MDC Semester III – Botany

Paper Title: Introduction to Botany

Unit I

History of Plant Classification

1. Classical & Medieval Period (Utility & Basic Morphology)

Early classification focused primarily on economic, agricultural, or medicinal uses, gradually shifting toward physical structure.

- **Theophrastus (370–285 BCE):** Known as the *"Father of Botany"*. In *Historia Plantarum*, he classified over 500 plants into four growth forms: trees, shrubs, sub-shrubs, and herbs.
- **Pedanius Dioscorides (40–90 CE):** Authored *De Materia Medica*, which grouped ~600 plants by their therapeutic properties. It served as the primary medical-botanical reference for over 1,500 years.

2. Renaissance & Mechanical Systems (16th–17th Century)

Botanists began relying on observable structures rather than utilitarian uses.

- **Andrea Cesalpino (1519–1603):** Considered the first true plant taxonomist; grouped plants using reproductive structures (flowers and fruits) rather than medicinal properties.
- **Gaspard Bauhin (1560–1624):** Published *Pinax Theatri Botanici* (1623), cataloging ~6,000 species and introducing early concepts of genus and species.
- **John Ray (1627–1705):** Introduced the distinction between **monocotyledons** and **dicotyledons** based on seed leaves (cotyledons).

3. The Artificial Era (18th Century)

Classification systems were constructed using a few convenient superficial traits for quick identification.

- **Carl Linnaeus (1707–1778):**
  - **Sexual System:** Classified plants into 24 classes based on stamen number and arrangement.
  - **Binomial Nomenclature:** Standardized two-part Latin naming (*Genus species*) in *Species Plantarum* (1753).

4. The Natural Era (Late 18th to 19th Century)

Botanists shifted toward overall structural affinity, grouping plants by shared morphological similarities rather than isolated arbitrary traits.

- **Antoine Laurent de Jussieu (1748–1836):** Developed a natural arrangement in *Genera Plantarum* (1789), organizing plants into major families.
- **Augustin Pyramus de Candolle (1778–1841):** Coined the term **taxonomy** and emphasized vascular anatomy (xylem and phloem).
- **George Bentham & Joseph Dalton Hooker:** Published *Genera Plantarum* (1862–1883), a pre-evolutionary natural system that remains widely used in herbarium management.

5. The Phylogenetic Era (Post-1859)

Following Charles Darwin's *On the Origin of Species*, classification shifted toward reflecting evolutionary relationships (common descent).

- **Adolf Engler & Karl Prantl:** Developed a phylogenetic system ordering plants from simple to complex structural features.
- **Charles Bessey (1845–1915):** Formulated explicit evolutionary principles ("Bessey's Dicta") to identify primitive versus derived traits.
- **Arthur Cronquist (1919–1992):** Introduced the widely adopted *Cronquist System* (1981) for flowering plants, relying heavily on anatomy, morphology, and chemistry.

6. The Molecular & APG Era (Late 20th Century–Present)

Modern taxonomy relies on DNA, RNA, and protein sequence data alongside cladistic analysis.

- **Angiosperm Phylogeny Group (APG):** An international coalition of botanists formed in 1998 that continually updates flowering plant classification based on multi-gene DNA analysis.
- **Key Major Reclassifications:**
    - Polyphyletic traditional groups (e.g., traditional "scrophulariaceae" or "dicots") were realigned into monophyletic clades.
    - Flowering plants are now grouped into core clades: **basal angiosperms**, **magnoliids**, **monocots**, and **eudicots**.

General Characteristics of Bacteria

1. Overview & Cell Structure

Bacteria are single-celled, microscopic organisms that lack a membrane-bound nucleus and organelles.

- Cellular Organization: Unicellular prokaryotes with no true nucleus; genetic material resides in a concentrated region called the nucleoid.
- Cell Wall Composition: Most bacteria possess a rigid cell wall composed of peptidoglycan (murein), which maintains shape and protects against osmotic lysis.
- Cell Membrane: Fluid phospholipid bilayer devoid of sterols (except in *Mycoplasma*), housing respiratory enzymes and transport mechanisms.
- Extrachromosomal DNA: Frequently contain plasmids—small, circular DNA molecules that carry non-essential genes, such as antibiotic resistance.
- Appendages:
  - Flagella: Rigid, rotating protein filaments used for locomotion.
  - Pili/Fimbriae: Hair-like surface projections used for attachment to surfaces or genetic transfer during conjugation.
- Capsule: An outer polysaccharide coating found in pathogenic strains that provides protection against host immune responses (phagocytosis).

2. Morphology & Cell Wall Classification

Bacteria exhibit distinct structural shapes and wall characteristics that determine their classification.

Morphological Shapes:

- Cocci: Spherical cells (e.g., *Staphylococcus*, *Streptococcus*).
- Bacilli: Rod-shaped cells (e.g., *Escherichia coli*, *Bacillus anthracis*).
- Spirilla / Spirochetes: Rigid or flexible spiral-shaped cells (e.g., *Treponema pallidum*).
- Vibrio: Comma-shaped curved rods (e.g., *Vibrio cholerae*).

Gram Staining Characteristics:

- Gram-Positive Bacteria: Possess a thick, multi-layered peptidoglycan wall that retains crystal violet dye, appearing purple under a light microscope.
- Gram-Negative Bacteria: Feature a thin peptidoglycan layer surrounded by an outer membrane containing lipopolysaccharides (LPS); they stain pink with counterstains like safranin.

3. Nutrition & Respiration

Bacteria display diverse metabolic capabilities, allowing them to thrive in varied environmental niches.

- Autotrophic: Synthesize their own organic molecules using inorganic sources.
  - Photoautotrophs: Utilize sunlight for energy (e.g., Cyanobacteria).
  - Chemoautotrophs: Obtain energy by oxidizing inorganic chemical compounds like sulfur or iron (e.g., *Nitrosomonas*).
- Heterotrophic: Depend on preformed organic matter for food (includes saprophytes, parasites, and symbionts).
- Respiratory Modes:
  - Obligate Aerobes: Require oxygen for survival and cellular respiration.
  - Obligate Anaerobes: Cannot survive in the presence of oxygen.
  - Facultative Anaerobes: Prefer oxygen, but can switch to fermentation in its absence.

4. Reproduction & Genetic Recombination

Reproduction is primarily asexual, while genetic variation is achieved through horizontal gene transfer.

- Binary Fission: The predominant mode of asexual reproduction where a parent cell replicates its chromosome and divides into two equal daughter cells.
- Endospore Formation: Certain strains (e.g., *Bacillus*, *Clostridium*) produce heat-, drought-, and chemical-resistant dormant spores under unfavorable environmental conditions.
- Genetic Recombination (Horizontal Gene Transfer):
  - Transformation: Direct uptake of naked exogenous DNA from the surrounding environment.
  - Transduction: Transfer of bacterial DNA from one host cell to another via a bacteriophage (virus).
  - Conjugation: Direct transfer of plasmids between bacterial cells through a sex pilus.

General Characteristics of Algae

1. Overview & Cellular Organization

Algae are a diverse group of photosynthetic, aquatic organisms ranging from microscopic unicellular species to massive multicellular kelps.

- Cellular Nature: Predominantly eukaryotic, containing membrane-bound organelles and a true nucleus (blue-green algae, or Cyanobacteria, are prokaryotes and now classified under Bacteria).
- Plant Body (Thallus): Non-vascular bodies lacking true roots, stems, leaves, or specialized internal transport tissues (xylem and phloem).
- Cell Wall Composition: Primarily composed of cellulose, often supplemented with other polysaccharides such as pectin, algin, agar, or carrageenan. Diatoms feature cell walls impregnated with silica.

2. Habitat & Occurrence

Algae inhabit almost any environment where moisture and sunlight are present.

- Aquatic:
  - Freshwater: Lakes, ponds, rivers (e.g., *Spirogyra*, *Chlamydomonas*).
  - Marine: Oceans and coastal habitats (e.g., *Sargassum*, *Fucus*, giant kelps).
- Terrestrial & Moist Habitats: Damp soil, rocks, tree bark, and walls.
- Specialized Associations:
  - Symbiotic: Form lichens in association with fungi.
  - Cryophilic / Thermophilic: Thrive in extreme temperatures such as snowfields (*Chlamydomonas nivalis*) or hot springs.

3. Pigmentation and Nutrition

Algae are primary producers that generate energy via photosynthesis using a variety of accessory pigments.

- Nutrition Mode: Autotrophic (photoautotrophic), utilizing sunlight to synthesize organic matter.
- Photosynthetic Pigments:
  - Chlorophylls: All algae contain Chlorophyll *a*; accessory forms include *b*, *c*, and *d*.
  - Carotenoids & Xanthophylls: Provide yellow-brown colour (e.g., fucoxanthin in brown algae).
  - Phycobilins: Red (phycoerythrin) and blue (phycocyanin) pigments prominent in red algae.

4. Major Algal Groups

Algae are broadly classified based on pigment composition, cell wall structure, and stored food reserves.

Group	Common Name	Major Pigments	Stored Food	Primary Habitat
Chlorophyceae	Green Algae	Chlorophyll *a*, *b*	Starch	Fresh & Marine water
Phaeophyceae	Brown Algae	Chlorophyll *a*, *c*, Fucoxanthin	Laminarin, Mannitol	Marine (Coastal)
Rhodophyceae	Red Algae	Chlorophyll *a*, *d*, Phycoerythrin	Floridean Starch	Marine (Deep sea)

5. Reproduction & Life Cycles

Algae exhibit diverse reproductive mechanisms to ensure adaptation and propagation.

- Vegetative: Cell division, fragmentation of the thallus, or tuber production.
- Asexual: Production of spores:
  - Zoospores: Flagellated, motile spores formed under favorable conditions.
  - Aplanospores / Akinetes: Non-motile, thick-walled spores designed for surviving harsh conditions.
- Sexual: Fusion of two gametes:
  - Isogamy: Gametes are identical in size and morphology (motile or non-motile).
  - Anisogamy: Gametes differ in size (smaller male, larger female; both typically motile).
  - Oogamy: Large, non-motile egg fertilized by a small, motile male gamete.

General Characteristics of Fungi

1. Cellular Organization & Structure

Fungi are non-photosynthetic eukaryotic organisms that occupy a distinct kingdom in biological classification.

