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**Course Handout of
"Plant Biology 1"
Intended for First-Year Engineering Students in
Agronomic Sciences**

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Chapter I: Introduction to plant biology

Introduction

- **Definition of plant biology**

Plant biology is a broad discipline that encompasses all aspects of plant life, both aquatic and terrestrial, including their morphologies, modes of reproduction (sexual and asexual), adaptations to various environments, and the mechanisms enabling sustainable interactions (such as parasitism and symbiosis) (Campell et al., 2008).

The living world consists of an immense collection of organisms in constant evolution. It is divided into two biotic groups (prokaryotes and eukaryotes) and six kingdoms: Archaea, Eubacteria, Protists, Fungi, Animals, and Plants (Margulis & Schwartz, 1988; Raven et al., 2013).

- **Major stages of discoveries in plant biology**

The time period	Big concepts	Discoverer researcher	Dates
Middle Ages (from 500 to 1453)	Anatomy, physiology, medicine	Hippocrate	459-377 before Jesus Christ
	Classification	Théophraste	370-285 before Jesus Christ
18th Century	The cell	Hoocke	1635-1703
	Plant tissues	Grew	1641-1712
The Age of Enlightenment	Binary classification (Plant and animal)	Linné	1707-1778
	Plant transpiration	Hales	1677-1761
	Breathing and mineral composition of plants	Lavoisier	1743-1794

I.1 Systematic

I.1.1. Introductory definitions

- **Taxonomy:** Concerned primarily with naming and classifying organisms into a hierarchical structure.
- **Systematics:** Encompasses taxonomy but also includes the study of evolutionary relationships and the processes driving biodiversity.
- **Classification:** The systematic grouping of living organisms (plants, animals, etc.) based on shared characteristics or traits.
- **Nomenclature:** The formal system of assigning names to taxonomic groups.

- **Hierarchy:** A structured system where each classification is part of a larger group and may contain smaller, subordinate categories.
- **Morphology:** The study of the form and structure of organisms, particularly plants.
- **Phylogeny:** The evolutionary history and ancestral relationships among organisms. Historically, plant taxonomy was based on morphology, but advances in molecular genetics now allow for the confirmation and expansion of these relationships through DNA sequence comparisons (Tudge, 2000; Raven *et al.*, 2005; Simpson, 2010).

I.1.2. Classification system of living world

The classification of living organisms follows a **hierarchical system** composed of **eight major taxonomic ranks**: Domain, Kingdom, Phylum (or Branch), Class, Order, Family, Genus, and Species. These main categories can be further subdivided into additional ranks, such as sub-phylum, super-class, sub-class, and sub-species, allowing for finer levels of classification within each group (Campbell *et al.*, 2002) (see Figure 1).

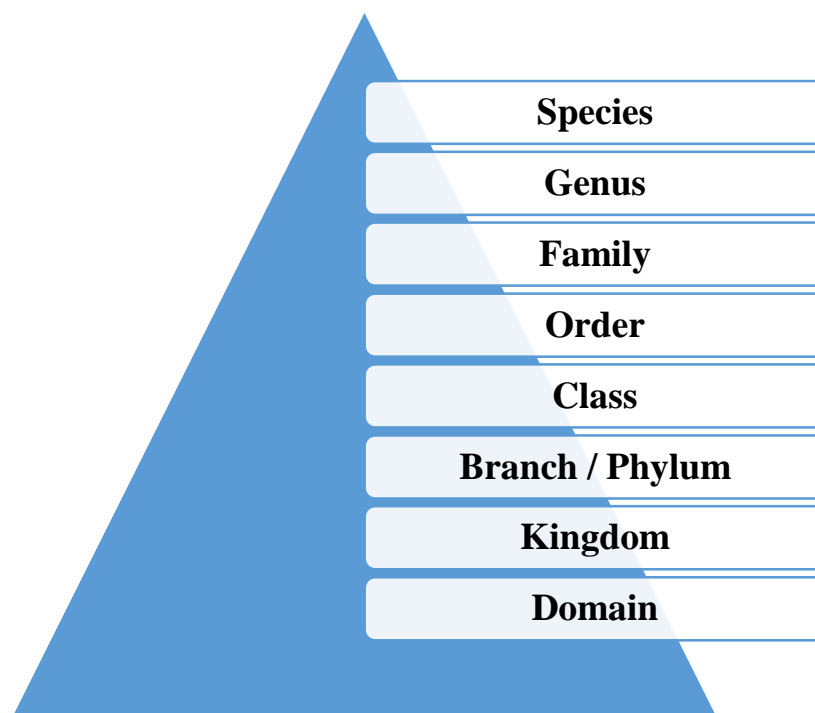


Figure 1. Classification hierarchy system (from bottom to top)

I.1.2.1. Binomial nomenclature

In biology, a plant (or animal) is identified by a **binomial nomenclature** consisting of two Latin names (Simpson, 2010):

- The **genus name**, with the first **letter capitalized**.
- The **species name**, with the first **letter in lowercase**.

Both names are either italicized or underlined. For example, *Pinus halepensis* or Pinus halepensis.

I.1.2.2. Historical and organization of the living world

- Classification of Carl von Linné (1707-1778)

Carl von Linné, also known as **Carl Linnaeus**, was a Swedish naturalist who laid the foundation for modern biological classification. Based on morphological characteristics, he subdivided the living world into two kingdoms: **Animalia** (Animals) and **Plantae** (Plants) (Stafleu, 1971; Koerner, 1999). (see **Figure 2**).

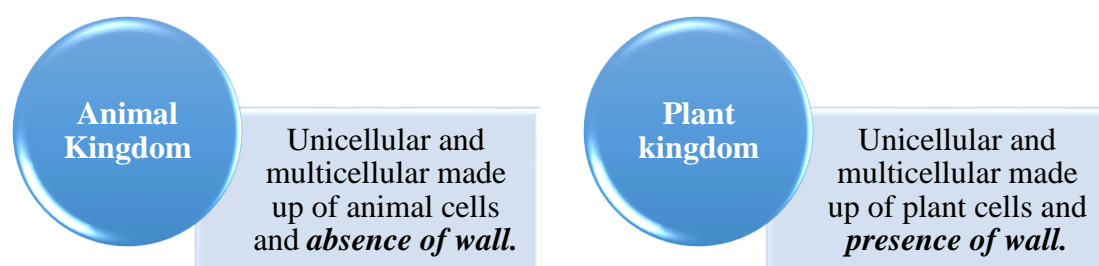


Figure 2. Classification of living world by **Carl von Linné (1707-1778)**

- Classification of Ernest Haeckel (1886)

Classify the living world into three kingdoms: Animals, Plants and Prokaryotes (unicellular prokaryotes).

- Classification of Robert Whittaker (1969)

Classify the living world into five kingdoms (see **Figure 3**):



Figure 3. Classification of living world by **Whittaker (1969)**

- Classification of Carl Woese et al. (1977)

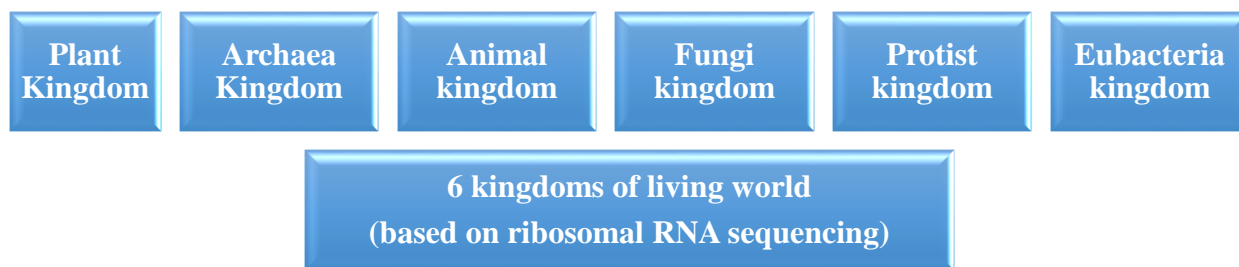


Figure 4. Classification of living world by **Woese *et al.* (1977)**

Based on ribosomal RNA sequences, we can now distinguish six major groups of life:

- **Archaea** (unicellular, prokaryotic)
- **Eubacteria** (unicellular, prokaryotic)
- **Protists** (unicellular, eukaryotic)
- **Plants** (multicellular, eukaryotic)
- **Animals** (multicellular, eukaryotic)
- **Fungi** (unicellular or multicellular, eukaryotic)

Archaea and Eubacteria possess *prokaryotic cells*, characterized by the absence of a nucleus. Their cells consist of an outer cell wall, a plasma membrane, and circular DNA floating within the cytoplasm (**Woese, 1990; Margulis, 1998**).

Protists, Fungi, Animals, and Plants are composed of *eukaryotic cells*, which have a plasma membrane (sometimes protected by an external wall), a cytoplasm containing a nucleus, a cytoskeleton, and an endomembrane system. These cells may also have locomotor structures, such as flagella, and include various intracellular organelles acquired through endosymbiosis, such as mitochondria and chloroplasts (**Woese, 1990; Campbell, 2008**).

- **Classification of Carl Woese (1999)**

The creation of a taxon higher than the kingdom is referred to as a "**Domain.**" All living organisms are now classified into three major domains based on differences in ribosomal RNA sequences and cellular organization (**Woese, 1990; Campbell, 2008**). (see **Figure 5**):

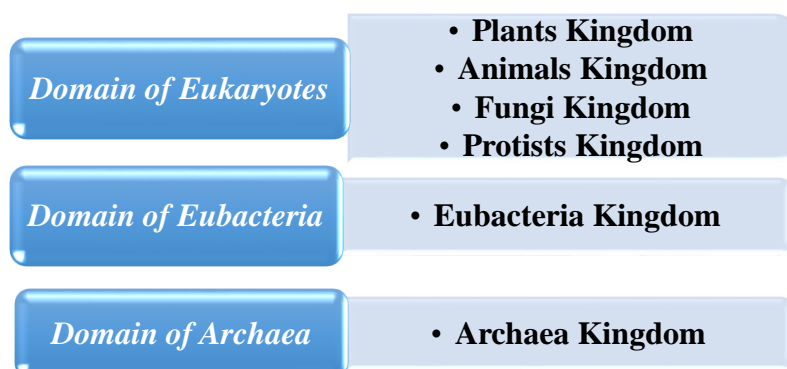


Figure 5. Classification of **Woese (1990)**

I.2.2. Organization of the plant kingdom

The plant kingdom is organized into two main evolutionary lineages:

a) Green lineage: This includes green algae, red algae, and terrestrial plants (land plants), which share common characteristics such as chlorophyll and cell wall structures (see **Figure 6** for green and red algae, and **Figure 7** for terrestrial plants) (**Graham et al., 2008**).

b) Brown lineage: This group consists primarily of brown algae, which have distinct pigmentation (fucoxanthin) and cellular structures adapted to aquatic environments (see **Figure 8** for brown algae) (**Graham et al., 2008; Raven et al., 2013**).



Figure 6. Green and red algae (Anonymous 1 & 2)



Figure 7. Terrestrial plants (Anonymous 3)



Figure 8. Brown algae (Anonymous 4)

According to the presence or absence of flowers, the plant kingdom is divided into two major categories:

a) Cryptogams (plants without flowers)

- **Phycophytes:** Aquatic, chlorophyll-containing thallophytes. Examples include green, brown, and red algae (see **Figure 9**).
- **Pteridophytes:** Plants that possess stems, leaves, roots, and a vascular system, but lack flowers. Example: Ferns (see **Figure 10**).
- **Bryophytes:** Plants that have stems and leaves but lack true roots, flowers, and a vascular system. Example: Mosses (see **Figure 11**).



Figure 9. Phycophytes (Different type of algae)

(Anonymous 5)



Figure 10. Pteridophytes (Ferns)

(Anonymous 6)



Figure 11. Bryophytes (Mosses) (Anonymous 7)

b) Phanerogams (flowering plants)

- **Prespermatophytes:** An intermediate group between Pteridophytes and Spermatophytes. These plants have ovules but do not produce seeds. Example: *Ginkgo biloba* (Raven *et al.*, 2013; Judd *et al.*, 2016).
- **Spermatophytes:** Divided into three sub-branches (Raven *et al.*, 2013; Judd *et al.*, 2016):
 - ❖ **Gymnosperms:** Derived from Greek "Gymno" meaning naked and "Sperma" meaning seed. The reproductive organ is the cone, and the ovules are exposed on the scales of the cones without any protective envelope (see **Figure 12**). Example: Pine trees.
 - ❖ **Angiosperms:** Derived from Greek "Angio" meaning closed and "Sperma" meaning seed. The reproductive organ is the flower, and the ovules are enclosed within an ovary (see **Figure 13**). Example: Flowering plants.
 - ❖ **Chlamydosperms:** Derived from Greek "Chlamydo" meaning envelope and "Sperma" meaning seed. In this endangered group, the ovules are surrounded by a simple envelope. Example: *Ephedra*.



Figure 12. Reproductive organs of Gymnosperms (Cones and scales) (Anonymous 8 & 9)

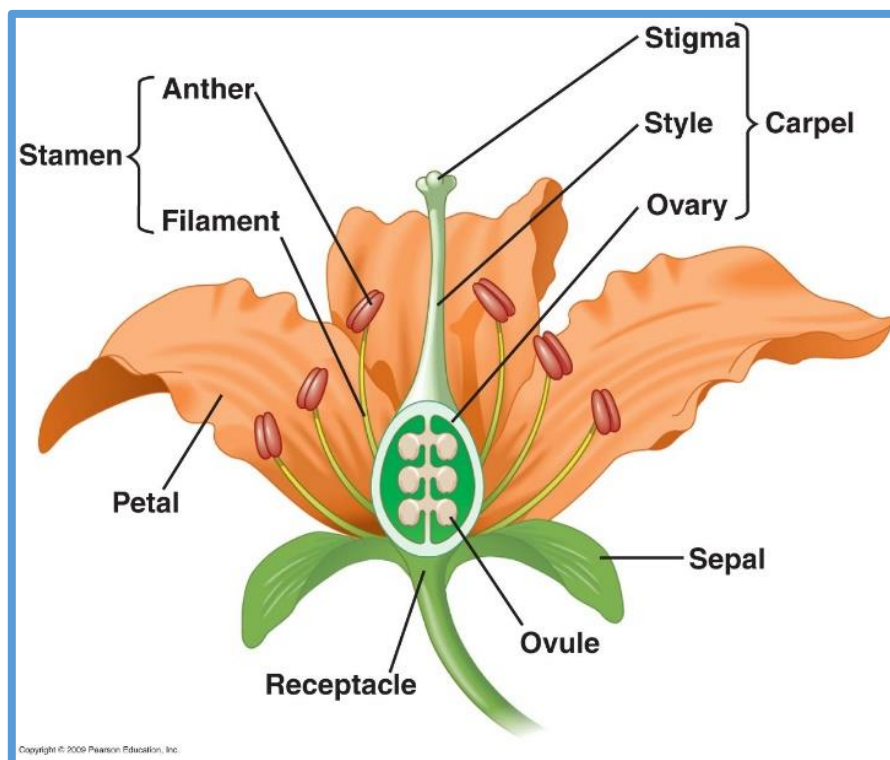


Figure 13. Reproductive organ of Angiosperms (Flower) (**Anonymous 10**)

I.2. Plant cytology

Plant cytology is the branch of biology that focuses on the structure, function, and life processes of plant cells. Understanding plant cells is essential for studying plant physiology, growth, development, and interactions with the environment (**Raven *et al.*, 2013**).

I.2.1. Structure of plant cells

Plant cells have several unique features (see **Figure 14**) :

- **Cell Wall:** Composed mainly of cellulose, it provides rigidity and support (**Campbell *et al.*, 2008**).
- **Plasma Membrane:** A semi-permeable membrane that controls the movement of substances in and out of the cell (**Alberts *et al.*, 2002**).
- **Cytoplasm:** The internal fluid where cellular organelles are suspended (**Taiz & Zeiger, 2010**).
- **Nucleus:** Contains the genetic material (DNA) and regulates cellular functions (**Raven *et al.*, 2013**).
- **Vacuole:** A large central organelle storing water, nutrients, and waste, also playing a key role in maintaining turgor pressure (**Campbell *et al.*, 2008**).
- **Chloroplasts:** Organelles responsible for photosynthesis, containing chlorophyll to capture light energy (**Raven *et al.*, 2013**).
- **Mitochondria:** The site of ATP production through cellular respiration (**Alberts *et al.*, 2002**).

- **Endoplasmic Reticulum (ER):** Involved in protein and lipid synthesis, with the rough ER housing ribosomes (Taiz & Zeiger, 2010).
- **Golgi Apparatus:** Modifies and packages proteins and lipids for transport (Alberts *et al.*, 2002).

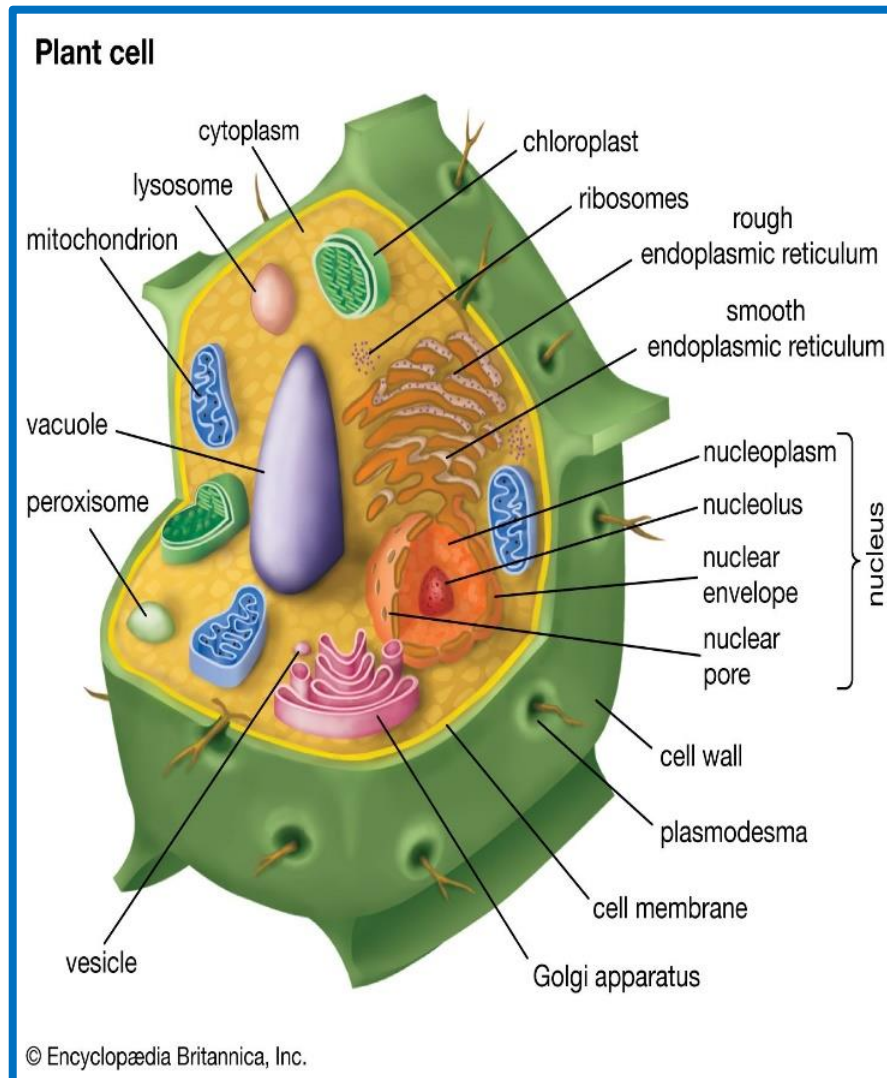


Figure 14. Plant cell structure (Anonymous 11)

I.2.2. Plant cell cycle

- **Interphase:** Cells grow and replicate their DNA in preparation for division (Raven *et al.*, 2013) (see Figure 15).
- **Mitosis:** Plant cells divide through four stages: prophase, metaphase, anaphase, and telophase (Campbell *et al.*, 2008) (see Figure 15).

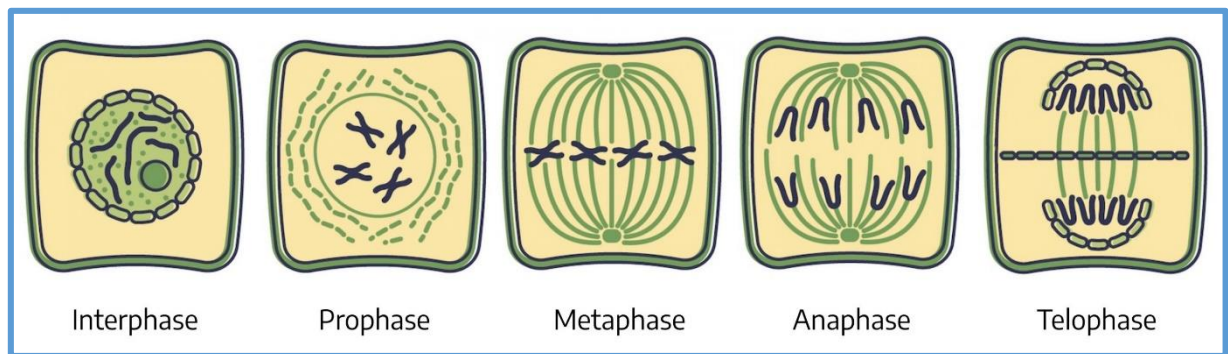


Figure 15. Different stages of plant cell cycle (**Anonymous 12**)

- **Cytokinesis:** The cytoplasm divides, completing the formation of two daughter cells (**Taiz & Zeiger, 2010**).

