces are absent. The cells are irregularly arranged. eg. Datura, Polygonum

**LACUNAR TYPE**, the thickenings are confined to the walls of the regions of bordering inter cellular spaces, this type is also called tubular collenchyma. eg. Leucas, Malva.

**LAMELLAR TYPE**, the thickenings are confined to tangential walls. The cells are arranged in parallel rows. eg. Clerodendron, Eupatorium.

3. **SCLERENCHYMA**:

Sclerenchyma is a simple dead mechanical tissue occurring in mature organs of the body. It is a simple permanent lignified tissue since it has a secondary wall containing lignin. The main function of sclerenchyma is to provide mechanical strength to the plant.

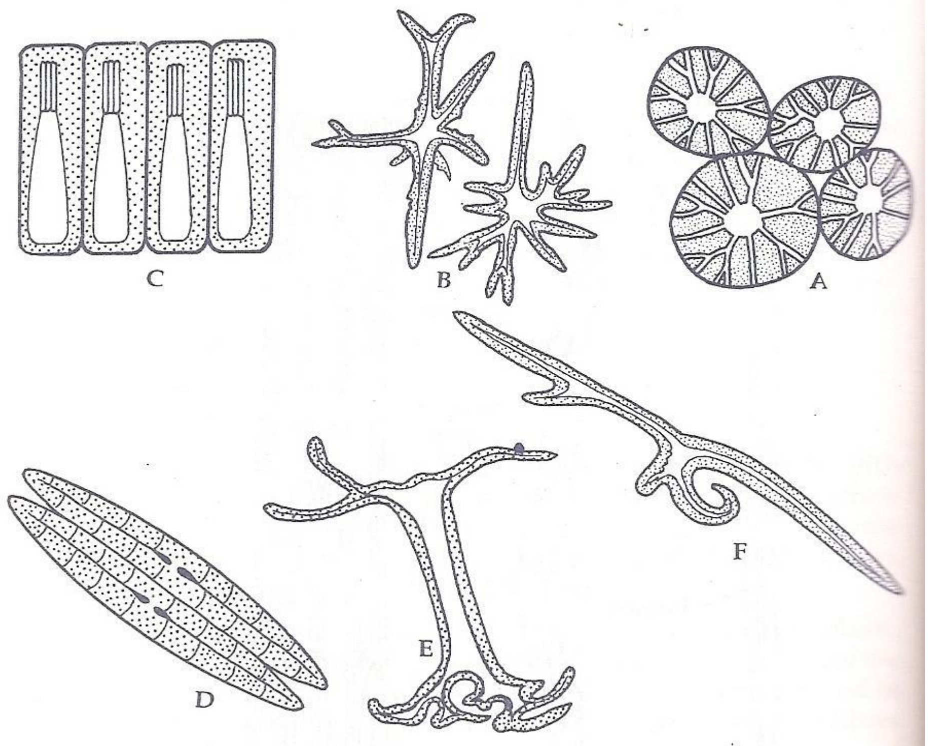
The term sclerenchyma refers to two types of cells namely the fibres and sclereids.

i. Fibres are highly elongated sclerenchyma cells with pointed ends, and the fibrous tissue has closely packed cells. Therefore intercellular spaces are absent. Fibres are dead cells at maturity since they do not have proto plasts. Fibres have definite position in the plant body. Fibres associated with **xylem** tissue are called **xylary** fibres, fibres associated with the pericycle tissue are called pericyclic fibres. Fibres have great economical value. eg. Flax, hemp, jute.

ii. Scleroids: They are most abundant in soft tissues like cortex, phloem, medulla, leaves, fruit wall etc. sclereids are short sclerenchyma cells. Sclereids are dead when mature (Figure - 7).

**Figure - 7**

**TYPES OF SCLEREIDS**




(A - F) Types of Sclereids
A. Brachysclereids (Stone cells) ; B. Astrosclereids
C - D. Macrosclereids ; E. Osteosclereid ; F. Trichosclereid.

On the basis of shape, sclereids are classified into <u>six types</u>. They are:

a. Brachysclerieds

b. Macrosclereids

c. Astrosclereids

d. Osteosclereids

e. Trichosclereids

f. Filiformsclereids

**Brachysclerieds** are short isodiametric, found in cortex, medulla phloem and in the pulp of fleshy fruits. eg. (Cocos nucifera) Coconut

**Macrosclerieds** are slightly elongated, rod like and they form palisade like layer. eg. Pisum Sativum (Pea)

**Osteosclereids** are rod like, with enlarged ends. They are bone shaped. eg. Mouriria

**Astrosclereids** are elongated and hair like, branched. They are found in aerial roots, leaves. Eg. **Olea**.

**Filiform Sclereids**: They are long and slender, filament like, found in leaves. Eg: Olea.

Apart from this, some special types of cells such as transfer cells are also present in plants.

**1:6 Transfer Cells:**

Parenchyma cells with inner wall protuberances occur in various anatomical structures concerned with short distance transfer of solutes, such as in nectaries, salt glands and vascular parenchyma, these cells were termed **transfer cells**.

The arrangement of the vascular tissue in the main vein resembles that in the petiole. The large veins in dicotyledons leaves may consist of both primary and secondary tissues, while the smaller veins consist of primary tissues only. In the small veins the parenchyma cells in contact with the sieve elements and tracheary elements constitute transfer cells. The specialized transfer cells develop wall protuberances which increase the internal cell surface. Some of the transfer cells represent companion cells because of their ontogenetic relation to the sieve elements. The xylem transfer cells in some plants have an important role in redirecting solutes from the xylem of a mature leaves to developing one. In some mature plants these cells may play a role in the xylem transpiration pathway.

**SELF ASSESSMENT QUESTIONS - II**

**ANSWER THE FOLLOWING QUESTIONS**

1. The main function of Schlerenchyma
2. Calcium oxalate is found in ____________
3. Sclerieids are classified into ____________

I. 1. Nageli,

2. Apical, Intercallary, Lateral

3. Tunica corpus, Quiescent Centre

II. 1. Mechanical strength

2. Storage Parenchyma

3. Six Types

**UNIT QUESTIONS**:

1. Brief about Tunica - Corpus theory.
2. Write a note on meristems.
3. Discuss about the Transfer cells.
4. List out the simple tissues.
5. Explain the types of Sclereids.

**RECOMMENDATIONS FOR FURTHER READINGS**:


1. Pandey, B.P (1978) Plant Anatomy, S. Chand and Co, New Delhi.
2. Vashista,P.C (1968) A Text Book Plant Anatomy.
3. Fahn, A 1982 Plant Anatomy (3rd edition). Pergoman Press, Oxford.
4. Mauselth, J.D (1988). Plant Anatomy. The Benjamin Cummings Publishing Co Inc., Mehlo Park, california, USA.

## NOTES

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## UNIT - II COMPLEX TISSUES, STOMATAL TYPES

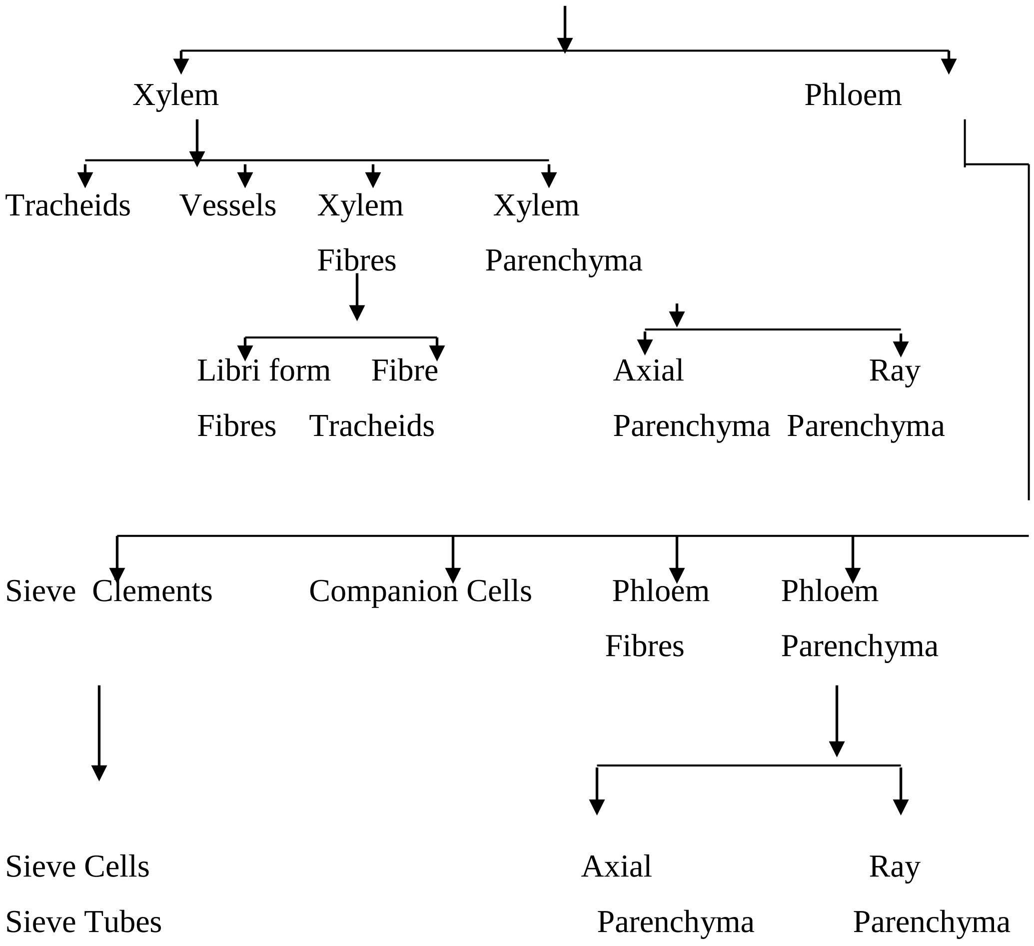
# UNIT - II

# COMPLEX TISSUES, STOMATAL TYPES

## 2:0 INTRODUCTION:

A group of different types of cells which act as a functional unit and perform a common function constitutes a **complex tissue**. In vascular plants **xylem** and **phloem** are the complex tissues. Xylem helps in conduction of water and mineral ions from the roots to the other parts of plant body, phloem helps in conduction of food materials from leaves to the other parts of the plant body. Xylem and phloem together constitute, conducting tissues. In flowering plants they are found in vascular bundles. The vascular tissues found in a group of plants called tracheophytes (pteridophytes, Gymnosperms and Angiosperms) are examples of complex tissues.

**COMPLEX TISSUES**




**2:1 XYLEM**: Xylem is a complex tissue which helps in conduction of water and mineral ions. The term xylem (xylos=wood) was coined by Nageli (1858). Xylem is a heterogenous tissue. It consists of four types of cells, They are:

a. Tracheids

b. Vessels

c. Xylem fibres

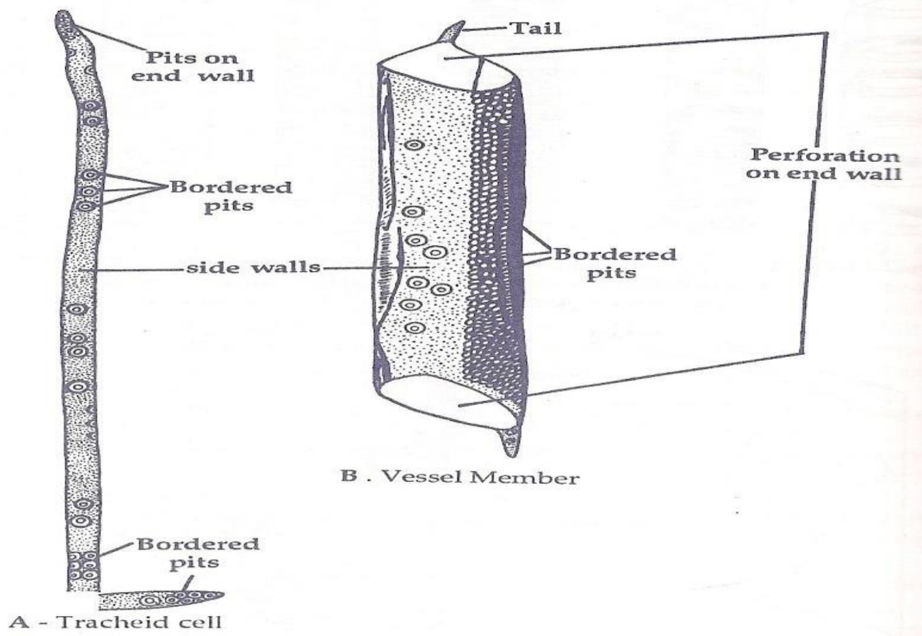
d. Xylem Parenchyma

Of these cells only xylem parenchyma is living, the remaining cells are dead. Xylem is also known hydrome.

**TRACHEIDS**: These types of tracheary elements are found in all vascular plants like pteridophytes, Gymnosperms and angiosperms. However the xylem of lower vascular plants like pteridophytes and gymnosperms are fully made up of tracheids. Tracheids are hollow elongated cells with pointed ends and are polygonal as seen in a cross section. They are the primitive type of tracheary elements.

The lignification occurs variously as annular, spiral, scalariform, pitted, pits of the bordered types are very comon on the side walls and end walls of tracheids.

b. **VESSELS**: These tracheary elements are also called **trachea**. They are found in higher vascular plants like the angiosperms. Some lower vascular plants like pteridophytes and gymnosperms have vessels. Vessels are shorter and wider than tracheids. A vessel can reach an average length of 2-140 mm. In some plants like Quercus and Eucalyptus vessels respectively of 2 meters length and 3 to 6 metres in length are present. Vessels have different types of secondary wall thickenings. The tail represents narrow extensions of cell wall at ends of the vessel(Figure - 8).

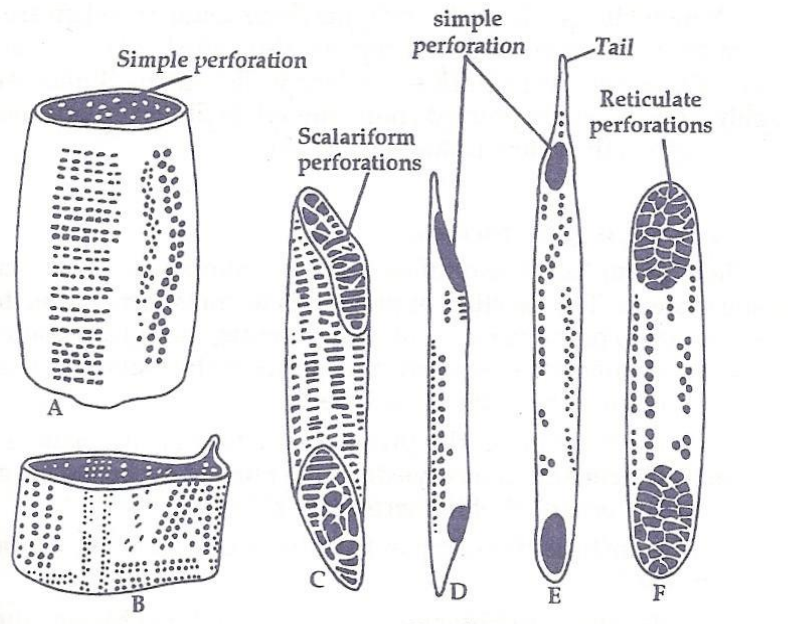



Comparison of tracheid cell (A) and Vessel member (B)

**Figure - 8**

Vessels are more efficient than tracheids in transporting water since they have perforate end walls. The end wall perforations can also be arranged as a net like manner (Figure - 9).

**Figure - 9**



Vessel types

c. **XYLEM FIBRES**:

The sclerenchyma fibres found in xylem are called xylem fibres or wood fibres. They are also called xylary fibres. The xylem fibres provide mechanical strength to the xylem tissue and the plant. The xylem fibres are of two types. They are libriform fibres and fibre tracheids. Libriform fibres are thin and long. Their walls are thick. Their lumen is narrow, pits are of simple type. Fibre tracheids are intermediate between tracheids and fibres. Their walls are comparatively thinner. The lumen is broad. Pits are of bordered type.

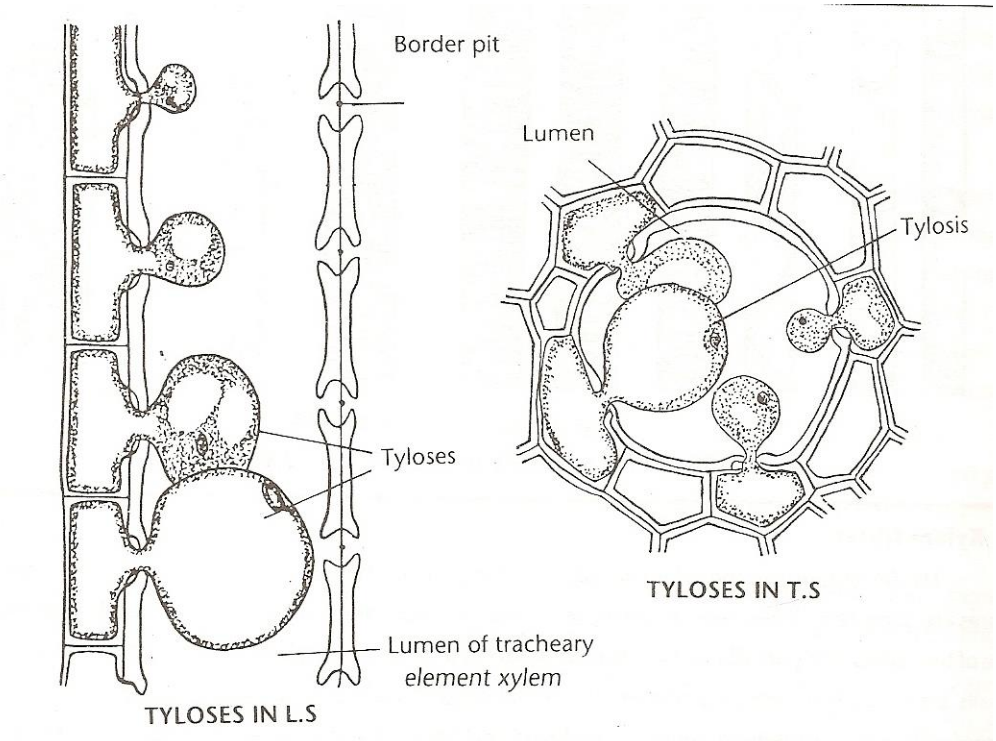
d. **XYLEM PARENCHYMA**:

The parenchyma found in xylem is called xylem parenchyma. It is also called wood parenchyma. The cells consist of thin cellulose walls. The cells are living. They are found in primary and secondary xylem. In primary xylem the parenchyma cells are arranged in longitudinal rows. In secondary xylem two types of parenchyma cells are present. They are axial parenchyma and ray parenchyma. The cells of axial parenchyma are vertically elongated and arranged in vertical rows. The cells of ray parenchyma are radically elongated and arranged in radial rows. The function of xylem parenchyma is to provide a degree of flexibility to the hard lignified xylem tissue. The parenchyma cells do store food and to play a role in the ascent of sap.

**TYLOSES**:

In many plants xylem parrenchyma cells develop balloon like protrusions into trachery elements. Such protrusions are called tyloses. Tyloses are formed by the enlargement of pit membranes. They block the lumen of trachery elements completely. Tyloses are formed when xylem elements become inactive or when they are injured. They prevent the conduction of water and mineral ions (Figure - 10).

**Figure - 10**




Depending upon the method of formation, xylem can be divided into two types. They are

1. Primary Xylem
2. Secondary Xylem

Xylem which is developed from procambium is called the primary xylem. The first formed primary xylem is called procambium. The later formed one is called meta xylem.

Xylem which is produced by vascular cambium is called the secondary xylem. It is abundant in dicot stems and roots.

The cambium ring cuts off new cells on its inner side are gradually modified into xylary elements, called the secondary xylem. It consists of a compact mass of thick walled cells, Scalariform and pitted vessels, tracheids wood fibres and wood parenchyma.

**ANNUAL RINGS**:

The secondary xylem normally consists of concentric layers, these layers appear as rings, and are called annual rings. Annual rings are characteristic of woody plants of temperate climates. Each annual ring corresponds to one year's growth and on the basis of these rings the age of a particular plant can easily be calculated. The determination of age of a tree by counting the annual rings is known as dendrochronology (Figure - 11, 12).