- **Cellular Nature:** Predominantly multicellular (e.g., mushrooms, molds), with yeasts being notable single-celled exceptions.
- **Cell Wall Composition:** The cell wall is composed primarily of **chitin** (a polymer of N-acetylglucosamine), along with glucans and proteins—distinguishing them from plant cell walls made of cellulose.
- **Body Structure (Thallus):**
  - The vegetative body consists of a network of thread-like filaments called **hyphae**.
  - A mass of interconnected hyphae is referred to as a **mycelium**.
- **Hyphal Types:**

- **Septate:** Hyphae divided into individual cellular compartments by cross-walls called septa.
- **Aseptate / Coenocytic:** Hyphae lacking cross-walls, forming a continuous multinucleate cytoplasm.

2. Nutrition & Metabolism

Fungi lack chlorophyll and cannot perform photosynthesis; they rely on organic compounds for carbon and energy.

- **Heterotrophic Mode:** They are **absorptive heterotrophs**. Fungi secrete digestive enzymes (exoenzymes) into their surrounding environment to break down complex molecules, then absorb the simple nutrients.
- **Nutritional Strategies:**
  - **Saprophytes:** Decompose dead plant and animal organic matter (crucial ecological decomposers).
  - **Parasites:** Live on or in host organisms, causing diseases in plants, animals, and humans (e.g., *Puccinia*, *Candida*).
  - **Symbionts:** Form mutually beneficial associations:
    - **Lichens:** Association between a fungus (mycobiont) and an alga/cyanobacterium (photobiont).
    - **Mycorrhizae:** Symbiotic associations between soil fungi and the roots of vascular plants.
- **Storage Product:** Excess food is stored primarily as **glycogen** and oil droplets (similar to animals, unlike plant starch).

3. Habitat & Environmental Requirements

- **Ubiquitous Distribution:** Found in soil, water, air, and on or within living and decaying organisms.
- **Optimum Conditions:** Prefer warm, moist, and dark environments for optimal growth.
- **pH Tolerance:** Prefer slightly acidic growth conditions (pH around 5.0–6.0).

4. Reproduction Mechanisms

Fungi reproduce through vegetative, asexual, and sexual processes, producing vast numbers of spores for dispersion.

- **Vegetative Reproduction:** Occurs through fragmentation, budding (common in yeast), or binary fission.
- **Asexual Reproduction:** Takes place via spores produced without genetic recombination:

- **Conidia:** Non-motile spores produced externally on specialized hyphae (conidiophores).
- **Sporangiospores:** Spores produced within a sac-like structure (sporangium).

- **Sexual Reproduction:** Involves three sequential steps:
    1. **Plasmogamy:** Fusion of protoplasts from two compatible haploid cells/hyphae, bringing two nuclei together.
    2. **Karyogamy:** Fusion of the two haploid nuclei to form a diploid zygote nucleus.
    3. **Meiosis:** Reduction division that restores the haploid state, producing genetically diverse sexual spores.

5. Major Fungal Groups

Fungi are broadly categorized based on their sexual spore-bearing structures and hyphal organization.

Group	Common Name	Hyphae Type	Primary Sexual Spores	Examples
Zygomycota	Conjugation Fungi	Coenocytic (Aseptate)	Zygospores	*Rhizopus* (Bread mold), *Mucor*
Ascomycota	Sac Fungi	Septate	Ascospores (in Asci)	*Saccharomyces* (Yeast), *Penicillium*, *Aspergillus*
Basidiomycota	Club Fungi	Septate	Basidiospores (on Basidia)	*Agaricus* (Mushroom), *Puccinia* (Rust)
Chytridiomycota	Chytrids	Coenocytic	Zoospores (Flagellated)	*Batrachochytrium*

General Characters of Bryophyta

1. Overview & Evolutionary Status

Bryophytes are small, non-vascular land plants that mark the evolutionary transition from aquatic algae to terrestrial vascular plants.

- **Amphibians of the Plant Kingdom:** They require water for sexual reproduction (specifically for motile flagellated sperm to swim to the egg cell).
- **Vascular Tissue:** Lack true vascular tissue (**xylem** and **phloem**); water and nutrient transport occurs via cell-to-cell diffusion or specialized conducting cells (leptoids and hydroids in some mosses).
- **Plant Body Structure:**
  - Lacks true roots, stems, and leaves.
  - Attached to the substratum by root-like unicellular or multicellular structures called **rhizoids**.
  - May be **thalloid** (flat, prostrate sheet, e.g., *Riccia*, *Marchantia*) or **foliose** (erect with leaf-like and stem-like structures, e.g., *Funaria*).

2. Life Cycle & Alternation of Generations

Bryophytes exhibit a distinct **heteromorphic alternation of generations**, where the haploid phase dominates.

- **Dominant Gametophyte (n):**
  - The main plant body is the independent, photosynthetic, free-living haploid gametophyte.
  - Produces sex organs and gametes.
- **Dependent Sporophyte ($2n$):**
  - The diploid phase is physically attached to and structurally dependent on the gametophyte for nutrition and water.
  - Consists typically of three parts: **foot** (anchorage/absorption), **seta** (stalk), and **capsule** (spore-producing region).

3. Sexual & Reproductive Characteristics

- **Sex Organs:** Multicellular, jacketed, and specialized to protect developing gametes from desiccation.
  - **Antheridium (Male Organ):** Club-shaped structure that produces biflagellated, motile **antherozoids** (sperm).
  - **Archegonium (Female Organ):** Flask-shaped structure containing a single non-motile **egg cell** (ovum).
- **Fertilization Process:**
  1. Water acts as a medium for antherozoids to swim to the archegonium.
  2. Fusion forms a diploid zygote ($2n$).
  3. The zygote undergoes mitotic division directly within the archegonium without an immediate meiotic rest, developing into the sporophyte.
- **Spore Production:** Meiosis occurs inside the sporophyte capsule to produce haploid **homospores** (spores of a single uniform type).

- **Germination:** Spores germinate directly into a gametophyte thallus or indirectly through a filamentous juvenile stage called a **protonema** (in mosses).

4. Major Subdivisions of Bryophyta

Bryophytes are traditionally divided into three distinct classes based on thallus and sporophyte structure.

Feature	Hepaticopsida (Liverworts)	Anthocerotopsida (Hornworts)	Bryopsida (Mosses)
Plant Body	Thalloid or leafy, dorsiventral	Thalloid, flattened	Foliose (leafy) with radial symmetry
Rhizoids	Unicellular	Unicellular	Multicellular with oblique septa
Sporophyte	Simple (Foot, Seta, Capsule)	Horn-like, continuous growth via basal meristem	Elaborate (Foot, Seta, Capsule with columella)
Special Structures	Elaters present for spore dispersal	Pseudo-elaters present	Peristome teeth for spore dispersal
Examples	*Riccia*, *Marchantia*	*Anthoceros*	*Funaria*, *Sphagnum*, *Polytrichum*

General Characters of Pteridophyta

1. Overview & Evolutionary Significance

Pteridophytes are spore-bearing vascular plants that represent a major evolutionary transition in land plants.

- **First Vascular Land Plants:** They are the earliest terrestrial plants to possess specialized conducting tissues (**xylem** and **phloem**), though xylem lacks true vessels (except in *Equisetum* and *Gnetales*) and phloem lacks companion cells.
- **Vascular Cryptogams:** Often called "seedless vascular plants" because they reproduce via spores rather than seeds.
- **Habitat:** Typically thrive in cool, damp, and shady environments, though some species are aquatic (*Azolla*, *Salvinia*, *Marsilea*) or xerophytic (*Selaginella lepidophylla*).

2. Plant Body Organization

Unlike bryophytes, the dominant phase in pteridophytes is structurally complex and fully independent.

- **Dominant Sporophyte ($2n$):** The main plant body is a diploid sporophyte differentiated into true **roots**, **stems**, and **leaves**.
- **Leaf Structure:**
    - **Microphylls:** Small, simple leaves with a single unbranched vascular vein (e.g., *Selaginella*, *Lycopodium*).
    - **Megaphylls:** Large, complex leaves with branched vascular networks, often called **fronds** (e.g., ferns).
- **Stele Types:** Vascular tissue organization in stems ranges from primitive **protosteles** (solid vascular core) to **siphonosteles** (hollow cylinder with pith) and **dictyosteles** (fragmented network).

3. Reproduction & Life Cycle

Pteridophytes exhibit an **alternation of generations** with independent, free-living sporophytic and gametophytic phases.

- **Spore Production:**
    - Spores are produced inside specialized structures called **sporangia**.
    - Sporangia are often clustered on the underside or margins of fertile leaves called **sporophylls**, forming distinct clusters called **sori** (singular: *sorus*).
    - In some groups (e.g., *Selaginella*, *Equisetum*), sporophylls aggregate at the tips of shoots to form compact structures called **strobili** or **cones**.

- **Spore Condition:**
    - **Homosporous:** Produce a single type of morphologically identical spore that yields bisexual gametophytes (e.g., *Nephrolepis*, *Lycopodium*).
    - **Heterosporous:** Produce two types of spores—smaller **microspores** (giving rise to male gametophytes) and larger **megaspores** (giving rise to female gametophytes) (e.g., *Selaginella*, *Marsilea*, *Salvinia*).
- **The Gametophyte (Prothallus):**
    - Spores germinate to form a small, inconspicuous, photosynthetic, non-vascular haploid stage called a **prothallus** (n).
    - Requires a moist environment for survival and fertilization.

4. Sexual Reproduction & Fertilization

- **Sex Organs:** Born on the prothallus; multicellular and jacketed.
    - **Antheridium:** Produces flagellated, motile **antherozoids** (sperm).
    - **Archegonium:** Flask-shaped structure housing the **egg cell**.
- **Water Requirement:** Water is strictly required as a swimming medium for antherozoids to reach the archegonium and fertilize the egg.

- **Precursor to Seed Habit:** In heterosporous species (like *Selaginella*), the female gametophyte is retained on the parent sporophyte for a duration, providing nutrition to the developing zygote—an important evolutionary milestone toward the seed habit seen in gymnosperms and angiosperms.

