MATS UNIVERSITY

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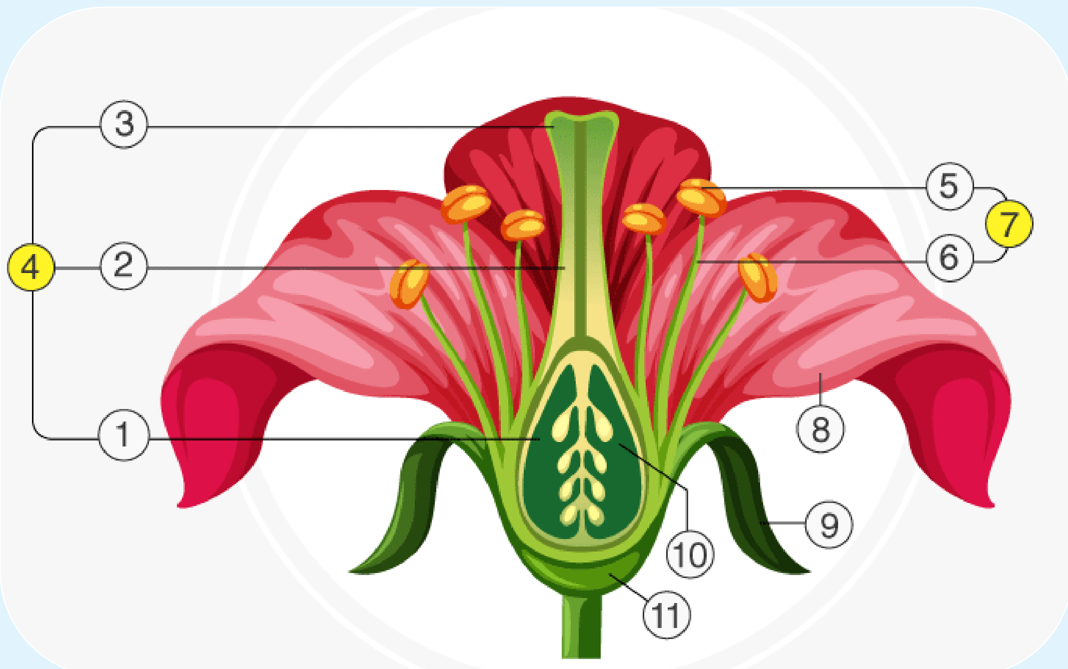
MATS CENTRE FOR DISTANCE & ONLINE EDUCATION

Structure Development and Reproduction in Flowering Plants

Bachelor of Science (B.Sc.)

Semester - 4



SELF LEARNING MATERIAL

DSCC401

STRUCTURE DEVELOPMENT AND REPRODUCTION IN FLOWERING PLANT

MATS UNIVERSITY

CODE: ODL/MSS/BSCB/401

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MODULE INTRODUCTION

Course has five module . Under this theme we have covered the following topics:

Contents

These themes of the Book discuss about in flowering plants, the flower is the reproductive organ, containing both male (stamens) and female (pistils) reproductive structures, which are essential for sexual reproduction through pollination, fertilization, and seed development. This book is designed to help you think about the topic of the particular module. We suggest you do all the activities in the modules, even those which you find relatively easy. This will reinforce your earlier learning.

MODULE -1

The Basic Body Plan of a Flowering Plant

1.0 Objectives

Understand the modular growth pattern in plants.

· Learn about different plant forms: annuals, biennials, and perennials.

· Study the evolutionary convergence of tree habits in gymnosperms, monocotyledons, and dicotyledons.

- Explore the ecological and functional aspects of plant growth forms.

UNIT 1.1

Modular Type of Growth

Modular growth in plants refers to the construction of the plant body through the repetition of basic units called modules. These modules, which can include shoots, branches, or even leaves, are relatively independent structures that contribute to the overall growth and development of the plant. This type of growth allows plants to adapt to various environmental conditions and to optimize resource capture.

1.1.1 What are Modules

- Plant modules are repeating units that can be considered the building blocks of a plant's architecture.
- Examples include:
  - **Shoots:** A module can consist of a stem, leaves, and buds.
  - **Branches:** Trees exhibit modular growth through the development of branches, which can be considered separate modules.
  - **Aquatic plants:** In some aquatic plants, new shoots arising from the parent plant can be considered modules.

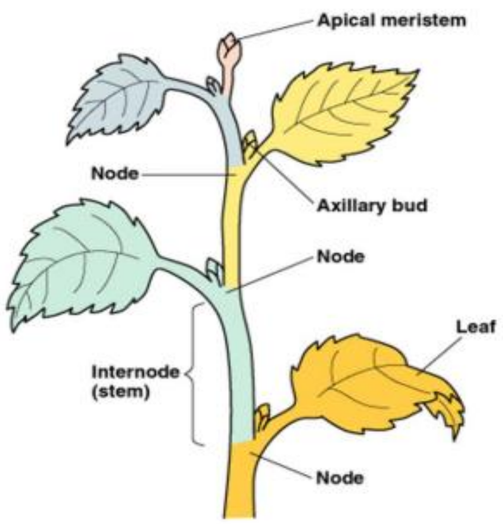

Fig. **1.1 Modules**

1.1.2 How does modular growth work

- Plant growth is not a continuous process but rather a series of module production.
- New modules are formed by the activity of meristems, which are regions of active cell division.
- Modules can be added, removed, or modified in response to environmental cues.
- This allows plants to adjust their structure and function to optimize resource acquisition and survival.

1.1.3 Advantages of modular growth:

- **Adaptability:**

  Plants can adjust their architecture to changing environmental conditions, such as light availability or water levels.
- **Resource Optimization:**

  Modular growth allows plants to allocate resources efficiently to different parts of the plant, maximizing their chances of survival and reproduction.
- **Damage Tolerance:**

  If one module is damaged, the rest of the plant can continue to function, minimizing the impact of injury.
- **Flexibility:**

  Plants can modify their growth patterns to occupy different environments, such as a forest interior or edge.

  Examples of modular growth:
- **Trees:**

  Trees develop branches, which act as separate modules, allowing them to grow taller and capture more sunlight.
- **Aquatic plants:**

Aquatic plants can produce new shoots in response to changing water levels.

- **Cereal crops:**
The growth and development of cereal plants can be analyzed as a modular process with overlapping stages of growth of modules (leaves, shoots, stems, and grains).

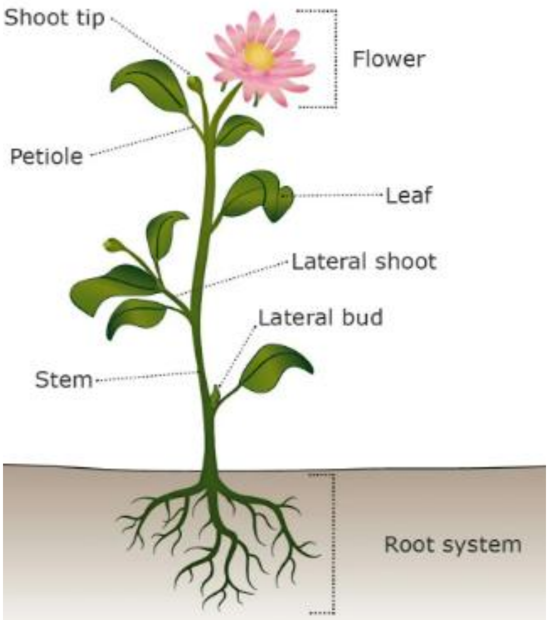

Fig. 1.2 Basic baody plan of palnt

1.1.2 Concept of Modular Growth in Plants

In plants, growth is fundamentally different from most animals. Instead of growing as a single, integrated organism with a fixed body plan, many plants grow through the repeated production of structural units called **modules**. A module is a basic unit of construction, typically consisting of an internode, a leaf (or leaf primordium), and an axillary bud. These modules are produced sequentially by the apical meristems throughout the life of the plant. Because growth proceeds by adding new modules, the final size and shape of a plant are not predetermined but depend on how many modules it produces and how they are arranged.

1.1.3 Formation and Repetition of Modules

The process begins at the shoot apical meristem, where cells divide and differentiate to form a phytomere a repeating unit that generally includes a node, an internode, a leaf, and an axillary bud. As the plant matures, these modules are repeated in a rhythmic sequence, giving rise to stems, branches, and inflorescences. The plant body is therefore not a single unit but a colony of repeated modules, each with its own developmental potential. This modular pattern can also be observed underground in rhizomes, stolons, and tubers, where repeated modules contribute to vegetative propagation.

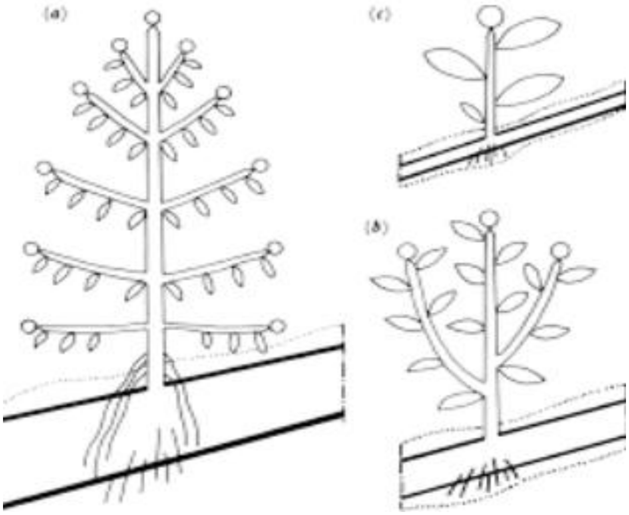

Fig. 1.3 Module type

1.1.4 Plasticity and Adaptive Advantage

One of the most important features of modular growth in plants is **developmental plasticity**. Because growth is modular, plants can modify the size, number, or type of modules they produce in response to environmental conditions. For instance, in nutrient-rich conditions, a plant may produce more branches (more modules), while in poor conditions, it may restrict growth or alter module size. If parts of the plant are damaged by herbivory or pruning, dormant buds within modules can be activated to replace lost structures. This capacity to regenerate and adjust is a key ecological advantage of modular growth.

Examples in Different Plant Types

Trees and shrubs are excellent examples of modular growth, where each branch system represents repeated modules organized hierarchically. In grasses and bamboos, new tillers arise as modules from basal buds, creating dense clumps. In aquatic plants such as *Hydrilla* or *Eichhornia*, modular growth occurs in stolons and runners that spread indefinitely, producing new individuals at nodes. Many climbing plants also exhibit modular growth through repeated leaf–stem units that enable them to extend and explore new spaces.

1.1.5 Significance in Ecology and Horticulture

Understanding modular growth is crucial in plant ecology because it explains how plants occupy space, compete for resources, and recover from disturbance. In horticulture and forestry, pruning, grafting, and training techniques are all based on manipulating modules to achieve desired shapes and productivity. This modular design is also the reason why many plants are immortal in theory they can keep growing indefinitely by adding new modules, provided the meristematic regions remain active and environmental conditions permit.

1.1.5.1 Modular Architecture of Trees

The modular construction of trees is one of the most elaborate and extensive forms of plant modularity, rendering these long lived organisms capable of obtaining truly impressive sizes, and to adapt to different environmental conditions over centuries or millennia. In contrast to herbaceous plants with relatively simple modular construction, trees are hierarchically organized into modules nested in larger structural units, which generates the complex three-dimensional shapes characteristic of these dominant elements of terrestrial ecosystems. At the root level, tree architecture results from the serial addition of modular units during primary and secondary growth. Apical meristems produce modules of new growth in both the shoot and root systems in a process known as primary growth, while lateral meristems (vascular cambium and cork cambium) add girth to stems (secondary growth) and also include bark for protection. This alternating system of growth lets trees explore their surroundings in both dimensions at once while building the structural support to remain as tall as possible. Tree architectural patterns are not random but are guided by specific developmental programmes, giving rise to characteristic forms of tree crowns (GDI & GAM, 2000; pre-Ch the above). These were early models explaining architectural diversity, first implemented by Hallé, Oldeman and Tomlinson, that highlight different solutions to the fundamental challenges of light capture, mechanical stability, reproductive display. From our analysis, about 23 basic architectural models can be distinguished based on essential developmental variables: growth pattern (rhythmic vs. continuous); branching pattern (monopodial vs. sympodial); orientation of the branches (orthotropic vs. plagiotropic); as well as the position of the reproductive structures. Architectural models of tree species have developed these developmental blueprints to guide growth under optimal situations. For example, the Rauh type, represented by various conifers and some angiosperms such as oak (Quercus), exhibits a monopodial trunk, rhythmic growth, and branches morphologically identical to the trunk. The Leeuwenberg model, which occurs in many tropical trees, is based on sympodial growth of branches in which the terminal structure is an inflorescence, and growth continues congruently through a lateral bud producing equivalent branches and often shows a forked or candelabra-like appearance. Though architectural models lay down the foundation for tree growth, real tree form is ultimately the outcome of the interplay between these inherent growth strategies and the environment, a phenomenon described as architectural plasticity. Based on light availability, mechanical stress, and other environmental factors, trees are able to alter many of the parameters of their modular architecture, such as internode length, branch angle, or leaf length and angle. This plasticity enables trees to maximize resource capture and mechanical stability along heterogeneous environments. Another important aspect of a tree modularity is the repetition of units of architecture. Reiteration happens when a portion of a tree reproduces the overall architectural pattern of the whole organism, essentially making "trees within trees." This process can take place through reactivation of dormant buds (proleptic reiteration) or development of adventitious buds (sylleptic reiteration) and can be adaptive (e.g., filling canopy holes) or traumatic (for a response to damage or stress). Reiteration plays a large role in giving older trees complex structures and enables them to shape themselves to meet their needs as their interfaces with their environment change over time.

Trees display modular growth, which leads to a hierarchical organization across spatial scales. Sh shoots (cohorts of modules produced in a single growth period) are built from the modules, which in plants consist of axillary buds and individual leaves. Shoots then become branches of successively higher orders until they make up the whole crown. This nested hierarchy enables semi-autonomous functioning at multiple levels, whereby individual branches function with some independence while remaining integrated with the whole organism by the conveyance of water, nutrients, carbohydrates, and signals. The hierarchy of this modularity has significant implications for the organization of the tree in terms of resource allocation and functionality integration. And branches are semi-autonomous, resourcing the overall tree while competing with the other branches for scarce resources. Such internal competition may result in self-pruning, where trees discard less productive twigs, directing the resources to more successful twigs. This process ensures crown shaping and plays a vital role in the adaptive response of trees to their environment. Trees have a modular architecture and growth patterns, which leads to their mechanical properties. Perennial species use secondary growth to produce woody tissues that provide structural support, and the hierarchical branching pattern used in trees distributes mechanical stresses through the structure. In trees, the need for height growth to compete for light must be balanced against the mechanical constraints of gravitational and wind forces. This balance is established through complex developmental responses to mechanical stimuli including the formation of reaction wood as well as shifts in allocation patterns between growth in height versus growth in diameter. The importance of tree architecture goes beyond mechanical stability, and includes maximizing light interception and carbon acquisition. The modeling of the architecture of the tree and subsequent plastic responses combine in a complex manner to affect the spatial structure of the branches and leaves within a crown, which is a key factor in light capture efficiency. In contrasting light environments, the light environments of different species vary based on light interception type: some species are biased toward open habitats and specialized for intercepting direct light, while others are biased toward forest understories and specialized for intercepting diffuse light. Tree architecture also has a powerful effect on hydrological processes. The three-dimensional configuration of branches and leaves plays a role in rain interception, stem flow, and through fall that influences the distribution of soil moisture and nutrient cycling under tree canopies. Because these hydrological effects generate micro environmental heterogeneity (hotspots, used here in the sense of spatially localized regions of environmental heterogeneity) with direct consequences for understory plant communities and soil processes, they are a prime example of how tree architecture induces ecosystem function. Another key aspect of tree architecture is reproductive display. In-situ placement of flowers and fruits in a crown may influence pollinator ventilation, seed dispersal, and reproductive success. Plants are often differentiated by the segregation of architectural construction between reproductive function and vegetative function, where flowers and fruits are situated in a manner maximizing visibility to pollinators and dispersers while vegetative components maintain efficient light capture. Tree architecture develops over time, a process called architectural ontogeny, which occurs in discrete stages from the initiation of the architectural model in juvenile trees to the complexification of crown structure in mature trees, followed by its simplification in senescent individuals. The ontogenetic trajectory interacts with environmental conditions to generate the extraordinary diversity of forms adopted by trees in natural and managed ecosystems. Technological advancements in three-dimensional modeling and analysis in recent decades have revolutionized our understanding of tree architecture. Terrestrial LiDAR scanning and other similar techniques enable detailed characterization of tree structure across multiple scales, revealing architectural patterns and linking them to functional dynamics. This increasing breadth of knowledge, together with technological advances, is opening up new frontiers in exploring the form and function of trees.

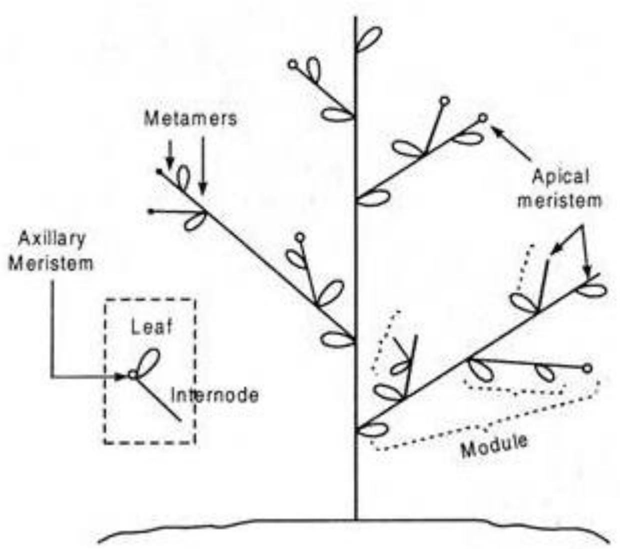

Fig.1.4 Module pattern

Summary:

• Modular growth refers to the way plants grow by repeatedly producing structural units (modules) such as **leaves, stems, buds, and roots**. Unlike animals (which have a fixed body plan), plants are *open systems* and can continue growth throughout life.

• **Basic Unit (Module)**:
The **phytomer** is the fundamental module, consisting of:

- A **node**
- An **internode**
- A **leaf (or leaf scar in woody plants)**
- An **axillary bud**

Multiple Choice Questions (MCQs):

1. Modular growth in plants is primarily due to the activity of:

a) Xylem and phloem

b) Meristems

c) Cork cambium

d) Endodermis

Answer: b) Meristems

2. The basic structural unit (module) in modular plant growth is called:

a) Node

b) Phytomer

c) Internode

d) Leaf

Answer: b) Phytomer

3. Which of the following is NOT an example of modular growth?

a) Rhizomes in ginger

b) Stolons in strawberry

c) Tillers in wheat

d) Embryonic growth in animals

Answer: d) Embryonic growth in animals

4. Branching in plants is a result of:

a) Lateral roots

b) Secondary xylem

c) Activity of axillary buds

d) Apical dominance only

Answer: c) Activity of axillary buds

5. Modularity in plants provides evolutionary advantages because it allows:

a) Continuous replacement of lost parts

b) Plasticity in growth forms

c) Survival under grazing or injury

d) All of the above

Answer: d) All of the above

Short Questions:

1.Define modular growth.

2.Name the three main parts of a plant module.

3.Why is modular growth considered indeterminate?

4. How does modular growth help plants survive injury?

5.Mention one ecological advantage of modular growth

Long Questions:

1. Explain the concept of modular growth in plants with suitable examples.
2. Discuss the structural organization of a plant module and its developmental origin.
3. Describe the advantages of modular growth in the survival and reproduction of plants.
4. Differentiate between modular and unitary growth and give examples.

UNIT 1.2

Diversity in Plant Form in Annuals, Biennials, and Perennials

If we consider plants based on their height some are too short while some are too tall. Most of the short plants have green coloured, thin, weak stems, whereas, the big and tall plants have thick, strong and woody stems that are hard to break.

Plants can also be classified as annuals, biennials and perenials based on their lifespan. Each of these classifications is described below.

1.2.1 Introduction of Annual, Biennial, and Perennial Plants

Annual plants grow from seed to seed in a single growing season/timeframe, so they live their full life cycle, germinating, producing seeds and dying in a season (or year), according to the National Garden Bureau. This determined lifespan has vast consequences for their growth, resource allocation, and ecological strategies. Widespread gene flow is a common trait of annuals whose agree with the strategy of diverting a large proportion of their resources to rapid vegetative growth followed by plentiful seed production, so that their genetic legacy may survive their own ephemeral nature Summary. Some plant species are closely associated with agriculture, such as common corn (Zea may), wheat (Triticum aestivum), rice (Oryza sativa), and sunflower (Helianthus annuus), while wildflower species, such as the California poppy (Eschscholzia californica), and common garden weeds, such as chickweed (Stellaria media), are other common examples of annual plants. Two growing seasons, or years, are covered by biennial plants' life cycle. In the first year biennials generally develop a root system and a close-to-the-ground cluster of leaves, sometimes keeping energy in modified root structures. Cold dormancy (vernalization) follows, and in the second year of growth they flower and produce seed, after which they die. This intermediate strategy discerns biennials from annuals in that biennials can store energy in a more major energy storage and has a greater reproductive effort than annuals in their second year. Carrots (Daucus carota), parsley (Petroselinum crispum), foxgloves (Digitalis spp.), and evening primrose (Oenothera biennis). Perennial plants, meanwhile, persist for three years or more including many woody species that live for decades or even centuries. Perennials differ in that they will not die after flowering and seed production, instead continuing to grow year after year, unlike annuals and biennials. This provides a long enough lifespan to pursue various growth strategies and spend resources in different ways. Perennials span from herbaceous forbs that die back to the ground every winter and grow back from basal or rhizomal structures that persist under the ground, to woody organisms like shrubs and trees that maintain an aboveground biomass year-round. Perennial is a vague category, ranging from herbaceous wildflowers like the black-eyed Susan (Rudbeckia hirta) and hostas (Hosta spp.), to shrubs such as rhododendrons (Rhododendron spp.) and roses (Rosa spp.), to graceful trees such as oaks (Quercus spp.) and coast redwoods (Sequoia sempervirens). There is some crossover between the categories. In frost-free temperatures, some plants normally considered annuals are more accurately described as short-lived perennials. In contrast, the perennial end of the spectrum does not encompass many plants, with some species able to be grown as an annual when their respective climate does not support perennialism outside of their natural growing area. Other plants are facultative with respect to life history, exhibiting some flexibility in behavior as an annual or biennial based on environmental cueing, or genetic differences. This plasticity reflects the dynamic nature of plant life history strategies is, in turn, is context-dependent.

1.2.1.1 General Characteristics

Where annual, biennial and perennial plants show contrasting and different; morphological, physiological and reproductive characteristics and these relate to their evolutionary adaptations to their niche and challenges to their ecology. Generally fast-growing, annual plants complete their life cycles within a season. They usually also have shallower and more simplified root systems than longer-lived plants, often with a large taproot or fibrous roots concentrated in the topmost layer of soil, to quickly extract nutrients and hydrology from the soil in their short lifespan. Their stems are often herbaceous and structurally rather simple, investing resources in rapid vertical growth rather than structural fortitude. Annuals make leaves quickly and in bulk to maximize the surface area for photosynthesis that keeps their fast-paced growth going. Annuals often flower.

Fig.2.1 The diversity in plant forms across **annuals**, **biennials**, and **perennials**

The diversity in plant forms across **annuals**, **biennials**, and **perennials** is vast and fascinating. These plant groups differ primarily in their **life cycles**, which dictate their growth patterns, reproductive strategies, and longevity. Let's explore the diversity within each category and understand how each plant form adapts to its environment.

1.2.1.1.1 Annuals

Definition: Annual plants complete their entire life cycle (germination, growth, reproduction, and death) within **one year**. They germinate from seed, grow, flower, produce seeds, and then die within a single growing season.

Diversity in Plant Form:

- **Growth Habit:** Annuals can vary greatly in growth form, from **herbaceous** (non-woody) plants to **woody** forms in some cases (e.g., certain annual vines or shrubs in tropical regions). The majority, however, are **herbaceous** plants.
    - **Examples:**
        - **Herbaceous Annuals:** Marigolds, sunflowers, wheat, and lettuce.
        - **Vines and Creepers:** Beans, cucumbers, and sweet peas.
        - **Groundcovers:** Creeping thyme, petunias, and pansies.
- **Reproductive Strategy:** Annuals tend to invest most of their energy into **rapid growth** and **early reproduction**. Their seeds are often produced in large quantities to ensure species survival. Some annuals, such as **weeds**, may also have adaptations for rapid seed dispersal.
- **Adaptations:** To cope with the short life cycle, annuals tend to be fast-growing and have high reproductive output. Some species also have seeds that can lie dormant in the soil for long periods, waiting for favorable growing conditions.

Examples:

- **Sunflower (*Helianthus annuus*)**: Large, tall, fast-growing plant with a single-season life cycle.
- **Wheat (*Triticum spp.*)**: An important cereal crop that grows, matures, and produces seeds within one year.

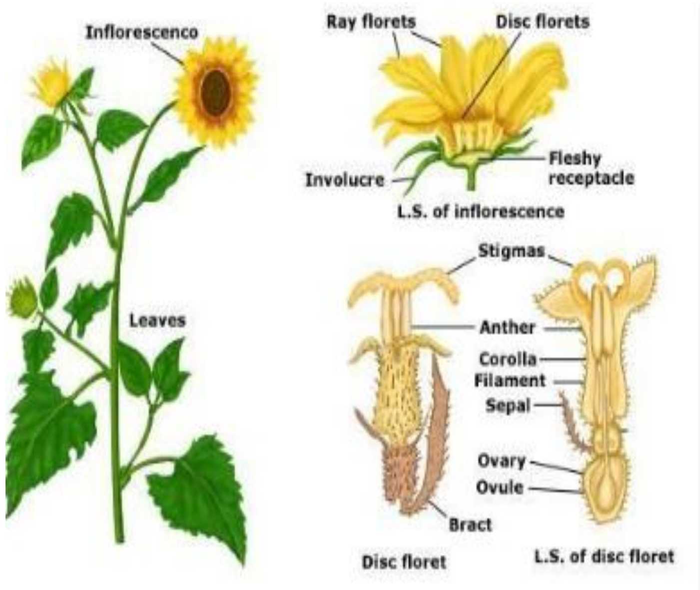

Fig. **2.2 Sunflower (*Helianthus annuus)***

1.2.1.1.2 Biennials

Definition: Biennial plants require **two growing seasons** to complete their life cycle. In the first season, they grow vegetatively (develop leaves, stems, and roots), and in the second season, they flower, produce seeds, and die.

Diversity in Plant Form:

- **Growth Habit:** Biennials are typically **herbaceous**, but their forms can vary from **small rosettes** (e.g., certain herbs) to taller, **flowering plants** (e.g., carrots and parsley). Most biennials form a **basal rosette** of leaves during the first year and then produce an upright flowering structure in the second year.
    - **Examples:**
        - **Herbaceous Biennials:** Carrots, parsley, and beets.
        - **Flowers and Vegetables:** Foxglove (*Digitalis purpurea*) and cabbage (*Brassica oleracea*).
- **Reproductive Strategy:** Biennials have a slower reproductive cycle than annuals. They invest in vegetative growth in the first year and delay reproduction until the second year. This delay

allows them to store energy for reproductive success in the following year.

- **Adaptations:** Biennials are often adapted to environments with **long growing seasons** but require a second year of growth before they can flower. Their storage of energy in the roots or stems during the first year ensures that they can survive the winter and reproduce the following spring.

Examples:

- **Carrot (*Daucus carota*)**: A biennial that produces edible roots in the first year and flowers in the second year.
- **Foxglove (*Digitalis purpurea*)**: Grows vegetatively in the first year and flowers in the second year.

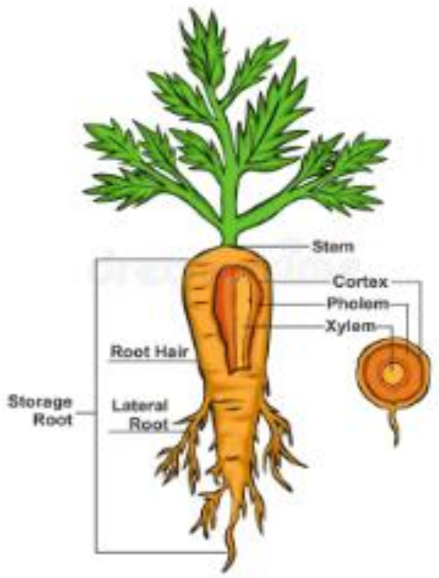

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Fig. **2.3 Carrot (*Daucus carota*)**

1.2.1.1.3 Perennials

Definition: Perennial plants live for **multiple years** and typically flower and produce seeds several times during their lifespan. Perennials grow continuously and may have periods of dormancy during unfavorable seasons, such as winter or dry periods.

