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BY

SUBTAIN ALI RANA

Lecturer Botany

(Higher Education Department)

PLANT MORPHOLOGY

PLANT ANATOMY

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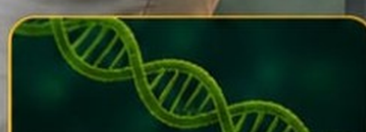

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Chapter: 1

Introduction to Botany

I. Definition and Scope of Botany

Botany (from the Greek *botanē* meaning "pasture" or "herbs") is the scientific study of plants—their structure, properties, biochemical processes, classification, evolution, and interactions with the environment and other organisms. It is a branch of **biology** (the study of life).

Modern Scope: Encompasses all plant-like organisms, including:

- **Land plants:** Trees, shrubs, herbs, grasses, mosses, ferns.
- **Aquatic plants:** Algae (seaweeds, phytoplankton).
- **Fungi and lichens** (historically included, now often in separate kingdoms but studied by botanists).
- **Other photosynthetic organisms:** Cyanobacteria (blue-green algae).

Core Aim: To understand how plants live, function, diversify, and sustain life on Earth.

II. Importance of Botany (Why Study Plants?)

1. **Foundation of Life:** Through **photosynthesis**, plants convert solar energy into chemical energy, forming the base of nearly all food webs (primary producers).
2. **Oxygen Production:** They release oxygen as a byproduct of photosynthesis, essential for aerobic respiration in animals and many microbes.
3. **Human Sustenance:**
   - **Food:** Direct sources (grains, fruits, vegetables, nuts, spices) and indirect sources (feed for livestock).
   - **Medicine:** Over 25% of modern prescription drugs are derived from plants (e.g., aspirin from willow, digoxin from foxglove, taxol from yew trees for cancer).
   - **Materials:** Timber, paper, fibers (cotton, linen, hemp), rubber, dyes, resins, and biofuels.
4. **Environmental Services:** Soil formation and conservation, water cycle regulation (transpiration, groundwater recharge), carbon sequestration (mitigating climate change), and providing habitat for countless organisms.
5. **Aesthetic and Cultural Value:** Ornamental plants, gardens, cultural symbolism, and psychological well-being.

III. Historical Context (Brief Timeline)

- **Prehistoric:** Empirical knowledge of edible/medicinal plants.
- **Ancient Civilizations:** Theophrastus (c. 371–287 BC), a student of Aristotle, wrote *"Enquiry into Plants"* and *"On the Causes of Plants,"* earning the title **"Father of Botany."**
- **Middle Ages:** Herbals (illustrated books of medicinal plants) dominated.
- **Renaissance & Enlightenment:** Invention of the microscope (17th century) led to discovery of plant cells (Robert Hooke). Systematized classification by **Carl Linnaeus** (18th century) with binomial nomenclature.
- **19th Century:** Development of cell theory, understanding of photosynthesis (von Sachs, Ingenhousz), and evolutionary theory (Darwin) profoundly impacted botany.
- **20th–21st Centuries:** Molecular and genetic revolutions (plant genomics, biotechnology, phylogenetics).

IV. Major Branches of Botany

Botany is highly interdisciplinary. Its branches can be categorized into **core/ fundamental** (studying basic plant biology) and **applied** (using botanical knowledge for human benefit).

A. Core/Fundamental Branches

1. **Plant Morphology:** Study of the **form and structure** of plants.

V. Interdisciplinary Connections

Botany interfaces closely with other sciences:

- **Chemistry:** Biochemistry of photosynthesis, plant secondary metabolites.
- **Physics:** Soil/water dynamics (hydrology), light capture in leaves.
- **Geology/Soil Science:** Plant nutrition, pedogenesis (soil formation).
- **Climatology/Meteorology:** Effects of climate on plant distribution; plants' role in climate.
- **Environmental Science:** Conservation, restoration ecology, biodiversity assessment.
- **Archaeology:** Analysis of plant remains (archaeobotany/paleoethnobotany).

Botany is a dynamic and essential science that has evolved from simple plant cataloging to a deep, integrative exploration of plant life at all levels—from molecules to ecosystems. Its branches, both fundamental and applied, are crucial for addressing global challenges such as **food security, climate change, biodiversity loss, and sustainable development**. Understanding botany is, fundamentally, understanding the foundation of life on our planet.

Branches of Botany: - MCQs

1. Which branch of botany is concerned with the microscopic structure of plant tissues?
   a) Plant Morphology
   b) Plant Anatomy
   c) Plant Physiology
   d) Plant Ecology
   Correct Answer: Plant Anatomy
2. A botanist researching how plants convert sunlight into chemical energy is specializing in:
   a) Plant Taxonomy
   b) Plant Anatomy
   c) Plant Physiology
   d) Paleobotany
   Correct Answer: Plant Physiology
3. Which branch investigates how plants interact with their surroundings and shape ecosystems?
   a) Plant Pathology
   b) Plant Ecology
   c) Plant Systematics
   d) Pomology
   Correct Answer: Plant Ecology
4. The branch that involves the classification and naming of plants is called:
   a) Plant Morphology
   b) Plant Taxonomy
   c) Plant Genetics
   d) Agronomy
   Correct Answer: Plant Taxonomy
5. A scientist studying kelp forests and phytoplankton would be a specialist in:
   a) Mycology
   b) Bryology
   c) Phycology
   d) Horticulture
   Correct Answer: Phycology
6. Which branch of botany traditionally covers the study of mushrooms, yeasts, and molds?
   a) Mycology
   b) Pathology
   c) Microbiology
   d) Phycology
   Correct Answer: Mycology
7. A botanist focusing on non-vascular plants like peat moss specializes in:
   a) Pteridology
   b) Bryology
   c) Agrostology
   d) Dendrology
   Correct Answer: Bryology
8. Which branch would analyze plant impressions in sedimentary rock to understand ancient ecosystems?
   a) Plant Geography
   b) Paleobotany
   c) Plant Genetics
   d) Forestry
   Correct Answer: Paleobotany
9. The branch concerned with blights, rusts, and other ailments affecting plants is:
   a) Plant Ecology
   b) Plant Pathology
   c) Ethnobotany
   d) Plant Physiology
   Correct Answer: Plant Pathology

Chapter: 2

Plant Systematics

Systematics

Systematics (often called **Biosystematics** for living organisms) is the **scientific study of the diversity of organisms and their evolutionary relationships**. It is a broader, more comprehensive field than taxonomy alone.

Key Aspects:

1. **Discovery and Description** of organismal diversity.
2. **Reconstruction of Evolutionary History (Phylogeny)** to understand patterns of relatedness.
3. **Classification** of organisms into a hierarchical system that reflects their evolutionary relationships.
4. **Development of Identification Tools** (keys, manuals, databases).
5. **Study of Processes** generating diversity (speciation, adaptation, extinction).

In essence: Systematics = **Taxonomy + Phylogenetics + Evolutionary Biology**

Classification

Classification is the **process of arranging organisms into ordered groups (taxa) based on their similarities, differences, and relationships**. It is a core product of systematic study.

Purpose: To impose order on biological diversity, creating a system for storage, retrieval, and communication of information.

Taxonomy

Often used interchangeably with systematics, but more precisely, **Taxonomy** is the **theory and practice of identifying, describing, naming, and classifying organisms**. It is a component of systematics.

The Four Core Tasks of Taxonomy (The Taxonomic Cycle):

1. **Identification:** Determining the identity of an unknown specimen by comparing it with known taxa (using keys, herbaria, museums, experts).
2. **Description:** Documenting the characteristics of a taxon (morphology, anatomy, genetics, ecology).
3. **Nomenclature:** Assigning a scientific name according to standardized, international rules (ICN, ICZN, ICNB).
4. **Classification:** Placing the taxon within a hierarchical system.

SYSTEMS OF CLASSIFICATION IN PLANT SYSTEMATICS

Plant systematics aims to organize plant diversity into a classification that reflects evolutionary relationships. Over centuries, multiple classification systems have been developed based on different principles, methodologies, and philosophical approaches.