**Figure - 11**

**ANNUAL RINGS**

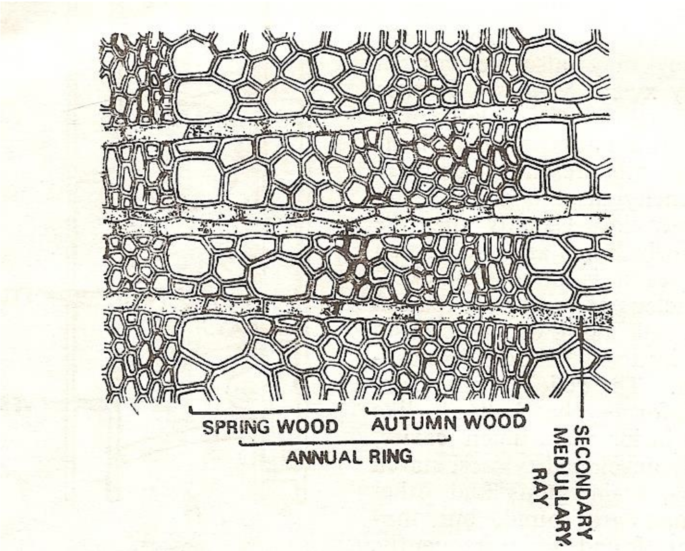



**Figure - 12**

**2:2 HEART WOOD AND SAP WOOD**:

The outer region of the old trees consisting of recently formed xylem elements is SAPWOOD (alburnum). The central region of the old trees, which was formed earlier is filled up with tannins, resins, gums and other substances is called heart wood (duramen).

The sap wood of a tree serves for conduction, support, and food storage; the heart wood only for support. In the transformation of sap wood into heart wood a number of changes occur. All living cells lose their protoplasts, the cell sap is withdrawn, water content is reduced, xylem becomes physiologically functionless. Heart wood, as timber, is more durable than sapwood. The proportion of sapwood and heartwood is highly variable in different plants. Some trees do not have clearly differentiated heartwood. Eg: ***Abies, Populus***.

In some cases, thin sap wood is present. eg. ***Taxus, Morus***, others possess a thick sapwood. eg., ***Acer, Fraxinus***, The haematoxylin is obtained from the heart wood of ***Haematoxylon Campechianum.***

**2:3 PHLOEM**: The Phloem tissue also called bast is a component of the vascular tissue system. It is a complex tissue which helps in conduction of food materials from leaves to other parts of plant. The term phloem was coined by **Nageli** (1858). It consists of four types of cells. They are

a. Sieve Elements

b. Companion Cells

c. Phloem Parenchyma

d. Phloem Fibres

a. **SIEVE ELEMENTS**: Sieve elements are the chief conducting elements of phloem. They are of two types:

i. Sieve Cells

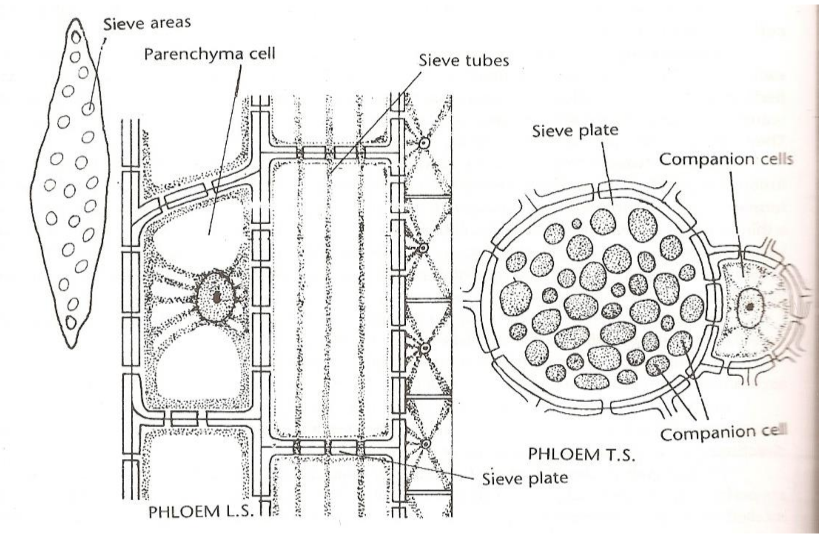
ii. Sieve Tubes

The **Sieve Cells** are elongated, narrow, cylindrical, living cells with protoplasts. The sieve cells are the conducting elements of the phloem found in lower vascular plants like the **Pteridophytes** and **Gymnosperms**. The cell walls show numerous unspecialized areas with performations. They are called sieve areas. Sieve cells help in conduction of food materials.

The **Sieve Tubes** are found in the phloem tissue of higher plants like the dicots and monocots. The sieve tubes are the shorter and broader than the sieve cells.

It is surrounded by a thin cellulose cell wall. Inner to cell wall there is a thin layer of cytoplasm. Nucleus is present in young sieve tubes. The end walls of sieve tubes are oblique. They are called ***sieve plates***. Sieve plates are perforated. The performations are called sieve pores (Figure - 13).

**Figure - 13**



b. **COMPANION CELLS**: Companion cells are special parenchyma cells associated with sieve tubes. The companion cell is always nucleate, companion cells are formed by oblique-longitudinal division of the mother cell of the sieve tube element. The cells have abundant granular cytoplasm and a prominent nucleus which is retained through the life of the Cell. Companion cells occur only in the angiosperms.

c. **PHLOEM PARENCHYMA**: Parenchyma present in phloem is called phloem parenchyma. The cells may be longer, broader, polyhedral in shape. The cells are living and surrounded by thin cellulose cell walls. The parenchyma cells store food in the form of starch, tannins and crystals. Primary phloem consists of vertically elongated cells in the form of axial phloem parenchyma. Secondary phloem consists of axial and ray parenchyma.

d. **PHLOEM FIBRES**: The fibres present in phloem are called phloem fibres. They are also called bast fibres. They are long and narrow with pointed ends. The fibres of primary phloem have cellulose walls. The fibres of secondary phloem have lignified walls. The fibres may be living or dead, living fibres store food materials. Dead fibres provide rigidity and mechanical support. Flax fibres obtained from ***Linum*** and Jute fibres from ***Corchorus*** are phloem fibres of economic importance.

**SELF ASSESSMENT QUESTIONS - I**

**ANSWER THE FOLLOWING QUESTIONS**

1. Vascular tissues found in ____________
2. Xylem is also known as ____________
3. Tyloses - Define

**2:4 TYPES OF PHLOEM**:

The phloem tissue in plants with secondary growth are of the following two types.

i. Primary Phloem

ii. Secondary Phloem

The primary phloem originates from a meristem called Procambium. The first formed phloem is called ***Protophloem***. The later formed primary phloem is called ***metaphloem.***

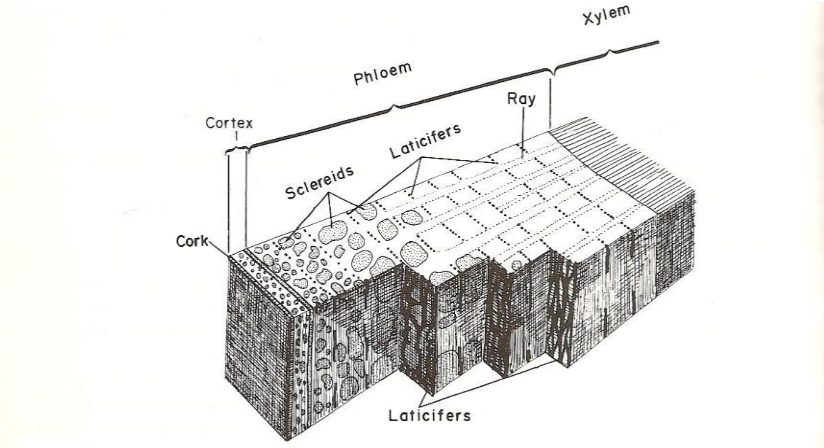
In plants with secondary growth like the gymnosperms and dicotyledons a meristem called vascular cambium produces secondary phloem during the process of secondary growth.

**2:5 SECRETARY TISSUE**:

The tissues concerned in secretion or excretion of materials constitute secretary tissue. The secretaries stored in specialized structures called glands, ducts or in specialized cells. The secretions include, gums oils, resins, nector latex etc.

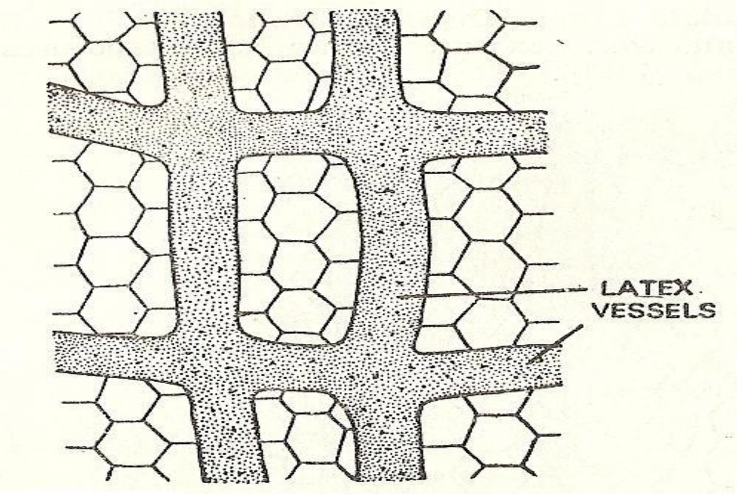
The main type of secretary tissue is ***laticiferous tissue***. It is composed of thin walled, elongated, multinucleated structures which contain colourless, milky juice called latex. Latex is emulsion of proteins, Carbohydrates, organic acids, fats, alkaloids, enzymes and rubber. Resins and rubber are the characteristic components of latex in many plants (Eg. ***Hevea, Ficus***) (Figure - 14, 15).

**Figure - 14**




Three-dimensional diagram of the bark of *Hevea brasiliensis*, showing arrangement of laticifers in the secondary phloem.

**Figure - 15**




Laticiferous tissue→latex vessels.

Laticiferous tissue is found in plants belonging to Apocyanaceae, Asclepiadaceae, Euphorbiaceae, Musaceae etc. Laticiferous tissue is of two types. They are:

1. Latex Cells
2. Latex Vessels

**LATEX CELLS** are the individual cells. They are smaller in size, branched or unbranched, cytoplasm is present. Inner to cytoplasm, latex is present. eg. ***Nerium, Euphorbia***.

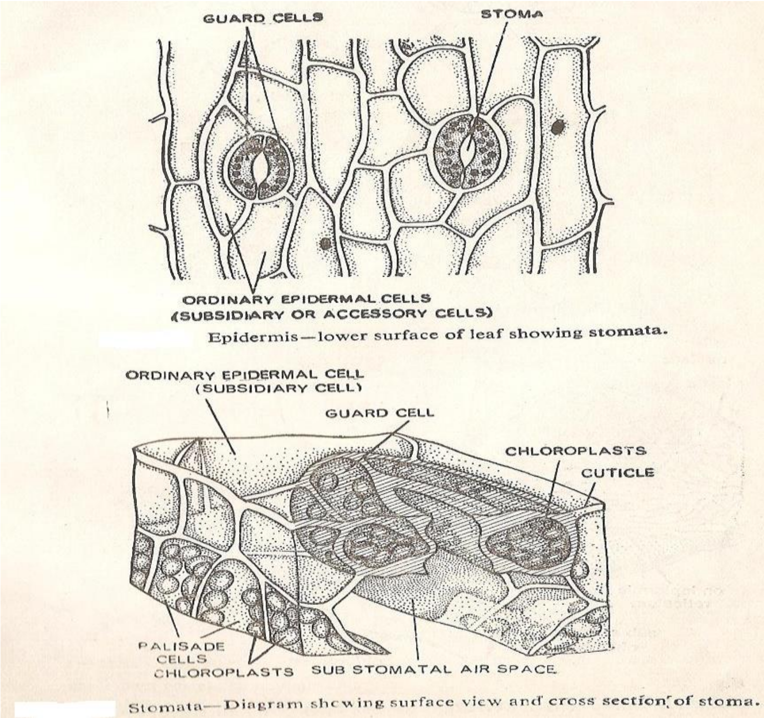
**LATEX VESSELS** are not individual cells, but formed from a vertical row of cells. The latex vessels are surrounded by thin cellulosic cell walls. Inner to cell wall a thin layer of cytoplasm is present. Eg. ***Hevea, Achras***.

## STOMATAL TYPES

### 2:6 GENERAL STRUCTURE:

Stomata are the minute pores present in the epidermis of aerial parts of the plant body. A stomata is surrounded by two specialized epidermal cells called guard cells. The epidermal cells surrounding the guard cells differ from the other epidermal cells in size and arrangement. These epidermal cells are called subsidiary cells. Guard cells and subsidiary cells together constitute stomatal complex. Each guard cell is kidney shaped. Guard cells control the opening and closing of stomata. Guard cell consists of a thin layer of cytoplasm, a large central vacuole. Plasmodesmata are found between the guard cells and epidermal cells. Stomata play an important role in exchange of gases between the intercellular spaces of the internal tissue and the outer atmosphere (Figure - 16).

**Figure - 16**




**OCCURENCE**:

Stomata occur on all parts of the plant except the root. On floral organs and in aquatic plants they may be few, abortive, or lacking. In leaves stomata may occur in both the upper and the lower epidermis; in woody plants they are commonly absent from the upper epidermis.

**TYPES OF STOMATA**:

The stomata may be basically classified into two major types.

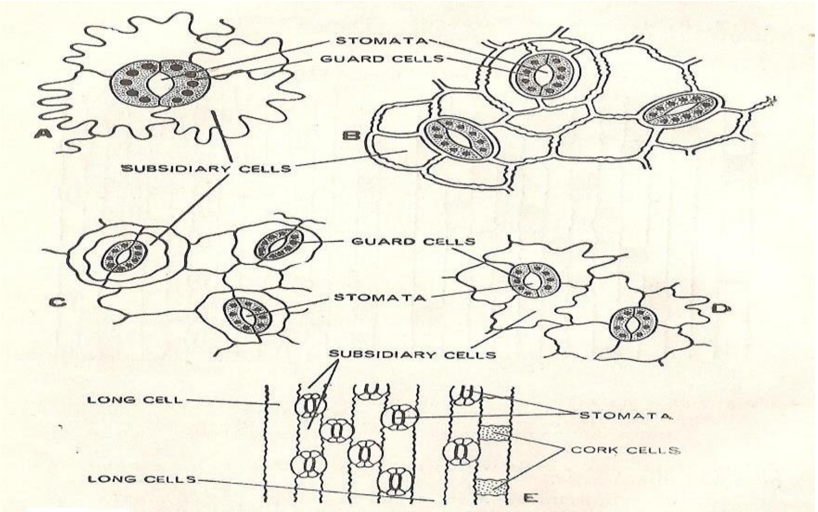
1. Dicotyledons type
2. Monocotyledons type

The dicotyledons type may be further classified into:

i. Ranunculaceous type
ii. Cruciferous type
iii. Caryophyllaceous type
iv. Rubiaceous type

In monocots only one type of stomata is present namely, ***Gramineous type*** (Figure - 17).

**Figure - 17**




Stomata—types of stomata. A, anomocytic or irregular celled type (ranunculaceous type); B, anisocytic or unequal celled type (cruciferous type); C, paracytic or parallel celled type (rubiaceous type); D, diacytic or cross-celled type (caryophyllaceous type); E, gramineous type.

**RANUNCULACEOUS TYPE** is also called as ***anomocytic*** (irregular celled). In this type the stoma remains surrounded by a limited number of subsidiary cells which are quite alike the remaining epidermal cells.

**CRUCIFEROUS TYPE** is also called as ***anisocytic***, (unequal celled). In this type the stoma remains surrounded by three subsidiary cells of which one is distinctly smaller than the other two.

**CARYOPHYLLACEOUS TYPE** is also called as ***diacytic*** (cross celled). In this type the stoma, remains surrounded by a pair of subsidiary cells and whose common wall is at right angles to the guard cells.

**Rubiaceous type** is also called as ***Paracytic*** (parallel celled). In this type, the stoma remains surrounded by two subsidiary cells which are parallel to the long axis of the pore and guard cells.

**GRAMINEOUS TYPE**:

They are commonly found in families like, ***gramineae*** and ***cyperaceae*** of monocotyledons. In this type, the stoma possesses guard cells of which the middle portions are much narrower than the ends.

**SELF ASSESSMENT QUESTIONS - II**

**ANSWER THE FOLLOWING QUESTIONS**

1. Protophloem - Define
2. Laticiferous tissues are ________, _________
3. Anisocytic stomata is ___________

## ANSWERS OF SELF ASSESSMENT QUESTIONS

I.
1. Tracheophytes
2. Hydrome
3. Balloon like protrusions in xylem parenchyma

II.
1. First formed phloem
2. Latex cells, latex vessels
3. Cruciferous type.

## UNIT QUESTIONS:

1. Brief about vessels.
2. Write a note on Annual rings.
3. Discuss about the Laticifers.
4. List out the types of stomata.
5. Explain the Phloem tissues.

## RECOMMENDATIONS FOR FURTHER READINGS:


1. Pandey, B.P (1978) Plant Anatomy, S. Chand and Co, New Delhi.
2. Vashista,P.C (1968) A Text Book Plant Anatomy.
3. Fahn, A 1982 Plant Anatomy (3rd edition). Pergoman Press, Oxford.
4. Mauselth, J.D (1988). Plant Anatomy. The Benjamin Cummings Publishing Co Inc., Mehlo Park, california, USA.

## NOTES

## UNIT - III PRIMARY AND SECONDARY STRUCTURE - DICOTS, MONOCOTS

| | |
|---|---|
| 3:0 | Primary and Secondary Structure of Dicot Stem |
| 3:1 | Organisation of Tissues in Dicot Stem |
| 3:2 | Secondary Growth in Dicot Stem |
| 3:3 | Anomalous Secondary Growth |
| 3:4 | Primary and Secondary Structure of Dicot Root |
| 3:5 | Organisation of Tissues in Primary Dicot Root |
| 3:6 | Primary Structure of Monocot Stem |

**SELF ASSESSMENT QUESTIONS - I**

| | |
|---|---|
| 3:7 | Primary Structure of Monocot Root |
| 3:8 | Differences - Dicot and Monocot Stem |
| 3:9 | Differences - Dicot and Monocot Root |
| 3:10 | Structure of Dicot Leaf |
| 3:11 | Structure of Monocot Leaf |
| 3:12 | Nodal Anatomy |

**SELF ASSESSMENT QUESTIONS - II**

| | |
|---|---|
| 3:13 | References |
| | Answers of Self Assessment Questions |
| | Unit Questions |
| | Recommendations for further readings |

## UNIT - III

## PRIMARY AND SECONDARY STRUCTURE - DICOTS, MONOCOTS

### 3:0 PRIMARY AND SECONDARY STRUCTURE OF DICOT STEM:

**Structure of stem Apex**:

The stem apex consists of group of meristematic cells. These cells constitute promeristem. In the stem apex internodes are highly condensed. To explain the organisation of stem apex, various theories have been proposed. The well accepted theory is tunica - corpus theory.

The stem of ***helianthus*** (Sun Flower) is well suited for study of Primary Structure. The transverse section of dicot stem shows three regions. They are

(a) Epidermis

(b) Cortex

(c) Stele

(a) **Epidermis**:

The epidermis is the outer most covering of the stem and it is made up of layer of cells. Inter cellular spaces are absent. The cells contain colourless plastids. The outer walls are cutinised. The cutin is a waxy substance and forms a layer called cuticle. It reduces transpiration. The epidermis produces numerous multi cellular outgrowths called trichomes. Stomata is present in epidermis. Because of presence of stomata, epidermis helps in exchange of gases and promoted transpiration.

(b) **Cortex**:

Cortex is the middle region. It is smaller than the stele. It shows three zones. They are

(a) Hypodermis

(b) General Cortex

(c) Endodermis

Hypodermis is the outer zone of the cortex. It is 3 - 6 layered and collenchymatous. Hypodermis gives mechanical support, flexibility.

General cortex is the middle zone of the cortex. The outer cells may contain chloroplasts. It helps in synthesis and storage of food materials.

Endodermis is the innermost layer of cortex. It consists of compactly arranged barrel shaped cells.

(c) **Stele**:

The stele is made up of stelar tissues. The stelar tissues are

(i) Pericycle

(ii) Vascular bundle

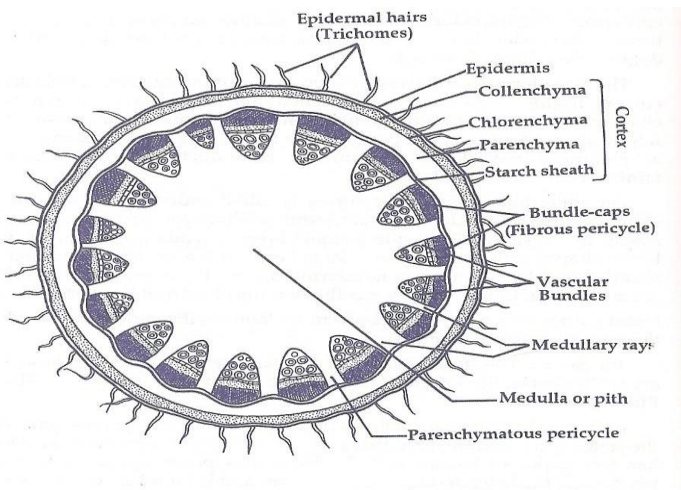
(iii)	Medulla, Medullary rays

**Pericycle** is the outer zone of the stele. It is a multi layered tissue and in sun flower stem the pericycle has two types of tissues namely fibers and parenchyma. Fibrous pericycle is made up of sclerenchyma fibres.