5. Classification of Pteridophyta

Pteridophytes are broadly divided into four major classes:

Class	Common Name	Key Characteristics	Representative Examples
Psilopsida	Whisk Ferns	Rootless, photosynthetic stems, protostelic	*Psilotum*
Lycopsida	Club Mosses	Microphyllous leaves, distinct strobili	*Lycopodium*, *Selaginella*
Sphenopsida	Horsetails	Jointed stems with silica deposits, whorled branches	*Equisetum*
Pteropsida	True Ferns	Megaphyllous leaves (fronds), sori on leaf underside	*Adiantum*, *Dryopteris*, *Marsilea*

General Characters of Gymnosperms

1. Overview & Evolutionary Significance

Gymnosperms (from Greek *gymnos* = naked, *sperma* = seed) are vascular, seed-bearing plants whose seeds are not enclosed within an ovary or fruit.

- **Naked Seeds:** Ovules are exposed on the surface of specialized leaves called **megasporophylls**, which are usually arranged to form cones.
- **Evolutionary Transition:** Represent an evolutionary link between non-seed vascular plants (pteridophytes) and flowering plants (angiosperms).
- **Habitat & Habit:** Primarily perennial, woody trees or shrubs, commonly adapted to temperate, cold, or xerophytic environments (e.g., *Pinus*, *Cycas*, *Sequoia*). Includes *Sequoia sempervirens*, one of the tallest living tree species.

2. Plant Body Organization & Vascular System

The dominant phase is an independent, diploid **sporophyte** ($2n$) with advanced structural differentiation.

- **Root System:**Generally possess a well-developed taproot system.
    - **Specialized Root Associations:**
        - **Coralloid Roots:** Found in *Cycas*, harboring nitrogen-fixing cyanobacteria (*Anabaena*).
        - **Mycorrhizae:** Fungal associations found on the roots of *Pinus* that aid in nutrient and water absorption.
- **Stems:** Can be unbranched (*Cycas*) or branched (*Pinus*, *Cedrus*). Stems exhibit secondary growth via a vascular cambium.
- **Leaves:** Adapted to withstand extreme temperature, wind, and drought:
    - **Pinnate/Simple Leaves:***Cycas* has large, pinnately compound leaves.
    - **Needle-like Leaves:***Pinus* leaves are needle-shaped with a thick cuticle, sun-sunk stomata, and reduced surface area to minimize transpiration.
- **Vascular Anatomy:** Well-developed vascular system.
    - **Xylem:** Contains tracheids for water conduction; lacks true vessel elements (except in the order **Gnetales**).
    - **Phloem:** Contains sieve cells and albuminous cells; lacks companion cells.

3. Reproduction & Cone Structure

Gymnosperms are strictly **heterosporous**, producing two types of spores in specialized unisexual cones (strobili).

- **Microsporangiate Cones (Male Cones):**
    - Consist of spirally arranged **microsporophylls**.
    - Bear microsporangia that produce haploid **microspores** via meiosis.
    - Microspores develop into highly reduced male gametophytes called **pollen grains**(winged in *Pinus* to aid wind dispersal).
- **Megasporangiate Cones (Female Cones):**
    - Consist of **megasporophylls** or ovuliferous scales bearing exposed **ovules** (megasporangia).
    - A single functional megaspore inside the ovule develops into a multicellular female gametophyte (**endosperm**).

4. Pollination, Fertilization & Life Cycle

- **Pollination Mode:** Anemophilous (wind-pollinated). Pollen grains drop directly through the micropyle of the exposed ovule into a pollination drop.

- **Gametophytes:** Highly reduced and completely dependent on the parent sporophyte for nutrition.
- **Fertilization:**
    - Pollen tube grows through the nucellus to deliver male gametes to the archegonia (**siphonogamy**).
    - **Single Fertilization:** Unlike angiosperms, gymnosperms undergo single fertilization.
    - The haploid female gametophyte serves directly as the food-reserve tissue (**endosperm**, n) *before* fertilization occurs.
- **Seed Formation:** The fertilized ovule develops into a seed consisting of a seed coat ($2n$), female gametophyte tissue (n), and an embryo ($2n$).

5. Major Divisions of Gymnosperms

Gymnosperms are traditionally grouped into four living orders:

Division / Order	Key Features	Examples
Cycadophyta	Palm-like appearance, unbranched stems, motile (flagellated) sperm, large terminal cones	*Cycas*
Coniferophyta	Cone-bearing evergreen trees with needle/scale-like leaves, non-motile sperm	*Pinus*, *Cedrus*, *Sequoia*
Ginkgophyta	Single living species, fan-shaped leaves with dichotomous venation, dioecious	*Ginkgo biloba*
Gnetophyta	Advanced group possessing true xylem vessels; shares traits with angiosperms	*Ephedra*, *Welwitschia*, *Gnetum*

Life Cycle of Angiosperms

1. Overview & Plant Body Organization

Angiosperms (flowering plants) represent the most advanced and dominant group of land plants. Their life cycle is characterized by an **alternation of generations** between a dominant, independent diploid sporophyte ($2n$) and a highly reduced, dependent haploid gametophyte (n).

- **Dominant Phase:** The diploid **sporophyte** ($2n$), which comprises the vegetative structures (roots, stems, leaves) and the reproductive organs (flowers).
- **Reproductive Unit:** The **flower**, a modified shoot bearing specialized reproductive floral whorls:
    - **Androecium:** Male reproductive whorl composed of **stamens**.

- **Gynoecium (Pistil):** Female reproductive whorl composed of one or more **carpels**.

2. Male Gametophyte Development (Microsporogenesis)

The male gametophyte is developed within the **anther** of the stamen.

1. **Microsporogenesis:** Inside the anther's pollen sacs (microsporangia), diploid microspore mother cells ($2n$) undergo **meiosis** to produce four haploid **microspores** (n).
2. **Microgametogenesis:** Each haploid microspore undergoes mitosis to form a **pollen grain** (the male gametophyte).
3. **Pollen Composition:** At maturity or dispersal, the pollen grain contains:
    - A **vegetative cell** (tube cell), which governs pollen tube growth.
    - A **generative cell**, which divides mitotically to form **two non-motile male gametes** (sperm cells).

3. Female Gametophyte Development (Megasporogenesis)

The female gametophyte develops inside the **ovule**, which is enclosed within the **ovary** of the carpel.

1. **Megasporogenesis:** A diploid megaspore mother cell ($2n$) inside the nucellus undergoes **meiosis** to yield four haploid **megaspores** (n). Three degenerate, leaving **one functional megaspore**.
2. **Megagametogenesis:** The functional megaspore undergoes three consecutive mitotic nuclear divisions without immediate cytokinesis, producing an **8-nucleate, 7-celled embryo sac** (the mature female gametophyte):
    - **Egg Apparatus (3 cells at micropylar end):** One **egg cell** (female gamete) flanked by two **synergids**.
    - **Antipodal Cells (3 cells at chalazal end):** Provide nourishment during early development.
    - **Central Cell (1 cell):** Houses **two polar nuclei** ($n + n$).

4. Pollination, Double Fertilization & Endosperm

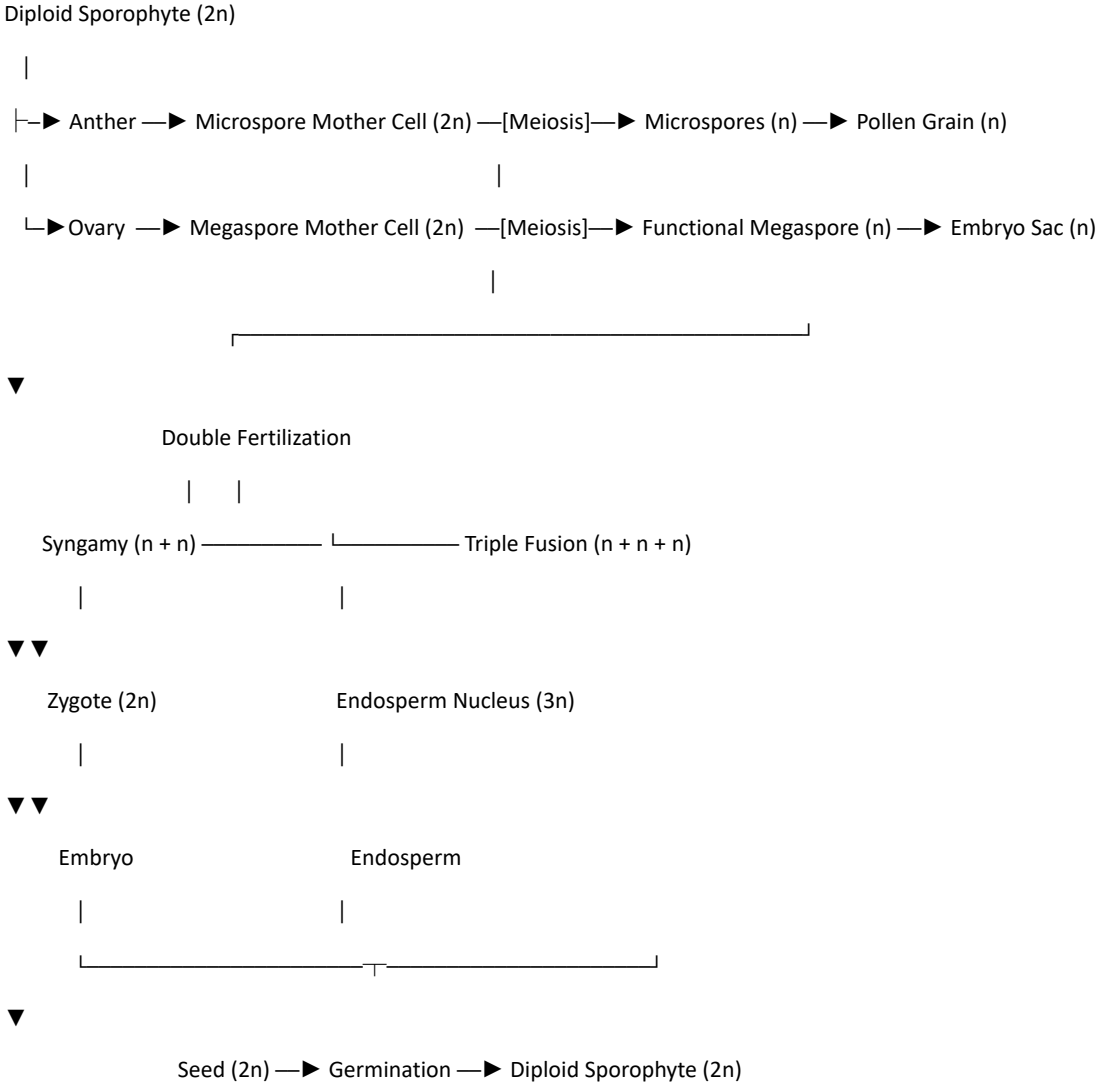
1. **Pollination:** Transfer of pollen grains from an anther to the receptive **stigma** of a carpel via wind, water, or animal vectors.
2. **Pollen Tube Growth:** The pollen grain germinates on the stigma, extending a pollen tube down through the style into the ovary, carrying the two male gametes into the embryo sac through the micropyle.
3. **Double Fertilization:** A hallmark feature unique to angiosperms:
    - **Syngamy (Generative Fertilization):** One male gamete (n) fuses with the egg cell (n) to form a diploid **zygote** ($2n$).
    - **Triple Fusion:** The second male gamete (n) fuses with the two polar nuclei ($n + n$) in the central cell to form a triploid ($3n$) **Primary Endosperm Nucleus (PEN)**.