II. CHRONOLOGICAL DEVELOPMENT OF MAJOR SYSTEMS

A. PRE-LINNAEAN SYSTEMS (Before 1753)

1. **Folk/Utilitarian Classifications**: Based on use (food, medicine, poison)
2. **Theophrastus (370-285 BC)**: "Father of Botany"; classified plants by form (trees, shrubs, herbs)

B. ARTIFICIAL SYSTEMS (18th Century)

Based on few, easily observable characters for convenience of identification.

1. CAROLUS LINNAEUS (1707-1778)

- **System**: **Sexual System** (24 classes based on stamen number, arrangement, fusion)
- **Work**: *Species Plantarum* (1753) – binomial nomenclature foundation
- **Principles**:
    - Based solely on floral characters (androecial features)

- **Collaborative effort** of systematists worldwide
- **APG I (1998)**: First major molecular-based reclassification
- **APG II (2003)**: Revised with broader circumscriptions
- **APG III (2009)**: Stabilized major groups
- **APG IV (2016)**: Current system; incremental changes
- **Principles**:
    - **Monophyletic groups only** (cladistic)
    - **Rankless hierarchy**: Clades over ranks
    - **Major clades**: Amborellales, Nymphaeales, Austrobaileyales as basal
    - **Eudicots** (true dicots) with tricolpate pollen
    - **Monocots as monophyletic** within magnoliids
- **Features**:
    - Recognizes 64 orders, 416 families
    - **Major groups**: Basal angiosperms, magnoliids, monocots, Ceratophyllales, eudicots
    - **Eudicots subdivided**: Basal eudicots, superrosids, superasterids

III. COMPARATIVE ANALYSIS OF MAJOR SYSTEMS

A. ARTIFICIAL vs. NATURAL vs. PHYLOGENETIC

Parameter	Artificial Systems	Natural Systems	Phylogenetic Systems
Basis	Few convenient characters	Overall morphological similarity	Evolutionary relationships
Goal	Easy identification	Reflect "natural affinities"	Reconstruct evolutionary history
Character weighting	Single/few characters	Multiple characters	Derived vs. ancestral characters
Group composition	Often unnatural groups	Natural but may be paraphyletic	Strictly monophyletic (in modern)
Example	Linnaeus Sexual System	Bentham & Hooker	APG IV
Time period	18th century	19th century	20th-21st centuries

B. COMPARISON OF MAJOR PHYLOGENETIC SYSTEMS

Feature	Engler & Prantl	Bessey	Hutchinson	Takhtajan	Cronquist	APG IV
Primitive group	Amentiferae	Ranales	Magnoliales	Magnoliidae	Magnoliidae	Amborellaceae
Monocot origin	Direct from primitive angiosperms	From ranalean dicots	From ranalean dicots	From Nymphaeales-like	From ancient dicots	Within basal angiosperms
Dicot groups	Archichlamydeae, Metachlamydeae	Polypetalae, etc.	Lignosae, Herbaceae	Magnoliopsida	Magnoliopsida	Eudicots, basal groups
Gymnosperms	Separate division	Separate	Separate	Separate	Separate	Separate (non-

Plant Systematics: MCQs

1. **Who is credited with establishing the modern system of binomial nomenclature?**
a) Charles Darwin
b) Theophrastus
c) Carl Linnaeus
d) Gregor Mendel
Correct Answer: Carl Linnaeus
2. **The starting point for modern botanical nomenclature for most plants is:**
a) Origin of Species (1859)
b) Systema Naturae (1735)
c) Species Plantarum (1753)
d) Genera Plantarum (1737)
Correct Answer: Species Plantarum (1753)
3. **The scientific study of biological diversity and evolutionary relationships is called:**
a) Taxonomy
b) Systematics
c) Morphology
d) Ecology
Correct Answer: Systematics
4. **The branch of biology dealing with the identification, naming, and classification of organisms is:**
a) Phylogenetics
b) Systematics
c) Taxonomy
d) Morphology
Correct Answer: Taxonomy
5. **The Father of Botany is generally considered to be:**
a) Aristotle
b) Theophrastus
c) Linnaeus
d) Dioscorides
Correct Answer: Theophrastus
6. **Which of these is NOT one of the four main tasks of taxonomy?**
a) Identification
b) Description
c) Evolution
d) Nomenclature
e) Classification
Correct Answer: Evolution
7. **The classification system that groups organisms based on overall similarity without considering evolution is:**
a) Cladistics
b) Phenetics
c) Phylogenetic systematics
d) Evolutionary taxonomy
Correct Answer: Phenetics
8. **The classification approach that groups organisms strictly by shared derived characteristics is:**
a) Phenetics
b) Cladistics
c) Artificial system
d) Natural system
Correct Answer: Cladistics
9. **Which of these classification systems was developed before Darwin's theory of evolution?**
a) Takhtajan system
b) Cronquist system
c) Linnaean sexual system
d) APG system
Correct Answer: Linnaean sexual system
10. **The earliest formal plant classification systems were primarily based on:**
a) DNA sequences
b) Medicinal properties
c) Flower color
d) Leaf shape
Correct Answer: Medicinal properties
11. **In the Linnaean hierarchy, the correct order from most inclusive to least inclusive is:**
a) Kingdom → Order → Class → Family → Genus
b) Kingdom → Class → Order → Family → Genus
c) Genus → Family → Order → Class → Kingdom
d) Kingdom → Family → Class → Order → Genus
Correct Answer: Kingdom → Class → Order → Family → Genus
12. **A group of organisms at any level in the classification hierarchy is called a:**
a) Taxon

Chapter: 3

ALGAE

INTRODUCTION

- **General Description:** A highly diverse, predominantly **aquatic** group of simple, **autotrophic** (self-feeding) organisms.
- **Biological Status:** Includes both **prokaryotic** (e.g., Cyanobacteria/Blue- greens) and **eukaryotic** (all other algae) members.
- **Key Identifier:** All possess **chlorophyll-a** as the primary photosynthetic pigment.
- **Body Plan:** Plant body is a **thallus** (not differentiated into true roots, stems, or leaves).

Key Morphological Features

- **Size Range:** Extremely variable.
  - **Smallest:** Unicellular (e.g., *Chlamydomonas*, 0.5–8 µm).
  - **Largest:** Macroscopic seaweeds (e.g., *Macrocystis*, can exceed 50m).
- **Thallus Complexity:** Ranges from **unicellular → colonial → filamentous → parenchymatous** (tissue-like).

Key Reproductive & Structural Distinctions from Higher Plants

1. **Sex Organs:** Usually unicellular or, if multicellular, **all cells are fertile** (except in *Charales*).
2. **No Embryo:** The zygote does **not** develop into a multicellular embryo while enclosed in the female sex organ.
3. **No Jacket:** Sporangia and gametangia lack a protective, sterile jacket of cells (again, except *Charales*).

Definition of Phycology

- The scientific study of algae.
- Also called **Algology**.
- **Etymology:** Greek - *Phykos* (seaweed) + *Logos* (study).

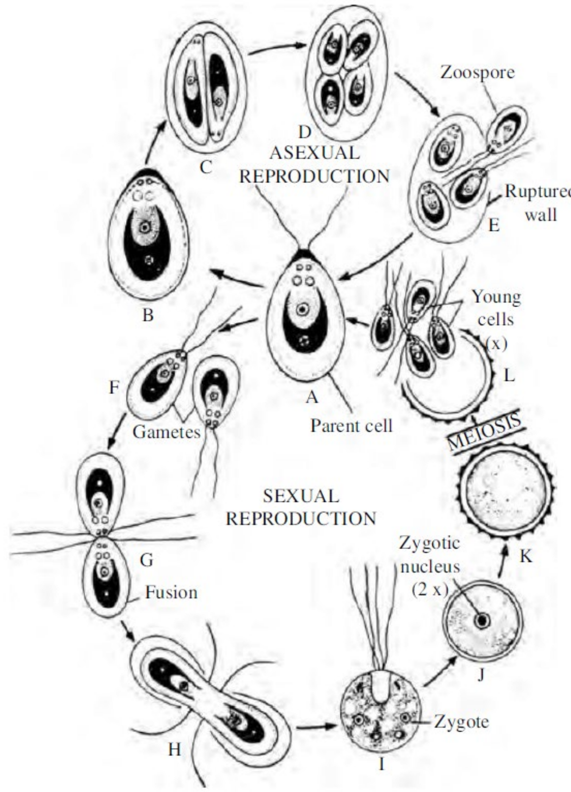
A Brief History of Algal Classification

Year	Scientist	Contribution
1753	**Carolus Linnaeus**	In *Species Plantarum*, ranked algae as an **order** under class *Cryptogamia*.
1886	**A.W. Eichler**	Ranked algae as a **class** under the division *Thallophyta*.
1674	**Antoni van Leeuwenhoek**	First to report unicellular algae using his microscope.

