Bachelor of Science
(B.Sc.-CBZ)

PLANT ANATOMY AND EMBRYOLOGY
(DBSZCO302T24)

Self-Learning Material
(SEM-III)

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Course Code: DBSZCO302T24
Plant Anatomy and Embryology

Table of Content

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COURSE INTRODUCTION

The Objective of this paper is to provide basic knowledge of plant internal architecture and cellular composition and reproduction. The course has 3 credits and 13 units. This will help them to understand how different plant tissue structures evolve and modify their functions with respect to their environment. Knowledge regarding anatomy equipped the students to identify different types of tissues and make them able to correlate their physiology in a better away. This will also help them to understand how different plant tissue evolve and modify their structure and functions with respect to their environment. Knowledge regarding embryology make them understand how reproduction play significant role in defining population structure, natural diversity and sustainability of ecosystem in a better way.

Course Outcomes: After the completion of the course, the students will be able to:

1. Describe the types of Tissue
2. Describe the Anatomical features of the root, shoot and leaves of the plant species
3. Explain the structural features of the anther and pollen grain.
4. Apply the scientific method for the staining and characterising the plant tissue
5. Apply knowledge of floral, fruit and vegetative features of the monocots and dicots.
6. Explain the significance of apomixis and polyembryony

Acknowledgements:

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UNIT-1

TYPES OF TISSUE: MERISTEMS AND PERMANENT TISSUE

Objectives

After reading this unit, students will be able to:

- Understand tissue and various types of tissue
- Diffrentiation of meristematic tissue
- Understand the various types of permanent tissue and its location

1.1 Introduction

The study of a plant's internal structure is often referred to as plant anatomy, or phytotomy. Plant anatomy is the study of the organized plant body's structure by dissection (anatomy-dissection). Plant anatomy generally refers to the study of internal morphology as it relates to various tissues. This unit discusses the internal anatomy of angiosperms, focusing mostly on the major tissues. Plant morphology, which describes the outward structure and physical shape of plants, was first included in it. However, since the middle of the 20th century, plant anatomy study considered as a separate and independent topic, and it now only relates to the internal structure of plants.

The cells of higher plants vary in kind, form, and origin, and the plant body is more complicated. The spermatophyte and vascular cryptogams exhibit a variety of cell types which group together to form various types of tissue systems, according to an analysis of their internal structure. Angiosperm plant bodies are differentiated as roots, stems, leaves, and flowers. These sections are all composed of various tissues with various cell types. A mass of like or distinct cells performing the same function is referred to as a tissue.

Primary plant bodies are those that were initially developed, and primary tissues are those which developed from them. The plant body of lower plants and monocotyledons is primary throughout the life span while secondary thickening or growth occurs in the stem and roots of most dicots and some monocots within the Gymnosperm genus, these tissues are referred to as secondary tissues. The fundamental structure remains mostly unchanged by the secondary growth. The relative distribution of the vascular and ground tissue systems distinguishes the three main plant structures: the root, stem, and leaves.

1.2 Types of Tissues

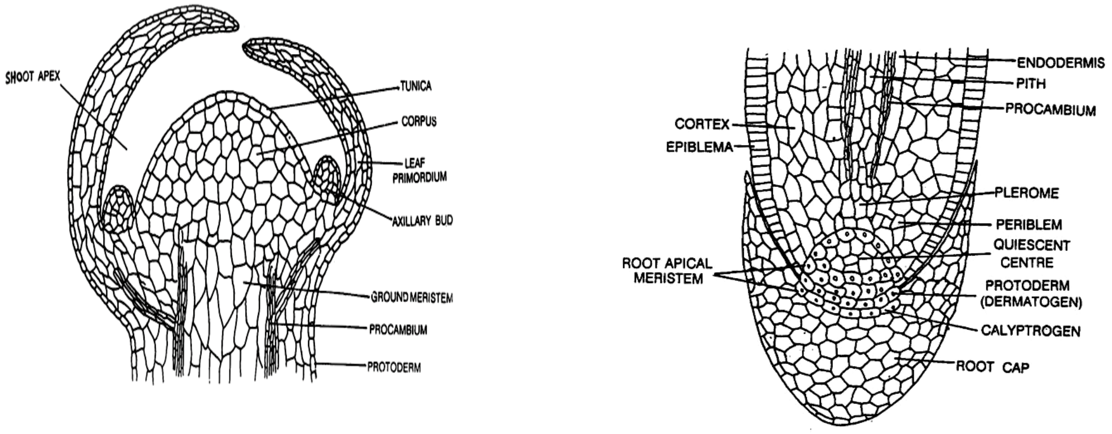
What are the tissues, we discuss the many types of tissue? Under general definition, a tissue is "a group of similar or dissimilar cells that perform a common function and have a common origin." Different tissue systems are found in the body of plants to support their various activities. The vascular tissue system helps in the conduction of food and water, the ground tissue system performs photosynthesis, and the epidermal tissue system protects internal cells and aids in gaseous exchange. Meristematic, permanent, and secretary tissues are the three categories into which the different tissue types are divided.

1.3 Meristematic Tissue

All embryonic cells have the ability to divide and multiply at first, but as the embryo grows into a plant body, this ability is limited to specific plant body parts known as meristems, which are active for the entirety of the plant body's life. A portion of the daughter cells produced by the division of meristematic cells stay meristematic, while the other daughter cells, known as derivatives, develop into distinct tissue components. Before beginning any kind of cell division, cells typically expand and accumulate more protoplasm and cell wall components. A group of cells that maintain their ability to divide or are in a continuous state of division is referred to as a meristmatic tissue.

Some characteristics of meristmatic cells include:

- Meristematic cells shape rounded, oval or isodiametric.
- Compactly organized, having thick cytoplasm and no intercellular space.
- Big nucleus with small vacuoles or without vacuoles
- Thin cell wall that does not collect reserve food material
- Divide in plane and always in active phase



A B

Figure 1.1 Meristematic tissues (A) Shoot Apical Meristem (B) Root Apical Meristem

The growing zones include meristems, which continuously divide to generate new cells that eventually mature to form the anatomical parts. This process, known as differentiation, transforms freshly formed cells into permanent, mature cells. Apical meristems, also known as primary meristems, are those that arise at the tips of stems, roots, and other branches. They are responsible for the initial growth of plants. It is divided into main and secondary meristems based on its place of origin.

The primary meristem, that forms the main body of the plant, develops during the early stages of development. The secondary tissue system of the plant body is formed by the later development of the secondary meristem.

1.3.1 Types of Meristem- Workers classify meristems according to many factors, including as their origin, location inside the plant body, plane of division, and function.

Meristems are classified as follows based on their origin:

- **Pro-meristem**- A mass of cells that represent the meristematic cells' first stage. They are found in a small area at the tips of roots and shoots. The primary meristem is produced by them.
- **Primary meristem**- Permanent tissue is produced by the meristematic cells that arise from the promeristem and are continuously dividing. The majority of monocotyledons and herbaceous dicotyledons primary meristem is found.
- **Secondary Meristem**: These are meristems that originated from the primary permanent tissue. They arise later in the organ's development and give rise to secondary permanent

tissue, although they are not there from the start. These cells cause the plant to undergo secondary growth, resulting in an increase in diameter.

Plant meristems are classified into the following types based on their position in the body:

- **Apical Meristem**-It is located at the tips of stems, roots, and frequently even leaves. It is because of this that plants grow. These cells never change location or ability to divide. Apical cells are found in groups in higher vascular plants, while they are found singly in vascular cryptogams.
- **Intercalary Meristem**- This primary meristem is also present in the bases of internodes and leaf sheaths of grasses, where it is inserted in between permanent tissues. When their parts separate due to the organ's growth, they arise from the apical meristem. The intercalary meristem, as in bamboos, is responsible for the elongation of internodes wherever the stem is jointed. It is possible to classify even prolonged leaf, blossom, and fruit growth as an intercalary growth.
- **Lateral Meristem**- Located in the plant's lateral zones, they cause a rise in the organ's diameter, which indicates that they are responsible for the of the thickness growth. Because the vascular and cork cambiums develop more tissues and thicken the plant body, they are known as secondary meristems. Secondary growth is the process that occurs in gymnosperms and dicotyledons.

The meristem is classified into the following types based on the plane of division in the plant body:

- **Mass Meristem-** This results in cell division in all planes, forming structures with irregular shapes, such as endosperms.
- **Plate Meristem**- It is made up of parallel cell layers that split into two planes anticlinally to resemble a plate. The development of leaf lamina exhibits this pattern.
- **Rib or File Meristem**: Cells divide in one plane either anticlinally or at right angles during this type of development. It appears throughout the lateral root's development.

  On the basis of function meristem ae categorized. These are categorized as -

Protoderm- The outermost layer form the epidermis,

Procambium- Develops into primary vascular tissue and

Ground meristem –Develops into ground tissue like cortex, pericycle and pith.

1.3.2 Shoot Apical Meristem -Apical meristem, or growing region, is made up of a small mass of essentially similar, rounded or polygonal cells that are in the process of dividing; these meristematic cells make up the promeristem. Promeristem cells quickly develop into three regions: plerome, periblem, and dermatogens.These three areas' cells proliferate and give rise to primary permanent tissues of mature stem. The section furthermore shows many outgrowths on both sides that arch over the developing apex of the stem; these are the immature leaves of the bud, which cover and protect the growing apex. The apical meristem theories developed by Nageli (1858), Hanstein (1870), and Schmidt (1924) are referred to as:

(a) Apical cell theory
(b) Histogen theory
(c) Tunica corpus theory

According to Apical Meristem Theory apical meristem is structural and function unit of all the tissues of root and shoot

(a) Apical cell theory-The hypothesis was postulated by Nageli in the years 1844–1859. The formation of different plant body parts may be attributed to the sequence of cell divisions in the apical meristem, which in plants consists of a single apical cell, according to the person who initially coined the name "meristem." The root and shoot apices of cryptogams, according to Nageli, have a single apical cell. This apical initially lens or wedge shaped. Prismatic or tetrahedral or tetrahedral.

The tetrahedral cells have three sides that face the inner and peripheral sides, and one side that faces the apex. According to Apical Meristem Theory apical meristem is structural and function unit of all the tissues of root and shoot .Nageli postulated that all the tissues of the root and shoot originate from this single apical cell. It is evident that Nageli's single cell hypothesis applies to thallophytes and vascular cryptogams, but it has been shown to be incorrect for all other cryptogams and phanerogams.

Even though Hofmiester supported this one hypothesis, he expressed concerns about its applicability, especially with relation to phanerogams. After extensive study it is observe that single apical cell theory is not universally supported and it was soon replaced by other theories.

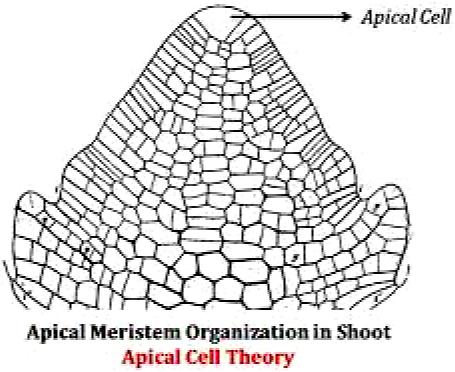


Figure 1.2

(b) Histogen theory- ‘Hanstein’ proposed this theory. This means that neither a single apical cell nor a group of meristematic cells that are responsible for growth of the entire plant body make up the shoot apex. The theory proposes that the three different zones of meristematic cells known as Histogens form the apical meristem. These are: Dermatogen: The outermost layer from which the epidermis originates. Periblem: It's found below the dermatogen. The cortex and endodermis are derived from it.

Plerome: Pith and vascular tissues originate from the inner core.

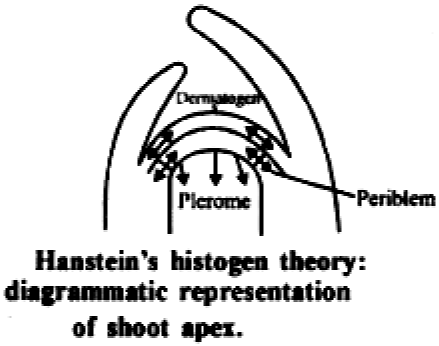


Figure: 1.3

(c) **Tunica-Corpus theory-** Schmidt proposed the tunica-corpus theory in 1924. This theory applicable to the apical meristem of the shoot and not the root, in contrast to the apical cell theory and the Histogen theory. The tunica and the corpus at the shoot apex were identified as two zones or regions.

Tunica: It is the shoot's apical meristem's surface layer. It is made up of one or more cell layers on the periphery. In longitudinal section, the cells of tunica are regularly oblong and compactly arranged. This layer's cell division is primarily anticlinal, which means that walls are arranged perpendicular to the surface, specially at the point of origin of leaf and axillary bud. the shoot apex develops in surface area since these layers only have surface development.

In tunica, two zones may be identified:

(a) The peripheral zone and (b) the central zone.

The central zone is surrounded by the peripheral zone, whereas the central zone is made up of one or more initials. Compared to the cells in the peripheral zone, the central zone cells are bigger in terms of both size and number of nuclei and vacuoles. The control apical zone leaf primordia and the periphery zone are separated by them. Although anticlinal divisions are the primary mechanism of tunica division, periclinal divisions can also occasionally be found in the periphery zone. In certain monocotyledons, periclinal division also takes place in the tunica. Typically, the tunica's outermost layer divides into the epidermis. distinct plants have distinct zones that can originate from tunica, such as cortex and stele.

Corpus: This meristematic zone lies below the tunica. Compared to tunica cells, the cells are bigger. The corpus cells divide in all directions to produce the central core of the shoot apex. Typically, the corpus develops as a single layer of the initial cell, which is situated below the tunica. By periclinal division, this first layer splits into many layers, and subsequently it divides in all planes to increase the size of the shoot apex. Cortex and stele often arise from the corpus.

The difference between the corpus and tunica is the plane and position of cell division; the tunica is more uniform. According to a recent study using an electron microscope, these two layers' ultrastructural differences are mostly quantitative.

Only the angiosperm shoot apex is covered by the tunica-corpus concept. With the exception of Gnetum, which exhibits a tunica-corpus pattern of development in the shoot apices, cryptogames and gymnosperms lack the ability to differentiate between the two zones of tunica and corpus. Variations exist across families, genera, and species, as well as at different developmental phases, with respect to the number of layers, plane of cell division, and fate of the tunica and corpus. It was useful to characterize the shoot apex of angiosperms using this purely descriptive theory.

Figure: 1.4

1.3.3 ROOT APICAL MERISTEM (RAM)- A median longitudinal section taken through the root's apex shows that the multilayered tissue which forms the root cap protects and covers the root. Behind the root cap is the apical meristem, often known as the growth area. Similar to the stem, the promeristem divides into three parts at an early stage.

(1) Dermatogen (2) Periblem (3) Plerome

The root apical meristem is arranged in opposite to the shoot apex during the embryonic stage. Unlike shoots, it has a simpler general structure but a more complex apex because of the root cap, which grows from the root's apical meristem, protecting the meristematic zone. One cell or many cells might make up the root apex. Root apex can be explained by the Histogen Theory of Hanstein (1868) and the Apical Cell Theory of Nageli (1978), but not by Tunica Corpus Theory.

Dermatogen- This is a single-layered structure, similar to the stem, but it merges into the periblem at the tip. A large number of new cells cut off immediately outside the dermatogen to generate calyptrogen, which is a term for small-celled tissue. Under the hard soil, these small cells are responsible for forming and replantishing, or regenerating, the root caps. In other plants, the dermatogen forms the root cap on its own, independent of the calyptrogen. Mucilage, that helps in the root's easier movement through the soil, can be altered in the walls of the root cap's outer cells.

Periblem- Similar to the stem, this has multiple layers higher up and a single layer at the apex. The outermost layer of the periblem often produces the outermost layer of the root, which develops the central part, or cortex, of the root in monocotyledons.

Plerome- The structure and function of the plerome are nearly identical to those of the stem. However, in this instance, procambial strands alternately give rise to bundles of vessels, sievetube bundles, and phloem bundles.

Theories of Root Apical Meristem

1. Apical cell theory by Negeli (1844)
2. Histogen Theory by Hanstein (1865)
3. Korper - Kappe theory by Schuepp (1917)

Apical cell theory by Negeli (1844)-Nageli's (1844) apical cell theory proposed the root apex of cryptogams, whereas Hanstein's (1865) histogen theory proved and demonstrated the three separate cell initials, or histogen, in the apical meristem of the root of angiosperms. The histogen theory was refuted by recent studies; however the root apex was described by a number of authors using the histogen theory. The Korper-Kapp hypothesis, this hypothesis was proposed by Schuepp (1917). Körper and Kappe, respectively, mean body and cap.

The body cap concept covers multiple aspects of apical activity and is only based on planes of cell division.

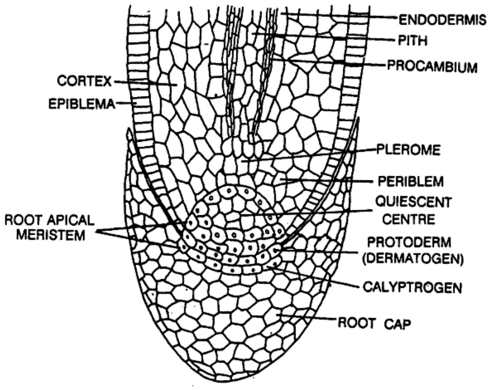


Figure: 1.5

1.4 Permanent or Mature Tissues

Meristem-derived cells progressively undergo structural, metabolic, and chemical changes as well as acquire specialized characteristics through a variety of differentiation processes. Not every cell is completely different from its meristem. Certain cells are unable to divide, whereas others still have the ability to do so. In a sense, only cells that are incapable of proliferating further should be considered permanent tissues; but, in a broader sense, cells originating from meristems that have developed specialized abilities such as photosynthesis, secretion, or storage are considered to be a component of matured tissue. These tissues' cells may have thick or thin walls and can be alive or dead. While thick walled tissue can be either dead or living, thin walled tissue is often living.

Two categories of permanent or mature tissues exist: Simple and Complex.

1: **Simple Tissue**: These tissues, which are essentially a group of simple, related cells with various structural components, make up the vegetative plant body. Simple tissues consist of a single kind of cell that forms a uniform cell system. These can be classified into one of three categories based on structural difference.

(A) **Parenchyma** – The basic fundamental tissue of the plant's body is called parenchyma. Every portion of the plant, including the pith and cortex of the stem and root, the mesophyll of the leaves, the flesh of the fruits, the floral parts, and even the xylem and phloem, contains it. Polyhedral forms and thin main walls characterize cells. Cortex and pith are examples of compactly packed cells, or more frequently, spaciously placed cells with intercellular gaps. Cells are active metabolites with thick cytoplasm.

Cells are made up of uniformly sized, isodiametric, thin-walled cells. Rounded, oval and polygonal in shape, parenchyma cells well-developed spaces between them. The cells are viable and contain an enough quantity of cytoplasm. Typically, a cell has one or more nuclei. In general, parenchymal cells store a variety of materials, including water, protein, starch, sucrose, and phenol derivatives.

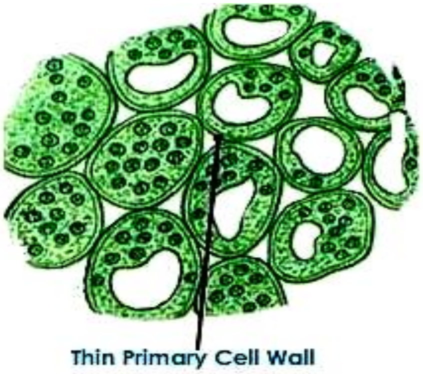


Figure: 1.6 Parenchyma

Parenchymatous cells are also structurally changed and can carry out specific activities. The plat body is made more rigid by the turgid parenchyma. Through these cells, water conduction is also maintained to some extent. The various kinds of parenchyma are as follows.

(i) **Aerenchyma**- In aquatic plants, the parenchyma undergoes change and the cortical cells form air spaces. Large and many intercellular spaces that are filled with air are referred to as aerenchyma in tissue. Even though the cells are smaller space, they provide aquatic plants the energy they need. These plants contain a lot of air spaces, that help in buoyancy and aeration. Air spaces can also be found in aroids, canna petioles, grass roots, etc.

(ii) **Chlorenchyma**: Chloroplasts are abundant in photosynthetic parenchyma cells. Chlorenchyma is the result of parenchymatous cells developing chloroplasts when exposed to sunlight. These cells are frequently observed in leaves and even in immature shoots. There are also many of intercellular spaces in the chlorenchyma cells. There are two kinds of chlorenchyma cells:

a. Palisade cells are elongated and compactly arranged.

b. Spongy cells are spaciously arranged and irregularly shaped.

(iii) **Collenchyma:**Collenchymas is simple, living tissue made up of elongated cells. It is a simple tissue because composed of one type of cell.Pectin deposits cause cell membranes to thicken. The main supporting tissue of dicot stems, leaves, and floral parts is called collenchymas. Collenchyma is typically absent in monocot stems and leaves (sclerenchyma is present in monocotyledones. The main feature of collenchyma is early development and adaptability to change in fast growing tissue.

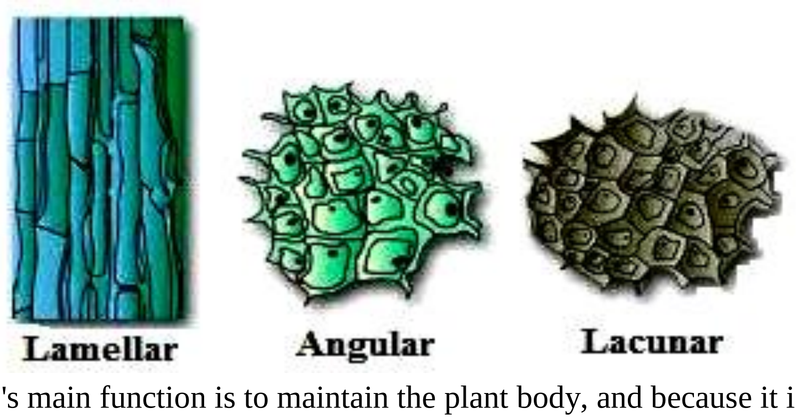
Typically, the collenchyma is located hypodermally, directly under the epidermis and the supporting organ. Compared to parenchyma, cells are thinner and more elongated. Collenchyma may also have chloroplasts, much like parenchyma. There may or may not be intercellular spaces. On the basis of the types of thickenings, three types of collenchyma are identified:

i. Lamellar collenchymas- Tangential wall thickening

ii. Angular collenchymas- Deposition of pectin is in the corners where several cells meet.

iii. Tubular or lacunar collenchyma.-Thickenings are around the intercellular spaces.

Figure 1.7 Vrious types collenchyma



The tissue's main function is to maintain the plant body, and because it is found in the petiole, stem, and leaf midrib at a peripheral position, this role is important.

iv. **Sclerenchyma -**Sclerenchyma cells have thick walls and are typically lignified. The secondary wall's formation is the cause of the thickness. The secondary wall is initially free from the primary wall, at least. When cells mature, they typically lack protoplasts, which indicates that they are dead. A hollow lumen is enclosed by the cell wall, which also typically has pits (simple type). This is supporting tissue that bending and stretching with plant organs, withstanding various strains without breaking down. They exhibit a variety of sizes and shapes; some of these are even the longest in the plant kingdom. This tissue's primary function is to provide mechanical support. Sclerenchyma cells are often divided into two categories: fibers and sclereids.

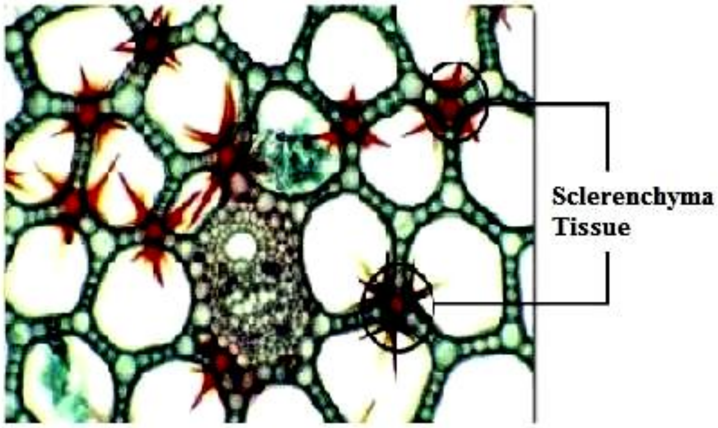


Figure 1.8 Sclerenchyma

Fibers: Typically, these are long, spindle-shaped structures with blunt or tapering ends. Boehmeria nivea has the longest fiber, measuring 55 cm. They're set up in clusters. 90% of the cell's surface may be made up of secondary thickening; the lumen is narrow. Cells have are often oblique, circular, or slit-like in shape. Xylary and extraxylary fibers are the two categories of fibers. The longest xylem elements are termed xylary fibers, or wood fibers. They are components of xylem.

Sclereids: Compared to thick-walled, spherical, oval, and cylindrical fibers, they are shorter.Sclereids occur single or in group with lignified walls and cells lack of living content. Sclerids can be present in the fruit wall, seed coat, and epidermal scales of aquatic plants that are submerged, as well as in the cortex, pith, mesophyll, and petiole on occasion.

The cells lack of living content and contain tubular canals known as simple pits. They may be simple or branched. Depend on structure sclereids are categorized in various types:

1. Starshaped are Asterosclereid (presentinleaf)
2. Similar in shapetopalisadecells or rodlike shaped are Macrosclereid (presentin seedcoat)
3. BoneShapethatareenlargedattheirends are Osteosclerei(present inleaf)
4. Likeparenchyma cells are Brachysclereidsareisodiametric(presentinbark,pithand cortex)

Asterosclerids **Macrosclereids**

Osteosclereids **Branchysclereids**

Figure 1.9 Vrioustypes of Sclereids

2. **Complex Tissue-**A complex tissue is made up of various types of cells that perform a same function. Since different types of cell make up the phloem and xylem, two transportation organs, they are examples of complex tissues. These two structures are made up of a mixture of

live and dead cells that have varying sizes and shapes. Vascular tissue is the combined term for xylem and phloem tissues.

VascularTissue- This tissue is heterogenous, complex, and composed of a variety of cell types. Its primary components are xylem and phloem, and its function is to transport nutrients, water, and minerals throughout the plant body.

Xylem (Wood) - Vascular plants have developed a highly specialized tissue known as xylem, which provides water, nutrients, minerals, and phytohormone signals throughout the plant while providing mechanical support. The tissue that transfers water from roots to leaves is called xylem. It is made up of both dead and live cells, such as tracheary components and parenchyma, as well as fibers.

Four different cell types form xylem: tracheids, vessels, xylem fibers, and xylem parenchyma. Angiosperms have this arrangement, although tracheids are lacking in Pteridophytes and Gymnosperms. This xylem combination is not universal; in fact, tracheids or vessels are lacking in several Angiosperm species.

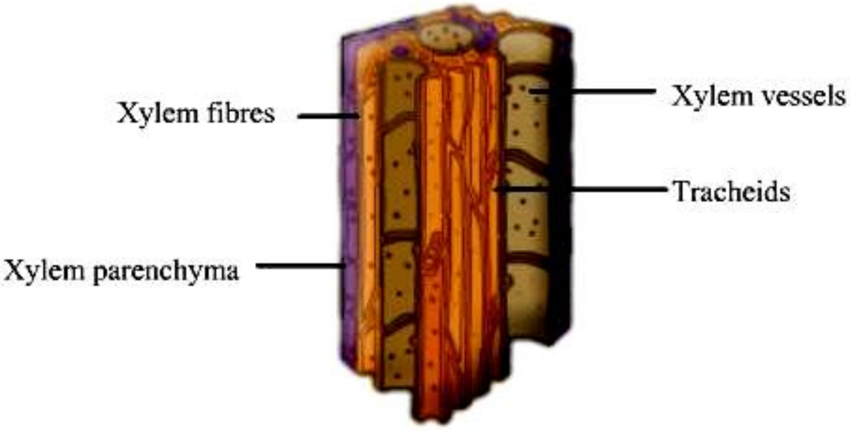


Figure 1.10 Xylem structure

There are two kinds of tracheary elements: 1) vessels and 2) tracheids. The expansion of vessels is limited and they are linked end to end form continuous tubular structures with perforations in the cross walls. These perforations effectively transfer water and minerals. The majority of angiosperms and several lower plants, like *Gnetum, Marsilea*, and *Selaginella*, have vessels.

Generally, tracheids are non-perforated and elongated.Conduction of water and minerals is not as efficient as in vessels. Tracheids are present in Pteridophytes, the majority of Gymnosperms, and a small number of Angiosperm.

In tracheary elements, secondary thickenings can deposit in several ways: Rings form known as annular thickening Continuous helices known as helical or spiral thickening Network like known as reticulate thickening Broad thickenings, with the exception of the pitted area called pitted

Xylem parenchyma In xylem element xylem parenchyma is responsible for storage function. Particularly in woody plants, many xylem parenchyma cells contain secondary lignified walls. In other instances, these cells have thin primary walls that include primary pit fields—plasmodesmata regions that allow water and mineral nutrients to pass from one cell to another. In living xylem tissue, mature xylem parenchyma cells may store starch, which is a kind of carbohydrates, and they can maintain functioning protoplasm. By developing callus and having the ability to differentiate into new, functioning xylem cells, these cells also contribute significantly to the healing of wounds.

Xylem fibers Sclerenchymatous cells called xylem fibers are present in both the primary and secondary xylem tissue. Primary xylem is made up of xylem components that differentiate from an apical meristem, whereas secondary xylem is made up of xylem elements that differentiate from vascular cambium. Because of the formation of lignified secondary walls, xylem is the tissue found in fossils that is best preserved. An organ develops strength and rigidity from fibers.

Primary Xylem- Xylem is differentiated into protoxylem and metaxylem. Protoxylem is found in roots away from the center (exarch xylem) and closest to the central axis in stems (endarch xylem). The subsequent thickenings of the protoxylem elements are circular, spiral, and occasionally reticulate.There are no fibers in protoxylem. Protoxylem is followed by metaxylem. There are just pitted secondary walls in Metaxylem. Metaxylem is more complex than protoxylem.

Secondary Xylem-Fusiform and ray initials make up the vascular cambium (intrafascicular and interfascicular cambium) that produces secondary xylem. Secondary xylem has orderly growth and is more complex than primary xylem. There are formed scalariform and pitted secondary thickenings. Because it is not as developed in water plants (Hydrophytes), it can be difficult to distinguish between xylem and phloem. Both the xylem and the phloem in this case are thin-walled, cortex-like structures. If the xylem's component parts developed from the apical meristem, it is referred to as the primary xylem. During the secondary growth phase, the vascular cambium gives rise to secondary xylem components.

Protoxylem is the earliest-forming cells, while metaxylem are the later-forming cells. Protoxylem and metaxylem are arranged in three main patterns in stems and roots.

Exarch condition is when a root has more xylem strands and the xylem develops centripetally, or from the outside inward. As a result, the protoxylem is closest to the periphery and the metaxylem is closest to the center of the root. It is generally accepted that vascular plants exhibit exarch development in their roots.

Endarch condition when a stem or root contains more xylem strands and the xylem grows centrifugally—that is, from inside out toward the periphery—the term "endarch". As a result, the metaxylem is closest to the periphery while the protoxylem is closest to the center of the stem or root. Seed plants usually exhibit endarch growth in their stems.

Mesarch condition is when a stem or root contains many more xylem strands, each of which develops from the middle in both directions. As a result, the protoxylem lies between the metaxylem and on both the middle and periphery of the strand (perhaps encircled by it). Mesarch development is found in many ferns' leaves and stems.

Phloem (Bast) -The conducting tissue that conducts food, referred to as bast, is called phloem. Sieve elements, companion cells, parenchyma cells, and fibers make up its composition. Similar to xylem, not all of these cell types are found universal. Companion cells are absent in pteridophytes and gymnosperms. There may not be any visible cell differentiation in certain hydrophytes. Primary phloem is derived from procambium, whereas secondary phloem originates from the vascular cambium.

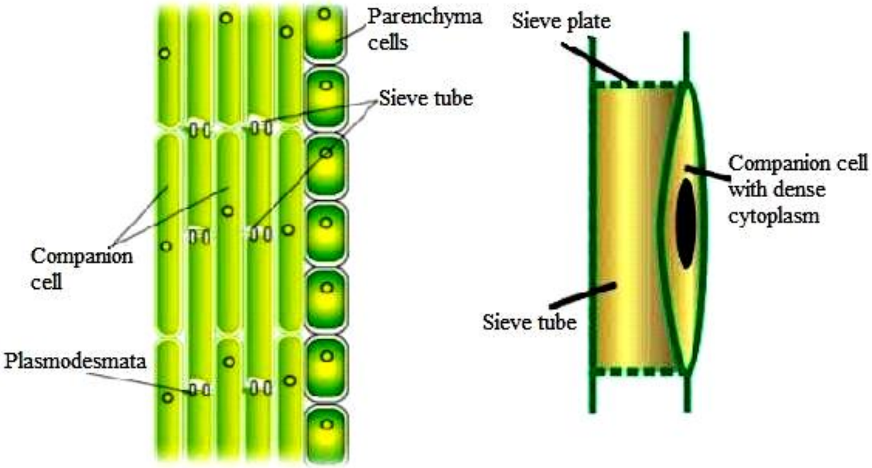


Figure 1.11: Phloem structure

Sieve elements: Members of sieve tubes and sieve cells are the two categories for this. Typically, sieve cells are long, thin, and taper at both ends. There are many sieve sections visible, and these cells overlap. Protoplasmic threads join adjacent sieve cells through a cluster of pores seen in sieve regions. Gymnosperms and Pteridophytes both have sieve cells. Specialized sieve areas known as sieve plates are located at the end walls of sieve tube members, which are tubular and arranged in a long series. These sieve plates frequently have an angle. The lateral walls of the sieve tube members could also include sieve areas in addition to sieve plates. Large pore regions may be seen in the sieve plate. Members of the sieve tube initially have uninucleated protoplasts.

The endoplasmic reticulum and nucleus gradually become disorganized. A combination of disorganized cytoplasmic materials and vascular sap may be found in the cell's center. The area around the vacuole lacks tonoplast.

Only Angiosperms have companion cells, which are specialized parenchyma cells connected to one or more sieve tube members. The companion cell and sieve tube member originate from the same meristematic cell. Companion cells of members of the sieve tube often form longitudinal series. A companion cell begins to divide. These cells most likely supply the energy needed for food conduction.

Companion cells: These are a specific type of parenchyma cell that is closely related to the sieve tube element in terms of origin, position, and function. Companion cells are specialized parenchyma cells that are connected with each sieve-tube member. They originate from the same parent cell through mitosis and maintain their connection to one another. The partner cells of photosynthates actively secrete into and remove them from the members of sieve-tubes. The primary phloem contains other unspecialized parenchyma cells that serve as storage.

Phloem parenchyma: The live phloem parenchyma has very thin cell walls. Phloem parenchyma cells, also known as border parenchyma cells and transfer cells, are found in leaf veinlets close to the tips of sieve tubes and finest branches. They play a role in food transportation in these areas. The packing tissue that exists between all other cell types is made up of these cells. Starch and other chemicals are stored in the phloem parenchyma.

Phloem fiber or Bast fiber-Bast fiber, which is derived from the bast around the stem of some dicotyledonous plants, is sometimes referred to as phloem fiber or skin fiber. They strengthen the stem and sustain the phloem's conducting cells. Although bast fibers obtained from wild plants like stinging nettle and trees like lime or linden, wisteria, and mulberry have been used in the past, the majority of the commercially significant bast fibers come from herbs grown in agriculture, such as flax, hemp, or ramie. Bast fibers are categorized as flexible, soft fibers. Because the important fibers are found in the phloem, they frequently need to be separated from the xylem substance and occasionally the epidermis as well.This is known as retting, and it can be performed by chemicals, pectinolytic enzymes, microorganisms on land or in water, or a combination of these. Bast fibers are found in bundles in the phloem, held together by calcium ions and pectin. The fiber bundles split into constituent fibers, which can measure several centimeters in length, by more severe retting. Because bast fibers frequently have higher tensile strengths than other types, they are utilized in burlap, paper, ropes, yarn, cotton and synthetic fiber mixes, and premium fabrics.

Primary phloem: It is divided into protophloem and metaphloem categories. Members of sieve tubes in protophloem do not have companion cells. The tissue of metaphloem survives longer. Its components are broader and longer. Dicotyledons often lack fibers, whereas monocotyledons and herbaceous dicots have parenchyma cells.

Secondary phloem: Like secondary xylem, secondary phloem has two systems of arrangement:
1) The axial system that produces the phloem fibers, parenchyma, and sieve components.
2) Ray parenchyma cells produced by the transverse system.

1.5 Specialized tissue or Secretary Tissue-Secretory tissues are made up of individual cells or groups of cells that secrete different kinds of substances. The secreted material may either be excreted, or released from, the secretory cell, or it may be deposited inside the cell. Materials may be excreted onto the plant's surface or into canals or intercellular spaces. While many of the materials found in the secretions—such as resins, rubber, tannins, and different crystals—are not used by the plant in any way, others—such as hormones and enzymes—help the plant growth. Single cells scattered among other types of cells to large formations containing several cells—the latter of which are sometimes referred to as glands—are examples of secretory structures.

Many plants have glandular or secretory epidermal hairs. These hairs made up of secretory cells borne on a stalk. The hair on the below of a stinging needle is bulbous, while the hair on top is long and fine. The hair breaks off at the tip and penetrates the skin, releasing a deadly substance when touched. Nectar-secreting glands in flowers that are pollinated by insects are known as nectaries. Nectaries can develop on any floral organ, such as an ovary, sepal, petal, or stamen, as well as on the flower stem.

Plants with special type cells or groups of cells that produce or secrete plant material are found in an extensive variety of species. Secretory tissues include the tissues in plants that secrete gums, resins, volatile oils, nectar latex, and other compounds. These tissues are categorized into two groups.

1. **Laticiferous tissues-** These include of ducts with thin walls, lengthy elongations, and many branches that carry a latex-colored, milky or yellowish juice. Rubber, hormones, alkaloids, proteins, carbohydrates, enzymes, tannins, and uncommon additional colors combine to produce an emulsion known as latex, which is a combination storage that is often milky white but can occasionally take on other hues. The papaya plant has a lot of latex. Within the parenchymatous cell mass, they were asymmetrically distributed. Again, latex is present in two types of laticiferous ducts:
   - Latex cell
   - Latex vessels

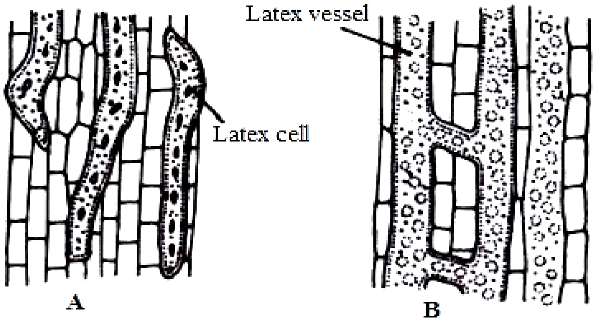


Figure 1.12: A. Latex cellsB. Latex vessels

2. **Glandular tissues-** The special structures that make up this tissue are known as glands. Certain secretory or excretory products are produced by these glands. A gland may have a central cavity or made up of isolated groups of cells that are separated from one another. They can be internal or external and found in various of forms.

   The following internal glands are present:
   - Oil-gland secreting essential oils, found in leaves of orange and lemon.
   - Glands in betel leaves that secrete mucus.
   - Glands that secrete tannin, gum, and other substances.
   - Digestive glands that release agents or enzymes for digestion.
   - Special water-secreting glands at vein tips.

Typically, external glands are short hairs with gland tips. They are:

- Hairs or glands that secrete water.
- Glandular hairs that secrete gum-like materials, such as plumbago and tobacco.
- Glandular hairs that, like nettles, secrete poisonous and irritating chemicals.
- Similar to carnivorous plants, honey glands.

Summary

Tissues are divided into three categories: meristematic, simple, and complex, depending on the types of cell structure and function. Actively proliferating cells with isodiametric form, abundant cytoplasm, and small or absent vacuoles, and active metabolism characterize meristematic tissues. Simple tissues are made up of cells that have a common origin, structure, and function. Parenchyma, collenchyma, and sclerenchyma are the three divisions. Complex tissues, such as secretary tissues and vascular tissues, are composed of several cell types that vary in origin, structure, shape, and function, but work together to accomplish a similar task.

Glossary-

- **Air space:** The spongy mesophyll has intercellular spaces. Water vapor and gasses the plant is releasing, such as oxygen (O2) and carbon dioxide (CO2), fill in these spaces.
- **Sclereid:** A kind of sclerenchyma that is composed of rough cells and is sometimes referred to as "stone cells." Pears have their faint gritty texture from sclerids.
- **Schlerenchyma:** Tissue composed of cells with strong walls and lignin for stability and strength
- **Sieve element:** Phloem tissue cell responsible for longitudinal conduction of food material. We refer to it as a sieve-tube element in flowering plants.
- **Sieve tube:** A set of sieve-tube components connected by sieve plates and arranged end to end.

Self- Assessment Questions

1. The conversion from meristematic to permanent tissue is known as:

(a) Cell division (b) Redifferentiation
(c) Dedifferentiation (d) Differentiation Ans. (c)

2. The tissue that is typically found in every plant organ is:

(a) Parenchyma (b) Chlorenchyma
(c) Collenchyma (d) Chlorenchyma Ans. (a)

3. Which meristem is responsible for increasing diameter?

(a) Lateral meristem (b) Primary meristem
(c) Intercalary meristem (d) Apical meristem. Ans. (c)

4. Which tissue is responsible for transport of nutrients in plants?

(a) Epidermis (b) Endodermis
(c) Xylem (d) Phloem Ans. (d)

5. What is the role of parenchyma tissue?

(a) Protection (b) Support
(c) Photosynthesis and storage (d) Transport of water and minerals
Ans. (c)

6. Where is the apical meristem found?

(a) At the tips of roots and shoots (b) Along the sides of stems and roots
(c) Between mature tissues (d) In the leaves Ans. (A)

7. Borderedpits arepresent in:

(a) Tracheids (b) Vessel wall
(c) Spongy tissue (d) Companion Cell Ans. (b)

Unit-2

ANATOMY OF ROOT, SHOOT AND LEAVES

Objective

After reading this unit, students will be able to:

- Root Anatomy
- Shoot Anatomy
- Leaf Anatomy

2.1 ROOT ANATOMY- Among the three primary vegetative organs, the root seems to have evolved last in terms of evolution. This might be explained by the fact that the majority of the early innovations made by land plants were focused on developing their stems and leaves in order to enhance photosynthesis. The developmental and structural characteristics of angiosperm root systems are often divided into two categories. The radicle serves as the source of the major root system, which in dicots is often dominant and gives rise to lateral roots with different levels of branching. The primary root of monocots is frequently transient, therefore their root systems, which also generate lateral roots, are composed of adventitious roots, which are typically formed from stems and leaves, and seminal roots, which are derived from mesocotyl.Apical meristem found in the root system is referred to as the root apical meristem. This causes extension development in a manner similar to that of the shoot apical meristem. The main difference is that roots, not leaves or branches, emerge from the root apical meristem and the growth goes down into the ground.. Roots are responsible for:

- Attaching the plant into the ground
- Water and nutrientsabsorbtion
- Storage nutrients
- Association with soil microbes

As roots expand, they penetrate the soil downward; avoid any obstructions like as rocks. As the root penetrates the soil, the root cap protects the root's apical meristem. Furthermore, it secretes a sticky slime that helps the root travel through the hard soil by lubricating the soil around the root tip.

The anatomy of a root is less complicated than that of a stem, and it exhibits several distinguishing characteristics. They are positively geotropic, devoid of chlorophyll, and light-insensitive. At the top of the roots are root hairs and a root cap. Vascular bundles are of the radial and exarch types, meaning that protoxylem is found towards the periphery and metaxylem is found toward the center.

2.1.1 Anatomy of Dicot Root:

Epiblema (Epidermis)-Epiblema is composed of densely packed, thin-walled parenchymatous living cells. Some of the cells in this outermost layer of the root develop root hairs. Epidermal cells produce root hairs that help in anchoring and absorption. Long, tubular, unicellular root hairs. Although some species have stomata, the root epidermis lacks them. The epidermis of the breathing roots in halophytes has specific pores. These roots are referred to as pneumatophores, and these as lenticels. Water and solute absorption and protection are the primary roles of the epidermis.