I.2.3. Photosynthesis and energy production

- **Photosynthesis:** Occurs in the chloroplasts and consists of two stages: light-dependent reactions that generate ATP and NADPH, and the Calvin cycle that fixes carbon into sugars (**Campbell *et al.*, 2008**) (see **Figure 16**).
- **Cellular respiration:** The breakdown of glucose in mitochondria to produce ATP for energy (**Alberts *et al.*, 2002**) (see **Figure 16**).

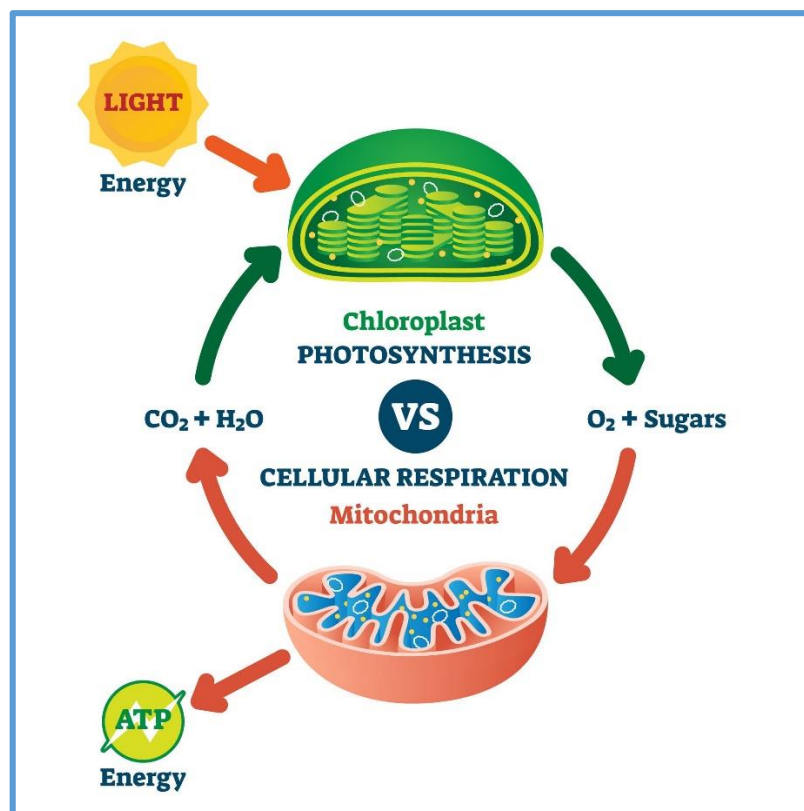


Figure 16. Relation between photosynthesis and cellular respiration (**Anonymous 13**)

I.2.4. Cellular reproduction and growth

- **Asexual Reproduction:** Cells divide by mitosis to produce genetically identical offspring (Campbell *et al.*, 2008).
- **Sexual Reproduction:** Involves meiosis to form gametes, introducing genetic diversity (Raven *et al.*, 2013).

Chapter II: Morphology of higher plants

Introduction

Plant Morphology or **Phytomorphology** is a branch of botany that focuses on describing the shape and external structure of plants and their organs. It plays a vital role in understanding plant form and function (Esau, 1977).

II.1. Root morphology

The **root** is a non-chlorophyllous, underground organ characterized by endogenous branching. Its main functions are to anchor the plant and absorb water and dissolved mineral nutrients from the soil (Raven *et al.*, 2013).

II.1.1. Organization of the root system

The root system is divided into several zones, starting from the top and progressing downward (see Figure 17) (Esau, 1977):

- **Collar:** The junction between the root and the stem, usually aligned with ground level.
- **Branching Zone (Zone of Maturation):** Located just above the root hairs, this is where lateral roots emerge.
- **Absorbent Hairs (Root Hairs):** Tiny hair-like extensions responsible for absorbing water and dissolved minerals from the soil.
- **Elongation Zone:** This region lies between the root cap and the root hairs and is where the root elongates due to the activity of the lateral and apical meristems.
- **Meristematic Zone (Zone of Division):** Situated at the root tip, where active cell division occurs, contributing to root growth.
- **Cap:** A protective organ that covers the tip of the root, allowing the root to penetrate the soil and safeguarding the delicate, developing tissues beneath (Raven *et al.*, 2013).

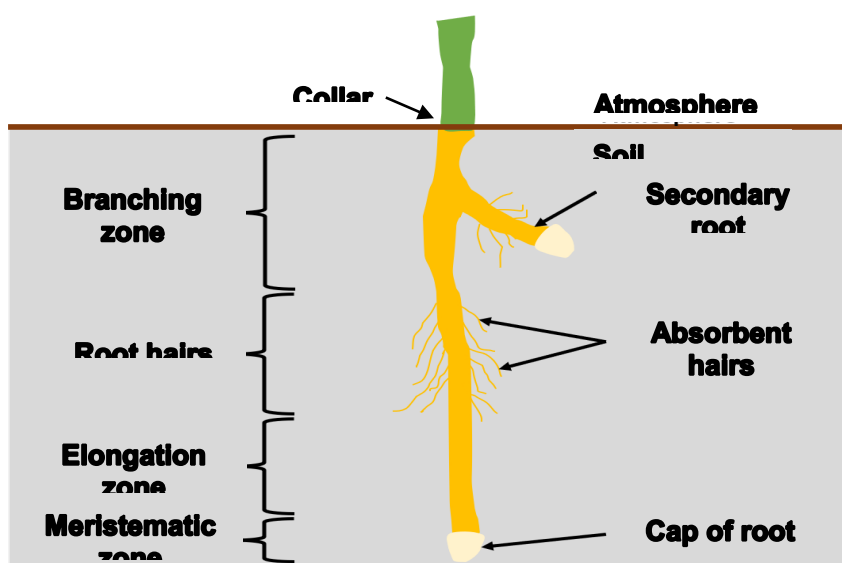


Figure 17. Organization of the root system (Anonymous 14)

II.1.2. Different types of root

Plants exhibit three main types of root systems, with additional specialized forms that provide adaptations to various environments:

- a) **Taproot:** A large, vertical root branching into numerous secondary roots. This system provides strong anchorage, enabling the plant to withstand environmental forces such as wind, gravity, and water runoff. Example: Fruit trees like apricot, citrus, and pomegranate (**Raven et al., 2013**) (**Figure 18**).
- b) **Fibrous:** This system consists of several roots of equal size that develop close to the soil surface. It enhances soil fixation and increases the contact surface for nutrient and water absorption. Example: Wheat, barley (**Raven et al., 2013**). (**Figure 19**).
- c) **Adventitious:** Roots that grow from any plant part other than the roots, such as stems or leaves. Example: Strawberry, many gymnosperms like pine (Esau, 1977). (**Figure 20**).
- d) **Others forms of adaptation roots:** There are eight distinct types of specialized roots adapted for specific environments or functions:
 - **Tubers Root:** Found in biennial plants, these hypertrophied roots store reserves that allow the plant to resume vegetative growth after adverse seasons. Example: Carrots, beets (see **Figure 21.a**) (**Raven et al., 2013**).
 - **Holdfasts Root:** Aerial adventitious roots that provide firm attachment to surfaces like walls or trees. Example: Climbing ivy (see **Figure 21.b**) (**Esau, 1977**).
 - **Respiratory Roots (Pneumatophores):** Aerial roots that supply oxygen to roots growing in oxygen-poor environments, such as swamps. Example: White mangrove tree (see **Figure 21.c**) (**Raven et al., 2013**).
 - **Stilt Roots:** Aerial adventitious roots that help stabilize the plant in unstable or shifting substrates by supporting the trunk. Example: Mangroves, maize (see **Figure 21.d**) (**Esau, 1977**).
 - **Pillar Roots:** Adventitious roots that help support tree branches. Example: Ficus (see **Figure 21.e**) (**Raven et al., 2013**).
 - **Buttress Roots:** Lateral aerial roots at the base of trees, used to stabilize the plant in light or sandy soils. Example: Ficus (see **Figure 21.f**) (**Raven et al., 2013**).
 - **Sucking Roots:** These roots are typical of parasitic plants, used to extract nutrients from host plants. Example: Mistletoe (see **Figure 21.g**) (**Esau, 1977**).
 - **Hanging Roots:** Roots found in epiphytic plants, allowing them to attach to other plants without parasitizing them. These roots are covered with a veil capable of absorbing rainwater. Example: Orchids (see **Figure 21.h**) (**Raven et al., 2013**).
 - **Strangler Roots:** Ficus species germinate on other trees and send aerial roots down the trunk, eventually enveloping and killing the host tree. Example: Ficus (**Figure 21.i**) (**Esau, 1977**).

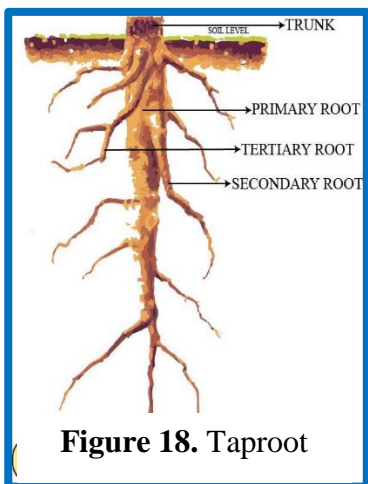


Figure 18. Taproot

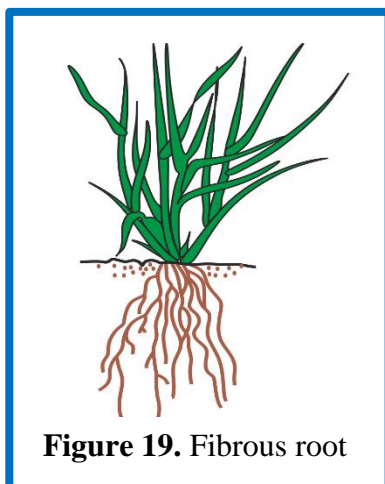


Figure 19. Fibrous root

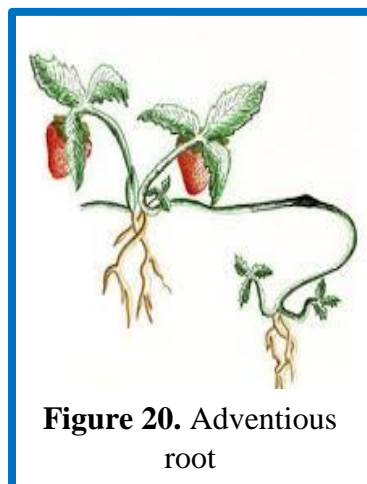


Figure 20. Adventitious root

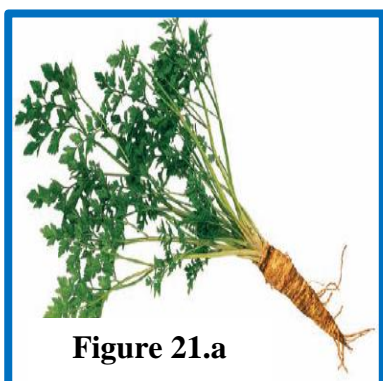


Figure 21.a



Figure 21.b

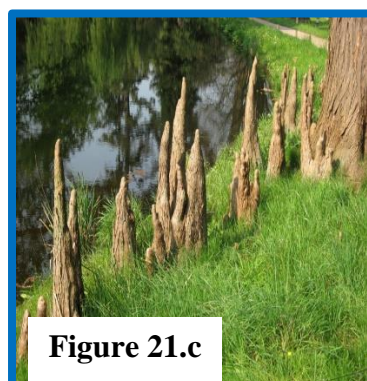


Figure 21.c

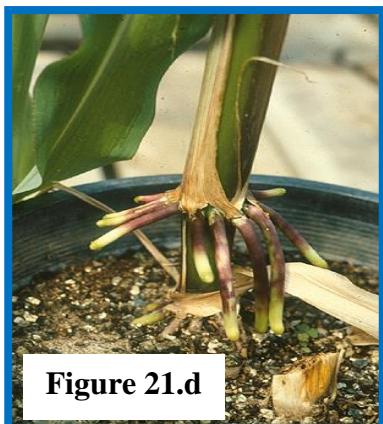


Figure 21.d

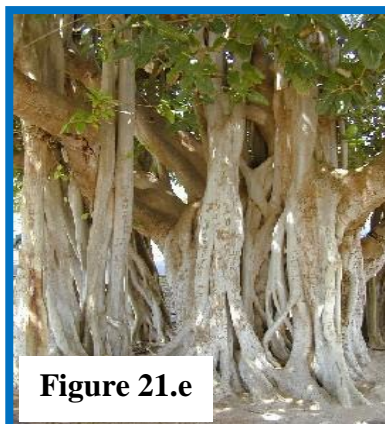


Figure 21.e

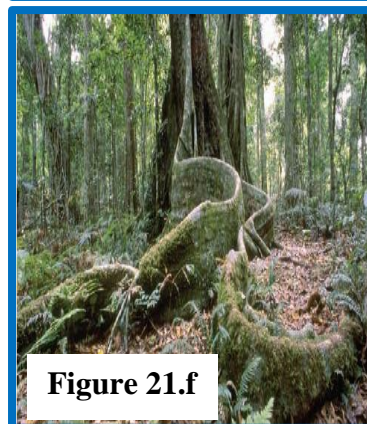


Figure 21.f

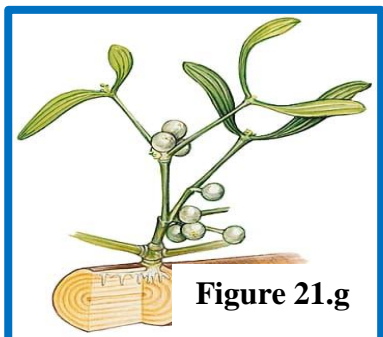


Figure 21.g



Figure 21.h

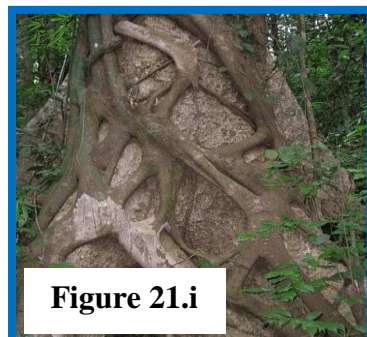


Figure 21.i

Figure 21. (a) Tubers root, (b) Holdfasts root, (c) Respiratory root, (d) Stilts root, (e) Pillar root, (f) Buttress root, (g) Sucking root, (h) Hanging root, and (i) Strangler root (Anonymous 15 to 26).

II.1.3. Root function

Roots perform several vital functions in plants:

- **Anchorage:** Roots anchor the plant firmly to the soil, providing mechanical stability and support, ensuring the plant remains upright (**Raven et al., 2013**).
- **Absorption:** Roots absorb water and dissolved minerals from the soil and transport them upward through the plant's vascular system to support various physiological processes (**Esau, 1977**).
- **Storage:** Roots serve as storage organs for carbohydrates produced during photosynthesis, which can be utilized during periods of low energy availability (**Esau, 1977**).
- **Hormone Production:** Roots produce and export plant hormones such as cytokinins and gibberellins. Cytokinins promote cell division, while gibberellins stimulate plant growth and elongation (**Raven et al., 2013**).

II.2. Stem morphology

The **stem** is generally the aerial part of the plant's axis, supporting the leaves and reproductive organs. It continues from the root, and the region where the root and stem connect is known as the collar (**Esau, 1977**).

II.2.1. Organization of the stem system

In a stem system, several parts can be distinguished (see **Figure 22**) (**Esau, 1977**):

- a) **Node:** The point where leaves and buds are attached.
- b) **Internode:** The space between two nodes.
- c) **Bud:** These are stem meristems covered by protective scales. There are three types of buds:
 - **Terminal Bud (Apical):** Located at the end of the main axis, responsible for the plant's length growth and the formation of axillary buds.
 - **Axillary Bud (Lateral):** Found in the leaf axils on the stem, responsible for producing leafy branches or flowers.
 - **Adventitious Buds:** These do not have a specific position and can appear in unexpected areas.

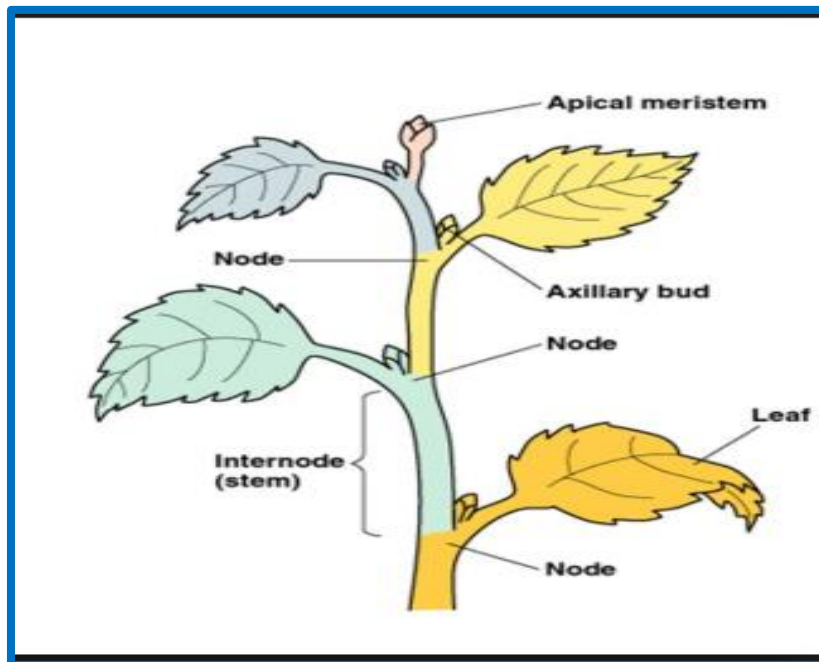


Figure 22. Organization of stem system (Anonymous 27)

II.2.2. Different types of stem

a) Erect Stems: These stems grow vertically, which is the most common growth habit for stems (Raven *et al.*, 2013).

b) Creeping Stems: These stems spread horizontally and are often involved in vegetative propagation. They can either grow on the surface (like stolons) or beneath the ground (like suckers) (see Figure 23) (Esau, 1977).

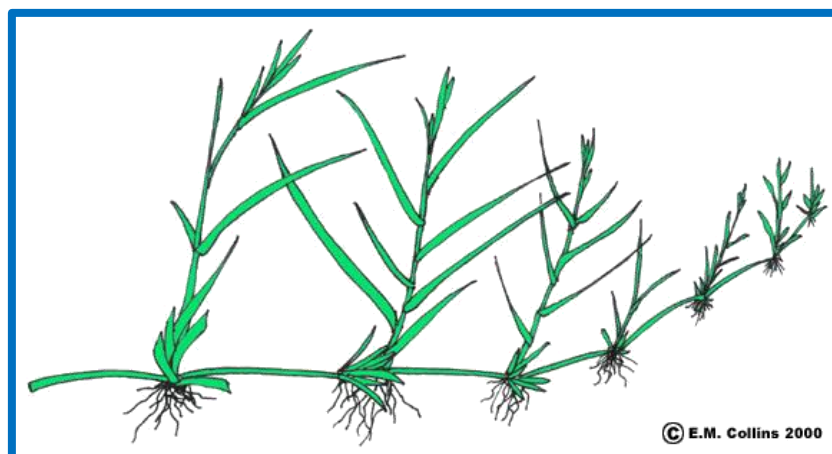


Figure 23. Creeping stems (stolons of strawberry) (Anonymous 28)

c) Climbing stems

These stems enable plants to climb over other structures or plants through various mechanisms:

- **Simple climbing stems:** Often equipped with holdfasts such as adventitious roots that allow the plant to attach to surfaces (**Raven *et al.*, 2013**). (**Figure 21.b**).
- **Twining stems:** These stems wrap around their support, using a coiling mechanism (**Esau, 1977**). (**Figure 24.a**).
- **Tendrils:** Tendrils are specialized organs that help the plant attach to structures for support. Tendrils wind around their support in response to contact, a phenomenon called haptotropism. Tendrils may originate from the stem, as seen in grapevines, or from leaves, as in legumes (**Raven *et al.*, 2013**). (**Figure 24.b**).