General Characteristics of Algae

1. **Massive Diversity:** Approx. 1560 genera & 17,535 species (Smith, 1955). The numbers are much higher now.
2. **Habitat:** Virtually universal – aquatic (fresh & marine), terrestrial, symbiotic, epiphytic, etc.
3. **Thallus Organization (Range):**
   - Motile Unicellular (e.g., *Chlamydomonas*)
   - Motile Colonial (e.g., *Volvox*)
   - Palmelloid (e.g., *Tetraspora*)
   - Dendroid (e.g., *Prasinocladus*)
   - Coccoid (e.g., *Chlorella*)
   - Filamentous (e.g., *Spirogyra, Ulothrix*)
   - Heterotrichous (e.g., *Fritschiella*)
   - Siphonous (e.g., *Vaucheria*)
   - Uniaxial (e.g., *Batrachospermum*)
   - Multiaxial (e.g., *Polysiphonia*)
   - Parenchymatous (e.g., *Ulva, Sargassum*)

- **Gamete Formation:** Vegetative cells undergo divisions similar to asexual reproduction but produce smaller, numerous **gametes** (usually 8-32). They look like small *Chlamydomonas* cells.
- **Mating Types:** Most species are **isogamous** (morphologically identical gametes) but have physiologically distinct **mating types (mt+ and mt-)** controlled by a single genetic locus.
- **Process:**
  1. **Agglutination: mt+** and **mt-** gametes clump together by flagellar adhesion (mediated by glycoprotein agglutinins).
  2. **Activation & Pairing:** Gametes shed their walls, and pairs fuse via a specialized **fertilization tubule**.
  3. **Fusion:** Plasmogamy (cytoplasmic fusion) followed by karyogamy (nuclear fusion) forms a diploid **zygote**.
  4. **Zygospore Formation:** The zygote secretes a thick, ornamented, and resistant wall (often with spines or ridges), becoming a **zygospore**. This stage can survive harsh conditions for months or years.
  5. **Germination:** When conditions are favorable, the zygospore undergoes **meiosis**, producing **four haploid zoospores** (or sometimes fewer if some nuclei degenerate). These are released and grow into vegetative cells.
- **Life Cycle: Haplontic** – the dominant, vegetative phase is haploid (n). The only diploid (2n) stage is the zygote.



Volvox

1. Common Names

- **"Globe algae"** or **"Rolling algae"** (due to its spherical shape and rotating motion).
- Often referred to as a **colonial green alga** or a **coenobial alga**.

2. Classification

- **Phylum:** Chlorophyta
- **Class:** Chlorophyceae
- **Genus:** ***Volvox***

3. Occurrence

- **Habitat:** Freshwater environments—quiet ponds, ditches, lakes, and lagoons with abundant nutrients (e.g., nitrogen, phosphorus).

4. General Structure (The Coenobium)

- **Organization:** A sophisticated, spherical **coenobium**—a colony with a fixed number of cells arranged in a specific manner, exhibiting **division of labor**.
- **Size & Shape:** Hollow sphere (**spheroid**) of gel-like matrix called **extracellular matrix (ECM)** or **glycoprotein sheath**, containing 500 to over 50,000 cells.
- **Polarity:** The colony has distinct **anterior** (pole facing direction of movement) and **posterior** poles. Anterior cells often have larger eyespots.

1. Scalariform (Ladder) Conjugation (Common)

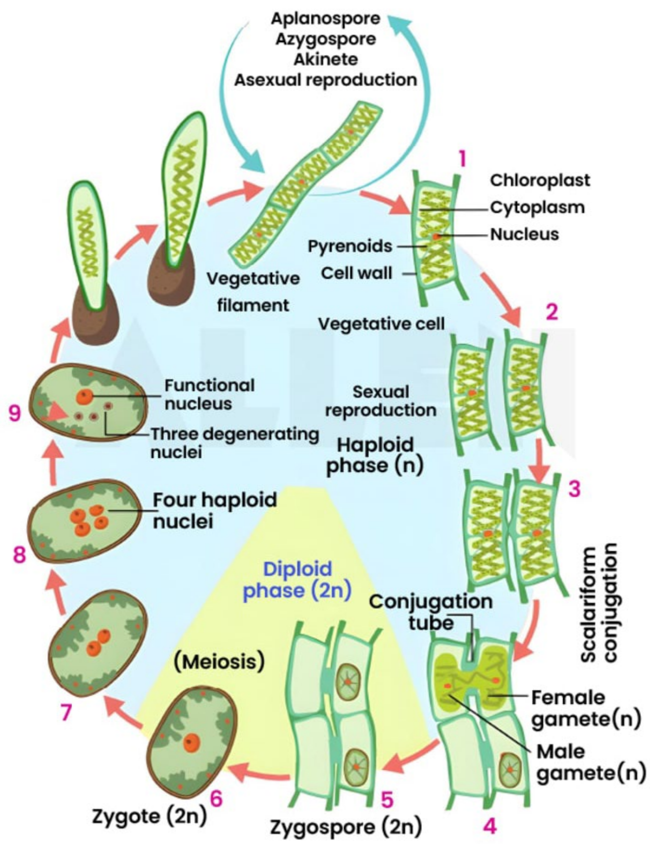
- Two parallel filaments align.
- Opposite cells produce **conjugation tubes** (outgrowths) that meet and fuse, forming a passageway (looks like a ladder).
- Protoplast of one cell (male, active) contracts and migrates through the tube into the opposite cell (female, stationary).
- Fusion of protoplasts forms a **zygospore** (diploid, 2n) in the female cell.
- Zygospore develops a thick, ornamented wall (3-layered: exo-, meso-, endospore) and enters a dormant period.
- After meiosis upon germination, 3 haploid nuclei degenerate; one survives to form a new haploid filament.

2. Lateral Conjugation (Less common)

- Occurs between adjacent cells of the *same* filament.
- A conjugation tube forms between two cells, and one protoplast moves into the other.

Zygospore Characteristics:

- Diploid (2n), product of karyogamy.
- Resistant to desiccation, extreme temperatures.
- Germinates after a dormancy period; meiosis produces 4 haploid nuclei, one forms a new filament.



Division Charophyta

I. Division Name (Phylum)

- **Scientific Name: Charophyta** (in traditional phycology) / **Streptophyta** (in modern plant systematics, which includes Charophyta and land plants, Embryophyta).
- **Common Name(s): Stoneworts** or **Brittleworts**.