**Vascular bundles** are made up of xylem and phloem. In the sunflower stem there are many wedge shaped vascular bundles, arranged in one ring. This arrangement is called ***eustele***. Each vascular bundle is conjoint, collateral and open. The primary phloem is made up of sieve tubes, companion cells and fibres.

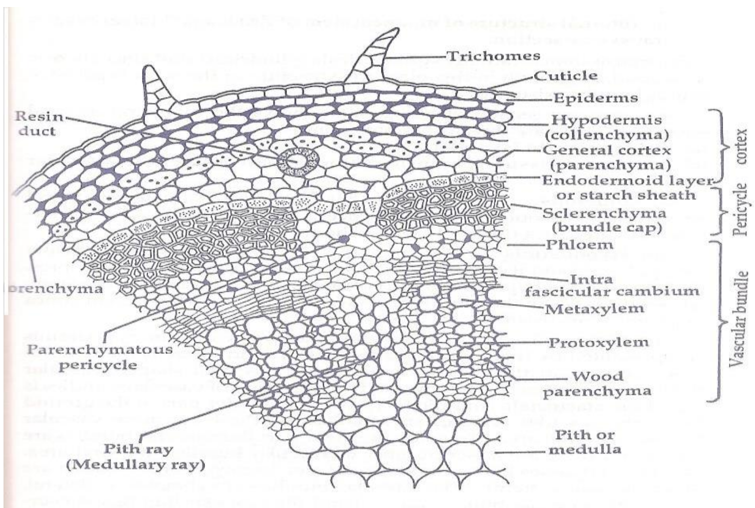
***Medulla*** is the central part of the stele. The medulla is also called pith. It is made up of parenchyma. The vascular bundles are separated by bands of parenchyma called ***Medullary rays***. They are formed from primary meristems (Figure - 18, 19).

**Figure - 18**




Ground plan of a transverse section of young stem of *Helianthus annus* (sunflower-diagrammatic).

**Figure - 19**



## 3:1 ORGANISATION OF TISSUES IN DICOT STEM

Dicot Stem

| Epidermis | Cortex | Stele |
| --- | --- | --- |
| 1. Stomata | 1. Hypodermis | 1. Pericycle |
| 2. Cuticle | 2. General Cortex | 2. Vascular Bundles, |
| 3. Trichomes | 3. Endodermis | 3. Medulla |
| | | 4. Medullary rays |

## 3:2 SECONDARY GROWTH IN DICOT STEM:

Secondary growth is common in Gymnosperms and dicots. It is absent in monocots and pteridophytes. But in monocot plants like ***Dracaena,Yucca*** anomalous secondary growth is present.

In a typical dicot stem secondary growth occurs in two stages. They are

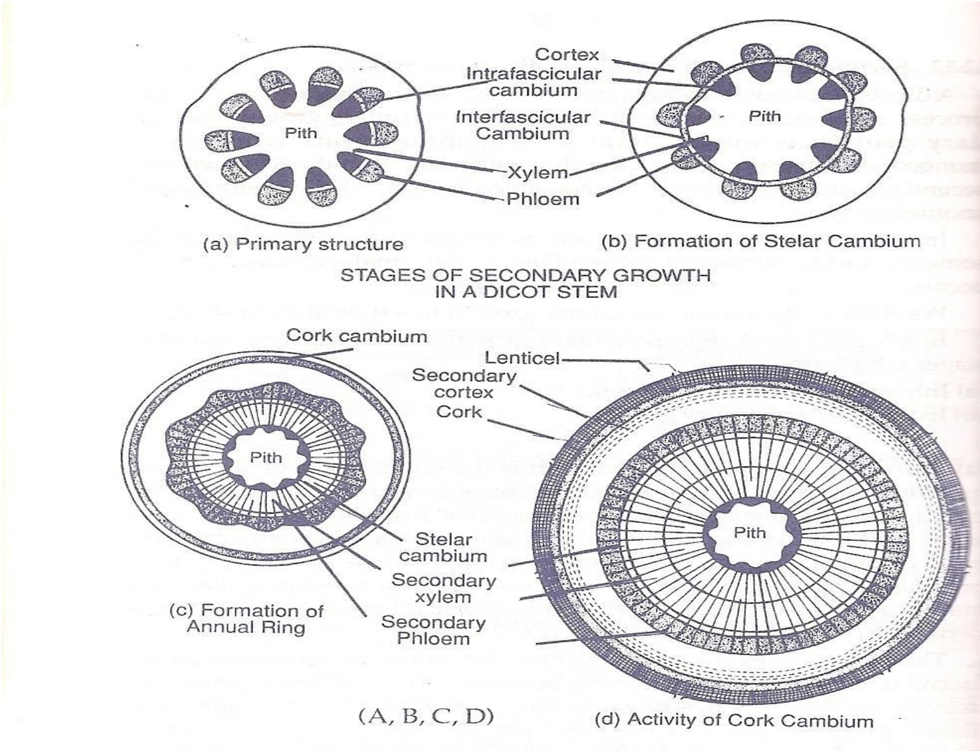
(a) Inter stelar Secondary growth

(b) Extra stelar Secondary growth

***Inter stellar*** is the initial phase of secondary growth which is initiated by the formation of a stellar cambium ring. The cambium ring has intra fascicular cambia and inter fascicular cambia which are obtained by dedifferentiation of parenchyma cells. The vascular cambium has two types of cells namely the fusiform initials and ray initials. The secondary xylem is produced in large quantities whereas secondary phloem is produced in relatively small quantity (Figure-20).

**Figure - 20**

**STAGES OF SECONDARY GROWTH**




Seasonal activity of the cambium results in the formation of

(a) Spring Wood

(b) Autumn Wood

***Extra Stelar*** is the second stage of secondary growth which follows the stelar secondary growth. The production of large quantities of secondary tissues particularly secondary xylem exerts a pressure on the epidermis, since the epidermis cannot grow. The rupturing of the epidermis is followed by the development of the cork cambium or phelloderm or secondary cortex. The ruptured regions of epidermis, phellogen produces a mass of loosely arranged parenchyma cells called complementary tissue. The complementary tissue is bounded by the ruptured epidermis. The entire structure is called a lenticels.

**3:3 ANOMALOUS SECONDARY GROWTH**:

The some of the dicotyledons show secondary growth that deviates from the normal secondary growth. This is known as ***anomalous structure***. In certain anomalous, extremely complex structures are formed. These complex structures are known as ***anomalies***. The anomalies are quite common in angiosperms. These anomalies may be catagorised as follows:

(a) Anomalous secondary growth in Dicotyledons.

(b) Anomalous secondary growth in Monocotyledons.

(c) Presence of cortical bundles.

(d) Absence of vessels in the xylem.

(d) Presence of medullary bundles.

(f) Intra xylary phloem.

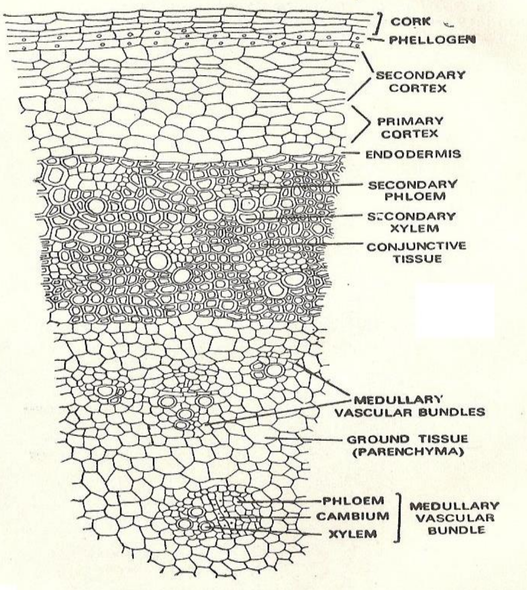
**Anomalous Structure in Boerhaavia**:

The stem of ***Boerhaavia*** (Nyctaginacae) several cambia arise successively in a centrifugal direction. Each cambium produces xylem and conjunctive tissue to the outside.

In ***Boerhaavia***, ***Bougainvillaea*** and ***mirabilis*** the anomalous secondary thickening occurs in the form of succession of rings of vascular bundles. The thin - walled parenchyma (lignified) are associated with the phloem (Figure - 21).

**Figure - 21**

**STEM - ANOMALOUS STRUCTURE**




The stem-anomalous structure. T.S. of a sector of stem of *Boerhaavia diffusa* showing periderm, anomalous secondary growth, thick-walled conjunctive tissue, and medullary bundles.

The development of vascular system in Boerhaavia (P.Maheshwari (1930)) is a follows:

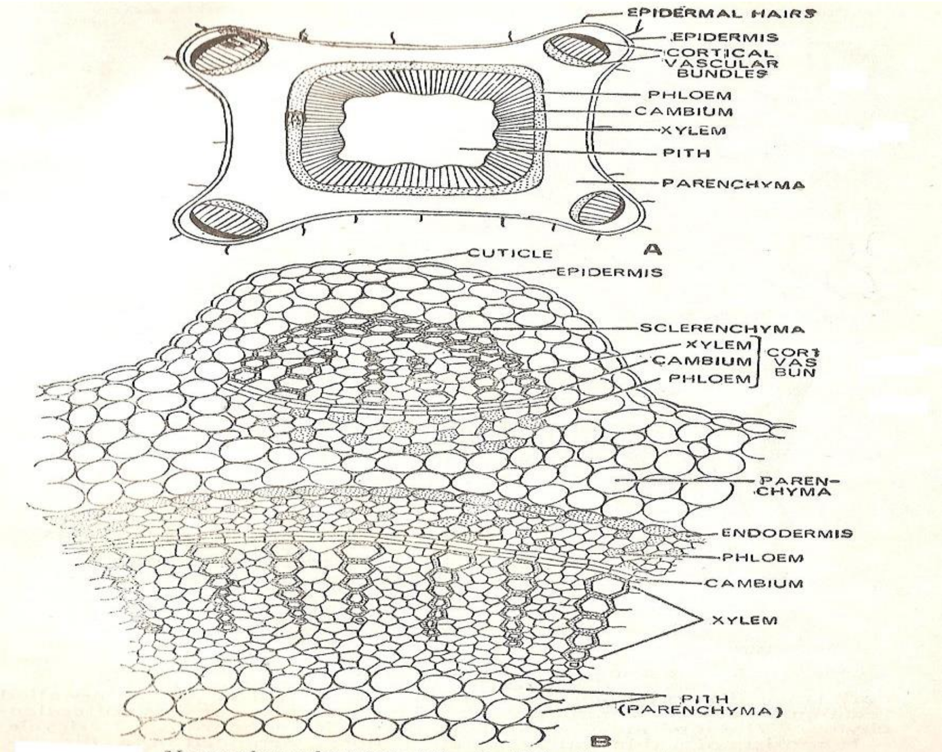
1. In T.S. of young stem shows two medullary bundles.
2. The bundles are basically separated, each provided with fascicular cambium.
3. The fascicular cambia of the bundles became inter connected.
4. The inter fascicular parenchymatous tissues are formed.
5. The new meristem is developed in the secondaryparenchymatous tissues.
6. The successive cambia are ontogenetically inter related with each other.

**Anomalous Structure in Nyctanthes**:

In some of the dicots, a ring of vascular bundles is found in cortical region, these bundles maybe referred as "Cortical bundles". The presence of cortical bundles has been studied in several families like cactaceae, cucurbitaceae and oleaceae (Figure - 22).

**Figure - 22**

**ANOMALOUS STRUCTURE IN NYCTANTHES**




*Nyctanthes arbortristis* (dicot)—T.S. of stem showing inversely oriented cortical vascular bundles. A, diagrammatic; B, detailed.

The development of vascular system in ***Nyctanthes*** (Oleaceae) (Majumdar 1940) is as follows:

1. A system of inversely oriented vascular bundles has been studied.
2. Apart from normal vascular bundles a ring in the central region,

   There are four inversely based bundles at the four ridges of the stem.
3. These bundles are collateral and open.

## 3:4 PRIMARY AND SECONDARY STRUCTURE OF DICOT ROOT:

The apical meristem is short and consists of few initial cells. The initial cells are closely packed, thin walled with dense cytoplasm and prominent nuclei. To explain the structure of root apex, ***Hanstein*** proposed histogen theory. The histogens are

1. Dermatogen
2. Periblem
3. Plerome

**Dermatogen** is the outer most layer. The cells of dermatogens divide anticlinally and form epidermis. Dermatogen merges with periblem and forms a **Calyptrogen. Periblem** is the middle region. The cells of periblem divide anticlinally and periclinally and produce the cortex. Plerome is the central region. The cells of plerome divide anticlinally and periclinally and form the **Stele**.

**Primary Structure of Dicot Root**:

In transverse section (T.S) it shows three regions. They are

1. Epidermis
2. Cortex
3. Stele

1. ***Epidermis*** is the outer most layer. It consists of a single layer of cells. The cells are compactly arranged, thin walled and living. Some cells show long tubular extensions called root hairs. It helps in absorption of water and mineral ions from the soil. Cuticle and stomata are absent, Epidermis is protective in function.

2. ***Cortex*** is the middle region. It can be divisible into

(a) Exodermis

(b) General Cortex

(c) Endodermis

***Exodermis*** is the outer zone of cortex. It is present just beneath the epidermis. It consists of two to three rows of compactly arranged cells. The main role of exodermis is to prevents exit of water from the root.

***General cortex*** is present beneath the exodermis. It consists of many layers of parenchymatous cells. The cells are colourless, and help in lateral transport of water and mineral ions.

***Endodermis*** is the inner most layer of cortex. It consists of compactly arranged barrel shapped cells. Endodermal cells are thickened with Suberin and lignin. These thickenings are called ***Casparian thickenings***. Endodermis prevents the leakage of water from the stele.

3. **Stele** is the central region. It can be divided into

(a) Pericycle

(b) Vascular bundles

(c) Conjunctive tissues

***Pericyle*** is the outer most layer of the stele. It consists of a single layer of thin walled, Parenchymatous cells. The cells are compactly arranged. The main role of pericycle is the formation of lateral roots and secondary cambium.

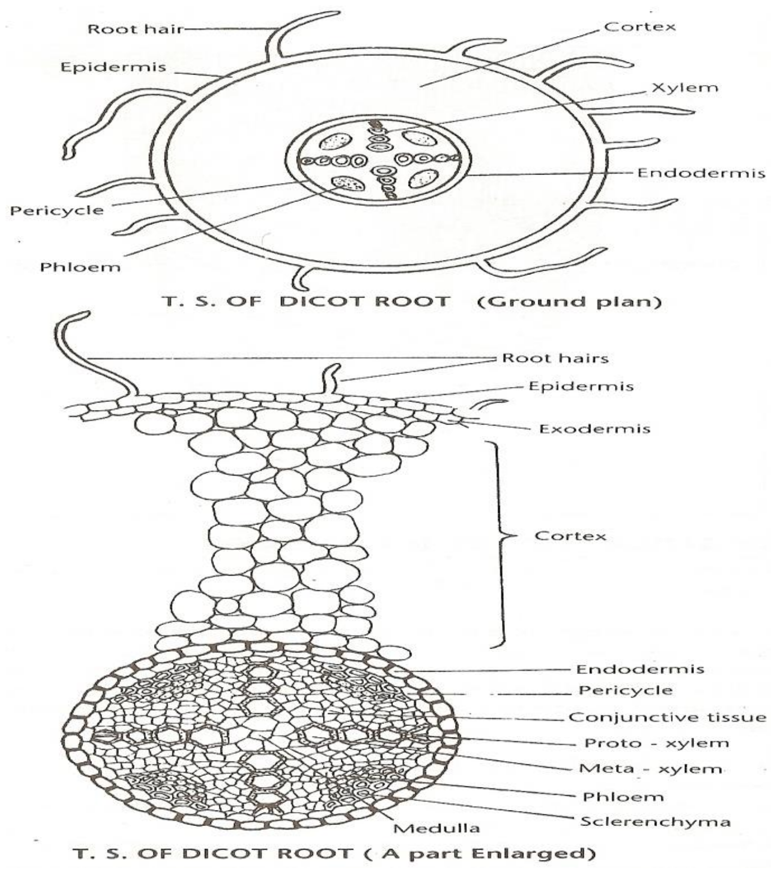
***Vascular bundles***: The xylem and phloem are present in separate patches in equal number. Xylem consists of only vessels. Phloem consists of sieve tubes. Companion cells and phloem parenchyma. Cambium is absent. Hence, Vascular bundles are closed. xylem helps in conduction of water and minerals. Phloem helps in conduction of food materials.

***Conjunctive tissue***: Parenchymatous tissue is present between xylem and phloem stands. This tissue is called conjunctive tissues. The main role of this tissue is formation of secondary cambium.

***Medulla*** is the central zone of the stele. It is parenchymatous. Inter cellular spaces are present (Figure - 23).

**Figure - 23**

**T.S. OF DICOT ROOT**



## 3:5 ORGANISATION OF TISSUES IN PRIMARY DICOT ROOT

Dicot Root

| Epidermis | Cortex | Stele |
| --- | --- | --- |
| Root Hairs | 1. Exodermis | 1. Pericycle |
| | 2. General Cortex | 2. Vascular Bundles |
| | 3. Endodermis | 3. Conjunctive tissues |
| | | 4. Medulla |

Secondary Growth in Dicot Root

The roots of gymnosperms and most dicots undergo secondary growth. The dicot roots are basically quite similar to that of dicot stems, but the process initiates in different manner. The secondary vascular tissues originate as a result of the cambial activity. The phellogen gives rise to the periderm.

The dicot roots posses a limited number of radial vascular bundles with exarch xylem. The cambial cells divide again and again and produce secondary tissues. The secondary vascular tissues form a continuous cylinder, the primary xylem gets embedded in it. The presence of medullary rays is a characteristic feature of the roots.

The ***periderm*** develops in the outer region of the root. The single layered pericycle becomes meristematic and divides, giving rise to phellogen (cork cambium). The phellogen produces two type of cells namely, phellem and phelloderm.

## 3:6 PRIMARY STRUCTURE OF MONOCOT STEM:

In monocots secondary growth does not takes place. Hence, the plant body consists of only primary tissues. A transverse section of monocots stem ***Zea mays*** shows four regions. They are 1.epidermis, 2. Hypodermis, 3. Ground Tissues, 4. Vascular bundles.

## ORGANISATION OF TISSUE IN MONOCOT STEM

Monocot Stem

Epidermis
1. Cuticle
2. Stomata

Hypodermis
Sclerenchyma

Ground Tissue
Parenchyma

Vascular bundles
1. Xylem
2. Phloem

1. ***Epidermis*** is the outer most region. It consists of a single layer of compactly arranged cells. The cells show vacuolated cytoplasm with a single nucleus. The outer walls of epidermal cells are cuticle. Cuticle prevents loss of water. Stomata is also present in epidermis. It helps in exchange of gases.

2. ***Hypodermis:*** A distinct cortex is absent in monocot stems. Hypodermis consists of 3 to 4 layers of sclerenchymatous cells. It provides mechanical support.

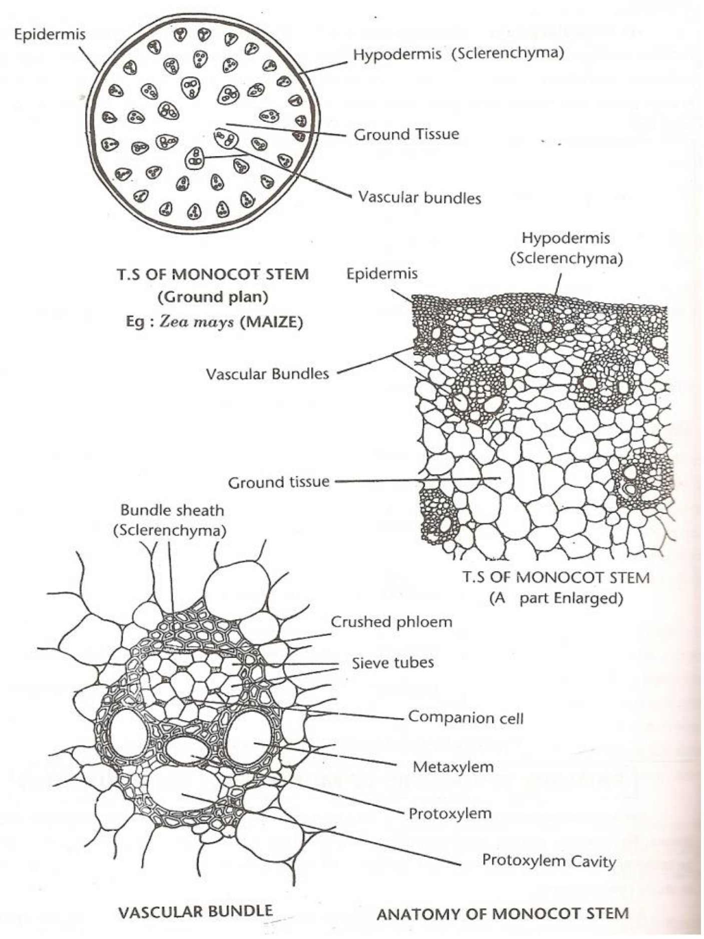
3. ***Ground Tissue:*** It is extensive and present beneath the hypodermis. It consists of parenchymatous cells. The cells are oval, thin walled and loosely arranged. The cells store food materials.