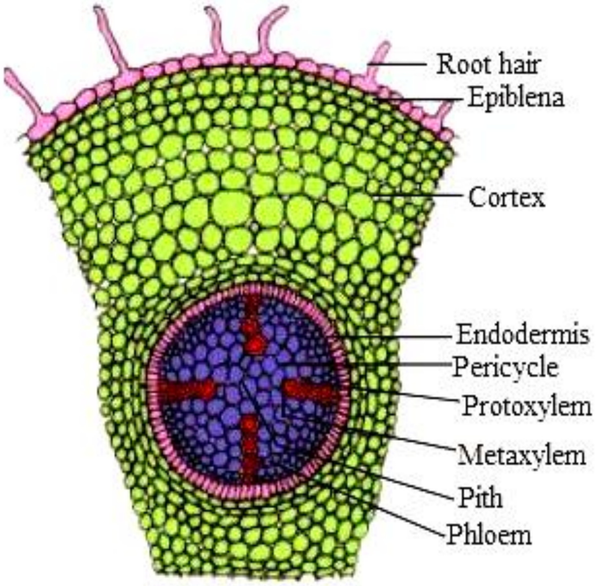


Figure 2.1 T.S.of Dicotroot

Cortex: The cortex of the root is made up of many intercellular gaps and thin-walled cells. Typically oval, circular, and polygonal in shape, cells have a specific way of being arranged. Certain herbaceous dicots that do not have secondary growth have permanent cortical retention and the development of diverse mechanical tissue types. There have even been reports of chloroplasts in Tinospora sp. cortex. The cortical portion of dicot roots also contains latex, mucilage, and tannin cells. Due to secondary growth, the cortex is replaced in the majority of dicots by suberized cells. Cortical cells provide root pressure, help in gaseous exchange, and let absorbed water to pass through, regain meristmatic activity during secondary growth, and form the cork cambium.

Endodermis: This uniseriate layer forms the plant's center cylinder. A unique layer called the endodermis has live cells with casparian strips in its transverse and radial walls. Casparian strips are bands of suberin that are deposited on the endodermis' walls. The movement of materials within the root and their passage into xylem cells is retained by the casparian strip. In addition to controlling the flow of materials within the root and their entry into the xylem, the endodermis stores the starch grain and serves as a storage organ.

Pericycle: This layer of parenchymatous cells, with thin walls, is next to the epidermis. It is in responsible for producing lateral roots and can be uni- or multiseriate. It continues to develop lateral roots, phellogen, and a portion of the vascular cambium by maintaining its meristmatic activity.

Vascular bundles: Radial and tetrarch vascular bundles are present. Phloem and xylem bundles occur in pairs, each consisting of four bundles. It is said that xylem is exarch, meaning that metaxylem faces the center and protoxylem sides

Pith: In older root pith is absent

2.1.2 Anatomy of Monocot Root:

Epiblema (Epidermis)-The outermost layer of a root, known as the epiblema, is made up of a single layer of tightly packed, barrel-shaped parenchyma cells. Since the cells are involved in water absorption, they are characterized by thin walls. There are no stomata or cuticles. A portion of the epiblema cells form root hairs, which are lengthy, unicellular projections. Therefore, the term "pilerous layer" also refers to epiblema.

Cortex: One of the main parts of the root's ground tissue is the cortex. Several layers of irregularly placed parenchyma cells serve as a representation of it. There are many intercellular spaces. The main function of the cortex is water storage. Additionally, the cells allow free water flow into the xylem vessels.

Endodermis: It is the innermost layer of the cortex made up of tightly packed barrel-shaped cells. Passage cells are a subset of thin-walled endodermal cells. Water can enter the xylem vessels through the passage cells. The radial walls of the remaining endodermal cells have thickening on them. They refer to these thickenings as "casparian thickenings." Suberin, a waxy material, is deposited to make them. The formation and maintenance of a physical force known as root pressure are significantly aided by the casparian thickenings.

Stele: Stele is the center cylinder of the root, made up of vascular bundles, pith, conjunctive tissue, and pericycle.

Pericycle: The stele's outermost layer, or pericycle, is made up of a single layer of parenchyma cells.

Conjunctive tissue: The loosely distributed parenchyma cells that are located in between the vascular bundles serve as its representation. The cells are designed specifically to store water.

Pith: The pith is the part of the root that is closest to the central axis. It consists of a small number of irregularly placed parenchyma cells.

Vascular bundles: Vascular bundles are arranged radially. There are eight bundles each of xylem and phloem. As a result, polyarchy is used to define the circumstance. It is said that xylem is exarch.

Monocot Root	**Dicot Root**
Outer cortex gave rise to the exodermis.	Cortex is not differentiated into exodermis
Cortex is wide	Cortex is narrow
Casparian strips are more prominent	Casparian strips are visible only in young root
Vascular bundles number 2-6	Vascular bundles are more than 6.

Conjunctive tissue is parenchymatous	Conjunctive tissue may be parenchymatous or sclerenchymatous

2.2 SHOOT ANATOMY- With a few exceptions, stems are typically above-ground organs that grow both positively phototropic (growing toward light) and negatively geotropic (growing away from the ground). Auxillary or adventitious buds give rise to lateral branches, while the embryo's plumule gives rise to the main stem. Clearly defined internodes and nodes—the latter being the areas to which the leaves are attached—can be identified in typical stems.

In younger stems, the epidermis has stomata, however in adult stems, lenticels are visible. Additionally, one may discern between herbaceous and woody stems based on the stem's toughness. The internal structures of immature dicot and monocot stems, secondary thickening in dicot stems, and variations in the internal structures of dicots and monocots will all be covered in this section.

A vascular plant's stem and root are its two primary structural axes. Nodes and internodes are the typical divisions of the stem: The nodes house one or more leaves in addition to buds that may develop into branches that bear inflorescences (flowers), leaves, or conifer cones. The nodes may potentially develop adventitious roots.

The four primary purposes of stems are as follows:

- Support and growth toward leaves, flowers, and fruits
- The stems provide the leaves light and give the plant a place to store its fruits and flowers
- Fluid transported by the xylem and phloem between the root and shoot
- Nutrient storage

Production of new living tissue: Every year, stems contain cells known as meristems that produce new living tissue. The stems with their appendages, leaves, lateral buds, flowering stems, and flower buds make up the shoots. A shoot is the new growth that develops after a germination of seed and shoots upward, eventually developing leaves. Perennial plant shoots are the new growth that appears in herbaceous plants from the ground, or new stem and/or flower development on woody plants in the spring.

Three tissues typically make up a stem: vascular, ground, and dermal tissue. The outer layer of the stem is covered in dermal tissue, which helps seal, protect, and regulate gas exchange. The ground tissue surrounds the vascular tissue and is often composed primarily of parenchyma cells. It occasionally helps in photosynthesis. Vascular tissue offers structural support as well as long-distance movement. In woody stems, much or all of the ground tissue may be collapsed. Aquatic plant stems lack the same level of waterproofing in their dermal tissue as their aerial stem. Plant species differ greatly in how their vascular tissues are arranged.

2.2.1 Anatomy of Dicot stems- When a dicot stem is studied in cross section, vascular bundles forms a distinct ring around the pith, which is present in the center of the stem. The epidermis cover the outside of the stem is protected by a waterproof cuticle. Additionally, trichomes—multicellular stem hairs—and stomata for gas exchange may be found in the epidermis. Above the pericycle and vascular bundles is a cortex made up of endodermis (cells carrying starch) and hypodermis (collenchyma) cells.

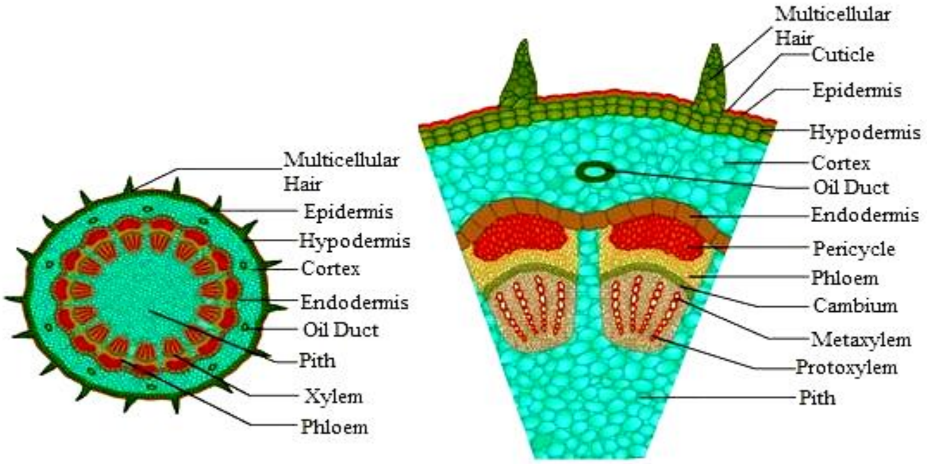


Figure 2.2 T. S. of Dicot stem; A. Diagrammatic; B. A portion enlarged

Epidermis: A single layer of densely packed live cells makes up the epidermis. The cuticle, a thin layer of waterproof material, covers and thickens the walls. The epidermis has guard cell-containing stomata. Trichomes, which resemble hair growths and can be either unicellular or multicellular, emerge from the epidermis in some stems.

- The cuticle protect inner tissues from drying out and losing water;
- The stomata provide gaseous exchange for respiration and photosynthesis;
- The cuticle keeps inner tissues from drying out and losing water;
- The stomata provide gaseous exchange for respiration and photosynthesis;
- The epidermis protects the underlying tissues from harm.

Cortex: The cells of the endodermis, parenchyma, and collenchyma make up this area. It is located inside the epidermis. Under the epidermis, collenchyma cells are composed of three to four layers of cells with thicker cell walls in the corners. Chloroplasts are present in the collenchyma cells. The young stem is strengthened by this tissue. During photosynthesis, the synthesis of organic food is carried out by the chloroplasts. A few layers of parenchyma, or thin-walled cells with intercellular gaps, sit underneath the layers of collenchyma cells. The majority of the cortex is composed of parenchyma cells. This is where they keep their synthetic organic food, mostly starch. The exchange of gases occurs in the intercellular air gaps.

Endodermis: The cortex's innermost layer is made up of the starch sheath. This is the single layer of closely spaced rectangular cells that surrounds the stem's stele. Starch is stored in the cells of this tissue. It permits the transfer of solutions from the vascular bundles to the cortex.

Vascular cylinder: This region includes the pith (medulla), pericycle, and vascular bundles. Sclerenchyma cells are dead, lignified fiber cells that make up the pericycle. These cells have tapered ends and thick, woody walls. It makes the stem stronger. It shields the vascular bundles from harm. The plant's pericycle has a ring that houses the vascular bundles. One feature that sets dicotyledonous stems apart is this unique ring of vascular bundles. The three primary tissues that make up an adult vascular bundle are cambium, phloem, and xylem. The xylem is found in the inside of the bundle, whereas the phloem is found on the exterior. The cambium causes secondary thickening by dividing the xylem and phloem.

Xylem transport water and dissolved ions from the root to the leaves. Additionally, the xylem supports and strengthens the stem. Synthesized organic food is transported from the leaves to other parts of the plant by the phloem. In order to create additional xylem and phloem cells, the cambium divides, which enables secondary thickening.

Pith (Medulla): It occupies the majority of the stem's center. Parenchyma cells with thin walls and intercellular air spaces make up this structure. The medullary rays, which are continuous with the cortex and pith, are a ring of parenchyma that runs between each arterial bundle. Water and carbohydrates are stored in the pith's cells. Through the air gaps between cells, they permit gas exchange. Materials are transported to the inner and outer regions of the stem via the medullary rays from the xylem and phloem.

2.2.2 Anatomy of Monocot stems- Throughout the monocot stem, vascular bundles are present, however they are more concentrated outside. Unlike the dicot stem, which often has none in the middle and a ring of vascular bundles around it, this stem is different. In monocot stems, the tip of the shoot is longer. For its protection, leaf sheaths rupture around it. Regarding almost all monocots, this is true. Only a few monocots—Palms and Bamboos being prominent exceptions—produce secondary growth and are hence rarely woody.
However, anomalous secondary development causes many monocot stems to enlarge in diameter. As you will see, the tissues of dicots and monocots are essentially the same. However, the arrangement of the vascular, ground, and epidermal tissue differs fundamentally.

The epidermis of a dicotyledonous plant has the same structure and functions as its stem. A single layer of densely packed live cells makes up the epidermis. The cuticle, a thin layer of waterproof material, covers and thickens the walls. The epidermis has guard cell-containing stomata. Trichomes, which are epidermal hair-like outgrowths that can be unicellular or multicellular, emerge from some stems. The underlying tissues are protected by the epidermis. By preventing internal tissues from drying out, the cuticle prevents water loss. Gaseous exchange is made possible by the stoma in order to support photosynthesis and respiration.

Ground Tissue- Ground Tissue is made up of small, internally epidermis-based sclerenchymas with thick walls. Larger parenchyma cells with thin walls come next in these cell layers. There are air spaces between cells in the parenchyma. Pith and cortex are not present. The stem is strengthened by sclerenchyma tissue. Starch and other synthetic organic foods are stored in parenchyma tissue. The exchange of gases is made possible via intercellular air spaces.

The ground tissue contains vascular bundles at random distributed throughout it. Smaller and more close to one another are the vascular bundles found closer to the stem's rind. Because the vascular bundles lack cambium, subsequent thickening does not happen. The vascular bundle is surrounded by thick-walled sclerenchyma fibers. Sheaths of sclerenchyma fortify the stem and shield the vascular bundles. Within the uneven intercellular air gap known as the lysigenous cavity are large xylem arteries. Thin-walled parenchyma cells around this area. Companion cells and sieve tubes, which have thin walls, make up phloem.

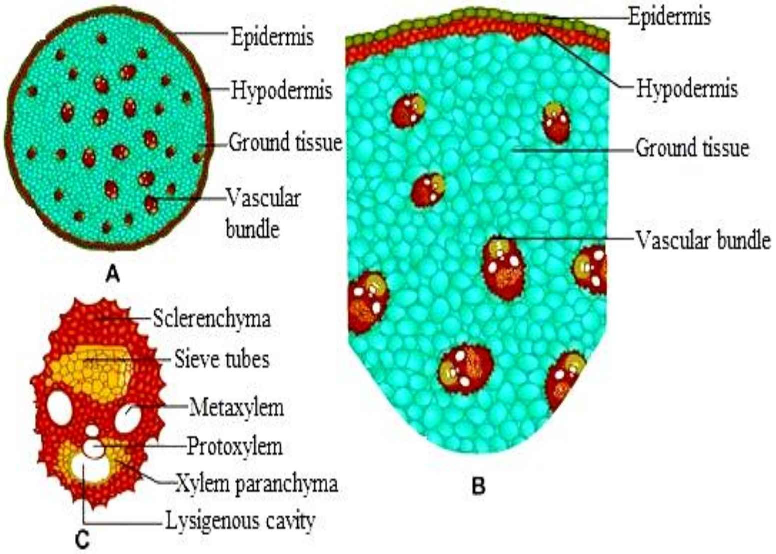
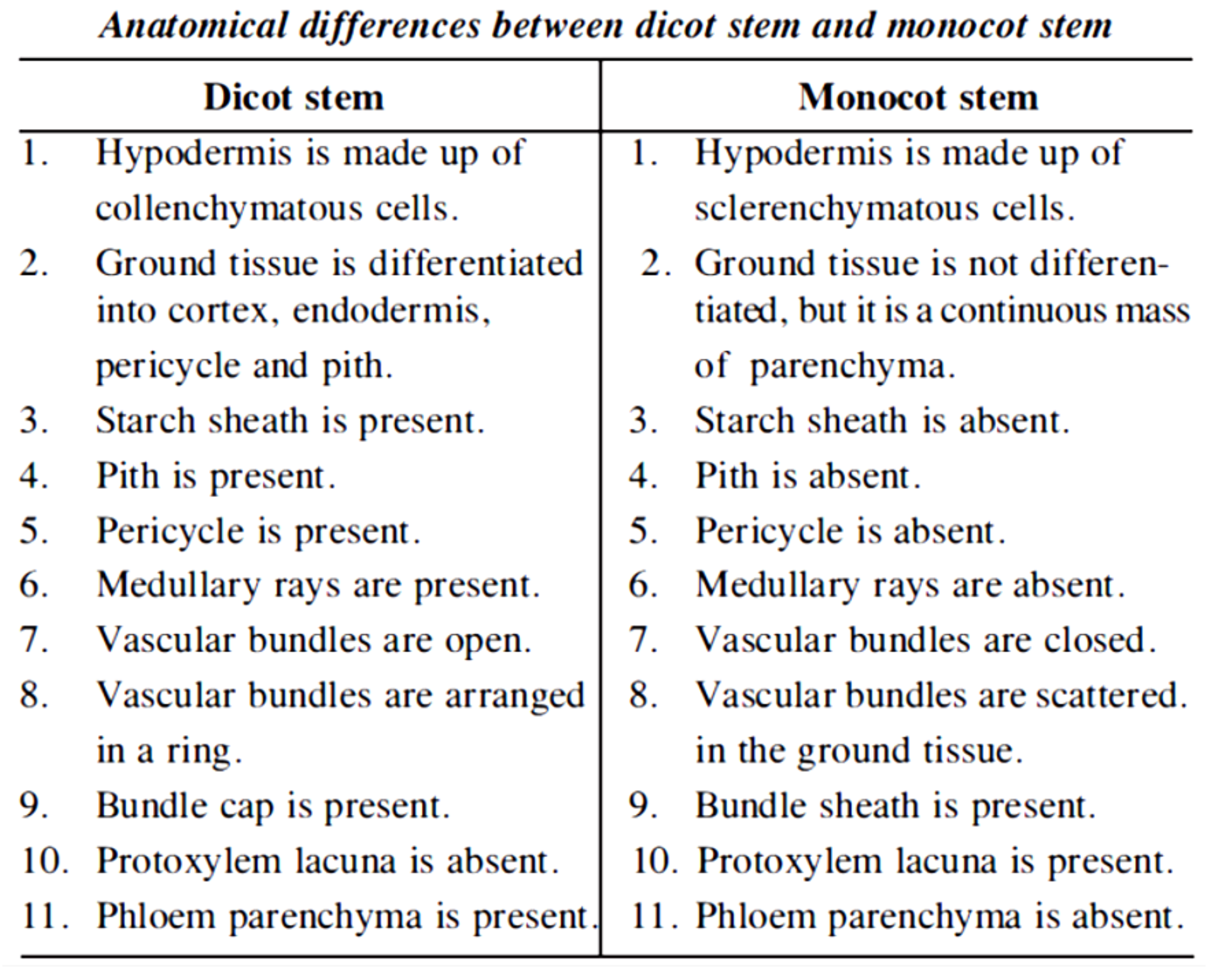


Figure 2.3 Monocot stem; A. Diagrammatic representation; B.T.S. of Monocot stem; C Vascular bundle



Anatomical differences between dicot stem and monocot stem

Dicot stem	Monocot stem
1. Hypodermis is made up of collenchymatous cells.	1. Hypodermis is made up of sclerenchymatous cells.
2. Ground tissue is differentiated into cortex, endodermis, pericycle and pith.	2. Ground tissue is not differentiated, but it is a continuous mass of parenchyma.
3. Starch sheath is present.	3. Starch sheath is absent.
4. Pith is present.	4. Pith is absent.
5. Pericycle is present.	5. Pericycle is absent.
6. Medullary rays are present.	6. Medullary rays are absent.
7. Vascular bundles are open.	7. Vascular bundles are closed.
8. Vascular bundles are arranged in a ring.	8. Vascular bundles are scattered. in the ground tissue.
9. Bundle cap is present.	9. Bundle sheath is present.
10. Protoxylem lacuna is absent.	10. Protoxylem lacuna is present.
11. Phloem parenchyma is present.	11. Phloem parenchyma is absent.

2.3 LEAF ANATOMY-

A leaf is the main lateral appendage of the stem and an organ of vascular plants. The shoot is made up of the stem and leaves. A mass noun that describes all leaves together is foliage.

A leaf is normally a slender, dorsiventrally flattened organ that is carried above ground and has a specific function for photosynthesis. The majority of leaves have unique upper (adaxial) and bottom (abaxial) surfaces that vary in terms of color, hairiness, stomata (pores that take in and release gases), and other characteristics. The majority of plant species have broad, flat leaves. Broadleaved plants are the term used to describe such species. Thin, needle-like leaves seen on many Gymnosperm species might be useful in frigid locations where snow and frost are common.

Other shapes and forms that leaves can take on include the scales found on some coniferous species. Certain leaves, like the scales on bulbs, are not above ground. Although succulent plants frequently have thick, luscious leaves, some leaves—like some cataphylls and spines—may not have any significant photosynthetic function and may even be dead at maturity. Most leaves have a major site of photosynthesis (palisade mesophyll) on the top side of the leaf blade or lamina, but certain species—like the mature foliage of *Eucalyptus*—have palisade on both sides, meaning that such leaves are considered to be isobilateral.

The main photosynthetic organ of the plant is the leaf. It is composed of a blade, or flattened section, joined to the plant by a structure known as a petiole. Occasionally, leaves are divided into two or more leaflets. Simple leaves are defined as having a single, undivided blade; complex leaves, on the other hand, have two or more leaflets.

2.3.1General Features of Leaves- Plants' powerhouse is their leaves. The majority of plants primarily produce food at their leaves. A leaf's internal structures transform solar energy into chemical energy that the plant may utilise as nourishment. The chemical in leaves called chlorophyll converts water (H2O) and carbon dioxide gas (CO2) into sugar and oxygen gas (O2) using the energy from sunshine. We refer to this process as photosynthesis. Most leaf types have developed an interior structure that maximizes light exposure for the chloroplasts, the photosynthetic organelles, and increases carbon dioxide absorption.

Stomata, which open and close in order to manage the exchange of CO2, O2, and water vapor with the environment, are responsible for controlling gas exchange. A plant leaf's stomata count can range from 1,000 to a million per square centimeter. Certain leaf forms have evolved to be able to adjust how much light they take in in order to guard against herbivory, prevent or lessen excessive heat, UV damage, or desiccation, or both.

Additionally, leaves have the ability to retain food and water. Succulent plants' leaves and bulb scales are two examples of how leaves have been altered to fulfill these purposes. It is necessary for leaves to have higher protein, mineral, and sugar concentrations than woody stem tissues in order for them to have photosynthetic structures. As a result, many animals eat a lot of leaves. This is accurate for those, for whom leafy greens are often staple foods.

The anatomy of leaf -

Epidermis: A leaf is composed of many layers that are covered in two layers of tough skin cells, known as the epidermis. The cuticle is a waxy material secreted by the epidermis. The leaf is shielded from germs, insects, and other pests by these layers. There are pairs of sausage-shaped guard cells among the epidermal cells. Every pair of guard cells creates a hole, or stoma in plural. Gases use the stomata to enter and exit leaves. The upper epidermis has a thick cuticle and no stomata, whereas the lower epidermis is light green, has a thin cuticle, and has stomata that are spaced apart. The epidermal cells are barrel-shaped and densely organized. The plant's epidermis helps it by:

- Water loss is prevented by the cuticle.
- The external layer protects the inside tissues from harm.
- Gaseous exchange for photosynthesis and respiration is made possible by the stomata.

The epidermis is translucent which allows light to reach the mesophyll tissue for photosynthesis. Inside the leaf found a layer of mesophyll cells.Greek for "middle" (meso) "leaf" (phyllon) is mesophyll. This leaves us with two layers of mesophyll: the spongy layer and the palisade layer. Spatial cells are more loosely packed and located between the palisade layer and the lower epidermis, whereas palisade cells are more columnar in shape and located directly under the epidermis.

Gas exchange is made possible by the gaps in between the spongy cells. The actual site of photosynthesis is found in the chloroplast-rich mesophyll cells, which can be either spongy or palisade in nature. This is the tissue below the surface. Palisade parenchyma, which is rich in parietal chloroplasts and has two to three layers, is located below the top epidermis. It is composed of tightly packed tubular cells. Above the lower epidermis is spongy parenchyma, which is made up of a variety of sized and shaped cells that are loosely organized to enclose air spaces, some of which open into stomata.

In the parenchyma cells, chloroplasts are parietal. Palisade mesophyll are lengthy cells that are used for the majority of food production. In the air spaces between the atypical mesophyll cells, gas exchange takes place.

Vascular tissue: The leaf veins consist of the vascular tissue, xylem, and phloem. In fact, veins are extensions that proceed from the tips of the roots to the leaf margins. The cells known as bundle sheath cells, which form the outer layer of the vein, encircle the xylem and phloem. The upper layer of cells in the image, called xylem, is somewhat lighter in color than the lower layer, called phloem. Remember that phloem transports food (sugar) and xylem transports water. The size of vascular bundles varies; they are all conjoint, collateral, and closed.The bundle sheath of parenchyma cells covers the vascular bundle. Metaxylem faces phloem, xylem faces the upper epidermis, and phloem faces the lower epidermis. Both the phloem and the xylem lack fibers. The phloem and xylem components are only conspicuous in large vascular bundles.
The description of the monocot and dicot leaf morphology and anatomy is provided below.

2.3.2Anatomy of Monocot leaf: Maize

Monocot leaves are vertically orientated and referred to as isobilateral.

Epidermis: This is uniseriate, with thick cuticle covering its barrel-shaped, densely packed cells. Because stomata are present on both the upper and lower layers of the epidermis, this condition is known as amphistomatic (more on the lower epidermis). Even though the leaf is called isobilateral, only the top epidermis has a small number of big, empty, colorless bulliform or motor cells.

These motor cells help in the leaf's rolling over during dry weather because of variations in turgidity. The rate of stomatal transpiration is slowed down by this leaf rolling action.

Mesophyll: Mesophyll does not differentiate into spongy and palisade parenchyma. Chlorenchyma cells are all identical, isodiametric, and organized almost compactly, with many parietal chloroplasts.

Vascular tissue: Numerous vascular bundles appear, and they are conjoint, collateral, closed, and organized in parallel series (venation is palmate-parallel). On the lower epidermis is phloem. The chlorenchymatous bundle that envelops each vascular bundle also acts as a temporary starch storage sheath. There are a few larger vascular bundles that have larger bundle sheath cells and more xylem and phloem. A sclerenchyma patch is present both above and below the major vascular bundles.

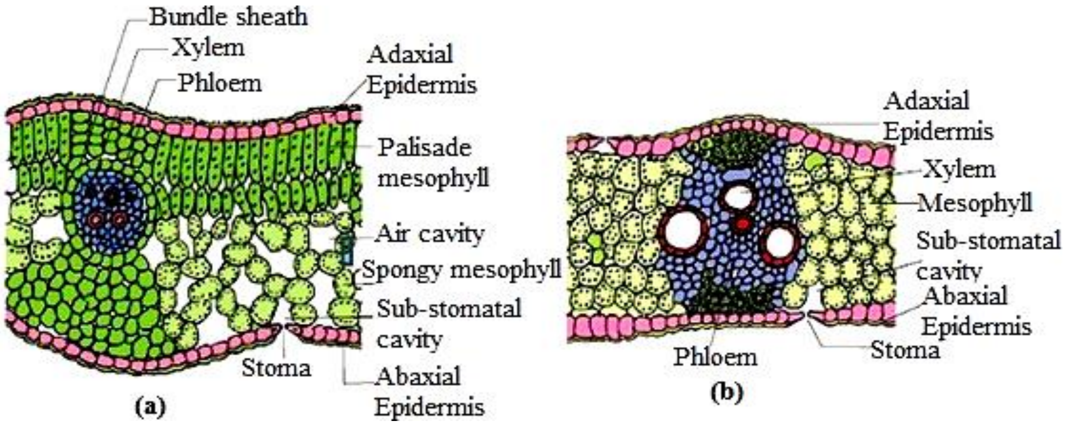


Figure 2.4 A.T.S. of Dicot leaf; B. T.S. of Monocot leaf

2.3.3 Anatomy of Dicot leaf- Sunflower

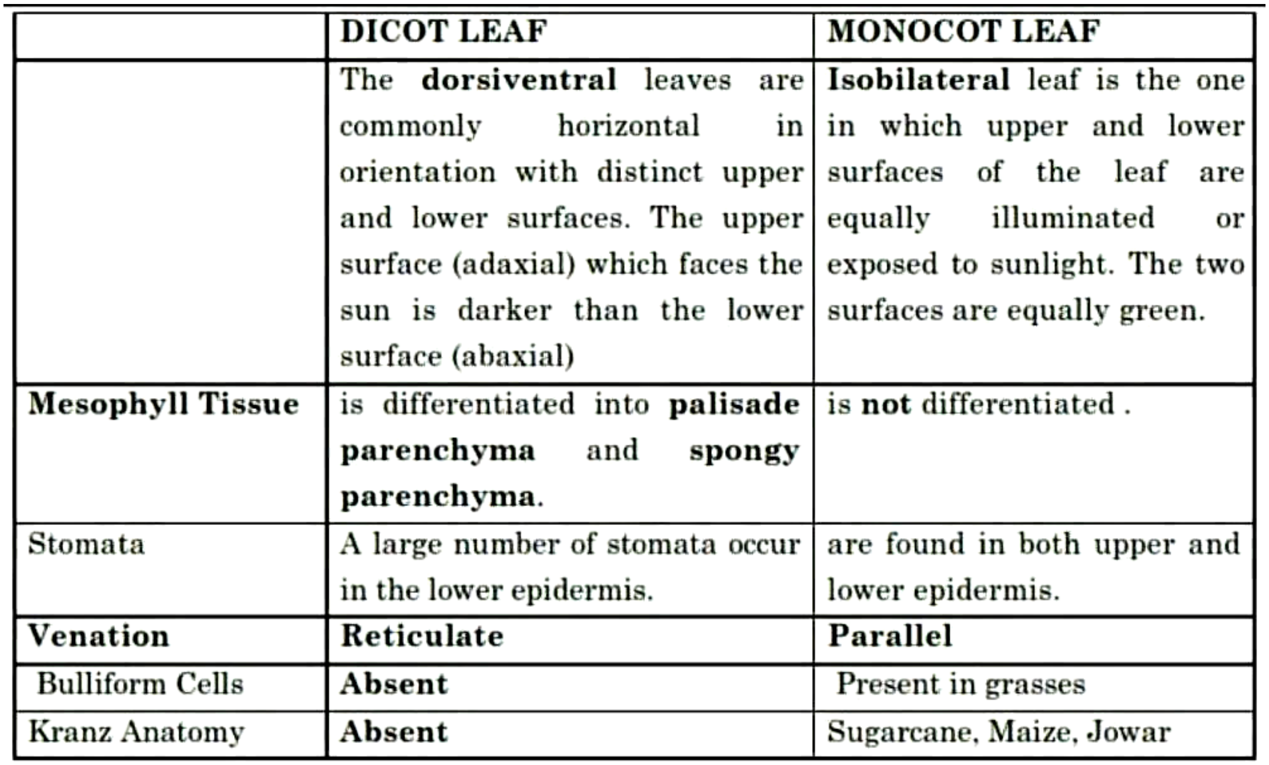
Epidermis: It is divided into two layers, one for each leaf surface. Barrell-shaped cells packed densely make up both levels. There are no spaces between cells. Both layers are surrounded by a cuticle. On both levels are multicellular hairs known as trichomes. Only the lower epidermis has stomata. This condition is described as hypostomatic

Mesophyll: The layer of ground tissue that lies between the two layers of the epidermis. It is made up only of cells called chlorenchyma. Two distinct zones, an upper palisade parenchyma and a lower spongy parenchyma, are typical features of the mesophyll.

a) Two or three layers of elongated, densely packed chlorenchyma cells make up palisade parenchyma. There are no spaces between cells. There are a lot of chloroplasts in the cells. Because of this, the dorsiventral leaf's top side appears greener than its bottom surface.

b) A few layers of irregularly shaped, round or oval chlorenchyma cells with noticeable intercellular gaps make up Spongy parenchyma. There aren't many chloroplasts in these cells. They round the vein or vascular bundle tightly. Few chloroplasts may be found in the cells. Gas diffusion through the empty areas left between sponge-like cells is aided. They only partially produce starch and sugar.

Vascular tissue: The vascular bundles are represented by veins. Because of reticulate venation, they are randomly distributed irregularly in the mesophyll. The center contains the biggest and oldest vein. The term for it is midrib vein. Every vein has a bundle sheath made of a single layer of parenchyma cells that are organized in a compact barrel form. Both xylem and phloem are enclosed by the bundle sheath. Xylem is found in the top epidermis, while phloem is found in the lower epidermis.Numerous protoxylem and metaxylem vessels can be seen in the xylem. Protoxylem faces the top layer of the epidermis. As a result, the vascular bundles and endarch xylem are referred to as conjoint and collateral. Many layers of collenchyma cells, known as bundle sheath extensions or hypodermal collenchymas, connect the midrib vein's bundle sheath to the upper and lower epidermal layers.



	DICOT LEAF	**MONOCOT LEAF**
	The **dorsiventral** leaves are commonly horizontal in orientation with distinct upper and lower surfaces. The upper surface (adaxial) which faces the sun is darker than the lower surface (abaxial)	**Isobilateral** leaf is the one in which upper and lower surfaces of the leaf are equally illuminated or exposed to sunlight. The two surfaces are equally green.
Mesophyll Tissue	is differentiated into **palisade parenchyma** and **spongy parenchyma**.	is **not** differentiated .
Stomata	A large number of stomata occur in the lower epidermis.	are found in both upper and lower epidermis.
Venation	**Reticulate**	**Parallel**
Bulliform Cells	**Absent**	Present in grasses
Kranz Anatomy	**Absent**	Sugarcane, Maize, Jowar

Summary

The tips of roots have a root cap, while the tips of the roots contain root hairs. Radial and exarch types of vascular bundles are found in xylem and phloem in various radii, protoxylem at the periphery, and metaxylem in the core. Nodes and internodes are the typical divisions of the stem: In addition to buds that can develop into branches, the nodes contain one or more leaves. Normally, a stem is composed of three tissues: dermal, ground, and vascular. The dermal tissue covering the outside of the stem acts as a protective layer, a gas exchange regulator, and a barrier against moisture. The bulk of the ground tissue that envelops the vascular tissue is frequently composed of parenchyma cells. Based on the makeup of the vascular bundles, monocot and dicot stems are distinguished. Vascular bundles are dispersed in monocots and grouped in a ring in dicots. Mesophyll cells, or palisade and spongy parenchyma, are found in dicot leaves. In contrast, the mesophyll of monocot leaves exclusively consists of spongy cells.

Glossary

Spongy mesophyll: layer of cells having a lot of air gaps between them and an uneven cell shape that lies underneath the palisade mesophyll. Some chlorophyll is present in these cells. Depending on the amount of gases present, the guard cells (stomata), which are made of spongy mesophyll cells, react by opening or closing.

Stem: The main support of the plant

Stoma: A plant's leaves include pores, or stomata, through which gases, including water vapor, enter and exit the plant. The two guard cells that generate stomata control how the pore opens and closes. On the bottom side of a leaf, there are often many more stomata than on the top

Vascular bundle: Veins maintain the leaf and carry nutrients and minerals as well as water through the leaf and out to the rest of the plant.

Self- Assessment Questions

1. Casperian strip found in

(a) Epidermis (b) Endodermis
(c) Xylem (d) Phloem Ans. (b)

2. Pith and cortex is notdifferentiating in:

(a) Monocot stem (b) Monocot leaf
(c) Dicot leaf (d) none Ans. (a)

3. In root vascular bundles found:

(a) Endarch (b) Exarch
(c) Mesarch (d) None of these Ans. (b)

Short questions:

1. Define two tissues are found within leaf?
2. What do you understand by "mesophyll"?
3. Which type of vascular bundleis found in dicot root?
4. Give a well label diagram of the dicot leaf.

Unit-3

STRUCTURE OF VASCULAR TISSUES

Objectives-

After reading this unit, students will be able to:

- About central vascular cylinder
- Structure and fuction of Xylem and Phloem
- Difference between xylem and phloem
- Arrangment of vascular bundle and its tpes

3.1 INTRODUCTION- Both plant organisms and human bodies need a circulatory system to survive. All plants do not always contain vascular tissue. Since algae are submerged in their supply of water and nutrients, they do not require it. Moreover, mosses lack vascular tissue. These plants diffuse water and other resources throughout them, which is one of the main reasons they don't become very tall. However, ferns and higher plants such as fir trees and conifers (Gymnosperms) and seed-bearing plants (Angiosperms) possess vascular tissue. Vascular plants are characterized by a wide range of characteristics, which allows for further classification of these plants into more specific groups. Vascular plants are classified according on how they reproduce. Ferns are vascular plants that reproduce by use of spores. It is common to refer to this kind of vascular plant as a seedless vascular plant. Most vascular plants are classed as either Gymnosperms or Angiosperms because they reproduce primarily by producing seeds rather than spores. Gymnosperms are vascular plants form cones to hold their seeds. Large trees like hemlocks, pines, spruces, and cedars are examples of common gymnosperms. Angiosperms, sometimes known as flowering plants, are vascular plants that produce their seeds inside of fruits or flowers. Common examples of Angiosperms are maple trees, lilies, dogwood trees, elm trees, and sunflowers.

Ground tissue, which essentially occupies the area surrounding the vascular tissue, makes up the majority of the tissue in a plant stem. After discussing the parenchyma, collenchyma, and sclerenchyma forms of ground tissue, we shall examine vascular tissue. The most prevalent type of tissue in plants, parenchyma serves a number of purposes, including food and water storage. Young stems and roots are supported in part by collenchyma tissue. Finally, the plant stem is rigidly supported and shielded by sclerenchyma tissue. Sclera is the Greek word for "hard." This will allow you to recall that sclerenchyma is rigidly supporting hard tissue.

Recall that the tissue responsible for transporting nutrients and water throughout a plant is called vascular tissue. It transports water and nutrients that the plant needs in a manner similar to that of roads and plumbing. Vascular tissue comes in two varieties: phloem and xylem. Food is transported by phloem, whereas water and dissolved minerals are transported by xylem. The similarity in pronunciation between the words "phloem" and "food" makes it simple to recall which vascular tissue is which, as was previously mentioned. This could serve as a helpful reminder that xylem transfers water and phloem moves food.

In vascular plants, vascular tissue is a complex conducting tissue made up of multiple cell types. The xylem and phloem are the main constituents of vascular tissue. Within, these two tissues move nutrients and fluids. Additionally, two meristems—the cork cambium and the vascular cambium—are connected to vascular tissue. The vascular tissue system of a given plant is made up of all of its vascular tissues collectively. Vascular tissue normally consists of long, thin cells. It is not surprising that the xylem and phloem have a shape akin to pipes given their role in the conduction of water, minerals, and nutrients throughout the plant.

Phloem's individual cells are joined end to end, much like a pipe's sections may be. New vascular tissue differentiates at the plant's developing tips as it expands. In order to preserve its connection throughout the plant, the new tissue is oriented in line with the old vascular tissue. Vascular bundles are the lengthy, distinct threads that make up the vascular tissue of plants. These bundles consist of protecting and supporting cells, as well as xylem and phloem. Phloem is usually found at the outside of stems and roots, while xylem is usually found closer to the interior of the stem. Some Asteridae dicots may also have phloem that is situated inward from the xylem in their stems.

Vascular bundles are found in between the spongy mesophyll of leaves. The adaxial (often higher) surface of the leaf is where the xylem is orientated, while the abaxial (often lower) surface is where the phloem is oriented. Because the phloem transfers plant-produced glucose and is located closer to the bottom surface, this explains why aphids are usually found on the underside of leaves rather than the top.

First, let's study xylem. Tracheids, which are elongated, non-living cells that enable fluid transmission.sometime the xylem can help in supporting the stem. In plants, fluids normally flow up via the stem and out through the leaves. Phloem, which transports nutrients from the leaves down the stem, is always composed of living cells, in contrast to xylem, which is composed of non-living cells.

The components of phloem that transport food through plants include sieve elements, such as sieve cells, plates, and tubes. Food components, such as sugars, are transported throughout the plant by the phloem, which are channels on the outer layer of the stem, either from storage tissues or the leaves where they are formed. Whenever a tree is chopped, sap, or the phloem, frequently seeps out of the tree. If you've ever experienced maple syrup, it's the refined version of the sap that comes from maple trees' phloem.

The main function of phloem is to transport sucrose produced in the leaves to the other parts of the plant. It also contains chemicals needed for defense and growth. The contents of phloem, which we typically refer to as "sap," go to various areas of the plant as needed, in contrast to xylem, which transmits water upward. Phloem, for instance, may transport sucrose from the leaves to the roots in the summer for storage and then return to the leaves in the spring to give the plant the energy required for budding. Phloem cells are living, as opposed to xylem cells.

3.2 STRUCTURE OF XYLEM- In vascular plants, xylem is one of two forms of transport tissue; phloem being the other. Water is transport via xylem through the shoots, out of the plant, and from the roots. Dead cells make up the majority of xylem, which is a hollow cylinder that passes indirectly from root to leaf across the entire plant. Water regularly evaporates from plants' leaves through a process called transpiration.The moisture that is absorbed through the roots is transported up through the xylem to the leaves in order to replace the water that has been lost since water molecules have a tendency to stay together due to their molecular structure. Due to the thick cell walls of the cells, xylem also serves as a method of support for the plant by moving dissolved minerals. The lengthy tracheary components that carry water are the most characteristic features of xylem cells. The shape of vessel elements—which are shorter and joined into lengthy tubes known as vessels—distinguishes them from tracheids.

Xylem found in following places:

- Vascular bundles, non-woody plants, and non-woody parts of woody plants all contain xylem.
- In woody plants' secondary xylem, a meristem known as the vascular cambium deposits it as a component of a stelar arrangement that isn't split into bundles, like ferns.

3.2.1 Primary and Secondary Xylem

Primary xylem-The xylem that forms during initial growth from procambium is known as primary xylem. Both protoxylem and metaxylem are included. Metaxylem develops before secondary xylem but after protoxylem. Compared to protoxylem, metaxylem has wider tracheids and vessels.

Secondary xylem-The xylem that develops during secondary growth from vascular cambium is known as secondary xylem. The two primary groups in which secondary xylem is present are the following, while it is also found in members of the "Gymnosperm" groups Gnetophyta and Ginkgophyta and to a lesser extent in members of the Cycadophyta.

Conifers (Coniferae): The number of conifer species is approximately 600. The secondary xylem of every species in this group has a comparatively homogeneous structure. A lot of conifers grow to be tall trees, and their secondary xylem is sold and utilized as soft wood.

Angiosperms: The estimated number of Angiosperm species is between 400,000 and 500,000. In monocots within this group, secondary xylem is uncommon. A large number of monocot Angiosperms grow into trees, and their secondary xylem is harvested and sold as hard wood.

Regulation of water movement is necessary, and stomata provide dynamic control. They can limit the quantity of water lost through transpiration by changing the rate of gas exchange. This is a crucial function in environments with erratic water supplies, and non-vascular hornworts seem to have evolved stomata before tracheids.Higher water transport pressures can be obtained using broader, robust-walled tracheids, but this exacerbates the cavitation issue. Cavitation is the process by which an air bubble grows inside a vessel, rupturing the bonds that hold water molecules together and preventing them from using their cohesive tension to draw in additional water. With the exception of a few highly evolved Angiosperms that have evolved a method to do so, a tracheid that has become cavitated cannot have its embolism removed and resume function. As a result, plantings are well worth the effort to prevent cavitation.

Increasing height also made use of another characteristic of tracheids: the help provided by their lignified walls. In most cases, a secondary xylem developed the strong, woody stem that was formed by the retention of defunct tracheids. Nevertheless, tracheids in early plants remained centrally located, with a layer of hard sclerenchyma on the outside of the stems, since they were too mechanically vulnerable.Even in instances where tracheids take a structural function, sclerenchymatic tissue provides support for them.

Vessel components of a tracheid have perforated end walls and are stacked in sequence to function as a single continuous vessel. Tracheids terminate with walls that greatly restrict flow. End walls were there by default in the Devonian and most likely served the purpose of preventing embolisms. An air bubble in a tracheid is called an embolism. This might occur from a gas dissolving out of solution or from freezing. Normally, once an embolism forms, it cannot be eliminated (but more on that later); the afflicted cell loses its ability to draw water up and becomes worthless.

Tracheids are characterized by their single-celled structure, which limits their length and, thus, their maximum useful diameter to 80 µm. Vessel components, made comprised of many cells connected at their ends, overcome this limitation and allowed larger tubes to develop, diameters of up to 500µm and lengths of up to 10µm. Conductivity increases with the fourth power of diameter, therefore increasing diameter has tremendous benefits.

Development

There are four terms that may be used to characterize xylem development: mesarch, exarch, endarch, and centrarch. Its nature changes from protoxylem to metaxylem as it grows in young plants. In the study of plant morphology, the arrangements of protoxylem and metaxylem are significant.

Protoxylem and metaxylem- A vascular plant's stems and roots develop one or more primary xylem strands as it grows. 'Protoxylem' refers to the first xylem to form. Protoxylem may be identified visually by its narrower vessels, which are composed of smaller cells. Some of these cells have thickenings in their walls that resemble helices or rings. Protoxylem has the ability to expand functionally, allowing the cells to develop and get larger when a stem or root lengthens. 'Metaxylem' later forms in the xylem strands.

The cells and vessels of the mexylem are frequently larger; the thickenings present in the cells are either transverse bars like ladders (scalariform) or continuous sheets with holes or pits in them (pitted). When the cells no longer need to grow in size, elongation ceases, and metaxylem functionally completes its development.