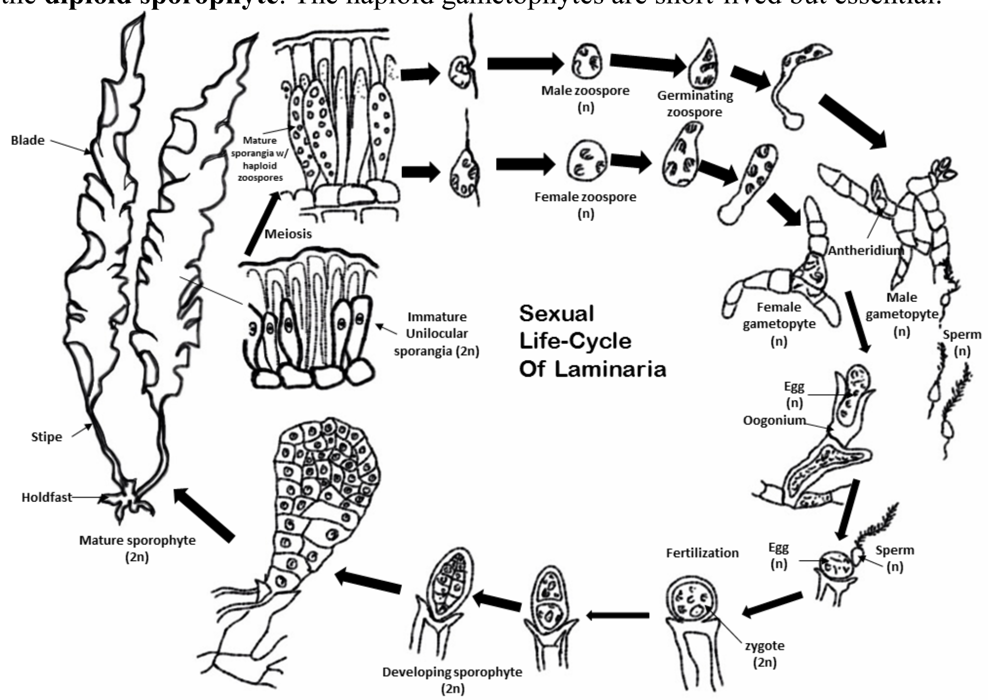
- Male Gametophyte: Produces **antheridia**, which release many small, biflagellate **spermatozoids**.

3. **Fertilization:** A spermatozoid fertilizes the egg, forming a diploid **zygote**.

C. New Sporophyte Development

1. The zygote germinates *in situ* on the female gametophyte.
2. It develops directly into a new, macroscopic **sporophyte**, completing the cycle.

- **Life Cycle Summary: Diplohaplontic, heteromorphic.** The dominant, perennial phase is the **diploid sporophyte**. The haploid gametophytes are short-lived but essential.



Rhodophyta

I. Division Name (Phylum)

- **Scientific Name: Rhodophyta**
- **Common Name(s): Red Algae**
- **Etymology:** From Greek *rhodon* = rose, red, and *phyta* = plant. Refers to their predominant red coloration.

Batrachospermum

1. Common Names

- **"Frog Spawn Alga"** or **"Frog's Eggs Alga"** (due to its distinctive, gelatinous, bead-like appearance resembling amphibian eggs).
- Sometimes called **"Freshwater Red Alga."**

2. Classification

- **Phylum: Rhodophyta** (Red Algae)
- **Class:** Florideophyceae
- **Genus:** ***Batrachospermum***

Reproduction (Sexual)	Auxospore formation (size restoration)	**Oogamy**; Alternation of Generations	**Oogamy**; Triphasic Life Cycle	**Oogamy**; Triphasic Life Cycle
Dominant Life Phase	**Diplontic** (2n)	**Diplohaplontic** (Sporophyte 2n dominant)	**Haplodiplontic** (Triphasic; Gametophyte n visible)	**Haplodiplontic** (Triphasic; Isomorphic gens.)
Specialized Structures	Silica Frustule with Raphe	Holdfast, Stipe, Blade with Intercalary Meristem	Beaded thallus, Carposporophyte (cystocarp)	Polysiphonous axis, Cystocarp, Tetrasporangia

Algae: - MCQs

1. **What is the primary pigment found in all algae?**
A. Chlorophyll b
B. Chlorophyll a
C. Phycoerythrin
D. Fucoxanthin
Correct Answer: Chlorophyll a
2. **Which algae are known for causing red tides?**
A. Diatoms
B. Dinoflagellates
C. Green algae
D. Brown algae
Correct Answer: Dinoflagellates
3. **What is the study of algae called?**
A. Mycology
B. Phycology
C. Botany
D. Ecology
Correct Answer: Phycology
4. **Which algae have cell walls made of silica?**
A. Dinoflagellates
B. Diatoms
C. Cyanobacteria
D. Red algae
Correct Answer: Diatoms
5. **From which algae is agar derived?**
A. Brown algae
B. Green algae
C. Red algae
D. Blue-green algae
Correct Answer: Red algae
6. **What is the common name for Ulva?**
A. Sea lettuce
B. Kelp
C. Irish moss
D. Nori
Correct Answer: Sea lettuce
7. **Which algae are considered prokaryotic**
A. Green algae
B. Red algae
C. Brown algae
D. Blue-green algae
Correct Answer: Blue-green algae
8. **What is the main pigment responsible for the brown color in brown algae?**
A. Chlorophyll a
B. Chlorophyll b
C. Fucoxanthin
D. Phycoerythrin
Correct Answer: Fucoxanthin
9. **Which algae form symbiotic relationships with fungi to form lichens?**
A. Green algae and cyanobacteria
B. Brown algae
C. Diatoms
D. Dinoflagellates
Correct Answer: Green algae and cyanobacteria
10. **What is the reproductive process in Spirogyra where two filaments exchange genetic material?**
A. Fragmentation
B. Conjugation
C. Binary fission
D. Spore formation
Correct Answer: Conjugation
11. **Which algae are used as a health supplement due to high protein content?**
A. Spirogyra
B. Chlorella
C. Diatoms

Chapter: 4

Fungi

I. General Characteristics of Fungi

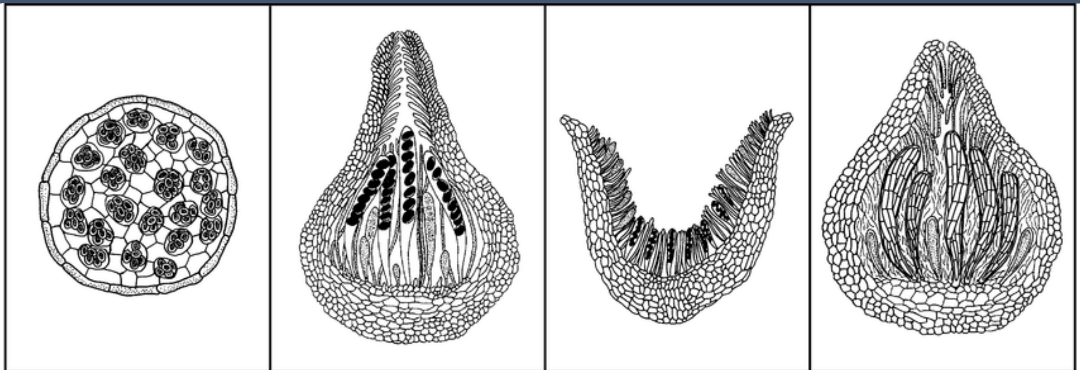
Fungi constitute a unique kingdom (Kingdom Fungi) of eukaryotic organisms, fundamentally distinct from plants, animals, and protists. Their defining characteristics revolve around their nutrition, structure, and life cycle.

A. Fundamental Defining Traits

1. **Eukaryotic Organization:**
    - Possess true, membrane-bound nuclei containing multiple chromosomes.
    - Contain a full suite of membrane-bound organelles: mitochondria, endoplasmic reticulum, Golgi apparatus, vacuoles, etc.
2. **Heterotrophic Nutrition (Absorptive):**
    - Fungi are **chemoheterotrophs**; they require pre-formed organic compounds for both energy and carbon.
    - They do **not** photosynthesize (lack chlorophyll).
    - **Mode: Absorptive (osmotrophic) nutrition**. They secrete a wide array of powerful **exoenzymes** (hydrolases) into their immediate environment. These enzymes break down complex substrates (e.g., cellulose, lignin, proteins) into simple, soluble molecules (monosaccharides, amino acids) which are then absorbed across the fungal cell wall and membrane.
3. **Body Plan (Thallus):**
    - The vegetative body is called a **thallus**. It is not differentiated into roots, stems, or leaves.
    - In most fungi, the thallus is a **mycelium**—a branched, filamentous network.
    - Unicellular forms (yeasts) exist but are derived from filamentous ancestors.
4. **Cell Wall Composition:**
    - A rigid cell wall provides structural integrity and defines cell shape.
    - The primary structural component is **chitin**, a strong, flexible polysaccharide of N-acetylglucosamine. This is a key distinguishing feature from:
        - Plants (cellulose)
        - Bacteria (peptidoglycan)
        - Oomycetes (water molds, which are not true fungi and have cellulose/glucan walls).
    - The wall also contains other polysaccharides (e.g., glucans, mannans) and glycoproteins.
5. **Storage Polysaccharide:**
    - Fungi store surplus food as **glycogen**, a highly branched polymer of glucose, similar to animals. They do not store starch (like plants).
6. **Reproduction:**
    - Fungi reproduce via **spores**, which are microscopic, dispersive units capable of germinating into a new mycelium.
    - Spores can be produced:
        - **Asexually (mitospores):** Through mitosis, genetically identical to the parent. Allows for rapid colonization.
        - **Sexually (meiospores):** Through meiosis following plasmogamy and karyogamy, generating genetic variation.
    - Reproductive structures are often the only part of the fungus visible to the naked eye (e.g., mushrooms, molds).