Diversity in Plant Form:

- **Growth Habit:** Perennials can be **herbaceous** (e.g., grasses, wildflowers) or **woody** (e.g., trees, shrubs). They may grow in a variety of forms, from low-growing groundcovers to large, tall trees.
    - **Examples:**
        - **Herbaceous Perennials:** Hostas, peonies, lavender, and daylilies.
        - **Woody Perennials:** Trees (e.g., oak, pine), shrubs (e.g., lilacs, roses), and vines (e.g., grapevines).
- **Reproductive Strategy:** Perennials invest in long-term survival and reproduction. They usually produce seeds over several seasons, and many have **vegetative reproduction** (such as runners or rhizomes) in addition to sexual reproduction via seeds. Some perennials can also regenerate from their roots or other vegetative parts if the aboveground parts die back.
- **Adaptations:** Perennials often have **extensive root systems** that store nutrients, which help them survive through dormancy periods and continue growing year after year. Many woody perennials also have secondary growth (wood) that allows them to increase in size over time, enabling them to reach greater heights and form larger canopies.

Examples:

- **Trees:** Oak (*Quercus spp.*), pine (*Pinus spp.*), and sequoia (*Sequoiadendron giganteum*).
- **Shrubs:** Rose (*Rosa spp.*), lilac (*Syringa spp.*), and azalea (*Rhododendron spp.*).
- **Herbaceous Perennials:** Lavender (*Lavandula spp.*), hosta (*Hosta spp.*), and peony (*Paeonia spp.*).

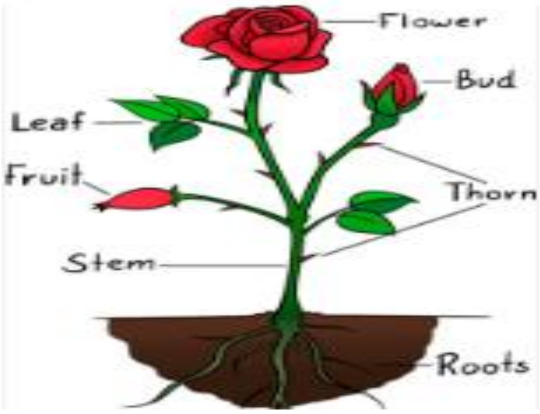


Fig. 2.4 Rose (*Rosa spp.*)

1.2.2 Comparison Table:

Annual Plants	Biennial Plants	Perennial Plants
Definition		
Annual plants complete their life cycle in one growing season.	Biennial plants are planted in one year, grow through the year, grow on and flower during the next year.	Perennial plants grow strong year after year.
Examples		
Mustard, watermelon, lettuce	Carrot, cabbage, onions	Mango, coconut, banana
Development		
They germinate, grow, bear fruits and flowers, and die off in the same year.	They germinate, grow leaves and stems in the first year. In the second year, they bear flowers and fruits.	They continue to bear flowers and fruits for several seasons after growth.

Plants in the categories of **annuals**, **biennials**, and **perennials** exhibit significant **diversity in form** due to their different life cycles and strategies for growth, reproduction, and survival. Each group has evolved specific adaptations suited to its environment, allowing them to occupy different ecological niches. Annuals are adapted for quick, single-season reproduction, biennials focus on two-year cycles of growth and reproduction, while perennials are built for long-term survival and reproduction over many years. These variations contribute to the complexity and richness of plant life across ecosystems.

Summary:

Annuals are plants that complete their entire life cycle beginning from seed germination, through vegetative growth, flowering, fruiting, and ending with death within a single season or year. They invest most of their energy in rapid growth and abundant seed production. **Biennials** require two years to complete their life cycle. During the first year, these plants remain in the vegetative stage, producing leaves, roots, and storage organs, often in the form of rosettes. In the second year, they utilize stored food reserves to initiate flowering, fruiting, and eventually die after reproduction. **Perennials**, in contrast, live for many years and produce flowers and seeds multiple times after reaching maturity. They may be herbaceous (such as tulsi) or woody (such as mango, neem, or rose). Perennials possess survival structures like rhizomes, tubers, bulbs, and woody stems, which enable them to withstand adverse conditions and regrow season after season.

Multiple Choice Question (MCQ):

1. Which of the following completes its life cycle in one growing season?

a) Carrot
b) Rice
c) Mango
d) Onion

Answer: b) Rice

2. Which of the following is a perennial plant?

a) Wheat

b) Mustard

c) Mango

d) Beetroot

Answer: c) Mango

3. Storage organs like roots and bulbs in biennials help in:

a) Photosynthesis

b) Food storage for second year reproduction

c) Seed dispersal

d) Leaf production

Answer: b) Food storage for second year reproduction

4. Which one is an example of an annual plant?

a) Onion

b) Rose

c) Sunflower

d) Carrot

Answer: c) Sunflower

5. Tulsi (Ocimum sanctum) is an example of:

a) Annual

b) Biennial

c) Perennial

d) Ephemeral

Answer: c) Perennial

6. In biennial plants, the first year is usually characterized by:

a) Flowering and fruiting

b) Formation of storage organs and vegetative growth

c) Seed dispersal

d) Dormancy

Answer: b) Formation of storage organs and vegetative growth

Short Question:

1.Define **annual plants** with two examples.

2.What is a **biennial plant**? Give one example.

3.Differentiate between annuals and perennials (any two points).

4.Why do biennials form **storage organs** in the first year?

5.Give one ecological advantage of perennial plants.

6.Name one **annual, biennial, and perennial** plant each.

Long Question:

1.General Characteristics of Annuals, Biennials, and Perennials plant.

2. Discuss the diversity of plant forms in **annuals, biennials, and perennials** with suitable examples.

3. Compare and contrast **annuals, biennials, and perennials** in terms of life span, reproduction, and adaptations.

4. Explain the **life cycle strategy of biennials** and describe how storage organs help in survival.

5. Describe the **ecological and evolutionary significance** of perennial plants.

6.Write an essay on **plant life span diversity** with reference to annual, biennial, and perennial plants.

7. With examples, explain how annuals, biennials, and perennials differ in their **growth patterns and reproductive cycles**.

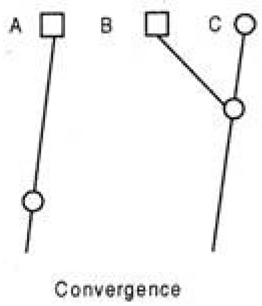
UNIT 1.3

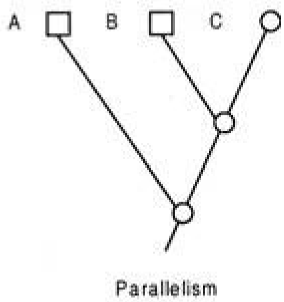
Convergence of Evolution of Tree Habit in Gymnosperms, Monocotyledons and Dicotyledons

The tree habit, characterized by a tall, woody, self-supporting trunk, has evolved independently in gymnosperms, monocotyledons, and dicotyledons, demonstrating convergent evolution. This means that distantly related plant groups have developed similar traits due to adapting to similar environments or ecological niches. While the basic body plan and growth patterns differ significantly between these groups, the selection pressures of needing to reach for sunlight and compete for space have led to the convergent evolution of a tree-like form.

1.3.1 Definition of Convergence:

Convergence is a phenomenon in nature found in all organisms. It is observed tendency of living forms that are quite unrelated phylogenetically, to respond to similar contingencies of life by developing similar structures. In the process of evolution this similarity way arises along two evolutionary lines, i.e., parallelism and convergence





1.3.1.1 Discussion on Convergence of Evolution of Tree Habit:

Trees are perennials. The groups of trees looking alike are few, e.g., palms (monocots), conifers (gymnosperms), etc. Generally, the convergence in tree habit can be seen in their height. The primitive pteridophytes, gymnosperms and angiosperms, etc., were trees. Progymnosperms were present in upper Devonian and lower Carboniferous period of Palaeozoic era. Many palaeobotamists believe in origin of gymnosperms from pteridosperms.

1.3.1.2The convergence in each group:

1.3.1.2.1 Gymnosperms:

- Gymnosperms were among the first to evolve a tree habit, with examples like ancient progymnosperms and early conifers.
- Many gymnosperms, particularly conifers, are well-adapted to cold, temperate regions and form dominant forest ecosystems.
- Their tree habit is characterized by a central trunk, branching patterns (often with a conical or pyramidal crown), and needle-like or scale-like leaves.

1.3.1.2.2 Monocotyledons:

- While most monocots are herbaceous, several lineages have independently evolved a tree-like form, notably palms.
- Palms, despite lacking secondary growth (true wood formation), achieve height and stability through a unique thickening of the stem and a crown of large leaves.
- Other monocot trees include tree ferns and some bamboos, showcasing the diverse ways this habit has been achieved within the group.

1.3.1.2.3 Dicotyledons:

- Dicotyledons are the most diverse group of flowering plants, with numerous lineages evolving into trees.
- Their tree habit is characterized by a central trunk, branching patterns, and a diversity of leaf shapes and sizes.
- Examples include oaks, maples, and many other familiar tree species.

Convergent Evolution:

- The convergence in tree habit is evident in the similar overall structure and function of these trees, despite their different evolutionary origins.
- Factors like height, stem strength, and crown shape are often similar, even though the underlying developmental and anatomical mechanisms may differ.
- This highlights how natural selection can lead to similar solutions to environmental challenges, even in distantly related organisms.

Summary:

Flowering plants (angiosperms) are structured into two main systems: the **root system**, which anchors the plant, absorbs water and nutrients, and often stores food; and the **shoot system**, comprising stems, leaves, and flowers all supported and connected by vascular tissues that transport water, minerals, and sugars .The **stem** serves as the structural axis, elevating leaves and flowers, facilitating transport via xylem and phloem, and enabling growth through meristematic tissues, **Leaves**, as primary sites of photosynthesis and gas exchange, contain specialized tissues like mesophyll, cuticle, and stomata to efficiently capture light and regulate water loss .Lastly, the **flower**, a modified shoot, carries out sexual reproduction and typically includes four arranged whorls sepals, petals, stamens (male), and carpels (female) all attached at a receptacle

Multiple Choice Questions (MCQs):

1. **What type of growth pattern is common in plants?**

a) Unitary Growth

b) Modular Growth

c) Linear Growth

d) Radial Growth

Ans. b) Modular Growth

2. Which of the following is NOT an example of a perennial plant?

a) Mango Tree

b) Rose Bush

c) Tomato Plant

d) Banyan Tree

Ans. c) Tomato Plant

3. What is the primary mode of reproduction in clonal plants?

a) Sexual Reproduction

b) Seed Formation

c) Vegetative Propagation

d) Spore Formation

Ans. c) Vegetative Propagation

4. Which plant category completes its life cycle in two years?

a) Annuals

b) Biennials

c) Perennials

d) Ephemerals

Ans. b) Biennials

5. Which part of the plant contributes to modular growth?

a) Root Hairs

b) Lateral Buds

c) Leaf Veins

d) Guard Cells

Ans. b) Lateral Buds

6. What type of plants exhibit a tree habit in gymnosperms?

a) Monocots

b) Dicots

c) Conifers

d) Herbs

Ans. c) Conifers

7. Which of the following is an example of a monocot tree?

a) Oak

b) Palm

c) Neem

d) Pine

Ans. b) Palm

8. The primary difference between dicot and monocot trees is:

a) Leaf Shape

b) Root Type

c) Vascular Bundle Arrangement

d) Seed Size

Ans. c) Vascular Bundle Arrangement

9. What is a key characteristic of vegetative propagation?

a) It requires pollination.

b) It does not involve seeds.

c) It occurs only in flowering plants.

d) It is limited to annual plants.

Ans. b) It does not involve seeds.

10. Which of the following plants undergoes clonal growth?

a) Rice

b) Bamboo

c) Corn

d) Sunflower

Ans. b) Bamboo

Short Questions:

1. Define modular growth in plants.
2. What is vegetative propagation?
3. How do annuals, biennials, and perennials differ?
4. Give an example of a monocot tree and a dicot tree.
5. What is clonal growth?
6. Describe two ecological adaptations of perennials.
7. What is the significance of modular architecture in trees?
8. Define convergence in tree habits.
9. How do gymnosperms differ from angiosperms in tree structure?
10. What role do lateral buds play in plant growth?

Long Questions:

1. Explain the concept of modular growth with suitable examples.
2. Discuss the ecological importance of annuals, biennials, and perennials.
3. How does vegetative propagation contribute to plant diversity?
4. Compare and contrast tree habits in gymnosperms, monocots, and dicots.
5. Describe the adaptations of different plant growth forms to their environment.
6. What are the similarities and differences in tree structure among plant groups?
7. How does clonal growth influence plant reproduction and survival?
8. Explain the role of genetic and environmental factors in shaping plant form.
9. Discuss the importance of understanding plant growth strategies in agriculture.

10. How has the evolution of tree habit contributed to plant success on land?

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MODULE- 2

THE SHOOT SYSTEM

Objective:

- Understand the structure and organization of the Shoot Apical Meristem (SAM).
- Learn about vascularization in monocots and dicots.
- Study the formation of internodes and branching patterns.
- Explore the role of cambium in secondary growth.
- Analyze growth rings and their significance in tree aging.

UNIT 2.1

The Shoot Apical Meristem: Structure, Organization, and Developmental Significance

2.1.1 Introduction to the Shoot Apical Meristem

The shoot apical meristem (SAM) is an archetypical and highly vital developmental centerpiece in plants, and is the central site of expansion and morphogenetic activity in plant organism's aerial fractions. This tiny but incredibly complex structure gives rise to the many above-ground plant organs we see including stems, leaves, and reproductive structures. Located at the apex of shoots, the SAM is, in fact, the ultimate pool of undifferentiated pluripotent cells which endlessly divide and differentiate to give the complex morphogenetic patterns witnessed during plant growth and development. The shoot apical meristem is a key platform for regulating cell proliferation, differentiation and stem cell maintenance. In contrast to animal stem cells, plant meristematic tissue exhibits a high level of plasticity and the ability to grow endlessly during the entire life of the plant. This phenomenon allows lants to grow indeterminately, allowing indefinite community response to diverse environmental signals and developmental cues.

2.1.2 Structure and Organization of the Shoot Apical Meristem

The **Shoot Apical Meristem (SAM)** is a critical region at the tip of the plant shoot responsible for continuous growth, formation of new tissues, and the development of various plant organs such as leaves, stems, and flowers. The histological organization of the shoot apical meristem is complex, involving distinct regions of cells with specialized functions. Understanding the structure and function of these regions is key to understanding how plants grow and develop.

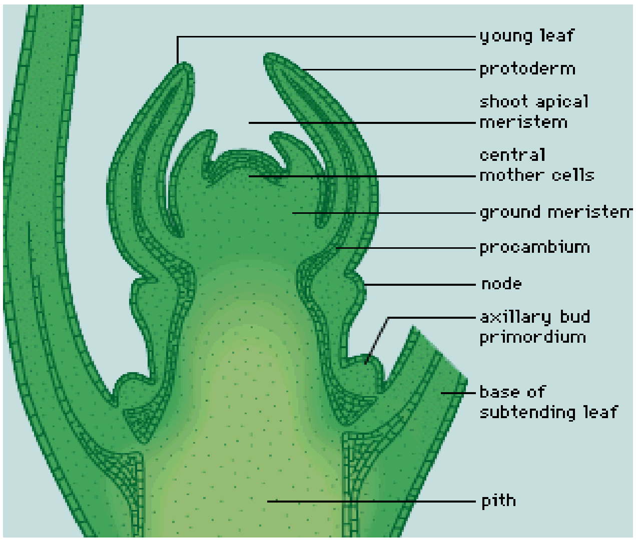


Fig.2.1 Structure and Organization of the Shoot Apical Meristem

2.1.2.1 Histological Layers of the Shoot Apical Meristem

The histological organization of the SAM can be broken down into three major zones:

1. Central Zone (CZ)

- **Function:** The central zone is the heart of the meristem and serves as a reservoir of slowly dividing cells. It is important for maintaining the stem cell population, ensuring that the meristem can continue to produce new cells for growth.
- **Cell Behavior:** Cells in this region divide very slowly or almost not at all, preserving the meristematic potential. This slow division helps maintain the meristem's identity and ensures a steady supply of cells for differentiation in other zones.
- **Histological Features:** The central zone is characterized by small, densely packed, undifferentiated cells that have a high capacity for self-renewal. These cells form the source of all new cells in the shoot system.

2. Peripheral Zone (PZ)

- **Function:** The peripheral zone is where active cell division occurs, and it is responsible for the initiation of new organs such as leaves and lateral shoots. This zone contributes to the formation of the plant's external structures.
- **Cell Behavior:** Cells in the peripheral zone divide more rapidly than those in the central zone, and their divisions are primarily in planes parallel to the surface of the meristem. This allows for the outward expansion of the meristem and the formation of primordia (early structures that will develop into leaves, flowers, or branches).
- **Histological Features:** The peripheral zone consists of larger, more loosely packed cells than those in the central zone. These cells are actively dividing and are typically arranged in concentric layers around the central zone.

3. Rib Zone (RZ)

- **Function:** The rib zone is involved in the formation of the central axis or the stem of the plant. It is where the vascular tissues (xylem and phloem) are generated, contributing to the overall elongation of the plant stem and the transport of water, nutrients, and sugars.
- **Cell Behavior:** Cells in the rib zone divide and differentiate into the tissues that will eventually form the central vascular system. The division planes are primarily perpendicular to the surface of the meristem, allowing for the formation of a solid axis (the stem).
- **Histological Features:** The rib zone consists of cells that are elongated and more tightly packed compared to those in the peripheral zone. The cells here give rise to the vascular tissue (procambium), which forms the vascular bundles in the stem.

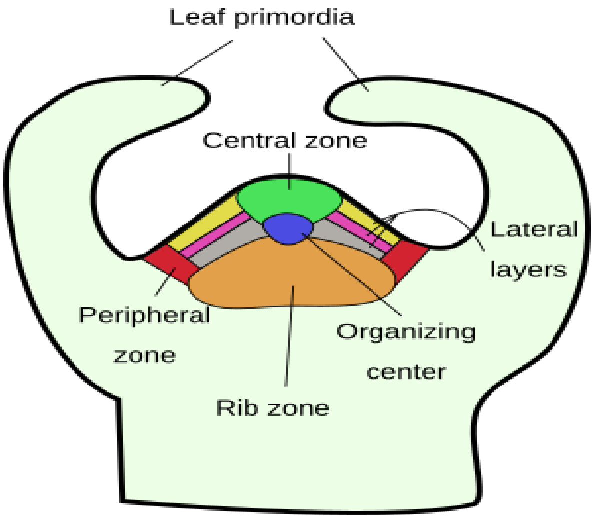


Fig. 2.2 Histological Layers of the Shoot Apical Meristem

2.1.2.2 Maintenance of Stem Cell State and Cellular Dynamics

Shoot apical meristem self-maintenance is a striking instance of cellular self-regulation and preservation. Molecular mechanisms operating in various pathways guarantee that stem cells are constantly replenished, but not in an unchecked manner. At the center of this process is the WUSCHEL (WUS) transcription factor that forms a feedback loop with the CLAVATA (CLV) signaling pathway, tightly regulating stem cell number and preventing runaway cell expansion. Stem cells in the SAM possess unique properties that set them apart from differentiated cells. They show a high degree of cellular plasticity because they can produce many different cell types, and they maintain an undifferentiated state. Such delicate balance is maintained by complex epigenetic regulation and clever molecular signaling mechanisms that orchestrate proliferation, differentiation, and stem cell identity. Stem cells are spatially organized into microenvironments that promote their specific functional needs. The organizing center, located in the central zone, emits vital cues that preserve stem cell identity and modulate their regenerative capacity. Intricate networks of molecular communication ensure coordinated behavior between neighboring cells and prevent premature differentiation.

2.1.3 Role of SAM in Organogenesis

Furthermore, organogenesis is arguably the most important role of the shoot apical meristem, whereby diverse plant organs are produced by its tightly regulated cellular differentiation and patterning. Leaf primordia, for example, form by localized proliferation and specification in particular areas of the meristematic tissue. How this scaffolding is organized spatially and temporally is directed by complex genetic regulatory networks that tightly coordinate organ formation. Formation of leaf primordia is initiated by local cellular protrusions having asymmetric cell divisions and differential expression. Accordingly, auxin accumulation is critical for establishing the position of future leaves, generating developmental domains that dictate cellular and organ differentiation. (Z) This mechanism exemplifies the incredible potential of the shoot apical meristem to orchestrate complex three dimensional patterns of cell behavior. Floral and inflorescent structures are likewise developed from the shoot apical meristem, which is responsible for coordinating the developmental processes that produce reproductive structures as well. From vegetative to reproductive growth is a key developmental transition regulated by complex molecular networks that alter the functional properties of the meristematic tissue. This reflects the ability of plant developmental systems to respond to environmental and internal physiological stimuli to undergo a process of transformation from biotic to abiotic stress.

2.1.4 Molecular Control of Meristem Function

Complex molecular regulatory networks that coordinate cellular behavior across levels of organization coordinate the functional integrity of the shoot apical meristem. WUSCHEL (WUS) and CLAVATA3 (CLV3) are transcription factors that form complex feedback circuits to finely tune the population dynamics of stem cells. These forms of molecular interactions form a robust system with the potential to support cellular homeostasis, while providing the basis for continuous growth and developmental plasticity. In meristematic cells epigenetic mechanisms are key regulators that facilitate quickly modifiable cell behaviors. Chromatin remodeling, DNA methylation, and histone modifications allow for dynamic regulatory landscapes that are responsive to environmental and developmental signals. These processes enable the shoot apical meristem to retain cellular plasticity while avoiding dysregulated proliferation. Another important layer of molecular regulation of the shoot apical meristem involves hormonal signaling. Plant hormones such as auxin and cytokinin generate complex signaling gradients that inform cellular differentiation and organ genesis. This combination of spatial and temporal activation of molecular signals is responsible for complex gene expression profiles that ultimately lead to distinct cellular identities and developmental paths.

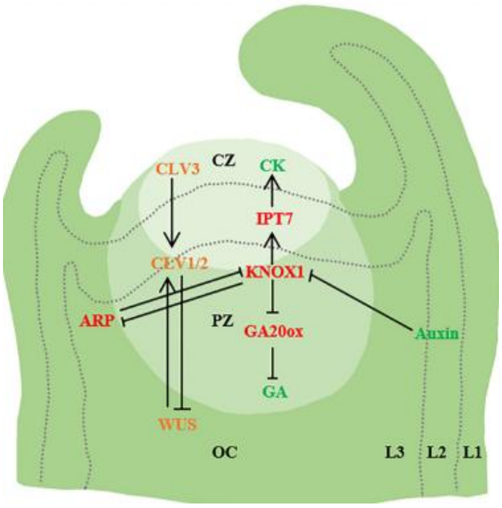


Fig.2.3 shoot apical zonation

2.1.4.1 Interactions with the Environment and Adaptations

For perennial plants, the shoot apical meristem is a key interface between the plant individual and the external environment by allowing adaptive responses to fluctuations in environmental conditions. Meristematic activity can be modulated by factors such as temperature, light availability, nutrient status, among other abiotic and biotic stress factors, thus leading either to detrimental consequences or, in some cases, alternative developmental strategies with potential growth advantages. The potential for such responsiveness underscores the adaptive value of keeping a flexible developmental system. For example, photoperiodic conditions can induce dramatic changes in the shoot apical meristem function, which are most significantly characterized by the transition from vegetative to reproductive development. Environmental cues are sensed and integrated via complex molecular signaling networks that alter cellular behaviors and developmental trajectories. These adaptive traits allow for the refinement of growth and reproductive strategies in reaction to changing ecological contexts. The integrated molecular mechanisms that can modulate proliferation, differentiation, and resource allocation underlying stress responses in the shoot apical meristem remain to be elucidated. In the face of harsh environmental conditions, plants have the ability to alter their meristematic activity to ensure survival and conserve resources. Such adaptive strategies reveal the remarkable regulatory potential of plant developmental programs.

2.1.4.2 Evolutionary Perspectives

Also, the shoot apical meristem can be considered as the most prominent and also unique evolutionary innovation, which is an important factor for the remarkable diversification of plant taxa as well as adaptation to the environments Julian E. M. Campbell. Core developmental mechanisms are conserved across lineages of plants, even as structural and functional forms display incredible diversity. The ecological success in colonizing various ecological niches and building complex morphological survival strategies has offered evolutionary plasticity to plants (Galili and Oppenheim, 2016; Karagyozov et al., 2020). The evolution of the embryophytes shows a gradual refinement of the meristematic organization with progressive complexity in different plant groups. Its developmental potential is limited to the gradual, stepwise addition of subunits connected with various degrees of branching, in contrast to its seed plant cousins, which have highly complicated shoot apical meristems that can produce complex architectural patterns. Article continues after the advertisement This process of development has a phylogenetic history as development itself is, and has been, increasingly adapted to tackle environmental problems. We have uncovered several endemically conserved molecular toolkits that regulate shoot apical meristem function in both monocots and dicots. Thus, key regulatory genes and signaling pathways display high levels of homology across distantly related plant groups, revealing the evolutionary conservation of plant developmental processes.

2.1.4.3 Technological Implication Agriculture

Regardless, these potential avenues provide insight into the biological processes controlling shoot apical meristem function with critical applications toward agbiotech and crop improvement efforts. Modulating meristematic activity provides several opportunities to produce crop varieties with superior

2.1.5 Theory of SAM:

SAM Theory (Classical Concepts of Organization)

Botanists have proposed several theories to explain the internal organization and functioning of the shoot apical meristem. The main ones are:

2.1.5.1 Apical Cell Theory

- The shoot apex is controlled by a single **apical cell**.
- This cell is tetrahedral (pyramidal) in shape.
- All tissues of the shoot arise from successive divisions of this single apical cell.
  Observed in: many pteridophytes and lower plants.

Limitation: In most seed plants, no single apical cell controls the apex.

2.1.5.2 Histogen Theory (Hanstein, 1868)

- The SAM is organized into **three distinct layers of tissues called histogens**:
  - **Dermatogen** → forms **epidermis**
  - **Periblem** → forms **cortex**
  - **Plerome** → forms **vascular tissues (stele)**
    Each histogen has a fixed histogenic potential. Later research showed more complexity than three simple layers.

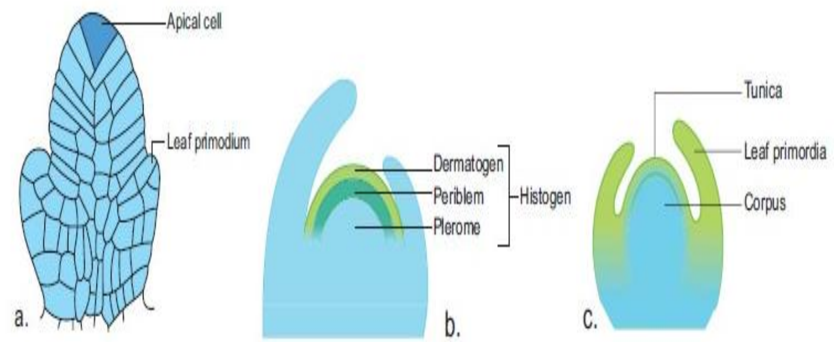
2.1.5.3 Tunica–Corpus Theory (Schmidt, 1924)

- SAM is differentiated into:
  - **Tunica** (outer layers): undergoes **anticlinal divisions** (perpendicular to surface) to increase surface area; forms epidermis.
  - **Corpus** (inner mass): undergoes **varied divisions** (anticlinal and periclinal) to increase volume; forms internal tissues.
    Explains layered structure (L1, L2, L3) commonly seen in histology.

2.1.5.4 Cytohistological Zonation Concept

- Instead of sharp layers, the apex is organized into **zones based on cell division rates and functions**:
  - **Central Zone (CZ)**: slowly dividing, stem cell reservoir.
  - **Peripheral Zone (PZ)**: actively dividing, forms leaves and lateral organs.

- **Rib Meristem (RM)**: forms pith and internal tissues. Explains dynamic behavior and molecular regulation (e.g., WUSCHEL and CLAVATA genes).



Shoot apical meristem a) Apical cell theory, b) Histogen theory, c) Shoot Tunica corpus theory

Fig. 2.4

2.1.6 Significance of SAM Theories

They help explain **how shoots grow continuously**.
Provide a basis for **tissue culture and meristem cloning**.
Fundamental in **genetic engineering** (meristematic tissues used for virus-free plants).

Summary:

The **shoot apical meristem (SAM)** is a mass of undifferentiated, actively dividing cells located at the **tip of the shoot**.It is responsible for **primary growth**, leading to the formation of **stems, leaves, and flowers**.**Structure**:

Tunica-Corpus Organization:

- *Tunica* (outer layers): divide anticlinally, maintain surface growth.

- *Corpus* (inner cells): divide in multiple planes, add bulk to the shoot.

Zones in SAM:

- *Central Zone*: slowly dividing, reservoir of stem cells.
- *Peripheral Zone*: actively dividing, gives rise to organs (leaves, axillary buds).
- *Rib Zone*: produces internal tissues like pith.

Multiple Choice Question (MCQ):

1. The shoot apical meristem is responsible for:

a) Secondary growth

b) Primary growth

c) Root elongation

d) Flower pollination

Answer: b) Primary growth

2. In tunica-corpus organization of SAM, tunica cells divide:

a) Periclinally

b) Anticlinally

c) Radially

d) Irregularly

Answer: b) Anticlinally

3. Which zone of the SAM acts as a stem cell reservoir?

a) Peripheral zone

b) Rib zone

c) Central zone

d) Leaf primordia

Answer: c) Central zone

4. Leaf primordia arise from the:

a) Central zone

b) Rib zone

c) Peripheral zone

d) Root cap

Answer: c) Peripheral zone

5. Transition to flowering in plants is regulated at the level of:

a) Root apical meristem

b) Shoot apical meristem

c) Cambium

d) Epidermis

Answer: b) Shoot apical meristem

Short Questions

1. Differentiate between tunica and corpus in SAM.
2. What is the function of the **peripheral zone** of SAM?
3. Name two hormones that regulate SAM activity.
4. Explain the role of SAM in **phyllotaxy**.
5. State one difference between **shoot apical meristem and root apical meristem**.
6. Give one example of a gene regulating SAM function.