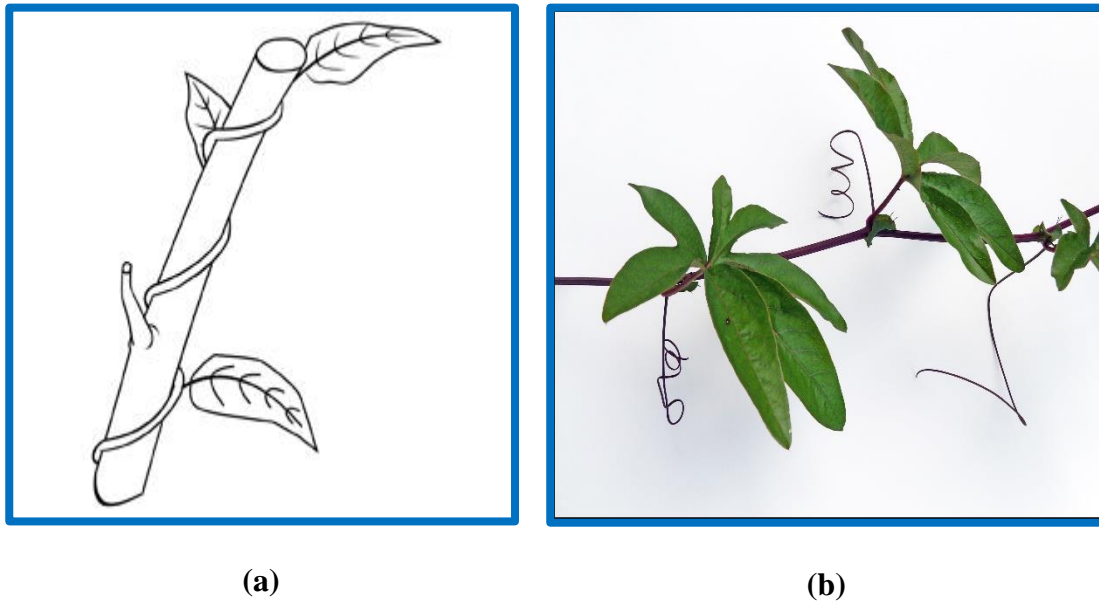


Figure 24. (a) Twining stem, and (c) Tendril stem (**Anonymous 29 to 30**)

- d) **Succulent stems:** found in plants such as cacti and some species of *Euphorbia*, store water to help the plant survive in arid, desert environments. This water storage is a key adaptation to drought conditions, allowing these plants to maintain hydration during prolonged dry periods (**Esau, 1977; Raven *et al.*, 2013**). (**Figure 25**).

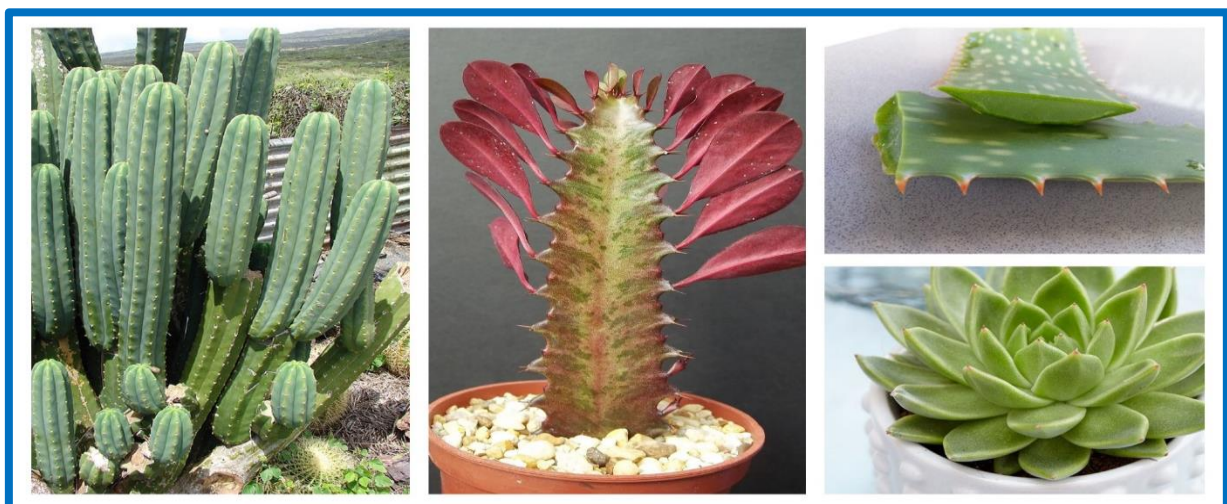
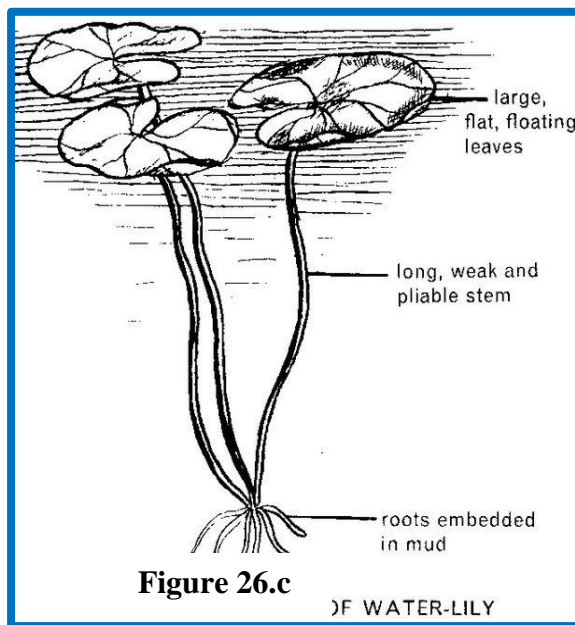
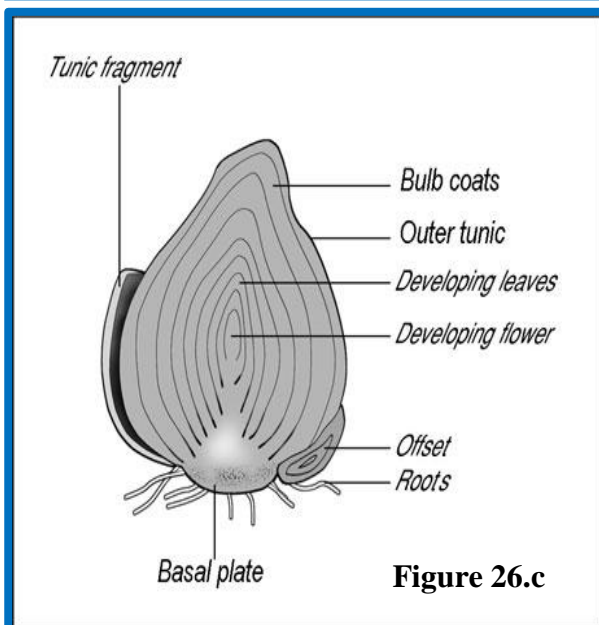
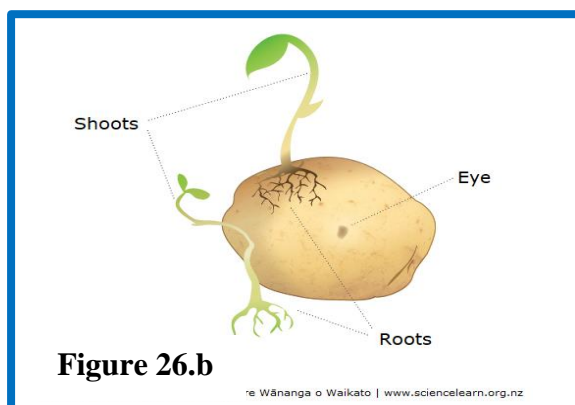
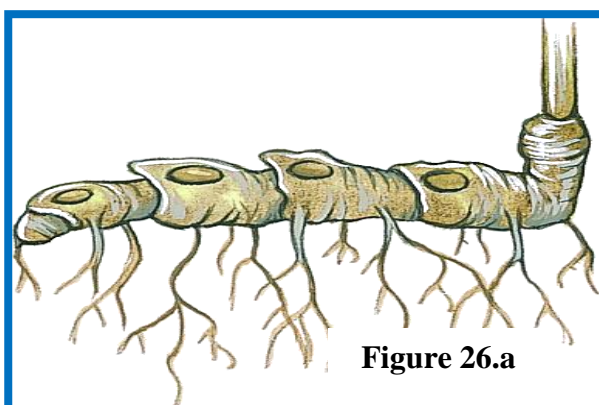


Figure 25. Succulent stem (**Anonymous 31**)

e) *Others forms of stems adaptation:*

- **Rhizomes:** These are underground, most often horizontal stems, characterized by scaly leaves and short nodes. Rhizomes periodically emit aerial branches (see **Figure 26.a**). Example: ginger (*Zingiber officinale*) (**Raven et al., 2013**).
- **Tubers:** Underground stems that are swollen due to the storage of nutrients, with internodes that are closer together than those in rhizomes (see **Figure 26.b**). Example: potato (*Solanum tuberosum*) (**Esau, 1977**).
- **Bulbs:** A short underground axis with fleshy leaves that store nutrients (see **Figure 26.c**). Example: onion (*Allium cepa*) (**Raven et al., 2013**).
- **Aquatic Stems:** These stems differ structurally from aerial stems and can remain fully or partially submerged in water (see **Figure 26.d**) (**Esau, 1977**).
- **Stemless Plants:** These plants have very short internodes, resulting in a rosette arrangement of leaves (see **Figure 26.e**). Example: lettuce (*Lactuca sativa*) (**Raven et al., 2013**).
- **Thorns:** In some species, stems are transformed into thorns, serving as a defense mechanism against herbivores (see **Figure 26.f**). Example: hawthorn (*Crataegus*) (**Esau, 1977**).



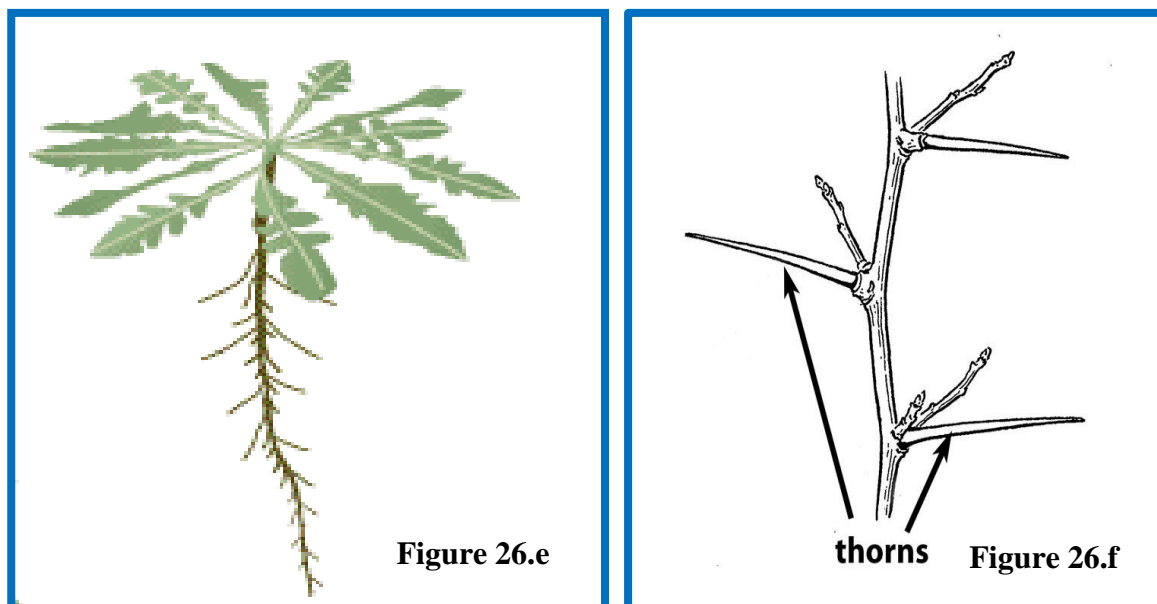


Figure 26. (a) Rhizome, (b) Tuber, (c) Bulb, (d) Aquatic stem, (e) Stemless plant, and (f) Thorn.

II.2.3. Stem function

The stem plays a fairly complex role; it supports, through wood fibers, the branches, leaves, flowers and fruits. It carries sap from the roots to the leaves, fruits and storage organs for the wood vessels.

II.3. Leaf morphology

Leaves form from the terminal bud during stem growth.

II.3.1. Morphological organization of the leaf

The morphology of leaves encompasses their physical structure, arrangement, and variations among different plant species. Understanding leaf morphology is crucial for identifying plant species and understanding their adaptations to different environments. Basic parts of leaves are (see **Figure 27**) :

a) Limb (Blade): it is a thin green broad (large) portion of the leaf with variable shape and seize. We distinguish the following parts:

- **Apex:** Leaf tip.
- **Margin:** Leaf edge boundary area. Margins can be smooth, jagged (toothed), lobed, or parted
- **Midrib:** Vascular tissue bundles that support the leaf and transport nutriments, it is a central main vein arising from petiole.
- **Veins and veinlets:** branch from the midrib.
- **Base:** area of the leaf that connects the blade to the petiole

b) Petiole: thin stalk that attaches the leaf to a stem

c) Accessory elements of the leaf base: leaf-like structures at the leaf base, such as:

- **Sheath:** this is the enlarged part of the base of the petiole which envelops the stem.
Example: It is very developed in Monocotyledons and mainly in the family Poaceae (Wheat, Rice ...etc.) and Cyperaceae.
- **Stipule:** these are 2 small green blades, located at the base of the petiole.
- **Ligule:** it is a splitting of the limb at the point of attachment to the sheath. It is found mainly in Poaceae (*Example:* Wheat, Barley ...etc.).

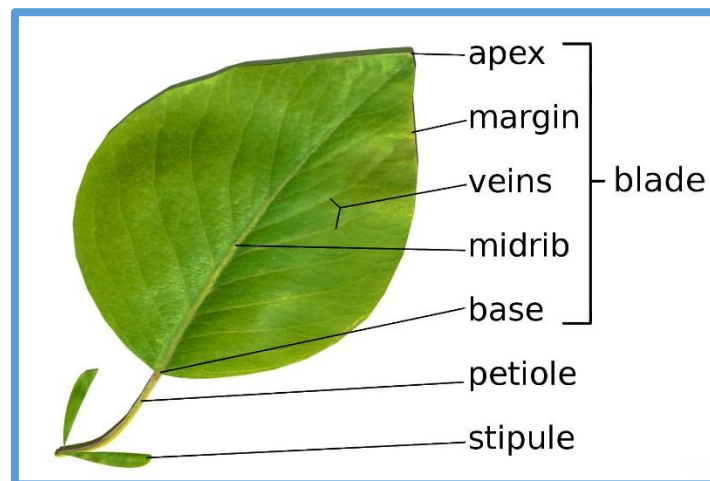


Figure 27. Organization of the leaf

II.3.2. Different types of leaves

II.3.2.1. Grouping of leaves

a) Simple Leaf: A simple leaf consists of a single, undivided blade connected to the stem by a petiole. Examples include *Mangifera indica* (Mango) and *Psidium guajava* (Guava) (Esau, 1977).

b) Compound Leaf: A compound leaf is made up of two or more leaflets attached to a single petiole. The midrib (rachis) of the leaf branches into different leaflets. An example is *Pisum sativum* (Pea) (Fahn, 1990).

Compound leaves can be further classified as follows:

- **Palmately Compound Leaf:** In a palmately compound leaf, the leaflets are attached at a common point at the tip of the petiole (see **Figure 28 to 29**) (Esau, 1977). This type can be divided into:
 - ❖ **Unifoliate:** These leaves have only one leaflet. Example: *Citrus spp.* (Fahn, 1990).
 - ❖ **Bifoliate:** These leaves have two leaflets. Example: *Balanites aegyptiaca* (Metcalfe & Chalk, 1950).

- ❖ **Trifoliate:** These leaves have three leaflets emerging from the same point. Example: *Oxalis spp.* (Fahn, 1990).
- ❖ **Quadrifoliate:** These leaves have four leaflets. Example: *Marsilea quadrifolia* (Metcalf & Chalk, 1950).
- ❖ **Multifoliate:** These leaves have multiple leaflets arising from a common point. Example: *Bombax ceiba* (Esau, 1977).

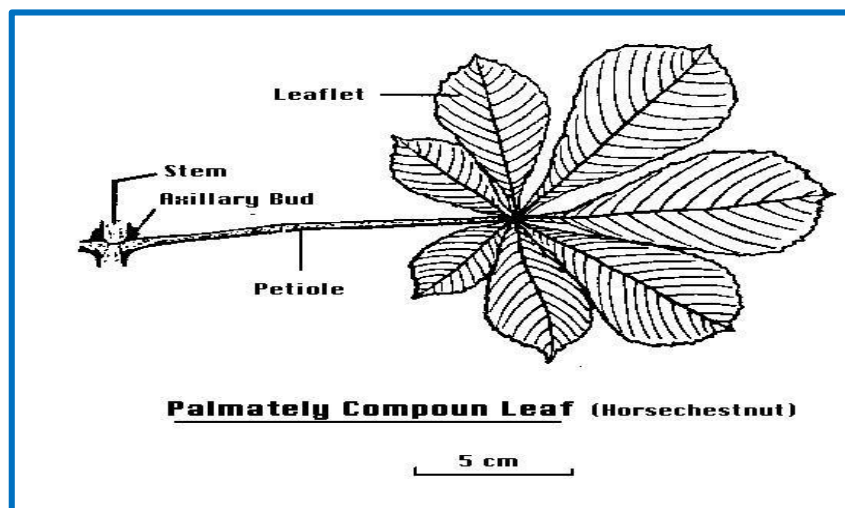


Figure 28. Palmately compound leaf



Figure 29. Different types of palamtely leaves

- **Pinnately Compound Leaf:** In a pinnately compound leaf, the midrib (rachis) is divided into multiple leaflets, all attached along a common central axis. An example is *Azadirachta indica* (Neem) (see Figure 30) (Esau, 1977). Pinnately compound leaves can be further classified into:
 - ❖ **Pinnate:** A compound leaf where leaflets are arranged on both sides of a common axis. Example: *Juglans regia* (Walnut) (Fahn, 1990).
 - ❖ **Unipinnate:** A leaf with leaflets arranged on either side of the central axis. Example: *Cassia spp.* (Metcalf & Chalk, 1950).

- ❖ **Bipinnate:** A leaf with a secondary axis bearing leaflets emerging from the central axis. Example: *Acacia spp.* (Esau, 1977).
- ❖ **Tripinnate:** A leaf where a tertiary axis bearing leaflets arises from the secondary axis. Example: *Moringa oleifera* (Fahn, 1990).
- ❖ **Decomound:** A leaf with more than three pinnate divisions. Example: Older leaves of *Coriandrum sativum* (Coriander) (Metcalf & Chalk, 1950).
- ❖ **Paripinnate:** A pinnate leaf without a terminal leaflet. Example: *Cassia spp.* (Esau, 1977).
- ❖ **Imparipinnate:** A pinnate leaf with an odd, terminal leaflet. Example: *Pisum sativum* (Pea) (Fahn, 1990).

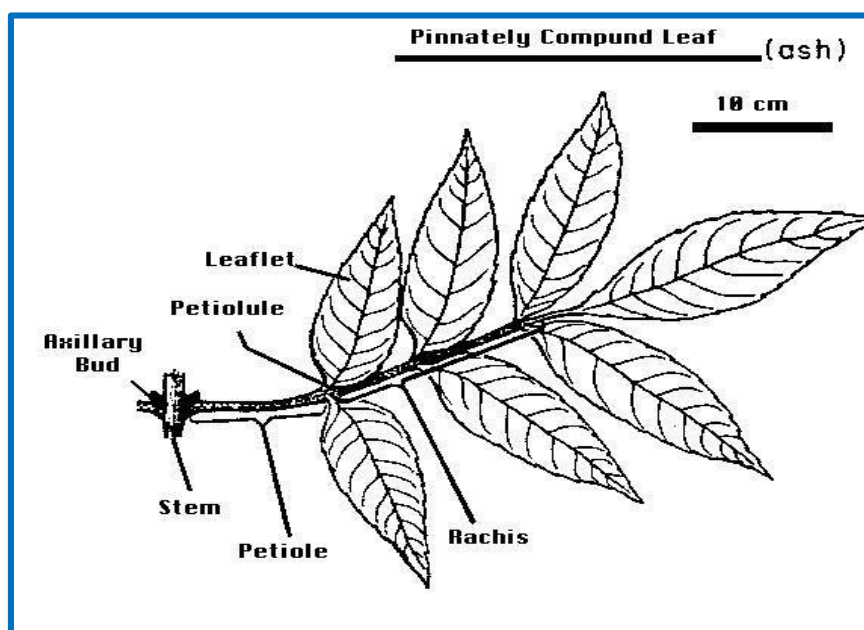


Figure 30. pinnately compound leaves

II.3.2.2. Venation

Venation is the arrangement of veins and veinlets in leaves. Different plants exhibit distinct venation patterns (see **Figure 31**). Generally, there are two main types:

- **Reticulate Venation:** In reticulate venation, the veinlets form a complex, interconnected network. This type is characteristic of dicotyledonous plants. An example is the rose plant (*Rosa spp.*) (Esau, 1977).
- **Parallel Venation:** In parallel venation, the veinlets run parallel to one another, typically seen in monocotyledonous plants. An example is paddy (*Oryza sativa*) (Fahn, 1990).

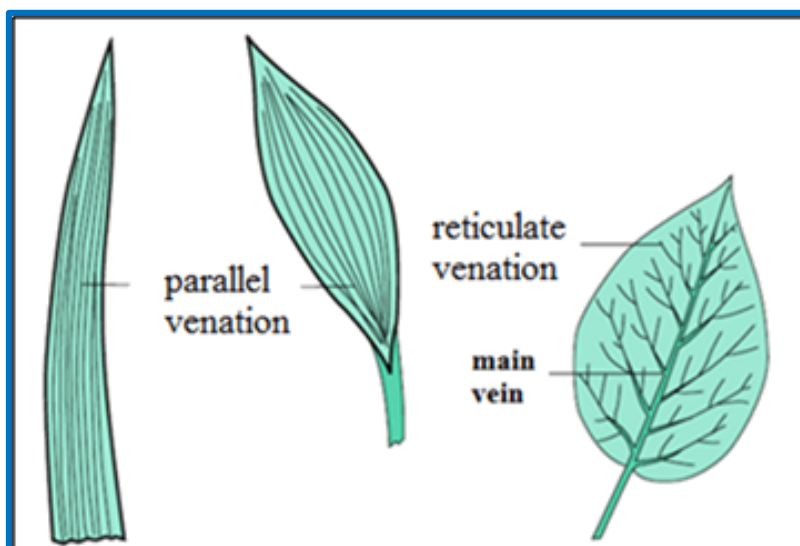


Figure 31. Different type of venation

II.3.2.3. Phyllotaxy

Phyllotaxy refers to the pattern of leaf arrangement on the stem (see **Figure 32**). Plants exhibit three main types of phyllotaxy: alternate, opposite, and whorled.