B. Summary Table of Distinguishing Features

Feature	Fungi	Plants	Animals



Aspergillus nidulans	Neurospora crassa	Peziza vesiculosa	Cochliobolus heterostrophus
Plectomycetes	Pyrenomycetes	Discomycetes	Loculoascomycetes
Cleistothecium	Perithecium	Apothecium	Pseudothecium

Classification

Major Phyla of Kingdom Fungi

Current classification recognizes **8-9 major phyla**, with the first five being the most significant and diverse.

1. PHYLUM: CHYTRIDIOMYCOTA ("Chytrids")

- **Key Diagnostic Feature:** Production of **motile zoospores with a single, posterior whiplash flagellum**. This is the **only fungal group with flagellated cells**.
- **Mycelium:** Coenocytic or simple, often rudimentary.
- **Cell Wall:** Chitin and glucan.
- **Ecology:** Mostly aquatic or in wet soils. Important decomposers of refractory materials (e.g., chitin, keratin). Some are serious parasites.
- **Significance:** Considered the most primitive, earliest-diverging lineage of true fungi.
- **Examples:**
  - *Batrachochytrium dendrobatidis* (causes chytridiomycosis, driving global amphibian declines).
  - *Neocallimastigomycota* (now often a separate phylum): Anaerobic chytrids in herbivore guts, with multiple flagella; crucial for cellulose digestion.
  - *Allomyces* (a model organism).

2. PHYLUM: ZYGOMYCOTA (sensu lato)

- **Note:** This group is **paraphyletic**. Modern taxonomy often splits it into several phyla (e.g., **Mucoromycota**, **Zoopagomycota**). The traditional description persists for introductory purposes.
- **Key Diagnostic Feature:** Formation of a thick-walled, resistant **zygospore** (from gametangial fusion during sexual reproduction).
- **Mycelium:** Coenocytic (aseptate).
- **Asexual Reproduction:** Non-motile **aplanospores** produced inside a **sporangium**.
- **Ecology:** Fast-growing saprobes on sugary/starchy substrates (e.g., bread, fruit), some are parasites of insects or other fungi.
- **Examples:**
  - **Order Mucorales:** *Rhizopus stolonifer* (black bread mold), *Mucor*, *Pilobolus* (the "shotgun fungus").
  - **Order Entomophthorales:** *Entomophthora muscae* (parasitizes flies).

3. PHYLUM: GLOMEROMYCOTA

- **Key Diagnostic Feature:** Formation of **arbuscular mycorrhizae (AM)**. They are **obligate symbionts** with plant roots.

- **Exosporium**: Outer, rough, pigmented (brown-black).
- **Endosporium**: Inner, smooth layers.

- **Size**: 50–200 µm diameter.
- **Ornamentation**: Warts, spines, or ridges (species-specific).
- **Content**: Dense cytoplasm with lipid reserves.

4. Germination

- **Dormancy period**: Weeks to months.
- **Process**: Outer wall cracks, germ tube emerges.
- **Germ sporangium**: Tip swells → forms sporangium with haploid spores.
- **Meiosis**: Occurs during germination; produces haploid nuclei.

D. Life Cycle of *Mucor mucedo*

Phase I: Vegetative Growth

1. Haploid spore germinates → forms mycelium.
2. Mycelium grows saprophytically on substrate.

Phase II: Asexual Reproduction

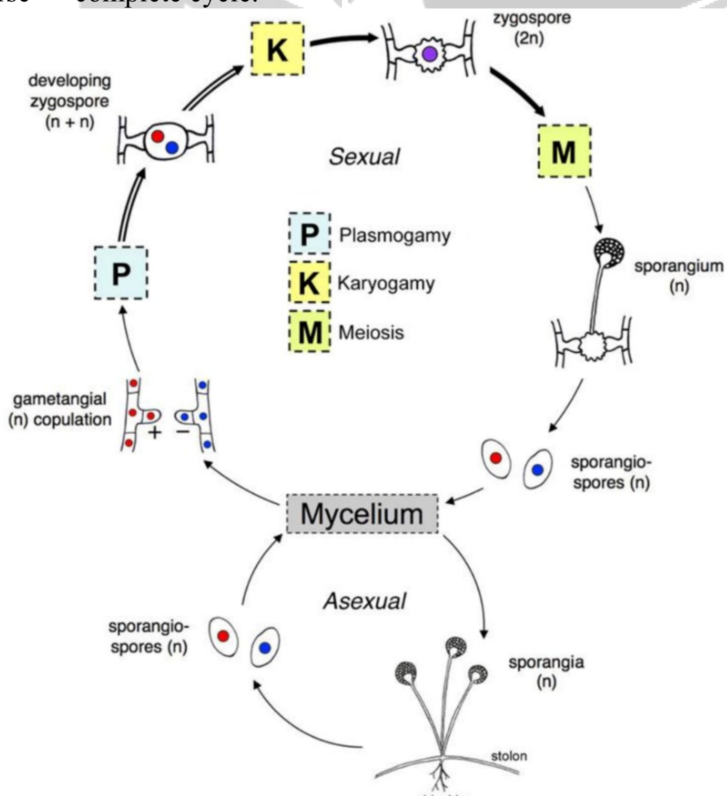
3. Sporangiophores form → bear sporangia.
4. Sporangia produce haploid sporangiospores.
5. Spores disperse → new mycelia.

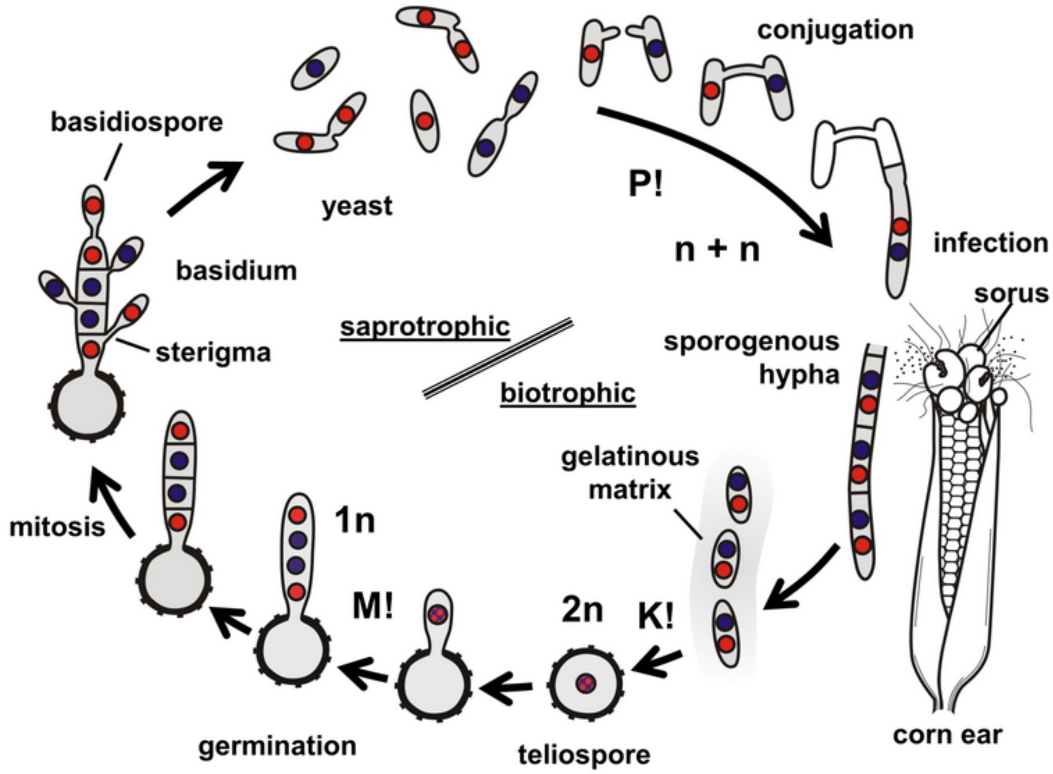
Phase III: Sexual Reproduction

6. (+) and (-) hyphae produce progametangia.
7. Gametangia fuse → form zygospore.
8. Zygospore undergoes dormancy.