4. ***Vascular Bundles***: The vascular bundles are irregularly scattered within the ground tissue. Each bundle is oval and surrounded by sclerenchymatous bundle sheath. Vascular bundles are conjoint, collateral, end arch and closed.

Xylem consists of vessels, tracheids, xylem parenchyma and xylem fibres. Xylem helps in transport of water and ions.Phloem consists of sieve tubes and companion cells. Phloem parenchyma is absent. Phloem helps in transport of food materials. In monocot stem the most advanced type of stele such as ***atacto stele*** is present (Figure - 24).

**Figure - 24**

**T.S OF MONOCOT STEM**




## SELF ASSESSMENT QUESTIONS - I

**ANSWER THE FOLLOWING QUESTIONS**

1. Trichomes - Define
2. Three types of cells in cortex
3. Casparian strips consists of _____________

## 3.7 PRIMARY STRUCTURE OF MONOCOT ROOT:

In monocots secondary growth is absent, the root therefore always retain the primary structure. The transverse section it shows three regions. They are

1. Epidermis
2. Cortex
3. Stele

**ORGANISATION OF TISSUES IN MONOCOT ROOT**

Monocot Root

| Epidermis | Cortex | Stele |
|---|---|---|
| Root Hairs | 1. Exodermis<br>2. General Cortex<br>3. Endodermis | 1. Pericycle<br>2. Vascular Bundles<br>3. Conjunctive tissues<br>4. Medulla |

1. **Epidermis**:

Epidermis is the outer most region. It consists of a single layer of cells. The cells are compactly arranged, thin walled and living, cuticle and stomata are absent. Because of the presence of root hairs, epidermis is also called ***epiblema or rhizodermis***. The roots epiphytes possess a spongy tissue (Velamen). The cells absorb moisture form the atmosphere. Root hairs help in absorption of water and mineral ions.

2. **Cortex**:

Cortex is the middle region. It can be divisible into

(a) Exodermis

(b) General Cortex

(c) Endodermis

***Exodermis*** is the outer zone of cortex. It is present just beneath the epidermis. It consists of two to three rows of compactly arranged cells. The main role of exodermis is to prevents exit of water from the root.

***General cortex*** it is present beneath the exodermis. It consists of many layers of parenchymatous cells. The cells are colourless, and help in lateral transport of water and mineral ions.

***Endodermis*** is the inner most layer of cortex. It consists of compactly arranged barrel shapped cells. Endodermal cells are thickened with Suberin and lignin. These thickenings are called ***Casparian thickenings***. Endodermis prevents the leakage of water from the stele.

3. **Stele**:

Stele is the central region. It can be divided into

(a) Pericycle

(b) Vascular bundles

(c) Conjunctive tissues

***Pericycle*** is the outer most layer of the stele. It consists of a single layer of thin walled, Parenchymatous cells. The cells are compactly arranged. The main role of pericycle is the formation of lateral roots and secondary cambium.

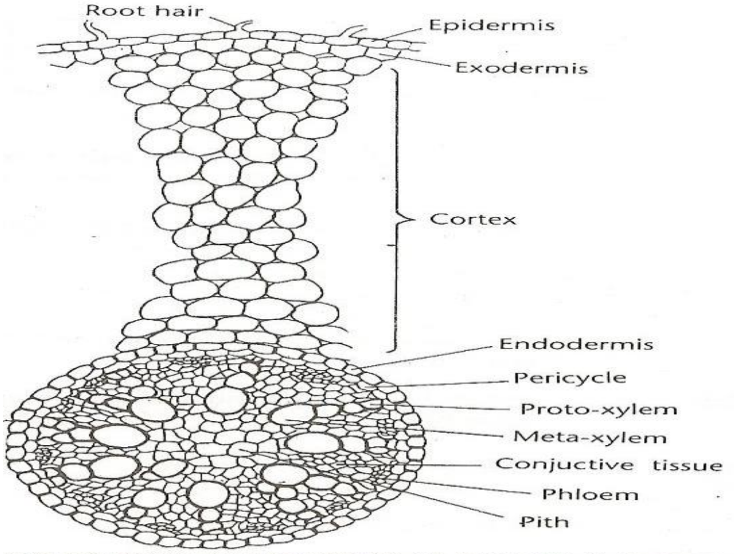
***Vascular bundles***: The xylem and phloem are present in separate patches in equal number. Xylem consists of only vessels. Phloem consists of sieve tubes. Companion cells and phloem parenchyma cambium is absent. Hence, Vascular bundles are closed. xylem helps in conduction of water and minerals. Phloem helps in conduction of food materials.

***Conjunctive tissue***: Parenchymatous tissue is present between xylem and phloem stands. This tissue is called conjunctive tissues. The main role of this tissue is formation of secondary cambium.

***Medulla*** is the central zone of the stele. It is parenchymatous. Inter cellular spaces are present (Figure - 25A, 25B).

**Figure - 25 A**

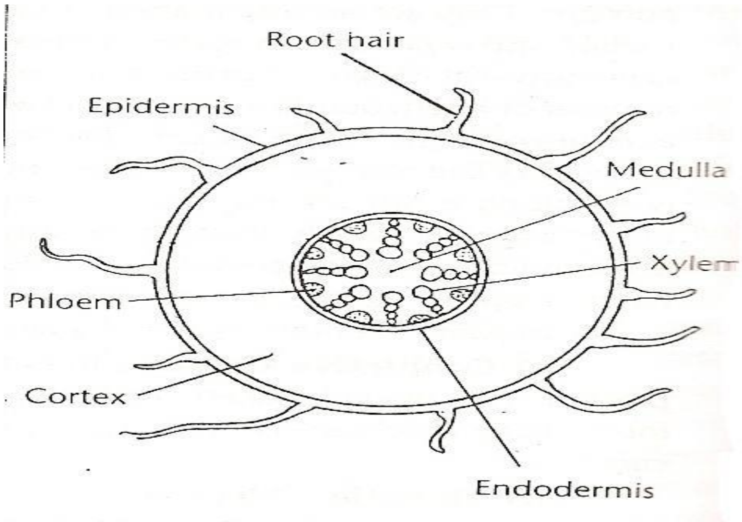
**T.S OF MONOCOT ROOT**




T.S OF MONOCOT ROOT (A PART ENLARGED)

**Figure - 25 BA**

**T.S OF MONOCOT ROOT**




T. S. OF MONOCOT ROOT (Ground plan)

### 3:8 DIFFERENCES BETWEEN INTERNAL STRUCTURE OF DICOT STEM AND MONOCOT STEM:

| Sl. No. | DICOT STEM | MONOCOTSTEM |
|---|---|---|
| 1. | Epidermal hairs (trichomes) are present | Epidermal hairs (trichomes) are absent |
| 2. | Cortex is well develops | Poorly developed |
| 3. | Endodermis is present | Absent |
| 4. | Pericycle is present | Absent |
| 5. | Bundle sheath is absent | Sclerenchymatous bundle sheath is present |
| 6. | Vascular bundle is conjoint, collateral, open | conjoint, collateral, closed |
| 7. | Xylem consists of many vessels | Few vessels only |
| 8. | Phloem parenchyma is present | Absent |
| 9. | Vascular bundles are uniform in size | Different size |
| 10. | Medulla, Medullary rays are distinct | Absent |

### 3:9 DIFFERENCES BETWEEN INTERNAL STRUCTURE OF DICOT AND MONOCOT ROOT:

| Sl. No. | DICOT STEM | MONOCOTSTEM |
|---|---|---|
| 1. | Secondary growth occurs | Does not occur |
| 2. | Cortex is smaller | Larger |
| 3. | Vascular bundles are 1 - 5 in number | Many in number |
| 4. | Proto xylem is monarch to tetrarch | Polyarch |
| 5. | Medulla is smaller or absent | Fairly large |

## 3:10 STRUCTURE OF DICOT LEAF:

Leaf is a thin, flat, exogenous, green lateral organ of the stem. On the basis of structure, leaves are classified in to three types. They are

1. Dorsiventral leaves
2. Isobilateral leaves
3. Centric leaves

In dorsiventral leaf, the upper surface is dark green and lower surface is pale green. Eg: ***Helianthus annus*** (Sunflower).

In isobilateral leaf, both upper and lower surfaces are uniform in colour and show similar structure . Eg: ***Zea Mays*** (Maize).

The centric leaves are erect, long and cylindrical

Eg: ***Allium Cepa*** (Onion).

**Internal structure of Dicot leaf**

The sunflower ***Helianthus annus*** is taken as an example for a typical dorsiventral leaf of a dicotyledon plant. A transverse section of dicot leaf shows three regions. They are

1. Epidermis
2. Mesophyll tissue
3. Vascular bundles

1. ***Epidermis*** is the outer most layer. Epidermis consists of a single layer of compactly arranged, barrel shaped cells. Chloroplasts are absent. The cuticle present on upper epidermis is comparatively thicker than the cuticle present in lower epidermis. Stomata are present on the epidermis. Epidermis protect the inner tissues.

2. ***Mesophyll Tissue***: It is parenchymatous and consists of two types of tissues. They are

(a) Palisade Parenchyma

(b) Spongy Parenchyma

***Palisade*** Parenchyma is present beneath the upper epidermis. Cells are thin walled, contain numerous chloroplasts. The cells are arranged in 1, 2 or 3 vertical rows at right angles to the upper epidermis palisade parenchyma carries out photosynthesis.

***Spongy*** parenchyma is present between palisade parenchyma and lower epidermis. The cells are irregular in shape and loosely arranged. The spongy parenchyma carries out photosynthesis and helps in gaseous exchange.

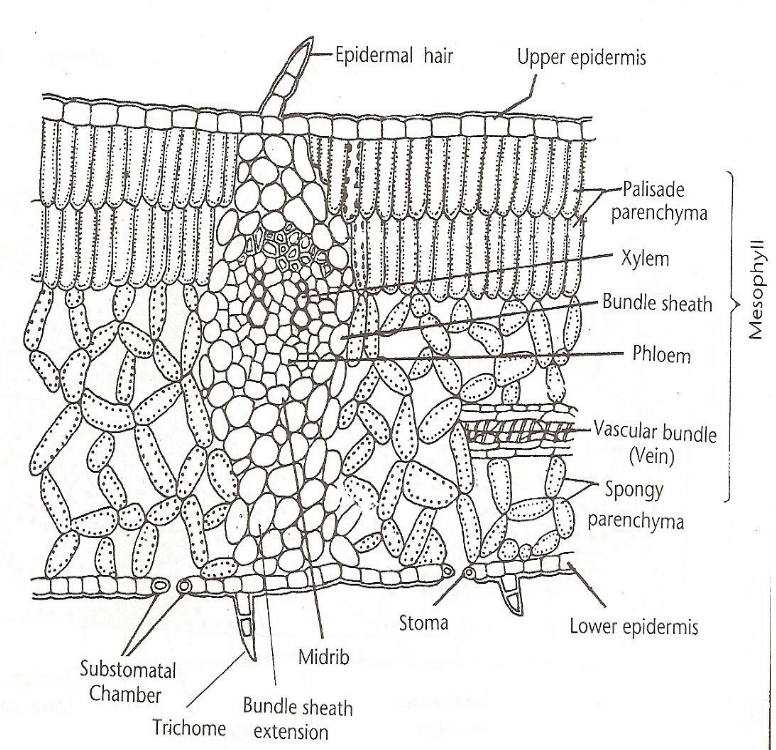
3. ***Vascular Bundles***: They are arranged in the form of veins, present at the base of leaf lamina are broader. They become narrower towards the leaf apex. They are conjoint, collateral and closed. Each vascular bundle shows xylem towards the upper epidermis and phloem towards the lower epidermis.

Xylem consists vessels, tracheids, xylem fibres and xylem parenchyma. Phloem consists of sieve tubes, companion cells and phloem parenchyma.

Each vascular bundle is surrounded by a single layer of parenchymatous cells. This layer is called bundle sheath. The cells are compactly arranged. Cells of bundle sheath are homologous to endodermis. They possess casparian strips (Figure - 26).

**Figure - 26**

**T.S OF DICOT LEAF**




DORSIVENTRAL LEAF (A PART) T.S (SUNFLOWER)

**ORGANISATION OF TISSUES IN DICOT LEAF**

Dicot Leaf

↓

- Epidermis
  - Upper Epidermis
  - Lower Epidermis
- Mesophyll Tissue
  - Palisade Parenchyma
  - Spongy Parenchyma
- Vascular Bundles
  - Xylem
  - Phloem

## 3:11 STRUCTURE OF MONOCOT LEAF:

The maize ***Zea Mays*** is taken as an example for a typical isobilateral leaf of a monocot plant. A transverse section of ***monocot*** leaf shows three regions. They are

(1) Epidermis

(2) Mesophyll tissue

(3) Vascular Bundles

1. ***Epidermis*** is the outer most layer. It consists of single layer of cells. The outer walls are cutinised. The cutin forms a layer called cuticle. Stomata are present of both the epidermal layers almost equally. In grasses the upper epidermis shows large, thin walled cells called ***bulli form*** cells. They are hygroscopic and help in rolling of leaf lamina, Epidermis protects the inner parts.

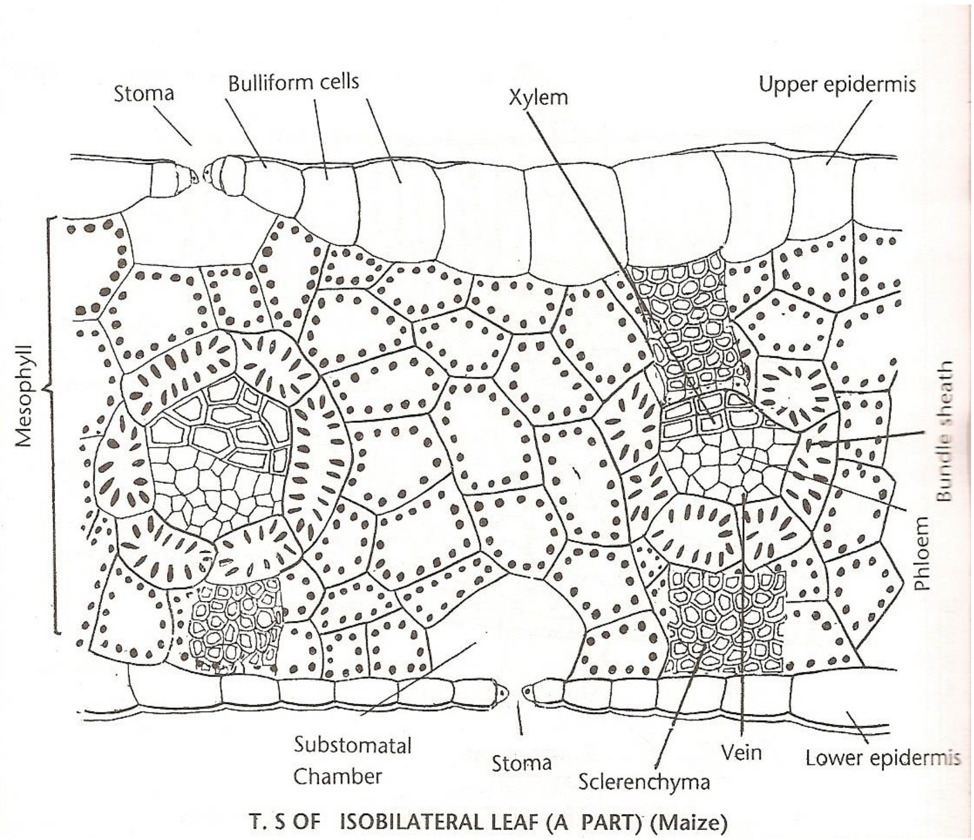
2. ***Mesophyll Tissue***: It is present between the upper and lower epidermis. It is not differentiated into palisade and spongy tissue. It consists of compactly arranged, thin walled isodiametric cells. They carries out photo synthesis.

3. ***Vascular Bundles***: Vascular bundles are arranged in parallel series. They are collateral, conjoint and closed. Most of the bundles are small in size but fairly large bundles are also occur. The xylem is found towards the upper side and phloem towards lower side in the bundles. Xylem consists of vessels, tracheids and xylem parenchyma. Phloem consists of sieve tubes and companion cells.

Selerenchyma cells occur in patches on both ends of the large vascular bundles which give mechanical support to the leaf. The maize leaf have the "Cane type" of anatomy called Kranz anatomy. The vascular bundles are surrounded by enlarged, parenchymatous chloroplast containing bundle sheath cells (Figure - 27).

**Figure - 27**

**T.S OF MONOCOT LEAF**




**ORGANISATION OF TISSUES IN MONOCOT LEAF**

**Monocot Leaf**

- Epidermis
  - Upper Epidermis
  - Lower Epidermis
    - (a) Bulliform Cells
    - (b) Stomata
    - (c) Cuticle
- Mesophyll Tissue
  - Isodiametric Cells
- Vascular Bundles
  - Xylem
  - Phloem

10. **DIFFERENCES BETWEEN INTERNAL STRUCTURE OF DICOT LEAF AND MONOCOT LEAF**:

| Sl. No. | DICOT LEAF | MONOCOT LEAF |
|---|---|---|
| 1. | Petiole present | Sheathing leaf base is present |
| 2. | Motor Cells (bulliform) absent | Present |
| 3. | Trichomes present | Absent |
| 4. | Stomata mostly restricted to lower epidermis | Almost equal in number on upper and lower epidermis. |
| 5. | Mesophyll is Heterogeneous | Homogeneous |

**3:12 Nodal Anatomy** - (Uni, tri and Multilacunarnode)

The node is nothing but knob or joint of a stem at which leaves arise. Pertaining a node or nodes are called ***Nodal***. A shoot bears nodes and inter nodes. At each node, portions of the Vascular system are deflected into the leaf, which is attached at this node. The leaf trace is a vascular bundle that connects the vascular system of the leaf with that of the stem. The parenchymatous regions in the vascular system of the stem, located adaxially form the diverging leaf traces are called ***leaf gaps*** (lacunae).

Basically there are three common types of nodes in the dicotyledons. They are,

(a) Unilacunar

(b) Trilacunar

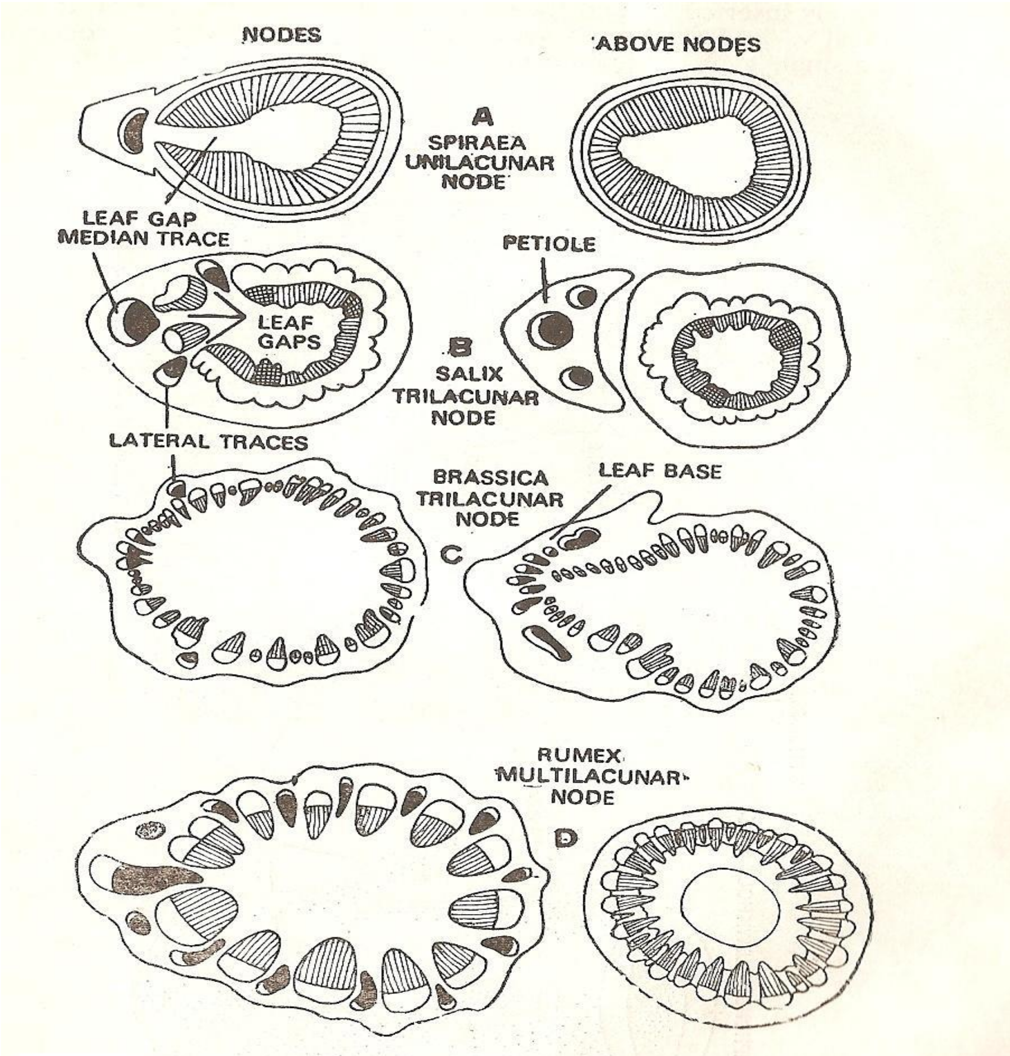
(c) Multilacunar

The node with a single gap and a single trace to a leaf is known as unilacunar node. The node with three gaps and three traces to a leaf is known as trilacunar node. The node with several to many gaps and traces to a leaf is known as multilacunar.