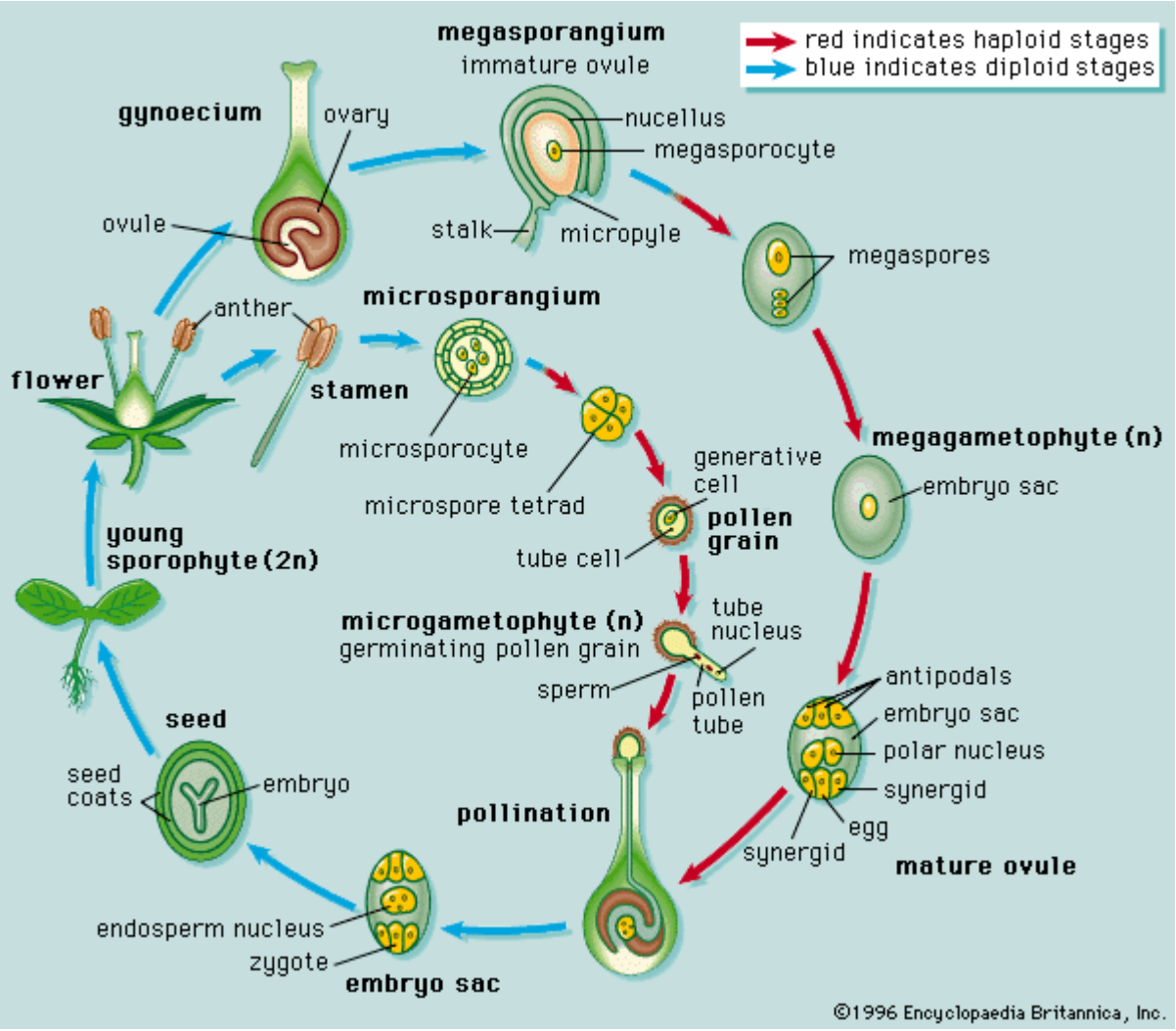
5. Post-Fertilization Changes & Seed Development

Following double fertilization, the flower undergoes structural transformation to form fruits and seeds:

- **Zygote ($2n$):** Develops into the **embryo** via mitotic divisions (consisting of radicle, plumule, and 1 or 2 cotyledons).
- **Primary Endosperm Cell ($3n$):** Divides to form the **endosperm**, a nutrient-rich tissue that nourishes the developing embryo.
- **Ovule:** Transforms into the **seed**, with its integuments hardening into the seed coat (testa and tegmen).
- **Ovary:** Swells and ripens into the **fruit**, enclosing the seed(s).

6. Summary of Life Cycle Phases





Unit-II

Classification Of Plants Onthe Basis On Habit, Habitat and Longevity

1. Classification Based on Habit

Habit refers to the general structural appearance, growth form, branching pattern, and texture of a plant's main body.

A. Herbs

- Structural Traits: Non-woody (herbaceous) plants with soft, green, and delicate stems. They generally lack secondary growth (thickening of wood) and remain short, rarely exceeding 1–2 meters in height.
- Key Characteristics:

    - Stems are flexible and can bend easily without breaking.
    - Their aerial parts often die back at the end of the growing season.
- Examples: Wheat (*Triticum aestivum*), Tomato (*Solanum lycopersicum*), Mint (*Mentha*), Mustard (*Brassica campestris*).

B. Shrubs

- Structural Traits: Medium-sized woody plants usually growing between 1 to 3 meters tall.
- Key Characteristics:
    - They branch heavily from near the base of the soil level rather than having a single clear trunk, giving them a bushy appearance.
    - Their stems are hard and woody, but not as thick as tree trunks.
- Examples: Rose (*Rosa* spp.), Hibiscus (*Hibiscus rosa-sinensis*), Jasmine (*Jasminum* spp.), Bougainvillea.

C. Trees

- Structural Traits: Tall, erect, and stout woody plants with a distinct main vertical axis called a trunk or bole.
- Key Characteristics:
    - Trunk undergoes pronounced secondary growth, producing thick bark and durable timber.
    - Branches develop at a significant height above the ground level to form a canopy.
- Sub-types:
    - Excurrent: Main trunk continues upward, with shorter lateral branches forming a cone shape (e.g., Pine, Cedar).
    - Deliquescent: Main trunk divides into several large spreading branches, forming a dome shape (e.g., Banyan, Mango).
    - Caudex: Unbranched trunk with a terminal crown of leaves (e.g., Coconut, Date Palm).
- Examples: Oak (*Quercus* spp.), Banyan (*Ficus benghalensis*), Mango (*Mangifera indica*), Neem (*Azadirachta indica*).

D. Climbers

- Structural Traits: Plants with long, thin, and weak stems that cannot support themselves vertically.
- Key Characteristics:
    - They rely on external mechanical support (structures, rocks, or other plants) to climb up toward light.

- Use specialized support structures like tendrils (modified leaves/stems), twiners (twining stems), or adventitious rootlets.

- Examples: Garden Pea (*Pisum sativum*), Grapevine (*Vitis vinifera*), Money plant (*Epipremnum aureum*), Passionflower (*Passiflora*).

E. Creepers

- Structural Traits: Weak-stemmed plants that trail horizontally along the surface of the soil.
- Key Characteristics:
    - Stems extend radially across the ground, frequently striking adventitious roots at their nodes to anchor and absorb nutrients.
    - Unable to climb vertically due to fragile vascular systems or heavy fruit structures.
- Examples: Pumpkin (*Cucurbita* spp.), Watermelon (*Citrullus lanatus*), Strawberry (*Fragaria* spp.), Sweet potato (*Ipomoea batatas*).

2. Classification Based on Habitat

Habitat refers to the natural physical environment, soil condition, moisture level, or ecological niche where a plant naturally grows.

A. Mesophytes

- Definition: Plants adapted to environment with moderate moisture levels and ambient temperatures (average terrestrial habitats).
- Adaptations:
    - Well-developed root systems with root caps and root hairs.
    - Broad, flat leaves with stomata usually located on the lower surface to regulate transpiration.
    - Well-differentiated vascular (xylem/phloem) and mechanical tissues.
- Examples: Wheat (*Triticum aestivum*), Sunflower (*Helianthus annuus*), Apple (*Malus domestica*), Corn (*Zea mays*).

B. Xerophytes

- Definition: Plants adapted to extremely dry, arid habitats with limited water supply (deserts, sand dunes).
- Adaptations:
    - Morphological: Leaves reduced to spines or scales to reduce transpiration surface area; stems modified into green photosynthetic organs (phylloclades).
    - Anatomical: Thick cuticles, sunken stomata covered with trichomes (hairs), and multiple epidermal layers.
    - Physiological: Fleshy tissues (succulence) for water storage and specialized photosynthetic pathways (CAM pathway) to keep stomata closed during the day.

- Examples: Prickly Pear Cactus (*Opuntia*), *Aloe vera*, Agave, *Euphorbia*.