- **Alternate phyllotaxy:** In this type, a single leaf develops at each node in an alternating pattern. Example: *Hibiscus rosa-sinensis* (China rose) (**Esau, 1977**).
- **Opposite phyllotaxy:** In opposite phyllotaxy, a pair of leaves arises at each node, positioned directly opposite to one another. Example: *Psidium guajava* (Guava) (**Fahn, 1990**).
- **Whorled phyllotaxy:** In this type, more than two leaves develop at each node, forming a whorl around the stem. Example: *Alstonia scholaris* (**Metcalf & Chalk, 1950**).

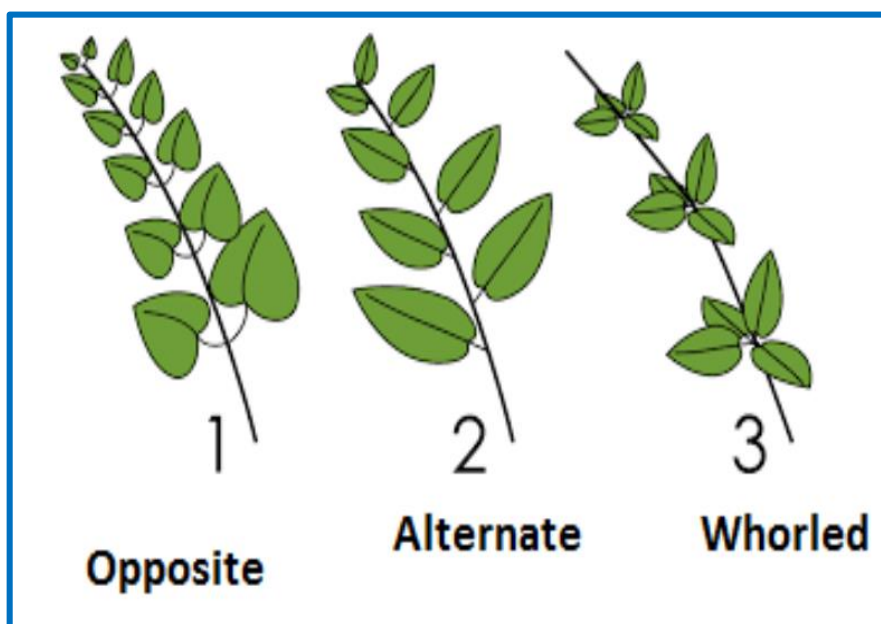


Figure 32. Different type of phyllotaxy

II.3.2.4. Modification of leaves

- **Storage Leaves:** Xerophytic plants and members of the Crassulaceae family have thick, succulent leaves that store water in their tissues, allowing them to survive in arid environments. These specialized leaves help the plants retain moisture during droughts (**Fahn, 1990**).
- **Leaf Tendrils:** In plants with weak stems, leaf tendrils are modified leaves that coil around nearby objects, such as sticks or walls, providing structural support to the plant. This adaptation helps the plant climb toward sunlight (**Esau, 1977**).
- **Leaf Spines:** In some plants, the leaves are modified into spines, which are sharp, needle-like structures. These spines serve dual functions: they act as defense mechanisms against herbivores and reduce water loss through transpiration. An example is *Opuntia* (**Fahn, 1990**).
- **Scale Leaves:** Scale leaves are thin, membranous structures that lack stalks and are typically brownish or colorless. In some plants, like *Allium cepa* (Onion), they can be fleshy and thick, storing food and water. Examples of plants with scale leaves include *Casuarina* and *Asparagus* (**Metcalf & Chalk, 1950**).
- **Leaflets Hook:** In certain plants, the terminal leaflets are modified into hook-like structures that assist the plant in climbing. An example is *Bignonia unguisati* (**Esau, 1977**).
- **Leaf Roots:** In some aquatic plants, leaves at the nodes are modified into adventitious roots that help the plant float on the water's surface. An example is *Salvinia* (**Fahn, 1990**).
- **Phyllode:** In some plants, the petiole becomes flattened and takes on the appearance of a leaf, often turning green to assist with photosynthesis. This modification is seen in *Acacia spp.* (Australian Acacia) (**Metcalf & Chalk, 1950**).
- **Insectivorous Leaves:** Certain plants, often found in nutrient-poor soils, have leaves modified to trap and digest insects. This adaptation allows the plant to obtain nitrogen, essential for growth (**Esau, 1977**).

II.3.3. Leaf function

Leaves perform several critical functions that support the survival and growth of plants:

- **Photosynthesis:** Leaves are the primary sites of photosynthesis, where they convert sunlight into chemical energy by producing glucose, which fuels the plant's growth and metabolism (**Fahn, 1990**).
- **Transpiration:** Through the process of transpiration, leaves regulate water movement within the plant. Water absorbed by the roots travels through the xylem to the leaves,

where it evaporates into the atmosphere, helping to cool the plant and maintain the flow of nutrients (Esau, 1977).

- **Guttation:** Guttation involves the removal of excess water from the xylem at the edges of the leaves, especially when stomata are closed at night. This process helps prevent internal pressure buildup in the plant. It is common in plants like grasses (Fahn, 1990).
- **Storage:** Some leaves, particularly in succulent plants, are adapted to store water and nutrients. These thick, fleshy leaves help the plant survive during periods of drought by retaining moisture (Metcalf & Chalk, 1950).
- **Defense:** In some plants, leaves are modified into spines that serve as a defense mechanism, protecting the plant from herbivores. An example is *Opuntia* (Prickly pear cactus), where spines reduce water loss and deter animals from feeding on the plant (Esau, 1977).

II.4. Flower morphology

Flowers are colorful and often fragrant structures in flowering plants that serve as the primary reproductive organs. They facilitate seed formation through pollination and fertilization (Esau, 1977). The different parts of a flower—such as petals, sepals, stamens, and carpels—work together to attract pollinators, ensuring reproductive success (Fahn, 1990). The diversity in flower shape, size, and color has evolved to enhance their appeal to various pollinators, contributing to the plant's genetic diversity (Thien, 1979).

II.4.1. Organization of the flower

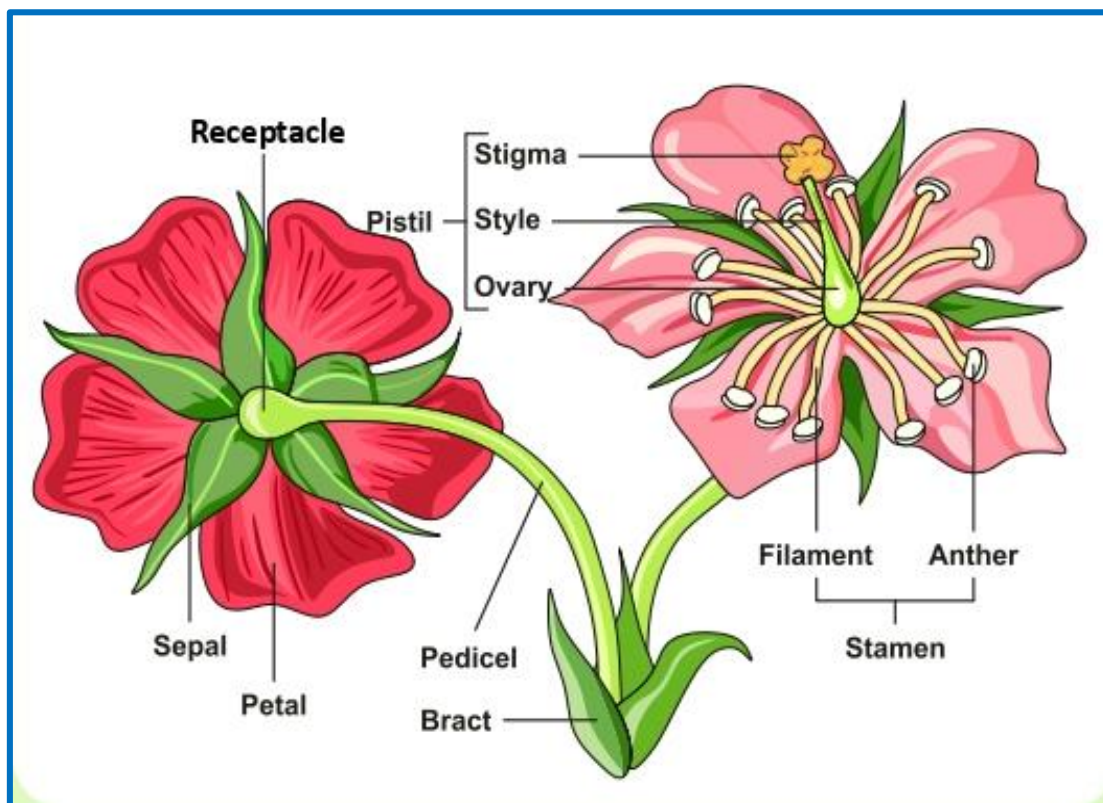


Figure 33. Structure of flower

The structure of a flower is broadly divided into several parts, often arranged in a whorled pattern (see **Figure 33**):

a) Bract: A modified leaf associated with a flower or inflorescence, providing protection or support (**Fahn, 1990**).

b) Pedicel: The stalk of the flower that connects it to the main stem.

c) Receptacle: The base of the flower located above the pedicel, which supports all the other parts of the flower (**Esau, 1977**).

d) Perianth: This is composed of two structures:

- **Calyx:** The outermost whorl, made up of individual sepals that resemble leaves, providing protection to the developing flower.
- **Corolla:** The inner whorl, consisting of petals that attract pollinators with their color and fragrance (**Fahn, 1990**).
- **Floral fusion;** In many flowers, the petals, sepals, and stamens often exhibit **fusion** to form specialized structures:
 - ❖ **Gamopetalous:** When the petals are fused together, they form a tubular structure, known as a **corolla tube**. This fusion can enhance the flower's efficiency in attracting pollinators by creating a more distinct and unified floral shape (**Esau, 1977**).
 - ❖ **Staminal Tube:** When the stamens are fused together, they form a **staminal tube**. This structure can help ensure efficient pollen transfer by concentrating the reproductive organs (**Fahn, 1990**).

e) Androecium: The male reproductive system of the flower, made up of one or more stamens (see **Figure 34**). Each stamen consists of:

- **Filament:** A slender, tube-like structure that holds the anther at its tip.
- **Anther:** The pollen-producing part, which contains four chambers or segments known as pollen sacs. During development, the anthers produce microspores, which form pollen grains that carry male gametes.

The pollen grains have a double-layered protective covering: the inner layer, called the **intine**, and the outer layer, called the **exine**. Pollen grains are released by the anthers and can undergo self-pollination (pollinating the same flower) or cross-pollination (pollinating a different flower) (see **Figure 35**) (**Thien, 1979**).

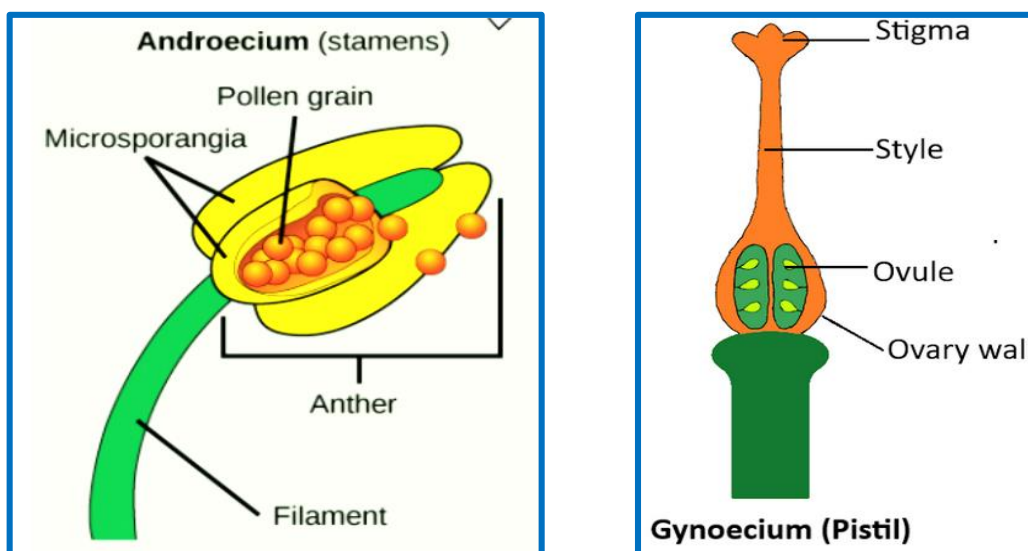


Figure 34. Structure of androecium and gynoecium

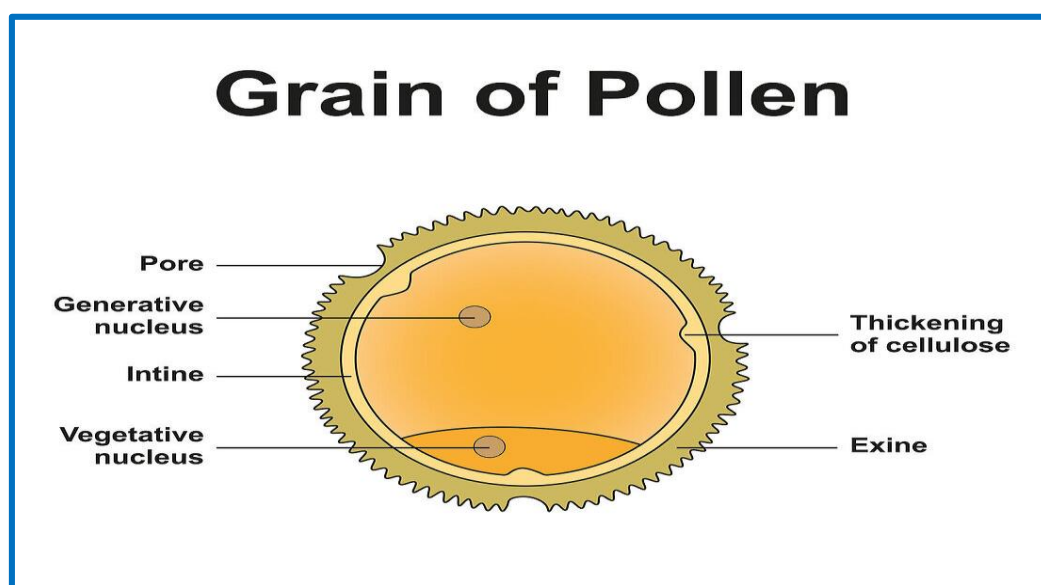


Figure 35. Grain of pollen

f) **Gynoecium (Pistil):** The gynoecium is the female reproductive part of a flower, comprising one or more pistils or carpels (see **Figure 34**). Each pistil consists of several structures:

- **Stigma:** The sticky terminal part of the style that captures pollen grains during pollination, allowing fertilization to occur (**Esau, 1977**).
- **Style:** A slender, tube-like structure that connects the stigma to the ovary. It provides a pathway for pollen tubes to grow from the stigma to the ovary (**Fahn, 1990**).
- **Ovary:** The swollen basal portion of the flower that contains one or more ovules, which house the female gametes. The ovary develops into the fruit after fertilization, enclosing the seeds (**Thien, 1979**).

The **gynoecium** plays a central role in plant reproduction by facilitating the union of male and female gametes, ultimately leading to seed formation.

Based on the **position of the ovary** in relation to other flower whorls, the gynoecium can be classified into three main types (see **Figure 36**) :

- **Hypogynous (superior ovary)**: In this arrangement, the ovary is positioned above all other floral whorls (sepals, petals, and stamens). Flowers with hypogynous ovaries typically have a more exposed ovary. Example: *Brassica* (**Esau, 1977**).
- **Perigynous (intermediate ovary)**: Here, the ovary is located at the same level as the other flower whorls, neither entirely above nor below them. The floral parts (sepals, petals, and stamens) arise around the ovary, forming a cup-like structure. Example: *Rosa* (**Fahn, 1990**).
- **Epigynous (inferior ovary)**: In this type, the ovary is positioned below the other flower whorls and is often surrounded or embedded within the receptacle. This arrangement helps protect the ovary as the flower develops. Example: *Apple* (**Thien, 1979**).

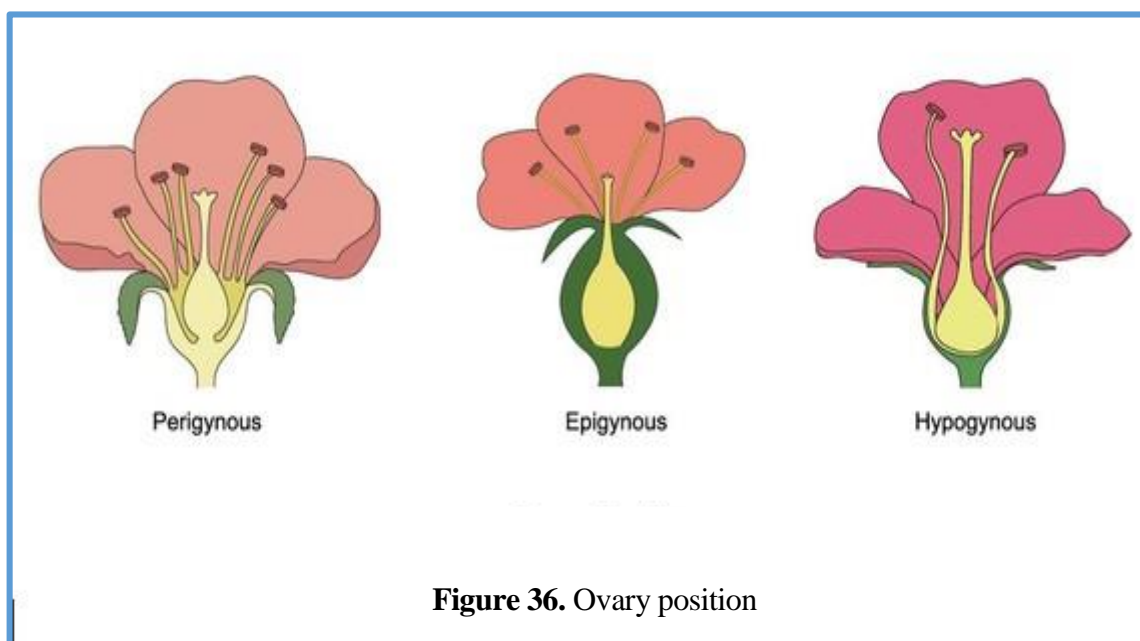


Figure 36. Ovary position

II.4.2. The inflorescences

So far we have learned about single or solitary flowers. But, in many plants, the flowers exist in a bunch on a branch along the same or different floral axis. These clusters or bunches of flowers are known as an inflorescence. Though the overall structure of the flowers in an inflorescence remains the same as seen in a solitary flower, the arrangement of these clusters of flowers varies depending on the type of arrangement of the floral axis.