Several monocots possess leaves with sheathing bases and nodes with a large number of leaf traces. In gymnosperms a unilacunar node is common. The ***nodal anatomy*** is always concerned with the study of systematic and phylogeny of angiosperms due to their phylogenetic importance (Figure - 28).

**Figure - 28**

**NODAL STRUCTURE OF DICOTYLEDONS**



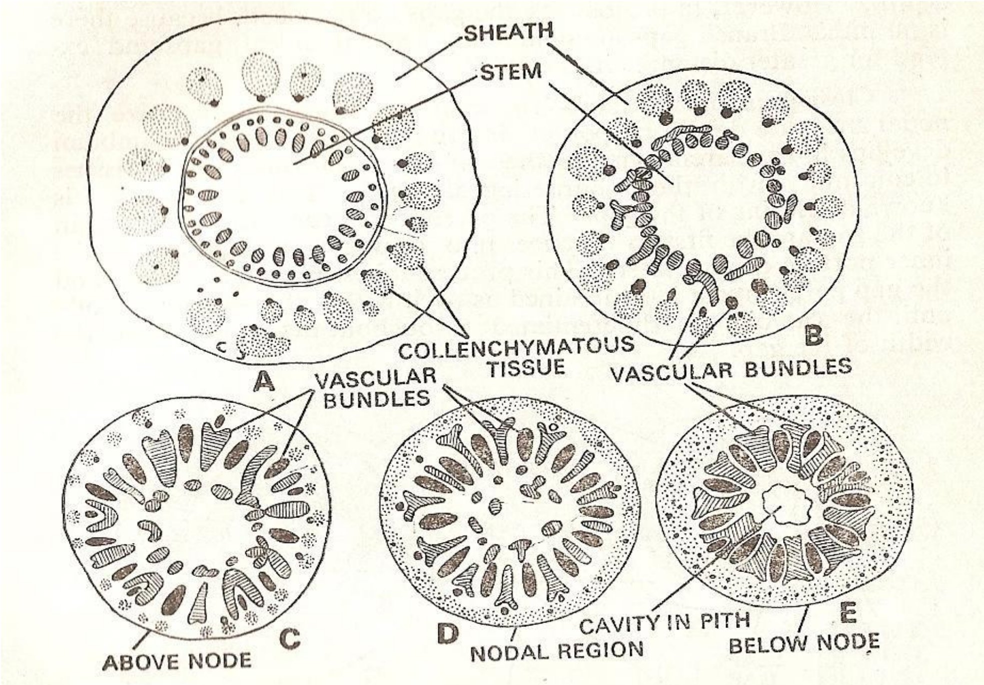

Nodal anatomy of dicotyledons. A. *Spiraea*—each leaf has one leaf trace and one leaf gap (unilacunar node); B, *Salix*—each leaf has three leaf traces and three leaf gaps (trilacunar node); C, *Brassica*—three leaf traces and three leaf gaps per leaf (trilacunar node); D, *Rumex*—many leaf traces and many leaf gaps per leaf (multilacunar node).

**Nodal structure in monocotyledons**

In monocots, (wheat stem) near the node the leaf sheath is considerably thick, and it has the smallest diameter above the junction. The collenchymatous bundle caps are present in the bundles of leaf sheath (Figure - 29).

## Figure - 29

## NODAL STRUCTURE OF MONOCOTYLEDONS




Nodal anatomy of *Triticum* stem. Bundles of sheath and their traces in stem are depicted in black; vascular tissue of internode and its continuation through node is hatched. A – E, transections of stem at various levels. Toward node, sheath increases and stem decreases in thickness.

Relation of secondary growth to leaf traces, Leaf and Branch gaps

The increase in thickness of secondary xylem the bases of the leaf traces are buried and since the cambium lies always between the xylem and phloem. The length of the buried part depends largely upon the angle at which the trace departs. Leaf gaps are closed by the gradual lateral extension of the cambium. The size and the shape of the gap determine in part the length of time before the gap is closed. In most of the angiosperms, leaf gaps are closed in the first season. Branch gaps, which are often large, are closed more slowly than leaf gaps.

**SELF ASSESSMENT QUESTIONS - II**

**ANSWER THE FOLLOWING QUESTIONS**

1. Pericycle is a part of ___________
2. Motor cells ___________
3. Leaf gaps ___________

I.
1. Multicellular out growth in epidermis
2. Hypodermis, General cortex, Endodermis
3. Suberin, Lignin

II.
1. Stele
2. Present in monocot Leaf
3. Lacunae

**UNIT QUESTIONS**:

1. Brief about Primary structure of dicot stem.
2. Write a note on Anomalous structure.
3. Discuss about secondary growth of Dicot root.
4. List out the differences between dicot, monocot leaf.
5. Explain the Nodal Anatomy with examples.

**RECOMMENDATIONS FOR FURTHER READINGS**:

1. Pandey, B.P (1978) Plant Anatomy, S. Chand and Co, New Delhi.
2. Vashista,P.C (1968) A Text Book Plant Anatomy.
3. Fahn, A 1982 Plant Anatomy (3rd edition). Pergoman Press, Oxford.
4. Mauselth, J.D (1988). Plant Anatomy. The Benjamin Cummings Publishing Co Inc., Mehlo Park, california, USA.

## UNIT - IV MALE AND FEMALE GAMETOPHYTE

# UNIT - IV

# EMBRYOLOGY OF ANGIOSPERMS

# MALE AND FEMALE GAMETOPHYTE

## 4:0 INTRODUCTION TO EMBRYOLOGY OF ANGIOSPERMS:

The branch of biology which deals with the study of development of zygote into embryo is called the embryology. It also includes microsporogenesis, megasporogenesis, development of male and female gametophytes, process of fertilization and development of endosperms.

The spermatophytes (Phanerogams) are known as 'Flowering' or seed bearing plants. They constitute the highest division of the plant kingdom and have the largest number of species of all groups of plants. There are two main groups of spermatophytes (Phanerogams),

(a) Gymnosperms

(b) Angiosperms

The gymnosperms are naked seeded plants those in which the seeds are not enclosed in the fruit. They may be regarded as lower flowering plants. The angiosperms are closed seeded plants, those in which the seeds are enclosed in the fruit. they may be regarded as higher flowering plants.

The seed is a complex structure and develops from the ovule only after the processes of pollination and fertilization. When the seed germinates, the embryo grows into a seedling, which gradually converts into a mature plant.

## 4:1 Structure and development of Anther

In angiosperms, the stamen is consider as male reproductive organ. It is also regarded as modified microsporophyll. The microsporophyll consists of three parts. They are filament, connective and anther. Among these, anther is the fertile part. A typical anther is tetra sporangiate. The anther consists of one or two anther lobes. Each anther lobe consists of two longitudinally arranged pollen sacs. Each pollen sac is considered as a microsporangium. The cross section of a very young anther consists of a homogenous mass of meristematic cells surrounded by an epidermal layer.

## 4:2 Structure of Microsporangium

A mature microsporangium consists of two regions namely,

(a) Anther wall

(b) Sporogenous tissue

The anther wall consists of four types of cells namely,

i. Epidermis

ii. Endothecium

iii. Middle layers

iv. Tapetum

***Epidermis*** is the outermost layer of anther wall. It protects the inner parts of the microsporangium. During anther development the epidermal cells undergo repeated divisions. In a mature anther they are greatly flattened.

***Endothecium*** is present beneath the epidermis. The cells of endothecium are radially elongated and show fibrous thickenings. The presence of fibrous bands, differential expansion and hygroscopic nature of the endothecium help in the dehiscence of anthers at maturity.

***Middle layers***: The cells of wall layers are thin walled and flattened. They store food materials, which get mobilised during later development of pollen.

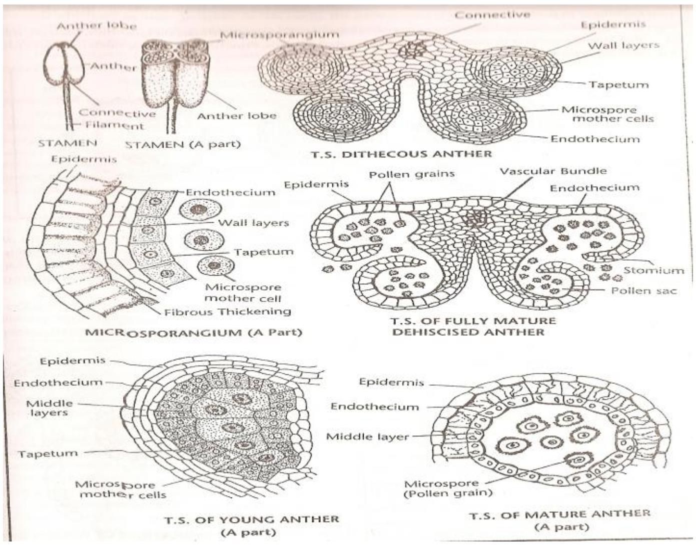
***Tapetum***: It is the inner most layer of anther wall. The cells of tapetum are large and thin walled. They contain dense cytoplasm and prominent nuclei. Tapatum is a nutritive tissue. It supplies food materials to the sporogenous tissue. The tapetum plays a significant role in the development of pollen.

**b) Sporogenous Tisue**

Sporogenous tisue consists of fertile cells. The cells may directly acts as microspore mother cells. Each microspore divides meiotically and produces four haploid microspores. The microspore tetrad separates in to four microspores (Pollen grains) (Figure - 30).

**Figure - 30**

**MICROSPORANGIUM**




## 4:3 STRUCTURE OF POLLEN GRAIN (Microspore):

The study of pollen grains and spores is called the palynology. A schematic illustration of a pollen grain is called palynogram. The structure, morphology and number of germ pore of pollen grains help in the classification of flowering plants.

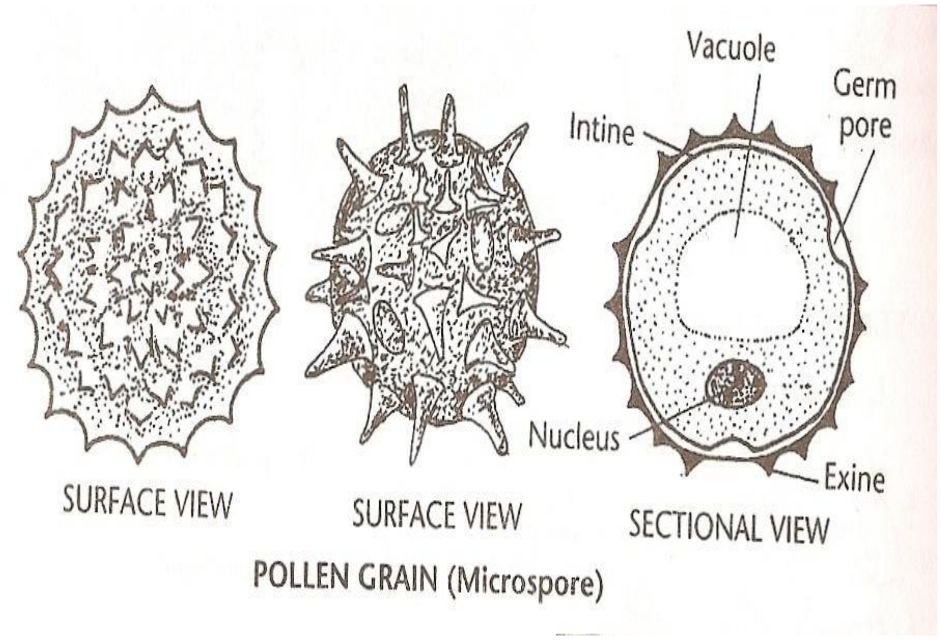
Pollen grain is haploid. The pollen grains are very small in size. They are unicellular, spherical. It is the first cell of male gametophyte. The pollen grain is surrounded by a thick wall called sporoderm. The sporoderm consists of two layers. The outer layer is called exine. It is thick and made up of sporopollenin. The inner layer is called in tine. It is thin and made up of pectin and cellulose. It forms pollen tubes.

The pollen grains came out of the anther at the two nucleate stage with a tube nucleus and generative cell. The generative cell produces tow non motile male gametes. The tube nucleus is found in the terminal part of the pollen tube.

Pollen grains are initially formed in groups of four (tetrads). Each pollen grain has two poles, at opposite ends of polar axis. The proximal pole is at the centre of the proximal face, where as the distal pole is at the centre of the distal face. An aperture is any weak area on the pollen surface which is colpi and short ones pores (Figure - 31).

**Figure - 31**

**POLLEN GRAIN**




**4:4 Scope of Palynology**:

1. The palynological research is playing a role in various field.
2. Aeropalynology is most important because of its application in paleobotany, forestry and medicine.
3. The analytical study provides useful information for establishing apiary garden.
4. The pollen grains provide vitamins, minerals and amino acids.
5. Pollen grains in the air has been useful in determining the allergens.

6. The applied palynology is playing a role in oil geology.

7. Pollen grains used as a tonics, pollen tablets, creams etc.

## 4:5 DEVELOPMENT OF MALE GAMETOPHYTE:

The pollen grain (Microspore) is the first cell of male gametophyte. It divides periclinally and produces two unequal cells. The larger cell is called vegetative cell. The smaller, lenticular cell is called generative cell. The generative cell gets separated from the spore wall. It becomes lens shaped or spherical. At two celled stage the pollen grain is liberated from the pollen sac.

**4:6 Stages in the formation of two celled**

**(Vegetative, Generative):**

Pollen from tetrad

↓

Cytoplasm is highly vacuolated

↓

Nucleus has been displaced

↓

Pollen mitosis

↓

Two celled stage

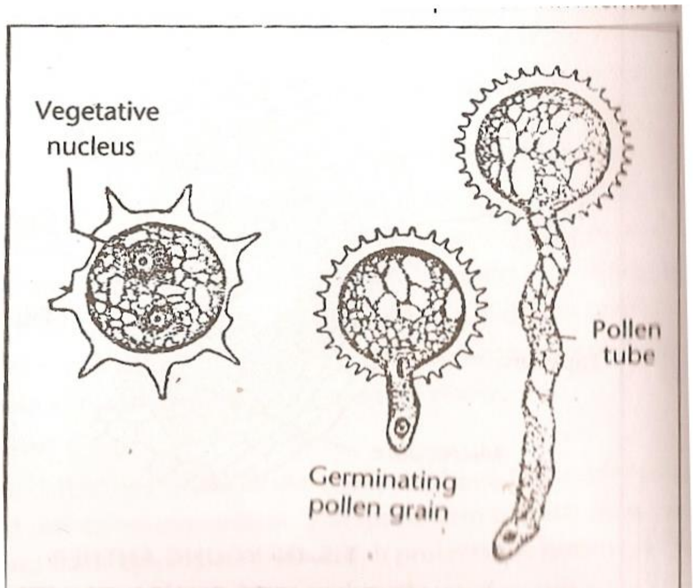
↓

Appearance of generative cell wall

During gametogenesis the pollen nucleus divides to form two cells (The vegetative and generative). The generative cell undergoes a mitosis division to form two sperms. The generative cell may divide inside the pollen grain or in the pollen tube, after the pollen has germinated. In some cases the DNA synthesis prior to first pollen mitosis takes place immediately before the division.

On reaching the stigma, pollen grains germinate with the help of stigmatic secretions, normally one pollen tube is developed from a pollen grain, such a pollen grain is called Monosiphonous. In some cases, several pollen tubes are developed from a pollen grain. Such a pollen grain is called polysiphonous, Eg: Cucurbitaceae, Malvaceae. After the formation of male gametes (Sperms) the pollen tube shows two male cells and one vegetative nucleus. The vegetative nucleus disappears before fertilization. The pollen tube passes through the style and reaches the ovule (Figure - 32, 33).

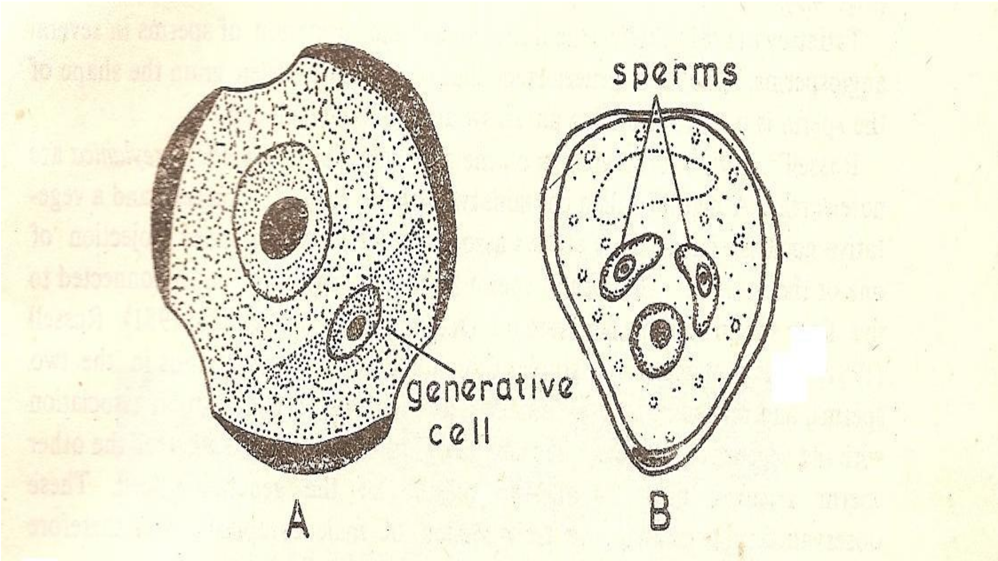
**Figure - 32**




STRUCTURE AND GERMINATION OF POLLEN GRAIN

**Figure - 33**

**POLLEN AT SHEDDING**




Pollen at shedding. *A.* Two-celled pollen of *Klugia*. *B.* Three-celled pollen of *Cyperus*.

**4:7 Pollen wall**:

The wall of the mature pollen grain is stratified. It comprises two main layers namely,

(a) Intine (Inner)

(b) Exine (Outer)

The exine comprises many sub layers, Tectum, Foot layer, endexine etc.

The intine is pectocellulosic in nature. The cellulose component is microfibrillar, with the microfibrils. The exine is composed of sporopollenin. It is derived from carotenoids.

**Pollen kitt**: The pollen kitt is an oily layer found on the outside of the mature pollen grains of many insect pollinated species. The pollen kitt is basically made up of lipid and carotenoids. The pollen kitt is useful for the dispersal of pollen. Because of the sticky nature it may be acting as an adherent to the insect body.

**SELF ASSESSMENT QUESTIONS - I**

**ANSWER THE FOLLOWING QUESTIONS**

1. Spermatophytes are also called __________
2. Tapetum - Define
3. Sporopollenin - Define

**4:8 Abnormalities of pollen grains**: The most of angiosperms, the pollen mother cell divides by a meiotic division resulting in four haploid nuclei, each of which form a functional spore. In some cases apart from the normal nuclei, the non-functional nuclei may also formed. Eg: ***Cyperus, Scirpus****:* The another interesting example from ***Datura***, under normal conditions they would form male gametes. Under special conditions due to various factors like temperature, they may form female gametophytes.