Long Questions

1. Describe the **structure and zones of the shoot apical meristem** with a neat diagram.
2. Explain the **tunica-corpus organization** of SAM and its role in shoot development.
3. Discuss the **developmental significance** of SAM in organogenesis and flowering.
4. Compare and contrast the **shoot apical meristem and root apical meristem**.

5. Explain how **genetic and hormonal regulation** controls the activity of the SAM.
6. Write an essay on the **organization and functional zones of SAM** and their role in growth and development.

UNIT 2.2

Vascularization, Morphology, and Structural Development in Monocotyledons and Dicotyledons

2.2.1 Vascularization: Vascularization refers to the development and arrangement of the vascular tissues in plants, which are responsible for the transportation of water, minerals, and organic compounds throughout the plant. These vascular tissues include **xylem** (responsible for water transport) and **phloem** (responsible for transporting sugars and other organic substances). The process of vascularization is essential for plant growth and development, enabling the plant to sustain its metabolic activities and respond to environmental conditions.

Vascular Tissues in Plants: There are two primary types of vascular tissues in plants:

- **Xylem**: This tissue is responsible for the transport of water and dissolved minerals from the roots to the stems and leaves.
- **Phloem**: This tissue transports the products of photosynthesis (mainly sugars, hormones, and amino acids) from the leaves to other parts of the plant.

Xylem Components:

- **Tracheids**: Long, tapered cells with thick walls that facilitate water transport and provide structural support.
- **Vessel Elements**: Shorter, wider cells with perforated end walls that form continuous tubes for more efficient water conduction (found mainly in angiosperms).
- **Fibers**: Strong, elongated cells that provide structural support.
- **Parenchyma**: Living cells that store water and nutrients and assist in lateral water movement.

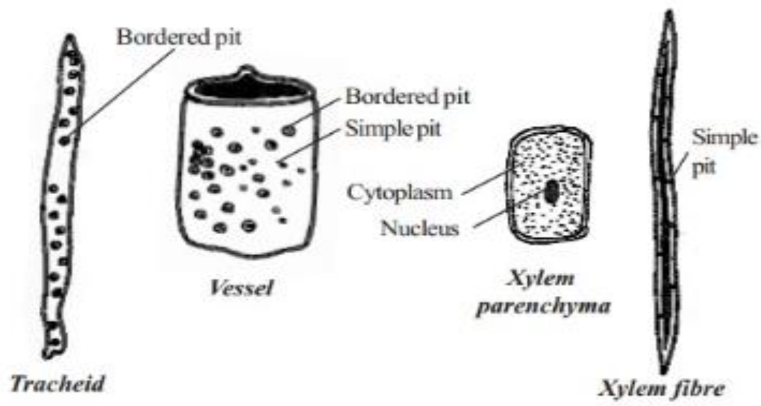


Fig. **2.5 Xylem Components**

Phloem Components:

- **Sieve Tube Elements**: Elongated cells that form the primary conduits for transporting sugars and other organic compounds. They are connected by **sieve plates**, which allow for the flow of substances between cells.
- **Companion Cells**: These cells are closely associated with sieve tube elements and help with the loading and unloading of substances into the sieve tubes.
- **Phloem Parenchyma**: Cells that store and transport nutrients within the phloem.
- **Phloem Fibers**: Provide structural support to the phloem tissue.

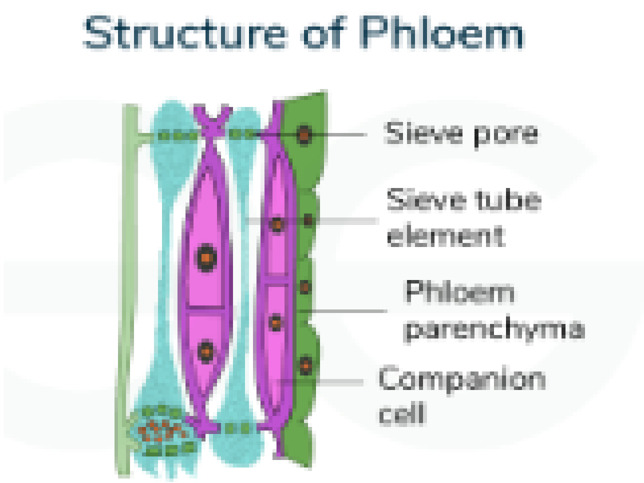


Fig.2.5 structure of Phloem

2.2.2 Vascular Tissue System in Plants

The vascular tissue system is organized into two main components: the **vascular bundles** and the **vascular cambium**.

Vascular Bundles:

- Vascular bundles are arrangements of xylem and phloem that run through the plant stem, roots, and leaves. The exact arrangement of xylem and phloem can vary depending on the type of plant.
  - **In monocots**, the vascular bundles are scattered throughout the stem.
  - **In dicots**, the vascular bundles are arranged in a circle or ring, with xylem on the inside and phloem on the outside.

Vascular Cambium:

- The **vascular cambium** is a meristematic tissue responsible for secondary growth in dicots and gymnosperms. It produces new xylem (wood) and phloem tissues during the plant's growth, increasing the diameter of stems and roots.
- **Secondary Xylem**: Produced towards the inside of the cambium, contributing to wood formation.
- **Secondary Phloem**: Produced towards the outside of the cambium.

2.2.2.1 Types of Vascularization in Plants

Vascularization varies across plant species, depending on whether the plant is a **vascular plant**, such as a **seedless vascular plant**, **gymnosperms**, or **angiosperms**, and whether it is a **monocot** or **dicot**.

Seedless Vascular Plants (e.g., ferns): These plants have a simple vascular system consisting of xylem and phloem. The vascular tissues are typically arranged in bundles within the stem, and the plant lacks secondary growth (woody tissues).

Gymnosperms:

- These plants (e.g., conifers) have a well-developed vascular system with xylem (mainly tracheids) and phloem. Gymnosperms exhibit secondary growth, with the vascular cambium producing both xylem and phloem during growth, leading to the formation of wood.

Angiosperms:

- **Monocots**: The vascular bundles in monocots are scattered throughout the stem. Monocots do not undergo secondary growth, so they do not produce wood. Examples include grasses, lilies, and palms.
- **Dicots**: The vascular bundles are usually arranged in a circle in the stem, and dicots typically undergo secondary growth, forming both wood (secondary xylem) and bark (secondary phloem). Examples include trees, shrubs, and most flowering plants.

2.2.2.2 Vascularization in Roots, Stems, and Leaves

- **Roots**:
  - In roots, the vascular tissues are typically arranged in a central cylinder. The xylem forms a central core, while phloem is located around it.
  - The vascular tissue in roots is responsible for the uptake of water and minerals and their transport to the stem and leaves.

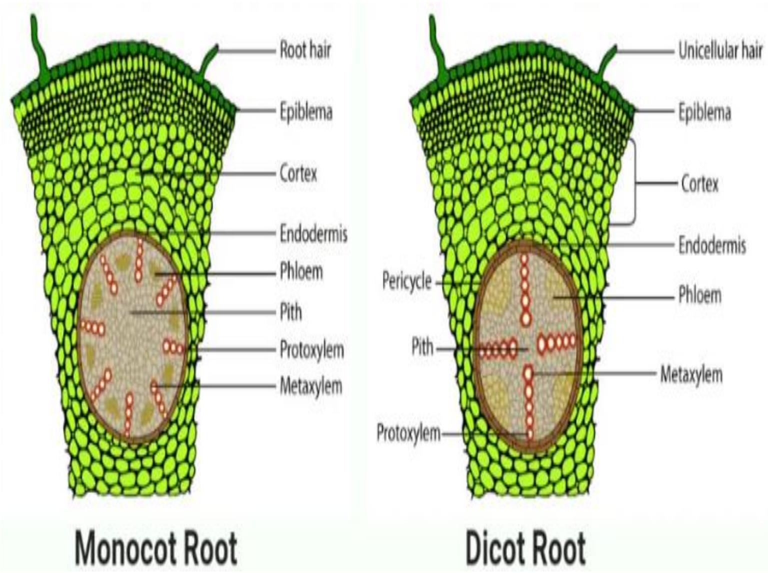


Fig.2.6 Monocot and Dicot root

- **Stems**:
  - Vascular bundles in stems can be arranged differently based on plant type:
    - **Monocots**: Vascular bundles are scattered throughout the stem.
    - **Dicots**: Vascular bundles are arranged in a ring in the stem.
  - The vascular tissue in stems supports the plant and is crucial for the transport of water, nutrients, and sugars.

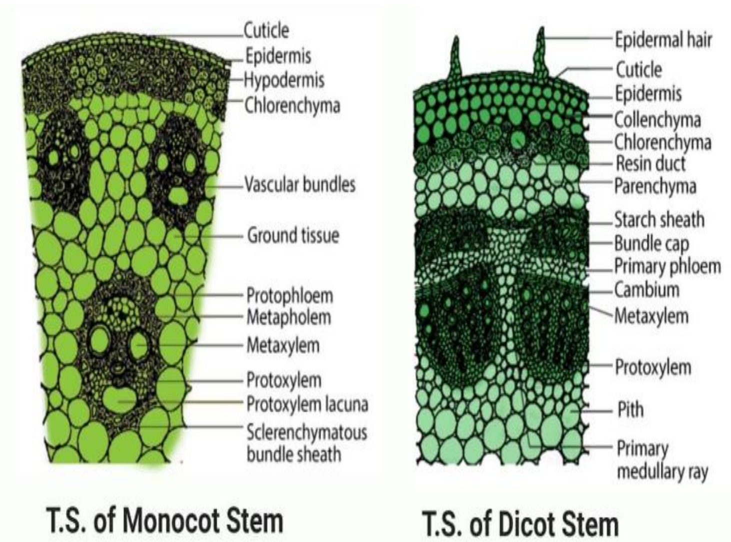


Fig.2.7 T.S. of monocot and dicot stem

- **Leaves**:
  - The vascular tissue in leaves forms the **vascular bundles** that are interconnected to form the **veins**. Xylem is located on the upper side of the leaf veins, while phloem is on the lower side. This arrangement helps with efficient transport within the leaf and between the leaf and other plant parts.

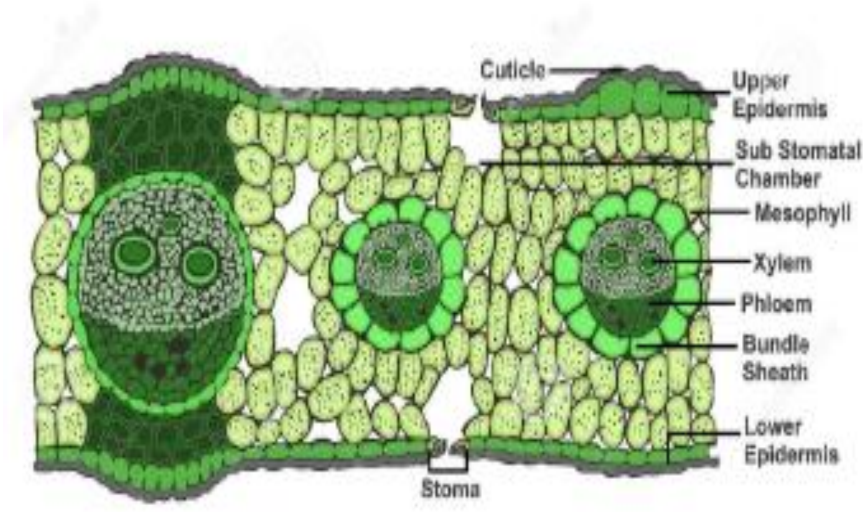


Fig. 2.8 A monocot leaf

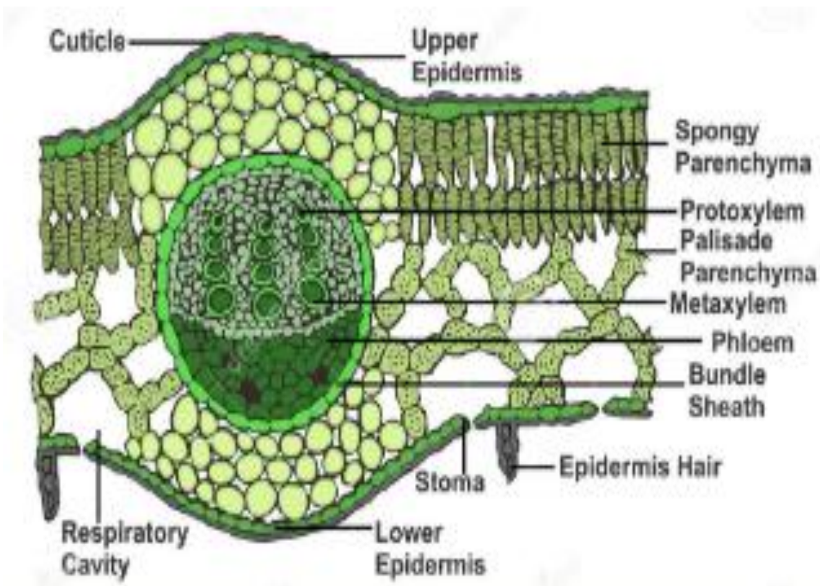


Fig. 2.9 A dicot leaf

2.2.2.3 Vascularization and Plant Growth

Vascularization is directly linked to the growth and development of plants. It ensures that the plant can transport essential nutrients and water to all its parts, and it supports the plant's ability to grow taller and wider through secondary growth.

- **Primary Growth**: The increase in plant length, which occurs through the activity of apical meristems (in the root and shoot tips), produces the primary vascular tissues (primary xylem and primary phloem).
- **Secondary Growth**: The vascular cambium produces new xylem and phloem, contributing to an increase in plant girth. This process is common in dicots and gymnosperms, leading to the formation of woody tissues.

2.2.2.4 Role of Vascularization in Transport

The vascular system plays a vital role in the **transportation of substances** throughout the plant:

- **Water and Mineral Transport (Xylem)**:
  - Xylem vessels are responsible for the transport of water and minerals from the roots to the leaves. The process is driven by **transpiration** in the leaves, creating a negative pressure that pulls water upward through the plant.
- **Sugar and Nutrient Transport (Phloem)**:
  - Phloem is responsible for the transport of sugars (produced during photosynthesis in the leaves) and other nutrients to other plant parts, including the roots and growing tissues. The movement of substances in the phloem occurs through **pressure flow**, driven by osmotic gradients.

2.2.2.5 Vascularization in Response to Environmental Factors

Vascularization can also change in response to environmental conditions:

- **Water Stress**: In drought conditions, plants may alter their vascularization by producing more xylem to increase water transport efficiency.
- **Injury or Damage**: When a plant is damaged (e.g., by herbivores or physical injury), the vascular tissue may form new connections or tissues to close wounds and restore transport capabilities.

Summary:

Monocotyledons (Monocots):

Vascularization: Vascular bundles are **numerous, scattered, closed** (no cambium), mostly **conjoint and collateral**.

Morphology: One cotyledon, parallel venation, fibrous root system, floral parts in multiples of 3.

Structural development: Primary growth only; **secondary growth absent** in most, but some (e.g., *Dracaena*, *Yucca*) show **anomalous secondary growth**. Stems lack a clear cortex-pith distinction.

Dicotyledons (Dicots)

Vascularization: Vascular bundles are **fewer, arranged in a ring**, usually **open** (with cambium). Distinct **xylem and phloem**, radial symmetry.

Morphology: Two cotyledons, reticulate venation, tap root system, floral parts in multiples of 4 or 5.

Structural development: Show **primary and secondary growth** (cambium produces secondary xylem and phloem). Stem differentiated into cortex and pith.

Multiple Choice Question (MCQ):

1. In monocot stems, vascular bundles are:

a) In a ring, open

b) Scattered, closed

c) In a ring, closed

d) Radial, open

Answer: b) Scattered, closed

2. Which of the following shows anomalous secondary growth?

a) Mango

b) Sunflower

c) Dracaena

d) Mustard

Answer: c) Dracaena

3. In dicot stems, vascular bundles are usually:

a) Closed and scattered

b) Open and arranged in a ring

c) Closed and concentric

d) Diffuse

Answer: b) Open and arranged in a ring

4. Parallel venation is a characteristic feature of:

a) Dicots

b) Monocots

c) Gymnosperms

d) Pteridophytes

Answer: b) Monocots

5. Secondary growth in dicots occurs due to:

a) Apical meristem

b) Intercalary meristem

c) Vascular cambium and cork cambium

d) Epidermal cells

Answer: c) Vascular cambium and cork cambium

Short Questions

1. Why do monocots usually lack secondary growth?
2. Give one example each of monocots and dicots with tree habit.
3. Write two morphological differences between monocot and dicot leaves.
4. What type of root system is found in monocots and dicots?
5. Mention one plant showing anomalous secondary growth in monocots.
6. Differentiate between vascular bundles in monocot and dicot stems.
7. State one structural adaptation of dicots for woody habit.
8. Give two examples of dicotyledonous plants with secondary growth.
9. Why are vascular bundles in monocots called "closed"?

Long Questions

1. Describe the **vascularization, morphology, and structure of monocots and dicots** with diagrams.
2. Compare the **structural differences** between monocot and dicot stems.
3. Discuss the **morphological differences** between monocot and dicot plants with examples.
4. Explain **secondary growth in dicots** and why it is absent in most monocots.
5. Write an essay on **vascular bundle organization in monocots and dicots** and its significance in classification.
6. Describe **anomalous secondary growth in monocots** with examples (*Dracaena*, *Yucca*).

UNIT 2.3

Cambium and its functions

2.3.1 Structure and function of the Cambium

The **cambium** is a type of meristematic tissue found in vascular plants, responsible for secondary growth. It plays a crucial role in the development and thickening of plant stems, roots, and other structures, allowing them to increase in girth. The primary function of the cambium is to bring about **secondary growth** in stems and roots, which increases the girth (diameter) of the plant. The cambium divides periclinally (parallel to the surface) to produce new cells on both sides: cells formed towards the inside differentiate into **secondary xylem (wood)**, while cells formed towards the outside become **secondary phloem**. This continuous production of secondary vascular tissues allows the plant to transport water, minerals, and food efficiently as it grows larger. In addition, the cambium provides mechanical strength by producing thick layers of wood over time, which supports tall growth and enhances the plant's ability to withstand environmental stress. Cambial activity also contributes to the formation of **annual growth rings** in many trees, which are valuable in determining the age of the tree and past climatic conditions. In summary, the cambium is a vital lateral meristem that plays a central role in the structural development, conduction system, and long-term survival of woody plants.

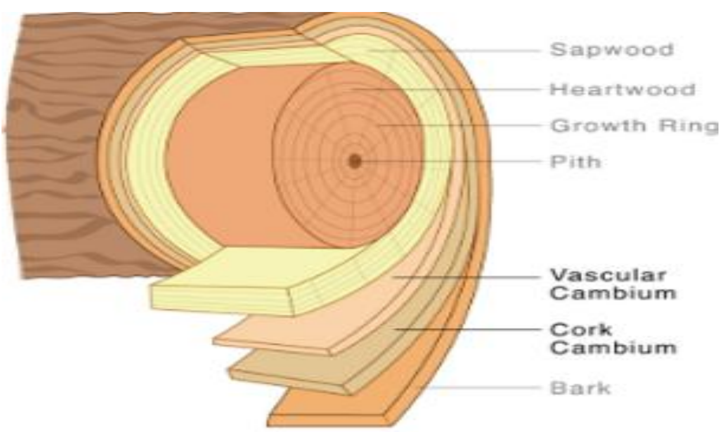


Fig. 2.10 Structure of the Cambium

1. **Location**:
   - The cambium is typically located between the xylem (wood) and phloem (vascular tissue responsible for transporting nutrients) in dicots and gymnosperms.
   - It can be found in a cylindrical layer surrounding the stem or root.
2. **Types of Cambium**:
   - **Vascular Cambium**: This is the most common type, responsible for the production of secondary xylem and secondary phloem.

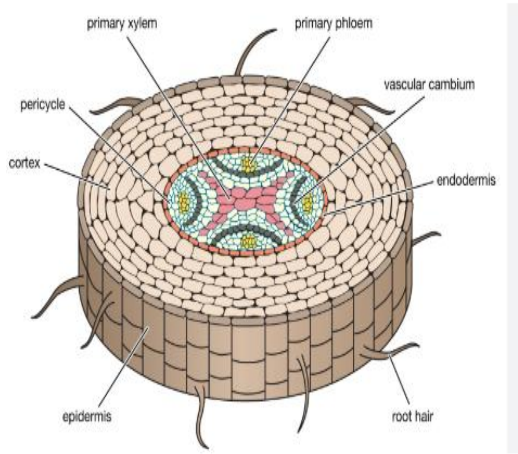


Fig 2.11 Vascular Cambium

   - **Cork Cambium**: Found in woody plants, it produces the outer bark (periderm) by forming cork cells and phelloderm cells.

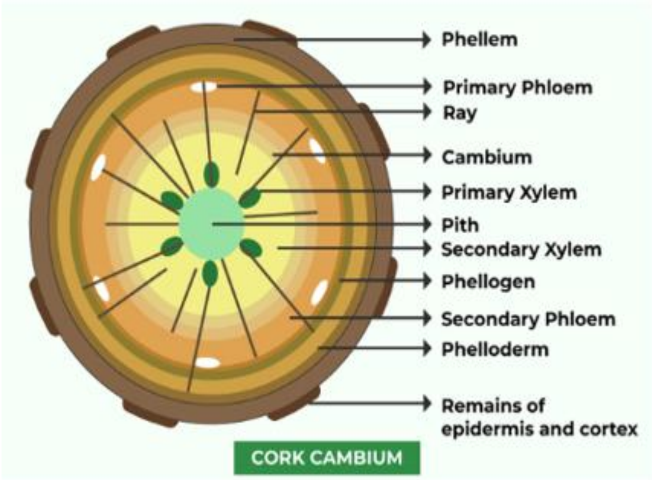


Fig. **2.11 Cork Cambium**

3. **Cell Characteristics**: The cambium is composed of thin-walled, actively dividing, undifferentiated cells called meristematic cells.
    - The cells are typically narrow and elongated, and they can divide both longitudinally and laterally to contribute to growth.

2.3.2 Function of the Cambium:

1. **Secondary Growth**:
    - **Vascular Cambium**: The primary function of the vascular cambium is to facilitate the secondary growth of the plant, producing new layers of xylem (wood) and phloem (vascular tissue) through cell division. As the cambium divides:
        - The **secondary xylem** (wood) is produced toward the inside.
        - The **secondary phloem** is produced toward the outside.
    - This growth allows the plant to become thicker and support larger structures as it matures.
2. **Cork Cambium**:

- The cork cambium produces cork cells (which form the bark) on the outer side and phelloderm cells on the inner side, contributing to the protection of the plant and the prevention of water loss.

3. **Repair and Regeneration**:
   - Cambium cells can also assist in the regeneration of damaged tissues, aiding in the plant's ability to recover from injury or external damage.

2.3.2.1 Importance:

- **Growth in Width**: The cambium is key in the lateral (or secondary) growth of plants, allowing for the formation of wood and bark.
- **Support**: The secondary xylem produced by the vascular cambium provides structural support, while the secondary phloem helps transport nutrients.
- **Adaptation**: In trees and woody plants, the cambium enables them to grow larger and withstand environmental stresses such as wind or heavy loads.

2.3.3 Formation of secondary xylem

Secondary xylem, commonly known as wood, is produced during the secondary growth of plants, primarily in woody plants like trees and shrubs. It results from the activity of the vascular cambium, a meristematic tissue responsible for secondary growth. The process involves the formation of xylem cells that contribute to the structural strength and transport of water and nutrients in plants.

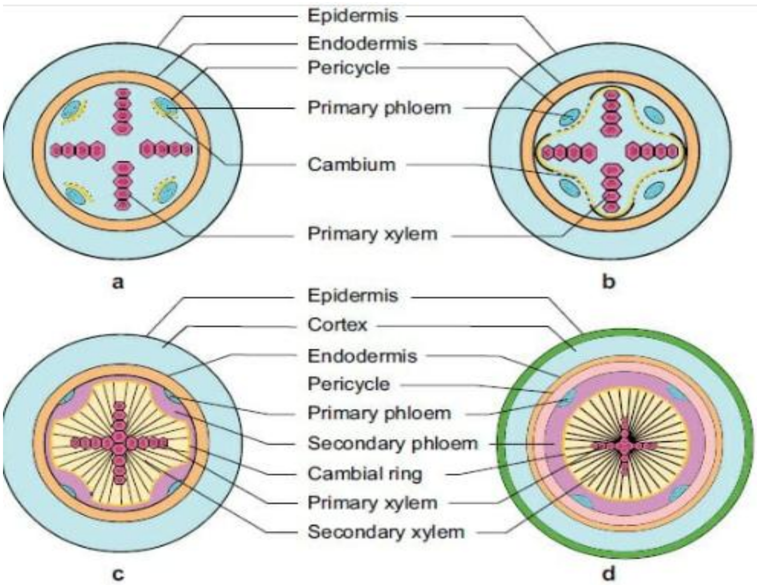


Fig.2.12 **Formation of secondary xylem**

2.3.3.1 Vascular Cambium Activity

- The **vascular cambium** is a thin layer of meristematic cells located between the primary xylem and primary phloem. During secondary growth, this cambium divides and produces new cells on both sides.
- The cambium gives rise to secondary xylem toward the inside (interior) and secondary phloem toward the outside (exterior) of the stem or root.

2.3.3.2 Development of Secondary Xylem

- As the vascular cambium continues to divide, it produces **secondary xylem cells**. The production of these cells occurs in a radial pattern, and the cells that form the secondary xylem have specialized functions.

2.3.3.3 Types of Secondary Xylem Cells

- **Tracheids**: Long, tapered cells with thick walls that serve in water conduction and structural support.

- **Vessel Elements**: Shorter, wider cells that form long tubes for efficient water transport. Found mainly in angiosperms.
- **Fibers**: These are long, lignified cells that provide mechanical support to the plant.
- **Parenchyma**: Living cells involved in the storage and lateral transport of water and nutrients.

2.3.3.4 Annual Growth Rings

- In temperate regions, secondary xylem growth can vary in size depending on environmental factors like water availability, temperature, and sunlight.
- As a result, the secondary xylem grows in layers, creating **annual growth rings**. These rings can be counted to determine the plant's age (a method known as **dendrochronology**).
    - **Early Wood (Spring Wood)**: Formed during the spring or early growing season when water is abundant. It has larger cells with thinner walls.
    - **Late Wood (Summer Wood)**: Formed during the late growing season when water is less available. It has smaller cells with thicker walls, providing structural strength to the plant.

2.3.3.5 Structure of the Secondary Xylem

- **Xylem Rays**: These are horizontal or radial rows of parenchyma cells that extend across the secondary xylem. They assist in lateral transport of water and nutrients.
- **Lignification**: The xylem cells undergo lignification (the process of depositing lignin in the cell walls), making the secondary xylem rigid, impermeable to water, and strong.

2.3.3.6 Role of Secondary Xylem

- **Water Transport**: Secondary xylem cells (especially tracheids and vessel elements) form continuous tubes that transport water and dissolved minerals from the roots to the leaves.
- **Support**: The thick cell walls of secondary xylem provide structural strength and support, allowing plants to grow tall and withstand environmental stresses such as wind.
- **Storage**: Some secondary xylem cells, especially parenchyma, store carbohydrates and other nutrients.

2.3.3.7 Formation of Heartwood and Sapwood

- As secondary xylem continues to form, older layers of xylem in the center of the stem or root become less active in water conduction and are filled with resins and other substances, forming **heartwood**. Heartwood is darker and provides strength but no longer participates in water transport.
- The outer layers of secondary xylem, still functional in water transport, form **sapwood**. The sapwood is lighter in color and conducts water and nutrients from the roots to the upper parts of the plant.

2.3.3.8 Cork Cambium and Periderm Formation

- The secondary xylem is covered by a protective layer known as the **periderm**. This tissue includes the cork cambium, which forms the cork, and the periderm, which replaces the epidermis during secondary growth in woody plants.