The two main types of inflorescences are:

- Indetermination inflorescence (Racemose inflorescence)
- Determination inflorescence (Cymose inflorescence)

II.4.2.1. Indeterminate inflorescence (Racemose inflorescence)

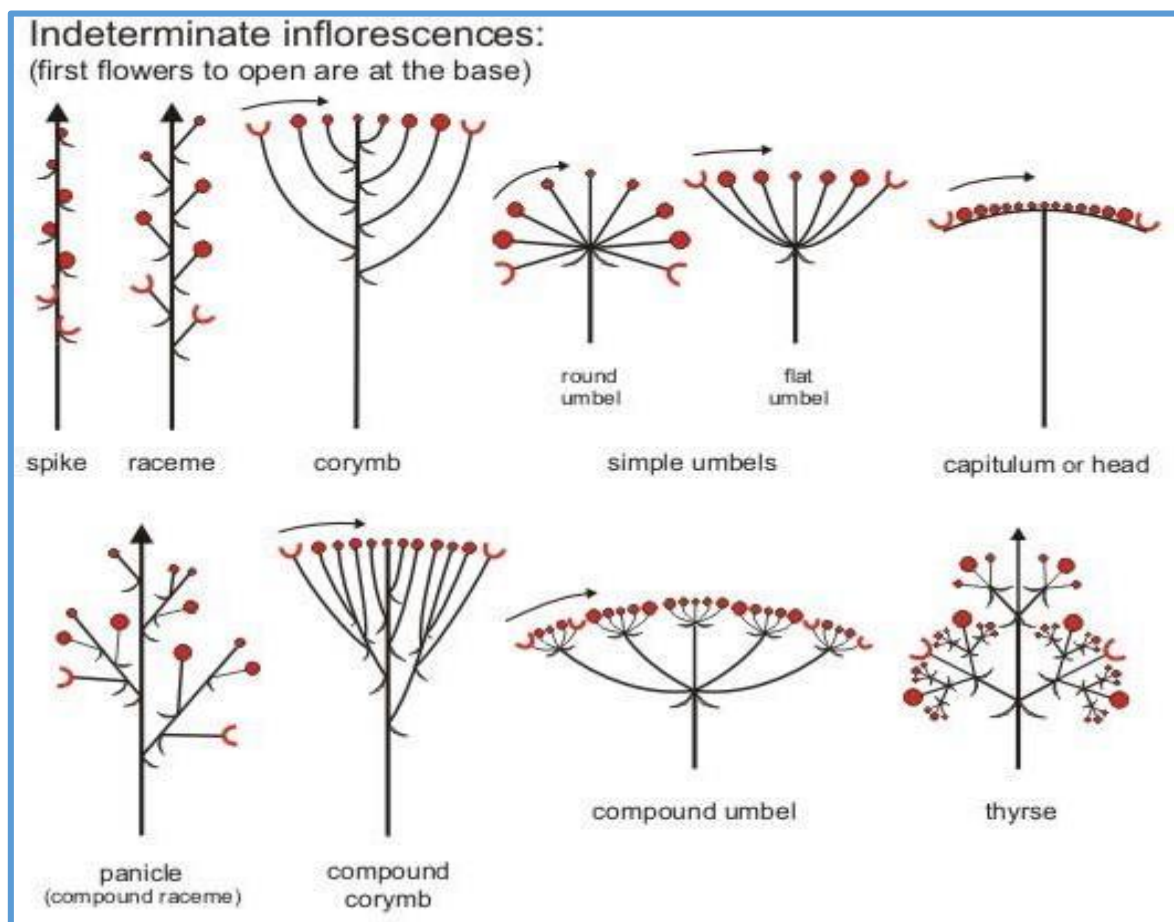


Figure 37. Indeterminate inflorescence

Indeterminate inflorescences are characterized by continuous growth of the main axis, with flowers developing progressively along the axis, from the base toward the tip (see **Figure 37**). Below are some common types of indeterminate inflorescences:

- **Spike:** An elongate, unbranched inflorescence in which the flowers are **sessile** (without stalks). Example: *Plantago* (**Fahn, 1990**).
- **Spikelet:** A small spike, characteristic of grasses and sedges. Each spikelet may contain one or more flowers. Example: Grasses like *Oryza sativa* (**Esau, 1977**).
- **Raceme:** An elongate, unbranched inflorescence with **pedicelled flowers** (flowers with stalks). The flowers are arranged along the central axis in an acropetal order (youngest at the top). Example: *Lupinus* (**Thien, 1979**).
- **Panicle:** A branched raceme, where the main axis produces lateral branches that bear pedicelled flowers. Example: *Oat* (**Esau, 1977**).
- **Corymb:** A flat-topped or slightly rounded raceme in which the pedicels of lower flowers are longer, so all flowers reach the same level. Example: *Iberis* (**Fahn, 1990**).
- **Compound Corymb:** A branched corymb with lateral corymbs arising from the central axis, creating a more complex arrangement. Example: *Hawthorn*.

- **Umbel:** A flat-topped or rounded inflorescence where the **pedicels** of all flowers originate from a common point. Umbels can be determinate or indeterminate. Example: *Allium* (Esau, 1977).
- **Compound Umbel:** A more complex umbel with primary rays originating from a common point, and secondary umbels (or umbels of umbels) arising from the tip of the primary rays. Example: *Carrot* (*Daucus carota*).
- **Capitulum (Head):** A dense, vertically compressed inflorescence with **sessile flowers** crowded on a common receptacle, often subtended by an involucre of phyllaries (specialized bracts). This structure is characteristic of the **Asteraceae** family. Heads can be determinate or indeterminate. Example: *Sunflower* (*Helianthus annuus*) (Fahn, 1990).
- **Thyrse:** A complex, many-flowered inflorescence with an indeterminate central axis and multiple lateral **dichasia** (determinate clusters of flowers). It is a mixed inflorescence, exhibiting both determinate and indeterminate growth. Example: *Vitex*.

II.4.2.2. Determinate inflorescence (Cymose inflorescence)

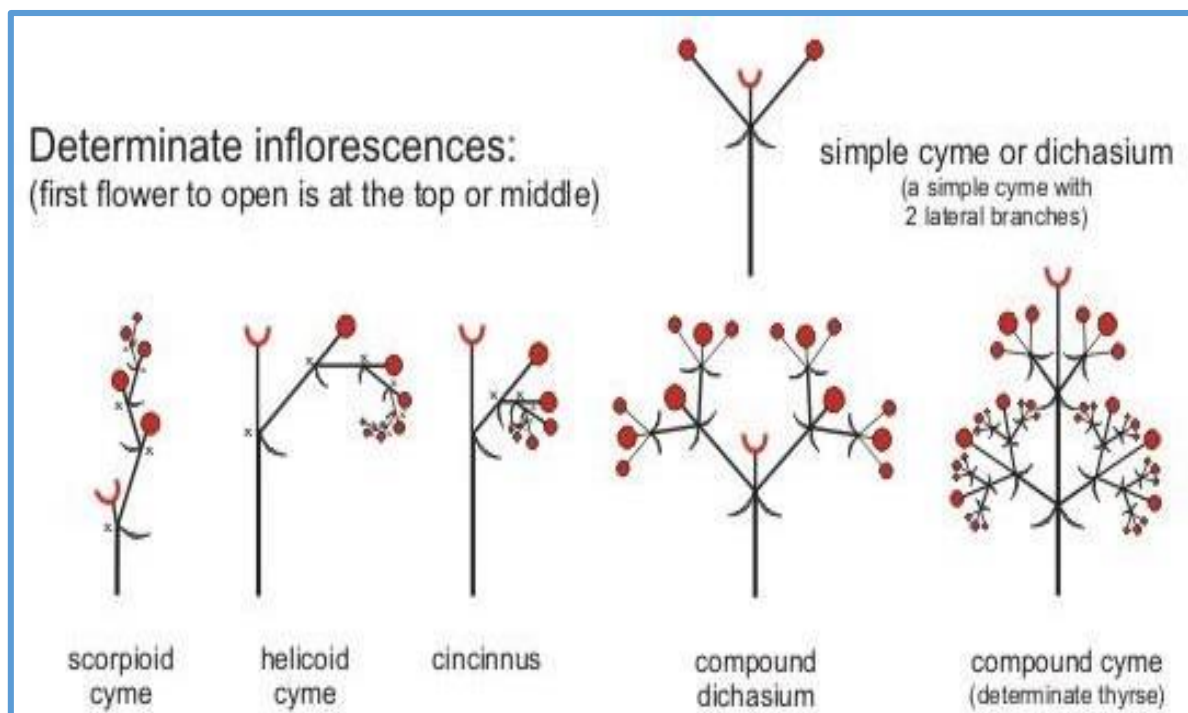


Figure 38. Determinate inflorescence

In **determinate inflorescences**, also known as **cymes**, the main axis terminates in a flower, and further growth continues from lateral branches. The flowers develop in a **basipetal** order, meaning the youngest flowers are at the bottom and the oldest at the top. A classic example of this type of arrangement is seen in **Jasmine** (Esau, 1977).

- **Simple Cyme or Dichasium:** This is a determinate inflorescence in which the central flower is flanked by two dichotomous lateral branches. The pedicels (flower stalks) of all flowers are of equal length, giving the inflorescence a symmetrical appearance. Example: *Dianthus*.

- **Compound Dichasium:** A **branched dichasium**, where each lateral branch develops its own dichasium, creating a more complex structure. Example: *Silene*.
- **Compound Cyme:** A **determinate thyrse**, where the lateral branches consist of smaller cymes, forming a highly branched inflorescence. Example: *Sambucus*.
- **Helicoid Cyme (Bostryx):** A determinate cyme where only one side of the axis develops, leading to a coiled or spiral appearance. The branches develop on one side due to the abortion of the opposing paired bud, resulting in an inflorescence that appears simple. Example: *Forget-me-not (Myosotis)*.
- **Cincinnus:** A modified helicoid cyme where the pedicels are very short, causing the flowers to form a compact, tight structure. Example: *Heliotropium*.
- **Scorpioid Cyme (Rhipidium):** A determinate cyme with a zig-zag arrangement. The branches develop alternately on opposite sides of the rachis due to the abortion of the opposing paired bud, giving the inflorescence a scorpion-like curve. Example: *Ranunculus*.

II.5. Seed morphology

A **seed** is a fundamental unit of plant reproduction, developing from the **ovules** after fertilization (Esau, 1977). It consists of a **seed coat** for protection and an **embryo**, which includes the **radicle** (the embryonic root), **embryonal axis**, and either one or two **cotyledons**. Monocotyledonous plants, such as wheat and maize, have one cotyledon, while dicotyledonous plants, like beans and peas, have two (Raven *et al.*, 2005). Seeds are usually housed inside a fruit, and under suitable conditions, they germinate to form new plants. Thus, the seed is critical for the dispersal and survival of plant species (Taiz & Zeiger, 2010).

II.5.1. Types and structure of seeds

II.5.1.1. Structure of a Monocotyledonous Seed

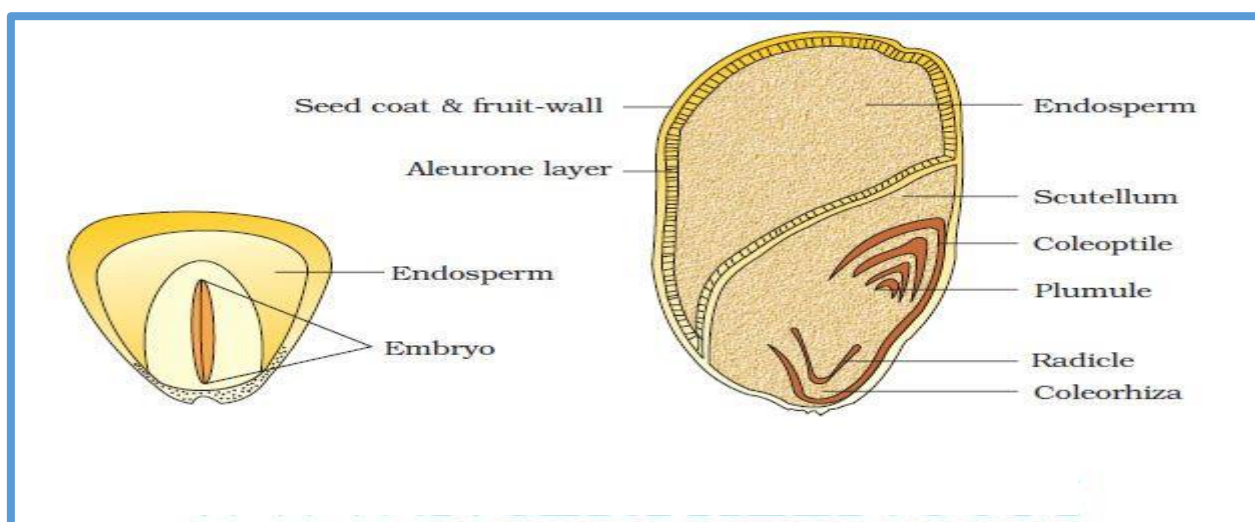


Figure 39. Monocotyledonous seed

A **monocotyledonous seed**, as the name implies, contains only one **cotyledon** (Esau, 1977). It has a single outer layer of the **seed coat**, which is often thin and fused with the fruit wall,

forming a protective structure known as the **hull** or **husk** (Raven *et al.*, 2005). The major parts of a monocot seed include (see **Figure 39**) :

- **Seed Coat:** In cereals like maize, the seed coat is membranous and fused with the fruit wall.
- **Endosperm:** This bulky tissue stores food and provides nourishment to the developing seedling. Most monocotyledonous seeds are **endospermic**, though some (e.g., orchids) lack an endosperm (Taiz & Zeiger, 2010).
- **Aleurone Layer:** This protein-rich layer forms the outer boundary of the endosperm and separates it from the embryo.
- **Embryo:** The embryo is small and located in a groove at one end of the endosperm.
- **Scutellum:** The large, shield-shaped cotyledon, specialized for absorbing nutrients from the endosperm.
- **Embryonal Axis:** Contains the **plumule** (which develops into the shoot) and the **radicle** (which forms the root).
- **Coleoptile and Coleorhiza:** The plumule and radicle are each enclosed in protective sheaths, called the **coleoptile** (for the shoot) and **coleorhiza** (for the root), respectively.

II.5.1.2. Structure of a Dicotyledonous Seed

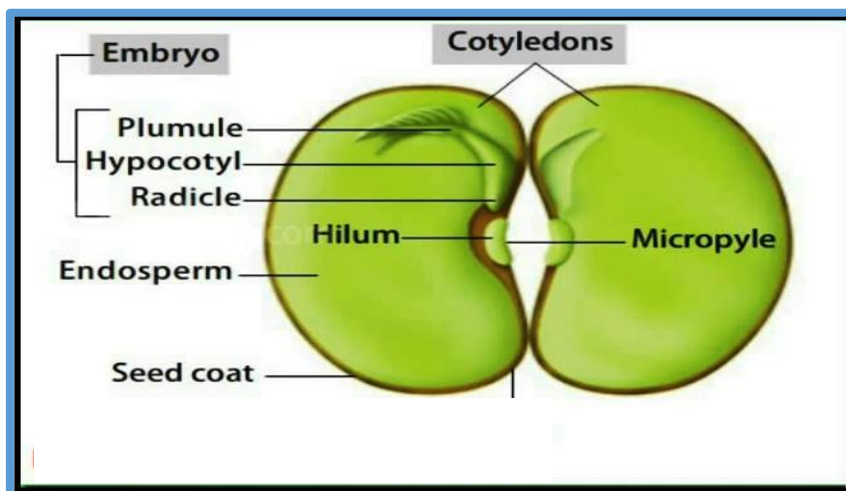


Figure 40. Dicotyledonous seed

Unlike monocotyledonous seeds, **dicotyledonous seeds** have two **cotyledons** (see **Figure 40**) (Esau, 1977). The major parts of a dicot seed include:

- **Seed coat:** The protective outer covering of a seed, which consists of two layers—the outer **testa** and the inner **tegmen**.
- **Hilum:** A scar on the seed coat that marks where the seed was attached to the fruit.
- **Micropyle:** A small pore above the hilum, allowing water absorption during germination.
- **Embryo:** The embryo consists of an embryonal axis and two cotyledons, which are typically fleshy and store nutrients (Raven *et al.*, 2005).
- **Cotyledons:** These contain reserve food materials for nourishing the developing plant.

- **Radicle and Plumule:** The radicle, which forms the root, and the plumule, which forms the shoot, are located at opposite ends of the embryonal axis.
- **Hypocotyl:** The part of the embryonic axis between the radicle and plumule, which develops into the future stem.
- **Endosperm:** Some dicot seeds, such as castor, are **endospermic**, meaning they retain the endosperm to store food. In non-endospermic seeds, such as beans and peas, the endosperm is absent at maturity (**Taiz & Zeiger, 2010**).

II.5.2. Function of seed

Seeds serve several important functions beyond germination and food storage:

- **Perennation:** Seeds help plants survive harsh conditions through dormancy, allowing them to withstand unfavorable environmental factors (**Sundararajan & Mahesh, 2014**).
- **Genetic Diversity:** Seeds promote genetic variation, aiding adaptability and resilience to changing environments (**Ellstrand et al., 2010**).
- **Dispersal:** Seeds enable plants to spread and colonize new areas via wind, water, animals, or mechanical forces, preventing overcrowding and enhancing survival (**Howe & Smallwood, 1982**).
- **Ecological Role:** Seeds provide food for many organisms, supporting food webs and overall ecosystem health (**Gurnell, 1999**).
- **Dormancy:** Seeds can delay germination until conditions are optimal for survival, which is crucial for timing their growth (**Baskin & Baskin, 2014**).
- **Agricultural Value:** Seeds are essential for crops like wheat, rice, and beans, playing a vital role in global food security and economic stability (**FAO, 2020**).

II.5.3. Dispersion of seed

Seeds are dispersed through different agents and mechanisms:

- Wind
- Animals
- Water
- Explosion

II.6. Fruit morphology

After fertilization, the **ovules** develop into seeds, and the **ovary wall** transforms into the **pericarp** (fruit wall), forming the fruit (**Esau, 1977**). The fruit's role is to protect the seed and aid in its dispersal. Occasionally, parts of the plant such as the **bracts**, **calyx**, **style**, and **stigma** may persist after fertilization.

Parthenocarpy, a process where fruits form without fertilization, results in seedless fruits like bananas and seedless oranges (**Raven et al., 2005**).

II.6.1. Structure of the fruits walls

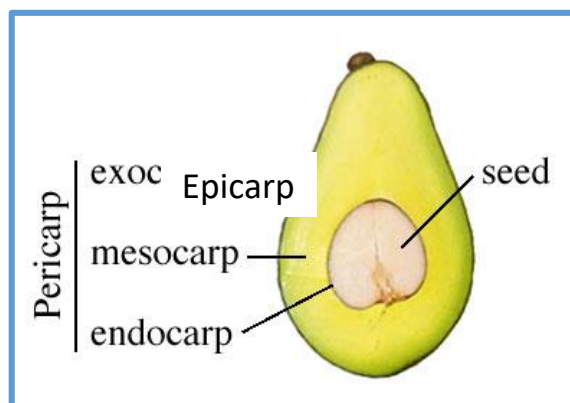


Figure 41. Structure of fruit

The fruit wall, known as the pericarp, consists of three distinct layers (see **Figure 41**):

- **Epicarp**: Outermost layer
- **Mesocarp**: Middle layer
- **Endocarp**: Innermost layer

II.6.2. Different types of fruit

II.6.2.1. Fruit simple

Developed from a *single flower*, with an ovary generally *mono* or *gamocarpellary*.

a) Indehiscent dried fruits

These more recent fruits are *Monosperms (uniseminate)*. The wall of these fruits is membranous, and more or less lignified (dry pericarp). There are 5 types:

- **Caryopsis**: A type of fruit in the Poaceae family where the seed coat is fused to the pericarp. Examples include wheat and corn (**Esau, 1977**) (see **Figure 42 a**).
- **Samara**: An achene with an extended pericarp that forms a wing, facilitating wind dispersal. Examples include ash and maple (see **Figure 42 b**)
- **Achene**: A small fruit in which the seed is not attached to the pericarp. Examples include acorns and clematis. (see **Figure 42 c**).
- **Nut**: A fruit characterized by a hard, bony pericarp. An example is the hazelnut. (see **Figure 42 e**).
- **Schizocarp**: A fruit that originates from a gamocarpellary ovary and splits into segments (mericarp) upon maturity. This type is common in families like Apiaceae, Lamiaceae, Malvaceae, and Geraniaceae. (see **Figure 42 f**).

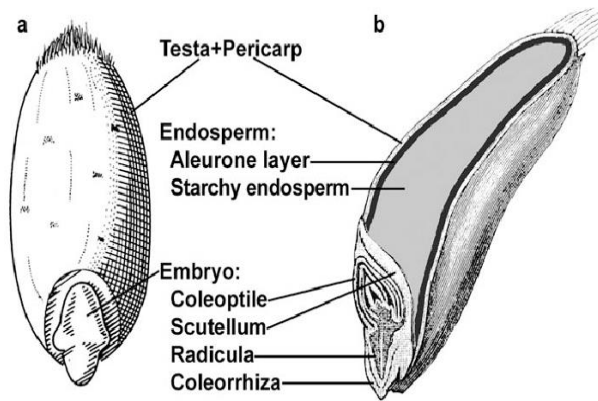


Figure 40 a. Caryopsis

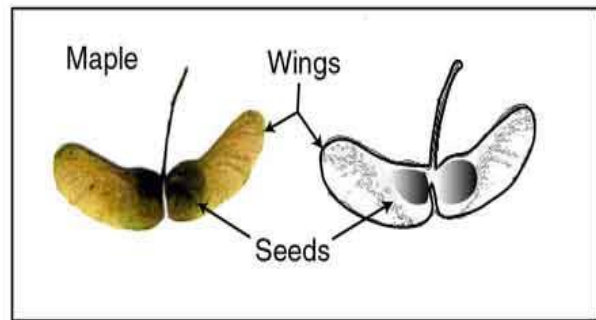


Figure 40 b. Samara

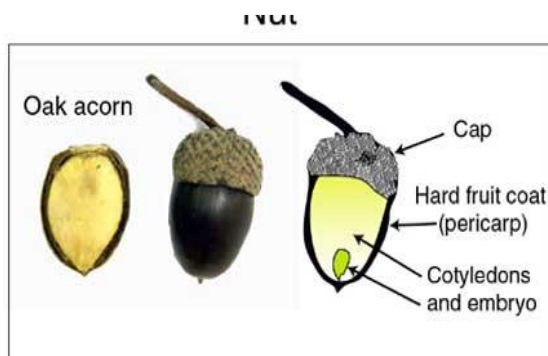


Figure 40 c. Achene (Oak)

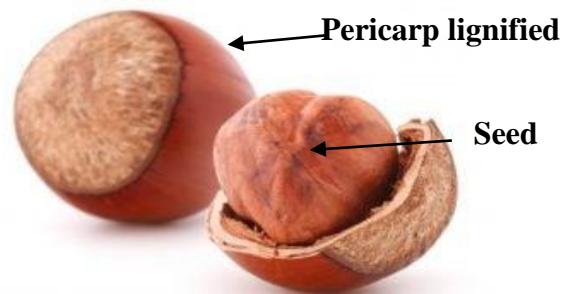


Figure 40 e. Nut

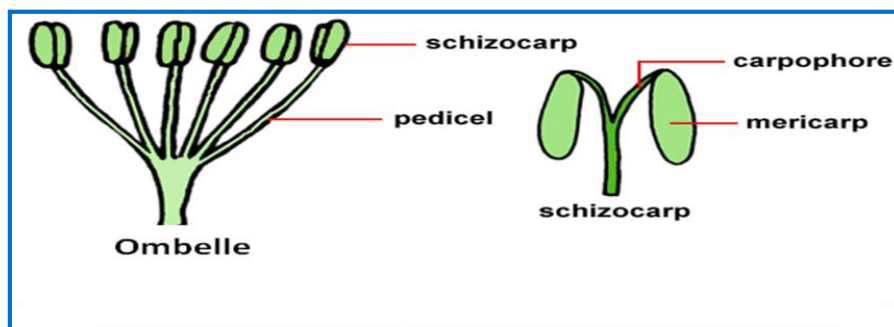


Figure 42 f. Shizocarp

b) Dehiscent dried fruits

These fruits are considered the most primitive and are typically multiseeded (polysperms), containing numerous seeds whose dispersal is facilitated by the fruit's dehiscence. The main types include:

- **Follicle:** Derived from a monocarpellary ovary, the dehiscence occurs along the carpel suture line. Examples include *Helleborus* and *Aquilegia* (see **Figure 43 a**).
- **Pod:** A specific type of fruit in the Fabaceae family (legumes), originating from a single-carpellary ovary. Dehiscence happens along the suture line of the carpel and the dorsal vein. Examples include beans and peas (see **Figure 43 b**).