3.2.2 Arrangement of protoxylem and metaxylem

The arrangement of protoxylem and metaxylem in stems and roots follows four basic patterns.

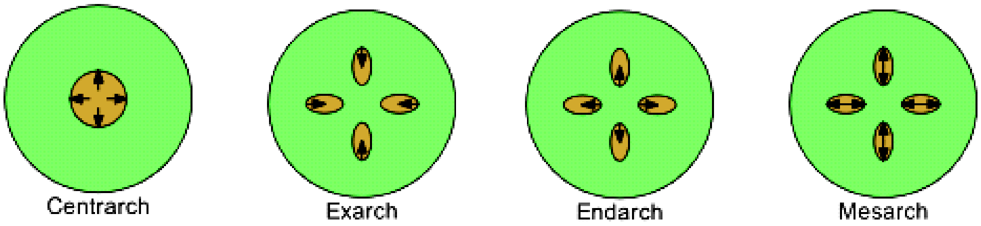


Figure 3.1: Patterns of protoxylem andmetaxylem

- When primary xylem develops from the center outward, forming a single cylinder in the middle of the stem, this condition is referred to as a centrarch. As a result, the metaxylem surrounds the central core, whereas the protoxylem is located inside it. There are no live plants that exhibit this pattern, however it was common in early terrestrial plants like "Rhyniophytes".

  On the basis of more than one strand of primary xylem three terms are found-

- Exarch is used when a stem or root contains many primary xylem strands and the xylem develops centripetally, or from the outside inward. As a result, the protoxylem is closest to the periphery while the metaxylem is closest to the middle of the stem or root. It is generally accepted that vascular plants exhibit exarch development in their roots.
- Endarch is used when a stem or root contains many primary xylem strands and the xylem grows centrifugally, or from the inside out, towards the periphery. In this way, the metaxylem is closest to the perimeter of the stem or root, whereas the protoxylem is closest to its center. Seed plants usually grow their stems in an endarch manner.
- Mesarch is used in cases where a stem or root contains many primary xylem strands, each of which grows from the middle in both directions. That means that the protoxylem lies between the metaxylem and on both the central and peripheral edges of the strand (maybe even encircling it). Mesarch development is found in the leaves and stems of many ferns.

3.3 STRUCTURE OF PHLOEM-

Phloem is the living tissue found in vascular plants that transports organic nutrients, or photosynthate, to all areas of the plant where they are required. One type of organic nutrition is sucrose. The term "bark" comes from the Greek word "phloios," which refers to the deepest layer of bark in trees, which is called phloem. The primary function of the phloem is to transport soluble organic matter produced during photosynthesis. Translocation is the process of translocation.

Phloem tissue is made up of three types of cells: parenchyma cells, which include both unspecialized and specialized companion cells, and albuminous cells; conducting cells, also known as sieve elements; and supporting cells, which include fibers and sclereids.

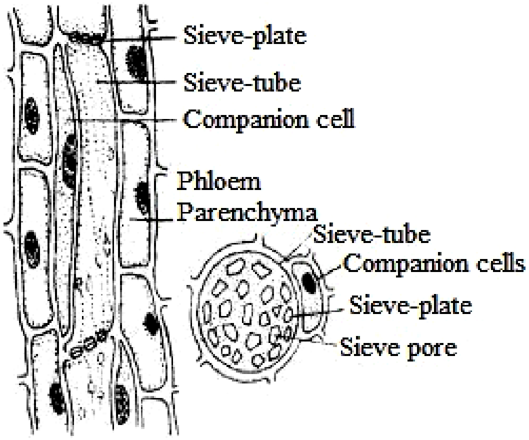


Figure 3.2 A. L.S.; B. T.S. of various types of Phloem tissue

Conducting cells (Sieve elements)-The type of cells called sieve elements are in responsible for moving sugars throughout the plant. They rely on companion cells or albuminous cells for most of their metabolic requirements because they are immature and lack a nucleus and few organelles. Vacuoles and other organelles, such ribosomes, are present in sieve tube cells prior to their maturation; however, upon maturity, these organelles usually migrate to the cell wall and disintegrate, ensuring that there are no blocks to the fluid's flow. One of the few organelles they do possess at maturity is the smooth endoplasmic reticulum, which is found at the plasma membrane and often near the plasmodesmata that connect them to their companion or albuminous cells.Groups of holes known as sieve regions arise from modified and larger plasmodesmata at the ends of all sieve cells. Platelets of the carbohydrate callose strengthen the pores.

Companion cells- Members of sieve tubes must be closely associated with companion cells, a specific type of parenchyma cell, in order for their metabolism to function properly. The (much smaller) partner cell of a sieve-tube element performs all of the cellular tasks of the element; in contrast, a normal nucleate plant cell typically contains a higher number of ribosomes and mitochondria. Plasmodiates bind the sieve-tube element to the thick cytoplasm of a partner cell. There are several plasmodesmata that form sieve regions on the common sidewall that the companion cell and sieve tube elements share.

Three different kinds of companion cells exist.

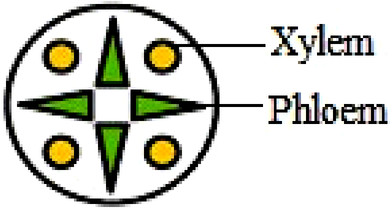
- Ordinary companion cells, which only contain the sieve tube as a link between their plasmodesmata and smooth walls.
- Transfer cells, which enable greater regions of transfer, are close to non-sieve cells and have walls that are heavily folded. They are experts in scavenging solutes from the cell walls that need energy to be actively pumped.
- Intermediary cells: these cells are connected to other cells by several plasmodesmata and have smooth walls.

Albuminous cells- Similar in function to companion cells, albuminous cells are only present in seedless vascular plants and gymnosperms because they are exclusively linked to sieve cells.

Other parenchyma cells- Generally undifferentiated, the other parenchyma cells in the phloem are used to store food.

3.4 Types of vascular bundles- Dependent on the inside structure of the plant, the vascular bundles are arranged differently. Vascular bundles of plants categorized as dicots and monocots are organized in a circular within the stem, with xylem on the inside and phloem on the outside. In dicots, there is a cambium layer in between each bundle; in monocots, there is none. In many circumstances, the xylem of these plants will eventually develop into woody tissue. The vascular bundles are categorized differently based on the relative positions of the xylem and phloem-

(A) Radial vascular bundle- The xylem and phloem tissues are found in distinct groups in various vascular bundle types, arranged in alternating radial positions. Phloem and xylem are arranged in distinct radii and alternate with one another; roots exhibit this kind of arrangement.



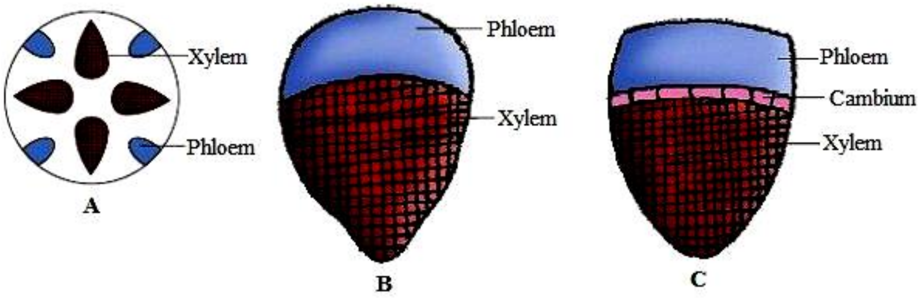


Figure 3.4 Radial type of vascular bundle

Figure 3.3 various types of vascular bundles (A) Radial; (B) Conjoint close; (C) Conjoint open

(B) Conjoint vascular bundles- Conjoint vascular bundles occur when the xylem and phloem tissues are found on the same radius and directly across from one another. In this instance, phloem is located outside the xylem cells, while xylem is often found towards the core. In dicot stems, it frequently occurs. Between xylem and phloem cells are a small number of meristmatic cells known as cambial cells. Vascular bundles are classified as closed type when there are no cambial cells present, and as open type when cambial cells are present between the bundles.

There are two types of collateral and bi-collateral joint vascular bundles, depending on the number and position of the phloem groups.

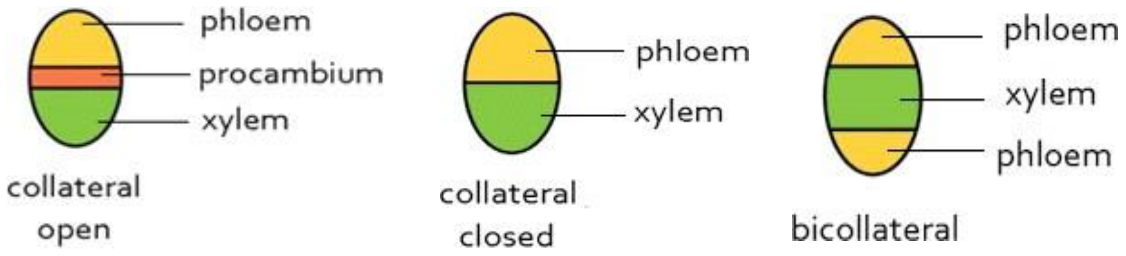


Figure 3.5

Collateral vascular bundles are a common type seen in dicotyledon stems, with the exception of some Convolvulaceae and Cucurbitaceae members. In this condition, phloem is found outward while xylem is found near the core. The xylem is surrounded by phloem inside the bundle, and there may or may not be cambial cells in between phloem and xylem patches. Vascular bundles are referred to be open type if cambial cells are seen between the xylem and phloem. On the other hand, it is referred to as closed type if there are no cambial cells between these two.

Bicollateral vascular bundle two phloem patches on either side of the xylem on the same radius are found in bicollateral vascular bundles. The inner, or internal, phloem stays towards the center, while the outer, or external, phloem, stays near the cylinder's edge. These vascular bundles do contain two cambium patches, though. Whereas the inner cambium divides the xylem and the inner phloem, the outer cambium divides the two. The inner cambium strip is either inactive or less active than the outer cambium, which has a concave shape and is more active.

(C) Concentric vascular bundles- Phloem tissue is sometimes surrounded by xylem or vice versa. Instead of being located in distinct bundles, xylem and phloem cells entirely encircle one another in this case.

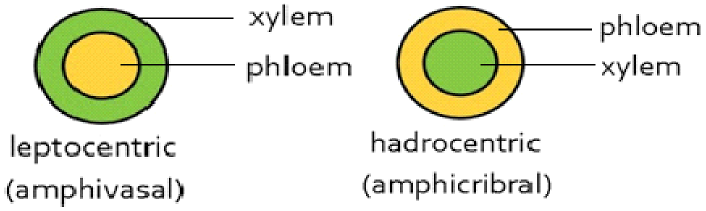


Figure 3.6 Structure of types of concentric vascular bundles

Amphivasal vascular bundles, also known as leptocentric types, are vascular bundles in which xylem envelops the phloem tissue from all sides. After secondary growth, such bundles can be observed in monocot plants like Dracaena.

Vascular bundles of the hadrocentric or amphicribal types are those in which the phloem completely envelops the xylem tissue. Pteridophytes like Lycopodium and Selaginella have these kinds of vascular bundles.

3.5 Role of Vascular bundles

- A vascular bundle is a part of the transport system of vascular plants. The two types of transport vascular tissue are phloem and xylem. Both of these tissues are part of a vascular bundle, which also comprises of supporting and protective tissues.
- Typically, the phloem is positioned abaxially while the xylem is adaxially located. This indicates that the xylem is located closer to the stem or root's center while the phloem is located closer to the outside. In most cases, the upper side of a leaf is its adaxial surface, while the lower side is its abaxial surface. Due to the phloem's proximity to the lower surface in transport the sugars produced by the plant, aphids are usually found on the underside of leaves as opposed to their upper surfaces.
- Water and dissolved minerals are transported upward by the xylem from the roots to any part of the plant that needs them. Since transpiration is necessary for water transportation to function, tension and hydrogen bonding in water. At functional maturity, xylem cells are dead. The parts of the plant that need sugar and other products from photosynthetic processes are transported by the phloem.When phloem cells work, they are living things that can move food items upward or downward. The majority of the "filling" in voids in plants are made up of plant tissues called parenchyma, which develop alongside the plant and aid in the storage of different materials. Growing plant stems also include the production of more xylem and phloem by the cambium tissue. To ensure that the required assets are transported throughout the plant, these tissues work.

3.6 Vascular cambium- The vascular cambium, a plant tissue located between the xylem and phloem in the stem and root of the plant, is the source of the secondary xylem growth inward toward the pith and the secondary phloem development outward toward the bark of a vascular plant.. It resembles a cylinder made of totipotent meristem cells that proliferate to generate new cells that eventually differentiate into secondary vascular tissues.

Monocots, which often lack secondary development, do not have vascular cambia, whereas dicots and gymnosperms have. There are several leaf varieties that feature vascular cambium as well. Water, minerals, or food that has dissolved are not carried through the plant by the vascular cambium. Nevertheless, it gives rise to the phloem and xylem, which carry out these tasks. The vascular cambia of the scion and rootstock need to line up for the graft to be effective and let the two to grow together. The vascular cambium in wood serves as a clear demarcation between the wood and the bark.

Intermediary xylem and main phloem cambium is referred to as intrafascicular cambium. Medullary ray cells that were previously intrafascicular cambium become meristematic and produce interfascicular cambium during secondary growth. Thus, the cambial ring—a continuous ring that splits the primary xylem and primary phloem—represents the intrafascicular and interfascicular cambia. The main xylem and phloem are subsequently forced apart by the vascular cambium, which also creates secondary xylem on the inside and secondary phloem on the outside of the ring.

Normally, the vascular cambium is made up of two different kinds of cells:

- Fusiform initials (axially orientated, tall cells)
- Ray initials which are tiny, angular to circular, almost isodiametric cells.

Fusiform cells vary in size depending on the species and are elongated with tapering ends. They are broad in the middle, tapering at both ends, and far longer than they are wide. On the other hand, Ray initials are significantly smaller and isodiametric. They make up the vascular cambium's axial system and radial system.

Fusiform initials give rise to the xylem and phloem parenchyma, which are sieve elements in the tracheary element fibers. From the ray initials, the vascular rays originated. Primary pit fields containing plasmodesmata are present in the thin cell walls of cambial cells, which are highly vacuolated. Xylem and phloem mother cells have thicker radial walls than tangential ones because cambial cells mostly divide periclinally, which causes the radial walls to thicken continuously.

Plants grow as a result of mitotic cell divisions occurring in growth foci known as meristems. The earliest (primary) meristems, such as the shoot apical meristem and root apical meristem, are derived from the embryo and are responsible for the growth of the shoot and root, respectively.

The main body of the plant, including the primary vasculature, is produced by these meristems. The vasculature of the primary shoot is found in distinct collateral vascular bundles that extend from the primary xylem to the pith parenchyma cells. The vascular tissue in roots is structured in a bisymmetric fashion, with two poles of primary phloem flanking the center axis formed by primary xylem. In both the root and shoot vasculature, procambial cells act as an intermediary between the primary xylem and phloem. As secondary growth begins, these cells divide periclinally, that is, parallel to the plant's surface or axis. This results in the formation of secondary phloem and xylem, which grow outward and inward respectively, as well as a secondary meristem called the vascular cambium, which forms an organ-specific continuous ring that will be discussed in more detail later.

Meristematic cells are small, cytoplasmic, and undifferentiated. The outermost cells are pushed out from the meristem by these cell divisions, where they differentiate into specific cell types, stop cell division, and begin turgor-driven cell growth. The maintenance of meristem indeterminacy requires a delicate balance between cell proliferation and differentiation into other cell types, both of which are clearly controlled by genetics.

The cells that develop into xylem and phloem are produced by vascular meristems. The major vascular meristem, procambium, is found in the apical meristems of the shoot and root. While the vascular tissue found in vascular bundles in the shoot apical meristem is the origin of the vascular tissue found in the main root and hypocotyl, it is generated from embryonic provascular tissue. A lateral vascular meristem known as the cambium arises primarily from the procambium embedded between the differentiated xylem and phloem in arabidopsis and other species that experience secondary development.

The tissues of the parenchyma and endodermis give rise to the cambium that lies between the vascular bundles in the shoot. As a result, in the root/hypocotyl, the entire ring of vascular cambium forms early on, whereas in the shoot (inflorescence stem), the formation of a closed cambial circle happens later, just after the vascular bundles' interfascicular cambium starts to form.

Normal Activity- The activity of the cork cambium in the extrastelar area and the cambium in the stellar region cause the secondary growth in the dicot stem. An annual ring forms as a result of stem secondary development. Dicot stems often have ring-shaped conjoint, collateral, open, and endarch vascular bundles. Every vascular bundle has the fascicular cambium, which lies between the xylem and phloem. The parenchymatous cells of the main medullary rays found between the fascicular cambium's borders undergo meristematic transformation during secondary growth. They form a strip interfascicular cambium by dividing and redividing. A complete ring of cambium is formed when the interfascicular cambium joins with the fascicular cambium on each side. Second, this cambial ring's activity signals the start of growth. Secondary xylem is cut down toward the center and secondary phloem is cut down toward the periphery by the cambium. More secondary xylem than secondary phloem is often produced by the cambium. The original tissues are forced away from one another by the growth of new secondary tissues, remaining only small patches or completely crushed tissues.

The vascular cambial cells divide to initiate the secondary growth. Two cells are produced as a result. which have the potential to develop into secondary xylem or phloem cells. he other cell of vascular bundle remains undifferentiated. This leads to the undifferentiated cell to divide once again, repeating the process indefinitely.

- The dicot stem's diameter increases as the vascular cambium cell divides and develops secondary xylem within and secondary phloem outside.
- During secondary growth, the main phloem becomes thinner as the thickness of the secondary phloem rises. Its outermost layer is made completely of cork cambium, a different kind of cambium from vascular cambium which helps in secondary growth.

- Cork cells are produced by the cork cambium, and periderm gradually replaces the epidermis.
- The result of this is the development of bark.
- Bark contains of all the tissue layers outside the vascular cambium. Like secondary phloem, cork, cork cambium and periderm

SUMMARY

A vascular bundle is a part of the transport system of vascular plants. The vascular tissue, which is separated into phloem and xylem, is where the actual transfer occurs. Water and nutrients are transported via xylem and phloem tissue, which make up vascular tissue. These tissues are always arranged next to one another in stems to form a structure known as a vascular bundle. Vascular tissue is made up of xylem tissue, which transports nutrients and water from the roots to other sections of the plant, and phloem tissue, which transports organic compounds from the site of photosynthesis to other parts of the plant. The xylem of vascular plants transports and stores soluble nutrients together with water. In plants, phloem carries sugars, proteins, and other organic molecules. The parameters used to determine the anatomy of plants are vascular bundles. Vascular bundles allow us to distinguish between a segment that belongs to the stem or the root. Furthermore, the orientation of the vascular bundles helps us identify if the plant is monocot or dicot. The cambial cells in between the vascular bundles aid in the production of wood, and we may calculate the age of the trees by counting the yearly rings that the cambium produces.

The xylem and phloem relative positions determine the classification of the vascular bundles. A vascular bundle is formed when distinct groupings of xylem and phloem tissues appear at different radial locations. Roots exhibit this. Conjoint vascular bundles are formed when xylem and phloem tissues are located on the same radius and directly across from one another. In dicot stems, it frequently occurs.

Vascular bundles are referred to as open type vascular bundles since cambial cells are seen between the xylem and phloem. The cambium produces the cork cambium, which gives birth to the bark, on the periphery and splits the plant, increasing its girth in a process known as secondary growth.

Glossary-

Bifacial (vascular cambium): A vascular cambium with two "faces," or sides, on which cells are created; in seed plants, phloem is produced on the exterior and xylem on the inside; contrast with unifacial (vascular cambium); refer to cambium.

Cambium: A secondary growth-producing lateral meristem

Collenchyma: Tissue made up of irregularly thickened cell walls; cellulose makes up collenchyma cells, which are pliable and sustain the plant's early sections without hindering growth.

Companion cell: A specialized phloem cell that was formed from the parent cell of the closely related sieve-tube element that is right next to it; the companion cell's nucleus supports both the cell that it is associated with and the cell that it is connected with.

Complex tissue: tissue with a variety of cell types, such as phloem

Cork: a plant tissue made up of cells with suberin-impregnated walls that are dormant at maturity; the cork cambium produces cork.

Cortex: A basic tissue that lies between the vascular tissue and the epidermis and is mostly made up of parenchyma cells

Cuticle: An impenetrable layer of cutin on the epidermal cell walls

Cutin: The waxy material that makes up a cuticle

Determinate growth: A type of development where the axis stops expanding, typically following the apical meristem's differentiation into a reproductive organ, such a cone or flower.

Dictyostele: A dissected siphonostele with at least two leaf bases that overlap

Ectophloic: Having phloem only on the stele's exterior; contrast with amphiphloic

Endarch: A type of xylem maturation where growth happens centrifugally, or from the inside out, and protoxylem is internal to metaxylem

Epidermis: The outer tissue of leaves, young stems, and roots, typically on cell thick

Exarch: A stage of xylem maturation when development happens centripetally, or from the outside in, and protoxylem is exterior to metaxylem

Self- Assessment Questions

1. During secondary growth, a formation of distinct annual rings is mostly dependent upon:

(a) Contrasting seasonal variation (b) Uniform climate
(c) Phellogen formation (d) Xylem quantity

Ans. (a)

2. The following is the waxy substance associated to the cork cell wall:

(a) Suberin (b) Hemicellulose
(c) Cellulose (d) Cutin

Ans. (a)

3 A simple mechanical tissue that is lignin-free is:

(a) Chlorenchyma (b) Sclerenchyma
(c) Collenchyma (d) Parenchyma

Ans. (d)

4.Which type of vascular bundles found in dicot stem -

(a) Open, collateral, endarch (b) Closed, collateral, endarch
(c) Closed, collateral, exarch (d) Open, collateral, exarch

Ans. (a)

5. The following abnormal secondary growth is found in :

(a) Helianthus (b) Maize
(c)Dracaena (d) Cucurbita

Ans. (c)

6. Casparian strips is characteristic feature of:

(a) Endodermis (b) Exodermis
(c) Cortex (d) Epidermis

Ans. (a)

Short Answer Question

- Explain conjoint types of vascular bundle with diagram.
- Give the detailed structure of secondary xylem.
- Explain he anatomical characters of phloem.
- Define cork cambium?
- Differentiate the endarch and exarch xylem

Unit-4

NORMAL AND ANOMALOUS GROWTH

Objectives –

After reading this unit students will be able to understand-

- Understand the secondary growth in plants.
- About different types of tissue which is responsible for secondary growth
- Types of wood and their position in plant
- Dendrochronology
- Abnormal behavior of cambium

4.1 Introduction- Since here is where cell division takes place; keep in mind that all plant stem growth occurs at the meristems of the shoot system. Plant stems have two different kinds of meristems: lateral and apical. The apical meristem is the site of primary growth, which extends the stem of the plant, as we just discussed. Previously, we studied the stem's the primary growth as well as the basic structure of the shoot system.

The apical meristem is the region of primary growth, which grows the plant stem. However, some plants need more than just stem length growth. Now, let's study this kind of growth. The stem of a plant has two different kinds of meristems: lateral and apical. Primary growth extends the stem of the plant and takes place in the apical meristem.During primary growth, plants grow their roots deep into the soil to provide support and facilitate the absorption of water and nutrients, as well as toward the sunlight required for photosynthesis. The apical meristem, a stem cell-like structure, is responsible for this "up and down" development. It divides to produce an undifferentiated cell that eventually develops into a new root or shoot tip. Secondary growth occurs when branches or stems expand outward and thicken. This kind of development is made possible by the lateral meristem, a tissue that resembles another stem cell, which is present in some plants, such as trees and shrubs. Lateral meristematic tissue introduces growth rings, which causes the plant to expand rather than develop upward or downward.We now understand how a plant has larger roots and taller stems. However, what about expanding? Even big trees with enormous trunks start as little seedlings. Secondary growth, which results from the lateral meristems in stems and roots, is what happens when a plant's length or girth increases.

Lateral meristems are regions with intense cell division activity, just as apical meristems. But instead of growing upward or downward, the cells they produce grow outward. Monocots do not go through secondary growth, however dicots use lateral meristems to increase their length. Cambia is the term for the lateral meristems that generate secondary growth; it simply refers to a layer of tissue that promotes plant development. The vascular and cork cambias are the two that are important for secondary growth.More vascular tissue, known as xylem and phloem, is produced by the vascular cambium. These tissues not only transport nutrients and water but also support the shoot system. They are referred to as secondary xylem and secondary phloem because they widen the plant by replacing the original (primary) xylem and phloem that originate from the vascular cambium.

The lateral meristem is the site of secondary growth, which increases the stem diameter. Only dicots exhibit this kind of growth, monocots secondary growth is absent. Vascular tissue occurs in two forms: phloem, which transports food through the plant stem, and xylem, which transports water and dissolved minerals. The arrangement of these structures varies slightly in monocots and dicots.

The xylem and phloem of monocots are scattered throughout the stem in paired bundles. Remember that monocots are simple flowering plants like grasses. In contrast, dicots, or highly developed flowering plants like apple trees and roses, have xylem and phloem arranged in rings, with the xylem on the inside and the phloem on the outside. This organization responsible for secondary growth of plant stems.

4.2 Cambium- In plants, lateral (outward) growth is facilitated by meristematic tissue called the cambium. In the stems of woody plants, there are two types of cambium that both expand the diameter of the stems. The plant's secondary vascular tissue (xylem and phloem cells) is produced by the division of the first type of cambium, called vascular cambium, which is located in the center of the stem. The outer ring of the bark of woody plants has a cambium called secondary cambium, sometimes referred to as cork cambium, that forms the cork cells of the outer layer and gives rise to the bark.

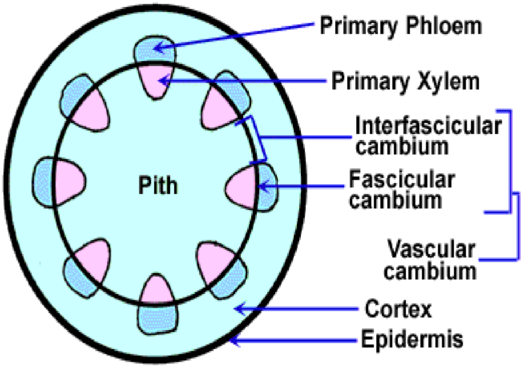


Figure 4.1 Cambium

The cambium layer is made up of a single layer of cells that divide parallel to the epidermis. It divides into two cells each time, one of which remains meristematic and the other of which develops into permanent tissue. Newly formed cells will develop in secondary phloem if they are directed toward the phloem, and secondary xylem if they are close to the xylem. As a result, the cambium becomes more active, the stem enlarges, and the cambium remains active for a considerable long period of time.

4.3 Normal Behaviour of Cambium- Primary tissues are formed by the division, differentiation, and development of apical meristem cells. The plant grow in length this is known as primary growth. Secondary growth is an increase of the plant organs' circumference or girth as a result of secondary tissues forming in the stelar and extra stelar areas, which is caused by the activity of secondary lateral meristems. Secondary growth typically occurs in the stem and roots of gymnosperms and dicots. Monocots lack the cambium responsible for secondary growth. However, several monocots—like dracaena, smilax, agave, coconut, etc.—takes place exceptional secondary growth.

Secondary growth in dicotyledon stem- Stellar region secondary-growth starts before extra stelar region secondary growth. It starts with the cambial ring development, and the specific actions that take place during this are listed below.

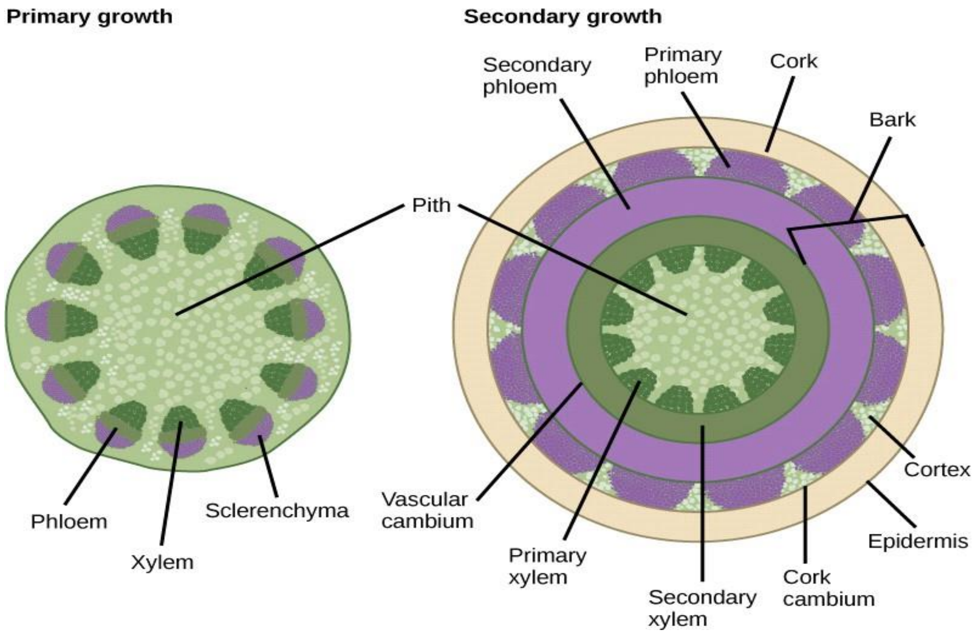


Figure 4.2 Primary growth and Secondary growth

4.4 Vascular cambium ring formation- The xylem and phloem cells that make up a vascular bundle are conjoint, collateral, and open type, meaning that cambium cells are found in between the xylem and phloem cells in the case of a dicot stem. An intrafascicular cambium is a cambium that is found inside the vascular bundle. This type of primary meristem exists. The formation of cambial rings is the initial stage of secondary growth, which occurs in plants after they reach maturity. Initially, the medullary ray cells situated among the vascular bundles undergo meristematic modification to generate the interfascicular cambium, which is a secondary lateral meristem.

The meristematic cells found outside the vascular bundle, known as the interfascicular cambium, originate from the medullary cells. Vascular cambial rings are the aggregate term for intrafascicular and interfascicular cambia. A single layer of cells makes up the vascular cambium, which forms into a full ring. A portion of the vascular cambium in the dicot stem is main, while other portion is secondary. There are two different kinds of cells in this vascular cambium's ring.

(i) Fusiform initials

(ii) Ray initials

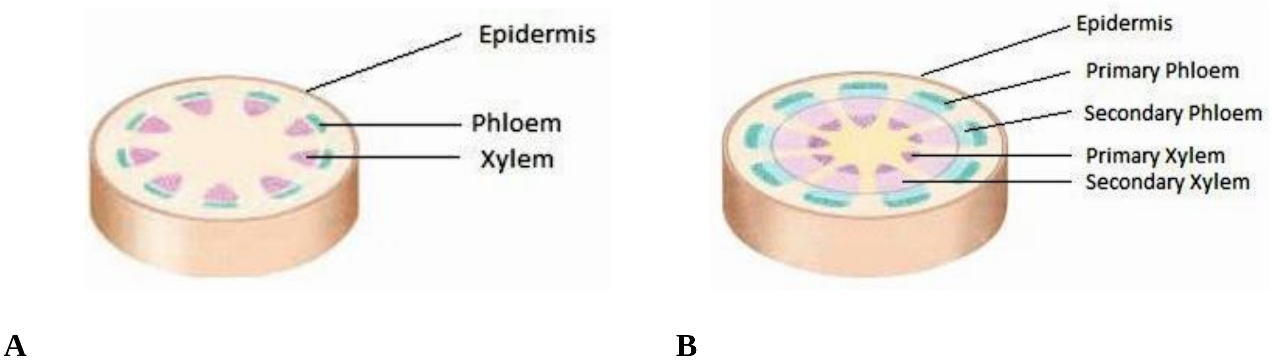


Figure 4.3 a. T.S. of stem before secondary growth; b. T.S. of stem after secondary growth

Ray initials are spherical (oval), whereas fusiform initials are long and have pointed ends. The vascular cambium has more fusiform initials. Fusiform initials exhibit tangential division or continuous periclinal division. In periclinal divisions, the cell's longitudinal axis is parallel to the plane of division. This type of activity forms some cells near the central axis, which differentiates into secondary xylem or wood, and some cells toward the radius (periphery), which differentiates into secondary phloem or bast.

The cambial ring as a whole now starts growing to produce cells on the inside and outside. Due to an unequal hormone distribution, more secondary xylem often forms than secondary phloem. Primary phloem is crushed and pushed to the outside by the pressure of secondary phloem. In the center of the stem, all primary tissues include pith, old secondary xylem, and primary xylem, degenerate due to pressure from the secondary xylem. As a result, the stern's central part starts to seem woody. These processes are ongoing in plants at all times.

Before secondary growth, the pith, primary xylem, cambium, primary phloem, pericycle, and endodermis are the cell sequences that persist from the center outside. However, secondary growth allows the vascular bundle's sequence change from the center to the primary xylem, secondary xylem, cambium, secondary phloem, primary phloem, and finally endodermis. Because of the pressure that the freshly produced secondary xylem creates, pith crashes. Plants frequently produce secondary xylem, and their original tissues continually deteriorate. Both the old and the new secondary xylem are degenerating.

The degeneration of the cells in the stem results in the formation of waste products including lignin, suberin, tannin, resin-gums, etc. All of these waste products are found inside the secondary xylem vessels and lumen (cavity) of tracheids. As a result, the central region of the stem's wood turns dark (black brown). It's referred to as Duramen or heart wood. Sap wood, sometimes referred to as alburnum, is the outside or peripheral wood that has a light appearance. The growth of secondary xylem causes the heart wood's diameter to rise. Sapwood is physiologically active wood, and its primary purpose is the conduction of water. The heart wood gives the stem its maximum mechanical strength.

Heart wood does not carry water conduction because:

- Waste products gradually fill the cavities in tracheids and arteries.
- The proliferation of parenchyma cells, which mostly enter vessel and tracheid lumens through wall pits, resembles that of a bladder. Tyloses are such bladder-like growths. Tyloses block water conduction.
- Tylosoids develop in place of tyloses in gymnosperms.
- Plants will not be affected if the heart wood in any stem is destroyed (nor will any essential functions be affected); nevertheless, if the sap wood is damaged, the plant will die because of the blockage of water conduction. The stem is made more rigid by the heart wood. Heart wood waste products have an antibacterial quality. Heart wood is immune to fungus and germs. Because heart wood repels insects, it is resistant to termites and does not absorb moisture during the rainy season. As a result, it is the highest grade wood.
- The rapid degradation of sap wood occurs when it is left exposed to the air.
- The oldest secondary phloem layer is found just outside the primary phloem, the youngest layer is found just inside the vascular cambium, and the oldest layer is found just inside the primary phloem.
- The youngest secondary phloem layer is located right outside the vascular cambium. A blocked xylem will cause the shoot to die first.

4.5 Classification of Wood-

(A) Wood is divided into two classes according to the amount of parenchyma:

1. Manoxylic wood: This type of wood has more parenchyma in it that is alive. It is loose, soft wood, like Cycas. There are many types of softer storage cells (parenchyma) mixed in with wood or xylem cells (tracheids) in these secondary vascular tissues. These plants' stems are softer than the wood from trees that is used for timber. Sago palms, cycads, the spurs or short shoots of Ginkgo trees, and several extinct seed fern groups are a few examples of plants that have manoxylic wood.

2. **Pycnoxylic wood**: There is less live parenchyma in such wood. The wood is hard. These types of wood are present in the majority of plants as well as in the secondary vascular tissues that contain minimal parenchyma and a large number of xylem cells, such as tracheids. This wood is more strong and durable. Conifers and other trees that grow cones, angiosperms, and the long shoots of Ginkgo are examples of plants that have pycnoxylic wood.

Figure 4.4 a. Manoxylic wood: **b. Pycnoxylic wood:**

These terms should not be confused with the distinctions between "soft" and "hard" woods. Agro-foresters use this terminology to distinguish between angiosperm (hard wood) and conifer (soft wood) trees. Conifers, which are mostly evergreen trees that bear cones, like pines, are known for their light-weight, light-colored wood that is strong in tension but weak in shear. As a result, this is known as "soft wood," which is typically less expensive and used to make paper pulp or cheap furniture. The wood of flowering plants, which are mostly deciduous trees like oaks and maples, is thicker, deeper in color, and more resilient to shear, tension, and compression. For this reason, it is referred known as "hard wood" and is utilized to create sturdy construction materials, flooring, and furniture.

(B) Based on parenchyma distribution, wood is divided into three categories:

1. Apotracheal: Parenchyma is scattered in this type of wood, such as gymnosperms

2. Paratracheal wood: This type of wood has parenchyma that is dispersed or grouped into masses or groups, such as dicot plants.

3. Syntracheal wood: *Terminalia arjuna* is one example of a wood in which parenchyma is collected around the vessels.

C) On the basis of vessels wood classification

Wood is divided into two types based on presence or absence of vessels.

1. Nonporous soft wood: this type of wood, such as gymnosperms, lacks vessels.

2. Porous wood: This type of wood contains vessels. Porous wood is separated into two categories on the basis of arrangement.

(a) Ring porous wood: this type of wood has vessels organized in a ring-like pattern. Such wood is more effective in conducting water, especially in temperate regions like Dalbergia.

(b) Diffused porous wood: In tropical regions like Azadirachta, this species of wood has a systematic distribution of vessels.

4.6 Formation of Annual rings:

Figure 4.5 Annual rings

The vascular cambium's unequal activity causes annual rings to develop. The cambium's activity varies throughout the year; it never stays the same. The vascular cambium's activity is influenced by both environmental and physiological variables. The cambium is less active in the winter and autumn season, and there is less secondary xylem or wood generated through the vascular cambium. During this time, small, thick-walled cells with narrow lumens arise. This is referred to as late wood or autumn wood.

During spring or summer, the vascular cambium is very active, resulting in a considerable amount of secondary xylem that is larger, thinner-walled, and has a broader lumen. This wood is referred to as early wood or spring wood.Compared to spring wood, which is lighter in color, autumn (or winter) wood is denser and darker in color.

Rings arise from the formation of the autumn and spring wood. Growth rings are seen in all types of wood. Thus, in a single year, two growth rings are formed. Annual rings are made up of two types of wood: rings made of autumn wood and rings made of spring wood. Consequently, there are two growth rings in an annual ring. A tree's age may be estimated based on the number of annual rings it has developed. Dendrochronology is the study of determination of age of the plant.

The yearly rings are counted from the base of the stem as it has the most annual rings and the upper part has less. Using an increment borer instrument, a piece is obtained from the base of the stem up to the center region. After counting the annual rings from that piece, they are once more placed (inserted) into the same stem at the same place.

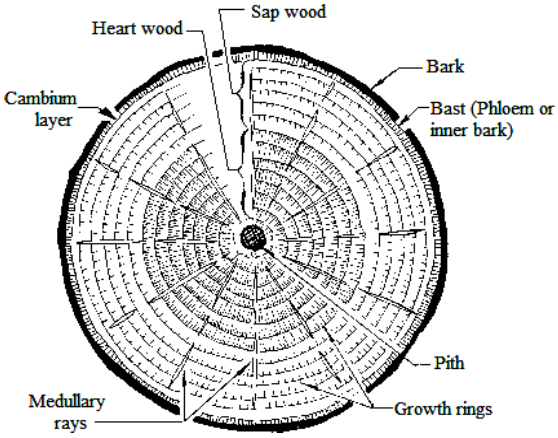


Figure 4.6 Stem showing annual rings

In regions where there are climatic variations are sharp, such as in temperate plants, more distinct annual rings occur. Tropical plants distinct annual rings are not formed with the exception of the Himalayan regions, India . Because the temperature in coastal places is constant throughout the year, less distinct annual rings form there. Deciduous plants develop more distinct annual rings than evergreen plants . Likewise, annual rings are less prominent in desert areas. Bands of secondary xylem and xylem rays make up annual rings. Pseudoannual rings are those that occur when drought circumstances persist in the middle of a growth season. These rings are composed of several annual rings.

4.7 Secondary Growth in Dicot Root- Vascular bundles of the radial type occur in dicot roots, where the phloem and xylem are found in different radii. Therefore, unlike in the case of stem, there are no cambial cells between xylem and phloem. Thus, in a dicot root, conjunctive tissue becomes meristematic during secondary growth and separates into curved vascular cambium strips below phloem bundles.This is the first step in the secondary growth of roots. The pericycle cells that are next to the protoxylem then similarly undergo meristematic growth to produce more cambium strips. Thus, the cells at the top of the xylem and the base of the phloem become meristematic first.A complete ring of vascular cambium forms as soon as the cells that are close to these cells also exhibit meristematic behavior. There is less vascular cambium formed by pericycles. Vascular cambium is mostly composed of conjunctive tissue.

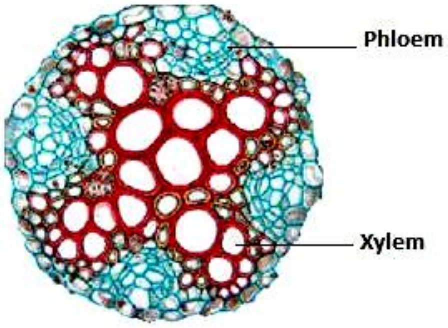


Figure 4.7 Xylem and Phloem (Root)

The shape of ring of vascular cambium is wavy in the initially, but after it becomes circular due to the pressure of secondary xylem. Conjunctive tissue-formed region of the vascular cambium becomes meristematic first and develops the secondary xylem toward the center. The pressure of the secondary xylem eventually causes the ring to become circular (pushing outwards). The vascular cambium of the root and the stem has the same level of activity. Vascular cambium forms secondary phloem near the outer side and secondary xylem toward the inner side. The pith rays are created by the component of the vascular cambium that is formed by the pericycle. Parenchyma made up these. Primary medullary rays are the term for these pith rays (multiseriate). The remaining vascular cambium also forms a few medullary or pith rays. We refer to them as unseriate secondary medullary rays. Consequently, the

secondary structure of roots has two different kinds of medullary rays. A basic characteristic of roots is the presence of two types of medullary rays. Following the secondary growth, the stem only contains secondary medullary rays. They both conduct food and water in a radial pattern.

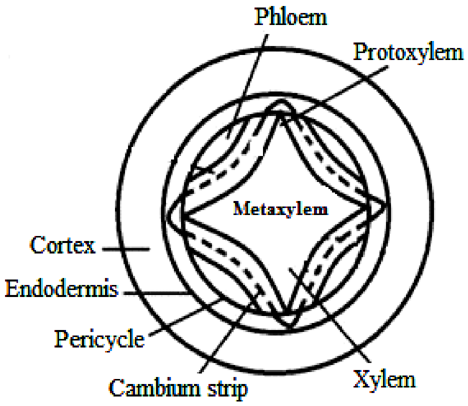


Figure 4.8 Dicot Root

The cork cambium develops in roots from the pericycle. The cork cambium forms secondary cortex on the inner side and cork near the outside. Though they are less common than in stems, lenticels are also present in roots. After a year or two of secondary growth, cortex totally degenerates in roots. This collapses as a result of the cork's pressure, but the stem degrades with time.

Secondary growth is essential for for roots to give strength to the developing aerial parts of the plant and complete the need of water and minerals. Since roots are not affected by environmental changes, they do not produce annual rings. Monocot roots secondary growth is absent.

4.8 Abnormal Behaviour of Cambium- To deviate from the normal or common type or order is to use the word anomalous. Because this growth condition is not common and only found in a small number of families or genera, it is reflected in the term "anomalous growth." It is possible to study two primary categories of plants that exhibit anomalous secondary growth.

- In those where a normal-type cambium is present and continues, but its activity is strange or irregular, vascular tissues with an atypical arrangement develop.
- Those in which the typical cambium either quickly develops into another cambium or does not form at all. The pericycle or cortex may give rise to this aberrant cambium, which exhibits abnormal activity.

Several kinds of dicots have secondary growth that differs significantly from typical secondary growth. Although the regular and abnormal types of growth are not clearly distinguished from one another, the deviating methods of secondary thickenings are referred to as abnormal or anomalous. The following is a list of these anomalies.

(a) (i) Anomalous position of vascular cambium: Vascular cambium is normally circular, however in some plants, the stems have folded cambium. These folds eventually separate and become independent of one another. A complete vascular bundle is formed by each fold. Numerous vascular bundles, such as those in Thinouia, Serjania, and Bauhinia, found in stems.

(ii) Abnormal Activity of vascular cambium: Typically, the maximum part of the vascular cambium forms the xylem and phloem, whereas just a small portion of the cambium forms the medullary rays. However, in some plants, such as Aristolochia and Vitis vinifera (Grape), parenchyma (medullary rays) develop from the largest portion of the vascular cambium, while xylem and phloem are rarely formed in other regions.

(iii) Sequential or successive ring of vascular cambium: Every year, a new ring of vascular cambium forms in some plants. This, like Bougainvillea, Boerhaavia, and Mirabilis, develops outside of the previous ring.