C. Hydrophytes

- Definition: Plants adapted to grow in aquatic environments—either fully submerged, partially submerged, or floating on water.
- Adaptations:
    - Structural: Poorly developed root systems (or complete lack of roots); thin cuticles or no cuticle.
    - Internal Structure: Abundant aerenchyma (air-filled spongy tissue) providing buoyancy and aiding internal gas exchange.
    - Floating Leaves: Stomata located exclusively on the upper surface (epistomatous leaves) coated with waxy layers to repel water.
- Examples:
    - Free-floating: Duckweed (*Lemna*), Water Hyacinth (*Eichhornia*).
    - Submerged: *Hydrilla verticillata*, *Vallisneria*.
    - Rooted with floating leaves: Water Lily (*Nymphaea*), Lotus (*Nelumbo nucifera*).

D. Halophytes

- Definition: Salt-tolerant plants adapted to grow in soils or waters with high salt concentrations (coastal mudflats, estuaries, mangrove swamps).
- Adaptations:
    - Specialized roots called pneumatophores (negatively geotropic breathing roots) with lenticels to facilitate oxygen uptake in waterlogged, anoxic mud.
    - Vivipary: Seeds germinate while still attached to the parent tree to ensure survival before dropping into saline water.
    - Salt-excreting glands on leaves or cell vacuoles designed to store high salt levels safely.
- Examples: Red Mangrove (*Rhizophora mangle*), *Avicennia*, Glasswort (*Salicornia*).

E. Epiphytes

- Definition: Non-parasitic plants that grow attached to the trunks or branches of larger trees purely for physical positioning and access to light.
- Adaptations:
    - Possess specialized hanging aerial roots with a spongy tissue called velamen that absorbs atmospheric moisture and dissolved nutrients directly from rain and mist.
    - Do not drain nutrients from the host plant (unlike parasites).
- Examples: Orchids (*Vanda*), Spanish Moss (*Tillandsia usneoides*), Staghorn Fern (*Platycerium*).

3**. Classification Based on Longevity (Lifespan)**

Longevity classifies plants by the time required to complete their lifecycle (germination, vegetative growth, flowering, seed production, and senescent death).

A. Ephemerals

- Lifecycle Duration: Entire lifecycle is completed in a matter of a few weeks (usually 3 to 6 weeks).
- Characteristics:
    - Common in arid regions or extreme seasonal environments. They germinate rapidly following brief rainfall, bloom, set seeds, and die before the severe dry season sets in.
    - Seeds remain dormant in the soil until the next favorable moisture spell.
- Examples: *Arabidopsis thaliana*, *Boerhavia repens*, Desert Gold (*Geraea canescens*).

B. Annuals

- Lifecycle Duration: Complete their entire lifecycle within a single growing season or one year.
- Characteristics:
    - The plant germinates, develops roots and leaves, flowers, produces seeds, and undergoes complete senescence/death within one year.
    - Typically herbaceous with rapid growth rates.
- Examples: Rice (*Oryza sativa*), Corn (*Zea mays*), Peas (*Pisum sativum*), Marigold (*Tagetes*).

C. Biennials

- Lifecycle Duration: Require two full growing seasons to complete their life cycle.
- Characteristics:
    - Year 1 (Vegetative Phase): Focuses on germination, leaf rosette development, and storing energy/food reserves in fleshy roots or bulbs.
    - Year 2 (Reproductive Phase): Uses stored energy to produce tall flowering stems (bolting), sets seeds, and dies.
- Examples: Carrot (*Daucus carota*), Radish (*Raphanus sativus*), Onion (*Allium cepa*), Sugar beet (*Beta vulgaris*).

D. Perennials

- Lifecycle Duration: Live for more than two years (often decades or centuries).
- Characteristics:
    - Polycarpic Perennials: Flower and produce seeds repeatedly every year after reaching maturity (e.g., Apple, Mango, Oak).

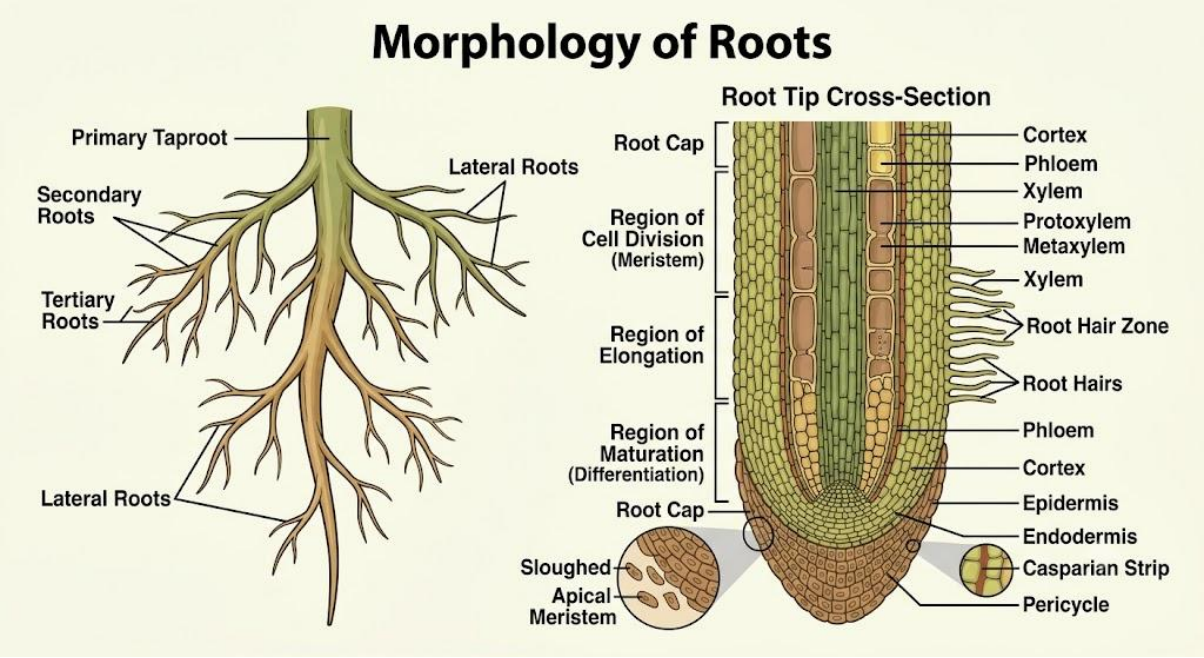
- Monocarpic Perennials: Grow vegetatively for several years (or decades), flower only once in their lifetime, produce massive seed crops, and then die (e.g., Century Plant - *Agave americana*, Bamboo species).
- Usually possess underground storage organs (rhizomes, tubers, bulbs) or persistent woody trunks to survive harsh seasonal winters/summers.

- Examples: Rose (*Rosa* spp.), Neem (*Azadirachta indica*), Mango (*Mangifera indica*), Redwoods (*Sequoia*).

Morphology, Functions & Types of Roots

1. Root System

The root system is the non-green, cylindrical, descending axis of a vascular plant that usually develops below the soil surface. It is positively geotropic, positively hydrotropic, and negatively phototropic. Unlike stems, roots lack nodes, internodes, leaves, buds, and chlorophyll (with a few exceptions like photosynthetic roots).



2. **Morphology & Regions of a Typical Root Tip**

A longitudinal section (L.S.) of a growing root tip reveals four distinct morpho-anatomical zones:

A. Root Cap (Calyptra)

- Structure: A thimble-like structure covering the apex of the root. In aquatic plants (e.g., *Pistia*, *Eichhornia*), it is replaced by loose, unanchored root pockets.
- Function: Protects the tender apical meristem from friction against soil particles. It secretes mucilage (a polysaccharide coating) that lubricates the root pathway through the soil and senses gravity (gravitropism via statoliths).

B. Region of Meristematic Activity (Apical Meristem)

- Structure: Located just behind the root cap, consisting of small, thin-walled, densely nucleated meristematic cells with dense cytoplasm.
- Function: Continuous mitotic cell division to add new cells both toward the root cap and toward the elongation zone.

C. Region of Elongation

- Structure: Lies proximal to the meristematic zone. Cells in this region undergo rapid enlargement and vacuolation.
- Function: Responsible for the primary increase in the overall length of the root.

D. Region of Maturation (Zone of Differentiation)

- Structure: Cells behind the elongation zone differentiate into permanent primary tissues (epidermis/epiblema, cortex, endodermis, pericycle, vascular bundle).
- Root Hairs: The epidermal cells (piliferous layer / epiblema) produce thousands of fine, delicate, unicellular tubular extensions known as root hairs, which drastically increase the surface area for water and mineral absorption.

3**. Primary Functions of Roots**

A. Primary (Physiological) Functions

1. Anchorage: Mechanically anchors the plant body firmly to the soil substrate.
2. Absorption: Absorbs water, macro-nutrients, and micro-nutrients from the soil solution via osmosis, diffusion, and active transport.
3. Conduction: Translocates water and absorbed minerals upward to the shoot system via xylem elements.
4. Hormone Synthesis: Synthesizes plant growth regulators, particularly cytokinins and gibberellins, which regulate shoot growth.

4. Fundamental Types of Root Systems

Plants primarily exhibit three core root architectures based on their embryonic origin and structure:

A. Tap Root System

- Origin: Direct elongation of the embryonic radicle.
- Structure: A strong, prominent primary root that grows deep vertically into the soil and gives off secondary and tertiary lateral roots in an acropetal succession (oldest at the top, youngest near the apex).
- Occurrence: Predominant in Dicotyledons and Gymnosperms.

B. Fibrous Root System

- Origin: The primary root developed from the radicle is short-lived and stops growing early.

- Structure: Replaced by a cluster of thin, thread-like roots originating uniformly from the base of the stem.
- Occurrence: Predominant in Monocotyledons (e.g., Wheat, Maize, Rice).

C. Adventitious Root System

- Origin: Roots that develop from any part of the plant body *other* than the embryonic radicle (e.g., from nodes, internodes, leaves, or cut branches).
- Occurrence: Found in both monocots and dicots (e.g., *Banyan*, *Grass*, *Sugarcane*).

5. Structural and Functional Modifications of Roots

Roots often undergo specialized anatomical and morphological changes to perform functions other than simple anchorage and absorption.