- **Capsule:** Formed from an open or closed gamocarpellate ovary, capsules exhibit various dehiscence types:
 - ❖ **Septicidal Capsule:** Dehiscence occurs ventrally and longitudinally along the carpel sutures. Example: *Foxglove*.
 - ❖ **Loculicidal Capsule:** Dehiscence occurs dorsally along the veins of the carpels. Example: *Eucalyptus*.
 - ❖ **Pyxis Capsule:** Characterized by transverse dehiscence, resulting in a circular slit that releases the apical cover. Example: *Henbane* (see **Figure 43 c**).
 - ❖ **Poricidal Capsule:** Exhibits dehiscence through the formation of pores or flaps at the top of the dried fruit. Example: *Poppy* (see **Figure 43 d**).
- **Silique:** A specific type found in the Brassicaceae family, formed from two welded carpels that separate on either side of the placenta, creating a false wall between the carpels. Example: *Cabbage* (see Figure 43 e).

These types of fruits are crucial for seed dispersal and contribute to the diversity of flowering plants (Esau, 1977).



Figure 43a. Follicule



Figure 43b. Pod



Figure 43c. Pyxis capsule



Figure 43d. Poricidal capsule



Figure 43e. Silique

c) Fleshy fruits (fleshy mesocarps)

- **Drupe:** A drupe is a fruit with a fleshy epicarp and mesocarp, and a hardened (lignified) endocarp. It can be categorized based on the number of seeds (Esu, 1977; Raven *et al.*, 2005):

- **Monospermy drupe:** A single seed protected by a nucleus comes from a *unilocular ovary* either uniovulate (*Example:* Apricot, Cherry, Peach) or multi-ovulate but only one ovule matures (*Example:* Olive) (see **Figure 44 a**).
- **Polyspermy drupe:** Several seeds protected by nuclei come from a *plurilocular ovary* of which each cell gives a nucleus (*Example:* Loquat, Medlar, Coffee) (see **Figure 44 b**).
- **Berry:** fleshy fruit with entirely fleshy pericarp. There are 4 types:
 - **Monospermy berry:** with a single seed (*Example:* Laurel, Date) (see **Figure 44 c**).
 - **Polyspermy berry:** with several seeds (*Example:* Tomato...etc.) (see **Figure 44 d**).
 - **Peponid:** is an enormous berry with a hard epicarp (*Example:* Cucurbits such as zucchini, melon, watermelon) (see **Figure 44 e**).
 - **Hesperide:** is similar to a berry, but with: *thick waxy epicarp* that has many essence pockets (zest). A *white spongy mesocarp*, and a *membranous endocarp* form the partitions which delimit the carpellary cavities whose sweet pulp is full of juice (*Example:* Citrus fruits, such as orange, kumquat, lemon, grapefruit) (see **Figure 44 f**).

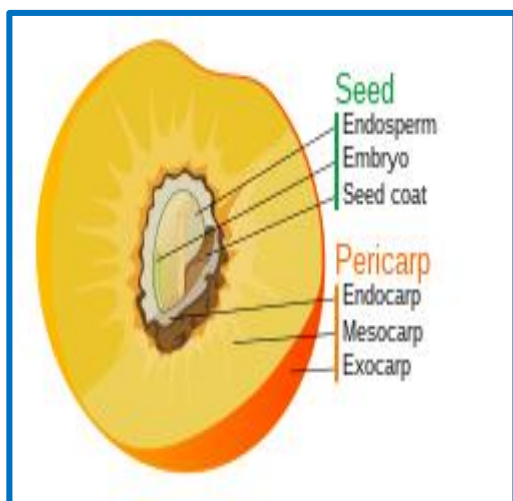


Figure 44 a. Monospermy drupe (Apricot)

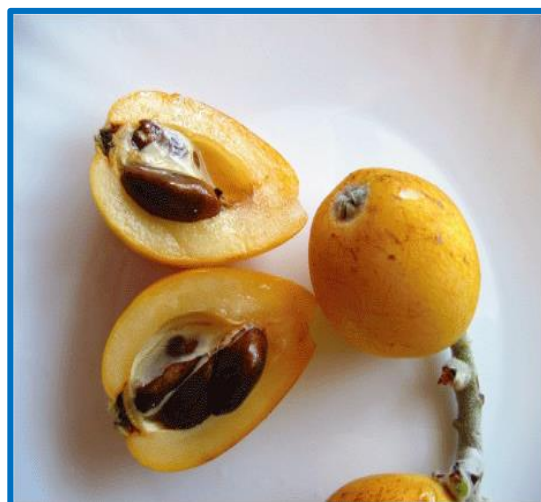


Figure 44 b. Polyspermy drupe (Medlar)



Figure 44 c. Monosperm berry (Date)



Figure 44 d. Polyspermy berry (Tomato)



Figure 44 e. Peponid

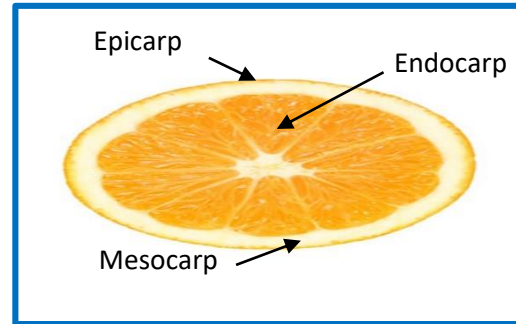


Figure 44 f. Hesperide

II.6.2.2. Multiple fruits

Developed from a single flower, with a dialycarpellate ovary (**Esu, 1977; Raven et al., 2005**)

- **Durpaceous** : is aggregate fruit formed by a set of drupes, each individual is termed a drupelet (*Example: Brambleberry, raspberry*) (see **Figure 45**).
- **Poly- achenes**: set of achenes (*Example: Buttercup*) (see **Figure 46**).

II.6.2.3. Composite fruits (infructescences)

Developed from the same inflorescence. The unit fruits resulting from the transformation of each flower can be inseparable, to which can be added the floral receptacle, the axis of the inflorescence and the floral bracts (*Example: Pineapple*), (see **Figure 47**).

II.6.2.4. Complex fruits

Combination of the ovary of the same flower with other floral parts (**Esu, 1977; Raven et al., 2005**).

- **Piridion**: when the flower has a lower ovary adhering to the receptacle. The latter when fruiting becomes fleshy and tender constitutes the most external part to which adheres the epicarp and the mesocarp, also fleshy. Only the cartilaginous endocarp is clearly distinguished and constitutes the kinds of cells which shelter the seeds (*Example: Apple, pear*) (see **Figure 48**).
- **False fruits**: is an aggregate fruit, the fleshy colored part that we consume results from the transformation of the receptacle and the small grains scattered on its surface are achenes (*Example: Strawberry*) (see **Figure 49**).

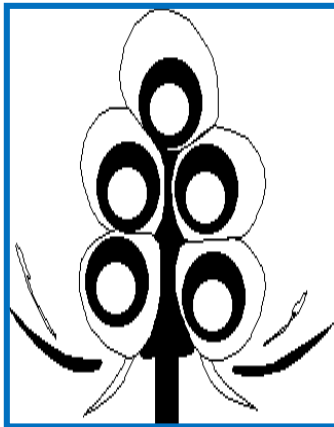


Figure 45. Drupaceous

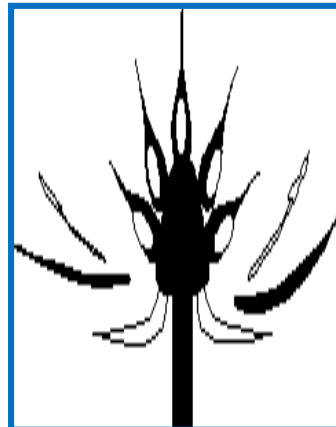


Figure 46. Polyachenes

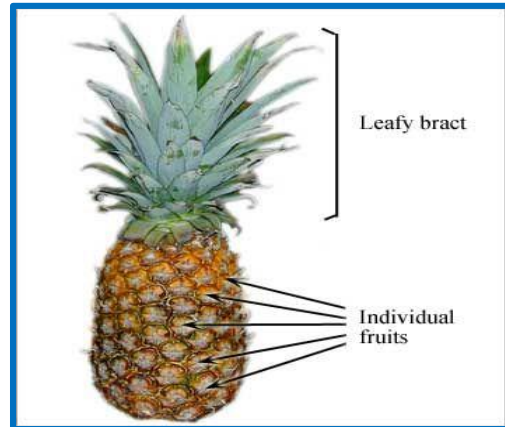


Figure 47. Composite fruit (Pineapple)

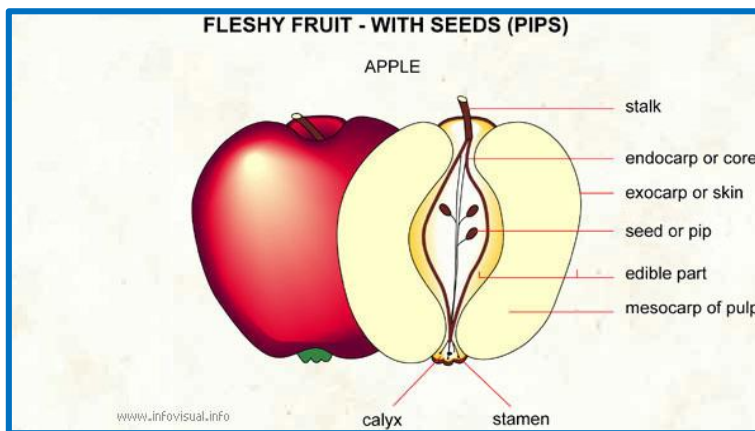


Figure 48. Pridion (Apple)

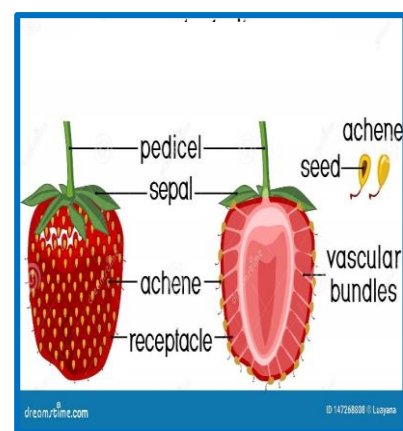


Figure 49. False fruit (Strawberry)

Chapter III: Different types of tissues

Introduction

Meristematic tissues are regions of actively dividing cells in plants that give rise to new cells and contribute to the plant's growth and development. These tissues are responsible for primary and secondary growth in plants. There are two main types of meristematic tissues (see **Figure 48**):

- **Primary meristem (Apical meristem)**
- **Secondary meristem (Lateral or Cambial meristem)**

Meristematic tissues are characterized by their ability to undergo rapid cell division, resulting in the production of new cells. As these cells mature, they undergo differentiation and specialize into various types of cells that form the different tissues and organs of the plant.

Meristematic tissues play a crucial role in plant growth, allowing plants to continuously produce new cells and tissues required for their development, repair, and adaptation to environmental changes.

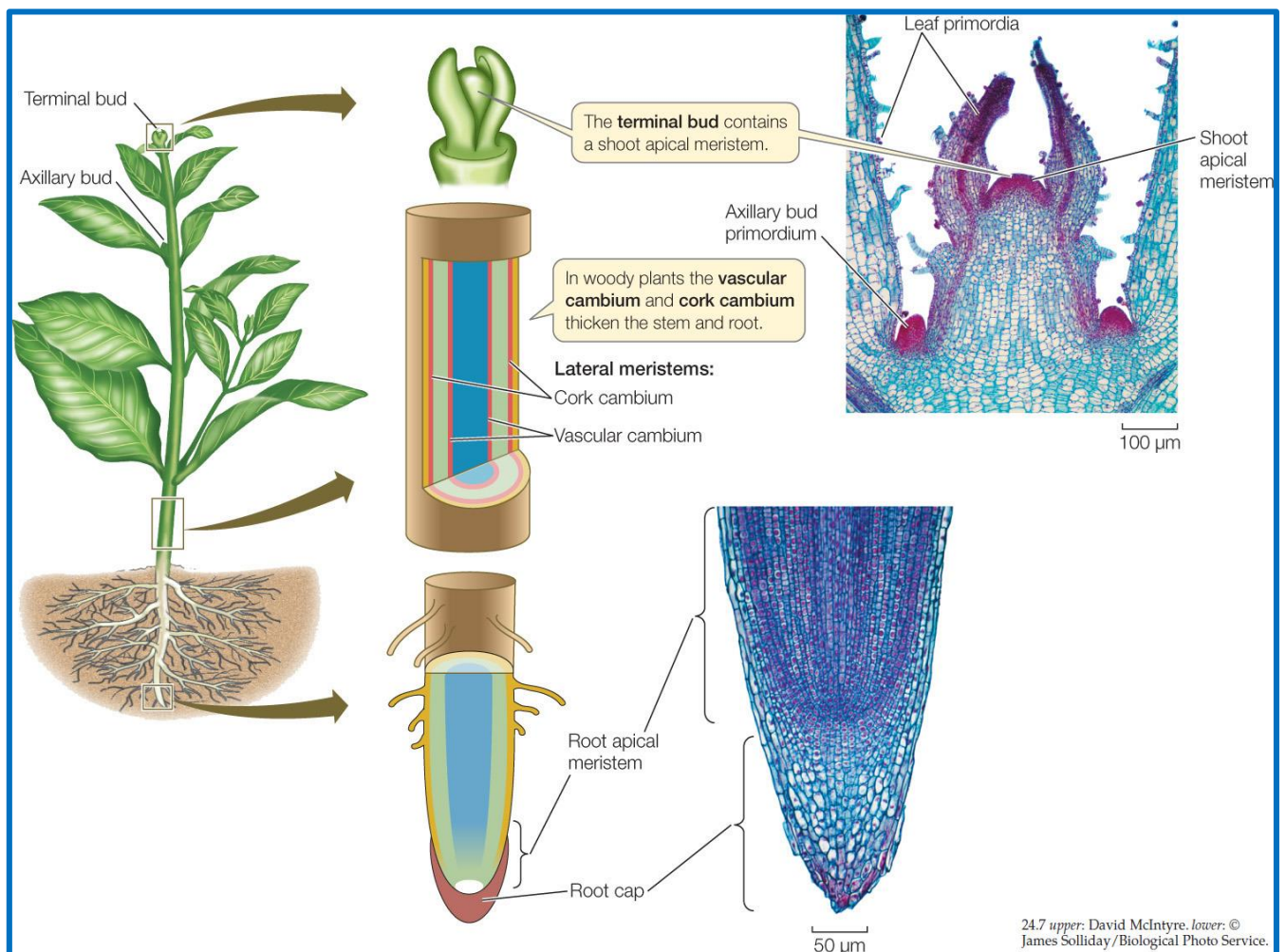


Figure 50. Apical and lateral meristems

III.1. Primary meristems (Apical meristem)

In plant biology, primary meristems refer to the meristematic tissues found at the tips of roots and stems in young plants. These primary meristems are responsible for the primary growth of the plant, which includes increasing the length of the roots and stems.

a) *Root meristem*

- ***Localization and role:*** The root meristem is found at the tip of a plant root. It's responsible for facilitating the growth in length of the root system.
- ***Structure:*** The root meristem called *apical meristem* is protected by a *root cap*, a structure made of specialized cells that cover and shield the delicate meristematic cells as the root pushes through the soil. The root cap also helps in navigating through the soil particles and protects the meristem from abrasion damage.

Root meristems are classified into different zones based on the stages of cell development and differentiation (see **Figure 51**):

- ***Meristematic zone (Zone of cell division):*** Cells in this zone divide rapidly to provide new cells for growth.
- ***Zone of elongation:*** In this region, cells from the meristematic zone start elongating and expanding, contributing to the increase in length of the root.
- ***Zone of maturation (Zone of differentiation):*** In this region cells undergo differentiation into specific cell types, such as: root hairs, epidermal cells, cortex, endodermis, and vascular tissues. This zone is where cells acquire their specialized functions and structures needed for nutrient absorption, transport, and support.

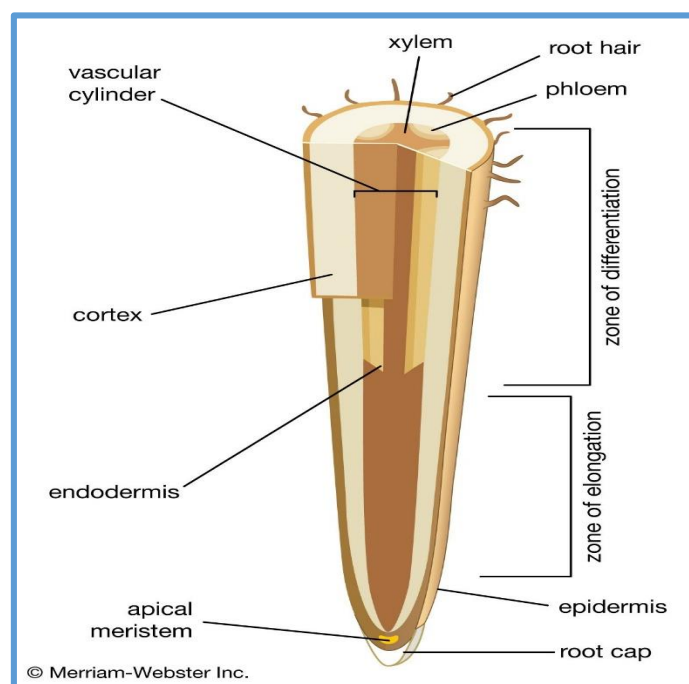


Figure 51. Root meristem (apical meristem)

b) Stem meristem

- **Localization and role**: Stem meristem refers to the specialized meristematic tissue found in the tips of plant stems. It's responsible for the increase in length or height of the stem.
- **Structure**: The stem meristem is protected by a structure known as the *apical meristem*. The apical meristem is found at the growing tips of the stem, specifically the terminal bud. It contains a group of undifferentiated cells that divide rapidly, generating new cells that contribute to the elongation of the stems, leaves, lateral buds and flower buds. The regions of the stem meristem are somewhat analogous to those found in the root meristem (see **Figure 52**):
 - ***Meristematic zone (Zone of cell division)***: The cells divide rapidly, creating new cells that add to the length of the stem.
 - ***Zone of elongation***: These elongated cells are the result of the continuous division and subsequent elongation that occurs in the meristematic zone.
 - ***Zone of maturation (Zone of differentiation)***: Cells further from the meristematic region undergo differentiation into specific cell types, forming tissues like the epidermis, cortex, vascular tissues, and other specialized structures necessary for the stem's functions.