Phase IV: Zygospore Germination

9. Zygospore germinates after meiosis.
10. Produces germ sporangium with haploid spores.
11. Spores disperse → complete cycle.





5. IMPORTANCE

A. HARMFUL EFFECTS (AGRICULTURAL SIGNIFICANCE)

Ustilago species are among the most **destructive plant pathogens**, causing **smut diseases** that lead to severe yield losses.

1. **Economic Impact (as outlined in textbook, p. 65):**
   - Smut diseases cause "serious reduction in the yield and quality of grain."
   - Infections are **systemic**; infected plants often appear normal until heading, when grains are replaced by spores.
   - Losses can be total in heavily infected fields.
2. **Major Diseases:**
   - **Corn Smut (*U. maydis*):** Forms large, grotesque galls on ears, tassels, and stems. While considered a delicacy in some cultures (*huitlacoche*), it is a major crop disease.
   - **Loose Smut of Wheat (*U. tritici*):** Entire inflorescence is replaced by spores, which are easily dispersed by wind.
   - **Covered Smut of Barley (*U. hordei*):** Spores remain within the glumes until threshing, facilitating seed-borne transmission.
3. **Control Measures (as per textbook principles):**
   - **Seed Treatment:** Use of systemic fungicides (e.g., carboxin, thiram).
   - **Cultural Practices:** Crop rotation, removal of infected debris, use of resistant varieties.
   - **Sanitation:** Cleaning machinery to prevent spore spread.

B. BENEFICIAL / UNIQUE ASPECTS

1. **Model Organism:** *Ustilago maydis* is a **genetic and molecular model** for studying:
   - **Dimorphism** (yeast vs. hyphal growth).
   - **Plant-fungal pathogenesis**.
   - **Mating-type systems** and **dikaryon formation**.

SUMMARY

PARAPHYSES

- **Type**: Simple, branched, or anastomosing.
- **Tips**: Often swollen, pigmented.

2. Asexual Reproduction

SOREDIA

- **Structure**: Powdery granules containing both fungal hyphae and algal cells.
- **Location**: In soralia (specialized structures).
- **Types**:
  - **Labriform**: Lip-shaped at lobe tips (*P. adscendens*).
  - **Capitate**: Head-like at lobe tips.
  - **Laminal**: On upper surface.

ISIDIA

- **Structure**: Cylindrical outgrowths with cortex.
- **Function**: Break off to form new thalli.
- **Occurrence**: Less common than soredia in *Physcia*.

PYCNIDIA

- **Structure**: Flask-shaped, immersed in thallus.
- **Products**: Pycnidiospores (spermatia).
- **Function**: Male gametes in sexual reproduction.

Fungi:- MCQs

1. The study of fungi is known as:
A. Phycology
B. Mycology
C. Lichenology
D. Bryology
Correct Answer: Mycology

2. The fungal cell wall is primarily composed of:
A. Cellulose
B. Chitin
C. Peptidoglycan
D. Silica
Correct Answer: Chitin

3. Fungi are predominantly:
A. Photoautotrophs
B. Chemoautotrophs
C. Heterotrophs
D. Parasitic plants
Correct Answer: Heterotrophs

4. The reserve food material in fungi is:
A. Starch
B. Glycogen
C. Laminarin
D. Inulin
Correct Answer: Glycogen

5. The vegetative body of a fungus is called:
A. Thallus
B. Mycelium
C. Hypha
D. Both B and C
Correct Answer: Both B and C

6. Fungi that can grow on living host plants are termed:
A. Saprophytes
B. Parasites
C. Obligate parasites
D. Symbionts
Correct Answer: Parasites

7. Coenocytic hyphae are characterized by:
A. Septate walls
B. Absence of cross walls
C. Branched structure
D. Haustoria
Correct Answer: Absence of cross walls

8. Specialized hyphal branches for absorbing nutrients in parasitic fungi are:
A. Stolons
B. Rhizoids
C. Haustoria
D. Appressoria
Correct Answer: Haustoria

9. Which of the following is NOT a fungal group?
A. Ascomycota
B. Basidiomycota
C. Bryophyta
D. Zygomycota
Correct Answer: Bryophyta

Chapter 5

BRYOPHYTES

General Characteristics of Bryophytes

I. Definition & Taxonomic Position

- **Bryophytes** are small, non-vascular, photosynthetic land plants.
- Represent the **oldest living lineage** of land plants (embryophytes), evolving from charophyte algae.
- **Three divisions**: **Bryophyta** (mosses), **Marchantiophyta** (liverworts), **Anthocerotophyta** (hornworts).
- Occupy a **transitional position** between aquatic algae and vascular land plants.

II. Habitat & Distribution

- **Primarily terrestrial** but require moisture for reproduction and often for survival.
- Found in **damp, shaded environments**: forests, riverbanks, rocks, soil, tree bark.
- Some tolerate **extreme environments**: arctic tundra, deserts (in dormant state), high altitudes.
- **Cosmopolitan distribution**, but diversity highest in humid tropical and temperate regions.
- **Ecological indicators** of air/water quality and soil conditions.

III. Morphological Characteristics

A. Plant Body

- **Thalloid or leafy structure**; lack true roots, stems, or leaves (vascular tissues absent).
- **Gametophyte dominant**: photosynthetic, independent, long-lived phase.
- **Sporophyte dependent** on gametophyte for nutrition, short-lived.
- **Rhizoids**: root-like unicellular (liverworts, hornworts) or multicellular (mosses) filaments for anchorage & absorption.
- **Leaves**: usually one cell thick (except midrib), no cuticle or stomata in many liverworts; mosses often have midrib and stomata on sporophyte.
- **No lignin** (except some support cells in moss sporophytes).

B. Size

- Generally small: a few mm to 10–20 cm tall.
- Largest mosses (e.g., *Dawsonia*) can reach ~50 cm.

IV. Reproductive Characteristics

A. Life Cycle – Heteromorphic Alternation of Generations

1. **Dominant Gametophyte (n)**:
   - Produces **gametangia**: **antheridia** (male, produce sperm) & **archegonia** (female, produce egg).
   - **Sperm biflagellate**, require water film to swim to archegonium.
   - Fertilization forms **zygote (2n)**.
2. **Dependent Sporophyte (2n)**:
   - Zygote develops into **embryo** → mature sporophyte (foot, seta, capsule).
   - **Capsule (sporangium)** produces **haploid spores** via meiosis.
   - Spores dispersed by wind/water → germinate into **protonema** (filamentous juvenile stage) → mature gametophyte.

B. Asexual Reproduction

- **Fragmentation** of gametophyte.
- **Gemmae**: multicellular asexual buds in gemma cups (e.g., *Marchantia*).
- **Tubers, stolons**.

Classification of Bryophytes

Hierarchical Classification (Traditional System)

The traditional classification divides bryophytes into three distinct classes, now often treated as separate phyla in modern systems.