A. Modifications for Food Storage

1. Conical Root: Broad at the base and tapering gradually toward the apex.
    - *Example:* Carrot (*Daucus carota*)
2. Fusiform Root: Swollen in the middle and tapering toward both the top and bottom ends.
    - *Example:* Radish (*Raphanus sativus*)
3. Napiform Root: Sub-spherical/swollen base that suddenly tapers into a thread-like structure at the tail end.
    - *Example:* Turnip (*Brassica rapa*), Beetroot (*Beta vulgaris*)
4. Tuberous Roots: Thickened adventitious roots formed without a definite shape.
    - *Example:* Sweet Potato (*Ipomoea batatas*)
5. Fasciculated Roots: Swollen adventitious roots occurring in clusters at the base of the stem.
    - *Example:Dahlia*, *Asparagus*

B. Modifications for Mechanical Support

1. Prop Roots (Stilt-like Aerial Roots): Thick aerial adventitious roots growing vertically downward from heavy horizontal branches. Upon reaching the soil, they anchor and undergo secondary thickening, acting as load-bearing pillars (e.g., Banyan Tree - *Ficus benghalensis*).
2. Stilt Roots: Short, obliquely growing adventitious roots emerging from the lower nodes of the stem near ground level to provide structural support against wind tipping (e.g., Maize - *Zea mays*, Sugarcane - *Saccharum officinarum*).
3. Buttress Roots: Large, plank-like, woody extensions formed at the base of giant rainforest trunks (e.g., Cotton Tree - *Bombax ceiba*).
4. Climbing Roots: Adventitious roots produced at nodes/internodes that attach to vertical supports via sticky secretions or physical crevices (e.g., Black Pepper - *Piper nigrum*).

C. Modifications for Specialized Physiological Functions

1. Pneumatophores (Respiratory Roots): Positively geotropic, peg-like vertical projections emerging above water or mud level in anaerobic marshy habitats. Contain breathing pores called lenticels for oxygen uptake (e.g., Mangroves like *Rhizophora*, *Avicennia*).
2. Hygroscopic / Epiphytic Aerial Roots: Hanging aerial roots covered by a multi-layered spongy tissue called velamen, which absorbs atmospheric moisture (e.g., Orchids - *Vanda*).
3. Haustorial Roots (Parasitic Sucking Roots): Projections produced by parasitic plants that penetrate host tissues to extract water and nutrients (e.g., *Cuscuta*).
4. Nodulated Roots (Nitrogen-Fixing Roots): Roots bearing small nodules inhabited by symbiotic nitrogen-fixing bacteria (*Rhizobium*) (e.g., Legumes like Peas and Beans).
5. Assimilation / Photosynthetic Roots: Green, chlorophyll-containing roots capable of performing photosynthesis (e.g., *Trapa*, *Tinospora*).

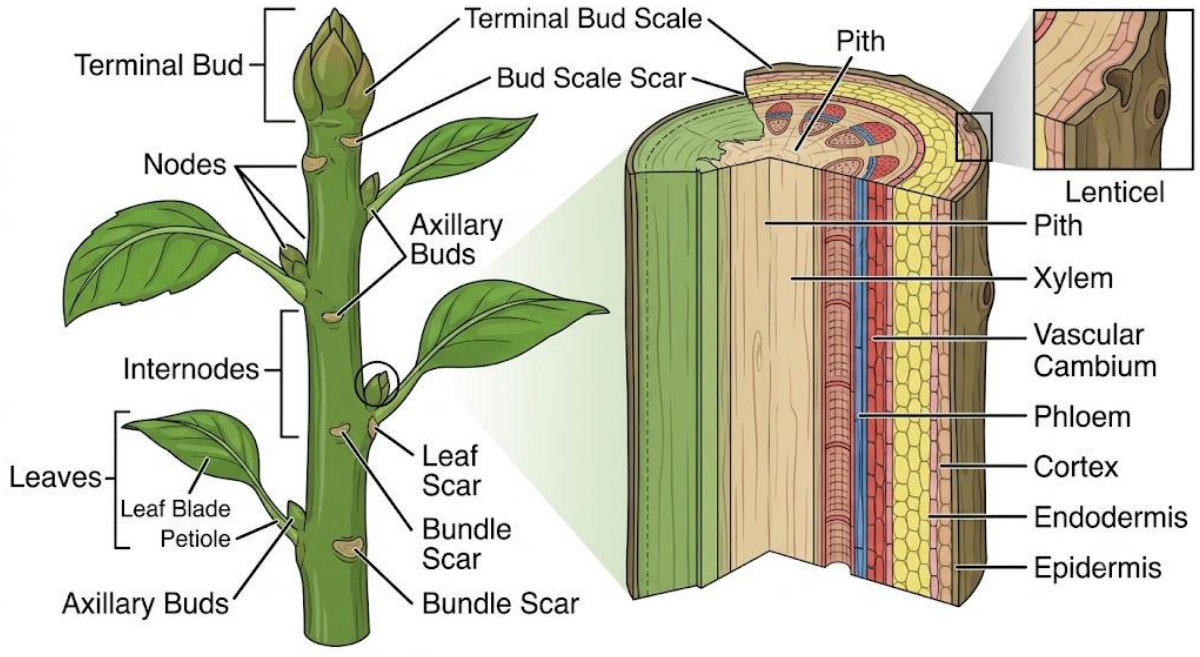
Morphology, Functions & Types of Stem

1. Introduction to the Shoot Axis (Stem)

The stem is the ascending axis of the plant body that develops from the **plumule** of the germinating seed. It is positively phototropic, negatively geotropic, and negatively hydrotropic. Unlike roots, the stem is divided into **nodes** and **internodes** and bears leaves, vegetative/floral buds, flowers, and fruits.

2. Morphology of a Typical Stem

An anatomical and morphological examination of a typical stem reveals the following structural features:



Nodes: Distinct swollen regions on the stem where leaves, branches, and adventitious roots originate.

- **Internodes:** The region or portion of the stem situated between two consecutive nodes.
- **Terminal (Apical) Bud:** Positioned at the apex of the stem, responsible for the primary vertical height growth of the shoot axis.
- **Axillary Bud:** Located in the axil (angle) between the leaf base and the stem. It can develop into a lateral branch or an inflorescence/flower.
- **Trichomes & Lenticels:** Multicellular epidermal hairs (**trichomes**) act as physical protection and prevent moisture loss, while small pores (**lenticels**) on woody stems facilitate gas exchange.

3. Primary Functions of Stems

A. Primary (Physiological) Functions

1. **Mechanical Support & Conduction:** Bears leaves, flowers, and fruits in optimal positions to receive sunlight. Conducts water and dissolved minerals from roots to leaves (via xylem) and translocates photosynthates from leaves to other plant parts (via phloem).
2. **Growth & Morphogenesis:** Produces new leaves, lateral branches, and reproductive structures through apical and intercalary meristematic activity.

4. Classification & Types of Stems

Stems are primarily classified into three functional and structural groups based on their growth environment: **Underground Stems**, **Sub-aerial Stems**, and **Aerial Stems**.

A. Underground Modifications (Storage & Perennation)

Underground stems are non-green, modified stems that live beneath the soil surface. They store food reserves and serve as organs of **perennation** (surviving adverse environmental conditions).

1. **Rhizome:** Horizontal, thick, dorsiventral stem growing beneath the soil surface with distinct nodes, internodes, scale leaves, and adventitious roots.
    - *Examples:* Ginger (*Zingiber officinale*), Turmeric (*Curcuma longa*), Ferns.
2. **Tuber:** Swollen terminal end of an underground stem branch storing starch. Features "eyes" which are nodes containing axillary buds covered by reduced scale leaves.
    - *Example:* Potato (*Solanum tuberosum*).
3. **Bulb:** Reduced, disc-like underground stem surrounded by fleshy scale leaves that store food and moisture.
    - *Examples:* Onion (*Allium cepa*), Garlic (*Allium sativum*).
4. **Corm:** Condensed, vertical, solid underground stem with a flat base and distinct circular nodes bearing scale leaves.
    - *Examples:Colocasia*, *Amorphophallus* (Elephant Foot Yam), *Saffron*.

B. Sub-aerial Modifications (Vegetative Propagation)

These stems run along or just beneath the soil/water surface and primarily function in rapid vegetative multiplication.

1. **Runner:** Thin, green, horizontal branch growing along the soil surface. Develops adventitious roots at each node where new daughter plants form.
    - *Examples:* Lawn grass (*Cynodon dactylon*), Strawberry (*Fragaria*).
2. **Stolon:** An arching lateral branch originating from the base of the main stem that grows upward initially before bending down to touch the ground and root at the node.
    - *Examples:* Jasmine (*Jasminum*), Mint (*Mentha*).
3. **Offset:** Short, thick, horizontal branch found in aquatic plants, consisting of a single short internode bearing a rosette of leaves above and a tuft of roots below.
    - *Examples:* Water Hyacinth (*Eichhornia crassipes*), Water Lettuce (*Pistia*).
4. **Sucker:** Lateral branch that originates from the underground portion of the main stem, grows horizontally below ground for some distance, and then obliquely turns upward to form a leafy shoot.
    - *Examples:* Chrysanthemum, Banana (*Musa*), Pineapple.

C. Aerial Modifications (Specialized Adaptations)

Aerial stems grow above ground and undergo structural changes to assist in photosynthesis, climbing, protection, or water storage.

1. **Stem Tendrils:** Slender, spirally coiled, sensitive structures derived from modified axillary or terminal buds that help weak-stemmed plants climb up mechanical supports.
    - *Examples:* Passiflora, Cucumber (*Cucumis sativus*), Grapevine (*Vitis vinifera*).
2. **Thorns:** Hard, straight, sharp, woody structures derived from modified axillary buds that serve a defensive role against herbivores.
    - *Examples:Citrus*, *Bougainvillea*.
3. **Phylloclade:** Flattened or cylindrical green, fleshy stem of unlimited growth that takes over photosynthetic functions in xerophytic plants. Leaves are reduced to spines or scales to reduce transpiration.
    - *Examples:Opuntia* (Prickly Pear), *Euphorbia*.
4. **Cladode (Cladophyll):** A phylloclade consisting of only **one or two internodes** in length.
    - *Examples:Asparagus*, *Ruscus*.
5. **Bulbils:** Swollen vegetative or floral axillary buds that store food and detach from the parent plant to function as organs of vegetative propagation.
    - *Examples:Agave*, *Dioscorea*.