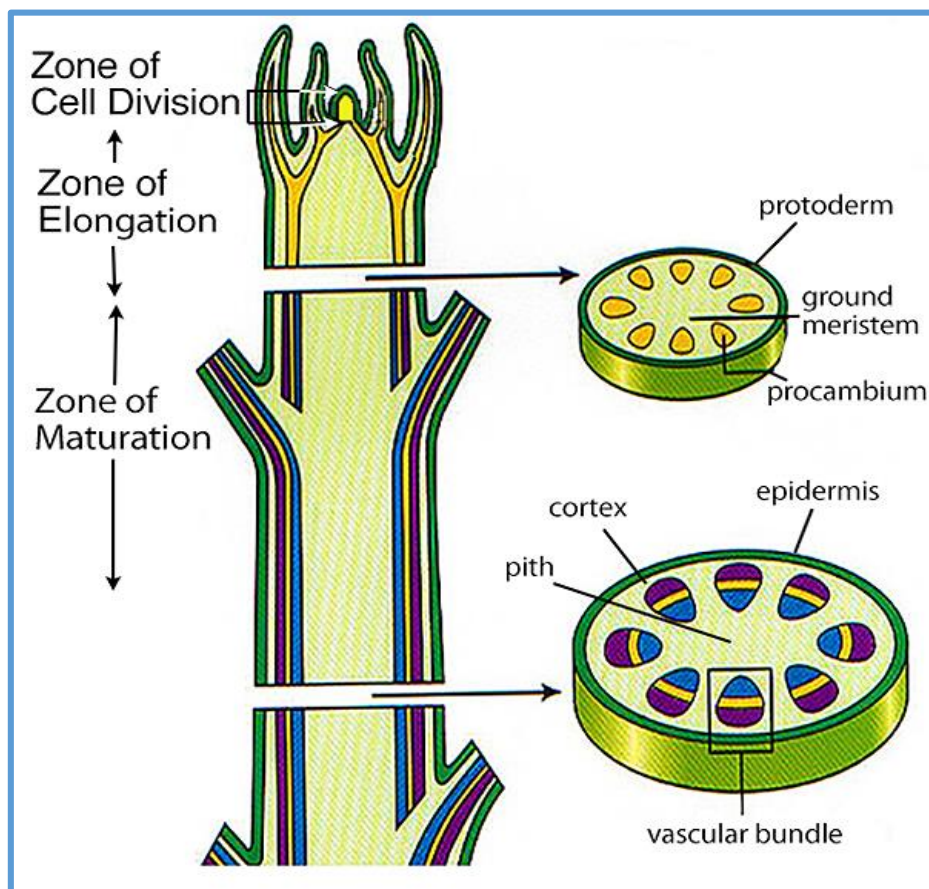


Figure 52. Stem meristem (apical meristem)

III.1.1. Primary tissues

In plants, primary tissues refer to the initial tissues formed from the activity of the primary meristems during the growth of the plant. These primary tissues are the fundamental building blocks of the plant body and are classified into 4 main types (see **Figure 53**):

- *Protective tissue (epidermis/ dermal tissue)*
- *Ground tissue*
- *Vascular tissue*
- *Secretory tissues*

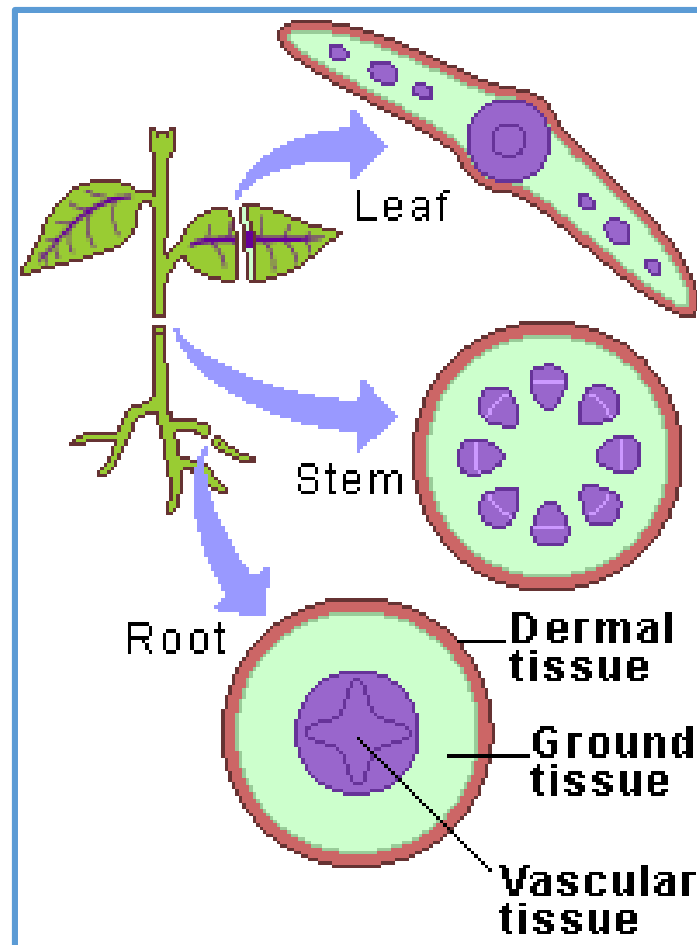


Figure 53. Different types of primary meristem tissue

III.1.1.1. Protective tissue (epidermis / dermal tissue)

In plants, the epidermis is a specialized protective tissue that serves as the outermost layer of various plant organs (see **Figure 54**).

- **Structure:** The epidermis is typically composed of a single layer of cells, but the cells may vary in shape, size, and structure depending on the plant organ and its function.
- **Type:** Including two types:

a- Epidermis

- **Epidermis:** Outermost cell layer of the stems, leaves, and flowers. It consists of stomata.
- **Rhizodermis:** Outermost cell layer of the roots forms of a long hair-like structures which creates larger absorptive surface area. Epidermal cells can help in the absorption of water in roots.

b- Cork (suber): Cork is constituted by a layer of cells formed by cortex, located in a strip of secondary meristem. It exists in old, brown stems (branches and tree trunks), as well as in old roots. Cork cells are dead and compactly arranged without intercellular spaces. Cork have a substance called suberin in their walls that makes them impervious to gases and water.

• **Function:** The epidermis plays several essential roles in plant function and protection:

- **Protection:** It serves as the first line of defense against environmental stresses, such as: a protective barrier, safeguarding the plant against physical damage, pathogens, and excessive water loss.
- **Regulation of water loss:** The epidermis contains a waxy, waterproof layer called the cuticle, which covers the outer surface of aerial parts of the plant. The cuticle helps reduce water loss by limiting transpiration, thereby minimizing dehydration.
- **Gas exchange:** Small specialized structures known as stomata are present in the epidermis of leaves and some stems. Stomata regulate the exchange of gases; such as O_2 , CO_2 , and H_2O allowing for photosynthesis and respiration.
- **Secretion and absorption:** The epidermis can include specialized structures like trichomes (hair-like structures), glandular cells, or root hairs that aid in the secretion of substances, such as resins or nectar, or in the absorption of water and nutrients from the soil.

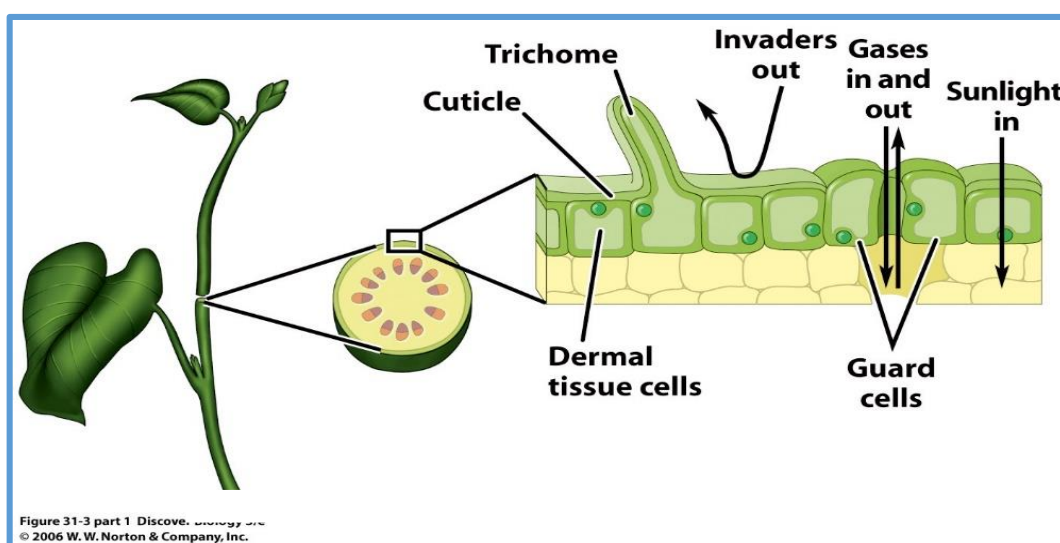


Figure 54. Dermal tissue cells

II.1.1.2. Ground tissue

DR. N. SOUILAH

The ground tissue system comprises the bulk of the plant's body and is responsible for various functions such as storage, photosynthesis, and support. The primary ground tissues consist of 2 types :

- *Filling tissue (Parenchyma)*
- *Supporting tissue (Collenchyma and sclerenchyma)*

III.1.1.2.1. Filling tissues (Parenchyma)

Parenchyma tissue are fundamental to building blocks and perform several essential functions in plant growth and development. Parenchyma cells have thin cell walls, a prominent nucleus, and a large central vacuole. They often have intercellular spaces between them. There are 2 major types:

a- *Chlorenchyma*: Is characterized by the presence of numerous chloroplasts. It is abundant in aerial organs (leaves and young stems), to which they give their green color. Its role is mainly photosynthesis, and the gaps ensure respiration. Within the mesophylls of the leaves we distinguish 2 types:

- ***Homogeneous chlorenchyma*:** in the leaves of Monocotyledons; there are 2 kinds:
 - *Chlorenchyma with meatus*: These are small rounded cells, detached from their apexes, constituting meatus.
 - *Chlorenchyma with gaps*: The same formation as chlorophyll parenchyma with meatus, but the cells may be separated by large gaps.
- ***Heterogeneous chlorenchyma*:** in the leaves of Dicotyledons; it is made up of 2 regions (see **Figure 55**):
 - *Palisade parenchyma*: towards the upper surface of the leaf, formed by one or two layers of elongated cells, tightly packed against each other and rich in chloroplasts.
 - *Spongy parenchyma*: towards the underside of the leaf, formed of short cells, more or less rounded, less rich in chloroplasts and reserving large gaps between them with a spongy mesophyll.

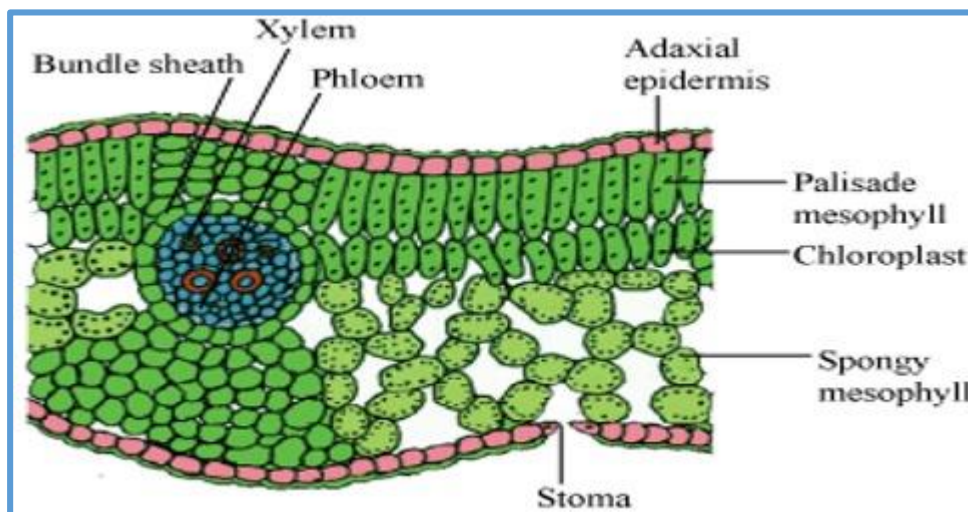


Figure 55. Heterogeneous chlorenchyma

- b- **Aerenchyma**: Parenchyma cells with extensive air spaces, commonly found in aquatic plants, aiding in buoyancy and gas exchange.
 - c- **Aquiferous parenchyma**: These are very large cells, provided with a very developed vacuole, rich in water and often in mucilage. They are abundant in the stems and leaves of succulents (fat plants: Cactus), where they provide a usable water reserve during periods of drought.
 - d- **Storage parenchyma**: Cells that store protein, starch, oils, water, and other nutrients, often found in roots, tubers, and fruits. They act as a food and water reserve.
- **Function**

- ***Metabolic functions***: They participate in various metabolic activities, including photosynthesis, storage of starch, proteins, and other nutrients, as well as secretion and gas exchange.
- ***Locations***: Parenchyma cells are found in various plant organs, including the leaves, stems, roots, and fruits. In leaves, they constitute the bulk of the mesophyll tissue and perform photosynthesis. In stems and roots, they function in storage and contribute to the plant's flexibility.
- ***Plasticity***: These cells possess a high degree of plasticity, allowing them to differentiate into other cell types when needed, such as during wound healing or in response to specific developmental signals.

III.1.1.2.2. Supporting tissues (collenchyma and sclerenchyma)

Support tissues are tissues providing flexibility and rigidity to plant organs. They have small, thick-walled cells. This is collenchyma which forms in young organs and sclerenchyma which is found in organs whose elongation is completed.

a- Collenchyma

- ***Structure***: It is made up of small cells, living, flexible, strongly elongated or isodiametric, with rectangular or acute ends. They are usually applied closely against each other and grouped in chains or cylinders in the cortex (= bark) of young shoots mainly such as stems, petioles or along the veins of the leaves (see **Figure 56**). Collenchyma has a cellulosic primary wall that is very thick and rich in water.

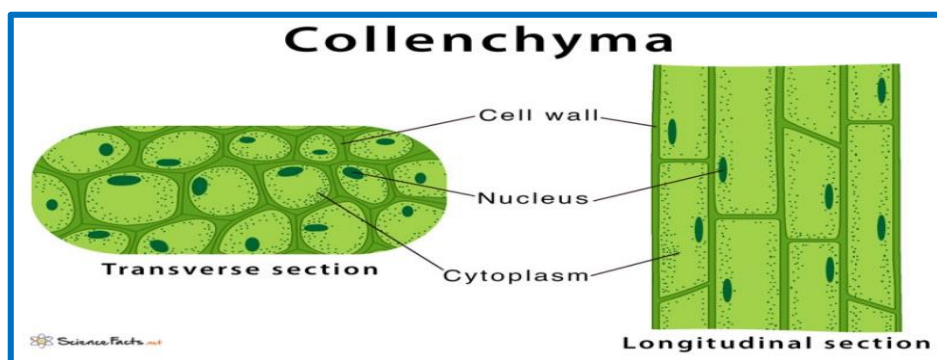


Figure 56. Collenchyma tissue

- **Function:** It provides support for the young parts of the shoots which are at the beginning of growth through flexibility and rigidity.
- **Types:** Depending on the thickening of the primary wall, collenchyma can be classified into 4 categories (see **Figure 57**):
 - **Lacunar collenchyma:** Lacunar Collenchyma contains intercellular spaces, and thickening is more around these spaces.
 - **Angular collenchyma:** In this type, the thickening occurs at the corners of the cells, giving them a distinct angular appearance. It is the most common collenchyma tissue.
 - **Annular collenchyma:** In annular collenchyma, the cell wall is uniformly thickened.
 - **Lamellar collenchyma:** Lamellar Collenchyma cells have continuous layers of thickening in their cell walls. The cell walls are unevenly thickened, with the thickest regions forming these layers.

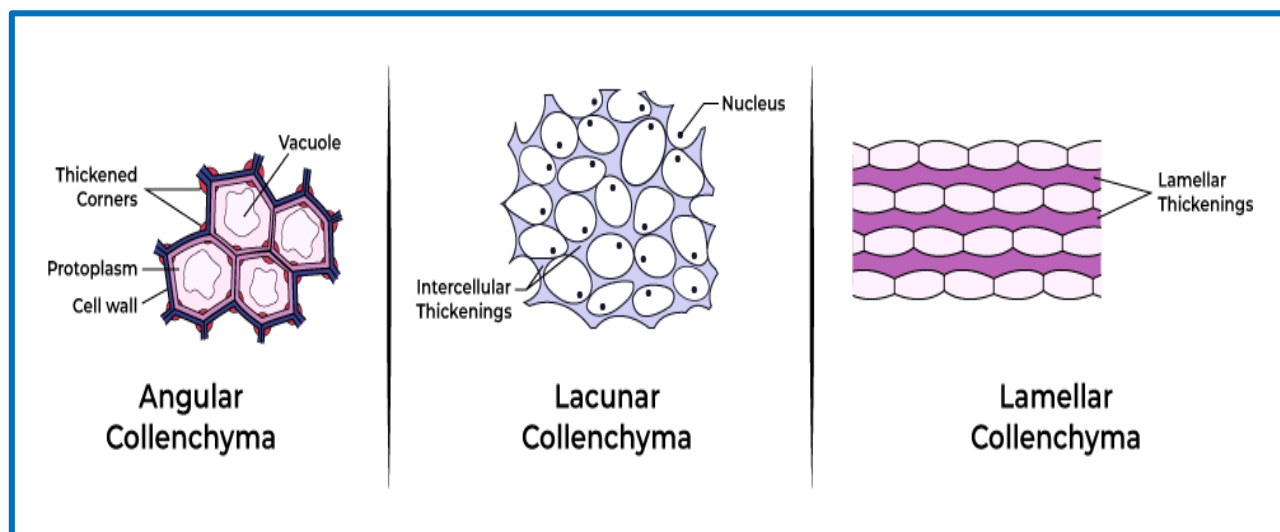


Figure 57. Different type of collenchyma (Angular, lacunar and lamellar collenchyma)

b- Sclerenchyma

- **Structure:** It is formed by dead, elongated, flexible cells scattered throughout the plant. Sclerenchyma is much stiffer than collenchyma. However, sclerenchyma cells produce a thick secondary wall, usually reinforced by lignin (lignin = cellular organic compound, nitrogen glycoside) and impermeable (see **Figure 58**).

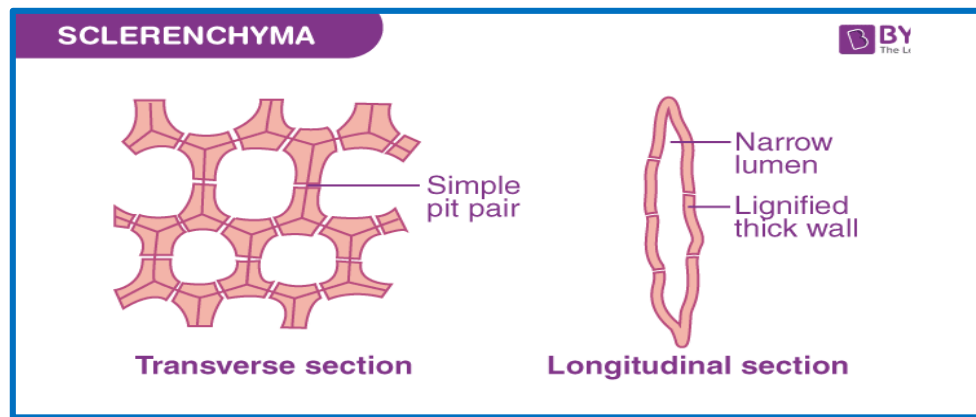


Figure 58. Sclerenchyma tissue

- **Function:** It provides support for the plant through rigidity and hardness.
- **Types:** Depending on the shape of the constituent elements of the sclerenchyma, 2 categories are distinguished (see **Figure 59**):
 - **Sclereids:** are short, isodiametric or irregular in shape. We distinguish: Brachysclereids (stone cells), Macrosclereids (malpighian cells), Osteosclereids, Astrosclereids (star-shaped cells), Trichosclereids, and Filiform sclereids.
 - **Fibres:** are elongated, needle-like pointed sclerenchyma cells. Depending on their location, we distinguish: cortical fibers, pericyclic fibers, bast fibers, woody fibers and medullary fibers.

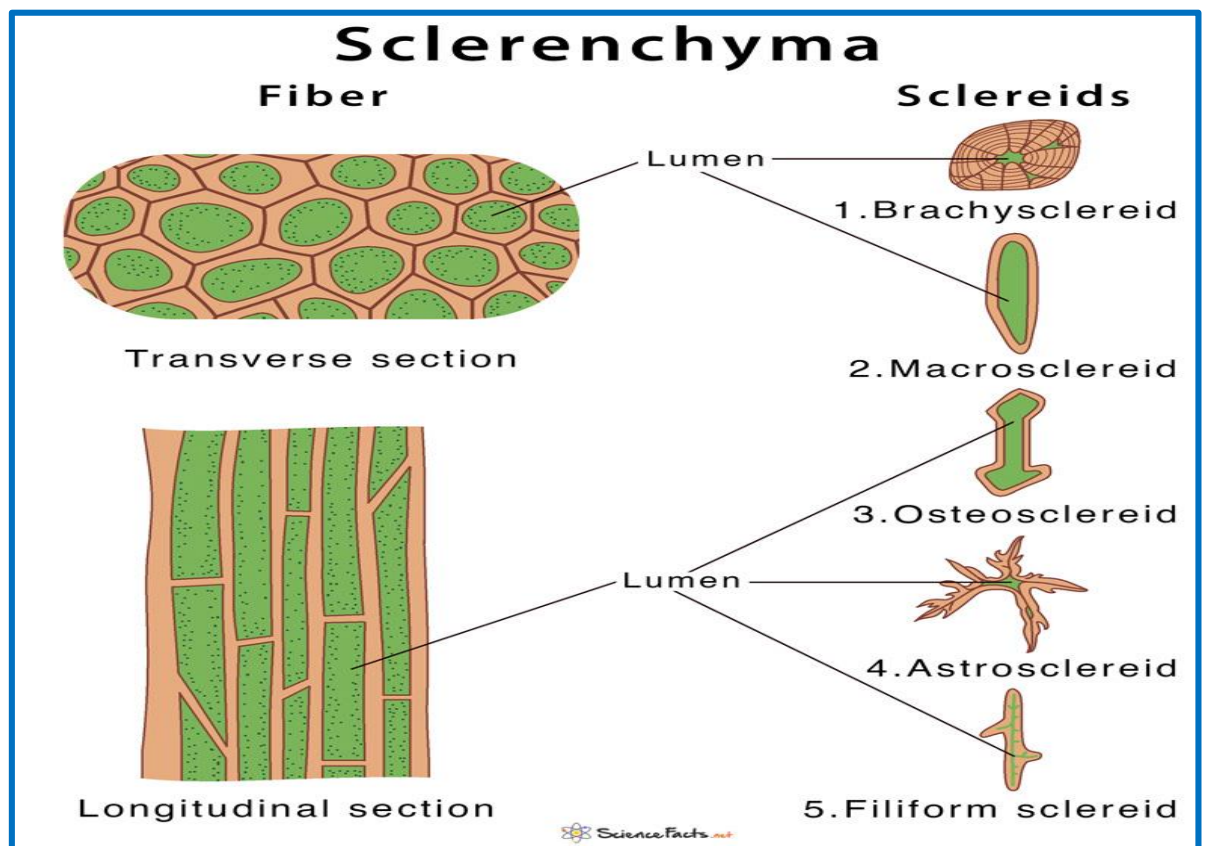


Figure 59. Different types of sclerenchyma (fiber and sclereids)

III.1.1.3. Secretory tissues

Cells or tissue associated with or facilitate the secretion is termed as the secretory cell or secretory tissue. The secretory tissue is broadly classified into 2 categories based on their position in the plant body. They are:

- a- **External secretory tissue**: Its unicellular or multicellular occur in the external surface of the plant, usually develop from the epidermis or sub-epidermal layers. There are 3 types:
 - **Glandular trichomes**: Are unicellular or multicellular epidermal hairs. Example: Digestives glands of *Drosera* (see **Figure 60**).