- Elater mother cells → elongate, develop spiral thickenings → become elaters (diploid, hygroscopic).
    - **Columella absent**.
    - **Dehiscence**: Capsule splits longitudinally into **4-8 valves** (like opening petals).

D. Spore and Elater Maturation

- **Spores**: Haploid (n), spherical, thick exine with ornamentation.
- **Elaters**:
    - Long, tapered cells with 2-3 spiral thickenings.
    - **Function**: Hygroscopic movements help disperse spores by twisting.
    - **Origin**: Diploid (2n), non-reproductive.

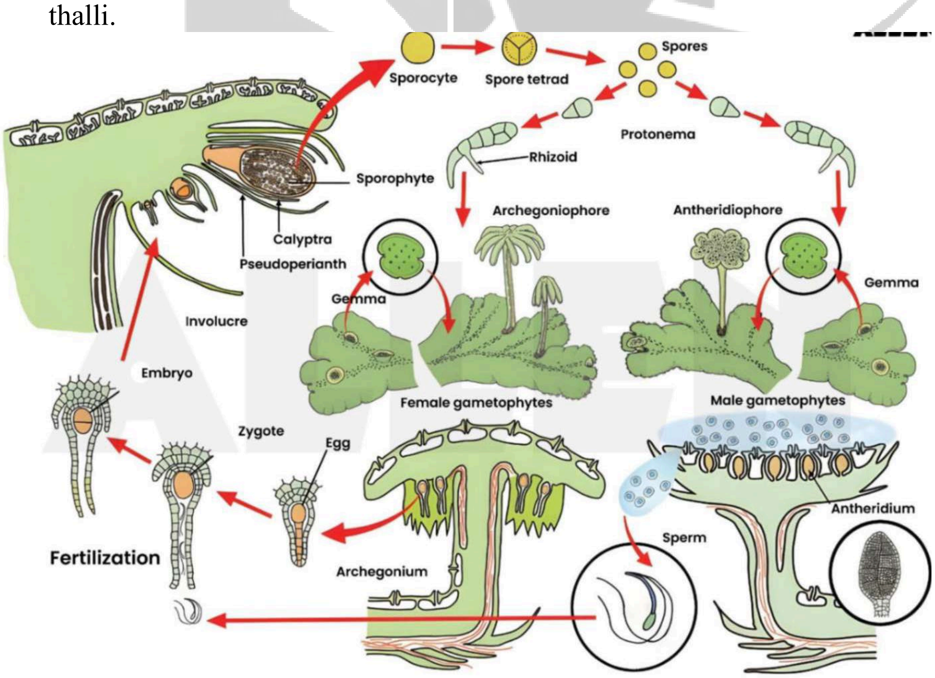
VI. SPORE DISPERSAL & GERMINATION

A. Dispersal Mechanism:

1. Capsule valves open under dry conditions.
2. **Elaters twist** with humidity changes, loosening spore mass.
3. **Wind dispersal** of lightweight spores.
4. **Raindrops** may also assist.

B. Spore Germination:

1. **Conditions**: Moisture, light, suitable temperature.
2. **Process**:
    - Spore absorbs water, exine ruptures.
    - Forms **germ tube** → divides → **protonema** (filamentous stage).
    - **Protonema characteristics**: Chlorophyllous, branched, rhizoid-like cells.
    - Apical cell of protonema develops into **thallus**.
    - **Sex determination**: Spores genetically predetermined to develop into male or female thalli.



Funaria (A Genus of Mosses – "Cord Moss")

1. SCIENTIFIC CLASSIFICATION

Rank	Classification
Phylum	**Bryophyta** (Mosses)
Genus	***Funaria***

M K P R E P A R A T I O N S

5. Bryophytes

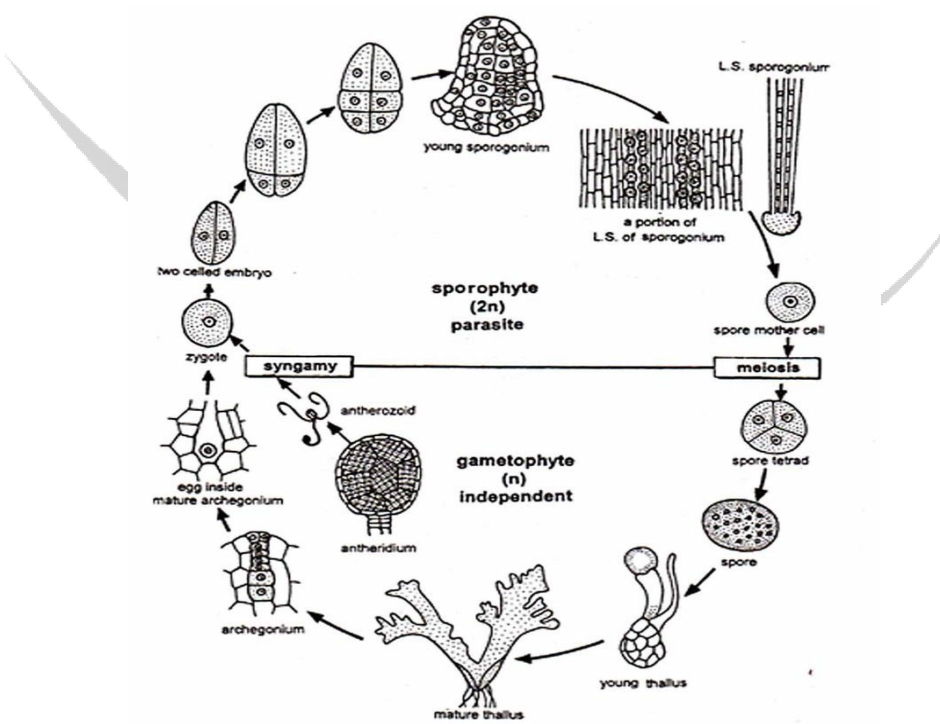
- **Pseudoelaters:** Mixed with the spores are sterile, **non-hygroscopic, often branched, multicellular filaments** called **pseudoelaters**. They help **loosen the spore mass** but do NOT have the spiral thickenings or hygroscopic movements of true liverwort elaters.

2. **Dehiscence (Spore Release):**
   - As the capsule matures from the tip downward, it dries out.
   - It splits longitudinally from the apex into **two valves (sometimes four)**, resembling opening a pea pod.
   - The twisting of the drying valves, aided by the loose spore mass containing pseudoelaters, allows **spores to be gradually shaken out by wind**.
   - The basal meristem continues to produce new capsule tissue above, so spore release is a **continuous process** over the life of the sporophyte.

E. Germination & New Gametophyte

- The haploid spore germinates under favorable moist conditions.
- It produces a small, initial filament that quickly develops into the **thalloid gametophyte** with a single apical cell, completing the cycle.

LIFE CYCLE



Comparative Table of Bryophyte Genera

Feature	*Riccia* (Liverwort)	*Marchantia* (Liverwort)	*Porella* (Leafy Liverwort)
1. Scientific Classification	**Phylum:** Marchantiophyta **Class:** Marchantiopsida **Order:** Marchantiales **Family:** Ricciaceae	**Phylum:** Marchantiophyta **Class:** Marchantiopsida **Order:** Marchantiales **Family:** Marchantiaceae	**Phylum:** Marchantiophyta **Class:** Jungermanniopsida **Order:** Porellales **Family:** Porellaceae
2. Gametophyte Form	**Simple thalloid**, dichotomously branched, rosette-like, dorsal groove. No	**Complex thalloid**, dichotomously branched, with dorsal **air pores** and ventral scales. Distinct **air**	**Leafy (Foliose)**, dorsiventral, creeping. Leaves in 3 rows (2 lateral, 1 ventral -

9. Special / Unique Features	- **Model organism** for bryology. - **Asymmetric, nodding capsule**. - **Calyptra is hairy and hood-shaped**.	- **Lamellae on leaves** (like mini-ridges) enhance photosynthesis. - **Vascular-like conducting tissues** (hydroids & leptoids). - **Epiphragm** for controlled spore dispersal.	- **Single chloroplast with pyrenoid** per cell. - **Symbiosis with Nostoc**. - **Basal meristem** in sporophyte. - **Stomata on sporophyte**. - **Pseudoelaters** instead of true elaters.
10. Common Habitat	Pioneer on disturbed, nitrogen-rich soils (e.g., burnt ground, gardens).	Acidic, poor soils (heaths, bogs, forests), well-drained sites.	Damp, shaded, often disturbed clay or garden soils.