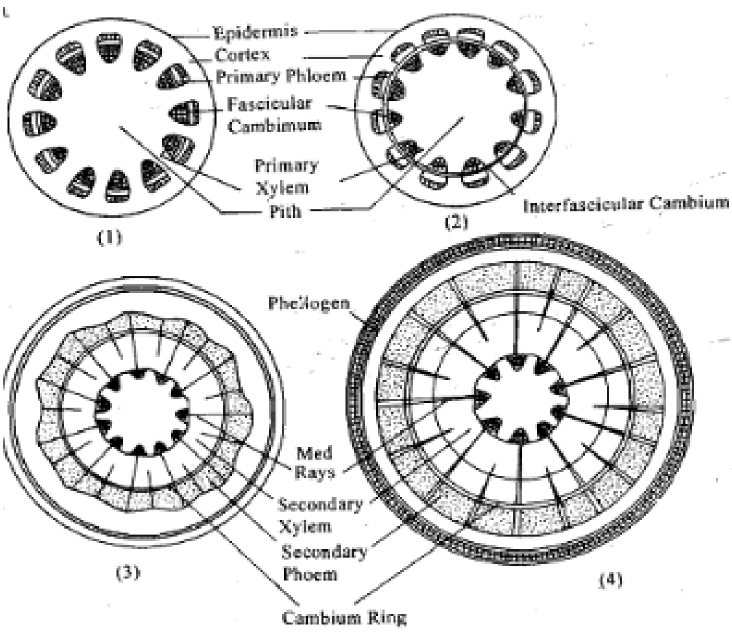


Fig. 2.13 Structure of the Secondary growth

2.3.4 A general account of wood structure in relation to conduction of water and minerals

Wood, also known as **secondary xylem**, plays a critical role in the conduction of water and minerals from the roots to the rest of the plant, especially in trees and shrubs with secondary growth. The structure of wood is specialized to ensure efficient water and nutrient transport, as well as to provide mechanical support to the plant. Here's a general overview of how the wood structure relates to the conduction of water and minerals:

2.3.4.1 Components of Wood (Secondary Xylem)

Wood is primarily made up of various types of cells that work together to transport water, minerals, and provide structural support. These components include:

- **Tracheids**
- **Vessel Elements**
- **Fibers**
- **Parenchyma**
- **Xylem Rays**

2.3.4.2 Water-Conducting Cells

The primary role of wood is to facilitate the upward movement of water and dissolved minerals from the roots to the leaves. This is primarily achieved through two main types of water-conducting cells: **tracheids** and **vessel elements**.

- **Tracheids**:
  - **Structure**: Long, tapering cells with thick, lignified walls and small openings called **pits**.
  - **Function**: Tracheids conduct water through the plant but are less efficient than vessel elements. They also provide structural support.
  - **Presence**: Found in both gymnosperms (e.g., conifers) and angiosperms, although in gymnosperms, tracheids are the main water-conducting cells.
- **Vessel Elements**:
  - **Structure**: Shorter, wider cells with thick walls and large openings at the ends, forming continuous tubes known as **vessels**.
  - **Function**: Vessel elements are more efficient than tracheids for water conduction due to their larger diameter and the formation of long, continuous columns.
  - **Presence**: Found mainly in angiosperms (flowering plants) and are the primary cells responsible for water transport in these plants.

2.3.4.3 Water Transport Mechanism

- **Capillary Action**: Water moves upward through the xylem due to the cohesion between water molecules and adhesion to the walls of the xylem cells. This creates a continuous column of water that can travel long distances.
- **Transpiration Pull**: Water evaporates from the leaves (through **stomata**), creating a negative pressure that pulls water up through

the plant from the roots. This process is aided by the cohesion of water molecules in the xylem vessels and tracheids.

- **Root Pressure**: In some plants, water is pushed upwards from the roots due to osmotic pressure, although this mechanism is less significant than transpiration pull.

2.3.4.4 Support and Strength

While conducting water, wood also provides structural support to the plant, allowing it to grow tall and withstand mechanical stresses like wind. The **lignin** in the cell walls of xylem cells (tracheids, vessel elements, and fibers) provides rigidity and strength, which helps in maintaining the integrity of the plant's vascular system during the movement of water.

- **Fibers**: These are long, thick-walled cells that provide mechanical strength to the wood. They do not conduct water but support the plant's vascular system by preventing collapse under pressure.

2.3.4.5 Xylem Rays and Lateral Transport

- **Xylem Rays**: These are radial rows of parenchyma cells in the wood that run perpendicular to the xylem vessels. While they do not directly conduct water, they facilitate the lateral (sideways) movement of water and minerals from one xylem vessel to another.
- **Parenchyma Cells**: These living cells, present in xylem rays and the xylem itself, store water and nutrients and assist in the lateral movement of water between vessels and tracheids.

2.3.4.6 Heartwood and Sapwood

- **Sapwood**: The outer, living layers of the secondary xylem that are actively involved in water conduction. The xylem vessels in the sapwood are functional and conduct water and minerals from the roots to the leaves.
- **Heartwood**: The inner, older layers of xylem that are no longer involved in water transport. Over time, the heartwood becomes

filled with resins, tannins, and other substances that help prevent decay, but it no longer participates in the conduction of water.

2.3.4.7 Lignification and Its Effect on Water Transport

- **Lignin** is a complex polymer deposited in the cell walls of xylem cells. Lignification strengthens the walls, making the wood rigid and resistant to decay. However, it also reduces the permeability of the walls, helping to prevent water loss and ensuring efficient transport through the plant.
- The degree of lignification is particularly high in the tracheids and vessel elements of the xylem, ensuring that these cells are structurally robust enough to handle the pressure exerted during water transport.

2.3.4.8 Annual Growth Rings and Water Conduction

- In temperate climates, **annual growth rings** in wood form due to differences in the size and structure of xylem cells produced during different seasons.
  - **Early wood (Spring wood)**: Formed in the spring when water is abundant. It has larger, thinner-walled cells that facilitate efficient water conduction.
  - **Late wood (Summer wood)**: Formed during the summer, when water is less abundant. The cells are smaller and have thicker walls, contributing to the structural strength of the plant but with less efficient water conduction.

2.3.4.9 Water and Mineral Transport in Roots

- Water and minerals are absorbed by the **root hairs** in the roots and then transported through the **root xylem** vessels to the stem. The process involves capillary action, osmotic pressure, and transpiration pull, with the xylem vessels serving as the main conduits.

Summary:

The **cambium** is a lateral meristem found between the primary xylem and phloem. It plays a crucial role in secondary growth, which increases the thickness or girth of stems and roots. Functionally, the cambium produces secondary xylem (wood) towards the inner side and secondary phloem towards the outer side. It also gives rise to vascular rays, which facilitate radial transport of food and water. The **structure of wood** is closely related to its function in conduction and support. In gymnosperms, conduction occurs mainly through tracheids, which are less efficient but provide structural strength. In angiosperms, conduction is more efficient due to the presence of vessels. Depending on seasonal patterns, wood can be ring-porous, with large vessels in spring and smaller ones in autumn (as in oak), or diffuse-porous, with vessels distributed uniformly throughout the year (as in maple).

Multiple Choice Question (MCQ)

1. The cambium responsible for secondary growth in stems is:

a) Apical meristem

b) Vascular cambium

c) Intercalary meristem

d) Epidermal meristem

Answer: b) Vascular cambium

2. Secondary xylem is commonly known as:

a) Phloem

b) Cork

c) Wood

d) Cortex

Answer: c) Wood

3. Which xylem element is the chief water-conducting cell in gymnosperms?

a) Vessels

b) Tracheids

c) Fibers

d) Xylem parenchyma

Answer: b) Tracheids

4. In angiosperms, efficient conduction of water occurs mainly through:

a) Fibers

b) Vessels

c) Rays

d) Pith

Answer: b) Vessels

5. Spring wood is characterized by:

a) Narrow vessels, thick walls

b) Wide vessels, thin walls

c) No vessels at all

d) Abundant fibers only

Answer: b) Wide vessels, thin walls

6. Annual rings are formed due to:

a) Seasonal activity of cambium

b) Activity of apical meristem

c) Deposition of cutin

d) Cork cambium activity

Answer: a) Seasonal activity of cambium

Short Questions

1. What is cambium?
2. Differentiate between vascular cambium and cork cambium.
3. Why is secondary xylem called **wood**?

4. Define spring wood and autumn wood.
5. State one function of xylem parenchyma.
6. Which elements of xylem are dead at maturity?
7. Write one difference between tracheids and vessels.
8. Why are annual rings used in dendrochronology?
9. Mention two functions of cambium in plants.
10. What is meant by ring-porous and diffuse-porous wood?

Long Questions

1. Describe the structure, origin, and functions of cambium.
2. Explain the formation of **secondary xylem** and its role in plant growth.
3. Discuss the **structure of wood (secondary xylem)** in relation to conduction of water and minerals.
4. Compare **tracheids and vessels** as conducting elements.
5. With diagrams, explain the **seasonal activity of cambium** and formation of annual rings.
6. Write an essay on the **importance of cambium and wood structure** in conduction and mechanical support.

UNIT 2.4

Characteristics of Growth Rings

2.4.1 Characteristics of growth rings, sapwood and heart wood; role of woody skeleton;

In woody plants, secondary growth plays a critical role in increasing the plant's size and strength. This growth is particularly evident in the formation of **growth rings**, **sapwood**, **heartwood**, and the **woody skeleton**. Each of these components has distinct characteristics and functions that contribute to the overall survival and stability of the plant.

2.4.1.1 Growth Rings: Growth rings (also known as **annual rings**) are formed in temperate zone trees as a result of the varying growth rates during different seasons of the year. These rings provide information about the age of a tree and the environmental conditions it experienced during its growth.

- **Formation**: Growth rings form due to the seasonal variation in the diameter of xylem cells produced by the vascular cambium.
  - **Spring (Early Wood)**: In spring, when water is abundant, the cambium produces large, thin-walled cells with a wide lumen. These cells allow for efficient water transport. This part of the growth ring is lighter in color and is called **early wood** or **spring wood**.
  - **Summer (Late Wood)**: In summer, when water is less available, the cambium produces smaller, thick-walled cells. These cells are less efficient at water conduction but provide greater structural support. This part of the growth ring is darker and is known as **late wood** or **summer wood**.
- **Function of Growth Rings**:
  - **Age Determination**: The number of growth rings can be counted to determine the age of a tree, a method known as **dendrochronology**.

- **Environmental Indicators**: The width of the growth rings can provide insights into past climate conditions. Narrow rings typically indicate dry or unfavorable growing conditions, while wide rings suggest favorable conditions with abundant water.

- **Visible Characteristics**:
  - **Annual Rings**: In temperate climates, one pair of light (early wood) and dark (late wood) rings form each year.
  - **In Tropical Climates**: Some trees do not form distinct growth rings due to continuous growth, but rings may still form during periods of stress or dormancy.

2.4.1.2 Sapwood: Sapwood refers to the outer, functional part of the secondary xylem in a tree, which is involved in the conduction of water and minerals from the roots to the leaves. It is also known as **living xylem**.

- **Characteristics**:
  - **Location**: Sapwood is located just beneath the bark and encircles the heartwood.
  - **Structure**: It is composed of active xylem cells such as tracheids, vessel elements, and parenchyma that are involved in water transport. These cells are still functional and can conduct water and nutrients.
  - **Color**: Sapwood is typically lighter in color compared to heartwood.
- **Function**:
  - **Water and Mineral Transport**: Sapwood contains functional xylem vessels (in angiosperms) and tracheids (in gymnosperms), which actively transport water and dissolved minerals from the roots to the leaves.
  - **Storage**: Some cells in sapwood, especially parenchyma, also store nutrients and starch, providing energy reserves for the plant.

2.4.1.3 Heartwood: Heartwood is the central, non-living part of the secondary xylem that no longer participates in water conduction. It is formed when older layers of sapwood become clogged with resins, tannins, and other substances.

- **Characteristics**:
    - **Location**: Heartwood is found in the innermost part of the tree, surrounded by sapwood.
    - **Structure**: The xylem cells in the heartwood are filled with various chemical compounds such as lignin, resins, tannins, and oils, which provide strength and resistance to decay.
    - **Color**: Heartwood is typically darker in color compared to sapwood, due to the accumulation of chemicals like tannins.
- **Function**:
    - **Support and Strength**: While heartwood does not conduct water, it provides structural support to the tree, enhancing its stability and resistance to mechanical stress.
    - **Decay Resistance**: The chemicals in the heartwood (such as tannins and resins) help to prevent decay, making it less susceptible to fungal and bacterial growth.
    - **Inactive Water Transport**: While it no longer actively transports water, the heartwood contributes to the overall strength of the tree, allowing it to remain stable over time.

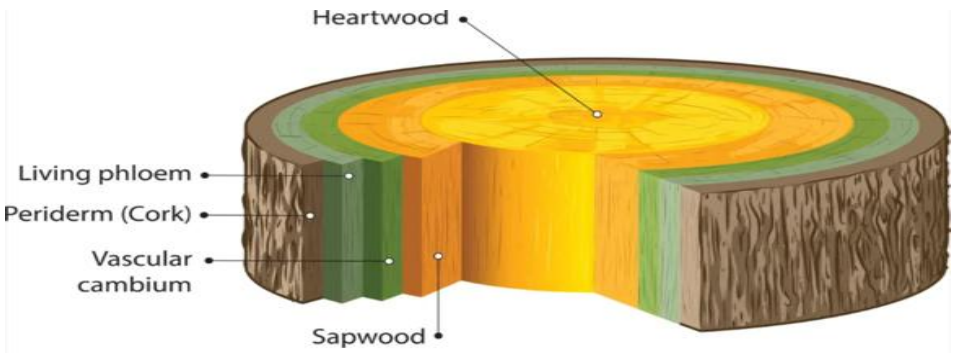


Fig.2.14 Heart wood and Sap wood

2.4.1.4 Role of the Woody Skeleton (Woody Tissue)

The **woody skeleton** of a plant is made up of secondary tissues, including the secondary xylem (wood), fibers, and lignified cell walls. This structure provides mechanical strength, support, and resilience to the plant.

- **Components of the Woody Skeleton**:
  - **Secondary Xylem (Wood)**: The xylem, composed of tracheids, vessel elements, fibers, and parenchyma, is the primary tissue that makes up the woody skeleton.
  - **Fibers**: These long, thick-walled, lignified cells provide additional support to the plant by reinforcing the vascular tissues.
  - **Lignin**: The deposition of lignin in the cell walls of xylem and fiber cells gives the wood its rigidity and strength. Lignin also helps in water conduction by preventing collapse under pressure.
- **Functions of the Woody Skeleton**:
  - **Support**: The woody skeleton provides the necessary support to hold up the plant against gravity, wind, and other external forces, especially in tall trees. The lignified xylem fibers and tracheids provide structural integrity to the plant.
  - **Transport of Water and Nutrients**: The xylem tissue, as part of the woody skeleton, plays a crucial role in the conduction of water and dissolved minerals from the roots to the leaves.
  - **Storage**: The wood also stores nutrients and starch in the parenchyma cells, which can be utilized when needed.
  - **Protection**: The woody skeleton helps protect internal tissues from physical damage, disease, and pest invasion.
  - **Elasticity and Flexibility**: In certain trees, the wood can have enough flexibility to bend without breaking, which helps the plant survive in windy conditions.

2.4.1.5 Secondary phloem

Secondary phloem is an essential tissue in vascular plants that facilitates the transport of sugars, hormones, and other organic compounds throughout the plant. It is produced during secondary growth by the **vascular cambium**, which also gives rise to secondary xylem (wood). Along with the secondary xylem, secondary phloem forms a critical part of the plant's vascular system. The **periderm** is a protective tissue that forms in plants during secondary growth, replacing the epidermis as the plant expands in girth.

Secondary Phloem

The secondary phloem forms as the vascular cambium produces new phloem cells toward the outside of the plant, replacing primary phloem produced during the plant's initial growth. It is responsible for transporting nutrients like sugars, amino acids, hormones, and other metabolic products throughout the plant.

Structure of Secondary Phloem: Secondary phloem is made up of several different cell types, each with a specific role in the transport process and the overall function of the phloem. The key components of secondary phloem include:

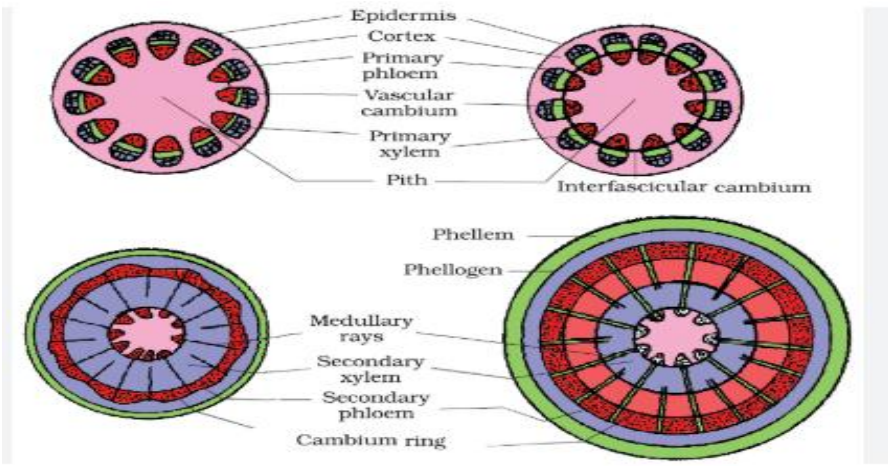


Fig. 2.15 Structure of Secondary Phloem

- **Sieve Tube Elements**:
  - **Structure**: These are elongated, living cells that lack a nucleus. They are arranged end-to-end to form **sieve tubes**, with perforated areas at their ends called **sieve plates**.
  - **Function**: Sieve tube elements are the main conduits for the transport of sugars and other organic compounds. The pressure generated by osmosis allows for the movement of substances through the sieve tubes.
  - **Phloem Loading/Unloading**: Companion cells are responsible for loading and unloading sugars and other materials into the sieve tube elements.
- **Companion Cells**:
  - **Structure**: These are closely associated with sieve tube elements and contain a nucleus and dense cytoplasm.
  - **Function**: Companion cells are vital for the metabolic functions of sieve tube elements, including loading and unloading sugars into the sieve tubes. They also support the sieve tube elements by maintaining their functions.
- **Phloem Parenchyma**:
  - **Structure**: These are living cells with thin walls that are located throughout the phloem tissue.
  - **Function**: Phloem parenchyma cells are involved in the storage of carbohydrates and other substances and assist in lateral transport within the phloem.
- **Phloem Fibers**:
  - **Structure**: These are long, thick-walled, dead cells that provide structural support to the phloem.
  - **Function**: The fibers give the phloem its strength and rigidity, preventing it from collapsing under pressure.

2.4.1.6 Function of Secondary Phloem

- **Transport of Organic Compounds**: The main function of secondary phloem is to transport **photosynthates** (mainly sugars like sucrose) produced in the leaves through the process of **photosynthesis** to the rest of the plant, including roots, stems, and developing tissues.

- **Hormone Transport**: Secondary phloem also transports **hormones** such as auxins, cytokinins, and gibberellins, which regulate various physiological processes within the plant.
- **Nutrient Distribution**: The phloem also distributes other organic materials, such as amino acids, lipids, and proteins, which are required for growth and maintenance of the plant tissues.
- **Storage**: Some cells in the phloem, particularly phloem parenchyma, store carbohydrates (like starch) and other nutrients, which are used when the plant needs energy.
- **Communication**: The phloem is involved in signaling and communication between different parts of the plant, particularly in response to stress or injury.

2.4.2 Periderm

The **periderm** is a protective tissue that forms during secondary growth in woody plants. It replaces the epidermis as the plant grows thicker, ensuring that the plant is adequately protected from desiccation, pathogens, and mechanical damage. The periderm is part of the **secondary plant body** and develops from the **cork cambium**.

2.4.2.1 Structure of Periderm

The periderm consists of three main layers:

1. **Cork (Phellem)**:
   - **Structure**: The cork is composed of dead, tightly packed cells that are filled with **suberin**, a waxy substance that makes the cells impermeable to water and gases.
   - **Function**: The cork acts as a barrier to water loss and protects the plant from pathogens, physical injury, and UV radiation.

2. **Cork Cambium (Phellogen)**:
   - **Structure**: The cork cambium is a lateral meristem that forms new cork cells to the outside and occasionally a few parenchyma cells to the inside.
   - **Function**: The cork cambium produces the cork (phellem) to the outside and occasionally produces some parenchyma cells, which can contribute to the formation of new tissues. As the plant grows, the cork cambium continuously produces new layers of cork.
3. **Phelloderm**:
   - **Structure**: The phelloderm consists of living parenchyma cells that are formed by the cork cambium on the inner side of the cambium.
   - **Function**: The phelloderm plays a role in storing food and contributing to lateral transport within the periderm.

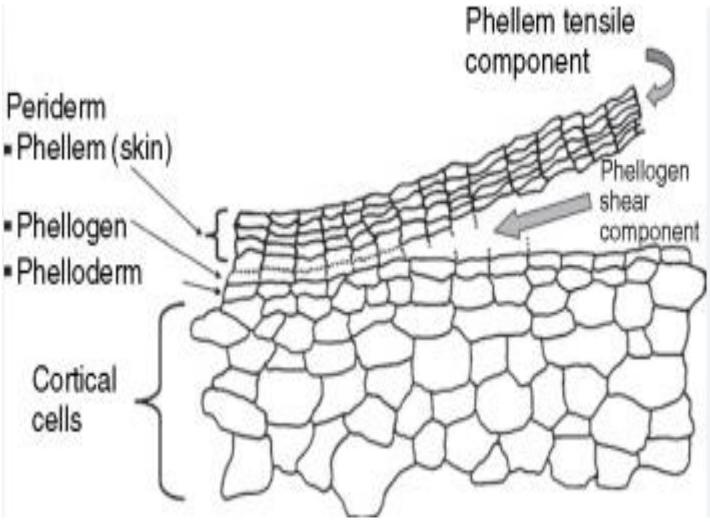


Fig.2.16 Structure of Periderm

2.4.2.2 Function of Periderm

- **Protection**: The periderm provides a protective outer covering for the plant, shielding it from external damage, dehydration, and microbial pathogens. The **suberin** in cork cells creates a waterproof barrier that prevents water loss from the stem or root.

- **Prevention of Pathogen Entry**: The cork layer provides a physical barrier to pathogens, preventing their entry into the plant tissues. It acts as a defense mechanism against fungi, bacteria, and insects.
- **Gas Exchange**: In older plants, the periderm also contains **lenticels**, which are small, spongy areas that allow for the exchange of gases (like oxygen and carbon dioxide) between the internal tissues of the plant and the outside environment.
- **Insulation**: The periderm also acts as an insulator, protecting the plant's vascular system from temperature fluctuations and physical damage.

*2.4.2.2.*1 Relationship Between Structure and Function

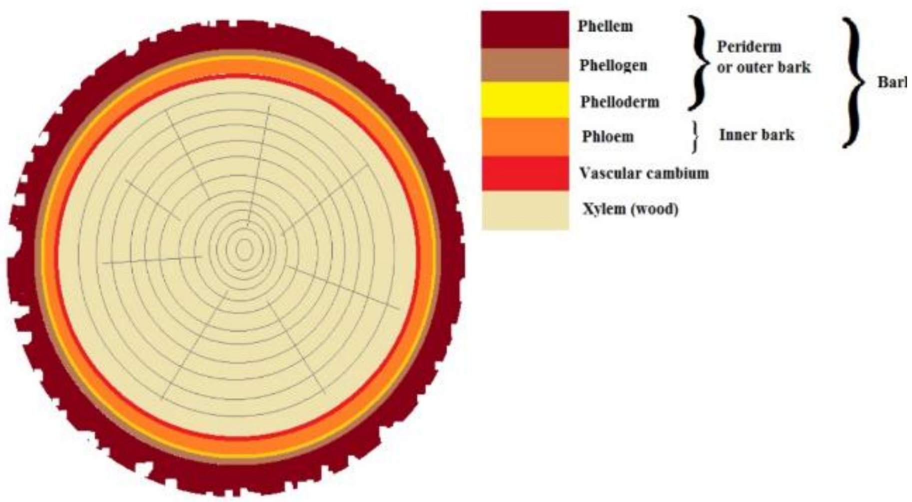


Fig.2.17 Relationship Between Structure and Function

- **Phloem**:
  - The **sieve tube elements** have thin cell walls and perforated sieve plates, facilitating the easy movement of sugars and organic materials.

  - The **companion cells** support the sieve tube elements metabolically by providing ATP and enzymes for loading and unloading.
  - **Fibers** provide structural rigidity to the phloem, ensuring the tissue maintains its shape and does not collapse under pressure.
  - **Parenchyma cells** store sugars and nutrients and assist in lateral transport within the phloem.
- **Periderm**:
  - The **cork** is composed of suberin, making it impermeable to water and gases, thus playing a crucial role in preventing water loss and providing defense against pathogens.
  - The **cork cambium** continuously produces new cork and parenchyma cells as the plant increases in girth.
  - The **phelloderm** provides additional storage and may participate in lateral transport of materials.

- **Secondary Phloem**: Primarily responsible for the transport of sugars, amino acids, hormones, and other organic compounds throughout the plant. It consists of sieve tube elements, companion cells, parenchyma, and fibers, each contributing to transport, storage, and structural support.
- **Periderm**: Forms during secondary growth, replacing the epidermis. It consists of cork (phellem), cork cambium (phellogen), and phelloderm, providing protection against water loss, pathogens, and physical damage. It also allows for gas exchange through lenticels.

Both **secondary phloem** and the **periderm** are essential for the survival of woody plants, ensuring both efficient transport of organic compounds and the structural integrity and protection of the plant as it grows and matures.

Summary:

Monocotyledons (Monocots) feature seeds with a single cotyledon. Their **vascular bundles are scattered** throughout the stem, known as an *atactostele*, and lack a distinct cambium layer—thus, they generally **do not undergo secondary growth** like woody thickening. Leaves typically exhibit **parallel venation**, and roots form a **fibrous, adventitious root system** that lacks a permanent taproot. Floral parts are mostly in **threes or multiples of three**, In contrast, **Dicotyledons (Dicots)** possess seeds with two cotyledons. Their **vascular bundles in stems are arranged in a ring**, with an active **cambium** that promotes secondary growth enabling woody stem development. Leaves typically show **reticulate (net-like) venation**, and roots develop a **prominent taproot system** with lateral branches. Flowers usually have parts in **four or five multiples**, and their pollen is trisulcate (three furrows or pores) versus monosulcate in monocots

Multiple Choice Questions (MCQs):

1. **The Shoot Apical Meristem (SAM) is responsible for:**

a) Root elongation

b) Primary shoot growth

c) Water absorption

d) Photosynthesis

Ans.b) Primary shoot growth

2. **Which plant tissue is responsible for transporting water?**

a) Phloem

b) Xylem

c) Cambium

d) Epidermis

Ans. b) Xylem

3. **In dicots, vascular bundles are:**

a) Scattered throughout the stem

b) Arranged in a ring

c) Found only in the leaves

d) Absent in the shoot system

Ans. b) Arranged in a ring

4. What type of branching pattern is commonly seen in monocots?

a) Dichotomous branching

b) Monopodial branching

c) Sympodial branching

d) None of the above

Ans. d) None of the above

5. What is the function of cambium in plants?

a) Absorption of water

b) Production of secondary growth

c) Photosynthesis

d) Seed formation

Ans. b) Production of secondary growth

6. Growth rings in trees are formed due to:

a) Alternating growth of xylem and phloem

b) Seasonal variation in cambial activity

c) Deposition of pollen grains

d) Increase in leaf number

Ans.b) Seasonal variation in cambial activity

7. What is the main function of secondary xylem?

a) Transport of sugars

b) Transport of water and minerals

c) Seed production

d) Leaf growth

Ans. b) Transport of water and minerals

8. The term “heartwood” refers to:

a) Outer layers of the stem

b) Older, non-functional xylem

c) Actively conducting phloem

d) Growing tip of the root

Ans. b) Older, non-functional xylem

9. Which tissue forms the bark of a tree?

a) Xylem

b) Phloem and periderm

c) Parenchyma

d) Meristem

Ans. b) Phloem and periderm

10. In dicots, internode elongation is mainly controlled by:

a) Gibberellins

b) Cytokinins

c) Abscisic acid

d) Ethylene

Ans. a) Gibberellins

Short Questions:

1. What is the function of the Shoot Apical Meristem (SAM)?
2. How does vascularization differ in monocots and dicots?
3. Define internode and explain its role in plant growth.
4. What are the different branching patterns found in plants?
5. What is the significance of canopy architecture?
6. Describe the role of cambium in secondary growth.
7. What is the difference between sapwood and heartwood?

8. Explain how growth rings help in determining the age of a tree.
9. What is the function of secondary phloem in plants?
10. How does the periderm contribute to plant protection?

Long Questions:

1. Explain the structure and function of the Shoot Apical Meristem (SAM).
2. Describe the process of vascularization in monocots and dicots with diagrams.
3. Discuss the significance of internode elongation and branching patterns in plants.
4. Compare and contrast secondary growth in monocots and dicots.
5. Explain the role of cambium in wood formation and secondary xylem development.
6. How do growth rings form, and what information do they provide?
7. Discuss the differences between sapwood and heartwood in terms of function.
8. Describe the role of secondary phloem in nutrient transport.
9. Explain the process of periderm formation and its role in plant protection.
10. How does canopy architecture influence plant survival and competition?

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MODULE- 3

THE LEAF

3.0 Objective:

- Understand the origin, development, and diversity of leaf structure.
- Study environmental factors influencing leaf size and shape.
- Explore the processes of senescence and abscission.
- Learn about the root system and its structural modifications.

UNIT 3.1

Origin, development, arrangement and diversity in size and shape

3.1.1 Origin of Leaf

The leaf originates as a **lateral organ of the shoot system** and arises **exogenously** from the **peripheral zone of the shoot apical meristem (SAM)**. Unlike roots, which originate endogenously, leaves develop from the **outer cell layers (protoderm and ground meristem) of the stem apex**. The first indication of a leaf's origin is the appearance of a **leaf buttress or primordium**, which is seen as a minute bulge on the side of the apical dome. This initiation occurs in a highly ordered spatial pattern, governed by **phyllotaxy**—alternate, opposite, decussate, or whorled—so that the leaves are arranged to minimize shading and maximize photosynthetic efficiency. The site of primordium initiation coincides with a localized **auxin maximum** in the shoot apex, and regulatory genes such as **KNOX, ARP, and PIN-FORMED (PIN) proteins** play crucial roles in determining where new leaves will form. As soon as the primordium is initiated, a **leaf trace** (a strand of vascular tissue) differentiates from the stem's procambial strands and grows into the developing leaf, establishing an early **vascular connection** between the stem and leaf. The origin process is also influenced by environmental conditions—light intensity, day length (photoperiod), and temperature can all affect the rate of leaf initiation and phyllotactic patterns. In different plant groups, this origin is modified: for example, in grasses (monocots), the primordium quickly forms a sheath and blade, while in dicots like tomato or hibiscus, the primordium expands laterally and differentiates into lamina, petiole, and stipules.