Apart from this, the ***male sterility*** is also occur in same angiosperms. Due to various reasons, namley.

(a) Premeiotic determination - Abortion, Anther suppression.

(b) Failure of anther dehiscence.

(c) Premature dissolution during microsporogenesis.

(d) Environmental factors - Temperature, Chemicals.

(e) The malfunctioning of Tapetum.

**4:9 Structure of Ovule (Mega sporangium):**

Ovule is the integumented megasporangium. It consists of nucellus which is surrounded by one or two integuments. The integuments leave a small opening at the apical end. This opening is called micropyle. The basel region of ovule at which nucellus, integuments and funicle fuse together is called chalaza. The ovule is attached to the placenta by a small stalk called funicle. Nucellus encloses the embryosac which is the female gametophyte. The anterior part of the ovule is called the micropylar end. The posterior part of the ovule is called the chalazal end.

1. **Integuments**:

They are the protective envelopes of the ovule. Mostly an ovule has either one or two integuments. Ovule with one integument is called unitegmic and those with two integuments are known as bitegmic. The unitegmic type of ovules are found in Gamopetalae (Asteraceae). The bitegmic type of ovules are found in polypetalae and monocots. In some members the ovules lack an integument and are called ategmic (olacaceae).

2. **Nucellus**:

Ovule consists of parenchymatous tissue. This tissue is called nucellus. Nucellus represents the wall of megasporangium. Each ovule has only one nucellus. Based on the quantity of nucellus ovules are classified in to two categories. They are,

(a) Tenuinucellate ovules

(b) Crassinucellate ovules

In ovules a single hypodermal cell is differentiated as archesporial cell. In certain ovules, the archesporial cell directly functions as megaspore mother cell. Hence, nucellus is represented by a single layer, are called tenuinucellate. Eg: *Rubiaceae*

In certain ovules the archesporial cell divides transversely and produces two type of cells namely,

(i) Upper primary parietal cell

(ii) Lower primary Sporogenous cell

The primary parietal cell divides and produces massive nucellus. So the primary sporogenous cell is moved in to nucellus. Such ovules are called Crassinucellate. Eg: *Cucurbitaceae*

3. **Micro pyle**:

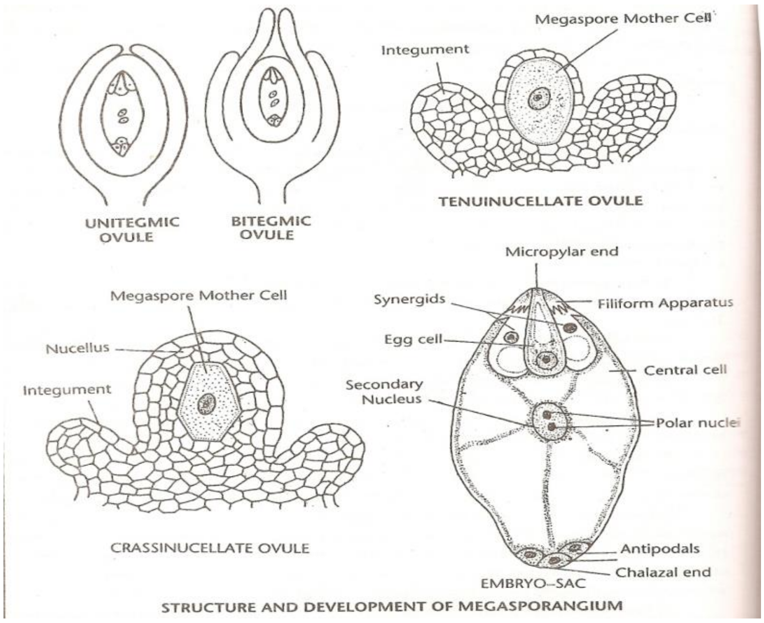
Integuments surround the nucellus completely leaving a small, narrow pathway at the apical region of the ovule. This opening is called micropyle. During fertilization the pollen tube enters the ovule through the micropyle.

4. **Chalaza**:

Chalaza is the basal region of the ovule. In this region nucellus and integuments fuse together. The vascular tissues that reach the ovule are terminated in chalaza (Figure - 34).

**Figure - 34**

**MEGASPORANGIUM**




**4:10 TYPE OF OVULES**:

On the basis of the position of micropyle with respect to the funicle, ovules are classified into six types. They are

(i) Orthotropous ovule

(ii) Anatropous Ovule

(iii) Hemianatropous Ovule

(iv) Campylotropous Ovule

(v) Amphitropous Ovule

(vi) Circinotropous Ovule

(i) Orthotropous ovule: The micropyle, chalaza and funicle lie on the same axis. It is found in the members of polygonaceae and piperaceae.

(ii) Anatropous Ovule: The body of the ovule is completely inverted due to unilateral growth of the funicle. This is the most common type of ovule in angiosperms, found in the members of polypetalae, gamopetalae and monocots.

(iii) Hemianatropous Ovule: The body of the ovule is placed at right angles to the funicle. This type of ovule is found in the members of malpighiaceae, primulaceae.

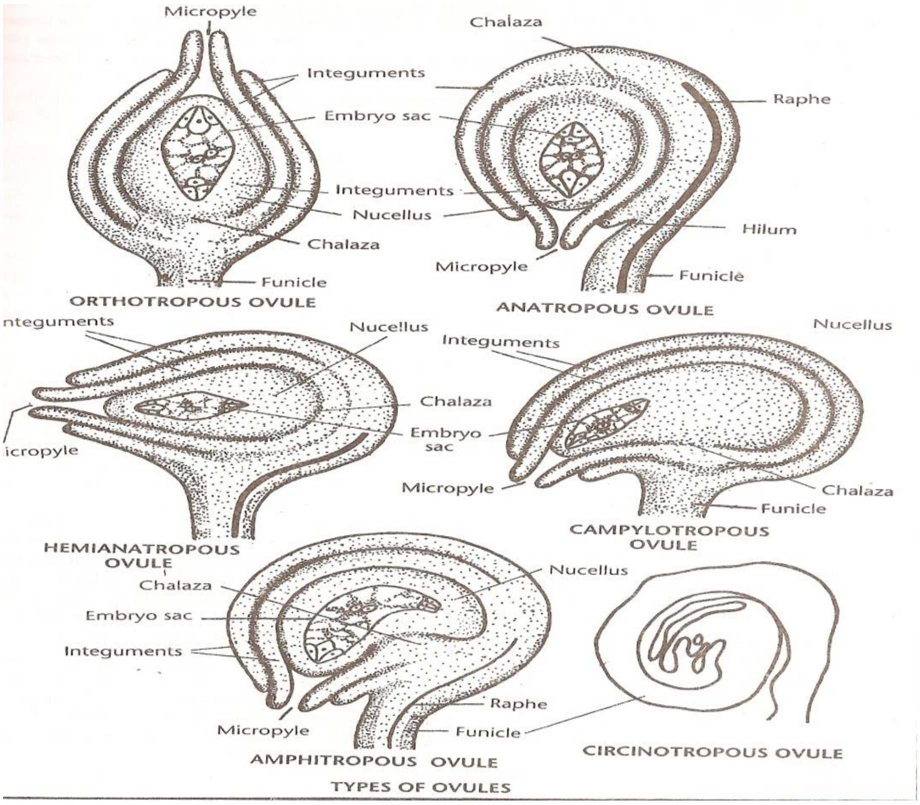
(iv) Campylotropous Ovule: The body of the ovule is placed at right angles to the funicle. The micropylar part curves downward like a horse - shoe on the funicle. This type of ovule is found in the members of Leguminosac, chenopodiaceac.

(v) Amphitropous Ovule: The body of the ovule shows more curvature. Embryosac becomes horse-shoe shaped. This type of ovule is found in the members of crossosomataceae, Leitneriaceae.

(vi) Circinotropous Ovule: It is the special type of ovule found in the family cactaceae. The funicle is long and encircles the anatropous ovule completely (Figure - 35).

**Figure - 35**

**TYPES OF OVULE**




**4:11 Structure and development of female gametophyte**:

In angiosperms the female gemetophyte is called the embryo Sac. It is seven celled and eight nucleated structure. There is a large central vacuole. It consists of three main parts. They are

(a) Egg apparatus

(b) Antipodal cells

(c) Central cell

The egg apparatus is present towards the micropylar end of the embryo Sac. It consists of three cells. They are a centrally situated egg and two, laterally situated synergids. The egg is completely surrounded by its own wall. The synergid cells are elongated, hooked towards the micropylar end. Each cell shows a nucleus at the upper and a vacuole at the lower end. The apical region shows fibre like structure, called the filiform apparatus. It may help in absorption and transport of food materials form nucellus into embryo Sac.

The antipodal cells are present towards the chalazal end of the embryo Sac. They are short lived, and the cells are regarded as vegetative cells. They are three in number.

The central cell is the largest cell of the embryo Sac. It shows a large central vacuole and two haploid polar nuclei. The two polar nuclei fuse together and form a diploid secondary nucleus (Figure-36).

**Figure - 36**

**STRUCTURE OF EMBRYO SAC**

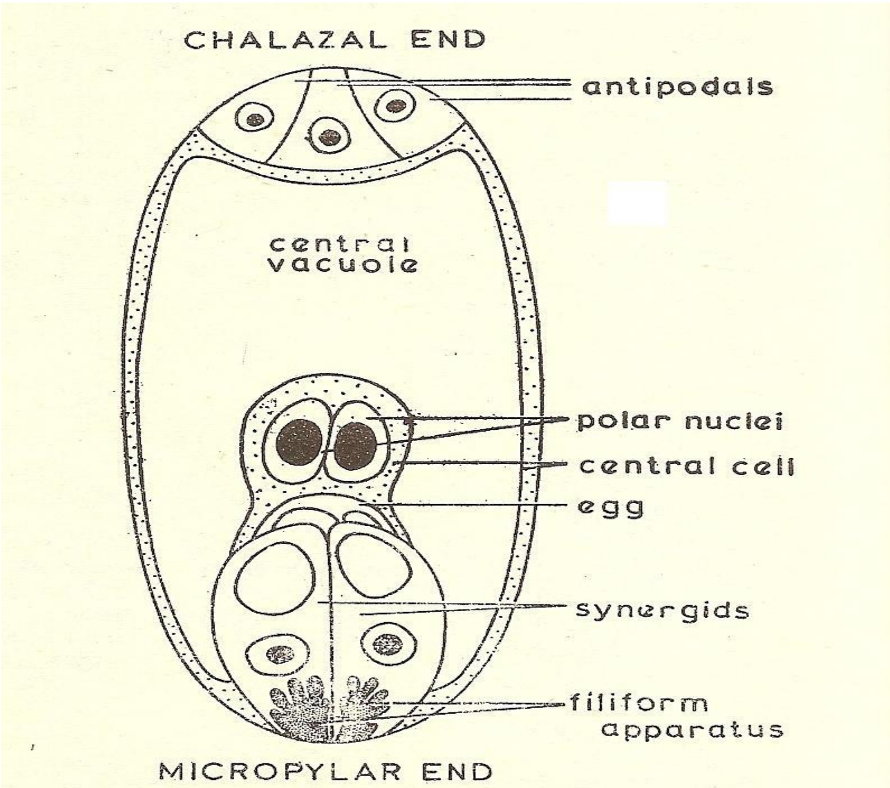
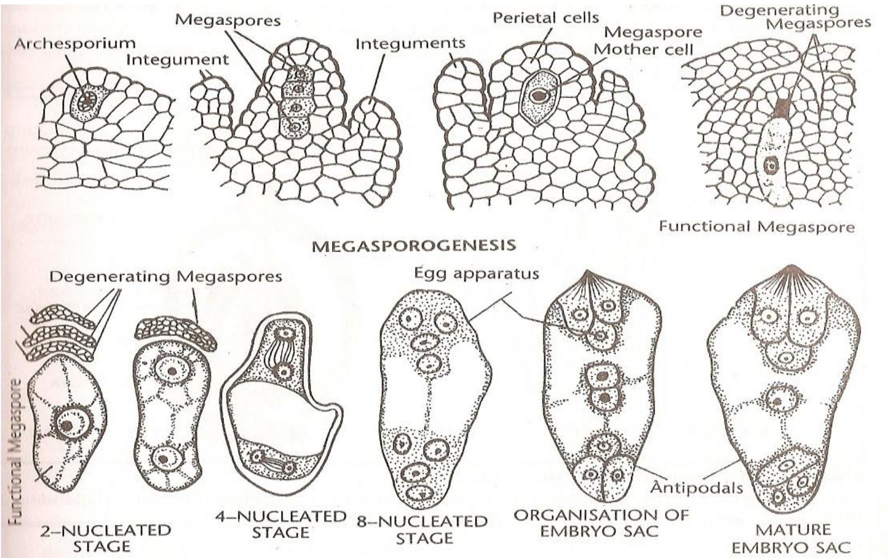



Diagram of an organised embryo sac. (modified *after* Jensen, 1972)

In the nucellus a single hypodermal cell is differentiated as archesporium. In tenuinucellate ovules the archesporium directly function as megaspore mother cell. In crassinucellate ovules the archesporium divides transversely and produces outer primary parietal cell and inner primary sporogenous cell. The primary sporogenous cell directly functions as megaspore mother cell. The megaspore mother cell divides meiotically and produces four haploid megaspores. Its nucleus undergoes nuclear divisions are produces eight haploid nuclei. The eight nuclei arranged in two groups of four each. Out of four, three nuclei organise into egg apparatus. The fourth nucleus behaves as upper polar nucleus. Out of four nuclei situated at the chalazal end three nuclei move to the antipodal cells. The fourth one behaves as lower polar nucleus. The polar nuclei fuse to form diploid secondary nucleus (Figure - 37).

**Figure - 37**

**DEVELOPMENT OF EMBRYO SAC**




**4:12 Types of female gametophyte (Embryo Sac)**:

Based on how many megaspore nuclei are involved in its formation, the embryo Sac may be classified into,

1. Monosporic Embryo Sacs
2. Bisporic Embryo Sacs
3. Tetrasporic Embryo Sacs

1. **Monosporic Embryo Sacs**:

The main character of a monosporic embryo sac is that it is derived from only one megaspore. The embryo sac is genetically identical because they are derived from a single nucleus.

Example for Monosporic - (poly gonum Type):

In the polygonum type, the embryo sac is formed by the chalazal megaspore. The mature embryo sac consists of egg apparatus, three antipodal cells and a central cell (binucleate).

2. **Bisporic Embryo Sacs**:

The main character of a biosporic embryo sac is the formation of dyad. It is possible by the first meiotic division, accompanied by wall formation.

Each megaspore nuclei undergoes two mitotic divisions, forms eight nuclei. The organisation of embryo sac is similar to the polygonum type. The embryo sac is genetically different, because they are derived from two meiotic products.

Example for Bisporic- (Allium Type):

In the Allium type, the embryo sac is derived from the chalazal dyad cell.

3. **Tetrasporic Embryo Sacs**:

The main character of a tetrasporic embryo sac is variation of nuclear behaviour. The end of meiosis the four haploid nuclei is formed. Cytoplasm forming a coenomegaspore. A tetrasporic embryo sac is more heterogeneous than a bisporic embryo sac.

Example for Tetrasporic - (Peperomia Type):

In the peperomia type, the embryo sac is sixteen nucleate. The organisation of the mature embryo sac is, egg apparatus, six peripheral cells and a central cell (8 polar nuclei). The arrangement of the four nuclei in the coenomegaspore is 1+1+1+1. (i.e) one nucleus at the micropylar end, one at the chalazal end, and two placed laterally, one on each side.

**SELF ASSESSMENT QUESTIONS - II**

**ANSWER THE FOLLOWING QUESTIONS**

1. Nucellus represents the ___________
2. Circinotropous ovule - Eg
3. Example for bisporic embryo sac

**ANSWERS OF SELF ASSESSMENT QUESTIONS**

I. 1. Phanerogams
2. Tapetum is a nutritive tissue
3. Present in exine of Pollen wall

II. 1. Wall of megasporangium
2. Cactaceae
3. Allium type

**UNIT QUESTIONS**:

1. Brief about Pollen grain.
2. Write a note on Structure of Anther.
3. Discuss about development of male gametophyte.
4. List out the type of ovule.
5. Explain the structure, development of female gametophyte.

**RECOMMENDATIONS FOR FURTHER READINGS**:


1. Bhojwani, S.S. and Bhatnagar S.P. The Embryology of Angiosperms, Vikas Publishing House Pvt Ltd., New Delhi.
2. Dwivedi J.N. 1988. Embryology of Angiosperms. Rastogi and Co., Meerut.
3. Maheswari, P. 1971. An Introduction to the Embryology of Angiosperms. Tata McGraw Hill Publishing Co., Ltd., New Delhi.
4. Swamy B.G.L., and Krishnamurthy, K.V. From flower to fruit. Tata McGraw. Hill Publishing Company Limited, New Delhi.

## NOTES

## UNIT - V POLLINATION, FERTILIZATION AND EMBRYO DEVELOPMENT

## UNIT - V

## POLLINATION, FERTILIZATION AND EMBRYO DEVELOPMENT

### 5:0 A BRIEF ACCOUNT ON POLLINATION

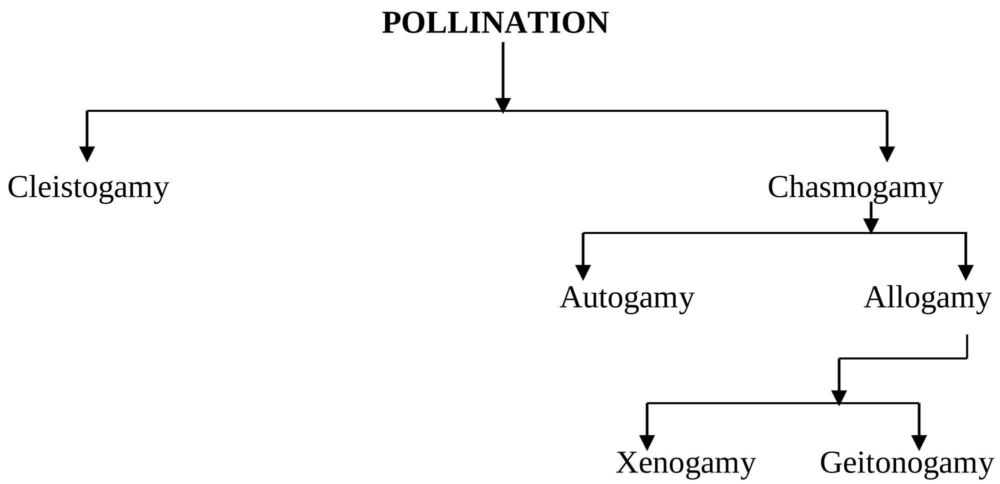
**Pollination**:

The transfer of pollen grains from the anther to the stigma of a flower is called the pollination. Pollination is the prerequisite for fertilization. It is an import biological process of sexually reproducing plants.

**Kinds of Pollination**:

The pollination in angiosperms is of two kinds, namely

1. Cleistogamy
2. Chasmogamy




1. **Cleistogamy**:

The bisexual flowers of certain plants never open. Such flowers are called cleistogamous flowers. The pollination that occurs in cleistogamous flowers is called cleistogamy. Eg: *Oxalis, Cormmelina*,

2. **Chasmogamy**:

The pollination takes place in opened flowers is called chasmogamy. This type of pollination takes place in most of the angiosperms. It is further divided in to,

(i) Autogamy (Self Pollination)

(ii) Allogamy (Cross Pollination)

The transfer of pollen grains from the anther of the stigma of the same flower is called autogamy. This type of pollination is possible only in bisexual flowers.

The transfer of pollen grains form the anther to the stigma of another flower of the same kind is called allogamy. It is further divided in to,

(a) Xenogamy

(b) Geitonogamy

The transfer of pollengrains from a flower to the stigma of the flower of the same kind present of different plant is called xenogamy.

The transfer of pollengrains of one flower to the stigma of another flower of the same plant is called geitonogamy.

**ADVANTAGES OF CROSS POLLINATION**:

1. The genetic variation is more than self pollination.
2. The seed production is also very high.
3. The plants are highly disease resistance.
4. The plants can grow in different agronomic conditions.

**5:1 Agents for cross Pollination**:

The cross pollinated crops mostly depends on some external agency. which mostly transfers pollengrains from the male plant to the stigma in the female plant. Some of the agencies are, wind, water, insects, birds and bats. Accordingly five types of pollination are recognized. They are

(i) Anemophily (wind)

(ii) Hydrophily (water)

(iii) Entomophily (Insects)

(iv) Ornithophily (Birds)

(v) Cheiropterophily (bats)

i. **Anemophily**:

The cross pollination is carried out by the agency of wind is called anemophily. Anemophilus flowers are inconspicuous, flowers are small and do not produce nectar or smell. Stamens have long drooping filaments. The pollengrains are usually small, dry and smooth. Mostly flowers are unisexual and more male flowers.