(iv) Formation of vascular cambium from pericycle: In plants belong to the Chenopodiaceae and Amaranthaceae families, the pericycle forms the vascular cambium. From the pericycle, a whole ring of vascular cambium forms.

(v) Interxylary phloem: This is also known as internal phloem. Usually, it appears as a continuous band or as strands around the pith. For the majority of plants, intraxylary phloem has a primary origin. After the growth of the exterior main phloem, the internal phloem develops. Because the bundles have internal phloem, they are regarded as bicollateral. Solanaceae, Apocynaceae, Lathyraceae, and other families exhibit this kind of development.

(b) Absence of vessels in the xylem: The aquatic plants, such as Elodea, Utricularia, Ceratophyllum, and Hydrilla, have vessels; however, some species, such as Zygozynum, Belliolum, and Drimys, lack vessels. Similar to gymnosperms, trachieds are the primary conducting channels in these species.

(c) Scattered vascular bundles in dicot: In dicots, vascular bundles usually form a ring; in certain taxa, however, they are scattered. Examples of these taxa are *Thalictrum, Piper, Peperomia, Podophyllum,Papaver,* and *Nymphaea*. The arrangement of vascular bundles in dicots and monocots is comparable.

(d) Exclusive phloem and xylem bundles: Vascular bundles can occasionally be incomplete, meaning that a bundle is only represented by one of the two types of strands: xylem or phloem. In Paeonia, incomplete bundles, which are exclusively represented by xylem, are present in addition to common vascular bundles. Phloem bundles are the only structures found in Cuscuta, Boerhaavia diffusa, Ricinus communis, and Antigonon leptopus.

(e) The presence of medullary bundles: Vascular bundles, sometimes referred to as medullary bundles, are found in the pith of some dicots. Only a small amount of secondary growth occurs in these bundles. Ranunculaceae, Amaranthaceae, Acanthaceae, Cactaceae, and Chenopodiaceae are the families that include these. They can be found in large or small numbers, but they are not necessary for the lateral organs like the leaf and branch to function. Their existence is solely a result of the lianas' mechanical function and growing translocation requirements.

f) Presence of cortical bundles: Some dicots also have vascular bundles in the cortex called cortical bundles, which are different from the typical ring of stelar bundles. Morphologically , these bundles are leaf traces that pass through the stem's cortical area and then enter the petiole. Below the ridges of Casuarina, a ring of cortical bundles orientated properly is present, but in Limonium vulgare, the vascular bundles are widely spaced irregularly.

(g) Intraxylary phloem: Intraxylary phloem is phloem that is found on the inside of the vascular bundles. It is sometimes referred to as medullary phloem because of its located on the pith's boundaries. It can appear as single patches (Solanum, Capsicum, Calotropis, etc.) or as a ring (Asclepias, Convolvulus, Eucalyptus, etc.). The provascular tissue gives rise to the internal phloem. With the exception of smaller or absent fibers, sieve tubes, and companion cells arranged in small groups surrounded by parenchyma, it resembles its external phloem.

(h) Vascular bundles arranged in a ring in monocots: In monocots, vascular bundles are scattered all across the ground tissue. However, on some cases, such as in *Tamus communis*, the vascular bundles are grouped around the pith in two rings; the inner ring has many large vascular bundles inside the pericycle, while the outer ring includes just two small bundles buried in the sclerenchymatous pericycle. Some grasses, such *Triticum, Hordeum, Oryza*, and others, have tubular stems with vascular bundles organized in two or more separate rings.

4.8.1 Bougainvillea stem-The Nyctaginaceae family plant bougainvillea is an example of a dicotyledonous stem with abnormal secondary growth. Within the lignified pith parenchyma at the stem's center, the primary vascular bundles in the Bougainvillea T.S. Slide the slide outward, and you will see that secondary vascular tissue has been produced to a rather large extent. On each side of it are secondary xylem and secondary phloem. Tracheids, fibers, and narrow-diameter vessels make up the secondary xylem. Small phloem pockets that resemble large-diameter metaxylem vessels will be scattered among the secondary xylem. The term "anomalous growth" is used in this case because, in reality, they are primary vascular bundles embedded inside the secondary xylem.

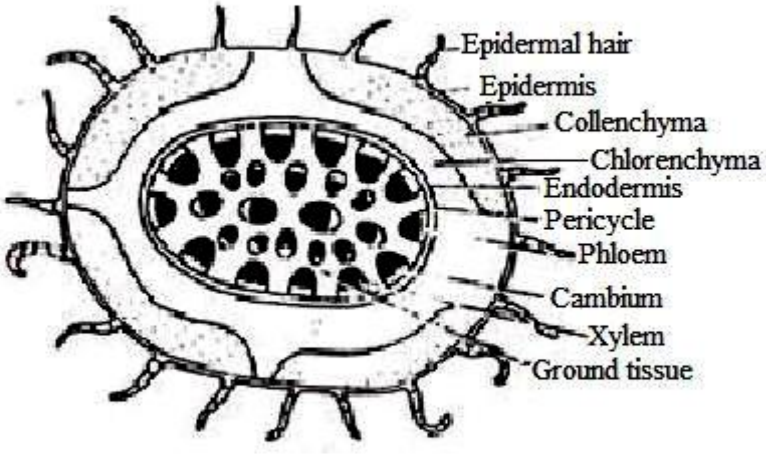


Figure 4.9 T.S. of Bougainvillea stem

The phloem is defined as phloem tissue that is situated between regions of the secondary xylem. This description includes phloem tissue. Although the physiological advantages of included phloem production is yet to be studied, one may hypothesize that in this case, the included phloem would be well-supplied with water and nutrients, as well as well-protected from pests and predators. Differential cambial activity leads to the abnormal growth.The outside lateral meristem becomes quiescent due to newly formed vascular cambia, and this cambium only becomes active again when the internal vascular cambium becomes less active. In Nyctaginaceae, vascular cambia are stated to generate arteries and accompanying axial parenchyma, fibers occasionally to the inside, and variable secondary phloem to the outside, but not rays as lateral meristems do.

4.8.2 Nyctanthes stem- The stem of the dicot plant Nyctanthes arbor-tristis has four inversely oriented vascular bundles at each of the four ridges in addition to the typical vascular bundles that form a ring in the center. These cortical bundles are open and collateral. Cortical bundles are vascular bundles that are found in the cortex in addition to the typical ring of stelar bundles.

These are the morphological remnants of leaves that enter the petiole after passing through the cortical part of the stem. The groups Oleaceae, Casuarinaceae, and Crassulaceae also have these forms of vascular bundles. These cortical bundles are as active in the development of new cells as they are in the secondary growth of the plant.

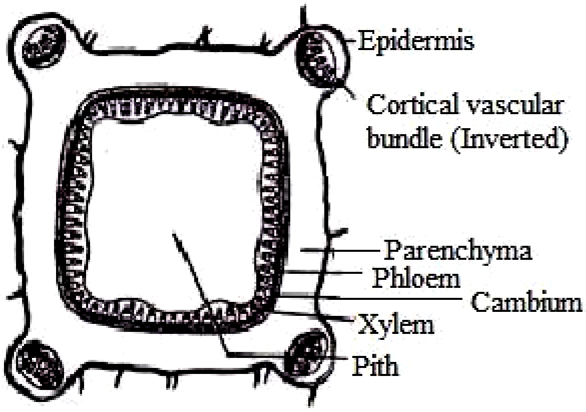


Figure 4.10 T.S. of Nyctanthes stem

4.8.3 *Dracaena* stem-As monocots, palm trees are tall and dense with no "normal" secondary growth. Although Dracaena is a monocotyledon, it is not a real palm since palms do not have the peripheral secondary thickening meristem that Cordyline and Dracaena do. The vascular bundles of the uncommon plant Dracaena are encircled by pronounced fiber bundles. Therefore, Dracaena is not unusual. A specialized secondary growth occurs in the stems, resulting in the formation of more parenchymatous components.

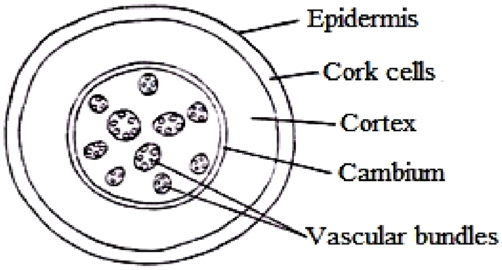


Figure 4.11 T.S. of Dracaena stem

Diffuse secondary growth is the phrase used to describe their later development pattern, which is characterized by an increase in ground parenchyma cell proliferation and new vascular bundles at the periphery.

The epidermis is followed by sclerenchymatous hypodermis in the normal anatomy of the juvenile Dracaena stem. In the ground tissue, there are several closed collateral bundles dispersed throughout. One of the ground tissue's outermost cell layers meristematicizes and serves as the cambium. The cambium developed in the area that stopped growing. This cambium develops just parenchyma on the exterior, with very little activity. It is more active on the inside. It generates alternating regions of parenchyma and xylem on the inner side. Conjunctive tissue refers to the parenchymatous cells that are found within. In a brief period of time, the cambium's inner side experiences a shift in activity, leading to the formation of phloem and subsequently xylem above the xylem.As a result, xylem surrounds the phloem and an amphivasal (leptocentric) vascular bundle ring forms. The xylem that grew earlier contains larger vessels, and a sclerenchymatous sheath forms surrounding each vascular bundle. After a while, the cambium changes its activity and starts to create xylem on the inside where it was previously creating parenchyma and parenchyma instead of xylem. Similar to the last instance, a ring of vascular bundles is formed by a shift in activity. More rings of vascular bundles emerge, and the cambium's activity continues to fluctuate on a regular basis. Vascular bundles end in one or two rings that are located in conjunctive tissue. Below the hypodermis, cork cambium develops and normally produces cork and cork cambium.

4.9 ACTIVITY OF CORK CAMBIUM- In plants, the epidermis is the outermost layer produced during primary growth. This layer serves as enough protection for the inner tissues in plants without lateral growth. On the other hand, this epidermis splits and falls off a thicker stem. Without the cork cambium, the plant would be susceptible to disease and water loss. The extra stelar region develops secondary growth as a result of the cork cambium's activity. Phellogen or extra stelar cambium is other names for cork cambium. The cork cambium's cells are rectangular in shape. The phellogen is made up of one type of cell and has a very basic structure relative to the vascular cambium.

Due to its meristematic modification, the cork cambium arises from either the hypodermis or the outer layer of cortex. First phellogens appear in the subepidermal area during their developmental stage.

Cork cambium- A tissue that is a component of the periderm in many vascular plants is called the cork cambium. The lateral meristem known as the cork cambium is in responsible for the secondary growth that takes the place of the epidermis in roots and stems. Gymnosperms, woody and many herbaceous dicots, and some monocots—which often don't have secondary growth—all include it. One of the meristems, or the group of tissues made up of embryonic (partially developed) cells from which the plant develops, is the cork cambium. It is among the several bark layers that lie between basic phloem and cork. The cork cambium's job is to create cork.

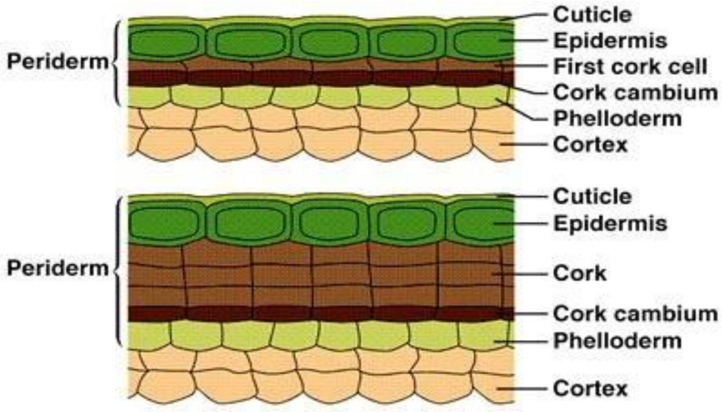


Figure 4.12 Activity of cork cambium

After several divisions, phillogene, also known as cork cambium, produces new cells that resemble cambial rings. The cork cambium likewise splits periclinally, forming cells that face the outside (epidermis) and the inside (cortex). The outermost cells undergo suberization of their middle lamella, resulting in cell death and the formation of cork or pellen. The cells that develop towards the inner are termed Phelloderm or secondary cortex; they differentiate into parenchyma and may include chloroplasts.

Collectively, phellogen, phellem, and phelloderm are referred to as periderm. It means the term "periderm" refers to the complete secondary tissue found in the cortex.

Phellogen + Phellem (cork) + Phelloderm = Periderm

Phellem, also known as cork, is similar to phellogen cells and grows in large amounts. They lack intercellular spaces and exhibit a uniform, polygonal shape. Due to the cork's and cambium's increased external activity, there is less phelloderm or secondary cortex. The walls of these cells are made of cellulose. They also have a form that is comparable to a phellogen cell. Their radial series layout helps to differentiate them from cortical cells.

Consequently, the periderm is made up of three layers:

- Phelloderm: made up of live parenchyma cells, located inside the cork cambium
- Phellogen, or cork cambium, is the meristem from which periderm arises.
- Phellem, or cork, an outer layer of air-filled protecting tissue that is dead at maturity

As can be observed by the various bark surfaces, such as smooth, fissured, scaly, flaking off, etc., the growth and development of cork cambium varies greatly across species and is also highly dependent on age, growing circumstances, etc.

SUMMARY

Primary growth in plant science is the growth that arises from stem and root tips elongating and producing primary tissue as a result of cell division. Conversely, secondary growth is the thickening of the stems and roots as a result of cell division in the cambia or lateral meristems. While monocots usually lack secondary growth, most seed plants do. Should secondary growth arise, it deviates from the typical pattern observed in other seed plants.Both the vascular cambium and the cork cambium, two lateral meristems, promote secondary development in many vascular plants. Secondary growth, which results from lateral meristems, broadens the plant's root or stem rather than making it longer. The diameter of the stem or root will increase as long as the lateral meristems continue to generate new cells. This process yields wood in woody plants and helps them grow into trees with larger trunks.

Anomalous secondary growth does not follow the pattern of a single vascular cambium producing xylem on the inside and phloem on the outside. A sequence of cambia arises beyond the oldest phloem in Bougainvillea, as an example of an anomalous secondary growth in dicots. The majority of monocots either have no secondary development at all or some sort of anomalous secondary growth. Diffuse secondary growth, for instance, occurs when parenchyma cells divide and enlarge, causing palm trees to increase the diameter of their trunks. A cambium arises in several other monocot stems that have abnormal secondary growth, but it only generates parenchyma outwardly and vascular bundles and parenchyma inside. A the primary thickening meristem that arises from the apical meristem causes some monocot stems to enlarge in diameter.

Glossary-

- **Apical meristem**: the totipotent, embryonic tissue found at the terminals of plant roots and shoots
- **Cambium**: a secondary growth-producing lateral meristem
- **Collenchyma**: Tissue with irregularly thickened cell walls; cellulose-based collenchyma cells are flexible and maintain the plant's immature sections without impeding development.
- **Cork:** a plant tissue made up of cells with suberin-impregnated walls that are dormant at maturity; the cork cambium produces cork.
- **Cork cambium:** During secondary growth, a thin, cylindrical sheath of meristematic cells generates cork cells to replace the epidermis (increase in width)
- **Cuticle:** An impenetrable layer of cutin on the epidermal cell walls
- **Manoxylic wood:** Wood type common to cycads that is rich in parenchyma
- **Mesarch:**This type of xylem maturation differs from endarch and exarch in that it takes place when the protoxylem is immersed in the metaxylem and develops both centripetally, or from the outside in, and centrifugally, or from the inside out.
- **Mesophyll:** Between a leaf's upper and lower epidermis is parenchyma tissue.
- **Metaxylem:** A type of primary xylem that, on average, has longer tracheids than protoxylem and differentiates and develops later than the latter.
- **Pith**: A vascular plant's primary parenchymatous tissue axis
- **Polystelic:**More than one stele are found
- **Primary growth**: Growth in length, controlled by the apical meristem

- **Procambium:**Primary xylem and primary phloem originate from this primary meristematic tissue; procambia are present in both apical and intercalary meristems.
- **Protoxylem**: the first primary xylem to develop and differentiate; protoxylem cells typically have a smaller diameter than metaxylem cells, and they typically occur before and during axis elongation.
- **Pycnoxylic wood**: dense wood, characteristic of Archeopteris conifers, with little parenchyma
- **Secondary growth**: The vascular cambium and cork cambium both begin and sustain the growth in width.
- **Secondary xylem**: Xylem produced by the vascular cambium
- **Siphonostele:** A stele type where the pith is surrounded by a ring of vascular tissue
- **Stele:**The position of the vascular tissue in stems and roots called the central vascular cylinder.
- **Tracheid:**A type of xylem cell that supports and conducts water, consisting of long, thin cells with tapered ends and lignin-hardened walls
- **Vascular bundle**: A strand of tissue composed mostly of xylem and phloem
- **Vascular cambium**: a lateral meristem in stems and roots that generates additional vascular tissue

Self -Assessment Questions-

1. Cork is develop by:

(a) Phellogen (b) Cambium (c) Phloem (d) Endodermis Ans. (a)

2. What is correct statement for monocot leaf?

(a) Mesophyll not differentiated into palisade and spongy tissues
(b) Absence of bulliform cells from epidermis
(c) Reticulate venation
(d) Well differentiated mesophyll Ans.(a)

3. Vascular cambium produces:

(a) Secondary xylem and secondary phloem (b) Primary xylem and primary phloem

(c) Primary xylem and secondary phloem (d) Secondary xylem and primary phloem

Ans (d)

5. Anomalous secondary growth found in:

(a) Yucca (b) Rice

(c) Maize (d) Wheat Ans. (a)

6. Which uncovered wood will decay faster?

(a) Sap wood (b) Soft wood

(c) Spring wood (d) Heart wood. Ans. (a)

7. A thin layer of cells with thin walls that is located between a dicot's phloem/bark and wood is :

(a) Pericycle (b) Vascular cambium

(c) Epidermis (d)Cork cambium Ans. (b)

8. Periderm is produced by:

(a) Pericycle (b) Cork cambium

(c) Phellogen (d) Intrafascicular cambium. Ans. (c)

Unit -5

STRUCTURE OF ANTHER AND POLLEN

Objectives-

After reading this unit students will be able to understand-

- Structure of Anther
- Development of Anther and pollen
- Process of Microsporogenesis
- Anther walls

5.1 Introduction-The male reproductive unit of flowering plants are called stamens. An anther, the site of pollen development and dispersal. The filament that contains the anther resemble a stalk and serves to both position and transfer nutrients and water to the anther, helping in pollen dispersal. In the majority of angiosperms, the anther dehisces at maturity by means of a longitudinal slit called the stomium, which releases the pollen grains.In flowering plants, the greatly reduced male gametophytes that develop in the sporophytic tissues of the anther are represented by the pollen grains. Male gametes, also known as sperm cells, are carried by these microgametophytes, also known as pollen grains, and are essential to plant reproduction during double fertilization.

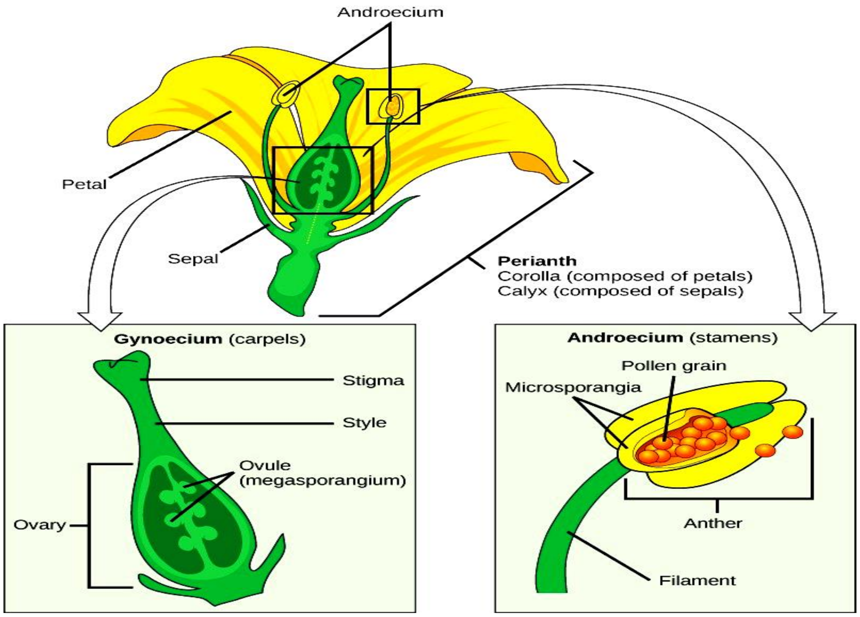
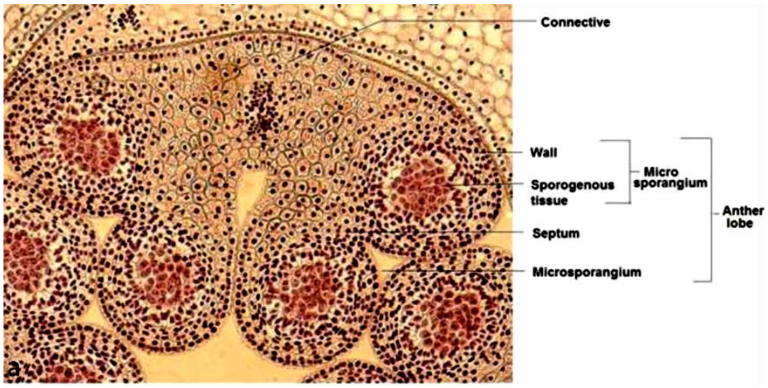


Figure 5.1 Diagram to show parts of a flower of an angiosperm

Figure 5.2

5.2 Structure of Anther - A typical anther has two microsporangia in each lobe and is a bilobed, dithecous structure. As a result, a tetrasporangiate structure with four microsporangia is an anther. The connective tissue is the non-sporangial tissue that connects the two anther lobes. The connective tissue contains one vascular strand inserted in it. The intersporangial septum, a strip of sterile tissue, divides the two microsporangia in each lobe. The enzymatic lysis of the septum in a mature anther causes the two sporangia in each anther lobe to confluence, forming a single



locule or theca. Certain plants, like Hibiscus rosa-sinensis, have anthers that are single lobed and made up of two microsporangia that, when they reach maturity, fuse together to produce a single theca, or monothecous.

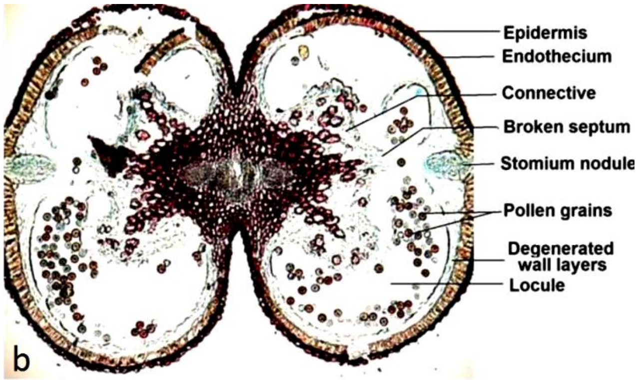


Figure 5.3 a. T.S. young tetrasporangiate anther b. T.S. old dithecous anther

5.3 Development of anther and pollen- A homogenous mass of cells enclosed by a distinct epidermis makes up a young, undifferentiated anther. Four groups of archesporial cells, one for each microsporangium, differentiate in the hypodermal position of a typical anther to form a four-lobed structure. Because of their size, thick cytoplasm, and conspicuous nuclei, archesporial cells are unique. Archesporial cells divide periclinally to generate primary parietal cells that face the epidermis and primary sporogenous cells that extend into the interior of anther protrusions. Primary sporogenous cells are formed in the center of the anther and primary parietal cells are formed near the epidermis by the periclinal division of archesporial cells. The anther wall layers are formed by a sequence of periclinal and anticlinal divisions of the parietal layer cells: an endothecium, which typically consists of 1-3 middle layers, and a tapetum. The sporogenous cells proliferate several times to generate secondary sporogenous cells before functioning as the microspore mother cells. Alternatively, the sporogenous cells—also known as the meiocytes, pollen mother cells, or microspore mother cells—act directly as the microsporocytes. The microspores' mother cells go through meiosis, grow into a unique callosic wall, and release tetrads of microspores. After emerging from the callose wall, these microspores, also known as pollen grains, grow and divide asymmetrically to produce a large vegetative cell and a small generative cell. At this stage, the pollen grains (2-celled pollen) are discharged in several taxa. In the others, before the pollen grains are released from the anther, the generative cell divides twice more to produce two male gametes, or sperm cells (3-celled pollen). After pollen germination, two-celled pollen grains go through their second mitotic division in the pollen tube.

Microsporogenesis- Microsporogenesis is the series of processes that lead to the production of haploid uninucleate microspores within the microsporangia.

Microgametogenesis-Microgametogenesis is the term used to describe the processes that result in the microspores developing into microgametophytes, or pollen grains carrying sperm cells.

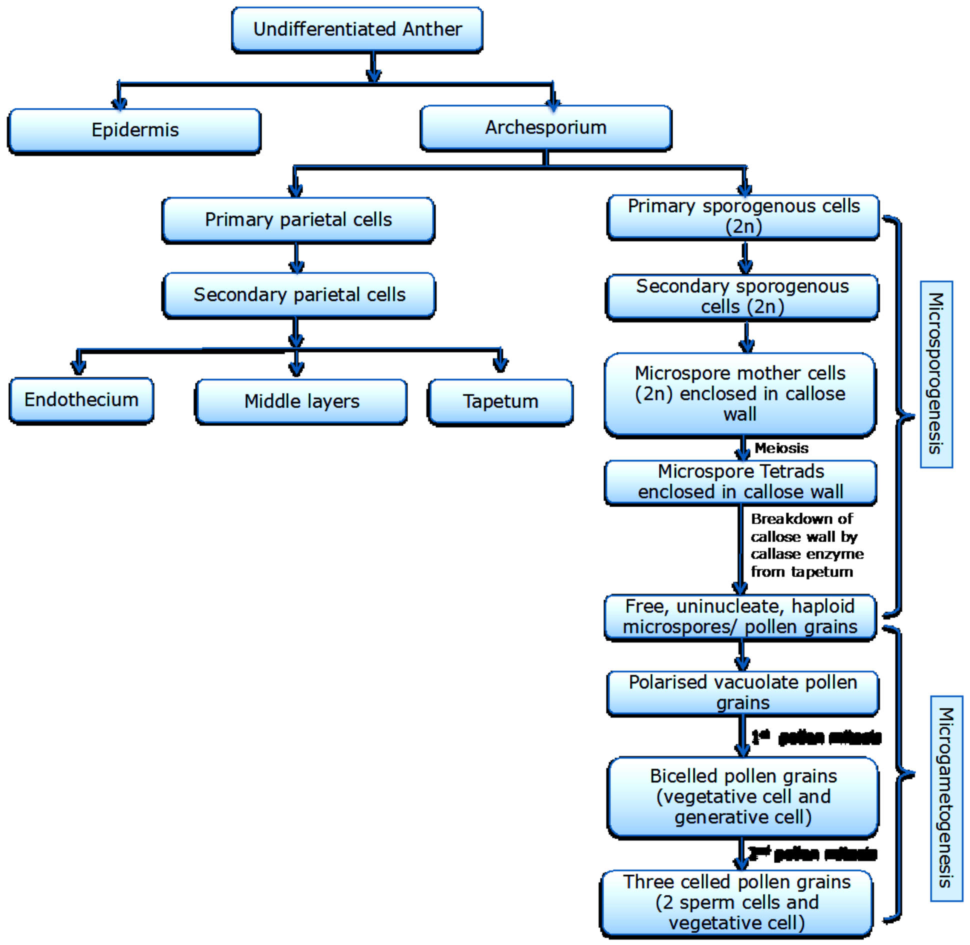
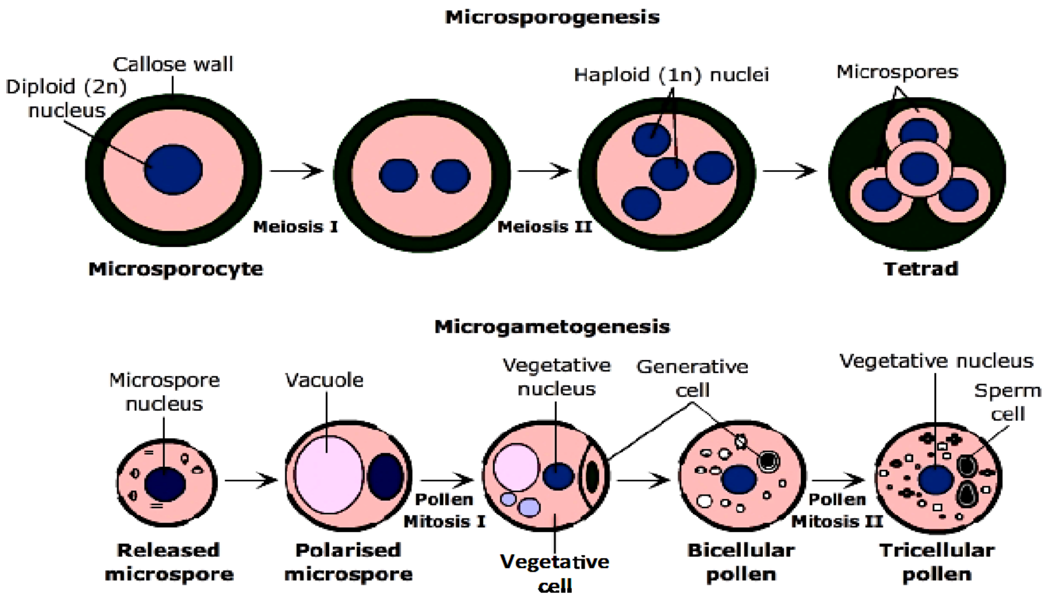


Figure 4. Schematic flowchart showing anther and pollen development
Source: Developed by author

Diagrammatic representation of the sequence of events in microsporogenesis and microgametogenesis.



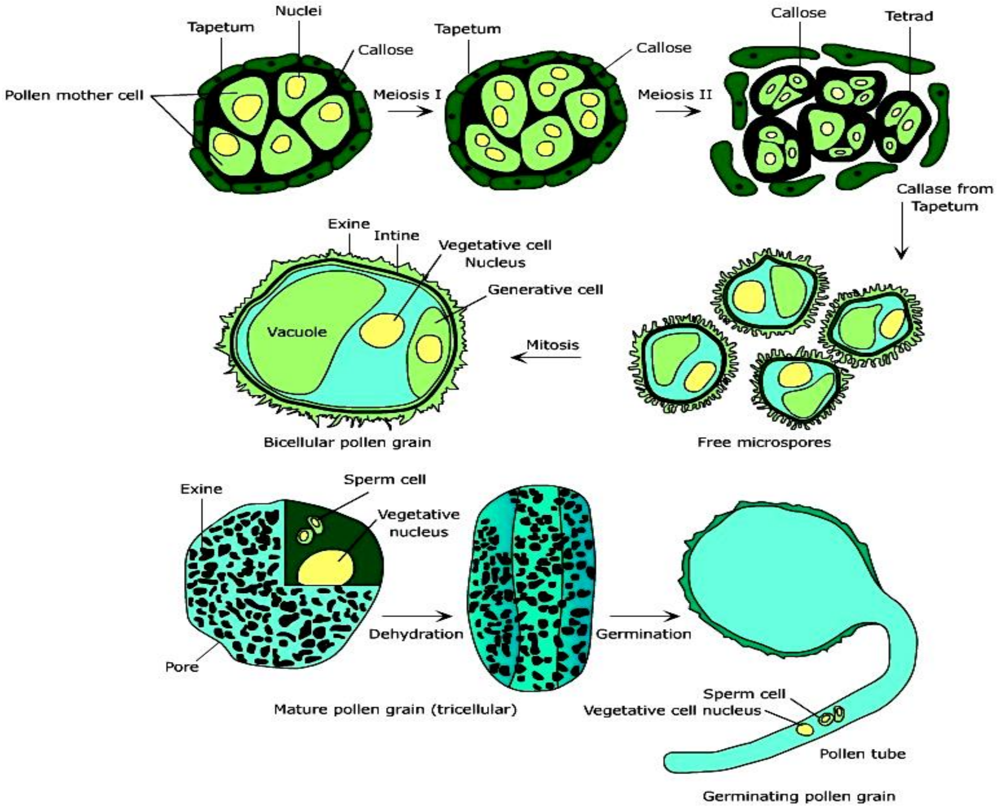


Figure 5.4 Schematic Diagram showing pollen development

5.4 Anther wall- The well-differentiated anther walls are following-

- Epidermis
- Endothecium
- Middle layers
- Tapetum

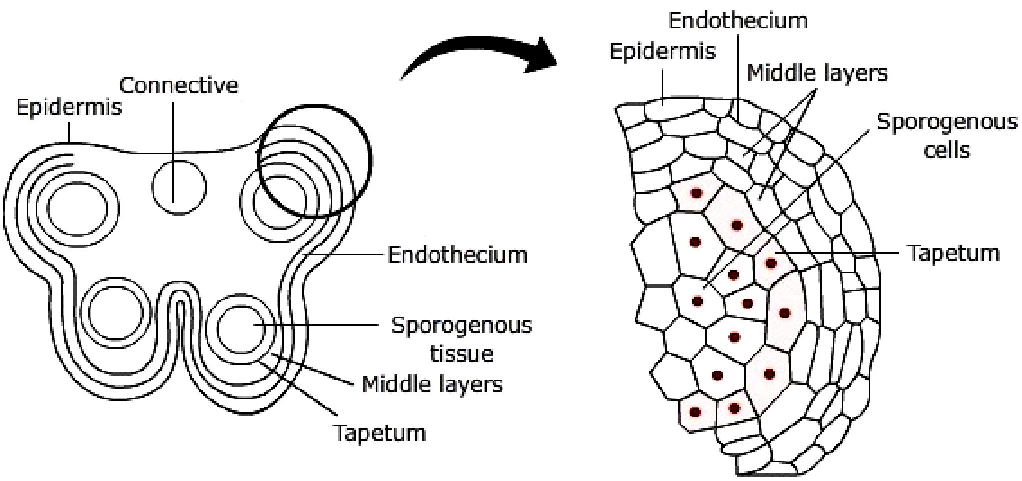


Figure 5.5 a and b. Diagrammatic view of TS anther showing wall layers

Epidermis-The anther's outermost layer, the epidermis and has a protection function. According to Goldberg et al. (1993), the endothecium and the epidermis work together to give the anther structural support and prevent water loss. The anther also participates in the dehiscence process. The epidermal cells are significantly stretched and flattened in a mature anther. In the region of the presumed stomium, the epidermal cells develop into small, specialized cells that divide to allow for the dehiscence and release of pollen grains at anther maturity.

Endothecium-The endothecium is the hypodermal layer of the anther wall that remains in the mature anther and is located beneath the epidermis. In most angiosperms, it is only found in the protuberant portion of the anther and is typically single layered. The endothecium's cells are often highly vacuolated and uninucleate. In the cells, a few starch granules are often found. When the anther is ready to dehisce and release pollen, these cells become maximally developed and radially elongated. Fibrous bands of lignocellulosic secondary thickenings have an upward deposition pattern and originate from the inner tangential walls of the endothecium cells. There are still thin outside tangential walls. At the point where the two sporangia converge, the endothecial cells do not thicken more. Anthers' dehiscence requires the mechanical force provided by these fibrous rings.

Middle layers

Middle layers usually number one to three; some angiosperms, like Lilium, have more layers in their anthers, while others, such as Wolffia and Vallisneria, lack them. The cells are vacuolated, uninucleated, flattened, and have thin walls. They contain a lot of reserve food material, such starch, which is released as pollen develops. The microspore mother cells undergo meiosis, which crushes the middle layers, which are often temporary or ephemeral. According to Bhojwani et al. (2014), one or more intermediate layers may last until the anthers dehisce in plants such as Lilium and Ranunculus. Certain plants have intermediate layers that can grow secondary thickenings that resemble endothecium cells, as seen in Heliconia species (Simao et al., 2007) and help with anther dehiscence.

Tapetum

The anther wall's outermost layer, known as the tacepum, envelops the sporogenous tissue entirely. It is often single-layered and serves a number of nutritional and secretory purposes that are connected to the growth, germination, and pollination of pollen. Many angiosperms have a dual-originated tapetum. The parietal layer contributes to the tapetum's outer layer, whereas connective tissue is responsible for its interior section. The cytoplasm of the tapetum cells is thick, with conspicuous nuclei and a profusion of organelles including plastids, mitochondria, endoplasmic reticulum, dictyosomes, vesicles, and ribosomes. Through mitotic division of nuclei (multinucleate), development of restitution nuclei, endomitosis, or polyteny, which indicates a high metabolic activity, the cells frequently become polyploid. At the tetrad stage of microsporogenesis, the tapetum reaches its peak development.

There are two types of tapetum:

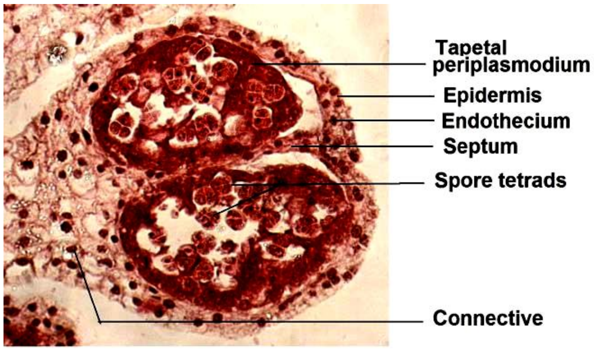
- Amoeboid tapetum
- Secretory tapetum

Amoeboid/ Invasive Tapetum

Monocots such as Arum italicum, Tradescantia bracteata, Butomus umbellatus, and Typha spp. often contain amoeboid tapetum. Members of the Poaceae family, or grasses, are an exception, since they typically exhibit secretory tapetum. The majority of the dicot family Asteraceae, including Helianthus annuus and Ambrosia trifida, also include amoeboid tapetum.

Amoeboid/ invasive type of tapetum is identified by:

- The inner radial and tangential walls of the cells break down early (usually during meiotic prophase or up to the tetrad stage),
- The invasion of the anther locule by tapetal protoplasts
- A multinucleate tapetal periplasmodium/syncytium that tightly engulfs and invests the developing microspores is formed by the fusion of tapetal protoplasts. The tapetal periplasmodium is an ordered and functioning entity with normal organelles and strong metabolic activity, according to ultrastructural investigations of the plasmodial tapetum.
- The passage of nutrients is more effective in the tapetal protoplasts than in the secretory tapetum because they maintain close contact with the developing pollen. It is a characteristic of amoeboid tapetum species that they do not generate orbicules, commonly known as ubisch bodies. Nonetheless, it has been shown that several species with amoeboid tapetum contain sporopollenin-like granules on their tapetal remains that are often smaller than the orbicules created by secretory tapetum. For instance, Butomus umbellatus (Fernando and Cass 1994), Persea palustris (Furness and Rudall 2001), and Tradescantia virginiana (Tiwari and Gunning 1986).



T.s. anther with amoeboid tapetum and spore tetrads

Figure 5.6

Secretory/ Parietal Tapetum- In dicotyledon (*Citrus limon, Capsicum annuum, Helleborus foetidus, Prosopis juliflora, Lycopersicon peruvianum*), secretory tapetum is common. However, some monocot groups like Liliaceae (Lilium longiflorum) and Poaceae (Sorghum bicolor, Avena sativa) include it. During the microspore formation process, the tapetal cells in secretory tapetum maintain onto their original place and identity. Towards the end of pollen development, the cells inevitably undergo in situ degeneration. Substances may be transported across the plasma membrane via secretion or exocytosis from the tapetal cells into the locule. Orbicules, also known as ubisch bodies, are sporopollenin granules or entities that are a defining component of the secretory tapetum. Orbicules and ubisch bodies are formed by the accumulation of sporopollenin in the progenitors of orbicules, also known as pro-orbicules or pro-ubisch bodies. Many plants have pro-orbicules that start in the secretory tapetal cells' endoplasmic reticulum (Echlin and Godwin, 1968; Vijayaraghavan and Chaudhry, 1993; Garcia et al. 2002; Rosenfeldt and Galati 2005). It is known that sporopollenin is transported via the orbicules between the growing pollen exine and the tapetum.

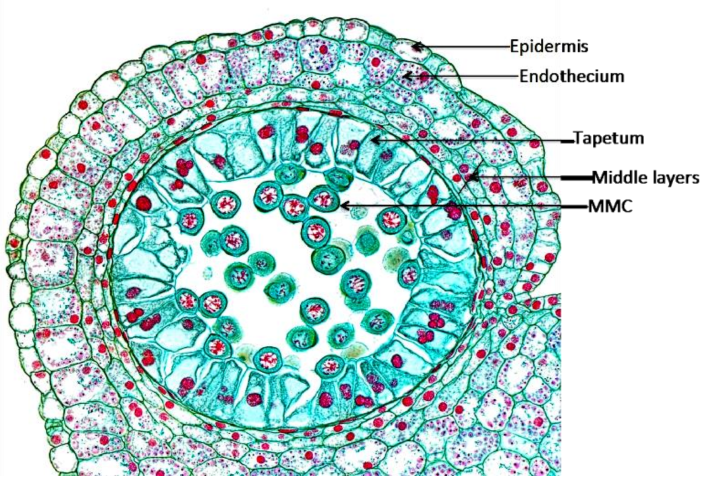


Figure 5.7 T.S. *Lilium* secretory tapetum

Orbicules

Orbicules are small sporopollenin particles, typically with a diameter of less than one micrometer to a few µm, however they often combine to form larger complex aggregates. To form the orbicules, also known as ubisch bodies, they are extruded into the anther loculus where they rapidly absorb the sporopollenin covering. In the tapetal cytoplasm, they start out as lipid droplets known as pro-orbicules or pro-ubisch bodies. They are typically observed closely interacting with the pollen grains as they line the inner tangential walls of the secretory tapetum.The orbicules, which are made of sporopollenin similar to that of the pollen exine, develop simultaneously with the growing pollen exine. Angiosperm ornamentation on the pollen exine and the orbicule wall often shows remarkable parallelism. In order to generate the orbicules and the mature exine of pollen grains that are particular to a given species, the sporopollenin condenses atop both the pro-orbicular cores and the exine initials. Spiny orbicules are typically seen on pollen grains containing echinate exine.

Functions of Orbicules

- The pattern of the external thickening of the exine, which is laid down by the spore cytoplasm in the tetrad stage, has been linked to the orbicules as a sporopollenin transport mechanism.
- They may have a role in pollinosis, a dangerous allergic reaction in the lower respiratory tract, and have been identified as allergen vectors in the tapetum of some plants (Vinckier and Smets, 2005).
- By forming a hydrophobic locule surface that allows pollen to separate readily, the orbicular wall may actively contribute to pollen dispersion.
- Orbicules with comparable ornamentation may also be valuable from a taxonomic standpoint, as pollen exine ornamentation provides valuable features for systematics.

Tapetal membrane

The tapetal membrane, an acetolysis-resistant membrane, forms in tandem with the tapetum's growth. The main components of the tapetal membrane, which comes from the secretions of the tapetal cells, include sporopollenin, insoluble polysaccharides such cellulose, and trace quantities of callose and pectin (Shivanna 2003). The tapetal membrane forms on the inner surface of tapetal cells in species that have secretory tapetum (towards the locule). The orbicules, also known as ubisch granules, are studded on this membrane. The membrane forms on the tapetum's exterior in species that have plasmodial tapeta (toward the endothecium). Heslop-Harrison speculates that this additional tapetal membrane functions as a culture sac, encapsulating the labile periplasmodium and the growing microspores.

Functions of Tapetum

One of the most important anther wall layers in terms of function is the tapetum, and tapetal abnormality is always associated with pollen sterility.

- The tapetum has a role to supply nourishment to the growing pollen (nurse tissue). Any nutrients that want to reach the sporogenous cells must go via the tapetum since it encloses the sporogenous tissues on all around. The growing pollen and the tapetal protoplasts in the plasmodial tapetum are closely associated, enabling the transfer of nutrients. In secretory tapetum, nutrients are secreted or released into the locule fluid, where they are absorbed by pollen that remains growing.
- The tapetum secretes an enzyme called callase (α^-1,3 glucanase), that helps in the breakdown of the callose wall around the microspore tetrads. Petunia cytoplasmic male sterility is caused by the tapetum's precocious release of callase.
- The pollen exine contains precursors of sporopollenin from the tapetum. Both the plasmodial and secretory tapetum exude the precursors, which are then converted into sporopollenin, the main element of the pollen wall's exine. After the tetrads release their microspores, the tapetum synthesizes sporopollenin, which deposits most of the exine. The exine blueprint is set when the tetrads are still covered in callose walls in many species. The tapetum's synthesis of sporopollenin is also linked to the production of orbicules in the secretory tapetum.
- The chemicals known as tryphine and pollenkitt are obtained from the tapetum. These are deposited on and inside the pollen exine after tapetum degeneration. In order to aid in pollination, tryphine and pollenkitt aid in the adhesion of the pollen grains to one another and to the insect pollinators. To stop the loss of water, they also seal the pollen grains at the openings. Pollenkitt consists primarily of hydrophobic lipids that contain species-specific carotenoids, glycolipids, and glycoproteins, whereas tryphine is a complicated combination of hydrophilic and hydrophobic components. While tryphine appears to be limited to the family Brassicaceae, pollenkitt, often known as "pollen glue" in German,

produces an oily, sticky coating around the pollen grains of numerous angiosperms pollinated by insects (Pacini and Hesse, 2005). The pollenkitt is responsible for the stickiness, smell, and yellow/orange color of the pollen grains. The biological roles of the pollenkitt include helping to disperse pollen, attracting insects, shielding pollen from the harmful effects of UV light, and being the pollen-borne component of sporophytic incompatibility.