Overall, the origin of a leaf is a highly coordinated developmental event beginning as a **small exogenous protrusion on the shoot apex**, regulated by genetic, hormonal, and environmental factors, and linked to the plant's vascular system. This careful origin sets the foundation for subsequent **leaf development, morphology, and specialization** that enable plants to perform photosynthesis, transpiration, and gas exchange effectively throughout their life.

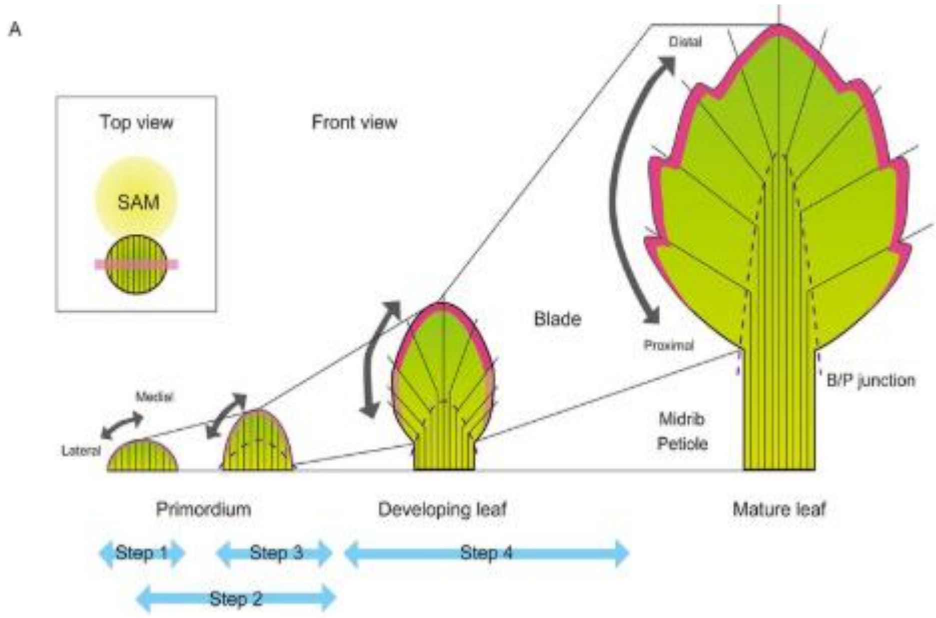

Fig. **3.1 Origin of Leaf**

3.1.2 Leaf development

Introduction

Leaves are lateral appendages of the shoot, specialized for **photosynthesis**, gas exchange, and sometimes storage or defense. They arise from the **shoot apical meristem (SAM)** in a highly controlled developmental process influenced by **genetics**, **hormones**, and **environment**.

3.1.3 Phases of Leaf Development

1 **Initiation at the Shoot Apex**

- In the peripheral zone of the SAM, certain groups of cells **switch fate** from stem-like behavior to leaf primordia formation.
- Leaf primordia appear as **small bulges** on the side of the SAM.
- Controlled by:
    - **Auxin maxima** (local concentration peaks trigger primordium initiation).

  - Transcription factors like **KNOX genes** (downregulated in leaf founder cells).

Outcome: Leaf primordium (a small dome-like outgrowth).

2 **Formation of Leaf Primordium**

- Cells in the bulge begin **rapid anticlinal and periclinal divisions**.
- Polarity is established:
  - **Adaxial (upper) side** – facing the SAM.
  - **Abaxial (lower) side** – away from the SAM.
- Boundary genes (e.g., **PHANTASTICA**, **KANADI**) specify these domains.

Outcome: Early leaf bud with dorsiventral identity.

3 **Growth and Pattern Formation**

- The primordium elongates and expands laterally.
- **Proximal–distal axis** (base to tip) forms by graded growth:
  - Base remains meristematic longer.
  - Tip matures earlier.
- **Leaf margins** develop lobes or serrations depending on species.

Outcome: Leaf blade (lamina) and petiole regions become distinguishable.

4 **Vascular Differentiation**

- Procambial strands differentiate within the primordium:
  - **Midvein** forms first.
  - Lateral veins branch in patterns (reticulate in dicots, parallel in monocots).
- Controlled by auxin transport channels (**PIN proteins**).

Outcome: A functional vascular network for photosynthate transport.

5 **Maturation and Specialization**

- Cells differentiate into **epidermis, mesophyll (palisade & spongy), and vascular tissues**.
- Stomatal patterning and trichome (hair) development occur.
- Hormonal interplay:
    - **Cytokinins** promote cell division.
    - **Gibberellins** promote expansion.

3.1.4 Leaf arrangement

The term **leaf arrangement** or **phyllotaxy** refers to the specific pattern in which leaves are borne on the stem or its branches. This arrangement is not random; it is genetically controlled and ensures that leaves are positioned to maximize exposure to sunlight for efficient photosynthesis while minimizing mutual shading. There are three primary types of leaf arrangement observed in most flowering plants. In the **alternate** type, a single leaf arises at each node, and successive leaves are arranged alternately on the stem in a spiral fashion; examples include sunflower, mustard, and china rose. In the **opposite** type, two leaves arise at the same node, placed directly opposite to each other; examples are guava, Calotropis, and Ocimum (tulsi). A variation of this is **opposite decussate**, where successive pairs of opposite leaves are at right angles to each other, as seen in Ocimum and Calotropis. The third major type is **whorled**, in which more than two leaves arise from the same node and form a whorl around the stem; examples include Alstonia and Nerium. Some plants show further modifications, such as rosette arrangement near the base or distichous (in two rows) on flattened stems. These patterns of leaf arrangement are crucial adaptations that help plants efficiently intercept light, carry out photosynthesis, and maintain balanced growth.

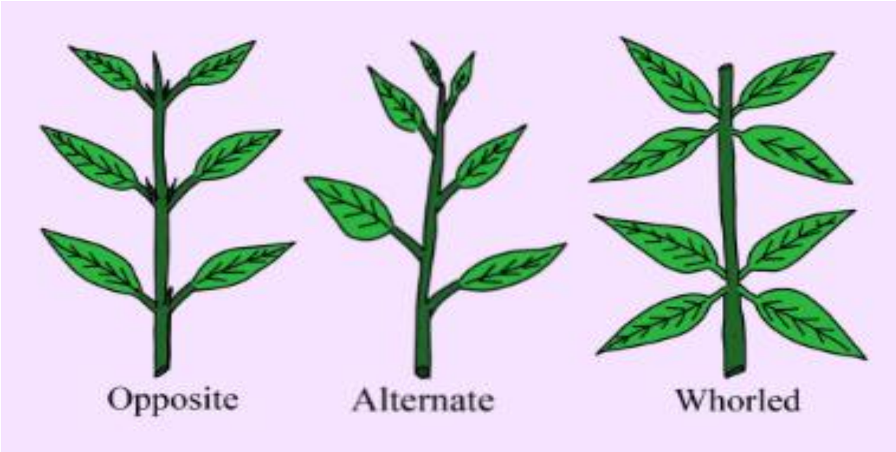

Fig.3.2 types of phyllotaxy

3.1.5 Diversity in size and shape

Leaves, though primarily designed for photosynthesis and gas exchange, exhibit remarkable diversity in size and shape across the plant kingdom. This diversity reflects adaptations to varied habitats, climates, and ecological functions. In terms of size, leaves can range from the extremely small, scale-like leaves of xerophytes such as *Casuarina* or *Asparagus* (reduced to minimize water loss), to the gigantic leaves of tropical plants like *Raphia regalis* (raffia palm) whose leaves can reach up to 20 meters in length, or *Victoria amazonica* (giant water lily) with leaves over 2 meters in diameter. Such variations allow plants to optimize light capture, reduce transpiration, or shed excess heat depending on their environment.

3.1.6 Shape of a leaf

The shape of a leaf refers to the outline and overall form of the leaf blade (lamina), and it varies greatly among plant species, reflecting adaptations to their environment and functions. A leaf may be **simple**, with a single undivided blade, or **compound**, where the blade is divided into leaflets. Among simple leaves, common shapes include **ovate** (egg-shaped with a broader base, as in guava), **lanceolate** (lance-like and tapering at both ends, as in bamboo), **cordate** (heart-shaped with a deep notch at the base, as in betel), **linear** (very long and narrow, as in grasses), **elliptical** (oval with a smooth outline, as in mango), and **orbicular** (rounded or circular, as in nasturtium). Some leaves have lobed shapes, such as **palmately**

lobed (like in cotton or geranium) or **pinnately lobed** (like in mustard). In compound leaves, the shape is defined by the arrangement of leaflets: **pinnate** leaves have leaflets arranged on either side of a central rachis (e.g., neem, rose), while **palmate** leaves have leaflets radiating from a single point (e.g., silk cotton tree). These diverse shapes are not merely aesthetic; they serve ecological roles, such as maximizing light interception, reducing water loss, or coping with wind and heat. For example, narrow linear leaves help grasses thrive in windy, dry habitats, while broad ovate or cordate leaves efficiently capture light in shaded forests. This wide variety of leaf shapes is therefore a direct outcome of evolutionary adaptation to different environments.

Fig.3.3 leaf shape

Summary:

The **origin of plant tissues** can be traced back to meristematic cells, which arise during embryogenesis. Meristems are of three types: **apical meristem** (responsible for primary growth), **intercalary meristem** (growth at nodes), and **lateral meristem** (secondary growth). From these meristems, permanent tissues develop through cell differentiation.

The **development of tissues** involves the transformation of undifferentiated meristematic cells into permanent tissues such as parenchyma, collenchyma, sclerenchyma, xylem, and phloem. This process includes cell enlargement, thickening of the cell wall, deposition of lignin, suberin, or cutin, and specialization for conduction, support, or storage.

Multiple Choice Question (MCQs):

1. The primary origin of tissues in plants is from:

a) Permanent tissue

b) Cambium

c) Meristematic cells

d) Epidermis

Answer: c) Meristematic cells

2. Collenchyma is characterized by:

a) Thick lignified walls

b) Cell wall thickening at corners

c) Large intercellular spaces

d) Dead cells only

Answer: b) Cell wall thickening at corners

3. In monocot stems, vascular bundles are usually:

a) Arranged in a ring

b) Scattered throughout ground tissue

c) Absent

d) Found only at periphery

Answer: b) Scattered throughout ground tissue

4. The conducting elements of xylem are:

a) Fibers and parenchyma

b) Vessels and tracheids

c) Companion cells

d) Sieve tubes

Answer: b) Vessels and tracheids

5. Palisade and spongy cells are examples of:

a) Xylem tissue

b) Collenchyma tissue

c) Mesophyll tissue

d) Phloem tissue

Answer: c) Mesophyll tissue

Short Questions

1. What are meristems? Name their types.
2. Differentiate between apical and lateral meristems.
3. Write one characteristic of parenchyma and collenchyma.
4. What is the main conducting element of xylem in gymnosperms?
5. Define permanent tissue with one example.
6. What is the arrangement of vascular bundles in dicot stems?
7. Name the two types of cells found in phloem.
8. What is the function of mesophyll cells in leaves?
9. Give one difference between vessels and tracheids.
10. Why do plant cells show diversity in size and shape?

Long Questions

1. Describe the **origin and development of different plant tissues**.
2. Explain the **arrangement of tissues in monocot and dicot stems** with diagrams.
3. Discuss the **diversity in size and shape of plant cells** with examples.
4. Compare the structure and functions of **xylem and phloem tissues**.
5. Explain how different types of **permanent tissues** arise from meristematic cells.
6. Describe the **tissue arrangement in leaves** and relate it to their function.

UNIT 3.2

Senescence and Abscission

3.2.1 Senescence: Senescence is the **final stage in the development of a plant organ or the whole plant**, characterized by the gradual deterioration of cells, tissues, and metabolic activities. It is a **highly regulated, programmed process**, not simply the result of aging or damage. During senescence, there is a breakdown of cellular components such as chlorophyll, proteins, and nucleic acids, and nutrients are mobilized from aging tissues to developing parts like young leaves, fruits, or seeds. For example, in deciduous plants, leaves undergo senescence in autumn: they lose chlorophyll, turn yellow or red due to the visibility of carotenoids and anthocyanins, and prepare for shedding. Senescence can occur at different levels—**whole-plant senescence** (e.g., in annuals after seed set), **organ senescence** (e.g., in leaves, petals, or fruits), or **cellular senescence** (e.g., in xylem elements that die after maturity). Though it involves the death of tissues, senescence is adaptive because it allows plants to **recycle valuable nutrients** and survive adverse conditions.

Definition: Senescence refers to the process of aging or the natural, programmed deterioration of plant cells, tissues, or organs. It is a critical stage in the life cycle of a plant, leading to the decline in function and eventual death of plant parts like leaves, flowers, fruits, or entire plants.

3.2.1.1 Features of Senescence:

- **Cellular Breakdown**: During senescence, cellular components such as proteins, lipids, and nucleic acids degrade. This leads to the loss of cell function and tissue structure.
- **Metabolic Changes**: There is a shift from anabolic (building) to catabolic (breaking down) processes. Nutrients like nitrogen, phosphorus, and sugars are mobilized and reallocated to other parts of the plant (e.g., roots or seeds).
- **Visible Symptoms**:

- **Leaf Yellowing** (Chlorosis): Chlorophyll breaks down, causing the leaf to lose its green color.
- **Wilting**: Loss of turgidity due to water and nutrient loss.
- **Abnormal Growth**: Reduced growth or stunted development.
- **Anthocyanin Production**: Some plants may produce red or purple pigments (anthocyanins) in response to stress during senescence.

3.2.1.2 Phases of Senescence:

1. **Initiation**:
   - Senescence is typically initiated by environmental signals such as aging, lack of water, low light, or reduced temperature.
   - Hormonal changes, particularly a decrease in **cytokinins** (growth-promoting hormones), and an increase in **ethylene** and **abscisic acid (ABA)**, trigger the senescence process.
2. **Progression**:
   - The breakdown of chlorophyll and other cellular structures begins, and nutrients are transported from the aging tissue to other parts of the plant.
   - **Reactive oxygen species (ROS)**, like hydrogen peroxide, increase in concentration, leading to oxidative stress and damage to cellular components.
3. **Final Stages**:
   - The tissue is ultimately degraded. In the case of leaves, this results in their shedding or the formation of **abscission zones** (explained below). The plant may reabsorb valuable nutrients before the final loss of function.

3.2.1.3 Senescence and Its Types:

Senescence is the **natural aging process** in plants, during which cells, tissues, organs, or even the entire plant undergo a gradual loss of function, leading ultimately to death. It is a genetically controlled and environmentally influenced process, often associated with the breakdown of cellular components, decline in photosynthesis, and remobilization of nutrients to younger parts or developing seeds. Senescence plays an important ecological role by recycling nutrients and regulating the plant's life cycle. Based on how and where it occurs, senescence in plants is classified into four main types:

3.2.1.3.1 Whole Plant Senescence:

This type is seen in **annual plants** like rice, wheat, and mustard, where the **entire plant ages and dies after flowering and fruiting**. Nutrients are translocated from vegetative parts to seeds, and after seed maturation, the plant completes its life cycle and dies.

3.2.1.3.2 Organ Senescence:

In many perennial plants, **individual organs** such as leaves, flowers, or fruits undergo senescence while the rest of the plant remains alive. For example, in deciduous trees like teak or poplar, **leaves senesce and fall (leaf fall)** seasonally, while the plant body survives.

3.2.1.3.3 Sequential Senescence:

This occurs in plants that maintain a continuous growth habit, such as many **perennial herbs and shrubs**, where **older leaves or organs senesce first** while younger ones remain active. As the plant produces new leaves at the tip, older basal leaves gradually age and die, ensuring continuous productivity.

3.2.1.3.4 Simultaneous Senescence (Synchronous):

In some plants, particularly certain monocarpic perennials (e.g., bamboo, agave), **all leaves or shoots senesce at once after flowering**, leading to death of the entire plant body in a short period. This mass senescence is often synchronized with reproduction.

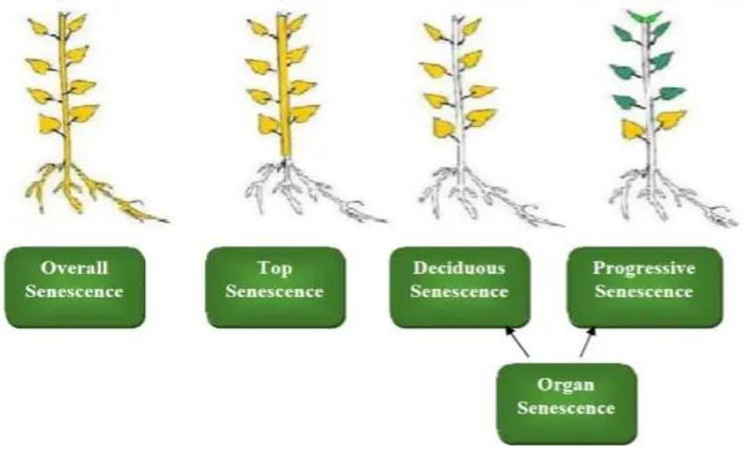

Fig. 3.4 Plant Senescence

3.2.1.4 Regulation of Senescence:

- **Hormones Involved**:
  - **Ethylene**: Promotes senescence in many plant tissues, including fruit ripening and flower fading.
  - **Abscisic Acid (ABA)**: Increases in concentration during environmental stress, contributing to the aging process.
  - **Cytokinins**: Delays senescence by promoting cell division and maintenance of metabolic activity.
  - **Gibberellins**: Generally counteract senescence and promote growth.

3.2.1.5 Functions and Ecological Significance of Senescence:

- **Nutrient Recycling**: During leaf senescence, nutrients such as nitrogen, phosphorus, and potassium are recycled and transported to other parts of the plant, especially to the roots or developing seeds.
- **Life Cycle Completion**: Senescence plays a key role in the plant's life cycle, allowing the plant to allocate resources to reproduction and seed development rather than sustaining old tissues.
- **Plant Survival**: Senescence helps the plant conserve resources during periods of stress or environmental changes.

3.2.2 Abscission: Abscission is the **process by which plants shed their parts**, such as leaves, flowers, or fruits, after they have completed their function or under stress conditions. This process takes place in a specialized region called the **abscission zone**, usually located at the base of the leaf stalk, fruit stalk, or flower stalk. In the abscission zone, cell walls in a layer of cells are enzymatically weakened by enzymes like **cellulase and pectinase**, which dissolve the middle lamella, allowing the organ to separate from the plant body. After separation, a protective layer is often formed on the exposed surface to prevent water loss and pathogen entry. Abscission is commonly observed in **leaf fall in deciduous trees**, **shedding of petals after pollination**, and **fruit drop** when they mature or under unfavorable conditions.

Definition: Abscission is the process by which plants shed or drop certain parts, typically leaves, flowers, or fruits. This is an active process that involves the formation of an abscission zone where cells undergo programmed cell death (PCD), leading to the separation of the organ from the plant.

3.2.2.1 Features of Abscission:

- **Separation Layer**: In the abscission zone, cells undergo weakening due to the degradation of cell wall components like **pectin** and **hemicellulose**. This results in a layer of cells that eventually break apart, causing the organ to detach.
- **Formation of Abscission Layer**: This layer forms at the base of petioles (leaf stalks), pedicels (flower stalks), or fruit stems, where the organ will eventually separate from the plant.
- **Role of Hormones**:
    - **Ethylene**: Ethylene plays a crucial role in initiating and promoting abscission. It triggers the formation of the abscission layer and increases the activity of enzymes that break down cell wall components.

- **Auxins**: Inhibit abscission under normal conditions. A decrease in auxin levels in the organ leads to the activation of ethylene and the abscission process.
- **Abscisic Acid (ABA)**: Can also contribute to the regulation of abscission, especially in response to environmental stresses.
- **Cytokinins**: Can delay abscission by maintaining cell activity and preventing the formation of the abscission zone.

3.2.2.2 Stages of Abscission:

3.2.2.2.1 Initiation:

- A decrease in **auxin** and an increase in **ethylene** signal the beginning of the abscission process.
- Environmental factors such as water stress, aging, or seasonal changes can trigger the process.

3.2.2.2.2 Development of the Abscission Layer:

- Cells in the abscission zone undergo changes in structure and function. The breakdown of cell wall components such as **pectinase** and **cellulase** occurs.
- The area of weak cells at the base of the petiole or stem becomes the abscission zone.

3.2.2.2.3 Separation:

- The separation layer forms, and the tissue becomes weak and brittle. This causes the organ to fall off or be shed from the plant.
- **Protective Layer**: Often, after abscission, a protective layer (such as a **suberized** or **lignified** barrier) forms at the wound site, preventing water loss and pathogen entry.

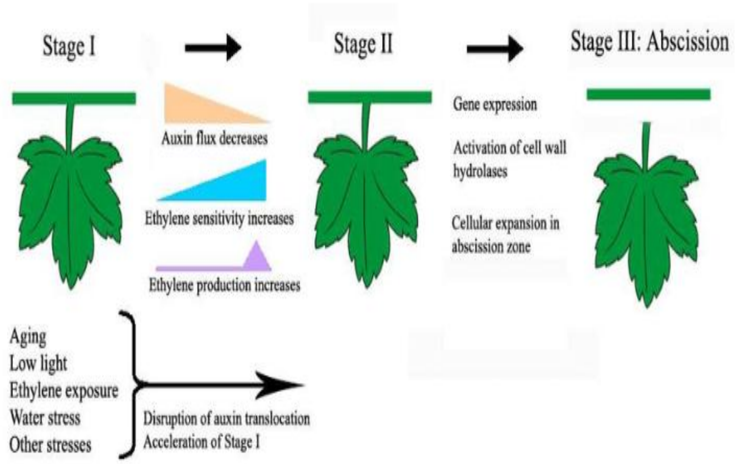

Fig. 3.5 **Stages of Abscission**

3.2.2.3 Types of Abscission:

3.2.2.3.1 Leaf Abscission:

- Common in deciduous plants, where leaves are shed at the end of the growing season (autumn). This reduces water loss and prevents frost damage.
- **Autumn leaf drop**: The characteristic color change and drop of leaves in many deciduous trees are due to the combined effects of senescence and abscission.

3.2.2.3.2 Fruit Abscission:

- Fruits drop from plants when they are mature, which can be regulated by ethylene or environmental cues.
- Fruit drop can occur prematurely due to stress or in the absence of proper pollination.

3.2.2.3.3 Flower Abscission:

Flowers that are not pollinated or are past their reproductive life may undergo abscission. This is common in many plant species as the plant conserves resources for seed development.

3.2.2.4 Ecological and Evolutionary Significance of Abscission:

- **Resource Conservation**: Shedding leaves or fruits during adverse conditions (such as drought or cold) helps plants conserve water and nutrients.
- **Protection Against Herbivory**: Dropping leaves or fruits may be a defense mechanism to deter herbivores from consuming plant parts.
- **Seed Dispersal**: In the case of fruits, abscission aids in the dispersal of seeds, facilitating the reproduction of the plant in new areas.

3.2.2.5 Environmental Factors Influencing Abscission:

- **Temperature**: Seasonal temperature changes can signal the time for abscission in temperate plants.
- **Water Stress**: Prolonged drought or insufficient water can trigger premature abscission in some species to conserve water and protect the plant.
- **Light**: Reduced light intensity in autumn can also initiate leaf sen

Summary:

Senescence is the **ageing process in plants** that leads to the gradual deterioration of cells, tissues, organs, or the whole plant. It is a **genetically programmed process** influenced by hormones and environmental conditions. Types include:

1. **Whole plant senescence** – seen in annuals after flowering and seed formation.
2. **Organ senescence** – aging of leaves, flowers, or fruits.
3. **Cellular senescence** – individual cells cease to divide and function.

Abscission is the **shedding of leaves, flowers, or fruits** from the plant. It occurs in a specialized region called the **abscission zone**, located at the base of the organ. The process involves two phases: (i) **formation of an abscission layer**, where cell walls weaken due to enzymatic action (cellulase, pectinase), and (ii) **separation**, where the organ detaches. After detachment, a protective layer forms to prevent infection and water loss.

Multiple Choice Question (MCQs)

1. Senescence in plants refers to:

a) Dormancy

b) Ageing and deterioration of tissues

c) Growth of organs

d) Formation of new leaves

Answer: b) Ageing and deterioration of tissues

2. Which hormone promotes senescence and abscission?

a) Auxin

b) Cytokinin

c) Ethylene

d) Gibberellin

Answer: c) Ethylene

3. The protective layer in abscission zone develops due to:

a) Deposition of lignin and suberin

b) Removal of chlorophyll

c) Enzymatic degradation of proteins

d) Deposition of starch

Answer: a) Deposition of lignin and suberin

4. Yellowing of leaves before falling is due to:

a) Breakdown of proteins

b) Accumulation of carotenoids after chlorophyll loss

c) ABA accumulation

d) High cytokinin levels

Answer: b) Accumulation of carotenoids after chlorophyll loss

5. Abscission occurs in a specialized region known as:

a) Mesophyll

b) Cambium

c) Abscission zone

d) Stomatal zone

Answer: c) Abscission zone

Short Questions

1. Define senescence and give its types.
2. Name two plant hormones that promote senescence.
3. What is the abscission zone?
4. Why do leaves turn yellow before falling?
5. Differentiate between whole plant and organ senescence.
6. Mention one adaptive significance of senescence.
7. Which enzymes are involved in abscission?
8. How does cytokinin influence senescence?
9. What is the role of ABA in leaf fall?
10. Write one difference between senescence and abscission.

Long Questions

1. Explain the **types of senescence** and their physiological changes.
2. Discuss the **role of plant hormones in senescence and abscission**.
3. Describe the **process of abscission** and explain its adaptive significance.
4. With examples, explain how senescence helps in **nutrient mobilization**.
5. Describe the **morphological and biochemical changes** that occur during senescence.

UNIT 3.3

The Root System

3.3.1 The Root System:

The root system of a plant is the underground part of the axis that anchors the plant firmly in the soil, absorbs water and minerals, stores food, and in some cases performs additional functions like vegetative propagation or aeration. Roots are typically non-green, lacking nodes, internodes, and leaves, and grow positively geotropic (downward) and hydrotropic (toward moisture). At the tip of each root is a **root cap** that protects the delicate apical meristem as it pushes through the soil, while behind it lies the **region of elongation** where cells lengthen, and further back is the **region of maturation** where root hairs develop to maximize absorption.

In flowering plants, two main types of root systems are recognized. In **dicotyledons**, the primary root emerging from the radicle of the seed persists and grows into a thick **taproot system** with lateral branches, as seen in mustard, neem, and carrot. This system penetrates deeply into the soil and often acts as a storage organ. In **monocotyledons**, the primary root is short-lived, and a cluster of **adventitious roots** arises from the base of the stem to form a **fibrous root system**, as seen in grasses, wheat, and rice. Fibrous roots spread horizontally, providing excellent anchorage and preventing soil erosion.

Roots also undergo modifications for specialized functions: **tuberous roots** in sweet potato store food; **stilt roots** in maize and sugarcane provide extra support; **pneumatophores** in mangroves like Avicennia help in gaseous exchange in waterlogged soils; and **prop roots** in banyan trees act like pillars. Overall, the root system is a vital organ complex that not only anchors and nourishes the plant but also exhibits structural and functional diversity to suit various ecological niches.

3.3.2 Types of Root Systems:

In flowering plants, the root system develops from the radicle of the embryo and is primarily responsible for anchorage and absorption. Based on the mode of origin and branching pattern, two main types of root systems are recognized: **tap root system** and **fibrous root system**.

In the **tap root system**, the radicle of the seed develops into a strong primary root, called the **tap root**, which grows vertically downward. From this main root, **lateral roots** (secondary and tertiary roots) arise in acropetal succession, forming a deep and well-branched system. Tap roots are typical of **dicotyledonous plants** such as mustard, carrot, mango, and neem. In many plants, tap roots undergo modifications for storage (e.g., carrot, radish, beet) or respiration (as in some aquatic plants). This type of root system penetrates deep into the soil, enabling the plant to access water from deeper layers and withstand drought conditions.

In the **fibrous root system**, the radicle of the seed is short-lived and soon replaced by numerous roots that arise in clusters from the base of the stem. These roots are slender, thread-like, and almost equal in size, forming a dense network close to the soil surface. Fibrous roots are typical of **monocotyledonous plants** such as wheat, rice, maize, and grasses. This system is very efficient in binding soil particles, preventing erosion, and rapidly absorbing nutrients and water from the upper layers of the soil.

Some plants also exhibit **adventitious root systems**, where roots develop from parts of the plant other than the radicle, such as stems or leaves. Examples include prop roots in banyan (for support), stilt roots in maize and sugarcane, and tuberous adventitious roots in sweet potato (for storage).