Eg: *Zeamays, Triticum sp*

ii. **Hydrophily**:

The cross pollination is carried out by the agency of water is called hydrophily. The hygrophilous flowers produce long, needle like pollengrains, Hydrophilous pollination may be of two types, namely

(a) Epihydrophily

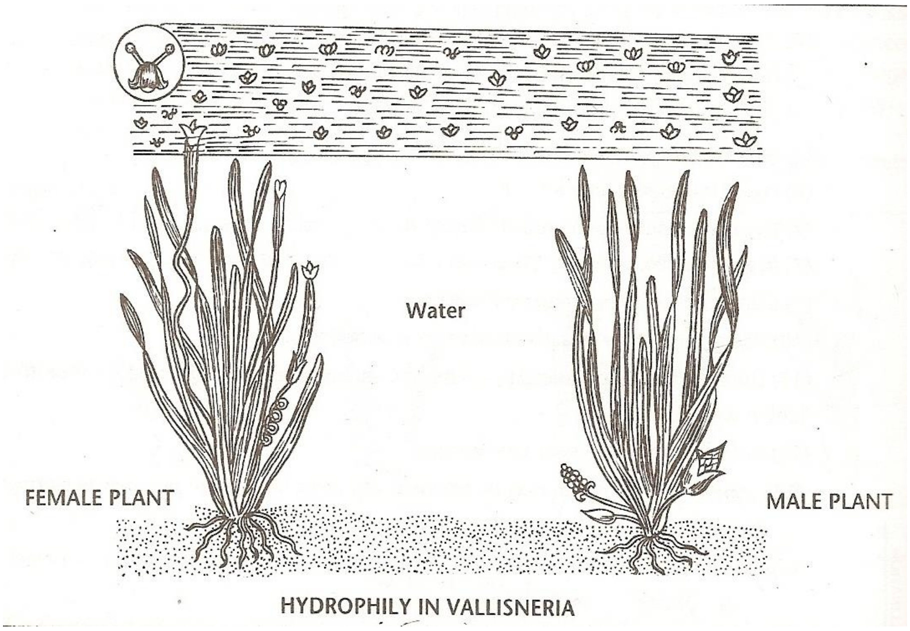
(b) Hyphydrophily

The cross pollination that is carried out of the water surface is called epihydrophily. Eg: *Vallisneria, Ruppia,*

Vallisneria is dioecious hydrophyte and produces unisexual flowers. The ripened male flowers float on the water surface. In each male flowers three stamens are exerted. The female flowers are spirally coiled pedicels. After pollination, the female flowers are pulled down to the bottom. Pollination that is carried out beneath the water surface is known as hyphydrophily (Figure - 38).

**Figure - 38**

**HYDROPHILY IN VALLISNERIA**




iii. **Entomophily**:

The cross pollination is carried out by the agency of insects is called entomophily. Some of the insects which help in pollination are flies, bees, moths and beetles. The entomophilous flowers shows certain adaptations to attract insects. They are colour, size, pollen, vector and scent. Eg: *Ocimum, Heliantus, Argemone, and Ixora*.

iv. **Ornithophioy**:

The cross pollination is carried out by the agency of birds is called ornithophily. usually the flowers are larger is size, brightly coloured and produce large amount of nectar. The birds like crows, humming birds help in pollination. Eg: *Erythrina, Bignonia*.

v. **Cheiropterophily**:

The cross pollination is carried out by the agency of bats is called cheiroptero phily. This type of pollination is restricted to few tropical plants. The pollinating bats have a long and slender muzzle and an extensive tongue. The bat, holds the flower by clasping the stamen ball. Eg: *Bauhinia*, *Musa*.

**5:2 ADAPTATIONS FOR CROSS POLLINATION**:

Plants have certain adaptations to ensure cross pollination. They are,

(a) Unisexuality

(b) Dichogamy

(c) Herkogamy

(d) Heterostyly

(e) Self sterility

(f) Pollen prepotency

(g) Sensitive stigmas

(a) **Unisexuality**:

The production of unisexual flower is called dicliny. Some plants produce staminate flowers and pistillate flowers separately. In such unisexual flowers only cross pollination takes place. Unisexual flowers are formed from bisexual ones. Eg: Monoecious flowers - *Zea mays*

Dioecious flower - *Vallisneria Spirallis*

Polygamous flower - *Mangifera indica*

(b) **Dichogamy**:

The ripening of androecium and gynoecium of a flower at different times is called dichogamy. Dichogamy is of two kinds namely,

(a) Protandry

(b) Protogyny

The maturation of androecium earlier than gynoecium is called protandry. Eg: *Gossypium sp*

The maturation of gynoecium earlier than androecium is called protogyny. Eg: *Solanum sp*

(c) **Herkogamy**:

In some bisexual flowers the structure of the male and female sex organs itself proves a barrier to self pollination. Eg: *Hibiscus, Gloriosa*,

(d) **Heterostyly**:

The presence of style in different lengths in flowers is known as heterostyly. Eg: *Oldenlandia, Oxalis*,

(e) **Self sterility**:

In some bisexual flowers the pollengrains are not able to germinate on the stigma of the same flower. Eg: *Passiflora*,

(f) **Pollen prepotency**:

In some plants when the stigma receives pollen from the same flower as well as from another flower, the foreign pollen germinates vigorously. Eg: *Dolichos,*

(g) **Sensitive stigmas**:

In some plants the stigmatic lobes are very sensitive.

Eg: *Mimulus*,

**5:3 A Brief Account on Fertilization**:

The fusion of male and female gametes is called fertilization. It is an important step in sexual reproduction. In angiosperms fertilization was first observed by strasburger (1884). The female gametophyte is deep seated in the ovary. The pollen grains are held at the stigma. They germinate on the stigma and produce pollen tubes. The pollen tubes grow through the style and reach the ovule. They enter the embryo sac and release the male gametes. The process of fertilization includes the following steps.

1. Germination of pollen grains.
2. Entry of the pollen tube into the ovule.
3. Entry of pollentube in to the embryo sac.

1. **Germination of pollen grains**:

The receptive surface of the stigma secretes sugary fluid in which pollen grains germinate. During germination the pollen grain produces a pollen tube through the germ pore in the pollen wall. The apical region of the pollen tube grows quickly. The tube nucleus is present nearer to the tip. Generative cell is present behind the tube nucleus. It divides mitotically and produce two male cells. The pollen tube penetrates the stigmatic and stylar tissues.

2. **Entry of the pollen tube into the ovule**:

The pollen tube reaches the micropyle of the ovule. The approach of the pollen tube to the micropyle was first observed by G.B.Amici (1924).

Entry of pollen tube in to the micropyle to achieve fertilization is called Porogamy. It takes place in about 80% of Angiosperms.

In some Angiosperms like *Betula*, *casuarina*, the pollen tube enters the ovule through the chalaza to achieve fertilization is called chalazogamy.

In some Angiosperms, the pollen tube enters through funicle or integuments. This pathway of entry is called mesogamy.

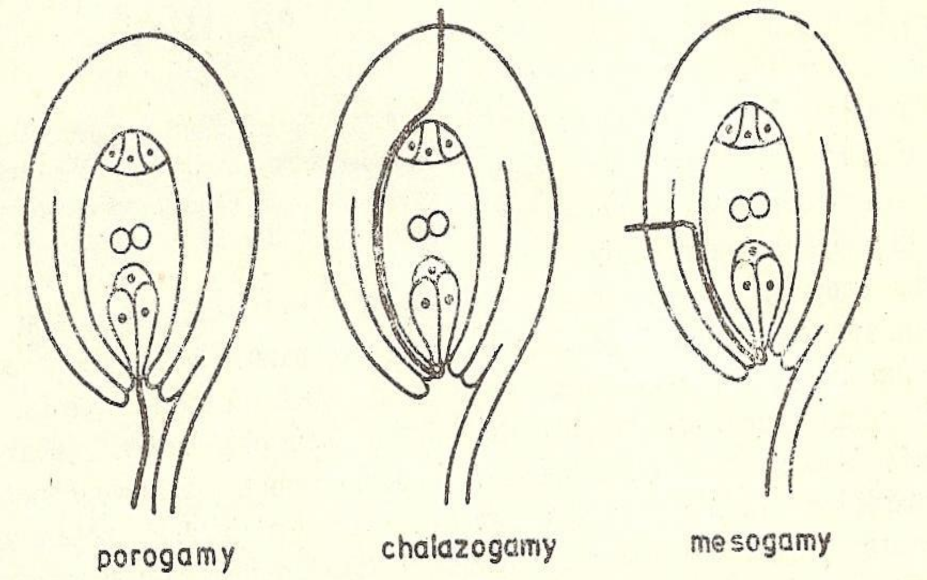
Eg: *Cucurbita*

3. **Entry of pollentube in to the embryo sac**:

The pollen tube enters the embryo sac through a pore formed on its membrane. This entry may take 15 minutes to 2 - 3 months. The content of pollen tube are discharged into the degenrating synergid through the apical pore. finally the vegetative nucleus degenerates (Figure - 39, 40).

**Figure - 39**

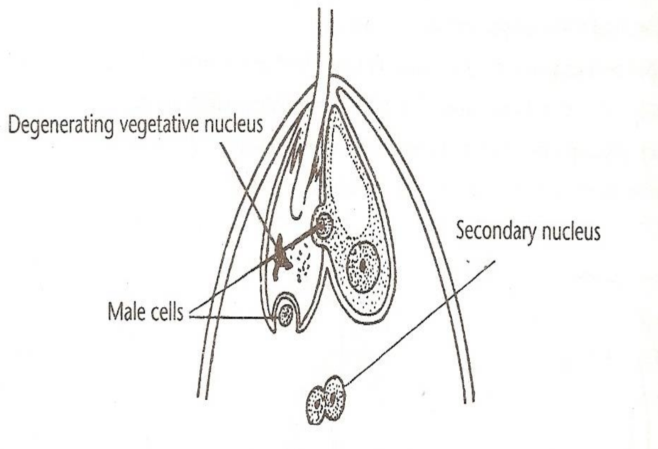
**MODES OF POLLEN TUBE ENTRY INTO THE OVULE**




Modes of pollen tube entry into the ovule.

**Figure - 40**

**FUSION OF MALE GAMETES WITH EGG AND SECONDARY NUCLEUS**




FUSION OF MALE GAMETES WITH EGG AND SECONDARY NUCLEUS

**5:4 Gametic Fusion**:

The male gamete fuses with the egg and forms zygote (2n). This fusion is called syngamy. The process of syngamy was first reported by strassburger (1884). Second male gamete fuses with the diploid secondary nucleus and forms triploid primary endosperm nucleus (PEN). This fusion is called triple fusion. The triple fusion was first reported by S.G. Nawaschin (1898).

In angiosperms the two male gametes released from pollen tube, one male gamete fuses with the egg. Second male gamete fuses with the polar nuclei. Because of occurrence of two fertilizations, this phenomenon is called the double fertilization. The double fertilization is specific to angiosperms. The primary endosperm nucleus (PEN) divides and forms endosperm.

**5:5 Post fertilization Modification**:

1. The floral parts like sepals, petals, stamens, styles and stigmas fall off.
2. Ovules develop in to seeds.
3. Ovary develops in to fruit
4. The integuments develops into seed coat.
5. The zygote develops into an embryo
6. Finally the synergids and antipodal cells degenerates.

**SELF ASSESSMENT QUESTIONS - I**

**ANSWER THE FOLLOWING QUESTIONS**

1. Cross Pollination is also known as ___________
2. Herkogamy is found in ____________
3. Syngamy - Define

## 5:6 ENDOSPERM - Introduction

In most of angiosperms endosperm is triploid, formed after fertilization. In gymnosperms endosperm is haploid and formed from female gametophyte before fertilization. Endosperm is the most important nutritive tissue for the developing embryos.

The primary endosperm nucleus divides mitotically and forms many nucleus in the embryo sac. After some time it forms a tissue called endosperm. It stores starch and protein molecules.

In monocots, some of the families shows aleurone layer around the endosperm in grains. It is made up of proteins in the form of aleurone grains. Eg: *Poaceae (Oryza, Triticum)*

In Dicots, some of the families the developing embryo utilizes the endosperm. The seed contain only embryo. Endosperm is absent. The seeds are non-endospermic in nature. Eg: Fabaceae - *(Cicer, Dolichos)*

In some plants the nucellus is not utilized completely. The nucellus that remains in a seed is called the perisperm. It is non endospermic in nature. Eg: *Piper nigrum*,

## 5:7 TYPES OF ENDOSPERM:

According to Davis (1966) the endosperm can be classified in to three main categories they are

(a) Nuclear endosperm

(b) Cellular endosperm

(c) Helobial endosperm

### (a) **Nuclear Endosperm**:

The nuclear endosperm, the first division and a few other nuclear divisions are not accompanied by wall formation. The nuclei are being pushed towards the periphery, thus a large central vacuole is formed. The number of nuclear divisions may vary in different plants.

Eg: *Malva*, *Primula*,

The wall formation is not found in some plants. Eg: *Melastoma*. The wall development is generally from periphery of the embryo sac towards the centre. The micropylar and chalazal endosperm haustoria are found in scleria foliosa (Nijalingappa et.al., 1979). In cocos *nucifera*, the primary endosperm nucleus under goes a number of free nuclear divisions, finally it becomes the coconut (cellular).

In some plants, the chalazal part remains in free nuclear condition and elongates to form a haustorial structure. The walls are incompletely dilimited, finally the peripheral cell layer takes place.

Eg: *Macadamia ternifolia*

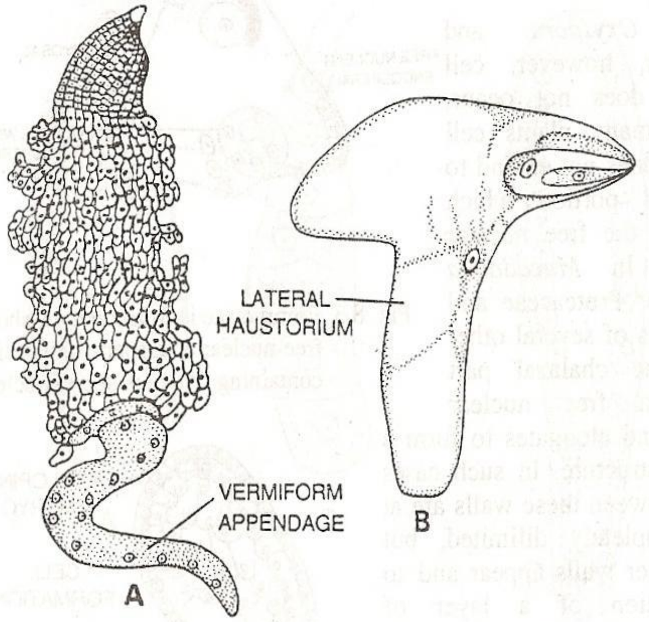
The plants like Grevillea, the lower coenocytic part of the endosperm develops in a coiled vermiform appendages (haustoria).

The primary endosperm nucleus, enters the base of the diverticulum and divides to form two daughter nuclei, one gives rise to the bulk of the endosperm and other moves into diverticulum.

Eg: *Agrostemma* (Figure - 41, 42),

**Figure - 41**

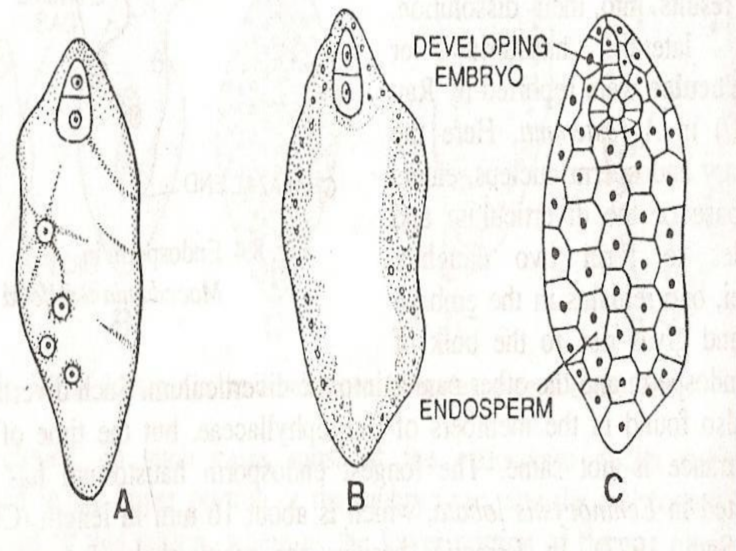
**ENDOSPERM**




Endosperm. A, vermiform appendage developed from basal part of endosperm in *Grevillea*; B, formation of lateral haustorium in *Agrostemma*.

**Figure - 42**

**NUCLEAR ENDOSPERM**




Embryo sac showing formation of nuclear type endosperm. Developing embryo is also seen.

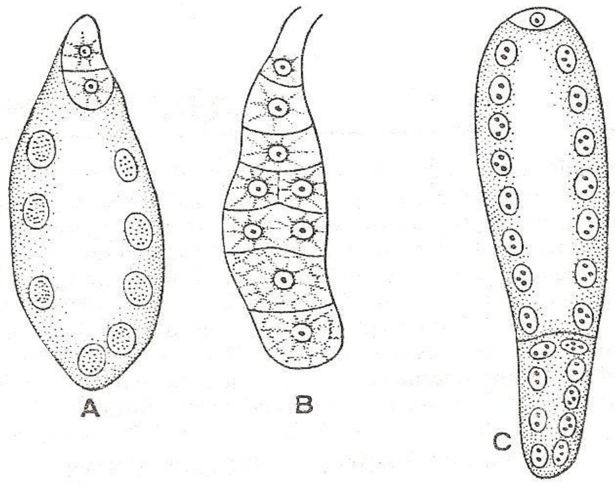
2. **Cellular Type**:

The cellular endosperm, most of the divisions are accompanied by wall formation. The free nuclear stage is absent in cellular type. In some plants like Nemophila, the endosperm mother cell divides and forms haustoria (Chalazal, Micropylar). The upper cell divides transversely and gives rise to a central cell (micropylar).

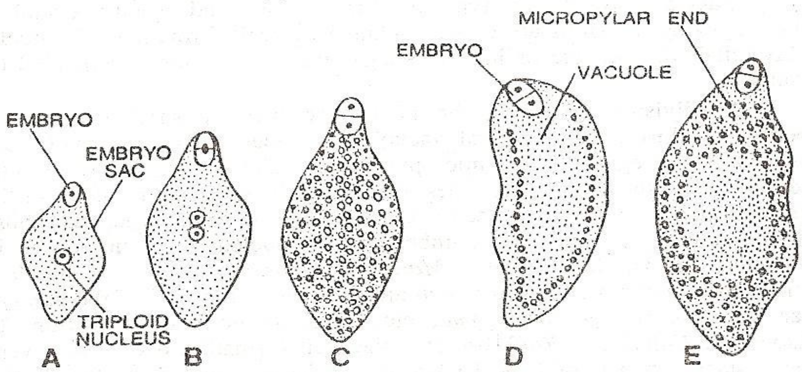
(Figure - 43).

**Figure - 43**

**DEVELOPMENT OF ENDOSPERM**




Development of endosperm. A, nuclear type; B, cellular type and C, helobial type.




A-E, stages in the development of nuclear type of endosperm.

In the members of the family Araceae and Nymphaeaceae, the prom inent endosperm haustoria are developed. The primary chalazal cell formed after the first division. In certain plants belongs to the family acanthaceae, both micropylar and chalazal haustoria are formed.

The aggressive type of chalazal haustorium is formed in Iodina *rhombifolia*. The haustorium is actually formed before fertilization. The division of the primary endosperm nucleus followed by the formation of two chamber (micropylar, chalazal).