Morphology, Functions & Types of Leaves

Exam

1. Introduction to Leaves

The leaf is a lateral, generally flattened, photosynthetic organ borne on the stem at a **node**. It develops exogenously from the shoot apical meristem and always possesses an **axillary bud** in its axil. Leaves are the primary vegetative organs responsible for light absorption, photosynthesis, and transpiration.

2. Morphology of a Typical Leaf



A complete leaf (foliage leaf) consists of three principal structural parts:

1. **Leaf Base (Hypopodium):** The lowermost part attached to the stem node.
    - **Pulvinus:** Swollen leaf base common in legumes (*Fabaceae*) that regulates turgor-driven movement (e.g., *Mimosa pudica*).
    - **Sheathing Base:** Wraps around the stem, typical of monocots (e.g., Maize, Grasses).
    - **Stipules:** Small, leaf-like lateral appendages often found in pairs at the leaf base.
2. **Petiole (Mesopodium):** The stalk connecting the lamina to the stem node.
    - **Petiolate Leaf:** Leaf possessing a petiole (e.g., Hibiscus, Rose).
    - **Sessile Leaf:** Leaf lacking a petiole; lamina attaches directly to the node (e.g., *Calotropis*).
3. **Lamina or Leaf Blade (Epipodium):** The broad, expanded green region of the leaf containing photosynthetic parenchyma (mesophyll) and vascular networks.
    - Key features include the **midrib** (primary vein), **veins/veinlets**, **margins**, and the **leaf apex**.

3. Venation Patterns

Venation refers to the arrangement and distribution of veins and veinlets within the leaf lamina.

- **Reticulate Venation:** Veins branch irregularly to form a complex net-like framework.
    - *Occurrence:* Predominant in **Dicotyledons** (e.g., Mango, Hibiscus).
- **Parallel Venation:** Veins run parallel to each other from the leaf base to the apex or from the midrib to the margin.
    - *Occurrence:* Predominant in **Monocotyledons** (e.g., Banana, Maize, Wheat).

4. Primary Functions of Leaves

1. **Photosynthesis:** Converts solar energy into chemical energy (carbohydrates) via chlorophyll embedded in mesophyll cells.
2. **Transpiration:** Evaporative cooling and water pull created by water vapor loss through epidermal **stomata**.
3. **Gas Exchange:** Regulates CO_2 uptake for photosynthesis and O_2 release via stomatal pores.
4. **Storage & Protection:** Specialized leaves store water, food, or provide physical defense (e.g., spines).

5. Structural Types of Leaves

Leaves are categorized based on the degree of incision of the lamina:

A. Simple Leaf

- The lamina is either completely unbroken or cut into lobes, but the incisions **do not reach the midrib** or petiole.
- An axillary bud is present in the leaf axil.
- *Examples:* Mango (*Mangifera indica*), Guava (*Psidium guajava*).

B. Compound Leaf

- The lamina is completely divided into distinct, independent segments called **leaflets** (pinnae).
- An axillary bud is present in the axil of the *entire compound leaf*, but **never** in the axils of individual leaflets.

1. **Pinnately Compound Leaves:** Leaflets are attached along a common axis termed the **rachis** (modified midrib).
    - **Unipinnate:** Leaflets attached directly to the main axis (e.g., Rose, Neem).
    - **Bipinnate:** Secondary rachis bears the leaflets (e.g., *Acacia*, *Mimosa*).
    - **Tripinnate:** Tertiary rachis bears the leaflets (e.g., *Moringa*).
2. **Palmately Compound Leaves:** Leaflets originate and radiate from a single common point at the tip of the petiole.

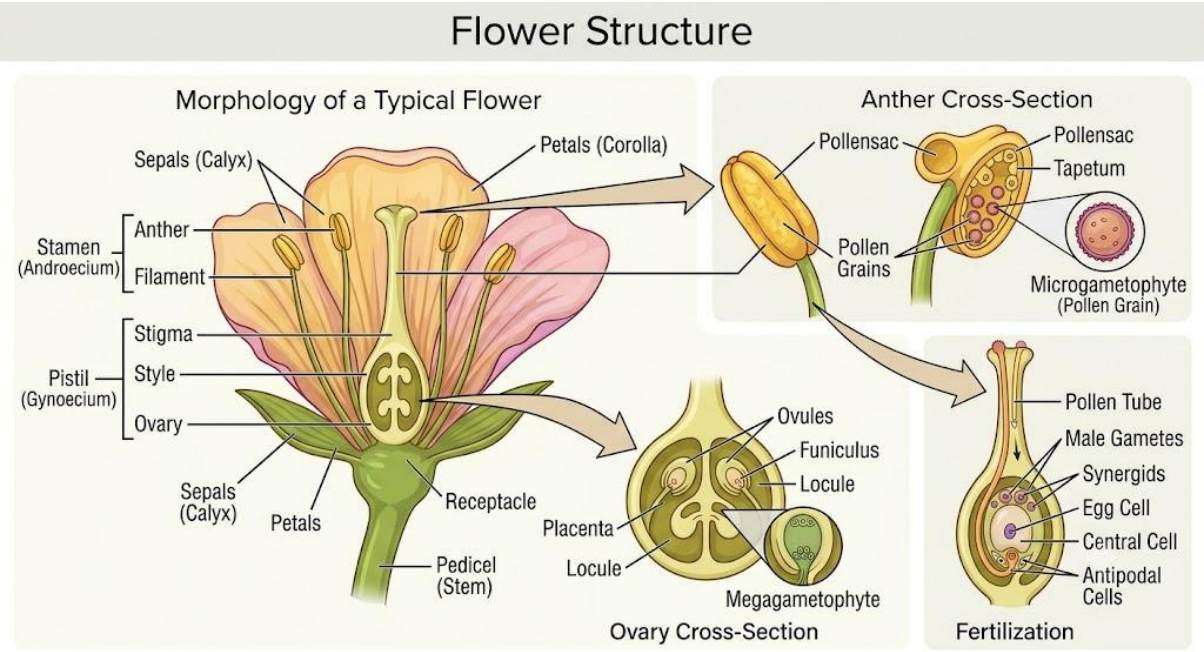
- **Unifoliate:** Single leaflet (e.g., *Citrus*).
- **Bifoliate / Trifoliate:** Two or three leaflets (e.g., *Oxalis*, Clover).
- **Multifoliate / Digitately Compound:** Five or more radiating leaflets (e.g., Silk Cotton - *Bombax ceiba*).

6. Major Functional Modifications of Leaves

1. **Leaf Tendrils:** Slender, coiled, sensitive structures that help weak stems climb up physical supports.
    - *Examples:* Pea (*Pisum sativum* – upper leaflets modified into tendrils), *Gloriosa* (leaf tips modified into tendrils).
2. **Leaf Spines:** Entire leaves or leaf parts reduced to sharp, hard structures to minimize transpiration and deter herbivores.
    - *Examples:* Cactus (*Opuntia*), Barberry (*Berberis*).
3. **Phyllode:** A flattened, green, expanded petiole that takes over the function of photosynthesis when true leaves are reduced or short-lived.
    - *Example:* Australian Acacia (*Acacia auriculiformis*).
4. **Pitcher & Bladder (Insectivorous Modifications):** Leaves modified into specialized trapping mechanisms to capture insects and digest them for nitrogen uptake in nutrient-poor soils.
    - *Examples:* Pitcher plant (*Nepenthes*), Bladderwort (*Utricularia*).
5. **Storage Leaves:** Fleshy, thickened leaves adapted to store water, mucilage, or reserve food.
    - *Examples:* Onion (*Allium cepa* – fleshy scale leaves), *Aloe vera*.

Flower Structure

A flower is the specialized reproductive structure of angiosperms (flowering plants). It is a modified shoot designed for sexual reproduction, carrying out pollination, fertilization, and seed/fruit formation.



A typical complete flower consists of four main floral whorls arranged sequentially on the receptacle (the swollen end of the flower stalk or pedicel):

1. Non-Essential / Accessory Whorls

These organs do not directly participate in gamete formation, but serve to protect the developing bud and attract pollinators.

A. Calyx (Outer Whorl)

- Individual Units: Sepals
- Morphology: Typically green and leaf-like.
- Primary Functions:
    - Protects the delicate floral organs during the bud stage against physical damage, desiccation, and pathogens.
    - Performs basic photosynthesis to support floral development.

B. Corolla (Second Whorl)

- Individual Units: Petals
- Morphology: Usually brightly colored, scented, and often possess nectar glands at their base.
- Primary Functions:
    - Attracts biotic pollinators (insects, birds, bats) via visual cues and aromas.
    - Encloses and protects the essential inner reproductive organs.

(Note: When the Calyx and Corolla are structurally indistinguishable, they are collectively referred to as a Perianth, with individual units called Tepals.)

2. Essential / Reproductive Whorls

These whorls contain the gametophytes and are directly involved in sexual reproduction.

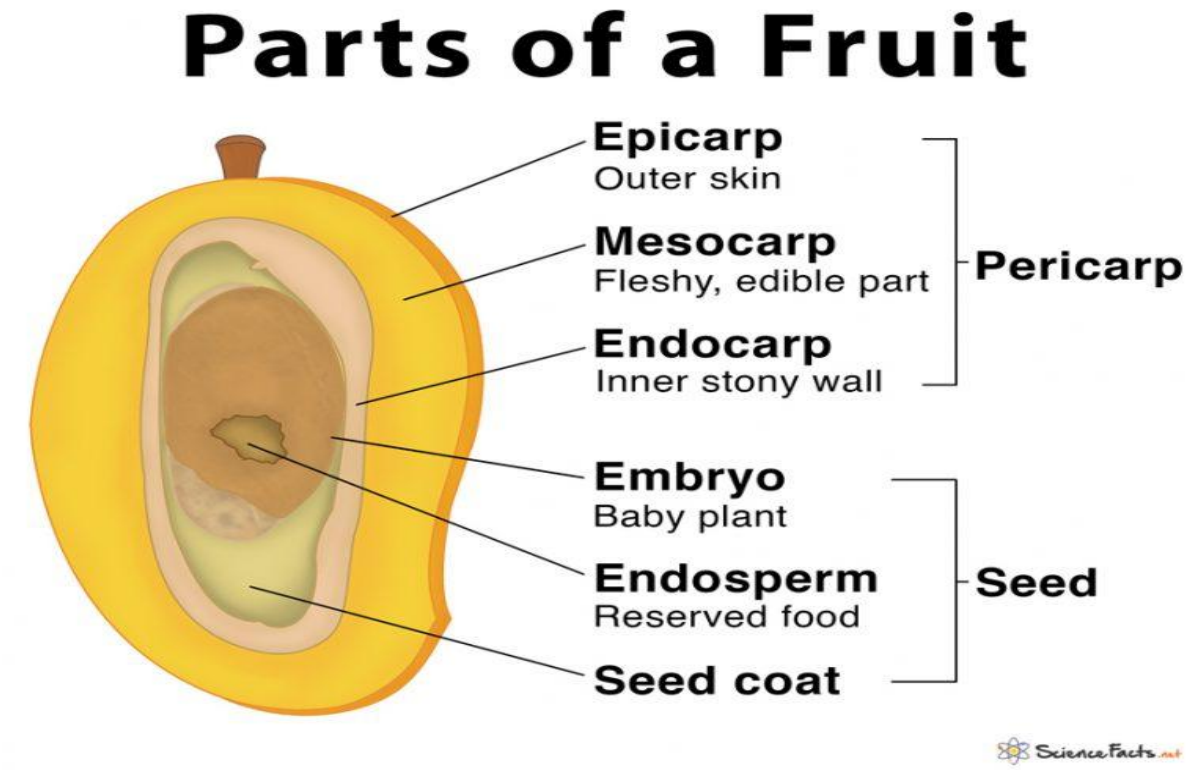
A. Androecium (Male Reproductive Unit)