- Pollen wall proteins are supplied in part by the tapetum. Both intine and exine proteins—which are produced from the tapetum—and proteins from the pollen cytoplasm are found in the pollen wall. The inter-bacular chambers of the exine contain the exine proteins of the tapetal origin. Sporophytic self incompatibility, in which the stigma either accepts and promotes the germination of compatible pollen or rejects incompatible pollen, is mostly influenced by the interaction of these exine-generated recognition proteins with the recognition proteins produced by the stigma. When pollen settles on an incompatible stigma, these proteins cause the stigma to produce callose plugs, which impede the expansion of the pollen tube and pollen grains.

Summary

- ➢ The development and dispersal of pollen occurs in an anther. To facilitate multiple fertilization, the sperm cells are transported to the female reproductive organs by the microgametophytes, also known as pollen grains, which grow inside the anther.
- ➢ An anther is normally a bilobed, tetrasporangiate structure with two microsporangia in each lobe. Because of the septum's disintegration during maturity, the two sporangia in each lobe confluence.
- ➢ Microsporogenesis is the process via which microspores or pollen grains form inside microsporangia. Microgametogenesis is the process by which microspores evolve into microgametophytes, or pollen grains carrying sperm cells.
- ➢ he epidermis, endothecium, 1-3 between layers, and tapetum make up the well-differentiated anther wall.
- ➢ At maturity, the specialized epidermal cells in the stomium region rupture to aid in pollen release and anther dehiscence.

- . The epidermis also acts as protection, providing structural support and preventing anther water loss.
- The lignocellulosic secondary thickening that the endothecium produces forms fibrous bands that supply the mechanical force required for anther dehiscence.
- Short-lived middle layers are crushed during pollen formation. Nutrients for the growing pollen are stored in the cells.
- The formation of pollen is greatly influenced by teatum. Two primary forms of tapetum exist: secretory/glandular/non-syncytial/parietal tapetum and amoeboid/invasive/syncytial/periplasmodial tapetum. One distinguishing hallmark of secretory tapetum is orbicules, also known as Ubisch bodies.
- The tapetum plays a role in the development of pollen by providing nutrients, sporopollenin precursors to the pollen wall exine, release of substances that coat the pollen, such as tryphine and polllenkitt, pollen wall proteins, and callase enzyme, which breaks down the callose wall surrounding microspore tetrads.

Glossary-

- **Amoeboid tapetum:**A type of tapetum in which the tapetum cells' walls break down before the protoplasts fuse to form a plasmodium that invades the anther locule and makes sure the growing microspores are in close contact with them. The majority of plants in this form of tapetum are devoid of orbicules.
- **Anther :**The part of a stamen that generates and releases the pollen grains is called an anther.
- **Anther dehiscence:** At maturity, the anther splits along a natural line of weakness.
- **Anther locule:**A liquid-filled region where pollen grains grow and mature inside the anthers
- **Endothecium:**The anther wall's hypodermal layer, which gives anther dehiscence its mechanical strength, is characterized by the deposition of fibrous bands of lignocellulosic thickenings.

- **Microgametogenesis**:the process by which male microgametes develop from microspores.
- **Microsporogenesis**:The series of events that causes haploid, uninucleate microspores inside the microsporangium to form.
- **Orbicules or Ubisch bodies:**Small sporopollenin bodies, which are often seen in the secretory tapetum, may be involved in the sporopollenin's transportation to the exine.
- **Pollenkitt:**Many insect-pollinated species have an oily, thick, viscous coating on their pollen grain surfaces that aids in sticking the grains together, the pollen to insect pollinators, and the stigma surface.
- **Secretory tapetum:**A type of tapetum in which the tapetal cells degenerate in situ at the end of pollen development while retaining their identity and position during microspore development. Orbicules are a defining feature of this kind of tapetum.
- **Tapetum:**The layer deep inside the anther wall, which is crucial for secretory and transport processes involved in pollen formation, pollination, and germination.

Self Assessment Questions-

1. Which part of the flower produces pollen**?**

a) Anther b) Stigma

c) Ovary d) Style

Answer: c)

2. How many lobes typically compose an anther?

a) Two b) One

c) Four d) Three

Answer: a)

3. The outermost layer of the anther is:

a) Tapetum b) Epidermis

c) Endothecium d) Middle layers

Answer: b)

4. The outer layer of the pollen grain is known as :

a) Intine	b) Exine
c) Endothecium	d) Microspore

Answer: b)

5. Pollen grains are develop in which part of the anther?

a) Filament	b) Pollen sacs (microsporangia)
c) Connective	d) Stigma

Answer: B)

UNIT – 6

STRUCTURE & TYPES OF OVULES

Objectives-

After reading this unit students will be able to understand-

- Structure of ovule
- Types of ovule
- Types of placentation
- Function of ovule

6.1 Introduction- Female reproductive part of the flower is called gynoecium or pistil.It consistsof three parts known as ovary, style and stigma. Ovule is also known as the megasporangium and is a component of the female reproductive system of seed plants. The female reproductive system in seed plants consists of ovaries at the base of vase like structure known as carpel comprising an aperture at the top called stigma, and a neck called a style. The female gametophyte is a haploid structure which is also known as a megagametophyte or the embryo sac.

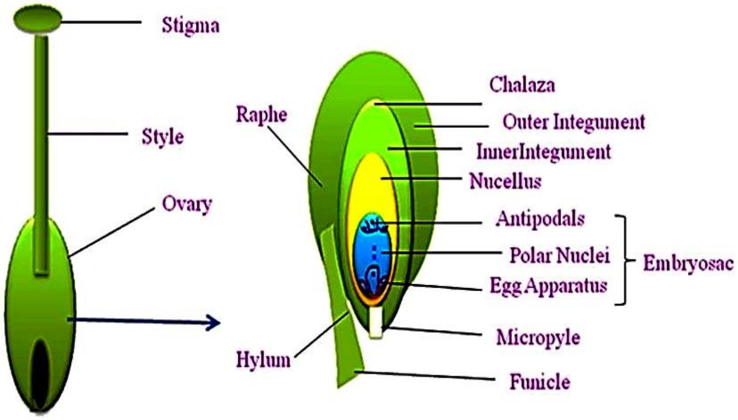


Figure 6.1: Structure of Gynoecium & L.S. of Ovule.

6.2 The ovule is composed of the following components

Ovule consists of variousparts such as Integuments, Endothelium, Obturator, Micropyle, Nucellus, Embryo Sac, Hypostase, Epistase

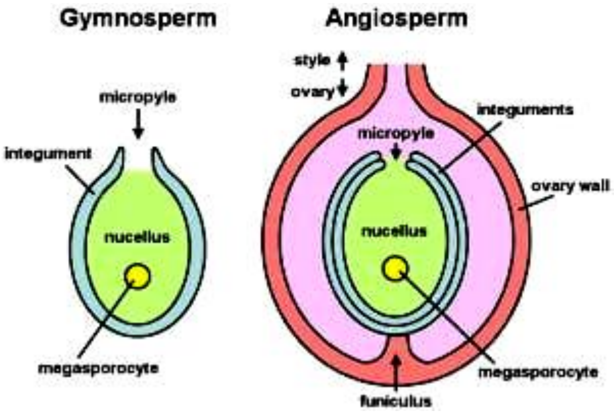


Figure 6.2

Integuments:

The outermost layer which surrounds the ovule, provides protection to it is called as an integuments. After the fertilization in ovule, the integuments metamorphose into the seed coat. One integument is present in Gymnosperms (unitegmic), whereas two integuments are present in Angiosperms (bitegmic).

The integuments do not entirely cover the nucellus. A small gap is present at the apex which is called the micropyle. A male gametophyte (pollen) enters the ovule through the micropyle opening and fertilizes it.

The nucellus and integuments are connected at the chalaza, which is located across from the micropyle.

Ovules are categorized on the basis of integuments.

1. **Unitegmic ovules: T**he ovule is enclosed by one integument is termed as In unitegmic ovules e.g.Sympetalae.
2. **Bitegmicovules:** Ovule with two integuments is called bitegmicovule e.g:Polypetalae.
3. **Ategmic ovules:** Ovules having no integument around nucellus are called ategmic ovulese.g. *Loranthus, Viscum, Santalum*.

4. **Aril:** In some plants, from the base of the ovule third integument develops known as aril e.g.*Litchi, Myristicafragrans*.
5. **Caruncle:** It is an outgrowth of the outer integument found near the micropylarregion e.g.*Ricinus*. Presence of caruncle is characteristic feature of the family Euphorbiaceae. This structure absorbs water and swells up leading to the separation of ovule from placenta. This is useful for dispersal of seeds in some plants.

Nucellus

It is the most significant component of the ovule. It contains nutritive tissue and act as a nutritive tissue for the growing embryo.

The nucellus, is the ovule's inner structure made up of a layer of sporophytic or diploid cells near the integuments. In some plants nucellar embryony, an asexual reproduction process occurs, that allows the diploid nucellus tissue to give birth to the embryo inside the seed. The perisperm which nourishes the embryo may grow from the nucellus after fertilization.

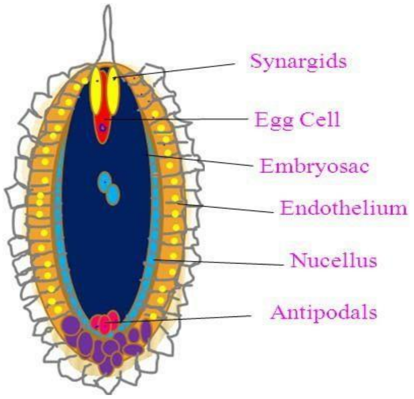
After the process of fertilization, the ovule develops a wall to develop into a seed, which subsequently germinates and give rise to form an adult plant.

In flowering plants *the Angiosperms*, the ovules are found inside of the ovary within the carpel whereas in *Gymnosperms* the ovules are present on the scales of female cones.

In flowering plants, the ovule is found inside the gynoecium, a part of the flower. The fruit wall develops from the ovary of the gynoecium, in which more than one ovule are produced. A funicule, a stalk like structure helps in connecting the ovules to the placenta.

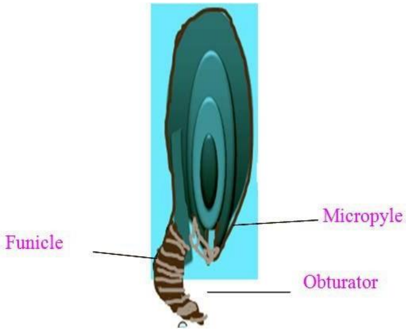
After Fertilization ovule develops into seed and integuments form the seed coat.

1. **Endothelium:** It is single layered present in the plants belonging to the sympetalae with unitegmic, tenuinucellateovules. The degeneration of nucellus takes place at an early stage of ovule development.Thus the inner most layer of the integument becomes specialized to perform nutritive function for the embryo sac. In *Helianthus* (Asteraceae) multi- layered endothelium of 10-12 layers arepresent.



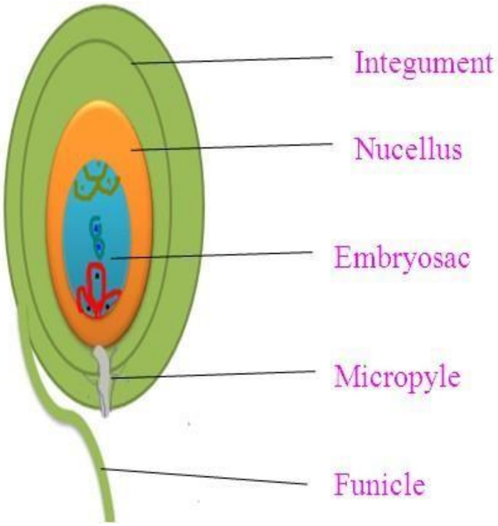
Radially elongated cells with densecytoplasm, nucleus having stored food reserves in the form of starch and fats are present.It performs nutritive function fordeveloping embryo and hence known as integumentarytapetum.

2. **Obturator:** This ovular structure directs the growth of pollen tube towards the micropyle It shows great variation in their origin, morphology, anatomy and extent of development. They may originate from funiculus or placenta or both. The most common type obturator is one formed by local swelling of funiculus e.g. Acanthacae, Anacardiaceae, Labiateae, Magnoliaceae



1. **Micropyle:** Integuments do not cover the nucellus of an ovule completely andleave a small opening known as micropyle. Pollen tube enters through this passageinto theovule.

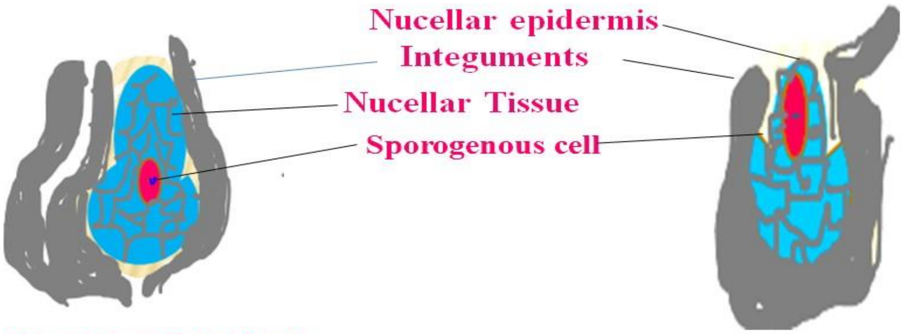
In bitegmic ovules either both the integuments or only the inner integuments is involved in the formation of micropyle. When both integuments are involved, the passage formed from the outer integument is called exostome and that formed by the inner integument is calledendostome.



2. **Nucellus:** Nucellus is a diploid tissue that is present in the body of ovule, enclosed by integuments. It is a wall of mega sporangium. Only one nucellus is present in each ovule, abnormally twin nucelli may occur in a common fold of integuments e.g. *Aegle marmelos. Hydrocleys nymphoides.* Nucellus develops from archesporium, below the nucellar epidermis. In Angiosperms, the ovules are classified into two types on the basis of the extent of nucellus.

I. CrassinucellateII. Tenuinucellate

I. **Crassinucellate:** In polypetalae and monocotyledon plants the archesporial cell divides to form an outer parietal cell and another sporogenous cell towards inner side. The parietal cell then further divides through periclinal and anticlinal divisions. forming massive nucellus called crassinucellate ovules.



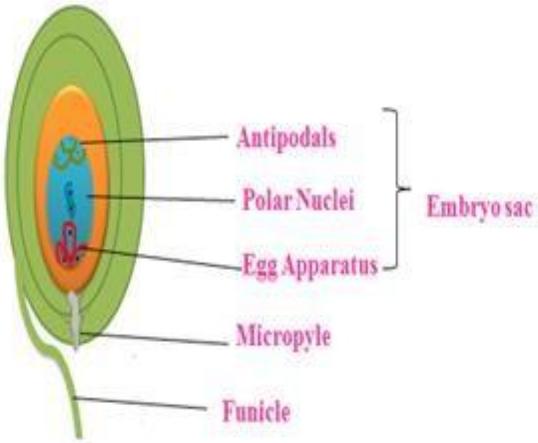
Crassinucellate Ovule

Tenuicellate Ovule

II. **Tenuinucellate:** In sympetalae the archesporial cell acts as a megaspore mother cell. In such ovules the nucellar tissue present around is single layered and the hypodermal sporogenous cell is present are known as tenuinucellate. Tenuinucellate ovules assumed to be more advanced than Crassinucellate ovulesNucellar tissue is generally confined to inner integument, but rarely it is projected into micropyle (Caryophyllaceae) or beyond it forming a beak like structure called nucellar beak e.g. members of Euphorbiaceae, Cucurbitacae, Nyctaginaceae. Nucellus is consumed by developing embryo sac or endosperm. In some plants nucellus is present in mature seed as nutritive tissue called perisperm.

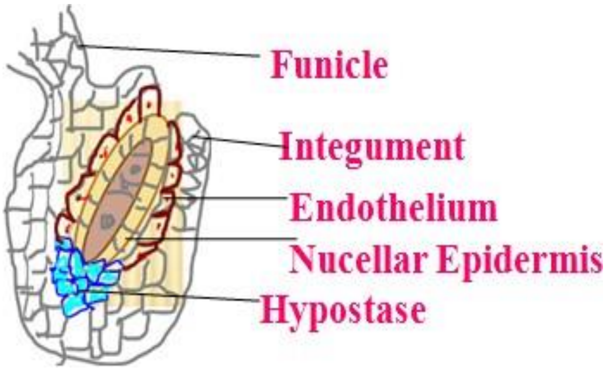
Embrayo sac: It is also called a female gametophyte. Embryo sac is a 7 celled or

nucleate structure presents in the nucellus. It comprises of a large central cell with two polar nuclei which later fuse to form the secondary nucleus. Egg apparatus is present at the micropylar end comprises of an egg cell and two synergids, three antipodal cells present at the chalazal end. Uninucleate and haploid cells of the egg apparatus and antipodal cells are present, whereas binucleate or diploid central cell is also present.



1. **Hypostase:** This is present below the embryo sac and above the vascular supply to the funiculus. It is a group of disc like or plate like cells derived from nucellar cells. Due to lignification the cells are thick walled and are poor in cytoplasmic contents. In some plants the cells of the hypostase may surround a portion of the embryo sac or may even extend into the micropylar half of the ovule.

Hypostase occurs in many families such as Amaryllidaceae, Liliaceae, Zingiberace Euphorbiaceae, Theaceae and Umbelliferae.In some plants it is present below the archesporium (Loranthaceae) or it may even persists in the mature seed *(Eg: Aristolochia)*.



Functionsofhypostase:

1. This term was for the first time proposed by Van Tiegham to a structure that forms a barrier or boundary for growing embryo sac and prevents from protruding into the base of the ovule
2. During hot dry seasons it helps in maintaing water balance in a resting seed.
3. It helps in transporting nutrients by connecting the vascular bundle in the funiculus with the embryo sac
4. It produces some enzymes or hormones useful for growth.
5. Provides protection to mature seed

3. Epistase:

It is a caplike structure of cutinized cells formed above the embryo sac by thenucellar epidermis, e.g. *Costus*. It is nutritive in function.

Different types of attachment or placentation patterns of ovules are present such as:

- **Basal placentation**
  A single ovule is present at the base of ovary with the placenta Eg: Marigold
- **Axile placentation**
  Ovule in a multilocular ovary is linked through axial placanta. Eg Lemon
- **Marginal placentation**

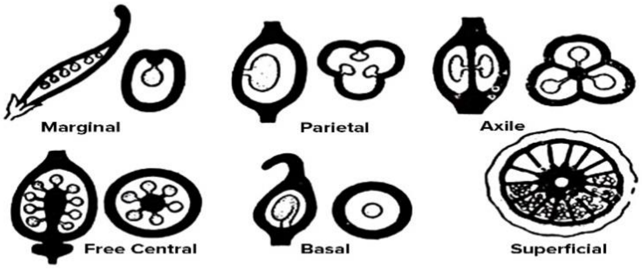
In this type of placentation, a ridge is formed by placenta and ovules are present in two rows on it. Eg. Pea

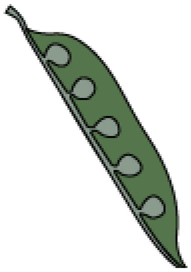
- **Free-central placentation**

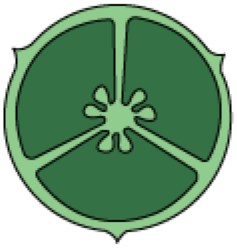
  Ovules are present on the central axis and no septa are present. Eg: Primrose

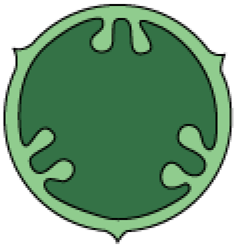
- **Parietal placentation**

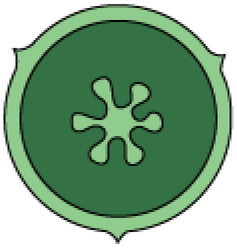
  Ovules are present either on the inner wall or periphery of ovary. Ovules are present in a single chamber or two chambers. Eg: Mustard

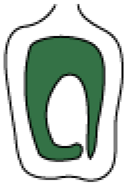



Marginal placentation


Axile placentation


Parietal placentation


Free central placentation


Basal placentation

6.3 Types of Ovules

On the basis of morphologies, ovules are categorized into six groups:

Amphitropous

The ovule’s structure is curved, and it is similar in structure to a horseshoe.

Orthotropous or Atropous

These types of ovules are straight, making in alignment the micropyle, the funicle connects the ovule to the placenta, and the chalaza, a point where the integuments and nucellus combine.

Anatropous

A hilum is the spot where the funicle connects the seed to the fruit wall. In this type the ovule is inverted during development, causing the micropyle to be located near the hilum.

Hemi-anatropous

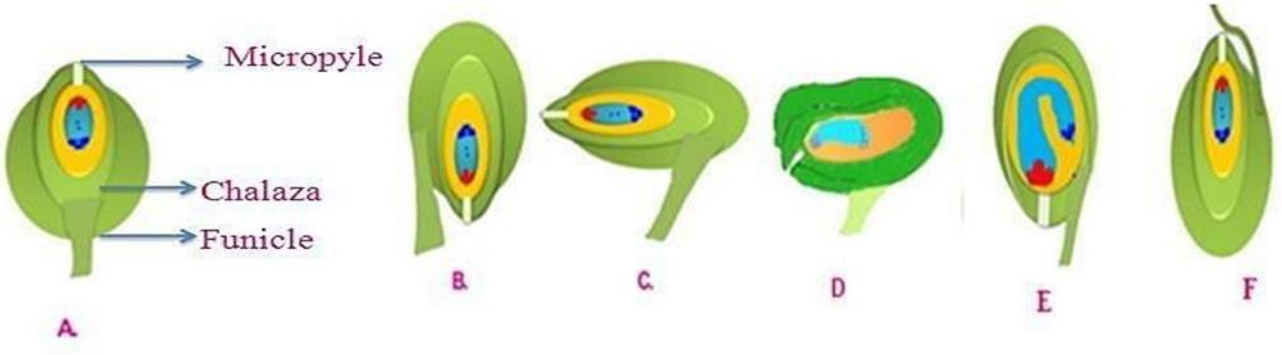
These ovules are present at 90^0 to the funicle.

Circinotropous

The funicle is particularly long, forming a nearly complete circle around the ovule, whose micropyle eventually points upward.

Campylotropous

The coordination present between the micropyle and chalaza is absent and the therefore the body is bent.



A. Orthotropous ovule B. Anatropous Ovule C. Hemianatropous Ovule

D. Campylotropous ovule E. Amphitropous ovule F. Circinotropous ovule

Summary

Flower has female reproductive part known as gynoecium or pistil consistingof three parts ovary, style and stigma. Ovule is also known as the megasporangium and is a component of the female reproductive system of seed plants. The female reproductive system in seed plants consists of ovaries at the base of vase like structure known as carpel comprising an aperture at the top called stigma, and a neck called a style. The ovule is composed of the following components

Ovule consists of variousparts such as Integuments, Endothelium, Obturator, Micropyle, Nucellus, Embryo Sac, Hypostase, Epistase. Ovules have been divided into six groups Amphitropous, Orthotropous or Atropous, Anatropous, Hemi-anatropous, Circinotropous, Campylotropous. Different types of attachment or placentation patterns are present such as: Basal, Axile, Marginal, Free-central and Parietal placentation

Self- assessment questions

Q1. What is the name of stalk by which an ovule is attached to the placenta

a). Funicle b). Hilum

c). Chalaza d). Micropyle Ans a). Funicle

Q2. Hilum represents the junction between

a). Funicle & Nucellus b). ovule and funicle

c). Micropyle and funicle d). Chalaza and funicle Ans b).ovule and funicle

Q3. The ovule of an angiosperm is equivalent to

a).megaspore b). megaspore spore cell

c). megasporophyll d). megasporangium Ans d).megasporangium

Q4. Embryo sac is found inside the

a). Megaspore b). Ovule

c). Integument d). Style Ans b). Ovule

Q5. A mass of nutritive material outside the embryo sac is known as

a). Epidermis b). Sporocarp

c). Ectoderm d). Perisperm Ans d) Perisperm

Short Questions

Q1. What are different types of ovules.

Q2. Write different types of attachment or placentation patterns of ovules

Q3. Write a note on Nucellus

Q4.What is integument and write its significance.

Q5.Write a note on Hypostase and mention its functions.

UNIT 7

Ultra structure of mature embryo sac and types

Objective-

After reading this unit students will be able to understand-

- Embryo sac
- Megasporogenesis
- Structure of Embryo Sac
- Types of Embryo sac

7.1 Introduction

Embryo Sac

An ovule of a female flowering plant consists of a structure known as embryo sac formed as a result of the process of Megasporogenesis and megagametogenesis. Embryo Sac plays an important part in the reproduction of female flowersby facilitating male sperm cells to enter and fertilize Embryo Sac.

Embryo Sac represents female gametophyte of a seed plant, made up of a thin-walled sac within the nucellus which contains the egg nucleus and other nuclei that produce endosperm upon fertilization. The mature embryo sac is made up of seven cells and eight nuclei. In plants different types of embryo sac development is seen out of which Polygonum type of embryo sac development is the most typical type. The Polygonum type of embryo sac is monosporic as one of the four megaspores present is produced by meiosis. Monosporic megaspore as a result of three sequential mitosiscycles in its nuclei result into the formation of eight-nucleated embryo sac

7.2 Megasporogenesis

Megasporogenesis takes place inside megasporangia. It is the process through which megaspores develop from megaspore mother cell. During meiosis haploid megaspores form a linear tetrad, three of the four megaspores degenerate out of which one usually remains functional near the chalaza end (polygonum type).

Ovule act as a center of Megaspore production and the development

Megaspore production and the development of the embryo sac occur in the ovule that is emerging from the ovary's placenta (female gametophyte).

The ovule is mainly composed of following parts: the stalk linking the ovule with the placenta known as Funiculus ; one or two integuments which surrounds the nucellus the central body.

The chalaza, represents an area where the nucellus, integuments, and funiculus meet.

An aperture called micropyle where the inner integument curves over the nucellus developed due to one or both integuments. The size of the nucellus varies in ovules. Crassinucellate ovules have larger nucelli whereas tenuinucellate have smaller nuclei.

Archesporium develops in the nucellus from hypodermal cell first forming the primary archesporial cell. Due to periclinal division

This cell undergoes periclinal division to create the primary parietal celland the primary sporogenous cell. The main sporogenous cell performs the role of the megaspore mother cell, going through meiosis to create megaspore.

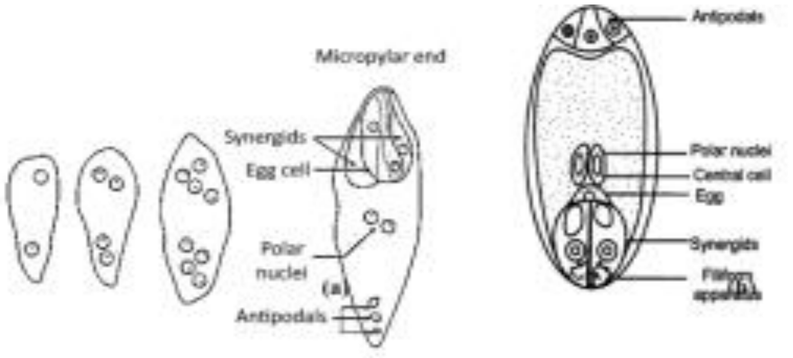


Fig: (a) Development of female gametophyte; (b) Mature embryo sac

Figure7.1

7.3 Structure of Embryo Sac

The egg and two synergids are present in the egg apparatus, these three cells are present at the micropylar end. At the other end of the embryo sac three antipodal cells are present.

Between the two groups of cells a big central cell is present resulting into the formation of two polar nuclei derived from each of the two groups of four nuclei.

The two polar nuclei unite and fuse to form a diploid secondary nucleus forming a seven-celled the mature embryo sac. In the embryo sac all the cells are haploid except the central cell.

Chemo-tropically active compounds are secreted by Synergids to control the expansion of the pollen tube. One of the synergids receives the content from the pollen tube and also serves as a prospective egg cell when egg is not functioning. Antipodal cells play no role in fertilization. A male gamete fuses with the egg nucleus during fertilization to create a zygote.

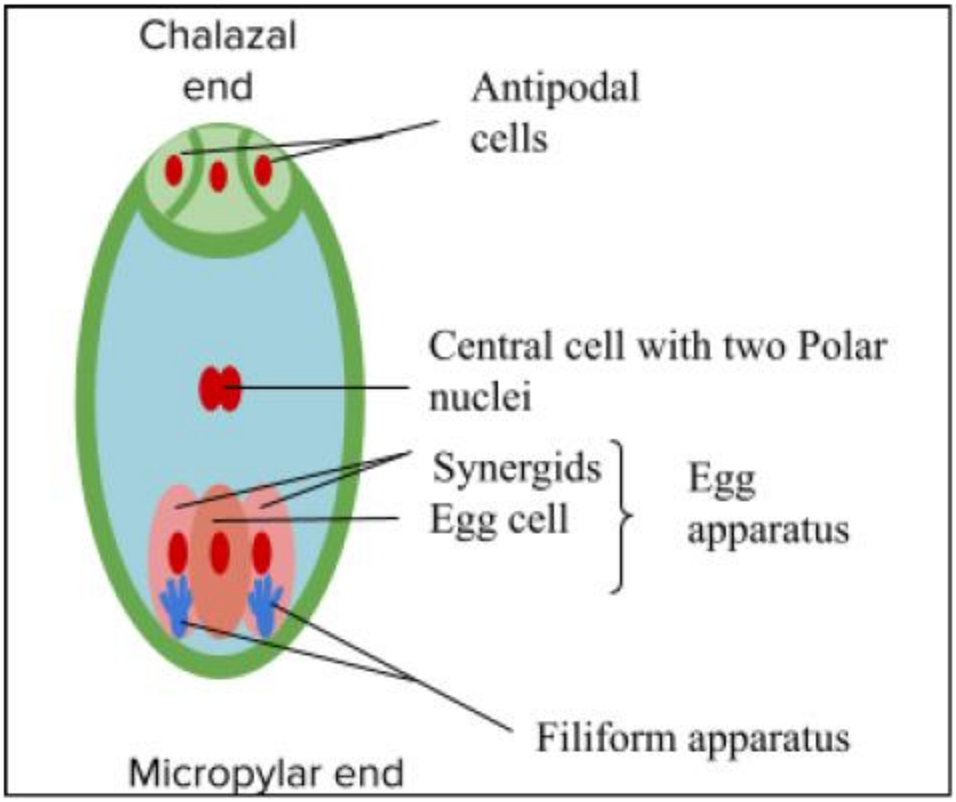


Figure7.3 Embyo sac

There are different types of embryo sac (female gametophyte)

- Basis for classification

- The number of megaspores taking part in the development of embryo sac
- The number of divisions occurring in the nucleus of the functional megaspore
- Organization of nuclei in the mature embryo sac

1. Monosporic embryo sac
2. Bisporic embryo sac
3. Tetrasporic embryo sac

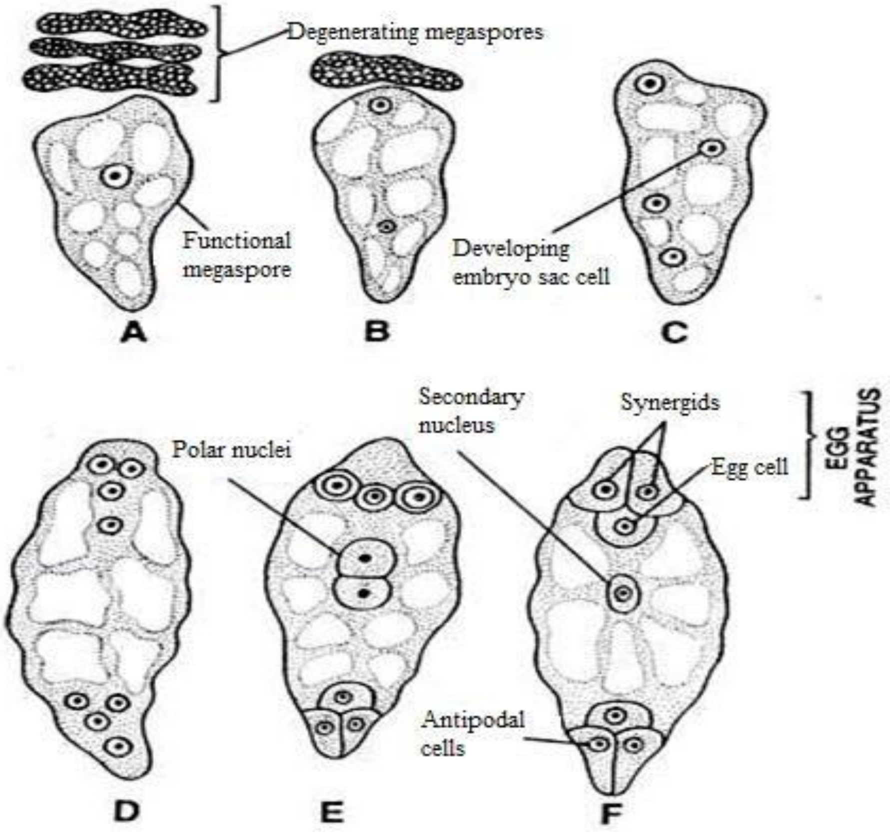


Figure 7.4 Femalegametophyte.A-F: development of theembryosac (Femalegametophyte) of normal type (*Polygonum* type)

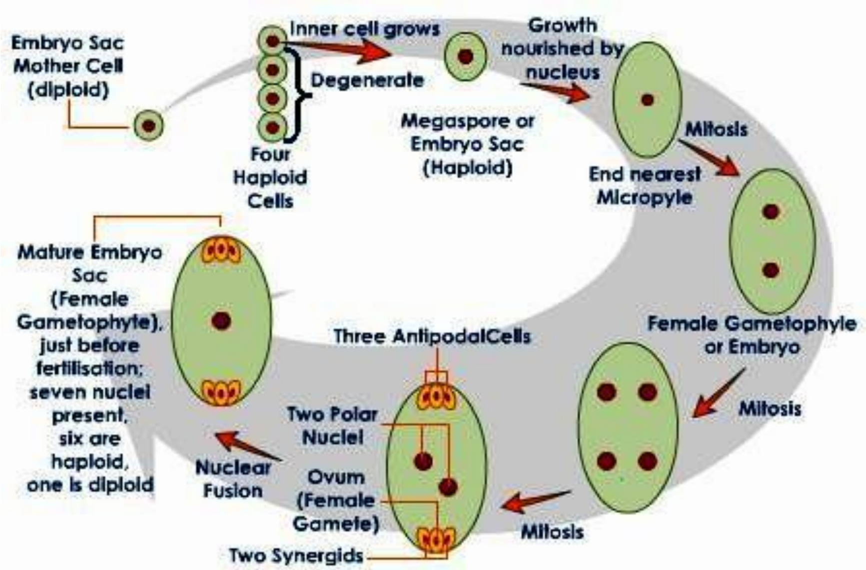


Figure 7.5 DiagrammaticrepresentationofembryosacdevelopmentinAngiosperms

MONOSPORIC EMBRYO SAC

This type of embryo sac develops from a single megaspore. All the nuclei present are genetically similar in this embryo sac.

As a result of reduction division the diploid megaspore mother cell present in the nucellus forms four haploid megaspores in the monosporic or Polygonum-type embryo sac. Three megaspores, at the nucellus micropylar end, degenerate resulting the presence of only one functioning megaspore.

Two types of Monosporic Embryo Sac are present

a). Polygonum type

It was for the first time described by Strasburger (1879) in the plant *Polygonum divaricatum* where the nucleus divides thrice to form eight nuclei embryo sac. This is most commonly available type which develops from the chalazal megaspore.

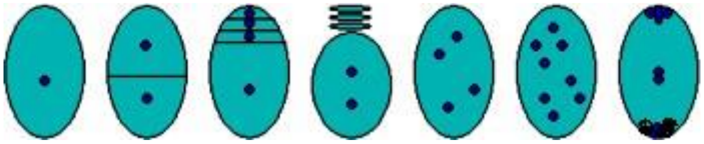


Figure 7.6 ***Polygonum*****typeembryo sac**

b).Oenothera type:

It is a 4 nucleated embryo sac (Egg apparatus- 3 cells and Polar nucleus- single cell) which develops from micropylar megaspore and does not have antipodals.Example – Onagraceae family.

Figure 7.7 ***Oenothera*****type**

BISPORIC EMBRYO SAC

After the second meiotic division due to the absence of cytokinesis and cell plate development in bisporic embryo sacs two megaspores, each containing two haploid nuclei are formed.

The megaspore near the micropyle degenerates, resulting a single functioning megaspore with two haploid nuclei.

In Megaspore Mother Cell the embryo sac Develops from one of the two dyads formed as a result of the first meiotic division

Both the nuclei of the functional dyad are involved in the formation of embryo sac. The 8 nucleated mature embryo sac is as a result of two mitotic divisions in each nucleus.These eight nuclei are organised into antipodals, egg apparatus and polar nuclei similar to Polygonum type of embryo sac. All the 4 nuclei derived from one megaspore nucleus are genetically different from the ones derived from the second megaspore nucleus.

On the basis of the position of functional dyad bisporic embryo sacs are of two types

a). ALLIUM TYPE: This develops from the chalazal dyad.

Figure 7.8 ***Allium*****type**

b). ENDYMION TYPE: This type develops from the micropylar dyad.

Figure 7.9 ***Endymion*****type**

TETRASPORIC EMBRYO SAC

The development of a single four-nucleate megaspore takes place due to the failure of cell plate formation during both meiotic divisions. The absence of meiotic division of the megaspore mother cell followed by lacking of cytokinesis all the four haploid nuclei lies in a single cell known as oeno-megaspore. The formation of embryo sac takes place by all four nuclei of coeno-megaspore. This type of embryo sac is genetically more heterogeneous than bisporic type.

Following features are considered for the classification of the tetrasporic embryo sacs

- The position of haploid nuclei in the coeno-megaspore
- The number of times these nuclei divide
- Organization of nuclei in the mature embryo sac.

TYPES OF TETRASPORIC EMBRYO SAC

I. No nuclear fusion present
    - Adoxa Type
    - Plumbago Type
    - Penaea Type

- Pepromia Type
- Drusa Type

II. Formation of triploid nucleus at the chalazal end of the coenomegaspore takes place after the second meiotic division by the fusion of the three megaspore nuclei. The haploid fourth nucleus remains at micropylar end.

- Fritillaria Type
- Plumbagella Type

ADOXA TYPE

The 8 nuclei type is formed by the mitotic division of the four haploid nuclei of the coeno-megaspore as similar to Polygonum type
Example – Adoxa, Sambucus, etc.

PLUMBAGO TYPE

Synergids and antipodals are absent in this type of embryo sac. Migration of four haploid coeno-megaspore occurs to the micropylar end, one at chalazal end and the rest of the two at the lateral sides. Division takes place in each of the nuclei to form four groups of two nuclei. From each group one of the nucleus moves towards the center of the cell and formation of four polar nuclei takes place. Egg is formed by the formation of a membrane in the remaining nucleus. Synergids are absent. Degeneration of other three nuclei takes place but sometimes they are also cut off by membranes and act as accessory egg cells. Example – Plumbaginaceae family

PENAEA TYPE

This type of embryo sac has 16 nuclei as a result of two successive mitotic divisions in the four haploid nuclei of the coeno-megaspore. These nuclei are arranged in four groups of four each, one each at the micropylar end, chalazal end and on the two lateral sides.One nucleus from each groups migrates towards the centre, to form polar nuclei. An egg apparatus is formed by the membrane formation in the three nuclei at the micropylar end.On maturity the remaining three groups of nuclei (one chalazal and two lateral) degenerate. After double fertilization highly polyploid (5x) primary endosperm nucleus is formed. Example – Family Euphorbiaceae & Malpighiaceae.

PEPEROMIA TYPE

The egg apparatus has a single synergid. Two successive mitotic divisions in four haploid nuclei of coeno-megaspore lead to the formation of 16 nuclei. Two nuclei at the micropylar end form egg and a synergid. Polar nucleus is formrd by eight nuclei in the centre of the cell. Antipodals are formed by the remaining six at the chalazal end.

- Example- Peperomia and Gunnera.

Figure 7.10 *Peperomia*type

DRUSA TYPE

It is a 16 nucleate embryo sac characterized by large number of antipodals where three nuclei form egg apparatus. Two act as polar nuclei and the remaining 11 nuclei are cut off by membrane and form antipodal cells. Example – Drusa, Chrysanthemum, etc.

FRITILLARIA TYPE

Two groups are formed by the four haploid nuclei of the coeno-megaspore. A triploid nucleus is formed at the chalazal end. The other group is represented by one haploid at the micropylar end Two mitotic divisions occurs in both the groups resulting in the formation of four triploid nuclei at the chalazal end and the other four haploid at the micropylar end.

The mature embryo sac comprises of three haploid nuclei that organize into egg apparatus, three triploid into antipodal. One haploid and one triploid nuclei fuse to form a tetraploid polar nucleus in the centre. Example – Fritillaria, Piper and Lilium.

PLUMBAGELLA TYPE

A triploid nucleus is formed at the chalazal end and a haploid at the micropylar end.

The initial development is somewhat similar to Fritillaria type. A single mitotic division occurs in each of these nuclei resulting in the formation of two groups of two nuclei each. Fusion of one triploid nuclei from chalazal end and one haploid nucleus from the micropylar end takes place to form tetraploid polar nucleus. Egg is formed by one haploid nucleus at the micropylar end. Single antipodal cell is formed by one triploid nucleus at the chalazal end. Synergids are absent.