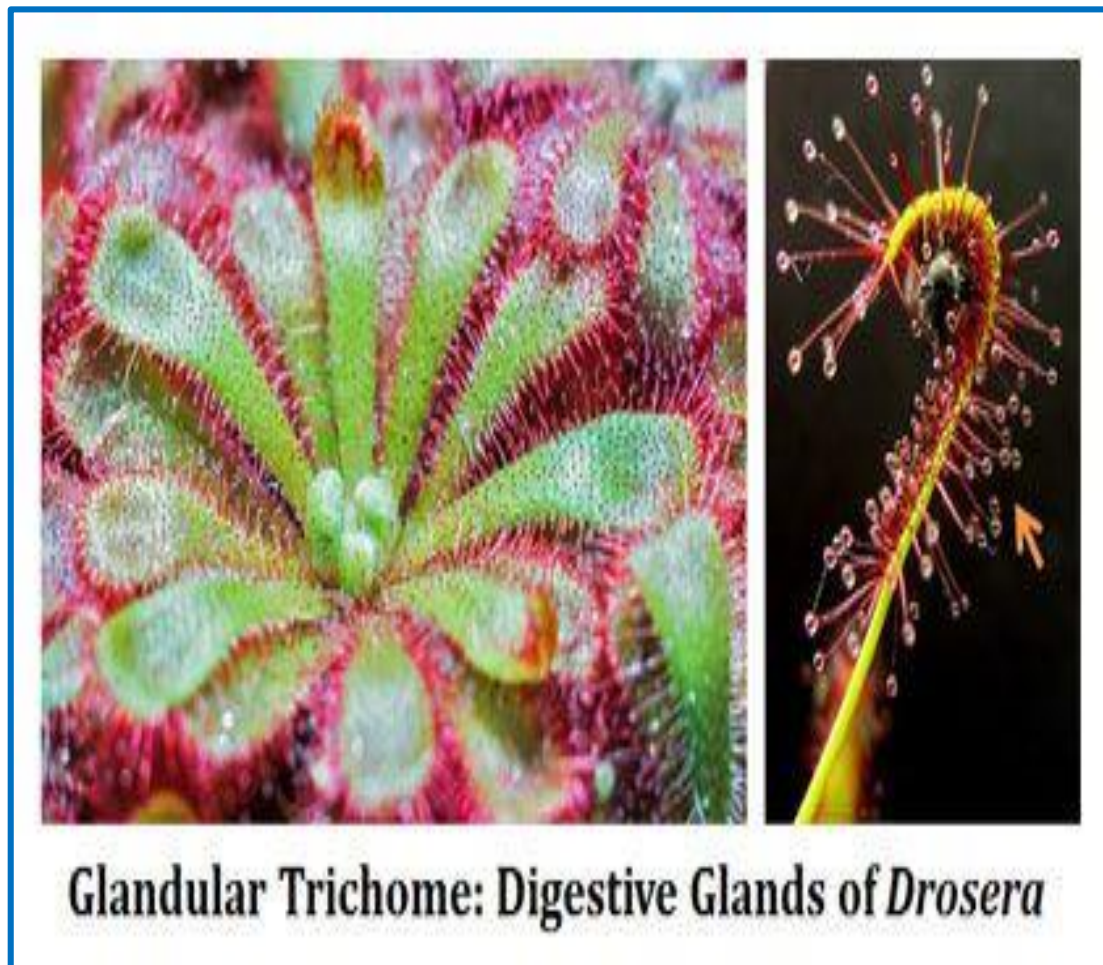


Figure 60. Glandular trichome (Digestive glands of *Drosera*)

- **Nectaries**: Secrete a sugary fluid (Nectar) associated with phloem (see **Figure 61**).
 - **Floral**: Associated with flowers (base of gynoecium or androecium).
 - **Extra-floral**: Are present on the vegetation parts, such as: Petiole, stem or pedicel.

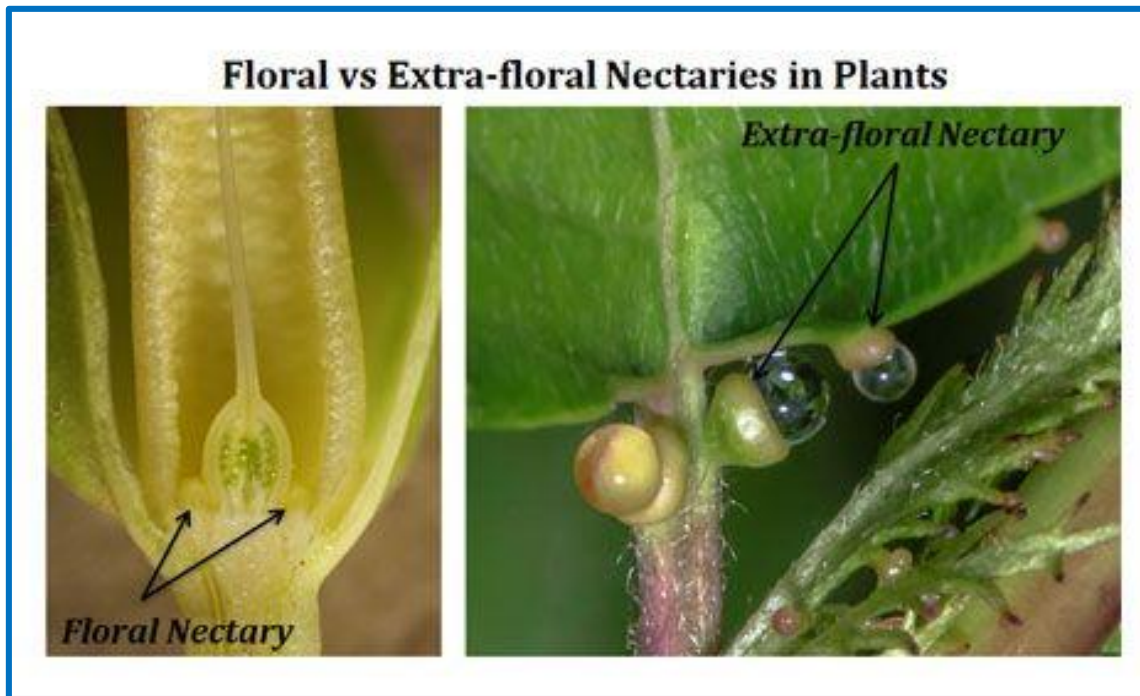


Figure 61. Floral and extra-floral nectaries in plants

- ***Hydathodes***: It's a pores (water stomata) on leaf, which exudes water as drops (guttation) (see **Figure 62**).

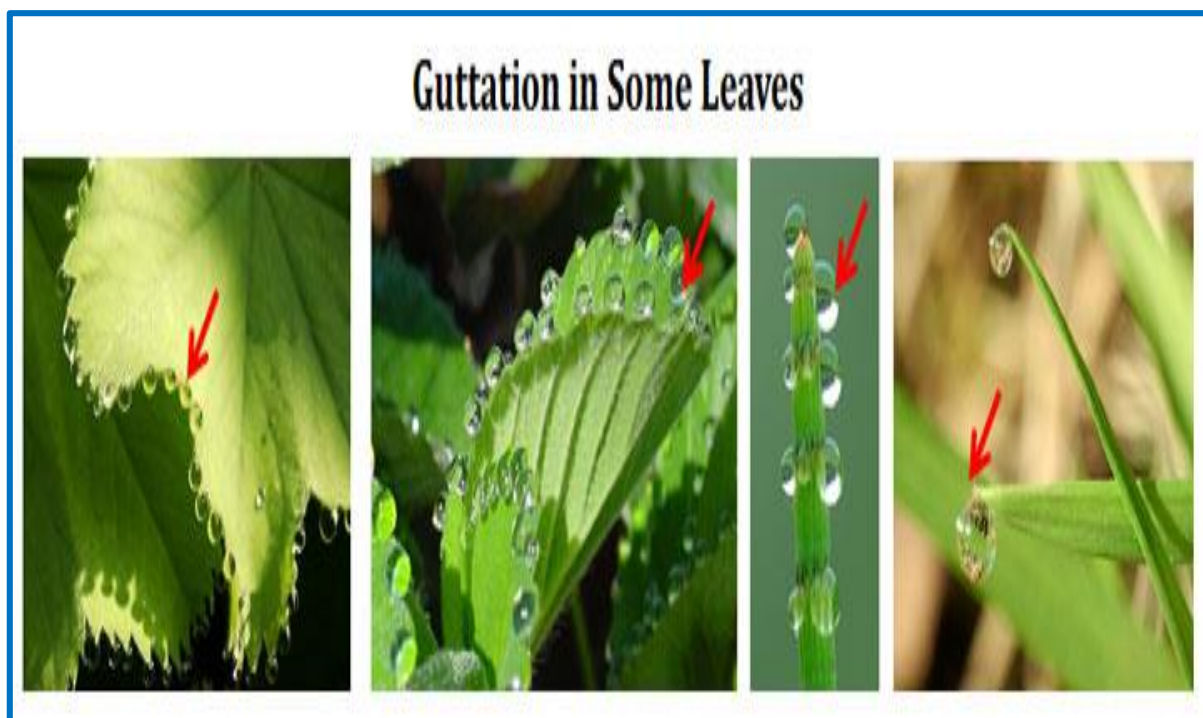


Figure 62. Guttation in some leaves

- ***Internal secretory tissue***: Is embedded inside the plants and they cannot be visualized externally. They store secretory products. There are 3 types:

- ***Internal secretory cells (Idioblasts)***: They can store tannin, mucilage, oils, crystals such as raphides and cystoliths
- ***Cavities and ducts***: These are cavities inside the plant body with secretory contents. Based on their origin we found 2 types (see **Figure 63**):
 - ***Lysigenous***: formed by lysis of some cells filled with the secretory contents. Example: In the members of Rutaceae.
 - ***Schizogenous***: formed by the separation of cells by the breakdown of middle lamella.

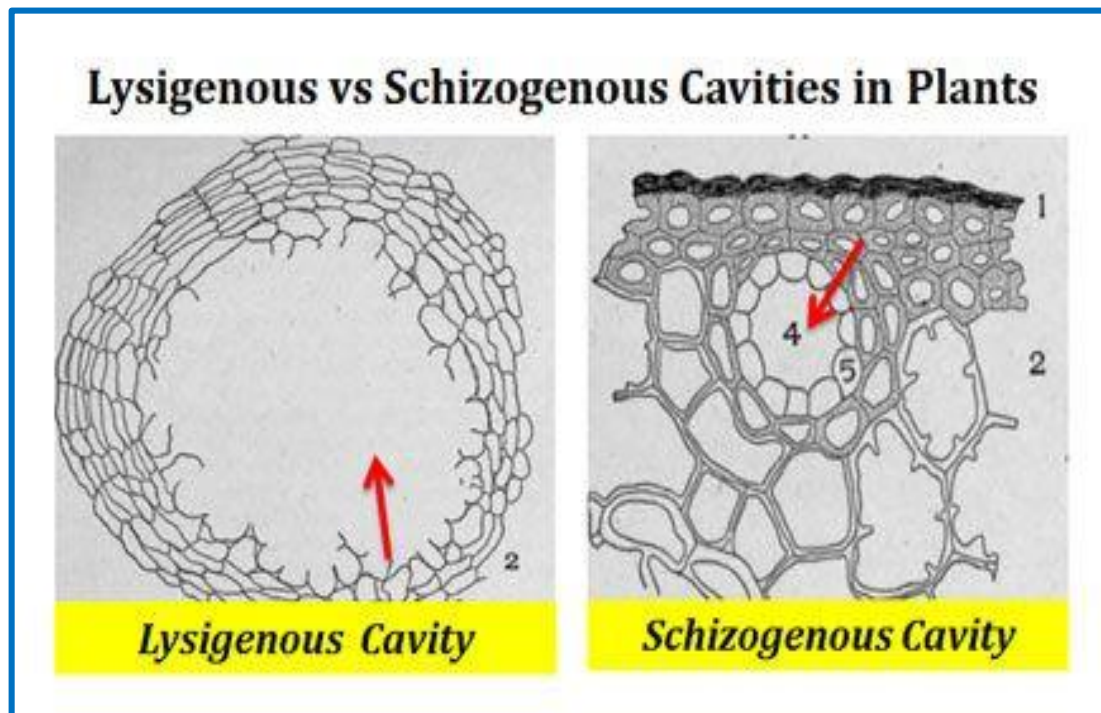


Figure 63. Lysigenous and schizogenous cavities in plants

- ***Laticifiers***: Are fused tube-like cells filled with a fluid called Latex (see **Figure 64**). 2 types of laticifiers:
 - ***Non-articulate (Latex cells)***: Originate from a single cell elongate
 - ***Articulate (Compound laticifiers)***: Originate from a series of cells arranged end to end. It resembles the xylem vessels (Latex vessels). There are 2 types:
 - ***Anastomosing***: with lateral connections are established with similar laticifier to form a reticulate structure. Example: Hevea.
 - ***Non-anastomosing***: No lateral connections are established. Example: Convolvulus.



Figure 64. *Opium poppy* exuding fresh latex from a cut.

III.1.1.4. Conductive tissue (primary xylem and primary phloem)

Primary conductive tissues are formed from the activity of primary meristems, which are responsible for the elongation of plant organs. They are typically found in young plants or species with shorter lifespans (see **Figure 65**). The primary conductive tissues consist of:

- **Primary Xylem:**
 - ❖ This tissue is primarily responsible for the transport of water and dissolved minerals from the roots to aerial parts of the plant.
 - ❖ It consists of specialized cells, including **tracheids** and **vessels**. Tracheids are long, narrow cells that facilitate water conduction and provide structural support, while vessels are wider cells that allow for more efficient water transport.
 - ❖ The xylem also has a lignified cell wall, which provides strength and rigidity, allowing the plant to withstand various stresses (**Esau, 1977**).
- **Primary Phloem:**
 - ❖ This tissue transports photosynthates (primarily sugars) produced during photosynthesis from the leaves to other parts of the plant, including growing tissues and storage organs.
 - ❖ The primary phloem consists of **sieve elements** and **companion cells**. Sieve elements are responsible for the transport of sugars, while companion cells assist in the metabolic functions of sieve elements (**Raven et al., 2005**).
 - ❖ Unlike xylem, phloem is living tissue at maturity and can facilitate the bidirectional flow of nutrients within the plant.

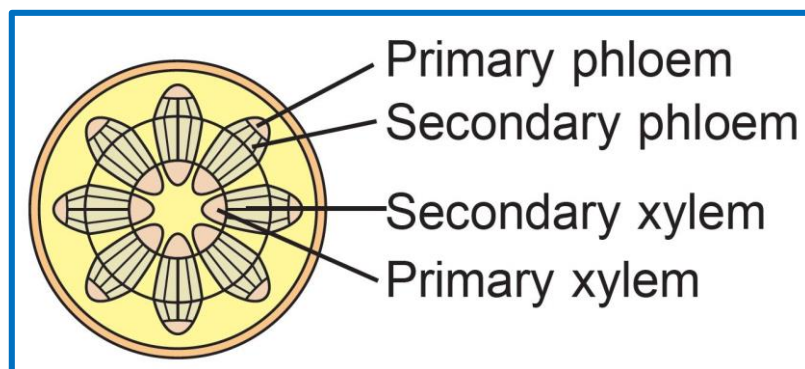


Figure 65. Primary and secondary conductive tissue (Phloem and xylem)

III.2. Secondary (lateral) meristems (the cambium and phellogen)

III.2.1. Types of secondary tissues

III.2.1.1. Conductive tissues (secondary xylem and secondary phloem)

Secondary conductive tissues are primarily found in most dicotyledons and are characterized by their development over several years or decades. These tissues arise from secondary meristems, particularly the cambium, which lies between the xylem and phloem. The cambium is responsible for producing additional layers of vascular tissue, leading to an increase in the plant's girth (see **Figure 65**). The secondary conductive tissues include:

- **Secondary Xylem (Wood):**
 - ❖ Secondary xylem is produced by the cambium and provides structural support to the plant.
 - ❖ It consists of tracheids, vessels, fibers, and parenchyma. The lignin in the secondary xylem enhances its mechanical strength, enabling trees and shrubs to grow taller and withstand environmental pressures.
 - ❖ Secondary xylem can also serve as a storage tissue for water and nutrients and plays a crucial role in the plant's overall physiology (**Esau, 1977**).
- **Secondary Phloem (Liber):**
 - ❖ This tissue transports nutrients and plays a role in the storage of carbohydrates.
 - ❖ Unlike secondary xylem, secondary phloem does not accumulate indefinitely, as the older layers are often crushed and replaced by newer layers, ensuring efficient nutrient transport (**Raven et al., 2005**).

III.2.1.2. Protective tissues (cork and phelloderm)

- **Cork (Suber):**
 - ❖ **Structure:** Composed of dead, thick-walled, and suberized cells filled with suberin, making it impermeable to water and gases.
 - ❖ **Function:**

- **Protection:** Shields against physical damage, pathogens, and herbivores.
 - **Water Retention:** Prevents excessive moisture loss.
 - **Insulation:** Protects from temperature fluctuations.
 - ❖ **Location:** Found in the outer layers of stems and roots, forming the periderm in woody plants.
- **Phelloderm:**
 - ❖ **Structure:** Made up of living, thin-walled parenchyma cells, located on the inner side of the cork cambium.
 - ❖ **Function:**
 - **Storage:** Stores nutrients and water.
 - **Photosynthesis:** May contain chloroplasts for limited photosynthesis.
 - **Support:** Contributes to structural integrity.
- **Formation:** Both tissues are produced by the cork cambium, which divides to create cork cells outward and phelloderm cells inward.
 - **Significance:** Cork and phelloderm are crucial for plant survival, helping to regulate water loss, protect against environmental challenges, and provide mechanical support, especially in woody plants.

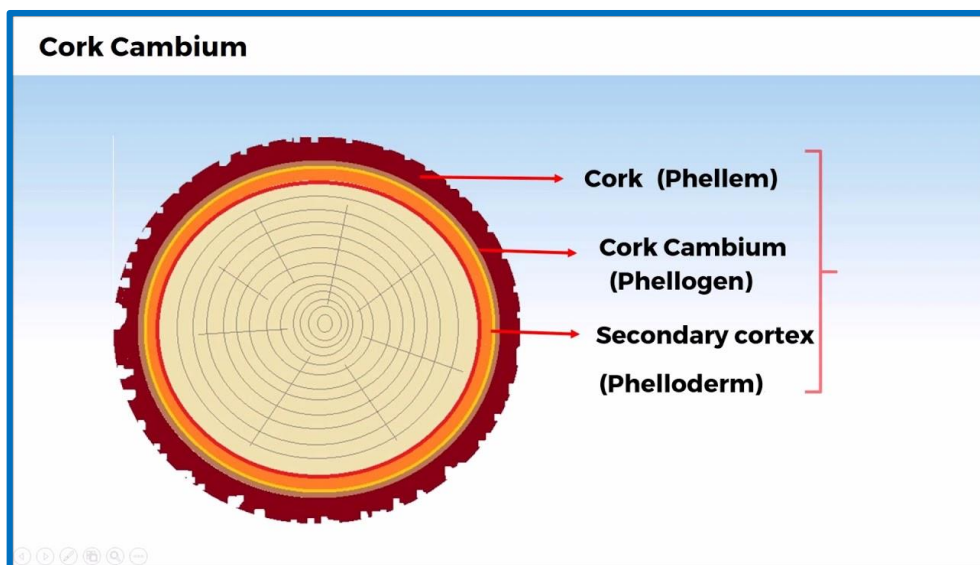


Figure 66. Cork and phelloderm tissue

III.2.2. Functions of conductive tissues

Conductive tissues are essential for the following functions:

- **Transport of Water and Nutrients:** Primary xylem is responsible for the upward transport of water and minerals, while primary phloem facilitates the downward and lateral movement of sugars and other nutrients.

- **Structural Support:** Secondary xylem provides the mechanical strength necessary for plants to grow tall and withstand physical stresses.
- **Storage:** Both xylem and phloem can serve as storage sites for essential nutrients and carbohydrates, aiding in the plant's survival during adverse conditions.
- **Adaptation and Growth:** The presence of secondary conductive tissues allows plants to adapt to their environments by increasing their girth, thereby improving their ability to compete for light and resources.
- **Regulation of Water Loss:** Conductive tissues play a role in regulating water loss through stomata, contributing to the plant's overall water management strategy (Raven et al., 2005).

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