- Individual Units: Stamens
- Structure: Each stamen consists of two main parts:
    1. Filament: A slender, elongated stalk that holds the anther in an optimal position for pollen dispersal.
    2. Anther: Usually a bilobed, tetrasporangiate structure containing pollen sacs (microsporangia) where microspores undergo meiosis to produce pollen grains (male gametophytes).
- Function: Synthesis, maturation, and release of pollen grains.

B. Gynoecium / Pistil (Female Reproductive Unit)

- Individual Units: Carpels
- Structure: A typical carpel is differentiated into three distinct regions:
    1. Stigma: The sticky or feathery receptive surface at the top designed to catch and anchor pollen grains.
    2. Style: The elongated tube connecting the stigma to the ovary through which the pollen tube grows toward the ovules.
    3. Ovary: The swollen, basal chamber containing one or more ovules (megasporangia) attached to the inner wall via the placenta.
- Function:
    - Houses the female gametophyte (embryo sac / egg cell).
    - Serves as the site for pollen tube growth, double fertilization, and subsequent development into seeds (from ovules) and fruit (from the mature ovary).

Fruit Structure



1. Definition

- **Fruit:** A mature, ripened ovary of a flowering plant (angiosperm) containing seeds, formed after fertilization.
- **True Fruit (Eucarp):** Develops exclusively from the ovary (e.g., mango, tomato).
- **False Fruit (Pseudocarp):** Formed from the ovary along with other floral parts like the thalamus or receptacle (e.g., apple, strawberry).
- **Parthenocarpic Fruit:** Fruit developed without fertilization; naturally seedless (e.g., banana).

2. Fruit Structure (Pericarp)

The wall of the fruit (developed from the ovary wall) is the **pericarp**, divided into three layers:

1. **Exocarp (Epicarp):** Outer skin or rind.
2. **Mesocarp:** Middle layer; usually fleshy or edible (fibrous in coconut).
3. **Endocarp:** Inner layer surrounding the seed; can be hard/stony (peach) or thin/membranous (orange).

3. Broad Botanical Classification

A. Simple Fruits

Develop from a single carpel or fused carpels (syncarpous) of a single flower.

- **Fleshy Simple Fruits:**
    - **Drupe:** Single seed inside a stony endocarp (*pit*) (e.g., mango, peach, coconut).

- **Berry:** Fleshy throughout, usually multi-seeded (e.g., tomato, grape, banana).
- **Pome:** False fruit with a core, where flesh develops from the receptacle (e.g., apple, pear).
- **Hesperidium:** Berry with a leathery rind containing juice sacs (e.g., orange, lemon).
- **Pepo:** Berry with a thick, hard outer rind (e.g., watermelon, cucumber).

- **Dry Simple Fruits:** Pericarp becomes dry at maturity.
  - *Dehiscent (splits open):* Legume/pod (pea, bean), capsule (poppy).
  - *Indehiscent (does not split open):* Caryopsis/grain (wheat, corn), achene (sunflower), nut (hazelnut).

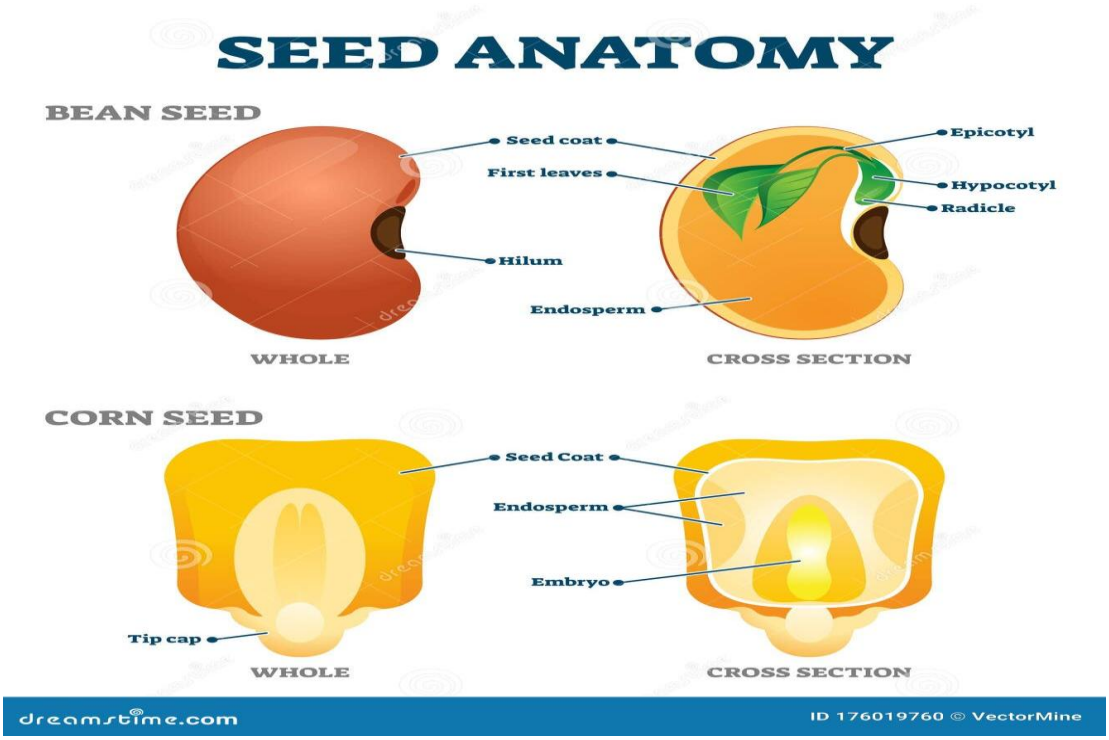
B. Aggregate Fruits (Etaerio)

- Develop from a single flower with multiple free carpels (apocarpous gynoecium).
- Formed as a cluster of small fruitlets on a single receptacle.
- **Examples:** Raspberry, blackberry, strawberry.

C. Multiple / Composite Fruits

- Develop from an entire **inflorescence** (cluster of flowers on a single axis) fusing together.
- **Examples:** Pineapple, fig, mulberry, jackfruit.

Seed Structure



A seed is the mature, fertilized ovule of a spermatophyte (seed plant), containing a protective outer layer, stored nutrients, and an embryonic plant capable of germinating under favorable conditions. It represents the ultimate product of sexual reproduction in Gymnosperms and Angiosperms.

1. Key Structural Components of a Seed

A typical seed consists of three primary parts:

A. Seed Coat (Testa & Tegmen)

- Origin: Develops from the protective integuments of the ovule following fertilization.
- Structure:
    - Testa: The outer, tough, protective layer.
    - Tegmen: The inner, thin, membranous layer (often fused with the testa).
- Markings on the Seed Coat:
    - Hilum: A scar on the seed coat where the seed was attached to the fruit wall (funiculus).
    - Micropyle: A small pore adjacent to the hilum that allows water and oxygen entry during germination.
- Function: Protects the delicate embryo from mechanical damage, desiccation, and pathogens.

B. Embryo (The Young Plant)

The embryo is the mini-plant formed from the zygote ($2n$). It consists of:

1. Radicle: The embryonic root axis that grows downward during germination to form the primary root system.
2. Plumule: The embryonic shoot apex that develops into the stem and foliage leaves above ground.
3. Hypocotyl: The region of the embryonic axis situated *below* the point of attachment of the cotyledons and *above* the radicle.
4. Epicotyl: The region of the embryonic axis situated *above* the cotyledons and *below* the plumule.
5. Cotyledons (Seed Leaves): Embryonic leaves attached to the central axis.
    - Dicotyledonous Seeds: Possess two fleshy cotyledons (e.g., Bean, Pea, Gram).
    - Monocotyledonous Seeds: Possess a single cotyledon, often called a scutellum in grasses (e.g., Maize, Wheat).

C. Endosperm (Nutritive Tissue)

- Origin: Formed via double fertilization (triple fusion of a sperm cell with two polar nuclei to form a triploid $3n$cell).
- Classification Based on Endosperm Presence:

- Endospermic (Albuminous) Seeds: Endosperm persists in the mature seed and serves as the primary food storage organ (e.g., Castor, Maize, Wheat, Sunflower).
- Non-Endospermic (Exalbuminous) Seeds: Endosperm is completely consumed by the growing embryo during seed development; food reserves are instead stored in the cotyledons (e.g., Bean, Pea, Gram).

2. Dicotyledonous vs. Monocotyledonous Seed Architecture

Feature	Dicot Seed (e.g., Bean)	Monocot Seed (e.g., Maize Grain)
Cotyledons	Two cotyledons	Single cotyledon (Scutellum)
Endosperm	Usually non-endospermic (stored in cotyledons)	Usually endospermic (rich in starch/protein)
Protective Sheaths	Absent	Coleoptile protects plumule; Coleorhiza protects radicle
Aleurone Layer	Absent	