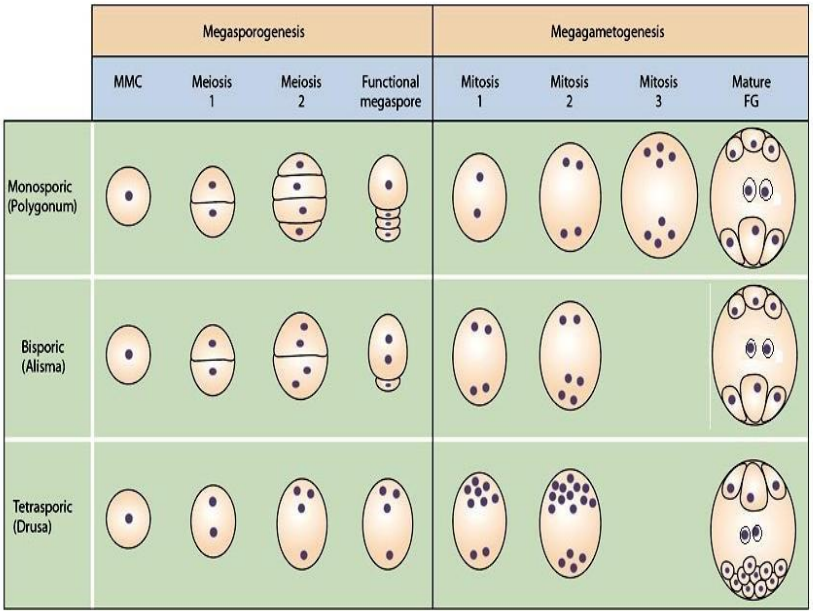


Figure 7.11 Diagrammatic representation ofthree main types ofembryosacdevelopment: monosporic, bisporic, tetrasporic

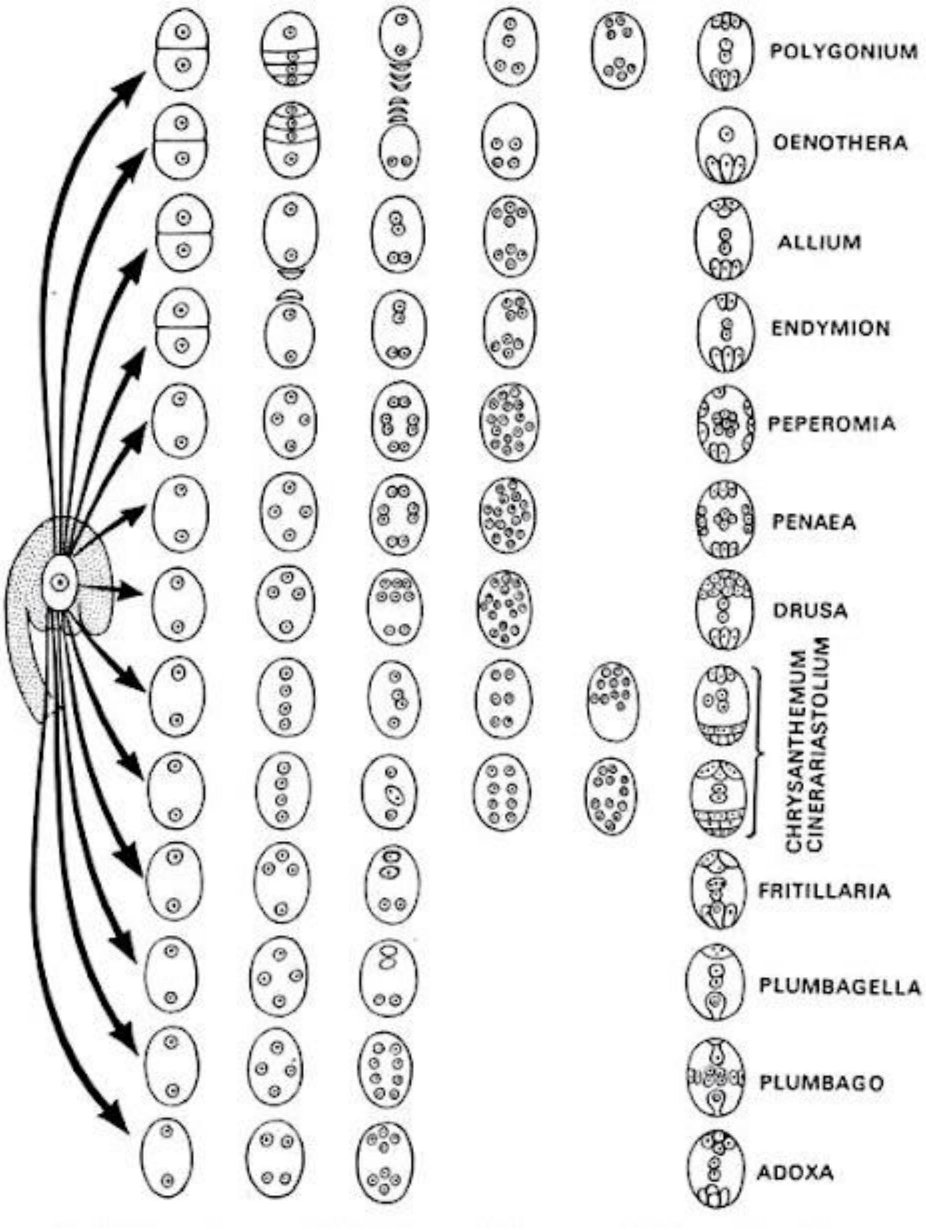


Figure 7.12 Female gametophyte Development of different types of embryo sacs in angiosperms.

Summary

In this unit we have discussed the development female gametophyte in different plant species. Similarly different types of embryo sac such asmonosporicembryosac bisporic and tetrasporic embryo sacs are also discussed. The process of development of the megasporesisknown as megasporogenesis. The female spores or megaspores are developed through a series of reduction division within the ovule. Eachmother cellundergoesmeiosisdivisiontoformfour haploid megaspores.Outof these four megaspores, onlyone haploid megaspore be comes functional whichformstheembryosac. After the meioticdivisions wallformation takes place and on its basisthreemain types of megasporogenesis process is seen in Angiosperms known to as monosporic, bisporic, and tetrasporic.Monosporic-8-nucleate embryo sac or *Polygonum* type of embryo sacdevelopsfromasinglemegasporeandhaseightnuclei.

Theembryosachas3antipodalcellsatchalazalend,an egg apparatus (one egg cell and two synergids) at micropylar end and two polar nuclei in the centre (total 8 nuclei) of *Polygonum*type. Secondarynucleus is formed as result of fusion of twopolarnuclei. The central cell is binucleate or diploid and the antipodal cells and cells of the egg apparatus are uninucleate and haploid.

Glossary

Megasporogenesis: Development of the megaspore within the ovule
Micropyle: Small opening formed by two integuments over nucellus

Nucellus: The body of ovule

Placenta: The portion of the carpellaryt issue to which theovules areattached

Placentation: The attachment distribution of ovules in theovary

Synergids: Thecells presenton eitherside of egg cellin mature embryo

Tenuinucellateovule: Presence ofhypodermal sporogenouscellandsingle layered nucellartissuearound it.

Unitegmicovule: Ovulewi tha singleintegument.

Multiple Choice Questions

1. Theexampleofmonosporictypeofembryosac is:

(a) *Peperomia* type (b) *Endymion*type

(c) *Allium* type (d) *Polygonum* type Ans (d) *Polygonum*type

2. Theexampleofbisporictypeof embryo sac is:

(a) *Oenothera* type (b) *Peperomia*type

(c) *Polygonum* type (d) *Allium*type Ans(d) *Allium*type

3. Theexampleof tetrasporictypeof embryo sac is:

(a) *Peperomia* type (b) *Allium*type

(b)*Polygonum* type (d) *Endymion* type Ans (a) *Peperomia* type

4. Which type of embryo sac has 16 nuclei.

a) Penaea type b) Drusa

c) Both of the above d) None of the above Ans c) Both of the above

5.Synergids and antipodals are absent in which type of embryo sac

a) Peperomia b)Plumbago type

b) Fritillaria d) Allium type Ans b) Plumbago type

Short Questions

Q1. Write a note on tetrasporic embryo sac.

Q2. Define megasporogenesis.

Q3. Write a note on Bisporic embryo sac.

Q4.What are the monosporic embryo sacs? Write its types.

Q5.Write a note on Fritillaria type of embryo sac.

Unit- 8

POLLINATION

Objectives-

After reading this unit students will be able to understand-

- Definition of Pollination
- Types of Pollination
- Advantage of Self and Cross pollination
- Pollination Mechanism

8.1 INTRODUCTION

Male gametes are produced by the process of microsporogenesis, whilst female gametes are produced later to megasporogenesis. Double fertilization occurs when fusion between one male gamete and the egg takes place to produce the zygote that becomes an embryo, is the next step in the sexual reproduction process after the gametophytes have formed. The central cell nuclei and the second male gamete combine to produce the endosperm, a nutritional tissue. Pollen must get from the stamen to the carpel's stigma in order for fertilization to occur. Pollination is the process of transfer pollen.Pollen is transfer by a range of factors, including the wind, water, and animals. In this unit, you will learn about the numerous agents involved in pollination, as well as the various forms of pollination and some of the significant adaptations shown by plants for successful pollination.

8.2 POLLINATION

Pollen grains are transmitted to a flower's stigma on the same plant or one of a different species, they start to germinate. Therefore, the term "pollination" refers to movement of pollen from the male reproductive organ, the anther, to the female reproductive organ, the stigma, of either the same flower or a different flower. It also describes the transfer of pollen from dehiscing anthers to the pistil.

Pollen grains are transferred from the male parent to the stigma of the female parent with the aid of certain agents since, as you may know, plants are unable to move to their mates for sexual reproduction. Through the process, the male gamete is transferred to the female reproductive structure, which facilitates fertilization and the production the offspring.

Anther dehiscence: The term refers to the simple process of pollen grains releasing from mature, dried anthers. Changes in the surrounding environment provide an external pressure that causes the anther wall to burst mechanically, releasing mature pollen from the anther sac. Endothecial cells that line the stomium support the anther wall's breaking. The dehiscence of anthers is influenced by the hygroscopic nature and differential expansion of the tangential walls of the endothecial cells. The stomium runs the whole length of the anther lobe in the majority of angiosperms. But it can also be limited to holes (Solanum, Cassia, Polygala), or a lid or valve (Berberidaceae).Stigmas, which are the receptive parts of the carpel, facilitate tube development and passage migration into the style and ovary and bind pollen of the same species.

8.3 Types of Pollination-

On the basis of source of the pollen, pollination is of two types:

1. **Self-pollination:** This process involves the transfer of pollen from one flower on the same plant to another, either from the anther to the stigma. This may occur to the unisexual or bisexual the flowers that grow on a single plant.
2. **Cross-pollination**: This is the process by which pollen is transferred from one flower to the stigma of a flower on a different plant in the same species. It may occur to monoecious and dioecious plants alike.

8.3.1 Self-Pollination

Pollen from the same flower or another flower on the same plant is transferred during this procedure. There are several forms of self-pollination:

Autogamy -The pollen grains from an anther are transferred to the stigma of the same flower in this method of pollination. This means pollination of flower by its own pollen. Flowers have stigmas and anthers that ripen at the same time and are arranged such that pollen grains are readily transported to the stigma of the flower. This type of pollination is found in members of Apiaceae and Cactaceae. In cleistogamy, pollination occurs within closed flowers even when flowers do not open. It has been observed that cleistogamous flowers show several unusual structural adaptations. Among these are underground bisexual flowers (Commelina bengalensis, Viola, Oxalis, Juncus, and Saxifraga) that never open. Therefore, both chasmogamous (which are open) and cleistogamous (which stay closed) flowers exhibit self-pollination.

Geitonogamy -In this case, any other flower on the same plant is pollinated by the pollen of a flower. Two different the flowers that are on the same plant participate in this type of pollination. Argemone mexicana, Tagetes indica, and Mirabilis jalapa are examples of flowers in this class that exhibit adaptations including homogamy, a situation in which a flower's stigma and anthers mature at the same time. Geitonogamy is considered a type of self-pollination since all of a plant's the flowers have genetic similarities.

Advantages and Disadvantages of Self-Pollination

In most species, a flower's structural and functional modifications reduce or eliminate the chance of self-pollination. Its certainty is the main benefit of self pollination. Self-pollination, however, causes inbreeding depressio. Fertilization does not occur via self-pollination in many species. The cause for this is because the stigma or style inhibits the formation of pollen tubes or the germination of pollen. Pollen must originate from another plant in order for fertilization to occur. This character is thought to be primitive and controlled by genetics.

Flowers that are not perfect, meaning absence of the necessary reproductive structures—stamens or carpels—in a dioecious or monoecious plant can be ceased from self-fertilizing. The term dioecious refers to the situation in which the male and female flowers are produced on distinct plants. When stamens and petals grow at separate periods in a flower, self fertilization is also inhibited. In some species, pollen is released by anthers before stigma tissues fully develop.

Self-fertilization occurs through self-pollination. It shows certain benefits such as more reliabile specifically in plant species who are distantly placed. The features of the parental are retained. Pollen never goes to waste and may be found in any type of flower—it's not needed for them to be flashy or vibrant. Because it is a form of inbreeding and causes progeny to lose vigor, this sort of pollination has one main drawback.

8.3.2 Cross-Pollination- You know that the process of pollen transfer from one flower's anther to the stigma of another plant individual in the same species is known as cross-pollination. This method, also known as xenogamy, produces offspring that are genetically distinct from either parent and is mediated by a variety of physical and biological factors. It also collects pollen from other plant individuals. For plants, the genetic variability is favorable.

Cross-pollination shows more diversity among angiosperms, which we will address later. The offspring are stronger and more suited to unfavorable environmental circumstances. Because there are multiple advantages to cross-pollination, bisexual flowering plants have developed a number of strategies to thwart self-pollination. Self-incompatibility, dichogamy, herkogamy, and heterostyly are some of these. These modifications, which enhance cross-pollination and inhibit self-pollination, are outlined below.

a) Self- incompatibility-It is a condition where the pollen grains from a flower either never germinate or develop very slowly when they are transferred to the stigma of the same flower. The growth of pollen is inhibited on the stigma or in the style. Pollen from different flowers does not develop on the stigma of a Malva flower, and in Petunia, an incompatibility response occurs in the style.

b) Dichogamy - There are some flowers that have a situation where the stigma becomes receptive before the pollen of that flower ages, or where the anthers discharge pollen before the stigma becomes receptive. Dichogamy is the term used to describe the situation in which the androecium and the gynoecium do not develop simultaneously. The receptivity of a flower's stigma and the dehiscence of its anthers do not coincide in some species. In sunflowers, self-pollination never occurs because the anther dehisces before the flower's stigma becomes receptive. We refer to the state as protoandry. The stamens of protoandrous flowers develop before the pistils. In contrast, in protogynous flowers—like Mirabilis—the pistil matures first and the stamens matures later.

c) Herkogamy -The position of the stigma and anthers in certain plants prevents self-pollination. Pollen grains are kept from coming into touch with the stigma of the same flower by the structural adaptations. The stigma of most kinds of herkogamous plants grows above the level of the anthers, preventing pollen from the same flower from landing on stigma.

d) Heteromorphy -Some plants produce the flowers that are morphologically distinct or different. Dimorphic flowers, such as primeroses (Primula vulgaris), are heteromorphic the flowers with two types of stamens and styles. There are two different kinds of the flowers on this plant. Some have pin-eye or lengthy hairstyles. These flowers have small pollen and short stamens, but they also have a stigma with large papillae and a long styled carpel. The other form of flower is called a thrum-eyed or short-styled flower; it has carpels with small stigmatic papillae, lengthy stamens, and large pollen size.

Self-pollination is prevented by variations in the length of the style, stamens, pollen, and stigmatic papillae. Small pollen from pin-eyed flowers gets caught in the stigma with micro sized papillae of thrum flowers, whereas large pollen grains of thrum flowers are better collected by the long papillae of pin flowers.

Heterostyly facilitates cross-pollination in some species. Plants with this characteristic have the flowers that have either large stamens and small pistils, or the opposite, as in the case of primula. Under these circumstances, it has been observed that there are two types of flowers: those with long styles, which are situated close to the anthers, and those with short styles, which are situated below the anthers and have a stigma that is half the length of the corolla tube.

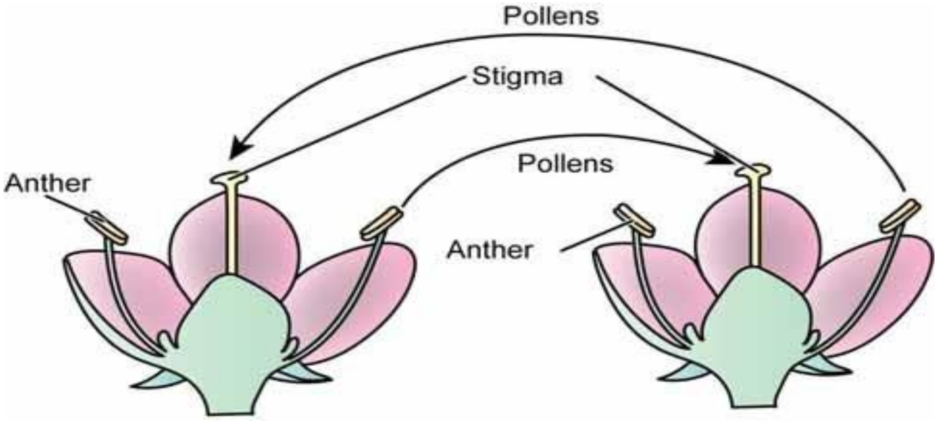


Figure 8.1 Flowers showing Heterostyly.

The style of Caryophylaceae members is much longer than the stamens. As a result, the stigma is not reached by the flower's pollen. Because the pollen in the anther sac of members of the Orchidaceae family form to form a single, compact unit known as the pollinium, the pollen is prevented from reaching the stigma of the same flowers.

e) Dicliny - This is the condition in which different flowers contain both the male and female reproductive organs, or stamens and anthers, on them. Because the blooms are unisexual, they are unable to self-pollinate.

Advantages and Disadvantages of Cross Pollination

There are many advantages of cross pollinated plants incomparison to self-pollinated plants. Cross-pollination increases the chance of different combinations of genes by increasing genotype reorganization. This is because a new gene combination is created when sperm and egg cells from different plants unite.

- The new offspring plants are better adapted than parent plants. This is a result of higher fitness brought on by genes acquired from other members of the same species. Plant populations can withstand environmental changes and stresses due to the variations in the gene pool.
- Plants produced through cross-pollination are advantageous to evolution.

Cross-pollination has several disadvantages as well. The main drawback is that the process is uncertain since it depends on favorable circumstances and pollinator presence. As plants have to produce more pollen grains than self-pollinated plants, the process also requires the use of resources.

8.4 POLLINATION MECHANISMS

A wide range of biotic and abiotic processes transport pollen grains to the stigma. Water and air are considered abiotic mediums, whereas insects, birds, mammals, bats, and other biotic mediums are considered abiotic. This part will discuss some of the common mediators of cross-pollination.

8.4.1 Anemophily

It's commonly referred to as wind pollination. It is seen in plants with small, unisexual flowers with short, unattractive perianths. These plants' flowers are unattractive to insects and other living vectors since they don't have an aroma or nectar. Large amounts of pollen are generated, and the grains of pollen have smooth walls, are light, and dry. On warm, dry days with strong winds, pollen is discharged. In order to help in pollen dissemination, anthers and styles often have an upright, lengthy shape. In most of the flowers the stigma of the pistil large in size and becomes feathery to capture and capture the flying pollen.Example- Members of Fagaceae (oaks), Betulaceae (birches), Salicaceae (poplars and willows) and many of the Poaceae (grasses) members.

Plants exhibit anaemophily, staminate, (male) and pistillate (female) unisexual flowers are produced in large number at the same time period. These flowers tend to aggregate in clusters to form catkins.

Slender stalks support the elevated staminate unisexual flowers above the plant's vegetative parts. The large, heavy pollen grains in maize fall on the corn tassels as the wind collects them from the anthers. The pollen is mostly captured by the sticky corn silk on the young ears. A pollen tube that grow the silk thread develops when the pollen grain germinates and fertilizes an ovule in the ovary. Willows (Salix sp.) have unisexual staminate the flowers in the form of loosely organized catkins that swing open in response to wind. Reminders that unisexual flowers have developed from bisexual flowers can be seen in some bisexual flowers as vestiges or reduced sterile structure.

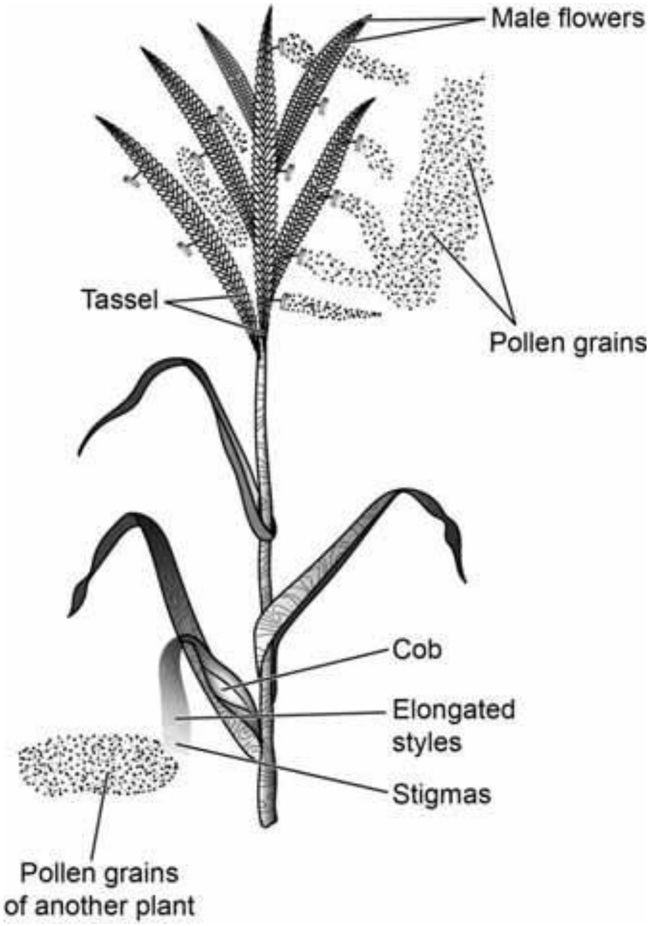


Figure 8.2 Wind pollination in maize.

8.4.2 Hydrophily

Water is used to help in this type of pollination. A different term for it is water pollination. It occurs to aquatic plants that have flowers submerged or at the water's surface. The specific gravity of pollen and the position of flowers must closely match in watery environments. Pollen grains should have a specific gravity that is either slightly higher than or equal to water if female flowers are borne on submerged parts. Pollen grains should not sink if the female flowers float on the water's surface, which indicates that the specific gravity of the pollen is lower than that of the water. The presence of starch granules affects the variations in specific gravity.

The flower are usually small and inconspicuous. These type of flower are known as hydrophilous flower. These flowers are also classified as hydrophilous and ephydrophilous. Ephydrophilous flowers are pollinated while they float on the water's surface, but hydrophilous the flowers are pollinated when they are submerged in water.

Plants such Ceratophyllum have flowers with 12–16 stamens, and each anther exhibits aerenchyma, which allows the anther to float on the water's surface. Pollen is released when the stamens detach and float on the water's surface. Long pollen grains effortlessly disperse throughout the water because their specific gravity is the same as that of water. The sticky lower surface of the style traps the pollens. This is an extremely typical case of hyphydophilia.

Male and female Vallisneria (Hydrocharitaceae) flowers are produced underwater. The female flowers are affixed to long, thin stalks that are spirally coiled. When fully grown, the small male flowers separate from the stalk and float on the water's surface to help with pollination.

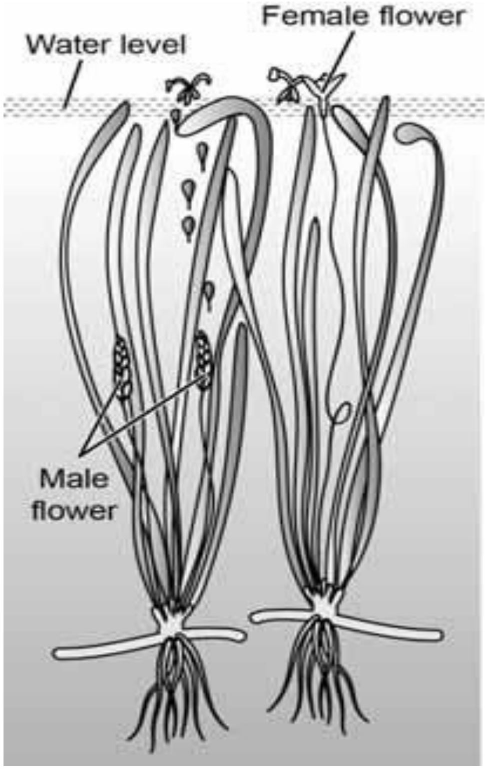


Figure 8.3 Diagrammatic representation of pollination in Vallisneria

The lengthy spiral stem helps to elevate the female blooms to the surface. Anthers come into touch with the stigma when the floating male flowers become trapped in the cup-shaped depression that forms around the female flowers. The big stigma of female flowers is where the pollen reaches. This plant is a representation of ephydrophily.

8.4.3 Entomophily

Insect pollination is another term for this process. In angiosperms, it is the most common type of pollination. Many insects, including flies, beetles, moths, ants, and butterflies, aid in the pollen transfer process.

Flowers attract insects because of their distinct color, symmetry, or fragrance. Some insects contact flowers in order to get nectar found in the spur or corolla tube. While nectar is the primary food source for insects in some flowers (Cassia sp.), it is absent from others (members of the Apiaceae and Euphorbiaceae). While nectar is often coated in hairs or a small perianth tube (Ricinus and Thevelia) or disguised by scales (Ranunculus), it is easily found to short-tongued insects like flies and beetles in some flowers. In several other flowers, the nectar is completely concealed, and long tongues are used to extract it. The term "concealed nectar" refers to nectar that is protected by a long spur or corolla tube. Insects visit flowers so as to consume pollen, which is one of their food sources.

The flowers are fragrant, colorful, and visually appealing when they are pollinated by bees. Nectar guides—specialized color patterns—draw bees and facilitate the transport of the greatest amount of pollen grains. Hymenopterophily or melittophily are terms used to describe bee pollination. In addition, bees are able to recognize and differentiate between various scents, hues, and sugar concentrations.

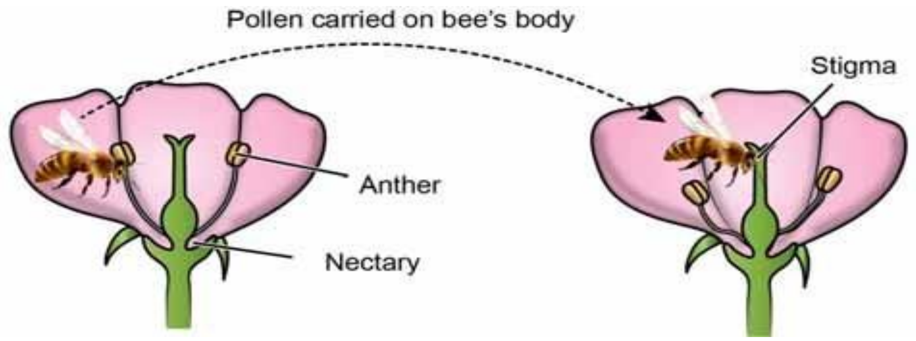


Figure 8.4 Pollination by bees.

Salvia has been studied as a typical example of pollination by insects. Salvia species have a unique floral mechanism known as a "turnapipe" that is appropriate for pollination by bees. The filament is joined to the connective in Salvia in such a manner that a lever mechanism is generated and the connective may swing on the filament. The corolla is bilipped, and the stamens are attached fixed to the corolla tube. The stamens are separated by a long connective. The anther has a productive half and a sterile half. Above the lower lip of the corolla, the sterile plate is formed by the joining of the sterile part.

The upper fertile lobe of the corolla lobe strikes the insect on its back when a bee or insect approaches the flower in search of nectar because its head pushes against the sterile plate. As a result, insects carry pollen on their backs. The pollen is collected off the insect's back by the forked stigmas on the flowers the bee visits.

The pollen and sugar-rich nectar that the bees gather is transformed into honey, which is then used to nourish the young. Since they visit several blossoms until the nectar is consumed, bees have been regarded as effective pollinators. The honey bee has a pollen basket. They cling pollen grains with their bristly hair. They use their legs to sweep the pollen into the basket or on both sides of their bodies. When the pollen-filled baskets are full, they return to the hive. Pollination occurs when some of the pollen is transferred to other flowers by dust.

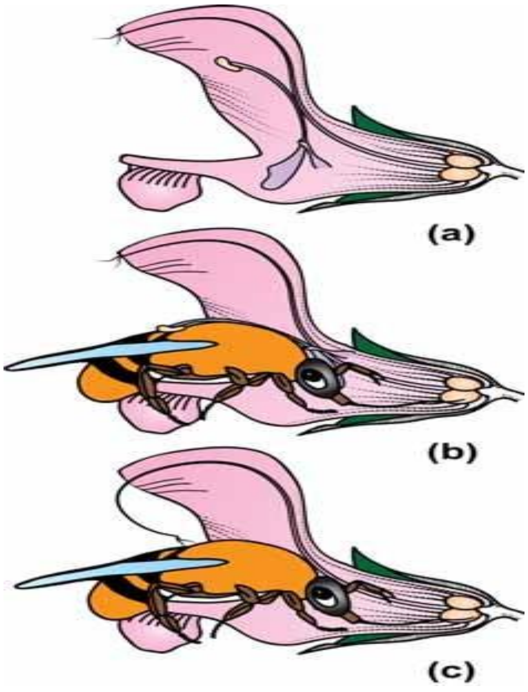


Figure 8.5 Pollination in Salvia. a) Flower of Salvia with a) bilipped corolla and stamens attached to corolla tube; b) sterile plate in the stamen being pushed by the bee; c) back of insect being dusted with pollen from the anther.

8.4.4 Ornithophily

Bird pollination is another term for this process. Pollination of this type takes place on plants that have red, yellow, or orange flowers. Large tubular, cup- or urn-shaped the flowers that release nectar are present. The parts of the perianth are firmly wrapped to form the tube. Birds typically pollinate bisexual flowers, meaning they have both male stamens and female pistils. Their inferior ovary, which shields the ovules, is often present. The stamens touch the visiting bird's head or breast. Flowers that are pollinated by birds tend to be larger in size and open throughout the day. Hovering birds are typically attract to flowers that are swinging or strongly attached to the stalk. Most of the time, the flowers are tubular, bilipped (bilabiate), with protruding stamen arrangements. Spurs contain the nectar. The flowers lack smell, yet they have an abundance of nectar. Hummingbirds, sunbirds, and honeyeaters are some of the birds that help in pollination. The majority of birds have strong vision and a decent sense of color, but a weak sense of smell.Small insects that the nectarines attract serve as food for the birds. Fuchsia, Hibiscus, and other plants from the families Orchidaceae, Fabaceae (Leguminosae), and Cactaccae are among the ornithophilous species. Common bird-pollinated trees in India include Butea monosperma (dak) and Bombax ceiba (semal). The majority of trees pollinated by birds flower in February and March, which coincides with birds' nesting season when they need the most food sources.

Figure 8.6 **Pollination by humming bird.**

7.4.5. Cheiropterophily

Cheiropterophily is the term for pollination performed by bats. It occurs in flowers that anthesise at night (nocturnal). Large, white, dull red or yellow the flowers with a hypanthium or perianth tube secreting copious amounts of pollen and nectar. Usually smelling like sour fruit, the flowers produce an unpleasant undesirable odor. The aroma of the flowers attracts bats, who then ingest the nectar. Pollen is transferred through movement to several flowers. These plants produce the flowers solitary or in clusters distant from the branches; the flowers can hang below the tree canopy like in the case of the baobab tree (Adonsonia digitata) and African sausage tree (Kigelai pinnata), or they can protrude above it like the Indian trumpet flower (Oroxylum indicum). the flowers pollinated by bats form like bells, open saucers with plenty of stamens, or hanging blooms with stamens gathered in a projecting brush. A bat uses its claws to grasp the flower, and as it laps up the nectar, pollen lands on its back.

8.4.6 Zoophily

Many plant species' nectar is a source of food for mammals. Primate, rodent, and marsupial species make up the majority of these pollinators. Rodents from the South African area pollinate the African lily, Massonia depressa. Pollination in animal pollinating species need a plenty of nectar and pollen. Certain flower species that have distinct shape, color, and scent are pollinated by animals. Animals are typically responsible for pollinating red flowers with less scent. Nectar is a benefit to animal pollinators. Slugs and snails pollinate the flowers of Aspidistra lurida, Chrysanthemum leucanlhemxim, and some Araceae. It is said that these flowers are malacophilous. Animals approach the flowers looking for of nectar and pollen.

SUMMARY

- Pollination is the process by which pollen is transferred from the stamen to the carpel's stigma prior to fertilization.
- Two recognized forms of pollination exist. Cross pollination is the transfer of pollen from one flower to the stigma of a flower from another plant of the same species (xenogamy), whereas self-pollination includes the transport of pollen from anther to stigma of the same flower (autogamy) or another bloom on the same plant (geitonogamy).

- Some adaptations of bisexual flowers inhibit self-pollination. These consist of heterostyly, herkogamy, dichogamy, and self-sterility. Under these circumstances, either the pistils become responsive before the anthers dehisce (protoandry) or the stamens mature before the pistils (protogamy). Anther dehiscence and stigma receptivity do not occur at the same time in flowers. Certain plants have unisexual blooms or variable pistil and stamen lengths.
- Pollen grains are transferred to stigma by biotic and abiotic pollinators. The stigma has strong adhesive contacts that help hold onto pollen grains. A variety of agents, including the wind (anemophily), water (hydrophily), big animals (zoophily), birds (ornithophily), insects (entomophily), and bats (cheiropetrophily), may help in pollination.
- Flowering plants have several obstacles that stop unwanted pollination. The pollen-stigma interaction is when the barriers are in effect. Pollen development is inhibited by the chemical interactions between pollen and carpels. The stigma and style proteins interact with the surface of the pollen tube in incompatible systems as the tube expands. The pollen grain cannot germinate if the protein is generated by incompatibility genes.

Self- Assessment Questions

1. Animophilly is pollination of plants By

a) Birds b) Bats c) Air d) Water

Ans (c)

2. Pollinia is characterstic feature of-
   - a) Solananceae b) Brasiccaceae c) Asclepiadaceae d) None of the above

Ans (c)

3. Benefits of cleistogamy is-
   - a) More vigorous offspring b) Vivipary
   - c) No dependence of pollinator d) Increase genetic variability

Ans (c)

4. What type of pollination takes place when pollen is moved from a single flower's anther to its stigma?

a) Cross-pollination b) Self-pollination

c) Geitonogamy d) Xenogamy

Ans. (b)

5. What is the term for pollination that occurs with the help of birds?

a) Entomophily b) Anemophily

c) Hydrophily d) Ornithophily

Ans. (A)

Short questions-

1. Define the pollination.
2. Differentiate between self and cross pollination
3. Give any two advantages of self pollination,
4. What is herkogamy?

Unit- 9

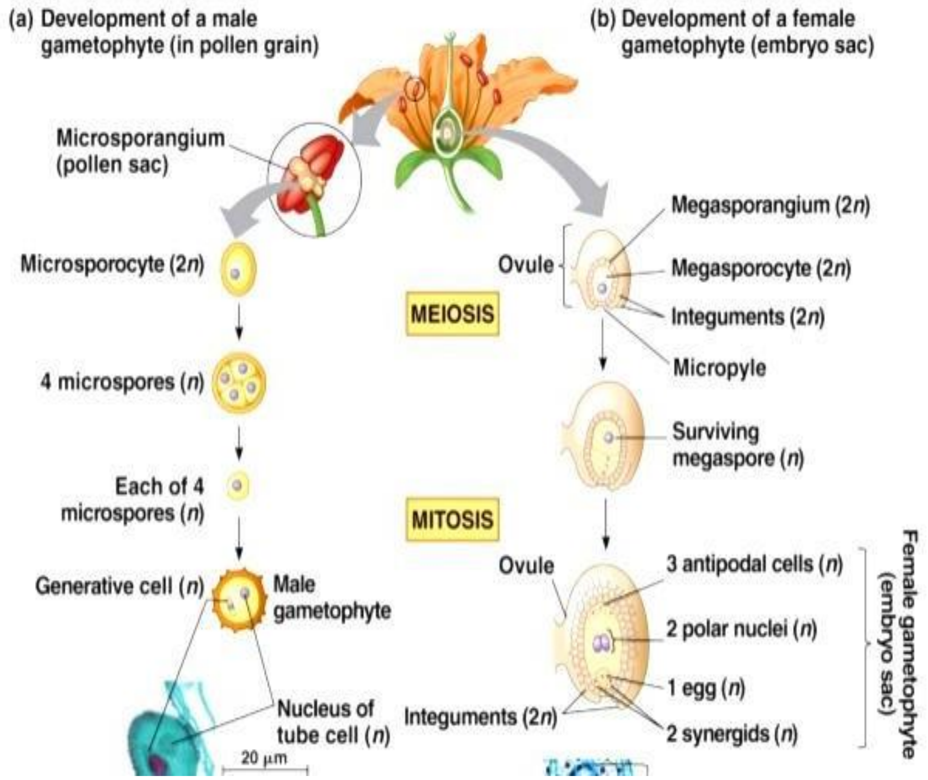
FERTILIZATION

After reading this unit, students will be able to understand:

- About Fertilization
- Entry of pollen tube into the ovule
- Syngamy
- Triple fusion
- Post fertilization development

Introduction-

Microspores, often known as pollen grains, are the first male gametophytic cell. The megaspore is the first female gametophytic cell. At the two or three-celled stage, the pollen grains liberated. Female gametophyte also known as embryo sac and in most of the plant species Polygonum type is prevalent. Pollination is necessary for fertilization, is the next biological stage after the formation of the male and female gametophytes. When pollination is complete, the stigma surface is heavily dusted with pollen grains.



Showing development of male and female gametophyte

Fertilization and post fertilization are one of the important processes found in the life cycle of flowering plants like apomixis, polyembryony and parthenocarppy.

Reproduction methods are of two types asexual and sexual reproduction. In Angiospermic plants sexual method of reproduction essential for fusion of male and female gametes. After the fusion of gametes zygote form and this process is called fertilization.

Male gametophytes, or compatible type pollen, reach the stigma in angiosperms, fertilization initiates. The stigma contains the pollen that is accepted by the gynoecium, the female reproductive organ.

It is very difficult for the pollen (male gamete) to reach the egg (female gamete) in the embryo sac. So to overcome this problem the pollen germinates on the stigma itself and generate a pollen tube which penetrate the stigmatic tissue, moves down the style, enters the ovary and ultimately reaches ovule. In the proximity of the female gametes, it discharges two male gametes, at this stage. One of the two male gamete form a zygote by fusing with the egg (a process known as syngamy). The other one form the endosperm by fusing with the secondary nucleus or the polar nuclei (triple fusion). This is known as the process of double fertilization and is a well known feature of the Angiospermic plants.

After sequence of divisions primary endosperm nucleus develop endosperm. Endosperm nourishes the growing embryo and poves to be a very nutritive tissue. Embryo develop by zygote, either dicot or monoco embryo, ats the case may be.

FERTILIZATION

“Fertilization is the process of fusion of two different reproductive units, called gametes.”

"Strasburger" reported the first discovery of the fertilization process in angiospemic plants in 1884. Angiosperm embryos have an embryo sac within the ovule that is separated from the stigma. The transfer of pollen from stigma to embryo sac is not facilitated by any devise in the gynocieum. As a result, when pollen reaches the stigma, it forms a pollen tube that helps male gametes travel from the stigma deep into the embryo sac.

The process of fertilization in Angiosperms is completed in following ways:

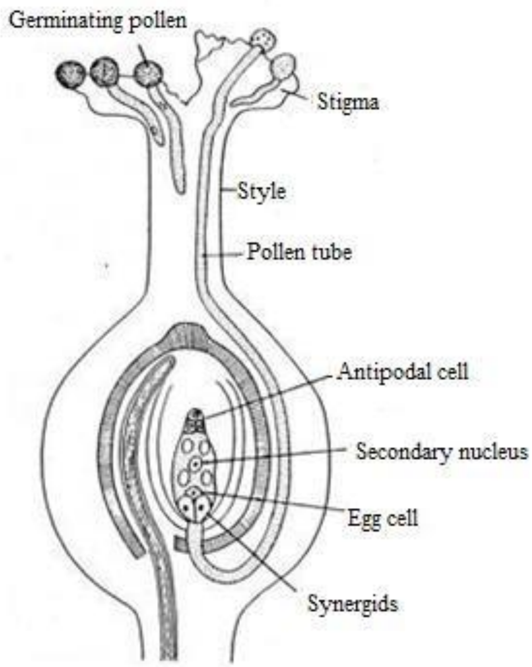
Germination of Pollen grains and growth of pollen tube

When the pollen is librate from anther it divide into two cells:

1. Generative cell
2. Vegetative cell

Two male gametes are produced by the generative cell. Germination of the pollen occurs when it lands on a compatible receptive stigma as a result of pollination. The pollen gets hydratesd on the surface of stigma. This result that pollen swells after absorbing water from its surroundings. The vegetative cell then forms a pollen tube. A suitable substrate for the germination of pollen grains is provided by the sugars, lipids, resins, and other substances found in the stigmatic fluid released by the stigma. An enzyme called cutinase is present in both pollen grains and pollen tubes, and it help in the tube's entry into the stigmatic tissue. Cutinase breaks down the stigma's cutin at the pollen tube's interface. The whole content of the pollen gets transfered into the pollen tube which includes two male gametes of generative cell.

The developing pollen tube moves through the style, via the stigmatic tissue and down the ovary wall. The style may be of two types it can be either hollow or solid. Incase the style is hollow, then the pollen tube grows along the epidermal surface but if solid style is present then the pollen tube travels through intercellular spaces between the all the cells lying in its path.



L. S. showing P ollen tube development in a flower

Pollen tube entry into the ovule

The pollen tube enters the ovule after it arriving the ovary. There are three different routes for the pollen tube entering the ovule.

1. By micropyle end
2. By chalazal end
3. By integument

Based on the methods in which the pollen tube enters the ovule, the following three terms are listed:

1. **Porogamy**: Porogamy is the term for a case in which the pollen tube enters through the micropyle and into the ovule. It is the commonest mode of pollen tube entry into the ovule
2**. Chalazogamy**: Chalazogamy is the term for a case in which the pollen tube enters the ovule by the chalazal end. In *Casuarina*, *Betula*, and *Juglans regia*, this type of pollen tube entry into the ovule by the chalazal ends is seen and therefore this type of fertilization is observed. Treub (1891) first mentioned chalagogamy in *Casuarina.*
3. **Mesogamy**: Mesogamy is a condition that occurs when the pollen tube enters the ovule through the funiculus or the integument. The type of ovule entry via the pollen tube and consequent fertilization process is seen in *Pistacia* (via the funiculus) and *Cucurbita* (by the integument).

Porogamy Chalazogamy Mesogamy

DifferentModes of entry of pollen tube into the ovule

On the basis of place of entry of pollen tube into the ovule, fertilization is divided into three types:

1. Porogamous
2. Chalazogamous
3. Mesogamous

Pollen tube entry into the embryo sac

Pollen tubes always enter the embryo sac from the micropylar end, which indicates that their entrance into the embryo sac is independent of their entry into the ovule. This means that it is not important which way the pollen tubes enter the ovule.

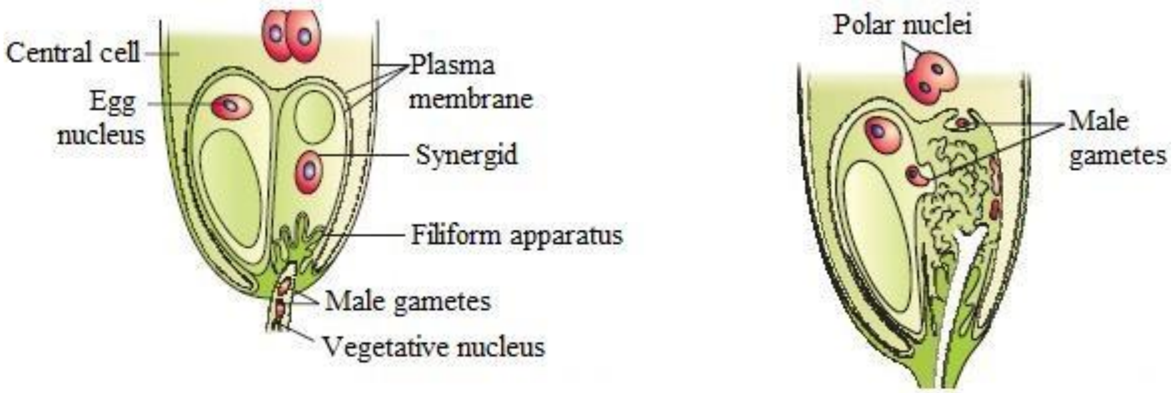
Once more, the pollen tube may enter the embryo sac by many pathways after passing through the micropyle. It may be:

(i) Between the one of the synergids and egg cell e.g. *Fagopyrum*
(ii) Between one or other synergids and the wall of the embryo sac e.g. *Cardiospermum*
(iii) Straight enters one of the synergids e.g. *Oxalis*

Therefore it can be said that synergids play an important role in determining the entry of pollen tube in the embryo sac alongwith this they also affect the dissemination of male gametes in the embryo sac.

Discharge of male gametes from pollen tube

The pollen tube oozes out at the tip of the embryo sac, releasing the two male gametes inside. Just before the pollen tube bursts, the tube nucleus becomes disorganized. The male gametes exhibit amoeboid mobility as soon as they are released; one goes toward the egg and the other toward the polar nucleus.



A: Enlarge view of an egg apparatus showing path of pollen tube growth; B: discharge of male gametes into a synergid and the movement of the male gametes, one into the egg and the other into the central cell

Syngamy- fusion of gametes

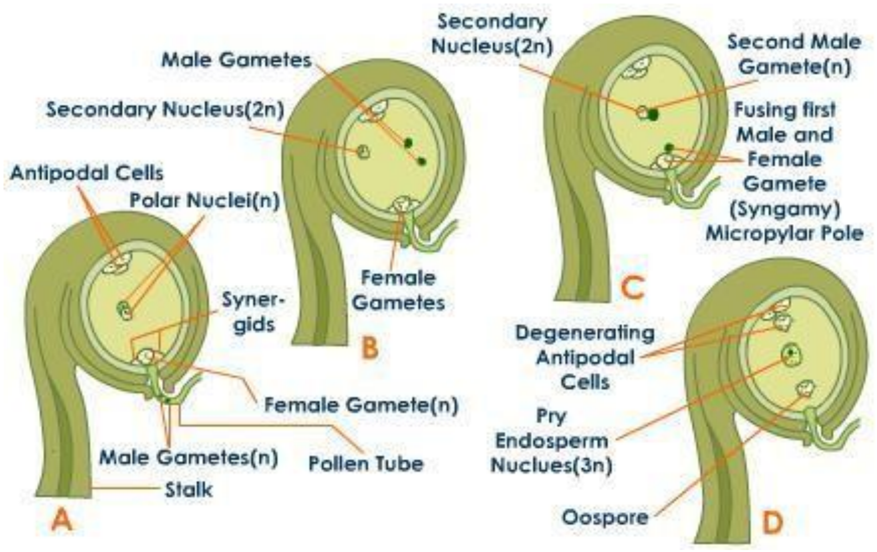
One of the male gametes fuse with the egg as soon as it reaches it.Because the egg and the male gamete are both haploid, a diploid zygote/oospore (2n) form as a result of this fusion. Fertilization is the process by which male and female gametes fuse together. This is also called syngamy.