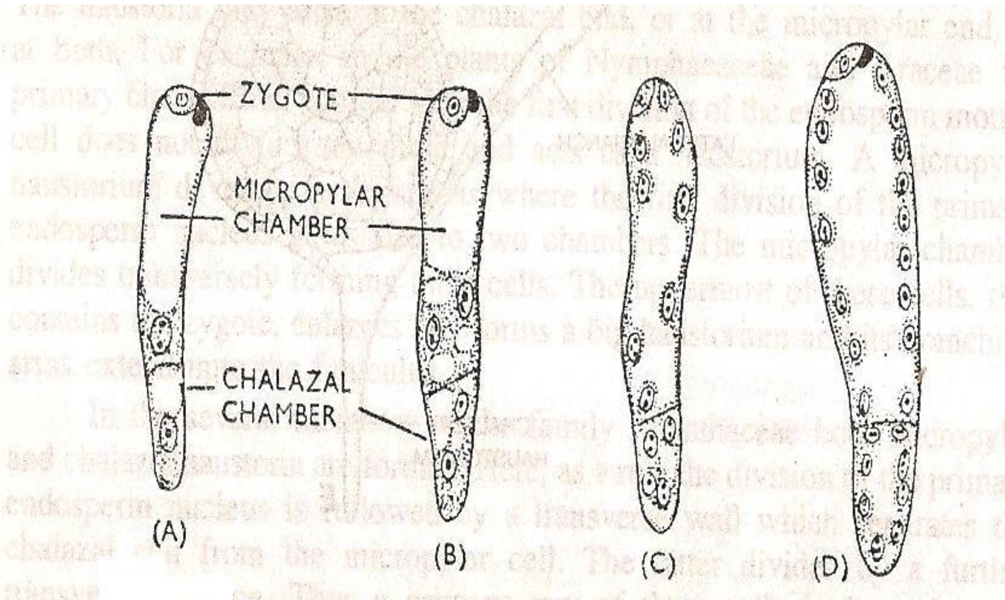
The division of endosperm mother cell is vertical and forms four cylindrical cell, followed by then formation of eight cells arranged in two tiers. Eg: Adoxa,

3. **Helobial Type**:

The Helobial endosperm, is mostly found in the members of Helobiales. The primary endosperm nucleus moves to the chalazal end of the embryo sac. The first division results in the formation of micropylar and chalazal chamber. In some plants like *Eremurus*, the free nuclear divisions occur in both micropylar and chalazal chamber. Finally it forms 32 nuclei in chalazal region and more nuclei in micropylar region (Figure - 44).

**Figure - 44**

**HELOBIAL ENDOSPERM**



Development of helobial type of endosperm in *Eremurus.*

**Ruminate Endosperm**:

The mature endosperm with any degree of irregularity and uneveness in its contour is called ruminate endosperm. The endosperm is irregularly ridged and furrowed and is termed as ruminate endosperm. It occurs in the families like, Annonaceae, Rubiaceae, Myristicaceae and palmae.

The rumination of the endosperm develops as a result of invaginations of the outer tissues and finally it appears as dark wavy bands. The endosperm exhibits unequal peripheral activity and leads to irregular configuration. Eg: *Andrographis*

**5:8 Cytological Nature of Endosperm**:

1. The most of the plants, endosperm is triploid.
2. The degree of polyploidization is very high during development.
3. The endomitosis occur in some endosperm cells.
4. The chromosomal abnormalities like, mitotic irregularities, bridges, breakage is quite common in the endosperm.
5. Endosperm is non-chlorophyllous in nature.

**5:9 Functions of Endosperm**:

1. The endosperm is rich in reserve food materials like, carbohyarates, proteins, fats etc.
2. The endosperm supply nutrients to the developing embryo.
3. The endosperm regulates the mode of embryo development.
4. The germination of embryo depends on the normal stage of endosperm.
5. It induces embryoids and plantlets from various plant tissues.

**5:10 DEVELOPMENT OF EMBRYO IN DICOT**:

(Embryogenesis) (Capsella - bursa - paustoris)

1. **Introduction**:

The fertilized egg is called zygote, which develops into an embryo. The zygote divides immediately after the first division of the primary endosperm nucleus (PEN). There is no basic differences in the early stages of the development of the embryos of Dicots and monocots. But in later stages there is a marked difference between the embryo.

2. **Development**:

Basically, five main types of embryos present in dicotyledons. They are,

(a) Crucifer type

(b) Asterad type

(c) Solanad type

(d) Caryophyllad type

(e) Chenopodiad type

Basal cell plays no role or little, in the development of the embryo. This type is known as crucifer type. Both basal and terminal cells play a role in the development of the embryo is called Asterad type.

The suspensor is formed from basal cell in the case of Solanad type. In caryophyllad type, the basal cell does not divide further. Both basal and terminal cells take part in the development.

Eg: *Chenopodiad type*.

The detailed study of crucifer type of the development of embryo has been discussed.

**Crucifer Type**: (Capsella bursa - pastoris)

In crucifer type, the zygote divides transversely forming two cells, namely,

(a) Basal Cell (Suspensor cell)

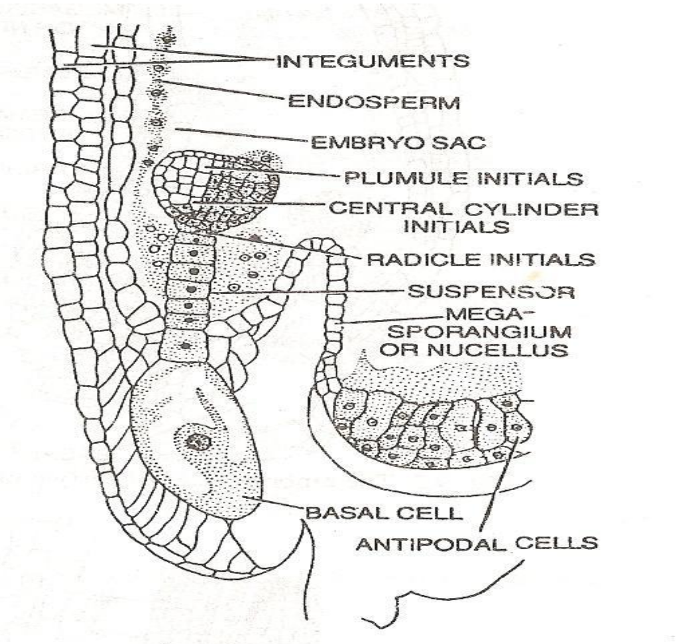
(b) Terminal Cell (Embryo cell)

The cell towards the micropylar end of the embryo sac is the basal cell and the other one makes to terminal cell. The terminal cell divides and forming 4 celled embryo. The 4 celled embryo (Proembryo) divide vertically and forms 8 celled embryo (Octant).

The 8 celled (Octant) embryo, divided into two regions, hypobasal and epibasal. The epibasal gives rise to plumule and cotyledons, whereas the hypobasal gives rise to hypocotyl. The outer cells divides by anticlinal, forming dermatogens. The inner cells divides by longitudinal and transverse divisions forming periblem and plerome. The cells of periblem gives rise to cortex, where as the plerome form the stele. Finally the mature embryo consists of short axis and two cotyledons (Figure - 45, 46).

**Figure - 45**

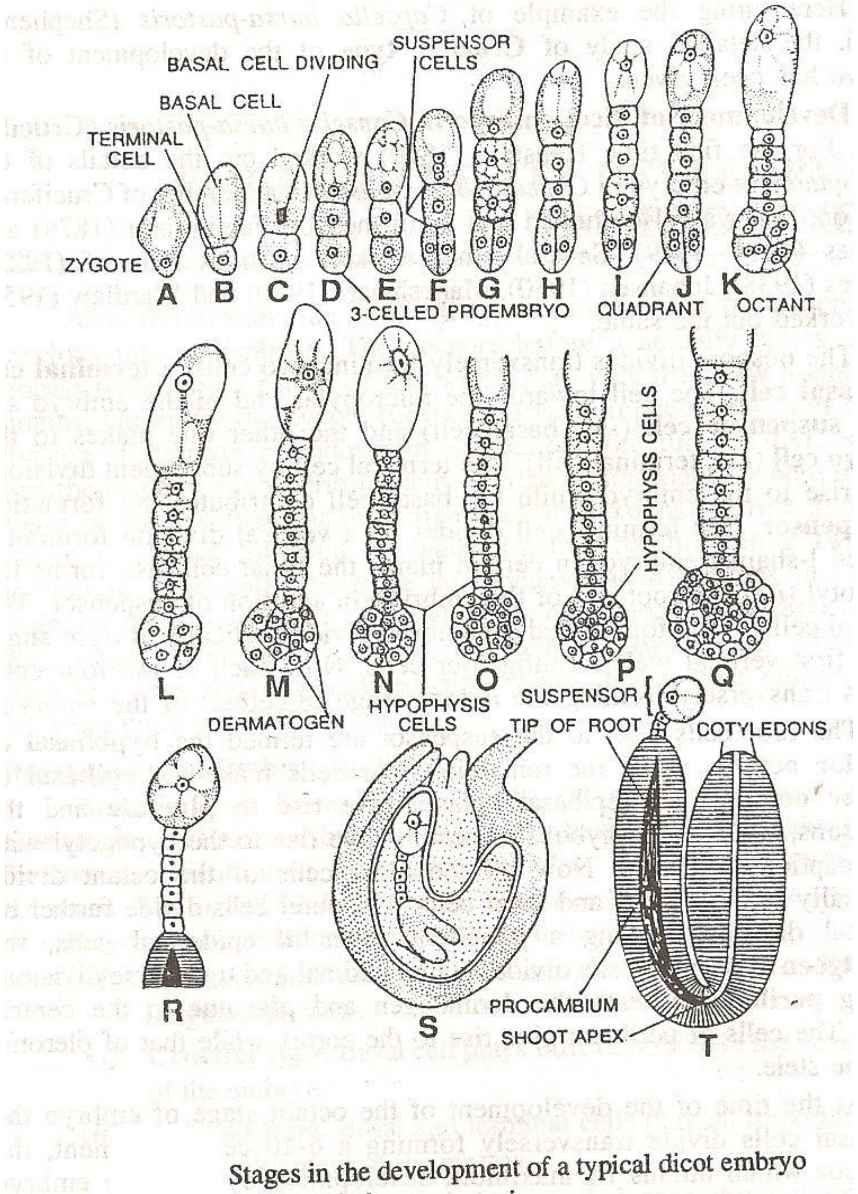
**DICOT EMBRYO**




The embryo. L.S. showing differentiation of embryo in *Capsella*.

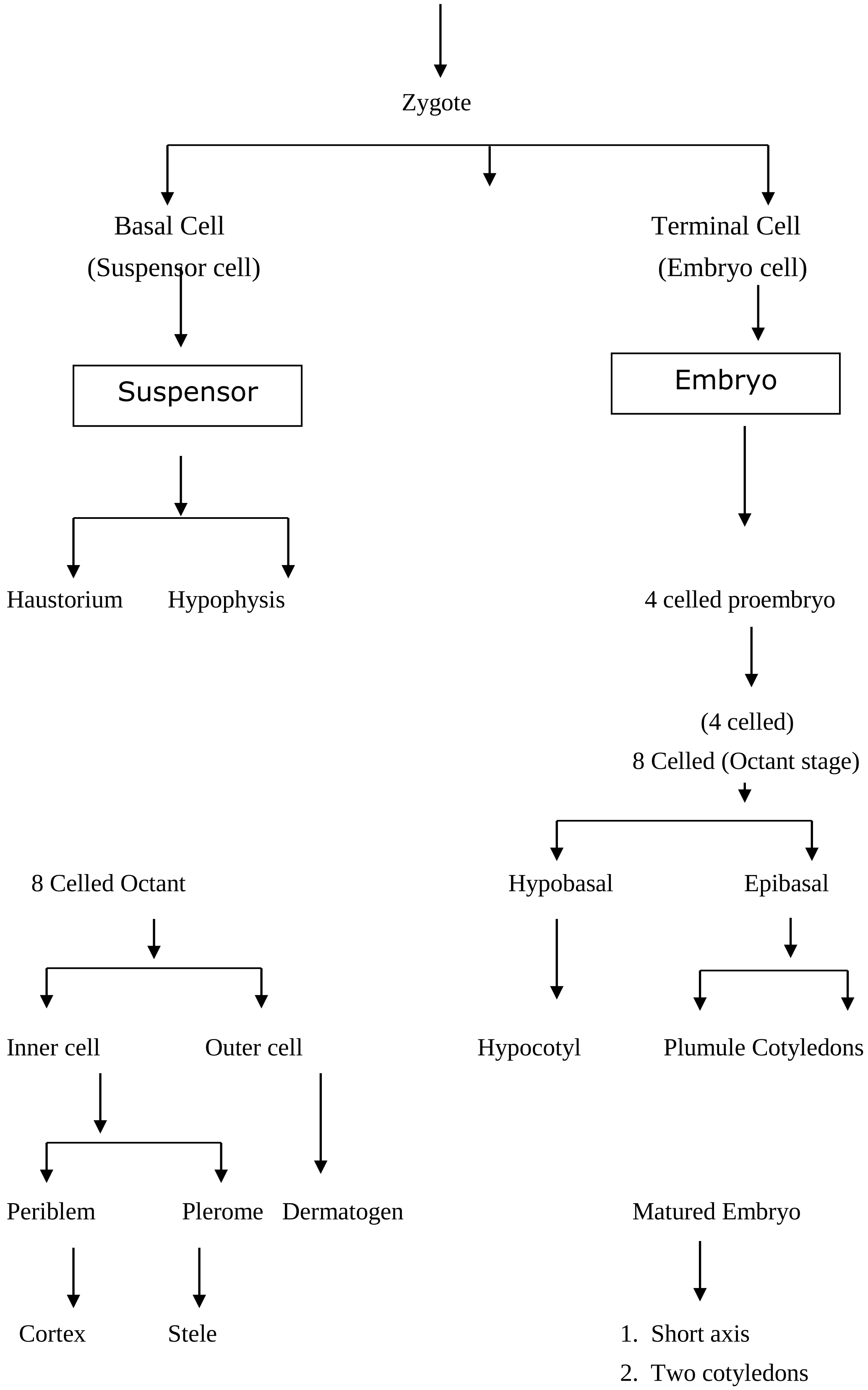
**Figure - 46**

**DEVELOPMENT OF DICOT EMBRYO**




Stages in the development of a typical dicot embryo in *Capsella bursa-pastoris*.

## DEVELOPMENT OF EMBRYO (Dicots)



## 5:11 DEVELOPMENT OF EMBRYO IN MONOCOT:

(Embryogenesis) (Najas)

The main the difference between the mature embryo of monocotyledons and dicotyledons is in the number of cotyledons. The detailed study of the development of embryo in Najas (Monocot) has been discussed.

**DEVELOPMENT OF EMBRYO**

↓

Zygote

↓

Basal Cell → Haustorium

Apical Cell → (2 celled) → Proembryo (4 celled) → 8 celled (Octant)

8 celled (Octant) → 4 axial cells; 4 Circumaxial cells

The zygote divides transversely and forms two type of cells, namely,

(a) Large basal cell

(b) Small apical cell

The basal cell, without any division, enlarges to form a single celled haustorium. The small apical cell divides transversely into 4 celled proembryo. By two vertical divisions, the 8 cells (Octant) are formed. The 8 celled octant normally consists of 4 axial cells and 4 circumaxial cells. The rapidly growin protion, forms the single cotyledon.

## 5:12 POLYEMBRYONY:

The occurrence of more than one embryo in the seed is known as polyembryony. The occurrence of polyembryony was initially reported in certain orange seeds by Antoni Van Leeuwenhoek in 1719. Later on in the year 1859, **Braun** reported the polyembryony in more than 58 cases. Polyembryony is quite common in gymnosperms, but in most of the plants belongs to angiosperms exhibit this mechanism.

Based on the origin, polyembryony may be divided in to four categories, they are,

1. Cleavage poly embryony.
2. Embryos from cells of the embryo sac other than the egg.
3. More than one embryo sac in the same ovule.
4. Activation of some sporophytic cells of the ovule.

1. **Cleavage poly embryony**:

The cleavage polyembryony is mainly due to the cleavage of proembryo. It leads to the establishment of embryonic primordia. Among angiosperms cleavage polyembryony is quite common in orchids (*Vanda*). The apical promeristem of the embryo in *Vanda* divides in to 3-9 primordia and finally converted in to an embryo.

2. **Embryos from cells of the embryo sac other than the egg**:

In this type the embryos may be produced from other parts of the embryo sac, such as synergids. The synergids, which behave like eggs, maybe fertilized by sperms or develop without fertilization. Embryos arising from unfertilized the embryos are produced fro antipodal cells. Eg: *Ulmus Glabra*

3. **More than one embryo sac in the same ovule**:

In this type, the multiple embryo sacs in an ovule may be developed from,

(a) The derivatives of megaspore mother cell.

(b) From two or more megaspore mother cell.

(c) From nucellar cells.

The nucellar cells in chalazal region may produce the additional embryo sac. Eg: *Trifolium*, some times the multiple embryo may also occur by the fusion of more ovules. Eg: *Phizophora*

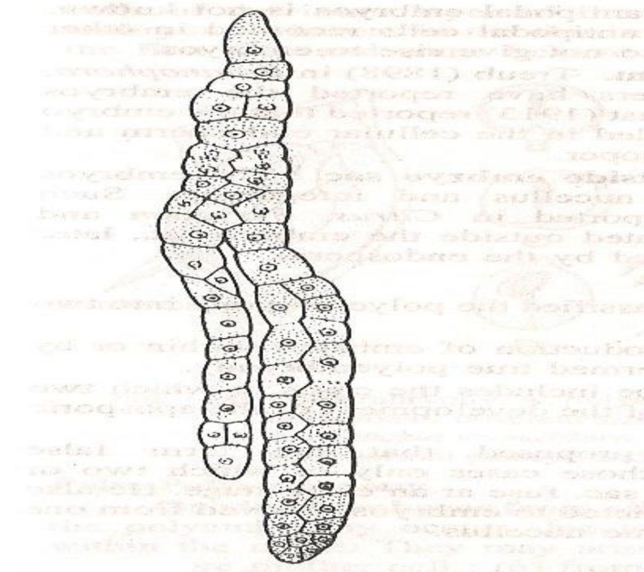
4. **Activation of some sporophytic cells of the ovule**:

In this type, the embryos arising from the maternal sporophytic tisue (nucellus, integuments). Nucellar embryony occurs in crassinucellate ovules, eg: *Opunita*. The embryos are generally identical to each other. The epidermal and sub epidermal cells participate in the formation of embryos. Eg: *Euonymus*,

(Figure - 47, 48).

**Figure - 47**

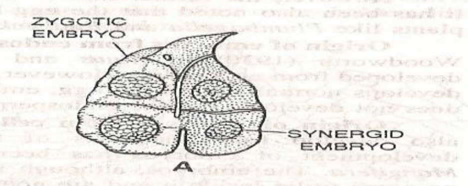
**POLYEMBRYONY**



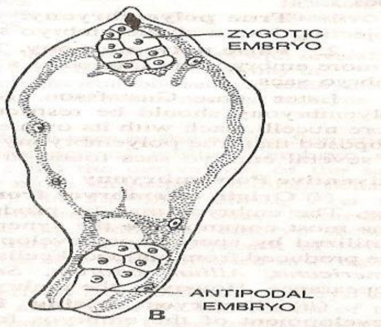
Polyembryony. This diagram illustrates the formation of additional embryos arising from the cells of suspenser.

**Figure - 48**

**POLYEMBRYONY**




Polyembryony. Formation of synergid embryo in *Lilium*.




Polyembryony. Formation of embryo from antipodal cell.

**Causes of Polyembryony**:

Many theories have been proposed to explain the occurrence of poly embryony. Some of the important theories are as follows,

(i) Necrohormone theory

(ii) Hybridization theory

The necrohormone theory has been proposed by Haberlandt in 1922. It indicates that the degenerating cells of the nucellus is responsible for the formation of adventive embryos. Eg: *Oenothera*,

According to Leroy (1947), the polyembryony is caused by one or more recessive genes. Eg: *Mangifera*,

The occurrence of multiple embryo is mainly due to hybridization.

**Significance of Polyembryony**:

1. The polyembryony is plays on significant role in plant breeding and horticulture.
2. The nucellar embryo are free from disease.
3. Nucellar, adventive polyembryony is of great value in horticulture.

4. It plays an important role in mutant selection.

5. The haploids, plays an significant role in the development of homozygous diploids.

**SELF ASSESSMENT QUESTIONS - II**

| **ANSWER THE FOLLOWING QUESTIONS** |
| --- |
| 1. Endosperm is ____________ |
| 2. Periblem gives rise to ________ |
| 3. Define poly embryony |

**ANSWERS OF SELF ASSESSMENT QUESTIONS**

I. 1. Allogamy

2. Hibiscus flower

3. Fusion of male gamete with egg

II. 1. Triploid

2. Cortex

3. The occurrence of more than one embryo in the seed.

**UNIT QUESTIONS**:

1. Brief about Pollination.
2. Write a note on cross Pollination.
3. Discuss about Gametic fusion.
4. List out the types of endosperm.
5. Explain the development of dicot embryo.

**RECOMMENDATIONS FOR FURTHER READINGS**:


1. Bhojwani, S.S. and Bhatnagar S.P. The Embryology of Angiosperms, Vikas Publishing House Pvt Ltd., New Delhi.
2. Dwivedi J.N. 1988. Embryology of Angiosperms. Rastogi and Co., Meerut.
3. Maheswari, P. 1971. An Introduction to the Embryology of Angiosperms. Tata McGraw Hill Publishing Co., Ltd., New Delhi.
4. Swamy B.G.L., and Krishnamurthy, K.V. From flower to fruit. Tata McGraw. Hill Publishing Company Limited, New Delhi.

## NOTES

## NOTES