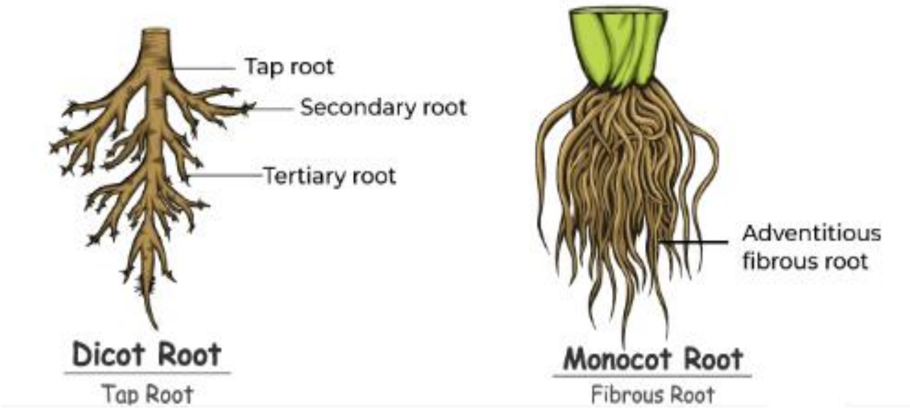

Fig.3.6 Root system

3.3.2.1 The Root Apical Meristem (RAM)

The root apical meristem is a region of actively dividing cells located at the tip of a root, responsible for the continuous growth and elongation of the root system. It lies just behind the **root cap**, a protective structure that shields the meristematic cells from mechanical injury as the root pushes through the soil. The RAM originates from the embryo (radicle) and remains meristematic throughout the life of the plant, constantly producing new cells that contribute to root tissues. Within the RAM, cells are small, thin-walled, rich in cytoplasm, and have prominent nuclei, enabling rapid cell division.

In many plants, the RAM is organized around a **quiescent center**—a group of cells with very low mitotic activity that serves as a reservoir of stem cells. Surrounding the quiescent center are **initial cells** or **derivatives** that divide repeatedly to give rise to different tissue systems. The derivatives on the outer side form the protoderm, which differentiates into the epidermis and root hairs; those toward the center form the procambium, which gives rise to primary xylem and phloem; and the ground meristem forms the cortex and endodermis. The RAM thus establishes the primary tissues of the root in a highly organized manner.

Functionally, the root apical meristem is essential for **root elongation**, allowing the plant to explore deeper soil layers for water and minerals. It also maintains a balance between cell division and differentiation, ensuring that as cells are displaced away from the apex, they mature into specialized tissues. The RAM's activity is regulated by plant hormones such as **auxins and cytokinins**, and its maintenance depends on precise genetic controls, including genes that regulate the quiescent center and stem cell identity.

The **Root Apical Meristem (RAM)** is the region at the tip of the root where cell division occurs, allowing the root to grow in length. This meristematic region plays a central role in the formation of the root and contributes to its growth and development.

Location of RAM:

- The RAM is located at the very tip of the root, just behind the **root cap**, which protects the delicate growing tip from physical damage as it pushes through the soil.

3.3.2.2 Structure of the Root Apical Meristem:

- The RAM consists of undifferentiated, actively dividing cells. It is the primary source of new cells for the elongation of the root. The cells in this region are small, cuboidal, and have large nuclei.
- The RAM is organized into specific regions:
    1. **Quiescent Center**: Located at the center of the RAM, this area has slower cell division rates and is thought to play a regulatory role in meristem activity.
    2. **Meristematic Zone**: Surrounds the quiescent center, where cells are actively dividing.
    3. **Elongation Zone**: Just behind the meristematic zone, where newly formed cells begin to elongate.
    4. **Differentiation Zone**: Cells in this zone begin to specialize and differentiate into mature tissues such as the epidermis, cortex, and vascular tissues.

3.3.2.3 Theory of RAM:

3.3.2.3.1 Apical Cell Theory for RAM:

The **Apical Cell Theory** is one of the earliest concepts proposed to explain the organization of the root apical meristem. According to this theory, the entire root apex originates from a **single apical cell** situated at the very tip of the root. This solitary cell is usually pyramidal or tetrahedral in shape, with its faces oriented in such a way that each face cuts off a new segment of cells. These segments, through subsequent divisions and differentiation, give rise to all the primary tissues of the root—epidermis, cortex, and stele. In simple terms, this theory suggests that one initial cell controls and generates the entire root tip structure.

This concept was well supported in many lower vascular plants such as **ferns, lycophytes, and some pteridophytes**, where a prominent single apical cell can indeed be observed under the microscope. However, in the majority of seed plants (both gymnosperms and angiosperms), the root apical meristem is not organized around a single cell but rather consists of a group of initial cells or a **quiescent center** surrounded by active initials. Therefore, while the Apical Cell Theory holds true for certain primitive plant groups, it is not applicable to most higher plants.

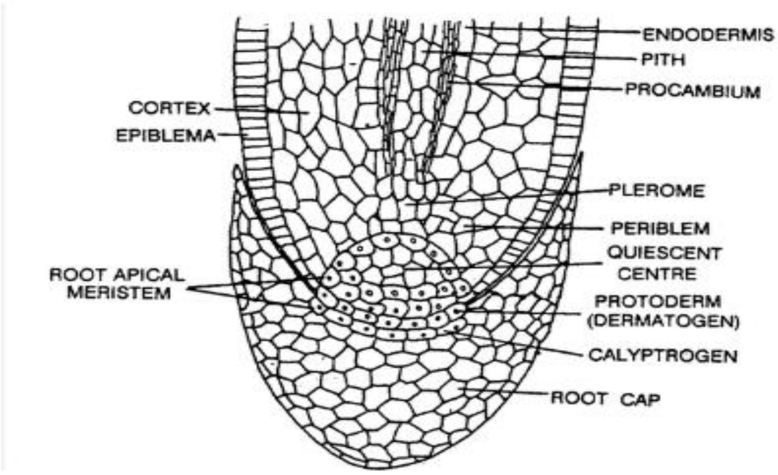

Fig. 3.7 Apical Cell Theory

3.3.2.3.2 Histogen Theory:

The **Histogen Theory** was proposed by **Hanstein in 1868** to explain the organization and tissue differentiation at the apical meristems of plants. According to this theory, the growing tip (apex) of a root or shoot is made up of three distinct layers of meristematic cells, called **histogens**, and each histogen is responsible for giving rise to a specific tissue system.

Dermatogen: This is the outermost layer of the apical meristem. The cells of the dermatogen divide and differentiate to form the **epidermis** (the protective outer layer of root or shoot). In roots, it also gives rise to root hairs.

> **Periblem:** Situated beneath the dermatogen, this histogen forms the **cortex**, which is the region between the epidermis and the vascular cylinder. The cortex often stores food and provides mechanical support.
>
> **Plerome:** This is the central core of meristematic cells located beneath the periblem. The plerome differentiates to form the **stele**, which includes the vascular tissues (xylem and phloem) and pith, responsible for conduction and storage.

According to Hanstein, these three histogenic layers are **permanent and independent in their functions**, meaning each maintains its own identity while continuously giving rise to its respective tissue system.

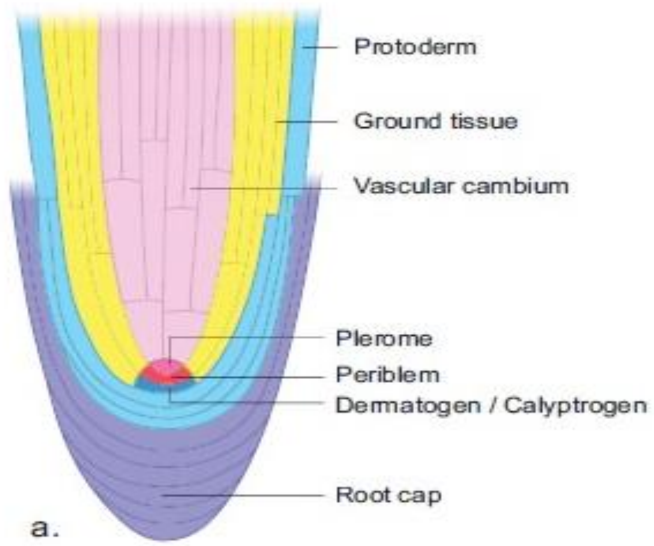

Fig. 3.8 Histogen Theory

Significance and Limitations:

The Histogen Theory was significant because it provided the first systematic explanation of how complex tissues originate from a meristematic apex. However, later studies showed that in many plants the boundaries between these regions are not always clear-cut, and cells from one layer may contribute to more than one tissue type. Despite this limitation, the Histogen Theory remains a **classical and foundational concept** in plant anatomy, especially useful in understanding tissue differentiation in roots and shoots of many higher plants.

3.3.2.3.3 Kapper–Kappey Theory (also called Korper–Kappe Theory):

The **Korper–Kappe theory** was proposed by **Schüepp (1917)** to explain the structural organization of the **root apical meristem (RAM)**, particularly in seed plants. According to this theory, the root apex is differentiated into two distinct regions based on the orientation of cell divisions: **Korper** (meaning “body” in German) and **Kappe** (meaning “cap”).

The **Korper region** lies internal to the root apex and forms the main body of the root. In this region, cell divisions occur in such a way that new cells are added both inward and outward, giving rise to the **cortex, vascular cylinder (stele), and other internal tissues** of the root. The Korper represents the central portion where the longitudinal and transverse divisions maintain the root's internal structure.

The **Kappe region** lies on the outer side of the apex and is responsible for producing the **root cap**, a protective layer that covers the delicate meristematic cells as the root pushes through soil. In this region, cell divisions are mainly periclinal (parallel to the surface), and the cap cells are regularly sloughed off and replaced by new ones from the meristem beneath.

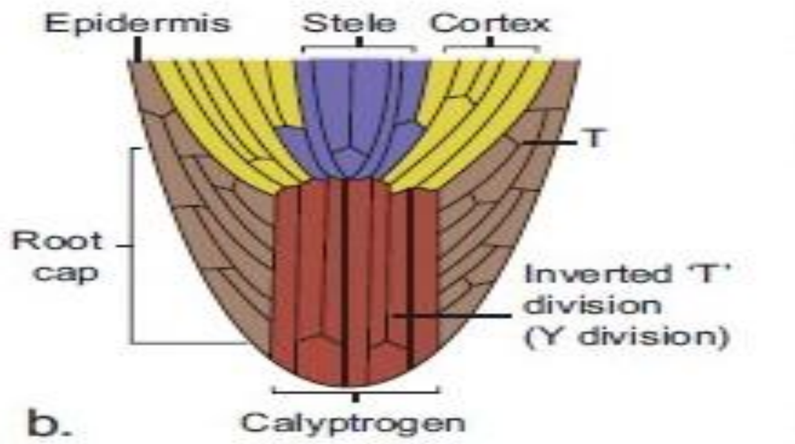

Fig.3.9 **Korper–Kappe theory**

Significance of the Theory:
The Korper–Kappe theory highlights that the root tip is not organized purely by histogenic layers, but rather by **functional zones** based on cell division patterns and developmental roles. It explains how one region (Kappe) is specialized for protection and the other (Korper) for forming the root's structural tissues. This view was an important refinement over the older **Histogen Theory**, giving a more dynamic interpretation of root apex organization in higher plants.

Function of the Root Apical Meristem:

- **Cell Division and Growth**: The RAM produces new cells through mitotic division, allowing the root to elongate and penetrate deeper into the soil. The cells produced in this region will eventually mature and differentiate to form the various tissues of the root.
- **Root Tip Protection**: The RAM is protected by the **root cap**, a structure that secretes mucilage to reduce friction and protect the meristem as the root grows through the soil.

Summary:

Roots anchor plants, absorb water and nutrients, and sometimes store food. In **monocots**, the root system is **fibrous and adventitious**, forming a dense network of thin roots near the soil surface—ideal for rapid nutrient uptake. Anatomically, monocot roots have numerous xylem and phloem bundles arranged in a ring around a prominent central **pith**, and lack a vascular cambium, which means **secondary thickening growth is absent**

Multiple Choice Questions (MCQs):

1. **The process by which leaves detach from plants is called:**

a) Senescence

b) Photosynthesis

c) Abscission

d) Transpiration

Ans. c) Abscission

2. **Leaf size and shape are influenced by:**

a) Only genetic factors

b) Only environmental factors

c) Both genetic and environmental factors

d) Water only

Ans. c) Both genetic and environmental factors

3. Which of the following is NOT a function of leaves?

a) Photosynthesis

b) Water conduction

c) Gaseous exchange

d) Seed production

Ans. d) Seed production

4. Which type of root system is found in monocots?

a) Taproot system

b) Fibrous root system

c) Adventitious root system

d) Both b and c

Ans. d) Both b and c

5. Senescence in leaves is mainly controlled by:

a) Auxins

b) Cytokinins

c) Abscisic acid

d) Ethylene

Ans. d) Ethylene

6. The region of active cell division in roots is called:

a) Root cap

b) Root hairs

c) Root meristem

d) Root cortex

Ans. c) Root meristem

7. Root nodules are associated with:

a) Water absorption

b) Nitrogen fixation

c) Mineral storage

d) None of the above

Ans. b) Nitrogen fixation

8. The protective layer formed before leaf abscission is called:

a) Cambium

b) Lenticel

c) Abscission zone

d) Stomata

Ans. c) Abscission zone

9. The primary function of root hairs is:

a) Photosynthesis

b) Protection

c) Absorption of water and minerals

d) Gas exchange

Ans. c) Absorption of water and minerals

10. Which structural modification helps roots store food?

a) Prop roots

b) Pneumatophores

c) Tuberous roots

d) Climbing roots

Ans. c) Tuberous roots

Short Questions:

1. What is the origin and development of a leaf?
2. How do environmental factors affect leaf morphology?
3. Define senescence and its types.

4. What are the physiological changes occurring during leaf abscission?
5. Compare the structure of monocot and dicot leaves.
6. What is the role of root hairs in plant survival?
7. How does root structure influence its function?
8. What is the difference between taproot and fibrous root systems?
9. Describe the role of root nodules in nitrogen fixation.
10. How do structural modifications help roots adapt to different environments?

Long Questions:

1. Explain the diversity in leaf size and shape with examples.
2. Discuss the molecular and physiological mechanisms of senescence and abscission.
3. Compare and contrast the root systems in monocots and dicots.
4. How do roots modify their structures for storage, respiration, and reproduction?
5. Describe the interaction between roots and microbes in nutrient absorption.
6. Explain how environmental factors influence leaf morphology and function.
7. What are the differences between primary and secondary root tissues?
8. How does the root system contribute to overall plant growth and survival?
9. Discuss the ecological significance of leaf abscission.
10. What are the structural and functional adaptations of roots in extreme environments?

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MODULE- 4

THE FLOWER

4.0 Objective:

- Understand the structure and development of flowers.
- Learn about the different types of pollination and their adaptations.
- Study pollen-pistil interaction and fertilization mechanisms.
- Explore fruit development and maturation.

UNIT 4.1

Flower: a modified shoot; structure, development and varieties of flower

A **flower** is the reproductive organ of angiosperms, and morphologically it is considered a **modified shoot** specialized for sexual reproduction. Normally, a shoot bears leaves on its nodes and grows indefinitely, but in a flower, the shoot apex becomes **determinate**, and its leaves are transformed into floral organs. The internodes are very short, and the leaves become highly specialized as **sepals, petals, stamens, and carpels**. This modification ensures that the plant can produce gametes, facilitate pollination, and form fruits and seeds for the next generation.

4.1.1 Structure of a Flower

A typical flower arises on a stalk called the **pedicel** and is attached to a flattened tip called the **thalamus** or receptacle. Floral parts are arranged in **whorls** on the thalamus:

- The **calyx** is the outermost whorl of green, leaf-like **sepals** that protect the flower in bud stage.
- The **corolla** is the whorl of brightly colored **petals** that attract pollinators.
- The **androecium** is the male reproductive whorl, consisting of **stamens**, each with a filament and an anther containing pollen sacs.
- The **gynoecium** (or pistil/carpel) is the female reproductive whorl, usually in the center, consisting of **ovary** (containing ovules), **style**, and **stigma**. The arrangement and fusion of these parts form the basis for identifying different flower types.

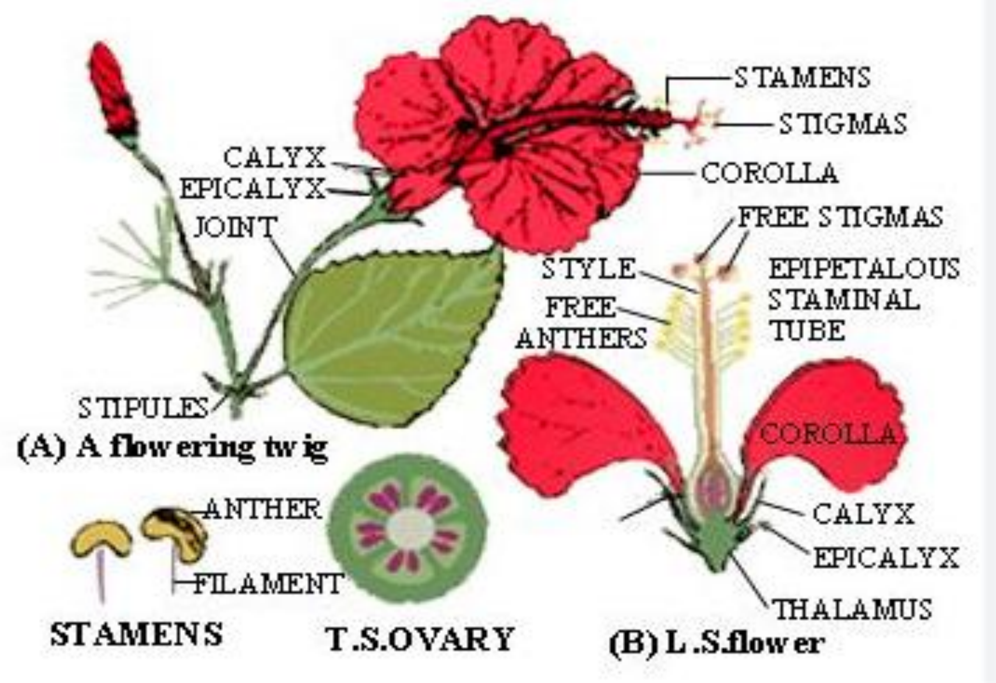

Fig.4.1 **Structure of a Flower**

4.1.2 Development of a Flower

A flower develops when a normal vegetative shoot apex changes into a floral apex under the influence of internal signals and environmental cues. In a vegetative shoot, the apical meristem produces leaves and branches indefinitely, but when it transitions to a floral meristem, it becomes determinate and starts producing floral organs in a fixed sequence. This transition is controlled by plant hormones such as auxins and gibberellins, along with factors like day length (photoperiod) and temperature. On the apex, small bulges called primordia arise and differentiate into floral parts in a specific order. The outermost primordia become sepals (forming the calyx), the next become petals (forming the corolla), followed by stamens (androecium, the male organs), and finally carpels (gynoecium, the female organ). This sequence of organ formation is regulated by floral identity genes, as described in the ABC model of flower development. As the flower matures, these parts grow and take on specialized functions such as protection, attraction of pollinators, or production of gametes, resulting in a complete structure capable of reproduction.

The development of a flower begins when a **vegetative shoot apical meristem** transitions into a **floral meristem** under the influence of genetic factors (floral identity genes) and environmental cues (day length, temperature). The apical meristem becomes determinate, and lateral primordia differentiate into sepals, petals, stamens, and carpels in a specific sequence. The ABC model of flower development explains how combinations of floral homeotic genes specify the identity of each whorl:

- A-class genes specify sepals,
- A + B specify petals,
- B + C specify stamens,
- C alone specifies carpels. This precise genetic control ensures the proper formation of a complete flower capable of reproduction.

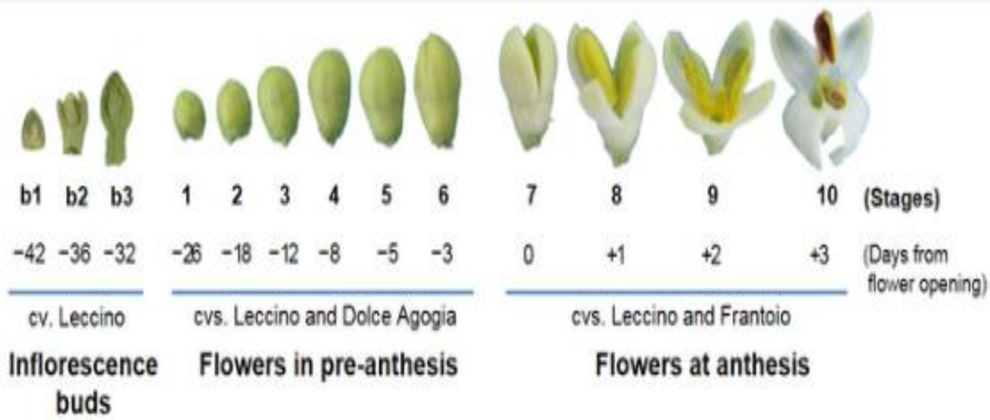

Fig.4.2 **Development of a Flower**

4.1.3 Varieties of Flowers

Flowers occur in many varieties, reflecting adaptations to different pollination mechanisms and environments. Based on reproductive organs, flowers may be **bisexual**, containing both stamens and carpels in the same flower (e.g., hibiscus, mustard), or **unisexual**, having either stamens (male) or carpels (female) alone (e.g., papaya, cucumber). According to symmetry, flowers may be **actinomorphic** with radial symmetry, where any plane through the center divides them into equal halves (e.g., china rose, mustard), or **zygomorphic**, showing bilateral symmetry with only one plane of division (e.g., pea, orchid). A few are **asymmetrical**, such as in canna, where no plane produces equal halves. Based on the position of floral parts relative to the ovary, flowers can be **hypogynous** with a superior ovary (e.g., mustard), **perigynous** with a half-inferior ovary (e.g., rose), or **epigynous** with an inferior ovary (e.g., sunflower). Flowers can also be classified as **complete**, if all four whorls (calyx, corolla, androecium, and gynoecium) are present, or **incomplete** if any whorl is absent. In addition, some special forms exist, such as **homochlamydeous flowers** where petals and sepals are not distinct (e.g., lily), and **composite flowers** where many small florets form a single flower head (e.g., sunflower, marigold).

Fig. **4.3 perigynous** with a half-inferior ovary (e.g., rose),

Flowers show great diversity in form, function, and arrangement. Based on reproductive organs, they are:

- **Bisexual (hermaphrodite)** flowers with both stamens and carpels (e.g., hibiscus, mustard).

Fig. 4.4 hibiscus,

- **Unisexual** flowers having either stamens (male) or carpels (female) (e.g., papaya, cucumber).

Based on symmetry:

- **Actinomorphic** (radial symmetry, e.g., china rose),
- **Zygomorphic** (bilateral symmetry, e.g., pea, orchid),
- **Asymmetric** (no symmetry, rare).

Based on position of floral parts relative to the ovary:

- **Hypogynous** (superior ovary, e.g., mustard),
- **Perigynous** (half-inferior ovary, e.g., rose),
- **Epigynous** (inferior ovary, e.g., sunflower).

Flowers may be **complete** (all four whorls present) or **incomplete** (one or more whorls missing), and may be **regular or irregular** in shape. There are also variations like composite flowers (sunflower), tubular flowers (allamanda), and specialized forms adapted for specific pollinators.

Fig.4.5 **Varieties of Flowers**

Summary:

A **flower** is a **modified reproductive shoot** of angiosperms, specialized for sexual reproduction. It arises from a **floral primordium** in the axil of a bract or at the tip of a shoot. The floral axis (thalamus/receptacle) bears **floral appendages** arranged in whorls.

Evidence for floral origin as a shoot includes:

- Flowers develop from apical meristems like vegetative shoots.
- Floral parts (sepals, petals, stamens, carpels) are homologous to leaves (leaf-like nature).
- Axillary position and transition of vegetative to floral buds.

Multiple Choice Question (MCQs):

1. A flower is morphologically considered as a:

a) Root

b) Stem

c) Modified shoot

d) Modified leaf

Answer: c) Modified shoot

2. Which floral whorl represents the male reproductive organ?

a) Calyx

b) Corolla

c) Androecium

d) Gynoecium

Answer: c) Androecium

3. Flowers with both stamens and carpels are called:

a) Dioecious

b) Unisexual

c) Bisexual

d) Incomplete

Answer: c) Bisexual

4. If a flower has a superior ovary, it is called:

a) Hypogynous

b) Epigynous

c) Perigynous

d) Acyclic

Answer: a) Hypogynous

5. The genetic basis of floral organ development is explained by:

a) Darwin's theory

b) ABC model

c) Mendel's law

d) Endosymbiotic theory

Answer: b) ABC model

Short Questions

1. Why is a flower considered a modified shoot?
2. Define complete and incomplete flowers with examples.
3. Differentiate between bisexual and unisexual flowers.
4. What is the function of the calyx?
5. Name the four whorls of a typical flower.
6. Differentiate between actinomorphic and zygomorphic flowers.
7. What is meant by hypogynous and epigynous flowers?
8. Write one difference between pedicellate and sessile flowers.
9. What is the receptacle/thalamus in a flower?
10. Which model explains the genetic control of floral organ development?

Long Questions

1. Justify the statement **"A flower is a modified shoot"** with morphological and anatomical evidence.

2. Describe the **structure of a typical angiosperm flower** with neat diagrams.
3. Explain the **development of floral organs** and the **ABC model** of floral organ identity.
4. Classify flowers based on **symmetry, sexuality, completeness, and ovary position** with examples.
5. Compare **hypogynous, perigynous, and epigynous flowers** with suitable diagrams.
6. Write an essay on the **varieties of flowers** and their adaptive significance in reproduction and pollination.

UNIT 4.2

Pollination

Pollination is the **transfer of pollen grains** from the **anther** (male reproductive organ) of a flower to the **stigma** (female receptive part) of the same flower or another flower of the same species. It is the first and essential step in sexual reproduction of flowering plants, leading to fertilization and seed formation. Pollination ensures that the male gametes carried within pollen grains reach the ovules inside the ovary.

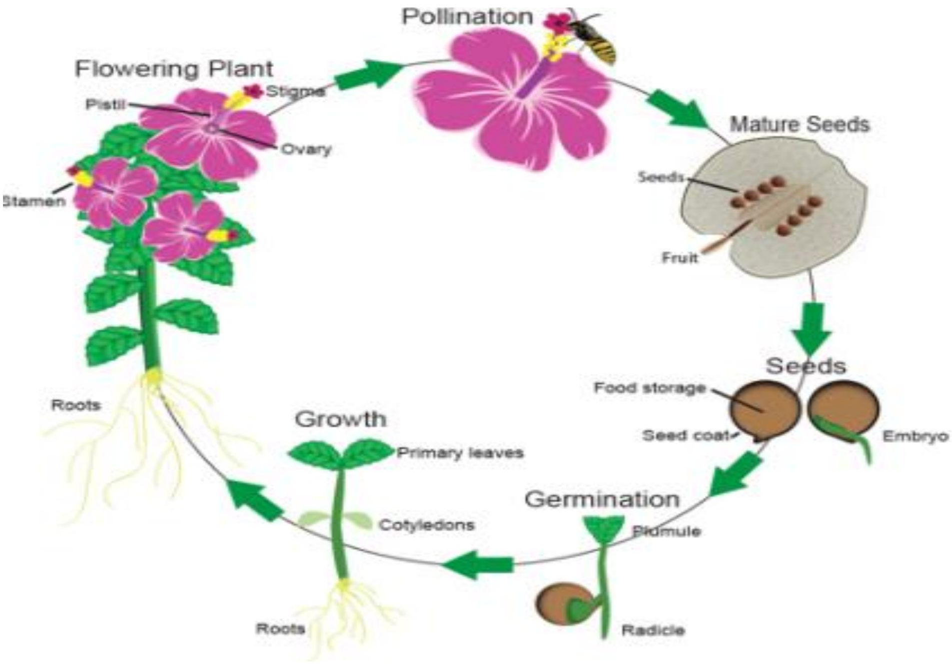

Fig. 4.6 Pollination

4.2.1 Self-Pollination (Autogamy):

In self-pollination, pollen grains from the anther are deposited on the stigma of the **same flower** or another flower on the **same plant**. It ensures genetic uniformity and purity of characters but limits variation.

Fig.4.7 **Self-Pollination**

4.2.1.1 Types of Self-Pollination:

- **Autogamy:** Pollen is transferred to the stigma of the same flower. (e.g., pea, wheat)
- **Geitonogamy:** Pollen from one flower reaches the stigma of another flower on the same plant. Genetically, it is self-pollination even though it involves two flowers. (e.g., maize, castor)

4.2.1.2 Adaptations for Self-Pollination:
In many flowering plants, certain structural and functional features favor **self-pollination**, ensuring reproductive assurance even when pollinators or cross-pollination agents are scarce. One important adaptation is **homogamy**, where the anthers and stigma of the same flower mature at the same time, allowing pollen to easily reach the stigma (e.g., wheat, rice). Another is **cleistogamy**, where flowers never open; the anthers release pollen directly onto the stigma within the closed flower, guaranteeing self-pollination without any external agent (e.g., viola, oxalis, balsam). Some plants exhibit **chasmogamous flowers** (open flowers) with structural traits that still favor selfing such as short stamens and stigmas positioned close together or anthers enclosing the stigma minimizing the chance of foreign pollen reaching the stigma. Additionally, flowers adapted for self-pollination often produce limited amounts of

pollen and nectar, as there is no need to attract pollinators, and they may lack showy colors or scents.