As previously mentioned, Strasburger made one of the most significant discoveries in 1884. The actual fusion of the male gamete with the female gamete was observed by him in *Monotropa*.

Since two male gametes are secreting by the pollen tube, what is the fate of the second male gamete? S. G. Nawaschin provided an answer to the fate of the second male gamete (1898). In *Fritillaria* and *Lilium* while working he discovered the process of fusion between one male gamete and the egg (syngamy).While the other male gamete fuses with the polar nuclei leading to the process of triple fusion. This remarlable research leads to the discovery of double fertilization process.

Triple fusion

The other male gamete form the triple fusion nucleus (3n), also known as the primary endosperm nucleus, by fusion with the two polar nuclei (or secondary nucleus, if the two have already fused).



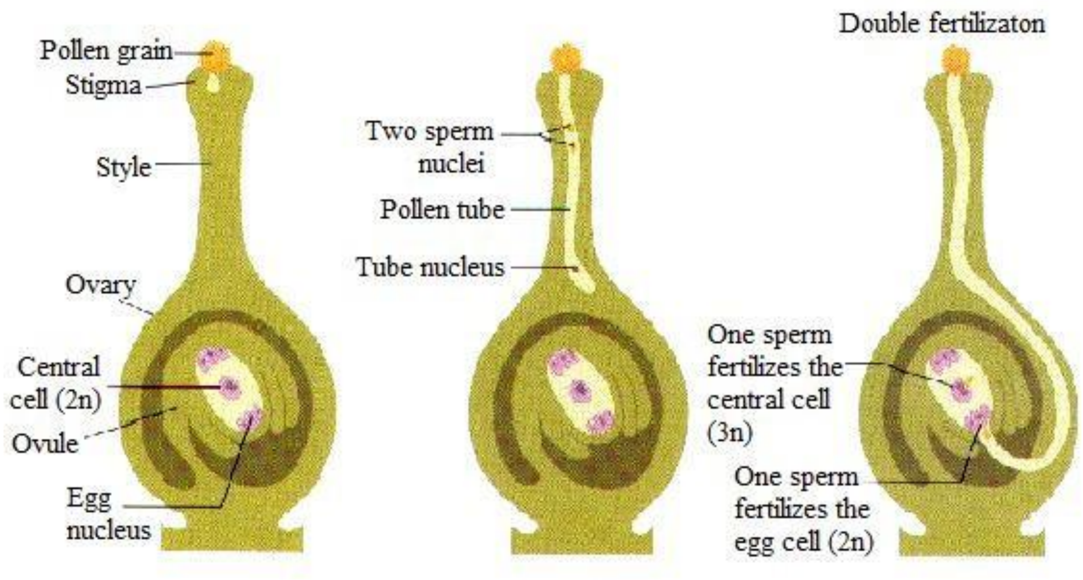
syngamy and triple fusion

Double fertilization

Two process of sexual fusion occurs in an embryo sac.One of the process is fusion of one male gamete with the egg (syngamy). In the second process fusion of the second male gamete with the polar nuclei or secondary nucleus happens leading to triple fusion, and therefore, this process is known as **double fertilization.**

As a result of first fusion (fertilization) the diploid zygote cell is formed which is the the mother cell of the embryo. The triploid or3n nucleus of thetriplefusion product (**primary endospermnucleus**)is present. This is thefirst nucleus of the endosperm.

S.G. Nawaschin (1898) first discovered double fertilization, unique phenomenon in angiosperms.First time observed in *Lilium* and *Fritillaria* species.



Processofdoublefertilization

SUMMARY

We have covered fertilization and the route taken by pollen on its way to the site of fertilization in this unit. As a result of pollination when the pollen grain reaches the receptive stigma, a long slender pollen tube is formed after its germination. The mature male gametophyte is represented by two male gametes and the tube nucleus which are present in the pollen tube.

- The pollen tube passes through the style, through the stigmatic tissue, and down the ovary wall.
- Once within the ovary, the pollen tube may travel via the chalazal end (chalazogamy), the micropyle (porogamy), or the integuments (mesogamy) to reach the ovule.
- Entry of pollen tube in the embryo sac takes place through the micropylar end, regardless of the path it takes to reach the ovule.
- The tip of the pollen tube explodes upon entering the embryo sac, releasing the two male gametes.

- Among the two male gametes, one fuse with the nucleus of the egg to generate an oospore or zygote (2n). The endosperm nucleus is developing when the second male gamete fuse with two polar nuclei (3n). Double fertilization is the term used to describe this event.
- The main endosperm nucleus produces endosperm after a sequence of divisions. The growing embryo is fed by the very nutritious tissue called endosperm.
- Eggs are formed by zygotes or oospores.

GLOSSARY

Chalazogamy: Pollentube enter through the chalazal end

Fertilization: Process of fusion of two different reproductive units, called gametes

Porogamy: pollen tube enterthrough themicropyle

Triplefusion: A unique feature of angiospermic plants where one male gamete fuses with the two polar nuclei to form primary endosperm nucleus.

Zygote: Egg and male gamete fuse and form zygote,i.e. a fertilized egg

SELF ASSESSMENT QUESTION

1. Pollentube enter through micropyle is called:

(a) Porogamy (b)Mesogamy

(c) Chalazogamy (d)None

Ans. (a)

2. Pollen tube enter through chalazal end is called:

(a) Porogamy (b)Mesogamy

(c) Chalazogamy (d)None

Ans. (c)

3. Entryof pollentube throughthefuniculusor integumentsis called :

(a) Mesogamy
(b)Porogamy
(c)Chalazogamy
(d)None of the above

Ans. (a)

4. After the syngamy produced-

(a) Oosphere
(b)Zygote
(c) Embryo
(d)Primaryendospermnucleus

Ans. (a)

5. What is the fate of zygote?

(a) Embryo
(b)Egg
(c) Endosoerm
(d)Polar nuclei

Ans. (a)

6. Endospermisdevelop by:

(a) Egg
(b)Embryo
(c)Primaryendospermnucleus
(d)Secondarynucleus

Ans. (c)

7. Two-celledproembryo :

(a) Apicalcellandterminalcell
(b)Suspensorcells only
(c)Sporecells
(d)Basalcellandterminalcell

Ans. (d)

8. Indicots embryodevelopment,thehypophysis isformedfrom:

(a)Terminalcell
(b)Embryocell

(c)Suspensor cell (d)None

Ans. (c)

9. Doublefertilizationinangiospermicplantsproduces :

(a) Diploidoosphereanddiploidendosperm(b)Diploidzygote andtriploid endosperm

(c)Diploidzygote andtriploid oosphere (d)Diploidendospermandtriploidzygote

Ans. (b)

10. Endosperm function is :

(a) Providenutrientto the embryo (b)Firstcellofmalegametophyte

(c) Produced bysyngamy (d)Productofmeiosisinmicrosporemothercell

Ans. (a)

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UNIT: 10

ENDOSPERM: TYPES, STRUCTURE AND FUNCTIONS

Objectives

After studying this unit, you would be able to

- Explain the endosperm development process
- Describe the endosperm structure after studying this unit.
- Enumerate the many kinds of endosperm and endosperm haustoria
- Provide as examples of endosperm functions
- Determine the endosperm's morphological makeup and list all of its variations.

10.1 Introduction

In the previous unit, you have studied about the double fertilization and its significance. You will thoroughly investigate the composition and growth of endosperm in this unit. A seed's endosperm is the portion that stores sustenance for the developing seedling. After twofold fertilization, this tissue is created inside the seeds of the majority of blooming plants. The dual fertilization of flowering plants makes them special. When there is double fertilization, the pollen tube carries two male gametes to the embryo sac. A gamete merges with the egg cell (female gamete), while another gamete forms the major endosperm nucleus by fusing with the polar nuclei or secondary nucleus in the central cell. The zygote, which develops into an embryo, is formed from the fertilized egg cell. The primary endosperm nucleus divides and develops into endosperm. In most of the plant species endosperm is triploid (3n). However, it is diploid in all members of Onagraceae and pentaploid *in Fritillaria*. It is nutritive and surrounds the developing embryo. It is used entirely or partially by the developing embryo. The early seedling continues to take nutrition from endosperm till it becomes independent of producing its own food by photosynthesis.

10.2 Development of Endosperm

A nutritive component called the endosperm helps in the growth of the seed. Many theories and hypotheses were put up to explain the evolutionary genesis of the endosperm towards the closure of the nineteenth century following the discovery of the female gametophyte and the process of multiple fertilization in flowering plants. A theory suggested that endosperm originated from an extraneous embryo. This paradigm proposed that the process of double fertilization led to the formation of two genetically identical persons (organismal duplication), which in turn promoted the functional divergence of the two embryos. For the advantage of its sister, one of the embryos therefore developed a novel feeding role. Subsequent phylogenetic analyses revealed that the genus Ephedra (Gnetales, Gymnospermae) can in fact create two embryos upon fertilization of a binucleate egg through the creation of twin zygotes. Phylogenetically, the embryology of basic angiosperms is more similar to that of primitive gymnosperm taxa. This is due to the fact that the majority of basal angiosperms generate diploid endosperm and have a four-celled embryo sac. Thus, this might represent a piece of the endosperm's paleo-embryonic ancestry.

According to the second idea, endosperm is homologous to female gametophytes of gymnosperms, which undergo fertilization and grow into endosperm. The findings that angiosperm endosperm growth is equally invasive and proliferative as that of the female gametophyte of gymnosperms lend credence to this theory. The genesis of endosperm is essentially connected to twofold fertilisation, according to contemporary theory. It is created when the sperm nucleus and polar nuclei, also known as secondary nuclei, fuse. The nutritive tissue known as endosperm is created when the main endosperm nucleus found in the embryo sac splits. Its structure is triploid (3n). In certain families, like the Podostemaceae, endosperm may be absent, and in some species, like the Orchidaceae, it may be short-lived. It can be absorbed by the growing embryo (as in the case of pea, bean, and *Arabidopsis*) or retained in the mature seed (as in the case of wheat, castor, and coconut).

Endosperm cells are densely packed together with no gaps between cells and are abundant in food reserves. The reserves found in cells include lipids, proteins, and carbohydrates; however, the proportions of these components differ among species. Endosperm provides nutrition for the developing fetus. From the proembryo stage until it reaches self-sufficiency and completes its development, it feeds the embryo. Gibberellins and cytokinins, two growth regulators, are derived from endosperm tissue. Nucleus and integuments are the sources of nutrients for endosperm. The formation of endosperm haustoria in certain families results in the partial or total absorption of integuments and nucellus.

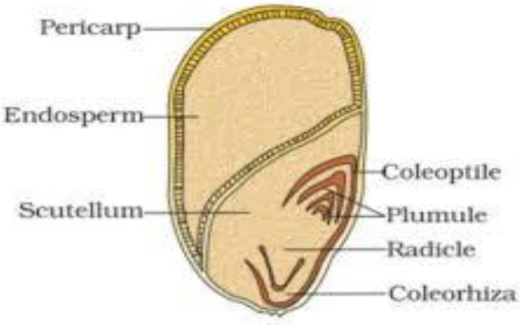


Fig. 10.1: L.S. of Endosperm in Maize grain

The degree of endosperm persistence varies among plants when seeds develop. In grain seeds, endosperm develops and is stored as a reserve tissue. By the time an embryo reaches maturity, endosperm has been broken down in a number of dicotyledonous species. Peas exhibit the presence of free-nuclear endosperm, which is non-persistent and absorbs. Nuclear divisions of endosperm in the family Orchidaceae either stop prematurely in the development of seeds or is absent in all.

10.3: Structure of Endosperm

As you are aware, endosperm is a triploid structure that arises from angiosperm double fertilization. The primary endosperm nucleus is formed when a male gamete fuses with either the polar nuclei or the fusion product of the polar nuclei, the secondary nucleus. Endosperm are produced by the primary endosperm nucleus repeatedly dividing (Fig. 12.1). Depending on the type of embryo sac, a plant's ploidy can vary because of differences in the number of polar nuclei, which can be 1, 2, 4, or 8. Only one polar nucleus, which produces diploid endosperm in *Oenothera*, contributes to the production of endosperm. Eight polar nuclei in *Peperomia* help in the development of the endosperm; as a result, the endosperm is 9n. Because of endomitosis and nuclear fusion, the endosperm may continue to become polyploid as it develops. *Arum* has the highest level of ploidy, with the endosperm nucleus growing to 24576 n.

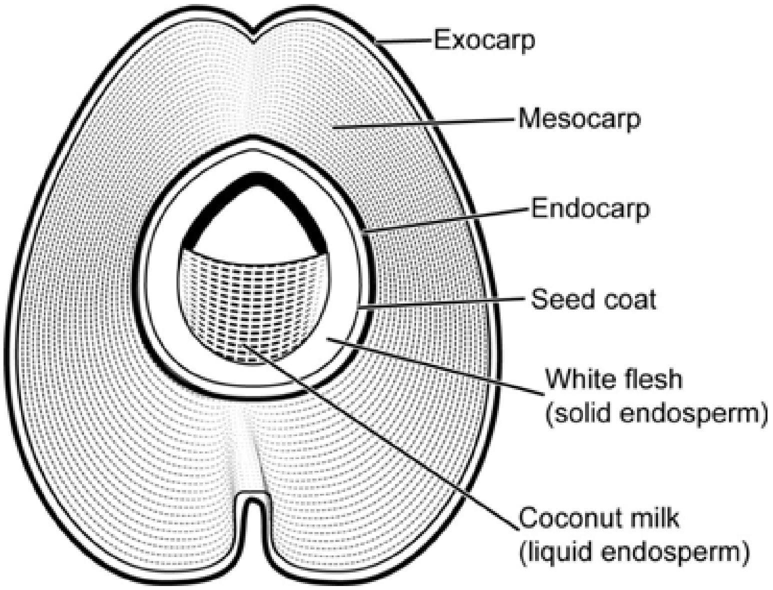


Fig. 10.2: L.S. of *Cocos nucifera* fruit with seed

The endosperm's massive, isodiametric, thin-walled cells may hold significant amounts of food. It has been observed that cells store proteins, carbohydrates, and oil. The deposition of food stores causes disarray in the nuclei of these cells. The endosperm in ripe seeds is a tissue that is not actively growing.Certain species, like wheat and rice, have abundant endosperm that is rich in starch or protein, whereas other species, like castor, sesame, and coconut, have endosperm that is packed with lipids.

The fruit of the coconut has a hard endocarp, a fibrous mesocarp that is the source of coir, and an impermeable exocarp. Inside, there is some liquid endosperm and solid white endosperm (the edible portion) surrounded by a thin seed coat. Only solid endosperm, the source of coconut oil, remains at maturity (Fig. 10.2).

The endosperm is often non-chlorophyllous. However, during seed development, the fruit wall and seed coat of some plants, like Crinum of the Amaryllidaceae family, are significantly reduced, enabling some light to pass through and reach the green endosperm for photosynthesis. The endosperm's outermost layer can occasionally become suberized and have a protective role. The outermost layer of the endosperm becomes specialized and forms the aleurone layer in members of the Poaceae (Graminae) family. The outermost peripheral layer's cells grow, have thick walls, and lose their meristematic activity as they mature. Aleurone grains begin to fill these cells. Two different kinds of inclusions are seen in aleurone grains: globoids that contain protein carbohydrate bodies and lipids and phytotin. Certain enzymes, including as amylases and proteases, are secreted by the cells of the aleurone layer during seed germination, converting the endosperm's stored food materials into a form that is appropriate for the growing embryo.

A nutritive tissue is the endosperm. It controls the growing embryo's pattern of development and gives it nourishment. Mature endosperm acts as a storehouse for fatty acids, proteins, and carbohydrates. Nutrient reserves kept in the integuments and nucellus are used by the growing endosperm.The haustoria of chalazal and micropylar help in the absorption of nutrients from the surrounding cells.

10.4: Natureof Endosperm

Endosperm is haploid, meaning it is either a continuation of the gametophyte tissue or, depending on the situation, diploid, triploid, or an aberrantly sized and shaped second embryo. Earlier researchers like Strasburger (1900) referred to the fusing of the second male gamete as vegetative fertilisation. In angiosperms, the primary endosperm nucleus develops endosperm, which is typically formed by the fusion of polar nuclei and a male nucleus; as a result, it is neither haploid nor diploid but rather typically triploid. In gymnosperms, the endosperm is a gametophytic (haploid) tissue, as it develops directly from the ongoing free nuclear divisions of the functional megaspore. Endosperm is regarded by many embryologists as the second or deformed embryo. The most widely accepted theory about the morphology of the endosperm in angiosperms holds that it is undifferentiated tissue with varying degrees of polyploidy, and that its purpose is to supply nutrients for the embryo's growth.Therefore, endosperm in angiosperms functions similarly to gymnosperms in terms of nourishment, but differs in origin due to its triploid origin.The evolutionary benefit is that, in angiosperms, gametophytic endosperm develops even in the absence of an embryo, resulting in some wastage, whereas in gymnosperms, endosperm develops only if the embryo has also developed in the seed.

10.5: Types of Endosperm

You have already studied about endosperm formation, structure, and nature. Three primary endosperm types have been identified in angiosperms, depending on the manner of development. These are as follows-

(i) Nuclear type

(ii) Cellular type

(iii) Helobial type

10.5.1: Nuclear type

This kind of endosperm has free nuclear divisions in the primary nucleus (without creation of wall). The endosperm starts off free and nuclear but eventually turns into a cell. Initially, nuclear divisions occur synchronously, but they subsequently become non-synchronous, meaning that nuclei can be observed at various stages of mitosis. The free nuclei that are created stay suspended in the center cell's cytoplasm. Later, the growing central vacuole gradually pushes the nuclei towards the periphery. The nuclei either expand independently or fuse together to become larger nuclei. Centripetal wall development is the result. Development begins at the micropylar end and moves toward the chalazal end, or it begins at the periphery and moves towards the center of the embryo sac. It forms a single layer of uninucleate cells. The endosperm becomes fully cellularized as a result of these cells' periclinal and anticlinal divisions (Fig. 10.3). Certain plants have one or two developing periphery layers, with the remaining cells remaining in their free nuclear condition (i.e., without the creation of cell walls). Certain plants do not create walls; instead, their cells stay in their unbound nuclear state. The majority of cells are uninucleate, but occasionally they divide to become multinucleate. The stages of coenocytic, cellularization, differentiation, and maturity are all involved in the development of nuclear endosperm.

The four main cell types found in the developed endosperm are transfer cells, aleurone, starchy endosperm, and the cells surrounding the embryo. Recent studies have shown that processes common to all species of angiosperms allow for the coenocytic and cellularization phases of endosperm formation. This involves anticlinal cell wall deposition and nuclear migration during the coenocytic stage. Centripetal cell development, which extends to the center of the endosperm cavity, is the process by which the endosperm coenocyte is fully cellularized. All internal cells become starchy endosperm cells, whereas cells covering the major vascular tissue become transfer cells. Cereals and other economically significant species are dominated by the nuclear type. When the fruit is still young in the coconut, the embryo sac is filled with a transparent liquid that contains a large number of free endosperm nuclei. We refer to it as liquid syncytium. Later, the peripheral develops into a jelly-like structure with many cells. The fruit ages, showing a huge number of nuclei in the core section that contains the sweet juice and a massive cellular endosperm surrounding it. The portion of the coconut that is edible is the cellular endosperm. The cellular endosperm in betel nut and the fruits of numerous other palms fills the entire embryo sac and turns woody and hard.

Fig. 10.3 depicts various stages of the nuclear type of endosperm development.

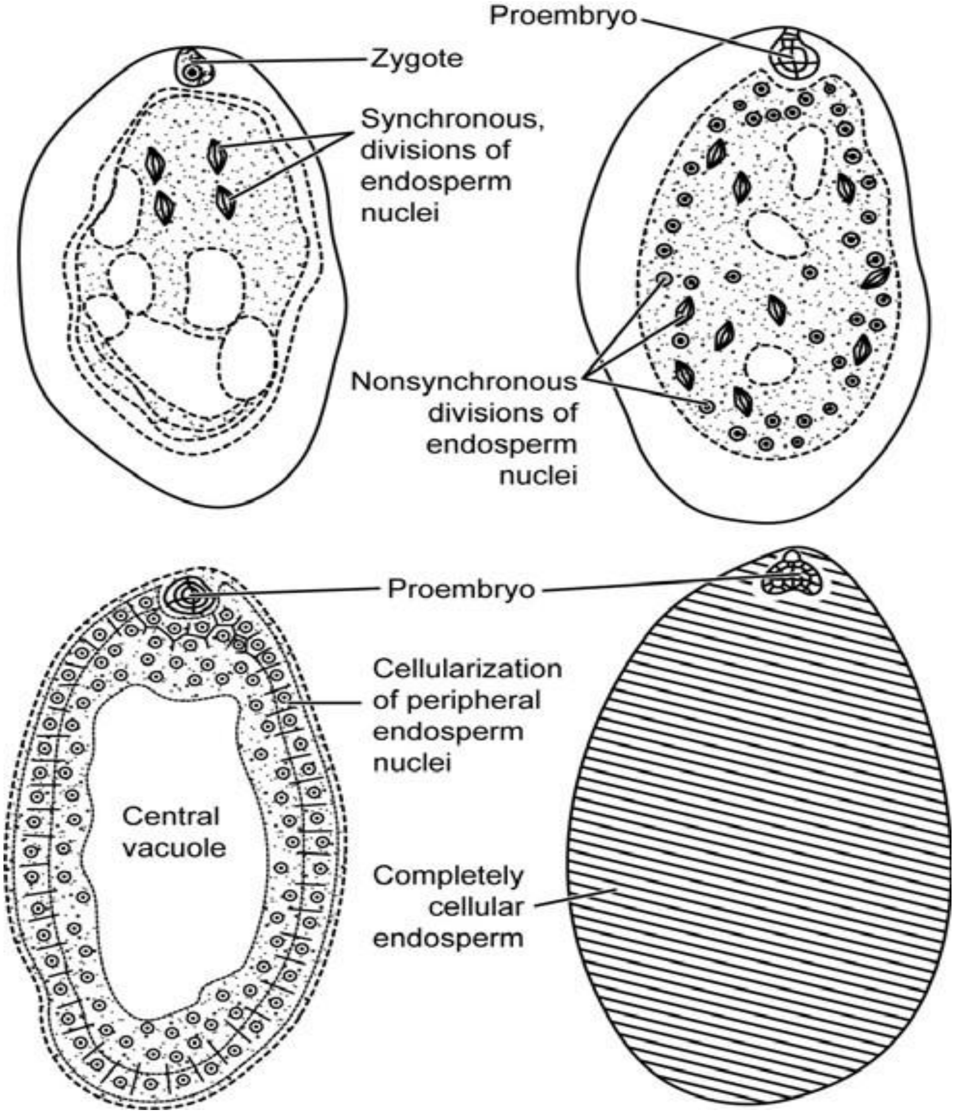


Fig.10.3: Developmental stages of nuclear type of endosperm.

10.5.2: Cellular type

The primary endosperm nucleus divides and usually transverse wall formation is followed after it. Sometimes longitudinal or oblique wall formation also occurs dividing the embryo sac into two cells. Four celled linear endosperm is formed by further transverse division. Irregularly shaped tissue are formed by repeated divisions

The embryo sac contains cellular endosperm and no free nuclear stage is present (Fig. 10.4). Examples of cellular type of endosperm are grasses,Balsam, *Pitunia*, barley, *Utricularia* etc.

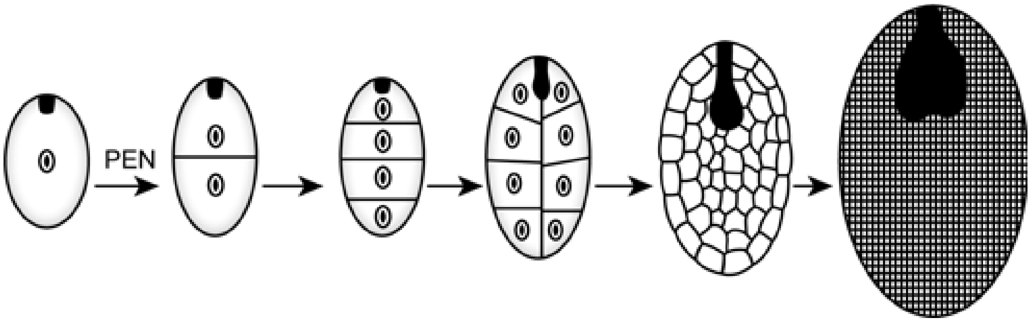


Fig.10.4: Development stages of cellular type of endosperm (PEN=Primary endosperm nucleus).

10.5.3: Helobial type

The primary endosperm nucleus moves towards the chalazal end of the embryo sac. Due to the formation of transverse wall the embryo sac is divide into two unequal parts, a large micropylar chamber and a small chalazal chamber. Free nuclear divisions happen in the micropylar chamber as a result of the wall formation. The nucleus either remains undivided or divides only few times in the chalazal chamber. Later the chalazal chamber degenerates (Fig. 10.5).

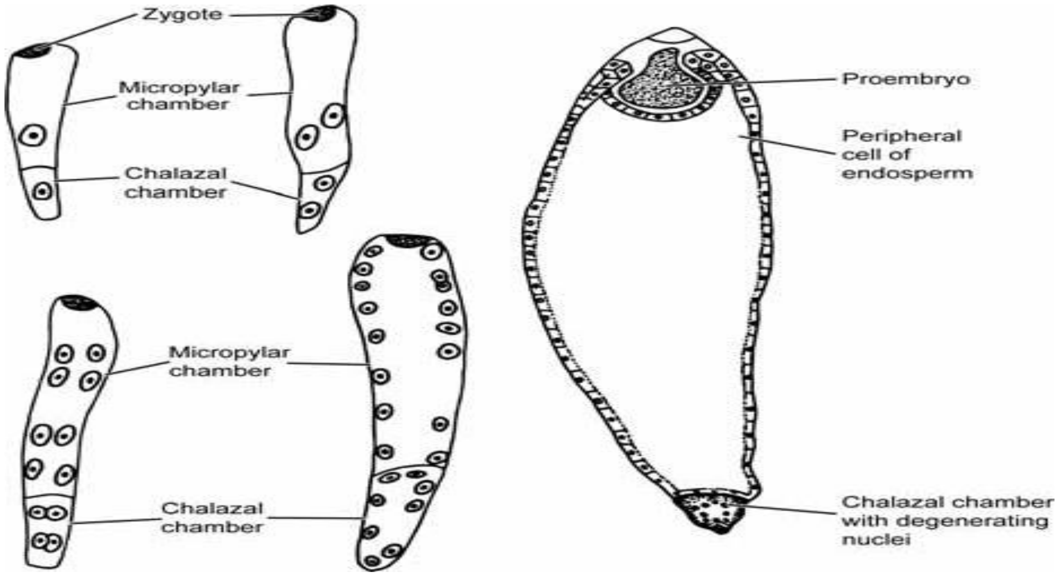


Fig.10.5**:** Various stages in the development of Helobial type of endosperm.

This endosperm is an intermediate between theother two types that is nuclear and the cellular type. Commonly seen in monocots example members of Helobiales. In dicotyledonous families, such as Santalaceae and Saxifragaceae typical type of endosperm has been observed.

In primitive and advanced families of angiosperms distribution of three types of endosperm i.e. Nuclear, Cellular and Helobial are seen.

The Helobial form of endosperm is primarily observed in monocotyledons, the Nuclear type is frequently observed in Polypetalae, and the Cellular type is found in Sympetalae.

Monocotyledons have Helobial type, Sympetalae has Cellular type while in Polypetalae Nuclear type of endosperm is commonly observed,

Since the Nuclear form of endosperm has been observed in many different species, it might be regarded as the most primitive type. Fig. 10.6 shows a comparison illustration of these three endosperm types

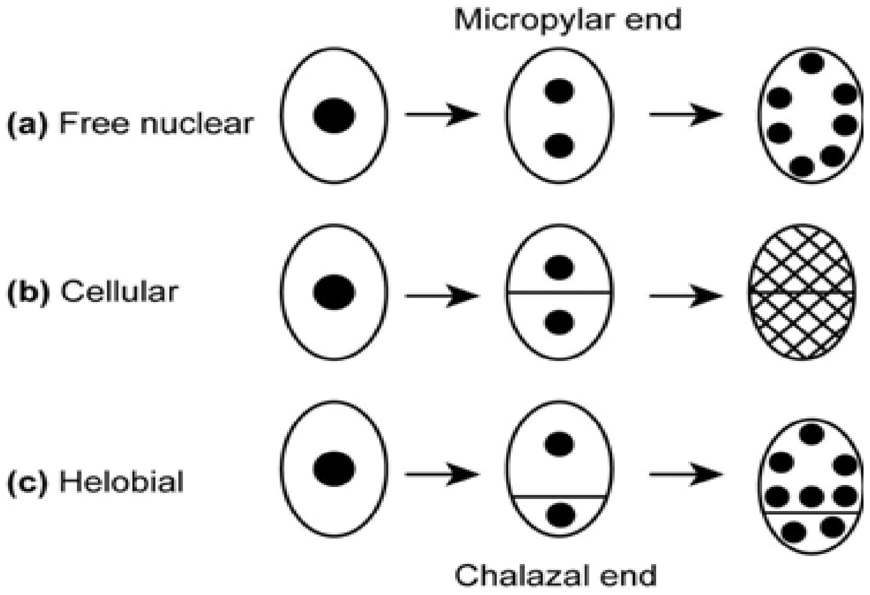


Fig.10.6: (a) Nuclear; (b) Cellular; (c) Helobial.

10.6: EndospermHaustoria

The three endosperm types mentioned above have the potential to form haustoria, or the singular haustorium, which is a unique structure. Haustoria are the lengthy, elongated endosperm structures that infiltrate the tissue of developing seeds and placentas while remaining free nuclear. One frequent characteristic of endosperm is the presence of haustoria. It is thought that they take up and transfer nutrients from the parent sporophyte, using them to fuel the endosperm's development. Plants such as Impatiens, *Nemophila,* and *Frankenia hirsute* have been observed to exhibit micropylar haustorium, whereas Cucurbitaceae, Leguminosae, and Euphorbiaceae members have been observed to exhibit chalazal haustoria. It has been observed that the Lauraceae, Scrophulariaceae, and Orobanchaceae exhibit the formation of both micropylar and chalazal haustorium.

10.6.1: Endosperm with Chalazal Haustoria

The upper portion of this kind of endosperm is free nuclear, but it eventually becomes cellular. The chalazal portion, which is still free of nuclear matter, gives rise to the haustorium. Vermiform appendages, a coenocytic coiled worm-like structure, originate from the lower portion. Aggressive in nature, the haustorium delivers nutrients to the main endosperm while invading the chalazal tissue. *Macadamia ternifolia, Magnolia obovata, Iodinia rhombifolia,* *Crotolaria,* and other plants have been observed to have this form of endosperm haustoria (Fig. 10.7). The Cucurbitaceae family's *Echinocystis lobata* has the longest endosperm haustorium. In *Lomatia*, the top cellular endosperm gives rise to several finger-like extensions in addition to the chalazal haustorium. They increase the endosperm's absorptive surface by penetrating the nutrient-rich nucellar tissue.

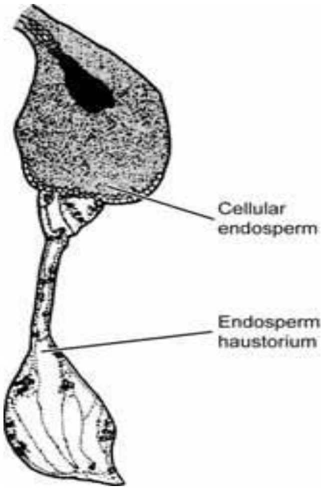


Fig.10.7: Endosperm with chalazal haustorium in Crotolaria

In *Crotolaria* and *Gravillea* species, the free nuclear chalazal zone elongates and takes on characteristics of a haustorium, while the wall formation is limited to the higher region (Fig. 10.7 & 10.8).

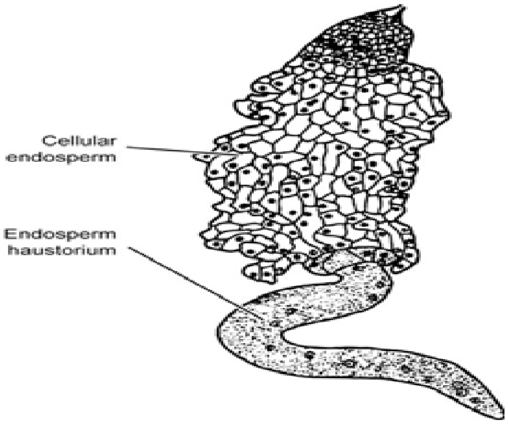


Fig.10.8: Endosperm with chalazal haustoriain *Grevillea.*

10.6.2: Endosperm with Micropylar Haustoria

In this case, the transverse wall comes after the division of the main endosperm nucleus. Upper little chamber and lower large chamber are formed as a result. A vast, branching haustorium arises from the terminal portion of the upper chamber. Its branches receive nourishment from deep within the funiculus (Fig. 10.9). *Hydrocera* and *Impatiens* species both have this kind of haustoria.

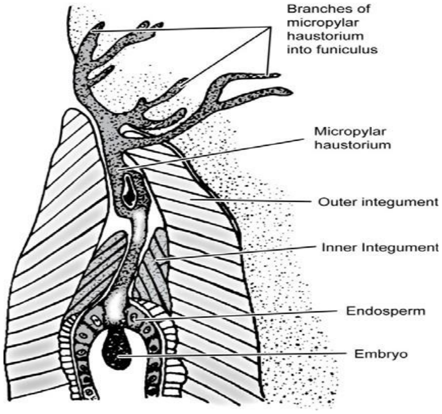


Fig.10.9: Micropylar haustorium in *Impatiens*.

10.6.3: Endosperm with Micropylar and Chalazal Haustoria

Certain texa, such as *Nemophila* (Figs. 10.10 & 10.11), have haustoria at both the micropylar and chalazal ends of the endosperm.A noticeable lateral branch emerges from the chalazal haustorium, develops in the direction of the funiculus, and makes direct contact with the placenta. The micropylar haustorium of *Melampyrum* is made up of a single cell with several tubular processes that grow and infiltrate the funiculus and integument tissue (Fig. 10.12). The nucellar tissue contains the brief chalazal haustorium. Chalazal haustorium in *Klugia notoniana* spreads laterally, and its branches penetrate integument subepidemal cells (Fig. 10.13).

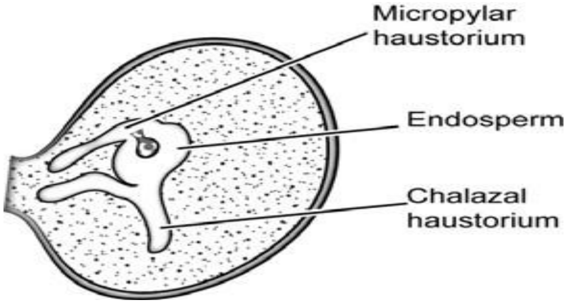


Fig.10.10:L.S.ofovulein*Nemophila*micropylarandchalazal haustoria

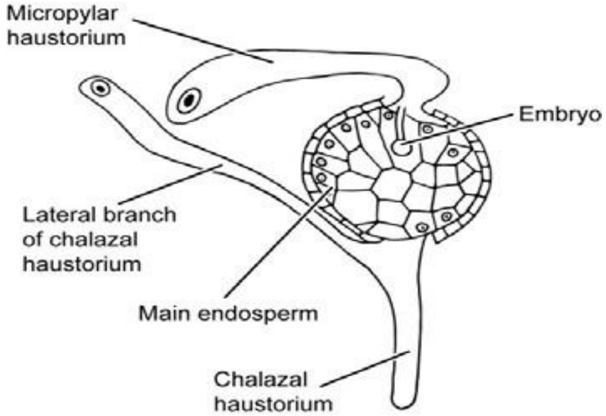


Fig.10.11:Enlargedendosperm

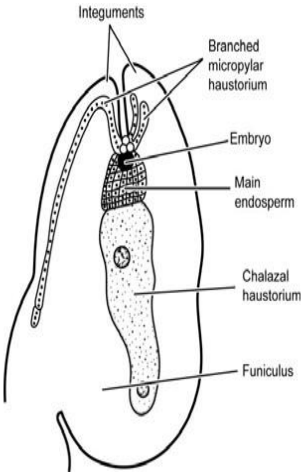


Fig.10.12:L.S.ofOvuleshowingchalazalandmicropylar haustorium.

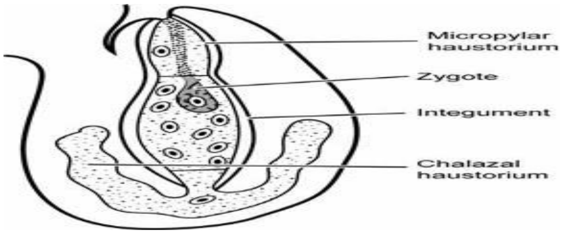


Fig.10.13: L.S. of ovule showing micropylar and chalazal haustorium; notethebranchesofchalazalhaustoriumthatentertheintegumentss.

Secondary haustoria: The chalazal and micropylar haustoria in *Centranthera* are transient. A subset of endosperm cells near the micropylar area generate tubular protrusions that penetrate the nucellus tissue and function as secondary haustoria.

Lateral haustoria: In certain species, the haustorium is lateral rather than micropylar or chalazal, indicating helobial endosperm formation. There aren't many nuclei in the Chalazal chamber. In addition to developing lateral outgrowths that stretch like a skirt on either side of the chalazal chamber, the micropylar chamber exhibits active nuclear divisions. These develop downward and penetrate the chalazal tissue as active haustoria.

Perisperm: The nucellus is normally eaten by the growing endosperm, but in some families—like the Amranthaceae, Portulacaceae, and Zingiberaceae—it survives and serves as a food source. The perisperm, or persistent nucellus, is what gives the growing embryo its nourishment. Endosperm in black pepper is dimunitive and restricted to the area around the embryo. Peristalsm that are high in nutrients occupy the majority of the seed.

10.7: Endosperm Variants

The subsequent stages of the formation of the endosperm have also shown variations. These consist of ruminating endosperm, mosaic endosperm, and composite endosperm.

10.7.1: CompositeEndosperm

The embryo sac's development is distinct in the Loranthaceae family. The ovary is ovule-free. Many embryo sacs that grow and enter the style are developed by the sporogenous tissue at the base of the ovary. The main endosperm nucleus of each embryo sac moves to the basal area, where it splits to form cellular endosperm. As the endosperm grows further, all of the embryo sacs extend and fuse together to form a composite endosperm mass (Fig. 10.14). The ovarian tissue that lies between the expanding endosperms in several embryo sacs is crushed. Only one proembryo that is part of a single embryo sac with a lengthy suspensor survives and matures, out of numerous that develop.

10.7.2: Ruminate Endosperm

In this kind of endosperm, seed coat ingrowths split the endosperm apart. The expanded surface of ruminate endosperm exhibits a considerable degree of irregularity and unevenness (Fig. 10s.15). This results in an appearance of ruminance. The meristematic expansion of the seed coat causes inward intrusion, which results in ruminations. In palms, the developing endosperm may become encroached upon by the seed coat expansion. Cut a betel nut in half, and you will see the ruminations coming out of the seed coat and into the endosperm. In Acanthaceae, the basal apparatus, primary and secondary haustoria, and ruminations are formed by the asymmetrical growth of the core cellular endosperm. In *Annona*, *Passiflora*, *Cocoloba*, and *Myristica*, ruminate endosperm is present.

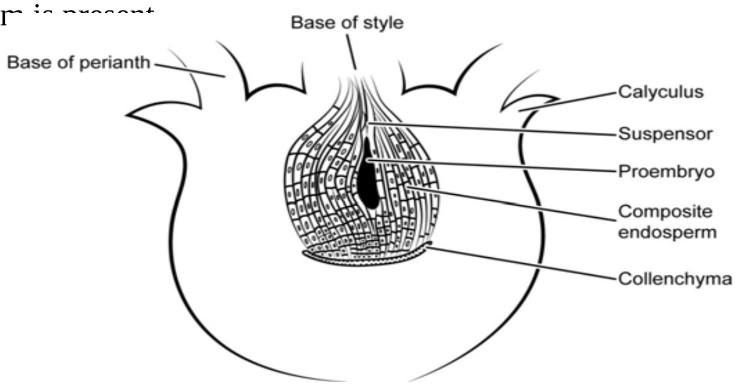


Fig10.14: Composite endosperm in Loranthaceae

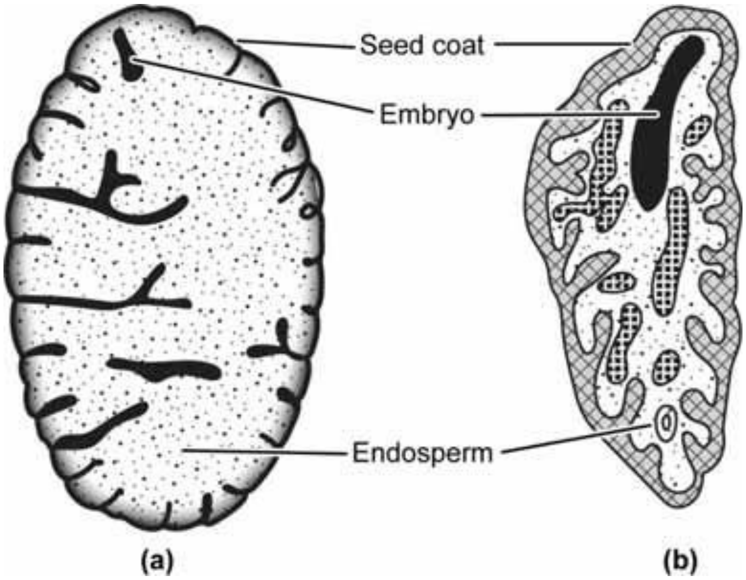


Fig. 10.15: Ruminate endosperm in a) *Asimina triloba*; and b) *Hedera helix.*

10.7.3: MosaicEndosperm

Certain plants have endosperm tissue that appears as two-colored patches, giving the appearance of a mosaic. It has been suggested that somatic mutations or aberrant chromosomal activity during mitosis are the causes of the creation of such endosperm. Red and white tissue patches can be detected in the grain of maize. There have been reports of this kind of endosperm in *Petunia, Lycopersicon,* and *Acorus.*

10.8: Functions of Endosperm

The endosperm of the majority of seeds serves as a food store. The endosperm's early stages are abundant in food sources. It nourishes the growing embryo and controls the exact mode of embryonic growth. The food reserves in the mature endosperm are broken down during seed germination to sustain the growing embryo that becomes the seedling. In certain plants, the endosperm consumes both the fruit wall and the seed coat. Some species with thin seed coats and fruit walls generate chlorophyll when exposed to sunshine. The majority of angiospermous plants have endosperm.

The Orchidaceae family's endosperm cannot develop past a few nuclear divisions.In legumes, it is used by the embryo and is absent from the mature seed (exalbuminous). In legumes, the developed seed food stores are located in the cotyledons rather than the endosperm. Lipids are abundant in castor seed endosperm.

It remains in the seed (albuminous) in monocotyledons. The mature endosperm of cereals is composed of many tissues. Live cells make up the outer layer of aleurone. Typically, the endosperm makes about 87% of the grain, with aleurone making up 10% of the endosperm overall. Lipids and protein are stored in the aleurone layer. Hydrolytic enzymes are created in the aleurone layer of the seed during germination and are released into the starchy endosperm for the embryo's and the seedlings' consumption and digestion.

Gibberellins, which disperse throughout the endosperm of barley and other cereals, are released from the embryo's scutellum when the grains are soaked in water. In reaction to the situation, the aleurone layer releases enzymes (α amylase) into the starchy endosperm and breaks down the protein reserves.An embryo's growth greatly depends on endosperm. Because endosperm development fails in the majority of inter-varietal and interspecific crossings, embryos do not form.

Summary

(i) A triploid structure called an endosperm is present in the majority of angiosperms. It functions as a nutritional tissue and aids in the development of the embryo; after germination, it provides the seedling with nourishment until it can stand on its own. Starch is abundant in seeds and cereal grains. However, as the majority of the endosperm is consumed by the growing embryo, there is no evidence of it in mature legume seeds.

(ii) Three varieties of endosperm can be distinguished based on their developmental stage: cellular, nuclear, and helobial. In certain species, haustoria may develop in endosperm. The development of haustoria may occur at the micropylar, chalazal, or both ends.