4.2.2 Cross-Pollination (Allogamy):

In cross-pollination, pollen grains are transferred from the anther of one plant to the stigma of a **different plant of the same species**. It introduces **genetic variation**, resulting in hybrid vigor and better adaptability. Cross-pollination is achieved through various agents, leading to further subtypes:

Fig.4.8 **Cross-Pollination**

4.2.2.1 Types of Cross-Pollination based on agents:

- **Anemophily:** Pollination by wind. Flowers are small, inconspicuous, and produce large quantities of lightweight pollen. (e.g., grasses, maize)
- **Hydrophily:** Pollination by water. Flowers release pollen that floats and reaches stigmas in aquatic habitats. (e.g., Vallisneria, Hydrilla)
- **Entomophily:** Pollination by insects. Flowers are brightly colored, scented, and often produce nectar to attract insects like bees and butterflies. (e.g., sunflower, hibiscus, rose)
- **Ornithophily:** Pollination by birds. Flowers are large, brightly colored, and rich in nectar. (e.g., Bignonia, Bombax)

- **Chiropterophily:** Pollination by bats. Flowers are large, pale-colored, and open at night with strong scents. (e.g., baobab, durian)

4.2.2.2 Adaptations for Cross-Pollination:

Plants that rely on **cross-pollination** show a range of specialized structural and functional adaptations to ensure that pollen from one flower reaches the stigma of another flower, thereby promoting genetic variation. One major adaptation is **dichogamy**, where the stamens and carpels of the same flower mature at different times. In **protandry** (e.g., sunflower, maize) the anthers release pollen before the stigma becomes receptive, while in **protogyny** (e.g., avocado, plantain) the stigma is receptive before the anthers release pollen. Another adaptation is **herkogamy**, a spatial separation of anthers and stigma within the same flower that prevents self-pollination; for example, in orchids and glories, stamens are placed away from the stigma. Some plants are **unisexual** (bearing male and female flowers separately), which forces cross-pollination (e.g., papaya, cucumber). In others, **self-incompatibility mechanisms** prevent a flower's own pollen from fertilizing its ovules even if it lands on the stigma (e.g., mustard, cabbage).

- Flowers adapted for cross-pollination often develop features to attract specific pollinators: bright colors, sweet scents, nectar guides, and large or conspicuous petals in insect-pollinated plants (**entomophilous**), light dry pollen and feathery stigmas in wind-pollinated plants (**anemophilous**), floating pollen in aquatic plants (**hydrophilous**), or nocturnal, large, and scented flowers for bats (**chiropterophilous**).

4.2.3 Significance of Pollination:

Pollination is a vital biological process in flowering plants because it ensures the **transfer of pollen grains** from the anther to the stigma, which is the first step leading to **fertilization, seed formation, and fruit development**. Without pollination, sexual reproduction in plants would not occur, and seed production would fail. Pollination is significant for maintaining **genetic diversity** in plant populations, especially through cross-pollination, which results in new gene combinations, improved adaptability, and hybrid vigor in future generations. It also contributes to **evolutionary success**, allowing plants to survive and thrive in changing environments.

From an ecological perspective, pollination is crucial in sustaining **ecosystem balance**, as it supports the reproduction of plants that form the base of food chains, and in turn provides food (nectar, pollen, seeds, fruits) for insects, birds, mammals, and humans. Economically, pollination is fundamental in **agriculture and horticulture**, directly influencing crop yields and quality in fruits, vegetables, oilseeds, and spices. Insect pollinators like bees and butterflies are therefore key to food production, and many agricultural systems depend on their activity.

Summary:

Pollination is the process of transferring **pollen grains** from the anther to the stigma of a flower, enabling fertilization and seed formation. It is an essential step in sexual reproduction of flowering plants.

Types of Pollination

1. **Self-pollination (Autogamy/Geitonogamy)**
    - Pollen is transferred to the stigma of the same flower (autogamy) or another flower of the same plant (geitonogamy).
    - Ensures reproductive assurance but reduces genetic variation.
2. **Cross-pollination (Xenogamy)**
    - Transfer of pollen between flowers of **different plants of the same species**.
    - Promotes genetic diversity and adaptability

Multiple Choice Questin (MCQs):

1. Pollination is defined as:

a) Transfer of pollen from anther to ovule

b) Transfer of pollen from anther to stigma

c) Fertilization in plants

d) Seed dispersal

Answer: b) Transfer of pollen from anther to stigma

2. Pollination by wind is called:

a) Hydrophily

b) Entomophily

c) Anemophily

d) Ornithophily

Answer: c) Anemophily

3. Pollination in Vallisneria occurs through:

a) Insects

b) Wind

c) Water

d) Bats

Answer: c) Water

4. Cross-pollination promotes:

a) Cloning

b) Genetic diversity

c) Uniformity

d) Reduced adaptability

Answer: b) Genetic diversity

5. A flower adapted for insect pollination will typically have:

a) Small, inconspicuous petals

b) Colorful, scented petals with nectar

c) Absence of nectar

d) Dry, lightweight pollen only

Answer: b) Colorful, scented petals with nectar

Short Questions

1. Define pollination.
2. Differentiate between self-pollination and cross-pollination.
3. What is anemophily? Give an example.
4. Name two plants pollinated by water.
5. What is geitonogamy?
6. Mention one adaptation for insect pollination.
7. Define herkogamy and dichogamy.
8. Why is cross-pollination advantageous?
9. Which type of flowers are pollinated by bats?
10. Write one agricultural importance of pollination.

Long Questions

1. Define pollination. Explain different **types of pollination** with examples.
2. Discuss **biotic and abiotic agents of pollination** and their adaptations.
3. Describe the **mechanisms promoting cross-pollination** in plants.
4. Compare **wind, water, and insect pollination** with suitable examples.
5. Explain the **significance of pollination in agriculture and biodiversity**.
6. With diagrams, describe **adaptations of flowers for animal pollination**.

UNIT 4.3

Pollen-Pistil Interaction

When pollen grains land on a stigma (the receptive part of the pistil), a **communication process** begins between the male gametophyte (pollen) and the female reproductive organ (pistil).

4.3.1Definition:

Pollen–pistil interaction is the series of **morphological, biochemical, and molecular events** that take place from the moment a pollen grain lands on the stigma until it successfully germinates and delivers the male gametes to the ovule for fertilization.

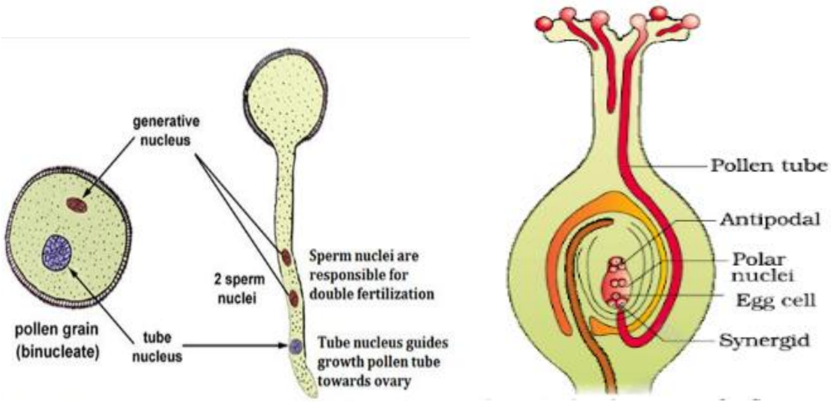

Fig. 4.9 pollen and pistil

4.3.1.1: Pollen deposition on stigma

- After pollination, pollen grains from an anther land on the stigma (the receptive surface of the pistil).
- The stigma examines the pollen grains through chemical signals on their outer wall (exine) and proteins in the pollen coat.

4.3.1.2: Recognition of pollen

- The stigma determines whether the pollen is **compatible** (right species, genetically acceptable) or **incompatible** (wrong species or self-pollen in self-incompatible plants).

- This recognition is controlled by **molecular interactions** between pollen coat proteins and stigma receptors.

4.3.1.3: Hydration and activation of pollen

- If compatible, the stigma secretes moisture, sugars, and enzymes.
- The pollen grain hydrates, swells, and the **pollen tube begins to emerge** through a germ pore.

4.3.1.4: Pollen tube germination

- The pollen tube grows out from the pollen grain and penetrates the stigma tissue.
- The vegetative (tube) cell leads the growth, carrying the two male gametes (sperm cells) inside.

4.3.1. 5: Pollen tube growth through style

- The pollen tube travels down the style toward the ovary.
- The style provides **nutritional guidance** (sugars, amino acids) and chemical signals to guide the pollen tube.
- If the pollen is incompatible, the style tissues may block the tube's growth (self-incompatibility mechanism).

4.3.1.6: Guidance to ovule

- The pollen tube reaches the ovary and is guided to the ovule by chemical attractants from the **synergid cells** near the micropyle.

4.3.1. 7: Fertilization

- The pollen tube enters the ovule through the micropyle and releases the two sperm cells.
- One sperm fertilizes the egg (forming the zygote), and the other fuses with the polar nuclei (forming endosperm), completing **double fertilization**.

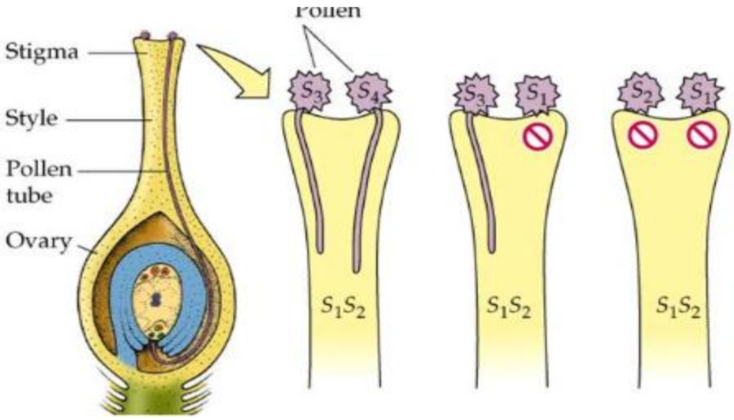

Fig. **4.10 Pollen-Pistil Interaction**

4.3.2 Significance of Pollen–Pistil Interaction

4.3.2.1 Ensures Species-Specific Fertilization

- The stigma and style tissues act as a *selective barrier*.
- Only compatible pollen (of the same species) is allowed to germinate and form a pollen tube.
→ Prevents wastage of gametes and ensures reproductive success.

4.3.2.2 Promotes Genetic Diversity

- Through recognition and rejection mechanisms (such as self-incompatibility), cross-pollination is encouraged.
→ Leads to new gene combinations, better adaptability, and evolution of new traits.

4.3.2.3 Prevents Inbreeding Depression

- Self-incompatibility mechanisms prevent self-pollen from fertilizing ovules in many species.
→ This maintains **hybrid vigor** and avoids weakening of the genetic pool.

4.3.2.4 Regulation of Fertilization

- The pistil can regulate which pollen grain fertilizes an ovule, even among many pollen grains arriving on the stigma.
  → This selection improves the chances of high-quality offspring.

4.3.2.5 Successful Double Fertilization

- By guiding the pollen tube to the ovule, the interaction ensures delivery of male gametes.
  → This leads to the formation of **zygote (embryo)** and **endosperm (nutritive tissue)**.

4.3.2.6 Agricultural Importance

Understanding pollen–pistil interaction helps plant breeders develop **self-incompatible hybrids** or control pollination.
→ Leads to production of high-yield and disease-resistant varieties.

4.3.2.7 Ecological Balance

By regulating cross-pollination, plants maintain ecological relationships with pollinators (bees, butterflies, etc.).
→ Promotes biodiversity in natural habitats.

4.3.3 Double fertilization:

Definition

Double fertilization is a unique and characteristic feature of angiosperms in which **two male gametes** delivered by a pollen tube take part in **two separate fusion events** inside the embryo sac:

1. **Syngamy** → one male gamete fuses with the egg cell to form the **zygote** (2n).
2. **Triple Fusion** → the other male gamete fuses with the two polar nuclei in the central cell to form the **primary endosperm nucleus (PEN)** (3n).

4.3.3.1 Process:

Double fertilization is a unique reproductive process found in angiosperms in which two separate fertilization events occur within the embryo sac after the entry of the pollen tube. When a pollen grain germinates on the stigma, it grows a pollen tube that carries two male gametes into the ovule through the micropyle. Once the pollen tube reaches the embryo sac, it penetrates one of the synergid cells and releases both male gametes. One male gamete fuses with the egg cell to form a diploid zygote, a process known as **syngamy**, which later develops into the embryo. Simultaneously, the second male gamete fuses with the two polar nuclei present in the central cell of the embryo sac, forming a triploid primary endosperm nucleus through a process known as **triple fusion**. This primary endosperm nucleus gives rise to the endosperm, a nutritive tissue that nourishes the developing embryo. Because both fertilization events occur almost simultaneously in the same embryo sac, this phenomenon is termed double fertilization. It is significant as it ensures that the formation of nutritive tissue (endosperm) only happens if fertilization has been successful, thus conserving the plant's resources and ensuring efficient seed development.

4.3.3.2 Triple fusion

Triple fusion is a unique event in the reproductive process of flowering plants (angiosperms) that takes place inside the embryo sac during double fertilization. After the pollen tube enters the ovule through the micropyle, it releases two male gametes into the embryo sac. While one male gamete fuses with the egg cell to form the diploid zygote (syngamy), the second male gamete fuses with the two polar nuclei located in the central cell of the embryo sac. This fusion of three haploid nuclei—one male nucleus and two female polar nuclei—results in the formation of a single large cell with a **triploid (3n) nucleus**, known as the **primary endosperm nucleus**. This process is called triple fusion because three nuclei are involved in the fusion event. The primary endosperm nucleus then undergoes repeated divisions to form the **endosperm**, which functions as a nutritive tissue, supplying food materials such as starch, proteins, and oils to the developing embryo. Triple fusion is therefore crucial for seed development, ensuring that the embryo has a ready food supply for its growth and germination.

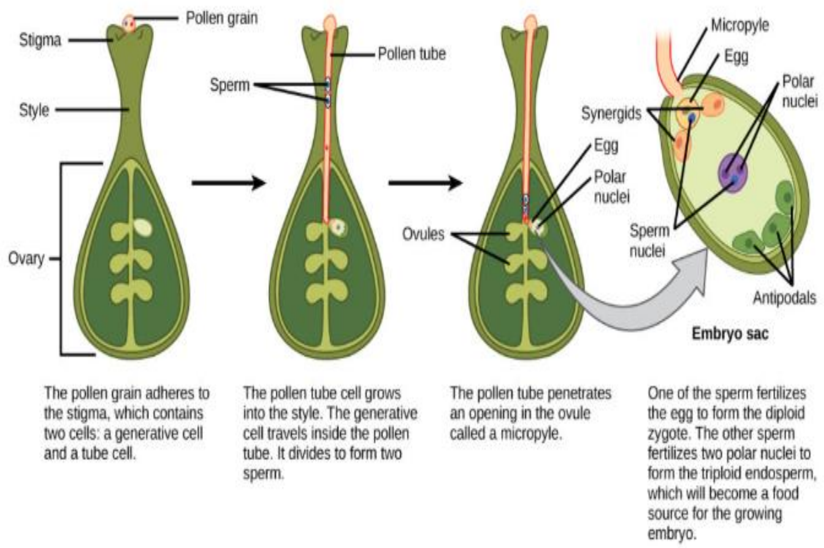

Fig. 4.11 Double fertilization

4.3.3.3 Significance:

Double fertilization is a remarkable and unique feature of angiosperms that ensures both the formation of the embryo and the development of nutritive tissue in perfect coordination. Its greatest significance lies in the fact that the endosperm, which serves as a food reserve for the developing embryo, is formed only after fertilization has successfully taken place. This prevents the plant from investing energy and resources into producing nutritive tissue when no viable embryo would be formed, thereby ensuring efficient resource utilization. The process also leads to the production of a diploid zygote and a triploid endosperm, creating a well-developed seed with both an embryo and an immediate food supply for its growth. This coordination contributes to the high efficiency of angiosperms in reproduction and seed formation, giving them an evolutionary advantage over other plant groups. Moreover, double fertilization promotes genetic diversity through sexual reproduction, which is essential for adaptation, survival, and crop improvement in agriculture. In essence, double fertilization is significant because it conserves energy, enhances reproductive success, and secures the future development of the plant through well-nourished seeds.

Summary:

The **pollen–pistil interaction** is the process by which a pollen grain, after landing on a stigma, is recognized and either accepted or rejected by the pistil. In compatible cases, the pollen grain hydrates and germinates, producing a pollen tube that grows through the style towards the ovule. This growth is guided by chemical signals from the female tissues (chemotropism). During this process, mechanisms like **self-incompatibility** prevent self-fertilization and encourage cross-pollination, thereby promoting genetic diversity.

Double fertilization, a unique feature of angiosperms discovered by Nawaschin and Guignard in 1898–1899, occurs after the pollen tube enters the ovule. The pollen tube releases two male gametes: one fuses with the egg cell to form the diploid zygote (syngamy), while the other fuses with the two polar nuclei of the central cell to form a triploid endosperm (triple fusion). Thus, two fertilization events occur simultaneously, giving rise to both embryo and nutritive tissue. This process ensures efficient resource utilization, as the endosperm develops only when fertilization is successful, making double fertilization a highly adaptive and distinctive feature of flowering plants.

Multiple Choice Question (MCQs):

1. Pollen–pistil interaction begins with:

a) Fertilization

b) Pollen germination on stigma

c) Pollen development in anther

d) Fruit development

Answer: b) Pollen germination on stigma

2. The guidance of pollen tube towards the ovule is called:

a) Hydrotropism

b) Phototropism

c) Chemotropism

d) Geotropism

Answer: c) Chemotropism

3. Double fertilization was discovered by:

a) Mendel

b) Nawaschin and Guignard

c) Strasburger

d) Hofmeister

Answer: b) Nawaschin and Guignard

4. Fusion of one male gamete with two polar nuclei forms:

a) Zygote

b) Endosperm

c) Synergids

d) Embryo sac

Answer: b) Endosperm

5. The fusion of egg cell with one male gamete is called:

a) Triple fusion

b) Syngamy

c) Autogamy

d) Apomixis

Answer: b) Syngamy

Short Questions

1. Define pollen–pistil interaction.
2. What is self-incompatibility? Mention its types.
3. What is the role of synergids in fertilization?
4. Define syngamy.
5. What is triple fusion?
6. Who discovered double fertilization?
7. Write one significance of double fertilization.
8. What guides the pollen tube towards the ovule?
9. Name the nutritive tissue formed after double fertilization.
10. Differentiate between sporophytic and gametophytic self-incompatibility.

Long Questions

1. Describe the process of **pollen–pistil interaction** and explain its importance.
2. Explain the **mechanisms of self-incompatibility** in plants.
3. With neat diagrams, explain the steps of **double fertilization in angiosperms**.
4. Discuss the **significance of double fertilization** in angiosperms.
5. Compare **syngamy and triple fusion** with diagrams.
6. Write an essay on **pollen germination, pollen tube growth, and fertilization process** in flowering plants.

UNIT 4.4

Fruit Development and Maturation

4.4.1 Introduction

Fruit development and maturation are crucial stages in the life cycle of a flowering plant. After fertilization, the ovary of the flower undergoes a series of **morphological, physiological, and biochemical changes** to become a mature fruit that protects the seeds and aids in their dispersal.

4.4.1.1 **Fruit Development (Post-Fertilization Changes)**

(a) Initiation

- Begins after **double fertilization**.
- The fertilized ovule develops into a seed, and the **ovary wall (pericarp)** starts transforming into a fruit.

(b) Hormonal Control

- Auxins, gibberellins, and cytokinins produced in the developing seeds stimulate ovary growth.
- Growth hormones prevent abscission of the ovary and promote cell division and enlargement.

(c) Structural Changes

- **Ovary wall** → becomes **pericarp** (fruit wall).
- **Ovules** → develop into **seeds**.
- Other floral parts (sepals, petals, stamens) may fall off or persist depending on the fruit type.

(d) Types of Fruit Development

- **True fruits:** Develop solely from ovary (e.g., mango, tomato).
- **False fruits (pseudocarps):** Other floral parts contribute (e.g., apple – thalamus also develops).

4.4.1.2 **Fruit Maturation**

Definition:

Maturation is the process by which a developing fruit undergoes final changes in color, texture, flavor, and chemical composition to become **ready for seed dispersal**.

(a) Physiological Changes

- Starch → converted to sugars (sweetening).
- Organic acids adjust (improves taste).
- Secondary metabolites (tannins, alkaloids) may reduce to remove bitterness.

(b) Structural Changes

- Cell walls soften due to enzymatic activity (pectinases, cellulases), making fruit edible.
- Pigments accumulate (e.g., chlorophyll degrades, carotenoids and anthocyanins develop giving yellow, orange, red colors).

(c) Hormonal Regulation

- **Ethylene:** Key hormone triggering ripening and maturation.
- Interaction with auxins and abscisic acid regulates the timing of ripening.

(d) Final Stage

- Mature fruit becomes attractive to dispersal agents (color, aroma, taste).
- Abscission layer forms at the stalk, facilitating natural fruit drop in many species.

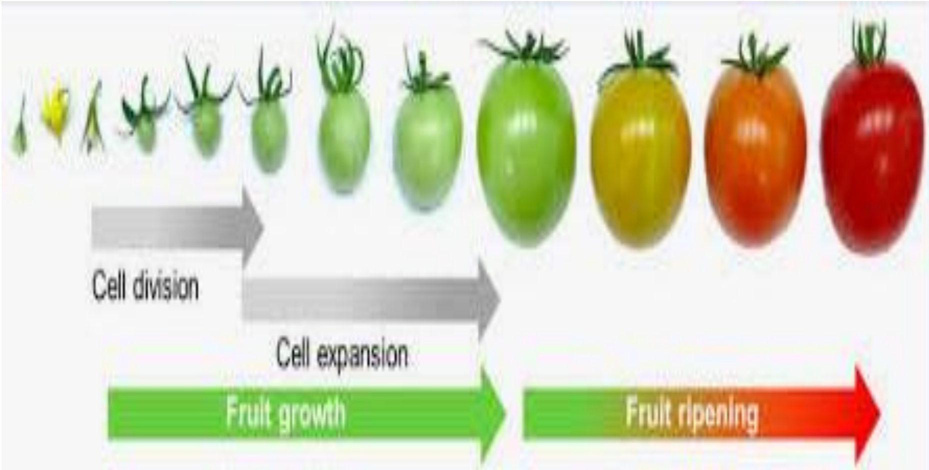

Fig 4.12 Fruit Development and Maturation

4.4.1.3 **Significance of Fruit Development and Maturation**

4.4.1.3.1 **Protection of Seeds**

- During fruit development, the ovary wall forms a protective covering (pericarp) around the seeds.
- This shields seeds from **mechanical injury, desiccation, and predators** while they mature.

4.4.1.3.2 **Aid in Seed Dispersal**

- Mature fruits often develop special structures (wings, hooks, fleshy pulp) or colors and aromas to attract dispersal agents such as wind, water, and animals.
- This ensures seeds are carried far from the parent plant, reducing competition.

4.4.1.3.3 **Ensures Seed Maturity Before Dispersal**

- Fruits hold seeds until they are physiologically mature and capable of successful germination.
- Prevents premature shedding of immature seeds.

4.4.1.3.4 **Contribution to Plant Reproductive Success**

- By coordinating with seed development, fruit maturation increases the chances of **fertile, viable offspring** and maintains species continuity.

4.4.1.3.5 **Agricultural and Economic Importance**

- Knowledge of fruit development helps in **crop improvement, controlled ripening, and storage**.
- Many edible fruits (mango, apple, tomato) and dry fruits (wheat, rice) form the basis of human diet and trade.

4.4.1.3.6 **Nutritional and Ecological Value**

- As fruits mature, they accumulate **sugars, vitamins, and minerals**, making them valuable food for humans and animals.
- Mature fruits support **ecological interactions** (birds, mammals) that help in pollination and dispersal cycles.

4.4.1.3.7 **Horticultural Practices and Post-Harvest Handling**

- Understanding maturation allows farmers to determine **harvest time** for best quality and shelf life.
- Controlled ripening improves **market value** and reduces wastage.

4.4.1.4 Fruit Development and Maturation – Factors Affecting: Fruit development begins soon after successful fertilization, when hormonal signals from the fertilized ovule stimulate the ovary to enlarge and differentiate into a fruit. Several internal and external factors influence this process and determine the size, quality, and timing of fruit maturation. **Hormones** play a central role: auxins, gibberellins, and cytokinins produced in the developing seeds and surrounding tissues promote cell division and cell enlargement, whereas abscisic acid and ethylene later regulate ripening and senescence. The **genetic makeup** of the plant species or variety also sets inherent limits on fruit size, shape, and texture. Among environmental factors, **temperature** is critical, as optimal warmth accelerates metabolic activities and growth, while extreme cold or heat can delay or damage developing fruits. **Light intensity and photoperiod** influence photosynthesis and therefore the supply of carbohydrates needed for fruit filling and sweetness. Adequate **water supply** and **soil nutrients** (especially nitrogen, phosphorus, and potassium) are essential for proper cell division and enlargement; deficiencies or imbalances can lead to poor fruit set or abnormal development. In addition, **pollination efficiency and seed development** directly affect hormonal balance and fruit growth, as many fruits require viable seeds for proper development. Finally, **cultural practices** such as pruning, thinning, irrigation management, and pest control have a significant impact by ensuring that the plant's resources are directed towards healthy, marketable fruits. Altogether, the harmonious interaction of these internal and external factors ensures normal fruit development and timely maturation with desirable quality attributes.

Summary:

A flower is the **reproductive organ** of flowering plants (angiosperms), designed to facilitate pollination and seed formation. It's built around a short stalk called the **receptacle**, which supports four concentric whorls:

- **Calyx** (sepals): Leaf-like structures that enclose and protect the developing bud.
- **Corolla** (petals): Often colored or scented to attract pollinators
- **Androecium** (stamens): Male parts consisting of filaments and anthers that produce pollen
- **Gynoecium** (carpels/pistils): Female part composed of stigma (pollen-receptive surface), style (pollen tube pathway), and ovary (houses ovules that develop into seeds)

Multiple Choice Questions (MCQs):

1. **The flower is a modified:**

a) Leaf

b) Root

c) Shoot

d) Stem

Ans. c) Shoot

2. **The male reproductive part of a flower is called:**

a) Pistil

b) Stamen

c) Ovary

d) Sepal

Ans. a) Pistil

3. **The transfer of pollen from the anther to the stigma of the same flower is called:**

a) Cross-pollination

b) Self-pollination

c) Wind pollination

d) Insect pollination

Ans. b) Self-pollination

4. **Which of the following is an adaptation for insect pollination?**

a) Small, dry flowers

b) Brightly colored petals

c) No scent production

d) Large amounts of pollen

Ans. b) Brightly colored petals

5. **Double fertilization is unique to:**

a) Gymnosperms

b) Bryophytes

c) Angiosperms

d) Algae

Ans. c) Angiosperms

6. The process in which pollen and pistil interact to ensure successful fertilization is called:

a) Pollination

b) Pollen-pistil interaction

c) Seed dispersal

d) Photosynthesis

Ans. b) Pollen-pistil interaction

7. The edible part of a fruit develops from the:

a) Ovule

b) Ovary

c) Stigma

d) Root

Ans. b) Ovary

8. Which hormone is responsible for fruit ripening?

a) Auxin

b) Cytokinin

c) Ethylene

d) Gibberellin

Ans. c) Ethylene

9. A fruit that develops without fertilization is called:

a) Parthenocarpic fruit

b) Dehiscent fruit

c) Drupe

d) Aggregate fruit

Ans. a) Parthenocarpic fruit

10. The primary function of endosperm in a seed is:

a) Photosynthesis

b) Water absorption

c) Nutrient storage for the embryo

d) Providing mechanical support

Ans. c) Nutrient storage for the embryo

Short Questions:

1. What are the major parts of a flower?
2. Explain the structure of anther and pistil.
3. Differentiate between self-pollination and cross-pollination.
4. How do flowers attract pollinators?
5. What is the significance of pollen-pistil interaction?
6. Define double fertilization and its importance.
7. What are the different types of fruits?
8. Describe the stages of fruit development.
9. How does ethylene affect fruit ripening?
10. What is parthenocarpy? Give an example.

Long Questions:

1. Explain the structure and function of a flower with labeled diagrams.
2. Describe the process of pollination and its different types.
3. How do plants adapt to different pollination mechanisms?
4. Discuss the molecular mechanisms of pollen-pistil interaction.
5. Explain double fertilization and its role in seed development.
6. Compare and contrast the types of fruits based on their formation.

7. Describe the hormonal regulation of fruit maturation and ripening.
8. What are the factors affecting fruit development and seed formation?
9. Explain the significance of self-incompatibility in plants.
10. How does fruit development contribute to seed dispersal?

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MODULE- 5

THE SEED

5.0 Objective:

- Understand the significance of seeds in plant life cycles.
- Study the structure, dormancy, and germination of seeds.
- Explore vegetative reproduction and its applications.
- Learn about the economic and ecological importance of seeds.