(iii) There have also been reports of several endosperm variations. These endosperm types are composite, ruminating, and mosaic.

(iv) Endosperm is normally triploid, but in certain species, it can also be diploid or polyploid.

(v) Endosperm is composed of isodiametric, thin-walled cells that contain a significant amount of reserve food materials.

Glossary

(i) **Chalazal haustoria**- Refers to the part of the ovule of a seed plant called the chalaza, where the integuments and nucellus are joined. It is situated across from the micropyle, which is the opening that allows pollen to enter the ovule.

(ii) **Endosperm-** A sperm cell from the pollen grain fuses with the embryo sac's center cell, which usually has two polar nuclei, to produce the endosperm. In most angiosperms, this union results in a triploid (3n) cell, which subsequently matures into the endosperm.

(iii) **Polyploidy**- An organism is considered to be polyploid if it possesses more than two full sets of chromosomes.

(iv) **Integuments**- The cells that surround the ovule in layers of protection are known as integuments.

(v) **Reserve food materials**- The substances that stored in different plant tissues and supply nutrients throughout times of growth, development, and germination are referred to as reserve food resources in plants.

Self Assessment Questions

Short type Questions

(i) Ruminate endosperm
(ii) Helobial endosperm
(iii) Endosperm haustoria
(iv) Mosaic endosperm
(v) Nature of Endosperm
(vi) Nucellus
(vii) Integuments
(viii) Ovule

UNIT -11

DICOT AND MONOCOT EMBRYO

Objetives

After completing this unit, you will be able to:

- Explain how embryogeny useful in evolution of angiosperms;
- Understand what embryogeny is;
- Discuss information about the dicot and monocot embryo;

11.1: Introduction

Seed is formed in the ovule as a result of series of changes after fertilization Alongwith the development of the endosperm, after a period of rest the oospore (zygote, the fertilized egg) developes into the embryo.

Embryogenesis is the process by which a mature embryo develops from a diploid oospore. Monocotyledons and dicotyledons both start embryonic development in the same way, but later differentiation differs significantly. Let's talk about monocotyledonous and dicotyledonous embryos first before moving on.

As the name suggests, a monocotyledonous embryo has a single cotyledon at the apex of the embryonical axis, whereas a dicotyledonous embryo has two cotyledons linked laterally to the same axis. There is no fundamental difference between the two types of embryos in their early stages of development, but it is quite easy to recognize them due to this organographic difference. Up until the globular stage, the development is remarkably identical.

The process of embryogenesis in all angiosperms begins with the division of the oospore, which then divides to form a transverse wall and develops into a two-celled proembryo. The cell facing the embryo sac's center is referred to as the terminal cell, and the cell next to the micropyle is known as the basal cell. While the terminal cell is in charge of the embryo's continued development and is referred to as the embryo cell, the basal cell forms the suspensor and may or may not participate to rest activities.

11.2: Development of The Embryo and Its Type

On the basis of plane of division of the terminal cell (also known as apical or embryo cell) in the 2-celled proembryo and also observing the contribution of the basal cell and terminal cells in the formation of embryo proper. Johansen (1950) have been reported six types of embryogeny (embryo development)among the Angiosperms.

1. Onagrad or Crucifer type (e.g. Annonaceae, Brassicaceae, Onagraceae, Pedaliaceae, Ranunculaceae, Scrophulariaceae).

2. Asterad type (e.g. Asteraceae, Balsamianceae, Violaceae, Vitaceae).

3. Solanad type (e.g. Campanulaceae, Linaceae, Solanaceae, Theaceae).

4. Caryophyllad type (e.g. Caryophyllaceae, Crassulaceae, Haloragaceae).

5. Chenopodiad type (e.g. Boraginaceae, Chenopodiaceae)

6. Piperad type (e.g. Loranthaceae, Piperaceae).

A. The terminal cell of 2-celled proembryo divides longitudinally:

(1). The basal cell plays only a minor role or none in the subsequent development of the embr proper……………………………………………………………………**Onagrad or Crucifer type**

(2). The basal cell and terminal cell both contribute to the development of embr proper…………………………………………………………………………………**Asterad type**

B. The terminal cell of 2-celled proembryo divides transversely. The basal cell plays only a min role or none in the subsequent development of the embryo proper

(3) The basal cell usually forms suspensor………………………………………**Solanad type**

(4) The basal cell undergoes no further division and the suspensor, if present, is always derived frc the terminal cell…………………………………………………**Caryophyllad type II.**

(5) The basal cell and terminal cell both contribute to the development of embr proper……………………………………………………………………………**Chenopodiad type.**

These five forms of embryogeny have been identified in plants whose oospores (zygotes) divide transversely to create terminal and basal cells during their initial division.

Additionally, a sixth form of embryogeny known as the Piperad type was described by Johansen (1950). The oospore's (zygote's) first division in this type is vertical.

11.3: Development of Dicotyledonous Embryo

The classical example is *Capsella bursa-pastoris* (shepherd's purse) of Brassicaceae. Due to the ovule's campylotropous nature, the embryo, endosperm, and embryo sac all have a horseshoe-shaped shape. Here, the embryo is developing in the Onagrad or Crucifer type.

1. The zygote (oospore) splits longitudinally. This leads to the formation of a two-celled proembryo.
2. A suspensor cell is a bigger basal cell located at the micropylar end. The smaller one, which is farther away, is known as an embryo cell or terminal cell.
3. The transverse division of the suspensor cell results in the formation of a filamentous suspensor consisting of six to ten cells. The suspensor facilitates the embryo's movement within the endosperm.
4. The haustorium, sometimes known as the vesicular cell, is the first suspensor cell to swell as it faces the micropyle.
5. Hypophysis is the term for the final suspensor cell, which faces the embryonic cell. It produces a root cap and radicle.
6. To generate the quadrant and octant stages, the embryo cell divides twice vertically and once transversely. Eight cells, two tiers of which are epibasal (terminal) and hypobasal (near the suspensor), make up the octant.

The two cotyledons and the plumule are eventually formed by the epibasal cells. The hypocotyl is made by the hypobasal cells. In order to produce the ground meristem, procambium, and outer layer of protoderm, the octant embryo goes through periclinal divisions.

The ground meristem creates the cortex and pith, the protoderm makes the epidermis, and the procambium gives rise to the steal or vascular strand. It is spherical at first, but as the cotyledons expand, it takes on a heart-shaped form before taking on the usual shape of, assume, *Capsella bursa-pastoris.*

Structure of Dicot embryo

Two cotyledons are present on the embryonal axis of the mature embryo. The embryonic axis creates the plumule (epicotyl) above the cotyledon level and the radical (hypocotyl) below it. The plumule develops into the shoot upon germination, whereas the radical produces the root system. Young seedlings are established using the reserve food material in the cotyledons (Figure 13.1).

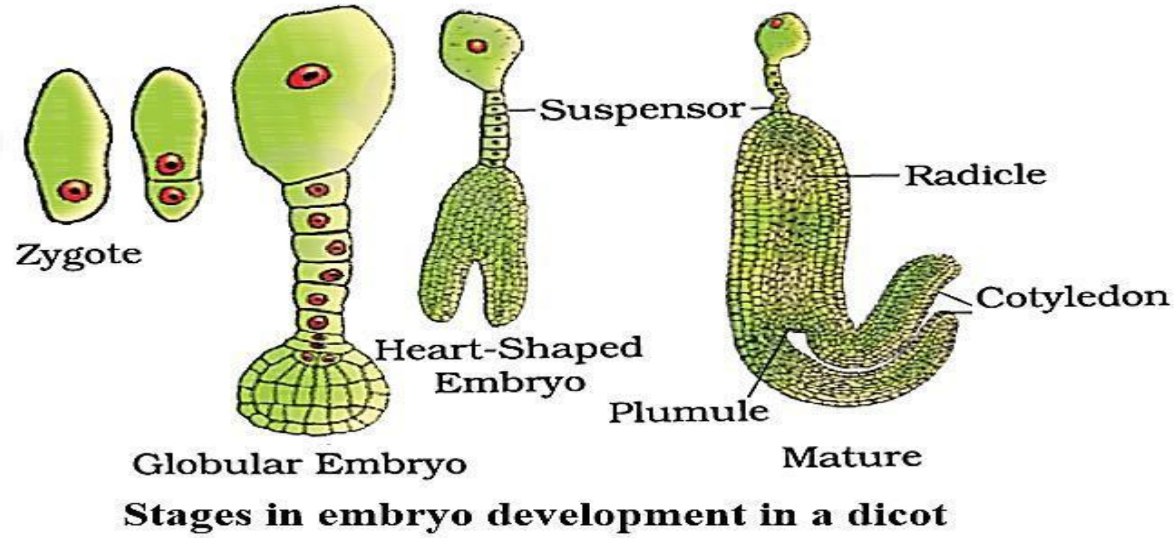


Figure. 11.1

11.4: Development of monocotyledonous embryo

The embryogeny of monocotyledons and dicotyledons is not fundamentally different, although there are some differences in later stages because in monocotyledons, only one cotyledon grows from the embryo rather than two. In order to explain the development of a monocotyledonous embryo, we will use Luzulaforsteriof Juncaceae as an example. Here, the embryo is likewise developing in the Onagrad or Crucifer type.

Up to the octant stage, the early development of dicot and monocot embryos is identical. Differentiation begins later.

1. To form basal and terminal cells, the zygote, also known as the oospore, elongates and divides transversely.

2. A big, inflated, vesicular suspensor cell is produced by the basal cell (in the direction of the micropylar end). It might serve as a haustorium.
3. To create two cells, the terminal cell divides by another transverse wall.
4. After several divisions, the top cell produces a single cotyledon and a plumule.
5. The terminal plumule is forced to one side by the scutellum, a cotyledon that grows quickly. The plumule eventually settles into a depression.
6. The central cell divides numerous times to generate the radicle and hypocotyl. It also expands the suspensor by a few cells.
7. Certain cereals have sheaths termed coleoptile and coleorhiza that emerge from the scutellum and cover the radicle and plumule, respectively.

Structure of Monocot embryo

Monocotyledon embryos only have one cotyledon. Scutellum is the name of this cotyledon in the Poaceae family of grasses. It is located on the embryonal axis' lateral side. The radicle and root cap of this axis are encased in a sheath known as the coleorhiza at its lower end (Figure 13.2). Epicotyl refers to the portion of the axis above the scutellum's attachment point. Its hollow foliar structure, known as the coleoptile, encloses a few leaf primordia and the shoot apex. The epiblast is the basic form of the second cotyledon.

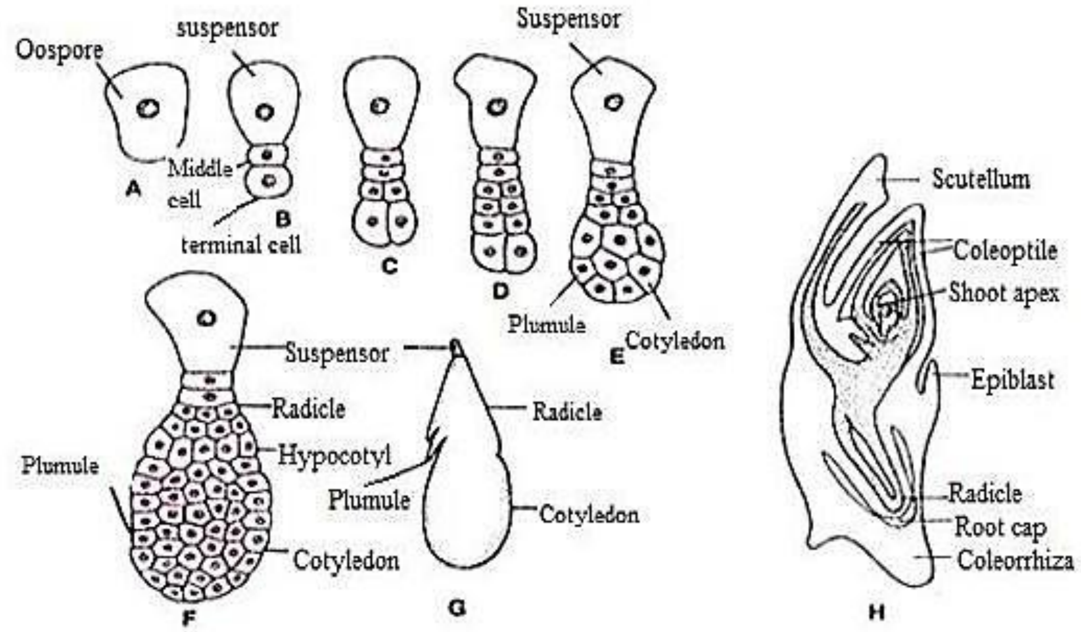


Fig. 11.2 A-G: Stages in development of a monocot embryo; H. A monocot embryo of a grass

Summary

1. The oospore or zygote develops the embryo.
2. Johansen(1950) identified six types of embryogeny (embryo development) among the Angiosperms, namely Onagrad or Crucifer, Asterad, Solanad, Caryophyllad, Chenopodiad, and peperad types, based on the plane of division of the terminal cell in the 2-celled proembryo and the contribution of the basal cell and terminal cells in the formation of embryo proper.
3. Two cotyledons plus an embryonal axis make up a typical dicotyledonous embryo.
4. One cotyledon plus an embryonal axis make up a normal monocotyledonous embryo.

Glosarry

(i) **Plumule**- The embryonic shoot found in a plant seed is called a plumule. It is the part of the embryo that will give rise to the plant's above-ground parts, such the stems and leaves.

(ii) **Scutellum**- Monocot seeds contain a modified cotyledon called a scutellum. It is a single structure that resembles a shield and is closely related to the embryo.

(iii) **Protoderm**- A layer of undifferentiated cells found in the meristematic tissue of plant embryos and young seedlings is known as the protoderm.

(iv) **Coleorhiza**- Monocot seeds contain a sheath-like structure called a coleorhiza that surrounds and protects the radicle, or embryonic root.

(v) **Coleoptile**- The monocot seed plumule, or developing stem tip, is covered and protected during germination by a cylindrical or hood-like sheath called the coleoptile.

Self Assessment Questions

Short question answers

1. Define the term embryogenesis.
2. Differentiate between monocot and dicot embryo.

3. Define the hypocotyls.

4. Draw a well-labelled digrarm to show the stages in development of a monocot embryo.

5. What is coleoptile?

Long question answers

1. Write a detailed note on embryogeny and its types.

2. Discuss the development of dicot embryo with suitable examples.

3. Write a note on developmental stages of a monocot embryo?

UNIT-12

APOMIXIS: DEFINITION AND TYPES

OBJETIVES

After completing this unit, you will be able to:

- Explain how polyembryony and apomixis are used in plant development programs.
- Understand what is apomix is.
- Discuss information about vegetative reproduction, agamospermy, and apospory.

12.1: Introduction

The term "apomixis" describes a group of reproductive processes that, in order to produce clonal seeds, always depend on preventing meiotic reduction and fertilization of the egg cell. Apoptoxism was long thought to be a strictly asexual abnormality that would eventually lead to extinction, but the integration of more than a century's worth of research in the fields of embryology, genetics, molecular biology, and ecology has shown that it is actually a widely distributed part of the dynamic processes that determine the evolution of flowering plants. Multiple adaptable and flexible developmental routes are involved in apomixis, and these pathways can be merged inside the ovule to create progeny. Here, we summarize the substantial corpus of work that has been done on parthenogenesis, haploid induction, and unreduced gamete production in flowering plants, both historically and now. We draw attention to the parallels and discrepancies between apomictic and sexual reproduction, as well as their implications for the evolution of asexual seed reproduction. Based on these parallels, we suggest a hypothesis linking the developmental origin of apomixis to a dynamic epigenetic landscape where changes in the environment affect female reproductive development in a reversible way via polyploidization and hybridization processes.

As apomixis allows true-breeding hybrids to be produced through seeds, it has great promise for transforming global food, feed, and fiber production. In addition to restoring hybrid vigor, apomixis may enable the production of commercial hybrids from seed-propagated crops in the absence of a reliable malesterility mechanism. We've already talked about the advantages apomixis presents for creating better hybrids and streamlining hybrid production.

More success than with any other grain crop has likely been accomplished in transferring the apomictic mechanism from wild *P. squamulatum* to farmed pearl millet. The BC6 generation, which has maintained high levels of apomixis, has received the mechanism. The postanthesis loss of 80–90% of the seed set has been an issue, though. Apomixis from *Tripsacum dactyoides* (L.) L. to maize and from *Elymus rectisetus* (Nees in Lehm.) to wheat are being transferred (Carman and Wang, 1992).

The biggest effect of apomixis could be achieved by using genetic techniques to clone and introduce the gene or genes governing apomictic reproduction into different sexual species. A transferred gene needs to be stable and able to express itself in an alien genome in order to be beneficial. Prior to being cloned and used to other species, the gene or genes causing apomixis must be located. *Pennisetum* is developing molecular markers associated with apomixis.

You will learn about agamospermy, apospory, apomixis, vegetative reproduction, and the use of polyembryony and apomixis in plant improvement initiatives in this unit.

12.2: Apomixis

Any plant that reproduces sexually has an impact on the structure and quantity of genetic variety within a population, which in turn affects the population's potential for evolution. There are two key steps in sexual reproduction:

(1) Meiosis, in which the mother cell of the megaspore and micropsore (a diploid sporophytic cell) divides reductionally to produce four haploid gametes, which signify the gametophytic stage.

(2) Syngamy, in which a diploid zygote is formed by the fusion of male and female gametes.

As a result, gametophytic and sporophytic stages of sexual reproduction demonstrate the generational alternation. These two steps are not always possible for certain plants to finish or interrupt, but the embryo still develops. Apomictic plants—so named because the process is called apomixis—are those in which the sexual process is replaced by an asexual one, and the child shares genetic similarities with its female parent.

One of the main components of agricultural productivity is seed. Therefore, for both the quantitative and qualitative advancement of agricultural production, an understanding of the mechanisms behind seed development in cultivated plants is essential. There are two methods of seed reproduction in angiosperms: asexual, or apomictic, and sexual, or amphimictic. Seed companies primarily use the former to breed new varieties, while basic research projects on the latter are gaining more and more attention from the scientific and industrial sectors. A controlled engineering of apomixis into sexual crops will have a significant and wide-ranging effect on agriculture. Actually, apomixis will make it possible to produce clonal seeds, which will lead to more affordable, reliable, and high-quality fruit and vegetable outputs. Because apomixis technology avoids the complications common to sexual reproduction, such as incompatibility barriers and vegetative propagation, like viral transfer, and reduces costs and breeding times, it is anticipated to have a revolutionary effect on agricultural and food production. However, a fuller understanding of the mechanisms governing plant reproductive growth is necessary for the development of apomixis technology in agriculture. Understanding the genetic regulation of the apomictic process and how it differs from the sexual process requires awareness of this precondition. Finding genes that are specifically or differently expressed during embryo and embryo sac development would significantly increase our molecular understanding of apomixis.

Hans Winkler described apomixis in botany as the substitution of asexual, nonfertilized reproduction for typical sexual reproduction. Its etymology translates to "away from" + "mixing" in Greek. Notably, meiosis is not included in this definition. As a result, "normal asexual reproduction" of plants, such as propagation from cuttings or leaves, has never been classified as apomixis; nonetheless, plantlets replacing seeds and bulbils replacing flowers have been identified as examples of apomixis. Offspring generated apomictically share the same genetic makeup as their parent plant..

Asexual reproduction in all its stages was included by some authors under the umbrella word "apomixis," but this usage of the term has since faded.

When referring to flowering plants, the term "apomixis" is frequently used narrowly to refer to agamospermy, or clonal reproduction via seed. Agamospermy may exist in gymnosperms, but it doesn't seem to exist in that group.

Put in another context, apomixis is a reproductive strategy that enables a plant to clone itself from seed by avoiding the sexual phase. In Pennisetum, an embryo develops from an egg cell that is chromosomally unreduced into an embryo sac that is produced from a vegetative nucellar cell. Apospory is the term for this kind of apomixis. In addition to the egg cell developing into an embryo without sperm fertilization, endosperm and seed development require pseudogamy, or fertilization of the central cell. The sole form of apomixis that has been proven in *Pennisetum* is apospory.

Types of Apomixis

(i) Vegetative Reproduction

(ii) Agamospermy

(i) Vegetative Reproduction: In this type of reproduction, plants multiply by the use of propagules, which are their vegetative portions. Bulbs, bulbils, runners, and suckers are examples of propagules.

(ii) Agamospermy: The two typical processes of meiosis and syngamy have been removed, yet seeds are still created as a means of propagation. Two varieties of agamospermy exist:

- **Adventive Embryony:** This is the term used to describe the development of an embryo from the sporophytic cell of the ovule, such as the nucellus and integuments. Mangos and citrus are typical instances of adventive embryogenesis. As adventive embryos emerge, cells (nucleus and integuments) become densely cytoplasmic and divide to produce a mersitematic mass of cells. In the embryo sac, zygotic and adventive embryos develop simultaneously. Although these two embryos appear identical, zygotic embryos have a suspensor while advntive embryos have not. Adopted embryony is widespread in many groups, including the Cactaceae, Boxaceae, and Euphorbiaceae.
- **Gametophytic Apomixis:** In this case, the unreduced female gametophyte's cell gives rise to the embryo. Diplospory is the term for when the unreduced embryo sac forms straight from the megaspore mother cell without passing through the reductional division. Apospory is the term used to describe the direct development of an unreduced embryo sac from any nucleus cell.

Diplospory

In this kind, the mother cell of the ovule megaspore differentiates but does not undergo a meiotic division. There is no callose on this apomictic megasporocyte. It is of the following types and divides by mitotic division to form the diploid embryo sac:

***Taraxacum* Type:** The mother cell of the megaspore divides meiosis twice, but after the first division, a restitution nucleus forms. A dyad with a somatic chromosome number is formed by the mitotic division of the MMC with restoration nucleus. Usually, the micropylar dyad degenerates as the chalazal dyad develops into an 8-nucleate embryo sac.

***Antennaria* Type:** The mother cell of a megaspore does not go through meiosis. It grows larger and functions like a diploid embryo sac. The embryo sac's nucleus divides during mitosis to produce eight nucletae, or embryo sacs of the Polygonum type. The embryo sac's cells are all diploid.

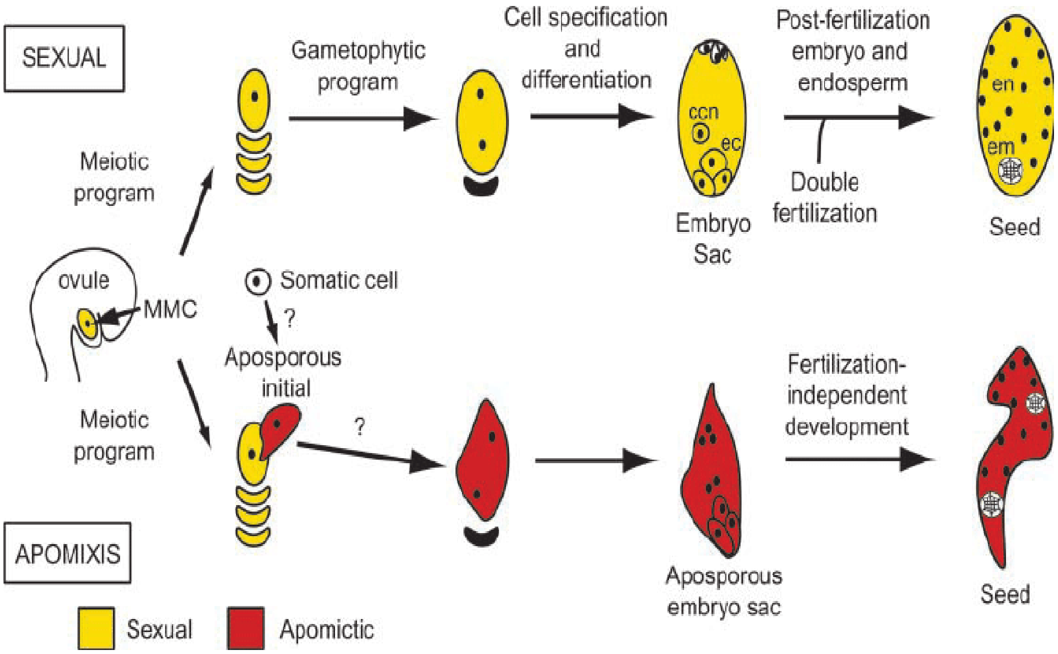
***Allium* Type:** The primary factor responsible for the formation of the unreduced embryo sac in megaspore mother cells is the doubling of premeiotic chromosomes. It's possible for endomitosis to cause chromosome doubling, which produces a dyad of unreduced cells during meiosis. In the chalazal dyad, two mitoses result in the creation of an eight-nucleate embryo sac.

Apospory

Apospory is the process by which a diploid embryo sac develops from integument or nucellus cells. The megaspore mother cell in this kind differentiates and proceeds through meiosis, which may or may not be finished to generate a linear tetrad. The nearby nucellar cell can become meristematic at any time and act like the mother cell of a megaspore. Referring to Figure 12.1, this cell undergoes mitotic division to generate a diploid embryo sac. Only the aposporous embryo sac develops and the sexual embryo sac degenerates in plants where apospory is required. There are two varieties of it:

- ***Hieracium* Type:** In *Hieracium*, a linear tetrad is formed when the megaspore mother cell divides during meiosis. At the chalazal end of the tetrad, a nucellar cell develops into the aposporous unreduced embryo sac and becomes functional simultaneously. Only the aposporic embryo sac develops as the other four megaspores eventually disintegrate. The aposporic embryo sac has eight nuclei.

- ***Panicum* Type:** *Panicum* and other grasses contain it. The aposporic embryo sac has four nuclei, consisting of a single polar nucleus and a three-celled egg apparatus. No antipodal cells can be found**..**



12.1: Diagram showing the formation of Apomictic Embryo Sac

12.2.1 Exploitation of Polyembryony and Apomixis in Plant Improvement Programmes

In the fields of plant breeding and horticulture, adventive polyembryony is extremely important. Since the parental type seedlings are produced by vegetative propagation using cuttings, it offers homogenous seedlings of that type. The only feasible method for producing virus-free clones of polyembryonate citrus cultivars is nucellar polyembryony. There are no illnesses present in nucellar embryos. In addition, nucellar seedlings exhibit the restoration of lost vigor following repeated vegetative propagation and have a superior root system than cuttings.

Since apomictic plants do not undergo meiosis, any chance of variants and recombinations is completely removed. Furthermore, these plants are incapable of adjusting to shifting environmental circumstances. Genetically, apomictic plants resemble their mother plant. Thus, choosing individuals with desired gene combinations and using them to create clones is the main benefit of apomixis. Apoptism is currently a top priority in applied plant genetic engineering. Apomixis has attracted a great deal of interest from the scientific and industrial sectors due to its significant contribution to crop improvement. Researchers are attempting to use genetic engineering and induced mutagenesis to spread this apomictic feature to other species of agricultural plants.

Summary

- Any plant's ability to reproduce sexually affects the quantity and composition of genetic variety within a population, which in turn affects the population's capacity for evolution.
- The gametophytic and sporophytic stages of sexual reproduction display the generational alternation.
- In certain plants, the embryo forms even when these two processes are unable to be finished or stopped.
- There are two methods of seed reproduction in angiosperms: asexual, or apomictic, and sexual, or amphimictic. Seed companies primarily use the former to breed new varieties, while basic research projects involving the latter are drawing more and more attention from the scientific and industrial sectors
- Apomixis will have a significant and wide-ranging effect on agriculture if it is properly involved into sexual crops.
- Because apomixis technology avoids the problems associated with sexual reproduction and reduces costs and breeding time, it is anticipated to have a revolutionary effect on agricultural and food production.
- In flowering plants, agamospermy—clonal reproduction by seed—is generally referred to as "apomixis" in a narrow meaning. Agamospermy may exist in gymnosperms, but it doesn't seem to exist in that group.
- In *Pennisetum,* an embryo develops from an egg cell that is chromosomally unreduced into an embryo sac that is generated from a vegetative nucellar cell. Apospory is the term for this kind of apomixis.

- In addition to the egg cell developing into an embryo without sperm fertilization, endosperm and seed development require pseudogamy, or fertilization of the central cell.
- The only type of an apomixis that has been verified in *Pennisetum* is apospory.
- Plants reproduce through their vegetative portions, or propagules, in a process known as vegetative reproduction. Bulbs, bulbils, runners, and suckers are examples of propagules.
- While seeds are produced in agamospermy plants as a means of propagation, the two typical processes of meiosis and syngamy have been removed.

Glossary-

(i) Apospory- The process of apospory includes using non-reproductive parent plant cells, usually from the nucellus or ovule, to produce an embryo or new plant.

(ii) Apogamy- In plant biology, apogamy is the process by which a gametophyte—usually haploid—develops directly from a sporophyte—usually diploid—without the need for fertilization.

(iii) Agamospermy- The process by which seeds develop in plants without fertilization is known as agamospermy. In agamospermy, unfertilized ovules give rise to seeds, frequently by means of asexual reproduction.

(iv) Apomixis- In a specific type of asexual reproduction known as apomixis, seeds develop in plants without the need for fertilization.

(v) Adventive embryony- In plants, asexual reproduction known as adventive embryony occurs when embryos develop directly from the parent plant's somatic cells, usually outside the ovule or without the need of the embryo sac.

Self Assessment Questions-

Short Answer Questions

1. Define the term apomixis.
2. What are the two processes in sexual reproduction?
3. Write a short note on adventive embryony.
4. Draw a well-labelled digrarm to show the formation of apomictic embryo sac.
5. What is apospory?

Long Answer Questions

1. Write a detailed note on apomixis and its types.
2. Explain vegetative reproduction, agamospermy and apospory with examples.
3. What is diplospory? Explain its types.
4. Write a note on exploitation of apomixis in plant improvement programmes.

UNIT- 13

Polyembryony-Definition and Types

Objectives

After completing this unit, you will be able to:

- Explain how polyembryony is used in plant development programs;
- Understand what polyembryony is;
- Discuss information about the induced polyembryony.

13.1 Introduction

The process by which a seed produces many embryos is known as polyembryony. These embryos may be created by the processes of apogamy or apomixis, or as a result of multiple syngamy (fertilization). Simple polyembryony is the term used to describe polyembryony that results from fertilizing many eggs. The phenomena is frequently observed in angiosperms, such as groundnut, orange, lemon, onion, and mango. Leeuwenhock was the first to report it (1719).

According to Johansen (1950), polyembryony is the process of producing many embryos from a single zygote. This type of polyembryony, known as cleavage polyembryony, is brought on by the cleavage of the proembryo (Orchidaceae).

Polyembryony can also occur when many embryos grow from cells other than the egg in the embryo sac (*Argemone*), when multiple embryos arise from the existence of multiple embryo sacs in a single ovule (Citrus), or when multiple embryos develop from cells outside the embryo sac (Mango, *Opuntia*).

Four types of Polyembryony were identified by Braun (1859):

1. Zygote or zygotic embryo cleavage.
2. The development of embryos from embryo sac cells other than egg cells.
3. The ovule's formation of many embryo sacs.
4. The ovule's sporophytic cells becoming active.

Two forms of polyembryony have been identified, depending on whether the embryos develop in one or many embryo sacs within the ovule. Depending on whether the embryos develop in separate embryo sacs within the same ovule or in the same embryo sac, it has been classified as "true" or "false."

13.2: Polyembryony

Polyembryony is the term used to describe the presence of many embryos within a seed. Orange seeds are where Antony Van Leeuwenhoek (1719) first saw the phenomena. Among conifers, it is rather typical (Gymnosperm). However, this phenomena is seen in a large number of dicotyledon and monocotyledon plants.

Origin of Polyembryony

On the basis of origin following four types of polyembryony have been recognised in angiosperms:

1. The embryo's origin from antipodal or synergid cells
2. Embryos originate from cells outside of the embryo sac
3. Embryos originate from endosperms
4. The embryos' origin from another embryo sac inside the ovule

Schnarf (1929) distinguished between two forms of polyembryony: true and false.

13.2.1: True Polyembryony

If the condition is true polyembryony, the embryos can develop from nucellar or integumentary cells outside the embryo sac (adventives embryony), from cells of the embryo sac other than the egg (apogamy), or from splitting of the zygote or proembryo (cleavage polyembryony). Few gymnosperms also exhibit polyembryony.

13.2.2: Pseudo-Polyembryony

The growth of two or more embryo sacs within the same nucellus or the fusing of two or more nuclei in an ovule constitutes pseudo or false polyembryony. An ovule may occasionally contain several embryo sacs, allowing for the development of two zygotic embryos in a seed. *Poa pratensis* and *Casuarina equisetifolia* can develop from one or more megaspore mother cells, or from derivatives of the same megaspore mother cell. It has been discovered that the extra embryo sacs in *Atraphaxis* and *Trifolium* occasionally originate from the chalaza cells.

True polyembryony, according to Gustafson (1946), is the formation of embryos from one or more embryo sacs contained in a single nucellus, whereas false polyembryony is defined as situations in which two or more nucelli, each with its own embryo sac, unite.

13.3: Types of Polyembryony

Three categories of angiosperm polyembryony were distinguished by Webbe (1940):

1. Simple Polyembryony: In gymnosperms, this type of polyembryony results in the fertilization of many archegonia, which produces a number of embryos.
2. Cleavage Polyembryony: In this type of embryogenesis, a single fertilized egg (zygote) produces many embryos.
3. Rosette Polyembryony: This type of polyembryony is called rosette polyembryony because it occurs in some gymnosperms. Additional embryos grow from the rosette cells.

(1) Simple Polyembryony: In this kind, the ovule contains one or more embryo sacs in which the embryos develop. Additionally, proembryonal or suspensor cleavage or budding from the zygotic embryo results in embryos. It is also possible to create embryos without fertilization. It happens in gymnosperms when an egg fertilizes multiple archaegonia in a female gametophyte (a process known as archegonial polyembryony).

(2) Cleavage Polyembryony: This happens when the zygote or proembryo splits into two or more pieces during the early stages of development. Gymnosperms, or conifers, are known to exhibit this kind frequently. However, angiosperms including *Nicotiana rustica*, *Isotoma longiflora*, and *Erythronium americanum* have been observed to exhibit it on occasion. The first transverse division of the zygote in *Erythronium* produces a big basal cell and a small terminal cell. The former grows larger without making any divisions, or it can make several divisions to create a collection of cells that give rise to embryos. The term "embryogenic mass" refers to the outgrowths that occur at the bottom of the cell as its volume rises. Multiple cells at the distal end of the embryonic mass create distinct embryos. A separate embryo develops from each branch that the filamentous proembryo branches into. The embryo produces buds or outgrowths that have the potential to develop into more embryos. Extra embryos are created from proembryonic suspensor cells in *Isotoma* and *Exocarpus.*

(3) Rosette Polyembryony: In this kind, the suspensor's rosette cells give rise to more embryos. This kind is frequently observed in gymnosperms.

Other cells found in the ovule or embryo sac that might develop into embryos include:

(a) Developing embryos from cells outside the embryo sac:

Nucleus and integument cells, such as those of *Citrus, Eugenia,* and *Mangifera*, can also grow into embryos. The inner cells of the inner layer of the integument give rise to embryos in spiral plants. These embryos eventually lie in the embryo sac where the endosperm feeds them. Because they are immune from disease and retain their superiority over time, embryos obtained through nucellus propagation are superior to those obtained through vegetative propagation.

(b)Embryos from embryo sac cells other than egg cells

Synergids embryos

Synergids and antipodal cells within the embryo sac may give rise to the embryo. The synergids have the option of developing without such fusion or being fertilized by sperm from a separate pollen tube. Synergid fertilization often happens following the extra pollen tube's entrance into the embryo sac. Additionally, the unfertilized synergid is encouraged to divide into a structure resembling an embryo (Fig. 13.1). The nature of these embryos is haploid. In the embryo sac, synergid embryos such as *Argemone mexicana* and *Phaseolus vulgaris* develop alongside zygotic embryos. Less commonly, but not vivibly, embryos from antipodal cells develop (*Ulmus americana, Allium odorum*, for example).

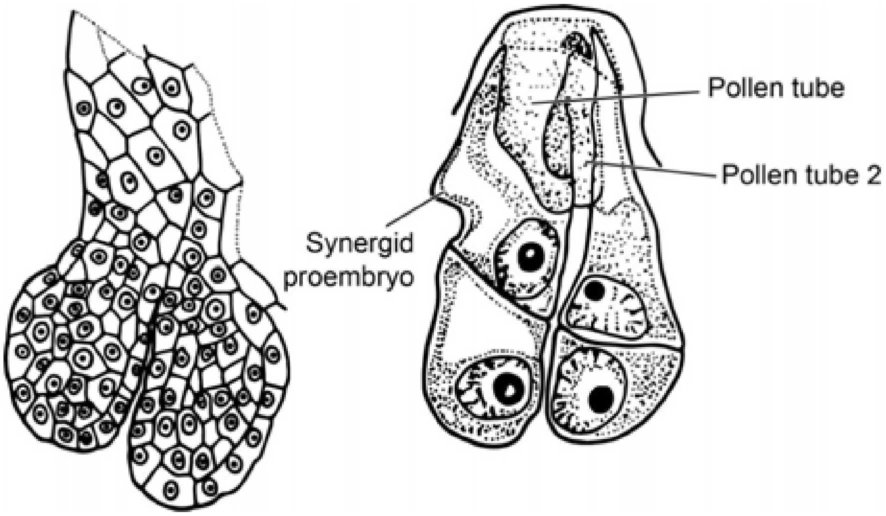


Fig.13.1:SynergidsPolyembryony:*Tamarixericoids*and*Dioscoreacomposite*.

Zygotic embryos

Two or more embryos (*Cocos nucifera, Primula auriculata*) are generated when the apical cells of the globular or filamentous proembryo that the zygote created are cleaved (Fig 13.2).

Embryos with suspenders

Buds or new embryos develop from the uniseriate suspensor of the immature proembryo in members of the Acanthaceae family. Diploid embryos are those derived from proembryonal or suspensor cells (Fig 13.2).Z

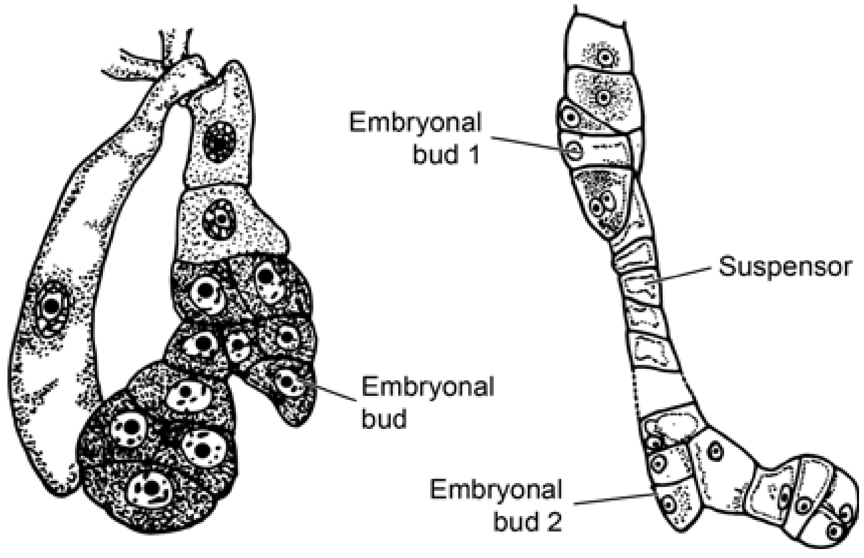


Fig. 13.2: Zygotic or suspensor polyembryony

Citrus seeds contain two to forty embryos, most of which are nucellar and one zygotic. There are five embryos in *Allium odorum*, and they are all produced using distinct techniques: two come from antipodal cells, one from zygote, one from synergid, and one from ovule integument.

13.3.1: Causes of Polyembryony

There are two theories that have been put out to explain polyembryony.

Necrohormone theory

According to Haberlandt's (1921, 1922) theory, the nucellus's deteriorating cells serve as a catalyst for the neighboring cells to divide and create adventive embryos. The theory is unsupported by any data.

According to Kappert (1933), polyembryony is a recessive genetic trait that is regulated by several genes. Plants that undergo hybridization have polyembryony as a result of gene recombination. According to Firetti-Leggieri et al. (2013), polyploidy and polyembryony are related.

13.3.2: Uses of Polyembryony

Compared to vegetative propagules, adventive embryos created through polyembryony are more disease-resistant and have a more homogenous genetic makeup, making them valuable in horticulture and agriculture. The seedlings produced from these embryos are identical to their parents. In horticulture, nucellar adventive polyembryony is very important. They generate strong plantlets that are devoid of viruses and disease, and they have well-developed root systems. These embryos are more uniform in appearance and produce seedlings with greater vigor.

Some of the agronomic advantages of apomixis involve rapid growth and multiplication of superior forms through seed from novel germplasms, the loss of pollinators and cross-compatibility issues that arise with sexual reproduction, the reduction of breeding costs and times, and the prevention of viral transfer in plants that are typically propagated vegetatively. Among crop species, apomixis is extremely underrepresented. It has been thoroughly investigated in tropical forage grasses like *Pennisetum, Panicum*, *Brachiaria, Dichanthium,* and *Citrus* (Fig. 13.3) as well as subtropical fruit trees like mangos and *Citrus.*

For these reasons, earlier polyembryony was thought to hold a lot of promise in horticulture. Nevertheless, the value of polyembryony is being utilized far less due to the advancements in tissue culture techniques. Biotechnologists, however, are interested in introducing apomixis genes into other crop hybrids so that these can be multiplied generation after generation without requiring the hybridization procedure.

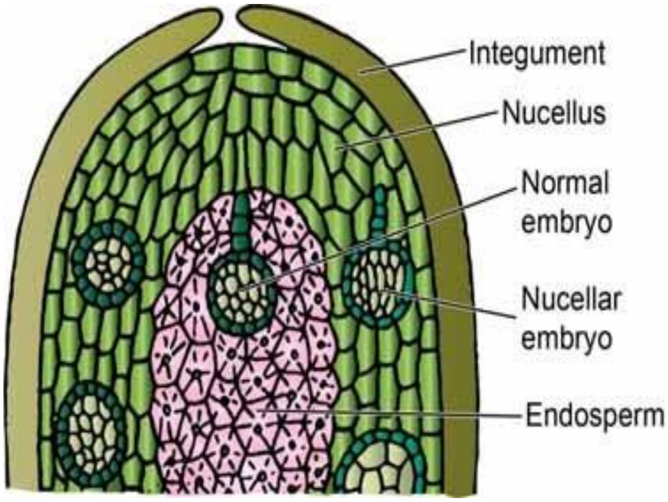


Fig 13.3: Citrus ovule section showing normal and nucellar embryos.

13.4: Summary

- The term "polyembryony" describes the development of many embryos within a seed. Instead of multiple syngamy, which is the outcome of fertilization, the process of apogamy or apomixis produces the embryos. Depending on whether the embryos develop in separate embryo sacs within the same ovule or in the same embryo sac, it has been classified as "true" or "false."
- In cases of real polyembryony, embryos can develop from nucellar or integumentary cells outside of the embryo sac (adventives embryony), from cells of the embryo sac other than the egg (apogamy), or from splitting of the zygote or proembryo (cleavage polyembryony).
- Cleavage polyembryony is the consequence of the zygote or proembryo splitting into two or more units. Examples of this include *Nicotiana rustica, Isotoma longiflora, Lobelia,*

and *Erythronium*. While cleavage polyembryony is unusual in angiosperms, it is widespread in gymnosperms.

- In adventive embryony, the ovule's diploid nucellar or integumentary cells—which are located outside the embryo sac—produce the embryos. We refer to these embryos as adventive or sporophytic. To put it another way, in this sort of embryo, the nucleus and integument are examples of diploid cells from which the embryo immediately grows.

Glossary

(i) Germplasm- The genetic resources (hereditary material) of any organism, particularly plants and animals, that can be passed down to the next generation is referred to as germplasm.

(ii) Biotechnology- For the purpose of to develop technologies and products that benefit society, biotechnology involves the molecular and cellular manipulation of biological processes.

(iii) Hybridization- Mating or crossing two individuals from different species, subspecies, variations, or genetically diverse populations is known as hybridization.

(iv) Synergids- Synergids are found within the flower's ovule, at the micropylar end of the embryo sac, near to the egg cell.

(v) Adventive embryony- The term "adventive embryony" describes the process by which embryos grow from cells other than those found in the ovule's embryo sac.

Self- Assesment Questions

Short Answer Questions

1. Define the term polyembryony.
2. Define the induced plyembryony?
3. Write a short note on adventive embryony.
4. Draw a well-labelled digrarm of *Citrus* ovule section showing normal and nucellar embryos.
5. What are the zygotic embryos?

Long Answer Questions

1. Write a detailed note on Polyembryony and its types.
2. Explain the true and pseudo-polyembryony with examples and also about the induced Polyembryony.
4. Write a note on exploitation of Polyembryony in plant improvement programmes.

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