UNIT 5.1

Significance of Seed

5.1.1Seed:

A **seed** is a mature ovule that forms after fertilization in seed plants (gymnosperms and angiosperms). It is a vital reproductive unit capable of developing into a new plant under suitable conditions. A typical seed consists of three main parts: an **embryo**, which is the young plant with a radicle (future root), plumule (future shoot), and one or two cotyledons (seed leaves); a **food reserve**, stored in cotyledons or endosperm, which nourishes the embryo during germination; and a **seed coat** (testa and sometimes tegmen), which is a tough protective covering that shields the embryo from mechanical injury, dehydration, and infection.

Seeds develop inside the fruit in angiosperms or are exposed on scales in gymnosperms. They represent a major evolutionary advancement because they ensure the **survival of the species**, even in adverse conditions, through **dormancy**—a resting phase during which metabolic activity is minimal. When environmental conditions such as water availability, oxygen, and temperature are favorable, seeds undergo **germination**, resuming growth to produce a new seedling.

Seeds also have adaptations that aid **dispersal** by wind, water, or animals, enabling plants to spread to new areas, reduce competition with the parent plant, and colonize diverse habitats. From an agricultural and economic perspective, seeds are fundamental because they are the primary means of propagation for most crops, easy to store and transport, and form the basis of human food (e.g., cereals, pulses, oilseeds), fiber (e.g., cotton), and industrial raw materials (e.g., castor, linseed).

5.1.2 Types of Seeds:

Seeds show remarkable diversity in structure and development, and they are broadly classified into different types based on various criteria. **On**

the basis of the number of cotyledons, seeds are of two main types: **dicotyledonous seeds** and **monocotyledonous seeds.**

- **Dicotyledonous seeds (dicot seeds):** These seeds contain **two cotyledons** within the embryo, which often store food and supply it to the germinating seedling. Examples include bean, pea, gram, and mustard. Dicot seeds usually have a well-defined embryo with a radicle, plumule, and two fleshy cotyledons enclosed in a seed coat (testa and tegmen).

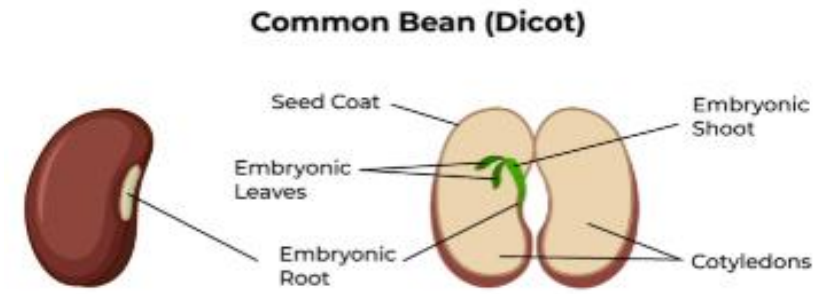

Fig.5.1 Dicotyledonous seeds

- **Monocotyledonous seeds (monocot seeds):** These have **one cotyledon**, often called a **scutellum** in grasses, with food stored in a separate **endosperm**. Examples include maize, rice, wheat, and other cereals. Monocot seeds are often endospermic, meaning the endosperm remains as a food source for the embryo during germination.

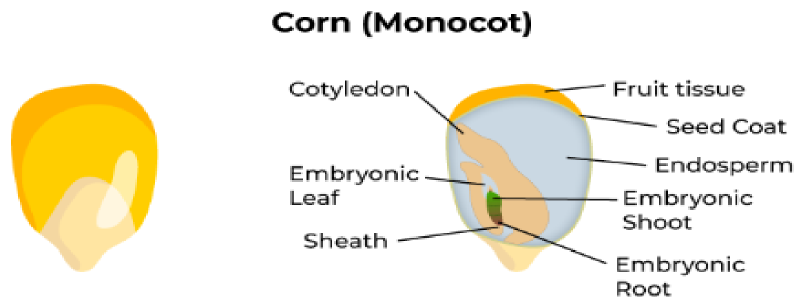

Fig.5.2 Monocotyledonous seeds

On the basis of food storage, seeds can also be **endospermic (albuminous)** or **non-endospermic (exalbuminous):**

- **Endospermic seeds** retain a portion of endosperm as a food reserve after embryo development, e.g., maize, coconut, castor.
- **Non-endospermic seeds** store food mainly in the cotyledons and use up the endosperm during seed development, e.g., pea, bean, groundnut.

On the basis of origin, seeds are present in **angiosperms** (enclosed in a fruit) and **gymnosperms** (naked seeds exposed on cone scales).

5.1.3 Structure of a Seed:

A seed is a mature, fertilized ovule that contains all the essential structures needed to develop into a new plant. A typical seed is made up of three main parts: the **seed coat**, the **embryo**, and the **food storage tissue**.

The **seed coat** forms the protective outer covering and usually consists of two layers: the outer **testa**, which is tough and hard, and the inner **tegmen**, which is thin and delicate. The seed coat protects the inner tissues from mechanical injury, dehydration, and microbial infection. A small scar on the seed coat, called the **hilum**, marks the point where the seed was attached to the fruit, and near it is a small pore known as the **micropyle**, through which water and oxygen enter during germination.

Inside the seed coat lies the **embryo**, the miniature plant. The embryo has three main parts:

- The **radicle**, which is the embryonic root that grows downward into the soil,
- The **plumule**, which is the embryonic shoot that grows upward, and

- The **cotyledons**, which are seed leaves that either store food (as in dicots) or help in food transfer from the endosperm (as in monocots).

Surrounding or alongside the embryo is the **food storage tissue**, which serves as a reserve for the young plant. In many dicot seeds like peas and beans, food is stored in the **cotyledons**, making them non-endospermic. In monocot seeds like maize and cereals, food remains stored in the **endosperm**, and the single cotyledon (called the **scutellum**) transfers this food to the embryo during germination.

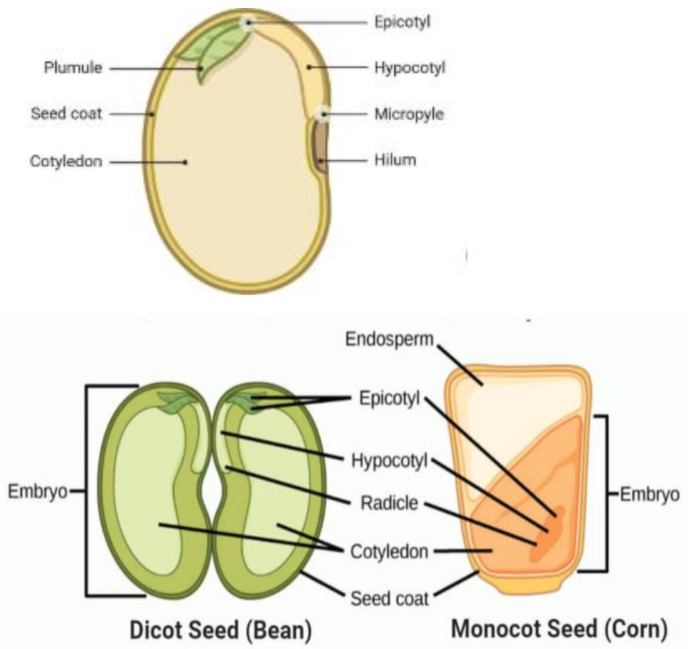

Fig. **5.3 Structure of a Seed**

5.1.4 Seed Dormancy:

Seed dormancy is a state in which **viable seeds fail to germinate** even when provided with all favorable environmental conditions such as water, oxygen, temperature, and light. It is a natural survival mechanism that prevents seeds from germinating at a time or place that would be unfavorable for seedling establishment. Dormancy allows seeds to **overcome adverse seasons** like drought, frost, or extreme heat, and ensures that germination occurs only under suitable conditions, thereby increasing the chances of survival of the next generation.

Dormancy may be caused by several factors. In some seeds, dormancy is due to **hard or impermeable seed coats** that prevent water or gas exchange, as seen in legumes like pea and bean. In others, it may result from **physiological immaturity** of the embryo at the time of seed dispersal (e.g., apple, citrus). Sometimes, the presence of **chemical inhibitors** in the seed coat or endosperm (like abscisic acid or phenolic compounds) prevents germination until they are leached away by rain. Some seeds require specific cues like **light, temperature fluctuations, or passage through an animal's digestive tract** to break dormancy.

Dormancy can be classified as **innate (primary)**, when it is naturally present in freshly harvested seeds, or **induced (secondary)**, when seeds become dormant due to unfavorable conditions after dispersal.

5.1.5 Significance of Seed:

Seeds are among the most important evolutionary innovations in plants, and their significance is both ecological and economic. Biologically, a seed serves as a **protective structure** for the young embryo, enclosing it in a tough seed coat that shields it from mechanical injury, desiccation, and microbial attack. Seeds often contain **stored food** in the form of endosperm or cotyledons, which nourishes the developing seedling during germination until it can photosynthesize on its own. One of the greatest advantages of seeds is their ability to enter a state of **dormancy**, enabling them to survive unfavorable environmental conditions such as drought, extreme temperatures, or nutrient scarcity and germinate only when conditions are suitable. Seeds also have diverse **dispersal adaptations**—such as wings, hooks, plumes, or buoyant tissues—that help them spread over wide areas by wind, water, or animals, reducing competition with the parent plant and allowing colonization of new habitats.

From a human perspective, seeds are the foundation of **agriculture and food security**. They are the primary propagules for most crops, easy to store and transport, and capable of remaining viable for long periods, allowing farmers to grow crops season after season. Seeds of cereals (like rice, wheat, and maize), pulses (like beans and lentils), oilseeds (like mustard and groundnut), and spices (like coriander and cumin) are staple components of human diets and economies. Seeds also contribute to **biodiversity conservation** and horticulture, as improved or rare plant varieties can be preserved and multiplied through their seeds.

5.1.6 Economic Importance of Seeds

Seeds are the backbone of **agriculture and economy** because they are the primary units of crop production. Almost all our major food crops—such as cereals (rice, wheat, maize), pulses (gram, lentils), and oilseeds (groundnut, mustard, sunflower)—are harvested as seeds, making them direct sources of human nutrition. Seeds of spices (coriander, cumin, fennel) and condiments have high commercial value, while seeds of plants like cotton and flax provide fibers for textiles. Many seeds (castor, linseed, sesame) yield oils used for cooking, medicines, paints, and soaps. Seeds are also important in **horticulture and forestry**, where high-quality seeds are used to propagate fruits, vegetables, ornamentals, and timber plants. Improved seeds produced through plant breeding and biotechnology increase yields, disease resistance, and stress tolerance, contributing to **food security and economic growth**. Seeds are easy to **store, handle, and transport**, which enables large-scale cultivation and trade across regions and countries.

5.1.7 Ecological Importance of Seeds

In nature, seeds play a crucial role in the **survival and spread of plant species**. The protective seed coat and stored food allow seeds to survive harsh conditions through **dormancy**, germinating only when the environment is favorable. Various adaptations—like wings, hooks, or buoyant tissues—help seeds in **dispersal by wind, water, or animals**, allowing plants to colonize new areas, maintain genetic diversity, and reduce competition with the parent plant. Seeds also act as a vital link in **ecosystems**, providing food for birds, insects, and mammals, thus supporting food chains and maintaining biodiversity. Their ability to persist in soil as a **seed bank** ensures vegetation recovery after disturbances such as fire, drought, or human activity, making them essential for **ecosystem stability and regeneration**.

5.1.8 Seed Germination

Seed germination is the process by which a resting seed resumes growth and develops into a young seedling under suitable conditions. When a mature, viable seed falls on moist soil, it absorbs water through the seed coat in a process known as imbibition. This rehydrates the cells, swells the seed, and activates enzymes that convert stored food in the cotyledons or endosperm into soluble forms to provide energy. The seed coat softens and splits, allowing the embryonic root, called the **radicle**, to emerge first and grow downward to absorb water and minerals. Next, the **plumule** (embryonic shoot) grows upward toward light, developing into the stem and leaves. Germination requires favorable environmental conditions such as adequate moisture, suitable temperature, proper oxygen supply, and in some cases light or darkness depending on the seed type. This process is vital for plant propagation and marks the beginning of a new plant's life cycle.

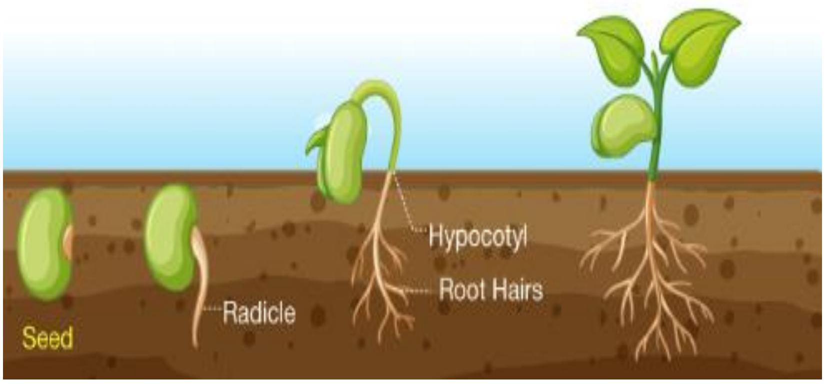

Fig.5.4 Process of Seed germination

Summary:

Seeds are a remarkable adaptation in higher plants, ensuring survival, reproduction, and dispersal. The seed protects the embryo with a seed coat, stores food for germination, and allows plants to withstand unfavorable conditions through dormancy. Seeds aid in dispersal to new habitats and thus maintain biodiversity. Agriculturally, seeds are the fundamental unit of crop production, forming the basis of food supply (grains, pulses, nuts, oilseeds). Seeds also have economic importance in medicine, industry, and trade. Evolutionarily, they represent a major advancement over spores, giving seed plants dominance in terrestrial ecosystems.

Multiple Choice Question (MCQs):

1. Which of the following is the main advantage of seeds over spores?
   a) Seeds are smaller
   b) Seeds have stored food and protection
   c) Seeds are unicellular
   d) Seeds germinate immediately
   Answer: b) Seeds have stored food and protection
2. Seed dormancy helps plants to:
   a) Germinate quickly after dispersal
   b) Survive unfavorable conditions
   c) Increase photosynthesis
   d) Prevent fertilization
   Answer: b) Survive unfavorable conditions
3. The seed coat primarily functions as:
   a) Storage of food
   b) Protection of embryo
   c) Photosynthesis
   d) Dispersal
   Answer: b) Protection of embryo
4. Seeds form the basis of agriculture because:
   a) They are sources of oxygen
   b) They ensure reproduction and food supply
   c) They provide structural support

d) They regulate transpiration

Answer: b) They ensure reproduction and food supply

5. Which of the following is NOT a significance of seeds?

   a) Source of food

   b) Ecological succession

   c) Energy storage for germination

   d) Photosynthesis in adult plants

   Answer: d) Photosynthesis in adult plants

Short Questions

1. Define seed and state its importance.
2. Mention two roles of seed dormancy.
3. Give two economic uses of seeds.
4. How are seeds better than spores for survival?
5. State two ways seeds help in dispersal.
6. Write two roles of seeds in agriculture.
7. Why are seeds considered a major evolutionary advancement?
8. Mention one example each of food and medicinal seed.

Long Questions

1. Explain the ecological and evolutionary significance of seeds.
2. Discuss the role of seeds in agriculture and food security.
3. Describe how seeds help in dispersal and survival during adverse conditions.
4. Elaborate the economic importance of seeds in human life (food, medicine, industry).
5. Write an essay on the significance of seed in plant evolution and biodiversity.
6. Compare the significance of seeds and spores in plant survival.

UNIT 5.2

Vegetative Reproduction

Definition:

Vegetative reproduction is a mode of **asexual reproduction in plants** where new plants are produced from **vegetative parts** such as roots, stems, leaves, or buds rather than from seeds or spores. The new plants formed are **genetically identical clones** of the parent because no fertilization or gametic fusion occurs. This type of reproduction is common in many angiosperms and is of great ecological and economic importance.

5.2.1 Natural vegetative reproduction

Natural vegetative reproduction is a form of asexual reproduction in which new plants develop naturally from the **vegetative parts** of the parent plant such as roots, stems, or leaves, **without any human intervention**. It is an adaptation that allows many plants to propagate rapidly and survive in diverse habitats. Various organs are specially modified for this purpose. In some plants, **roots** develop adventitious buds that grow into new shoots, as seen in sweet potato and dahlia. Many plants use **stems** as reproductive organs; for example, **rhizomes** in ginger and turmeric spread underground and produce new shoots, **tubers** like potato bear "eyes" (buds) from which new plants arise, **corms** in colocasia store food and give rise to daughter plants, and **bulbs** such as onion and garlic have fleshy scales that develop into new plants. Above-ground stem modifications also help in propagation; **runners** (stolons) in strawberry and grasses creep along the ground and root at the nodes, while **suckers** in mint and chrysanthemum arise from underground stems and form independent plants. Even **leaves** can participate in natural vegetative reproduction; for instance, Bryophyllum leaves develop small plantlets along their margins, which fall off and grow into new individuals.

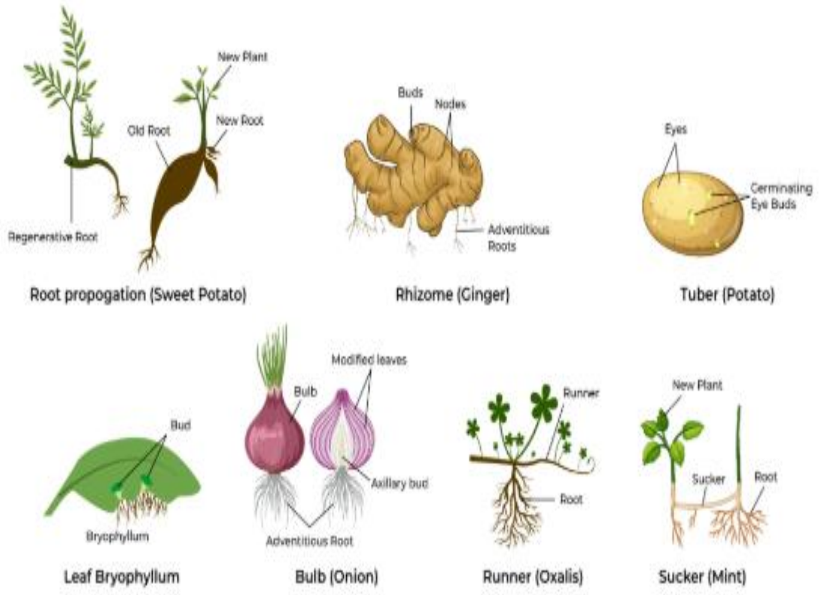

Fig. **5.5 Natural vegetative propogules**

5.2.2 Artificial Vegetative Reproduction:

Artificial vegetative reproduction is a method of **asexual propagation carried out by humans**, where new plants are produced from the vegetative parts of a parent plant—such as stem, root, or leaf—using various horticultural techniques. This method is widely used in agriculture and gardening to multiply plants that have desirable traits like high yield, disease resistance, or ornamental value. The most common techniques include **cutting**, where a portion of stem, root, or leaf is cut from the parent plant and placed in soil to develop roots and shoots (as in rose, sugarcane, and coleus); **layering**, where a living branch is bent to the ground, covered with soil, and allowed to root before being separated from the parent (as in jasmine and grapevine); and **grafting**, in which the tissues of two different plants are joined—one providing the root system (stock) and the other the shoot system (scion)—to combine the qualities of both plants (as in mango, apple, and citrus). Another method is **budding**, where a single bud from one plant is inserted into another plant's stem so it can grow as part of the new plant (commonly used in rose and fruit trees). In modern horticulture, **tissue culture or micropropagation** is used to produce large numbers of disease-free clones from small pieces of plant tissue under controlled laboratory conditions (as in banana, orchids, and ornamental plants).

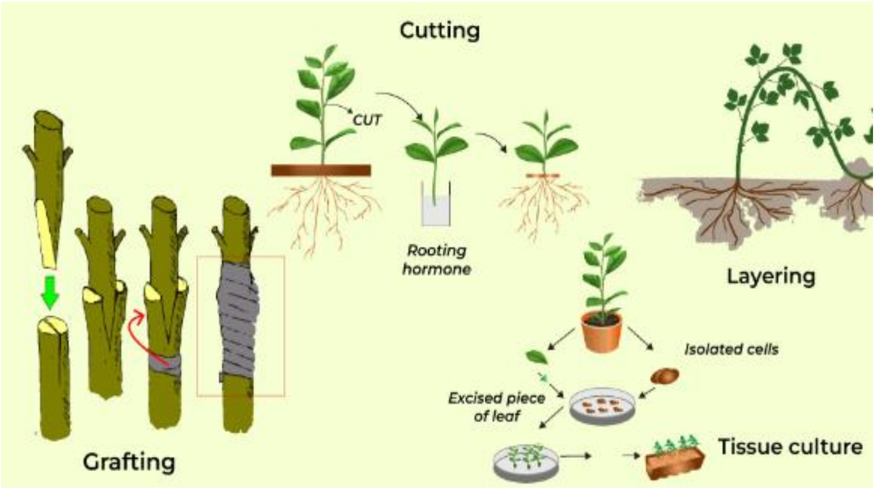

Fig. **5.6 Artificial Vegetative Reproduction**

5.2.2.1 Cutting: In plants like **Lemon, Orange**, etc., a part of the root is cut or excised and planted in a new place to grow a new plant. In plants like **Rose, Grape**, etc the stem is cut and planted to grow new plants. In plants like **Sansevieria**, etc. the leaf is cut and planted in a new place to grow a new plant. All these cut or excised parts are provided with growth promoters like IBA, and NAA to promote the new plant's growth.

5.2.2.2 Grafting: In plants like **Mango, Guava**, etc. the stem system of the desired variety is cut and inserted into the root system of another healthy plant. The stem system is called a Scion and it can be single or multiple whereas the root system is called stock and it is only one. This method can be performed in plant varieties of the same species to give rise to new healthy or multiple plants.

5.2.2.3 Layering: In plants like Jasmine, Tomatoes, etc. a single stem or multiple stems can be bent and buried in the soil to give rise to a new plant (s). Before burying the stem, an incision is made in the node from which a new plant arises. In the case of air layering or Gootee instead of burying the stem a patch of soil and peat moss is wrapped around the incised node.

5.2.2.4 Tissue Culture: It is also called **Micropropagation** and is done for plants like Bananas, Orchids, etc. in which cells or tissues of a plant are cultivated in a suitable medium in a laboratory from which multiple disease-free plantlets can be produced.

1. Vegetative reprouction allows for the maintenance and propagation of desirable traits and qualities such as disease resistance, fruit quality, and decorative features.
2. Facilitates rapid plant multiplication, making it faster and more effective than cultivating plants from seeds for propagation.
3. Ensures uniformity in terms of traits and performance among propagated plants, allowing it to be used in commercial agriculture and landscaping.
4. Allows for the cultivation of sterile hybrid plants that cannot produce viable seeds, safeguarding valuable hybrids in agriculture and horticulture.
5. Many vegetatively propagated plants grow strong root systems fast, boosting their chances of a successful establishment when transplanted.
6. Reduces the requirement for seed production, saving resources and improving the environment.
7. Promotes the protection and conservation of relatively uncommon plant kinds and animals that might not generate seeds.

5.2.3 Advantages of Vegetative Reproduction:

Vegetative reproduction offers several important advantages to plants and to cultivation practices. Since it is a form of **asexual reproduction**, the new plants produced are **genetically identical clones** of the parent, ensuring that all desirable traits—such as flower color, fruit quality, disease resistance, or growth habit—are preserved without variation. This method enables **rapid multiplication** of plants in a short time, which is particularly useful for crops and ornamentals that are in high demand. It also allows propagation of plants that **do not produce viable seeds**, have long juvenile phases, or produce seeds that are difficult to germinate, such as banana, pineapple, sugarcane, and seedless grapes. Many vegetative structures, like tubers or bulbs, store food, which supports the young plant during initial growth and increases the chances of survival. In addition, some vegetative methods (like runners or suckers) enable plants to **quickly colonize new areas**, helping them spread in nature and resist unfavorable conditions. For agriculture and horticulture, vegetative reproduction shortens the time to flowering and fruiting, ensuring **early and uniform yield**.

5.2.4 Disadvantages of Vegetative Reproduction: Although vegetative reproduction is highly useful, it also has some limitations and drawbacks. Because it is a form of **asexual reproduction**, all offspring are **genetically identical** to the parent plant. This lack of genetic variation means that if a disease, pest, or unfavorable environmental condition affects the parent plant, the entire population of clones is equally susceptible, which can lead to large-scale losses. Over time, continuous cloning may also lead to the **accumulation of harmful mutations** and reduced vigor in the population. Another disadvantage is that vegetative propagation often **requires more care, labor, and resources** when done artificially, as techniques like grafting, layering, or tissue culture need skill, equipment, and maintenance. Plants produced through vegetative means may also be **less adaptable** to changing environments because they lack the variability seen in sexually reproduced plants, which often gives populations better survival chances. Moreover, in some cases, vegetative structures like tubers or bulbs are bulky, making **storage and transportation** more difficult compared to seeds.

5.2.5 Significance of Vegetative Reproduction:

Vegetative reproduction holds great significance both in the natural world and in agriculture or horticulture. In nature, it provides plants with an **efficient and reliable means of multiplication**, allowing them to quickly cover ground and colonize new habitats without depending on seeds, pollinators, or specific environmental conditions for germination. Many perennial plants, shrubs, and grasses survive and spread through runners, suckers, rhizomes, or tubers, ensuring their persistence even under adverse conditions. For humans, vegetative reproduction is of immense practical value because it allows the **propagation of plants with desirable traits**, such as high-yielding varieties, seedless fruits, disease-resistant lines, or ornamentals with specific flower colors. Techniques like grafting, budding, and tissue culture ensure that these traits are **fixed and uniform** in the new plants, which is essential for commercial agriculture, floriculture, and gardening. Moreover, it enables the reproduction of plants that **do not produce viable seeds** or take many years to mature from seed, such as banana, pineapple, sugarcane, and many fruit trees, thereby saving time and ensuring quicker harvests. Vegetative propagation also plays a key role in **conservation programs**, where rare or endangered species are multiplied and preserved.

Summary:

A **seed** is the reproductive unit of seed-bearing plants (gymnosperms and angiosperms), formed after fertilization and containing an **embryo** capable of developing into a new plant. It is enclosed by a **seed coat** (testa) that protects it from physical damage, pathogens, and dehydration. Inside, the seed stores nutrients either in the **endosperm** or **cotyledons** to support the embryo during germination.

In angiosperms, seeds develop from fertilized **ovules** within the ovary, while in gymnosperms, they develop on cone scales without an enclosing fruit. Seeds can be classified based on the number of cotyledons (**monocots** with one cotyledon, **dicots** with two). They remain dormant until favorable conditions (water, oxygen, temperature, sometimes light) trigger **germination**, during which the radicle (embryonic root) emerges first, followed by the plumule (embryonic shoot).

Multiple Choice Questions (MCQs):

1. **The outer protective layer of a seed is called:**

a) Embryo

b) Seed coat

c) Endosperm

d) Cotyledon

Ans. b) Seed coat

2. **The food storage tissue in most monocot seeds is:**

a) Cotyledon

b) Endosperm

c) Seed coat

d) Embryo

Ans. b) Endosperm

3. **Which of the following factors is NOT essential for seed germination?**

a) Water

b) Light

c) Oxygen

d) Temperature

Ans. b) Light

4. **The ability of a seed to remain inactive before germination is called:**

a) Seed dormancy

b) Seed dispersal

c) Seed formation

d) Seed viability

Ans. a) Seed dormancy

5. **The process by which new plants are formed from vegetative parts of a parent plant is called:**

a) Sexual reproduction

b) Pollination

c) Vegetative reproduction

d) Double fertilization

Ans. c) Vegetative reproduction

6. **Which of the following is an artificial method of vegetative reproduction?**

a) Budding

b) Fragmentation

c) Grafting

d) Spore formation

Ans. c) Grafting

7. **The primary function of a seed is:**

a) Photosynthesis

b) Water transport

c) Protection and dispersal of the embryo

d) Nutrient absorption

Ans. c) Protection and dispersal of the embryo

8. **The part of the embryo that develops into the shoot system is:**

a) Radicle

b) Plumule

c) Cotyledon

d) Endosperm

Ans. b) Plumule

9. **A seed bank is used for:**

a) Storing food grains

b) Conserving plant genetic diversity

c) Producing hybrid seeds

d) Enhancing seed dormancy

Ans. b) Conserving plant genetic diversity

10. Which hormone helps in breaking seed dormancy?

a) Abscisic acid

b) Ethylene

c) Gibberellin

d) Cytokinin

Ans. c) Gibberellin

Short Questions:

1. What are the main components of a seed?
2. Differentiate between monocot and dicot seeds.
3. What is seed dormancy, and why is it important?
4. How does water affect seed germination?
5. Explain the role of endosperm in seed development.
6. Define vegetative reproduction with examples.
7. What is the significance of seed banks?
8. Describe the structure of an embryo in a seed.
9. How does temperature influence seed germination?
10. What are the advantages of vegetative propagation?

Long Questions:

1. Explain the process of seed development with diagrams.
2. Discuss the different types of seed dormancy and methods to break dormancy.
3. Describe the factors affecting seed germination in detail.
4. Compare and contrast sexual and vegetative reproduction in plants.

5. Explain different methods of vegetative propagation with examples.
6. How do seeds contribute to plant diversity and conservation?
7. Discuss the economic importance of seeds in agriculture and industry.
8. Explain the role of plant hormones in seed dormancy and germination.
9. How does seed dispersal affect plant distribution and survival?
10. Describe the process of grafting and its applications in horticulture.

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