Bryophytes: - MCQs

1. The dominant phase in the bryophyte life cycle is:
A. Sporophyte
B. Gametophyte
C. Zygote
D. Protonema
Correct answer: B

2. Which of these is NOT a bryophyte?
A. *Marchantia*
B. *Funaria*
C. *Equisetum*
D. *Sphagnum*
Correct answer: C

3. The plant body of bryophytes is:
A. Always a thallus
B. Differentiated into roots, stems and leaves
C. Either thalloid or foliose but lacks true roots
D. Always a leafy shoot
Correct answer: C

4. Bryophytes are called "amphibians of plant kingdom" because:
A. They live in water
B. They need water for fertilization
C. They have flagellated sperms
D. Both B and C
Correct answer: D

5. Which structure is responsible for attachment in bryophytes?
A. True roots
B. Rhizoids
C. Holdfasts
D. Stolons
Correct answer: B

6. In bryophytes, the sporophyte is:
A. Independent and dominant
B. Partially parasitic on gametophyte
C. Completely parasitic on gametophyte
D. Short-lived and free-living
Correct answer: C

7. The male sex organ in bryophytes is called:
A. Archegonium
B. Antheridium
C. Oogonium
D. Sporangium
Correct answer: B

8. The female sex organ in bryophytes is called:
A. Archegonium
B. Antheridium
C. Oogonium
D. Carpel
Correct answer: A

9. Which of these bryophytes has the simplest sporophyte?
A. *Marchantia*
B. *Funaria*
C. *Riccia*
D. *Anthoceros*
Correct answer: C

10. In *Riccia*, the sporophyte consists of:
A. Foot, seta and capsule
B. Capsule only
C. Foot and capsule
D. Seta and capsule
Correct answer: B

11. Elaters are found in the capsule of:
A. *Funaria*
B. *Marchantia*
C. *Sphagnum*
D. All mosses
Correct answer: B

Chapter 6

Pteridophytes

Introduction

Pteridophytes are vascular, cryptogamic (spore-producing) plants that represent a crucial evolutionary link between bryophytes (non-vascular plants) and spermatophytes (seed plants). They are often called "vascular cryptogams."

1. Plant Body:

- **Sporophyte Generation is Dominant:** Unlike bryophytes, the independent, photosynthetic, and conspicuous plant body is the diploid sporophyte. It is the dominant phase in the life cycle.
- **Differentiation:** The plant body is well-differentiated into true **roots, stem, and leaves**.
- **Habit:** Most are herbaceous perennials. A few (e.g., tree ferns like *Cyathea*) are arboreal.

2. Vascular System:

- They possess a well-developed **vascular tissue system** (xylem and phloem) for conduction of water, minerals, and food.
- **Xylem:** Typically consists of **tracheids** (vessel elements are generally absent). In some groups (e.g., *Selaginella*), vessels may be present.
- **Phloem:** Composed of sieve cells.
- **Stele Types:** The arrangement of vascular tissues (the stele) varies and is an important taxonomic character. Types include:
  - **Protostele** (Solid core of xylem surrounded by phloem; e.g., *Rhynia*, *Lycopodium*)
  - **Siphonostele** (Vascular tube with a central pith; e.g., many ferns)
  - **Dictyostele** (Dissected siphonostele forming a network of vascular bundles; e.g., most ferns)

3. Leaves:

- Leaves are called **fronds**, especially in ferns.
- Two main evolutionary types exist (detailed in Section III):
  - **Microphylls:** Small, simple leaves with a single, unbranched vein. **Ligule** present in some (e.g., *Selaginella*, *Isoetes*).
  - **Megaphylls:** Large, complex leaves with branched vascular supply (veins forming a network or pattern).

4. Spore Production:

- Spores are produced inside **sporangia**.
- Sporangia are borne on leaves, which are then called **sporophylls**.
- Sporophylls may be:
  - **Similar to vegetative leaves** (homosporous ferns).
  - **Aggregated into a compact structure** called a **strobilus** or cone (e.g., *Lycopodium*, *Selaginella*, *Equisetum*).
- **Homospory vs. Heterospory:**
  - **Homosporous:** Produce only one type of spore (e.g., *Lycopodium*, most ferns). Spores germinate into bisexual gametophytes.
  - **Heterosporous:** Produce two distinct types of spores—**microspores** (male) and **megaspores** (female)—in microsporangia and megasporangia respectively (e.g., *Selaginella*, *Isoetes*, *Salvinia*, *Marsilea*). Spores germinate into unisexual gametophytes.

5. Gametophyte Generation:

- The spore germinates to form a haploid, independent **gametophyte** called a **prothallus**.
- It is small, thalloid, and short-lived.

- It bears the sex organs: **antheridia** (male) and **archegonia** (female).
- **Nutrition:** It is photosynthetic (autotrophic) in most homosporous pteridophytes. In heterosporous types and some homosporous ones (e.g., *Lycopodium*), it may be partially or wholly subterranean and dependent on mycorrhizal association.

6. Sexual Reproduction & Fertilization:

- **Flagellated spermatozoids (antherozoids)** require a thin film of water to swim from the antheridium to the archegonium for fertilization. This is a key limitation, tying them to moist environments.
- The zygote develops into an embryo and eventually a new sporophyte, often initially dependent on the gametophyte.

7. Apomixis: Some ferns reproduce asexually via **apospory** (gametophyte develops from sporophyte tissue without spores) or **apogamy** (sporophyte develops from gametophyte tissue without fertilization).

II. Occurrence (Ecology & Distribution) of Pteridophytes

1. Habitat:

- **Primary Habitats:** They are predominantly **mesophytic**, thriving in cool, damp, shady, and humid places. This is due to their requirement of water for fertilization and the vulnerability of the delicate gametophyte to desiccation.
- **Diverse Adaptations:** However, they exhibit remarkable adaptation and can be found in a variety of niches:
  - **Epiphytes:** Grow on other plants (trees) for support (e.g., *Platycerium* - Staghorn fern, *Asplenium nidus* - Bird's nest fern).
  - **Xerophytes:** Adapted to dry conditions (e.g., *Selaginella lepidophylla* - Resurrection plant, *Cheilanthes* - Lip fern).
  - **Hydrophytes/Aquatics:** Free-floating (e.g., *Salvinia*, *Azolla*) or rooted in water (e.g., *Marsilea*, *Ceratopteris*).
  - **Lithophytes:** Grow on rocks or in rock crevices (e.g., many *Selaginella* species).
  - **Terrestrial Forest Floor:** Most common habitat (e.g., *Dryopteris*, *Adiantum*, *Pteris*).

III. Evolution of Leaf in Pteridophytes

The evolution of leaves in vascular plants is a major event, and pteridophytes display two fundamentally distinct types, believed to have evolved independently. The leading theory explaining their origin is the **Telome Theory** proposed by Walter Zimmermann (1930).

A. The Telome Theory

- The basic structural unit of primitive vascular plants (like *Rhynia*) was a **telome** – a cylindrical, dichotomously branching axis terminating in sporangia.
- The theory proposes that leaves evolved through a series of evolutionary processes (**telome processes**) acting on these telomic systems:
  1. **Overtopping:** One branch of a dichotomy grows more vigorously, becoming the main axis, while the smaller, lateral branches become potential leaf precursors.
  2. **Planation:** Lateral branches shift from a 3D to a 2D arrangement (in one plane).
  3. **Webbing/ Fusion:** The spaces between the planated branches become filled with photosynthetic tissue (mesophyll), forming a flat lamina or blade.
  4. **Reduction:** Simplification of the structure.

B. Two Lines of Leaf Evolution

1. Microphyllous Line (Lycophylls)

- **Definition:** Small, simple leaves with a **single, unbranched vascular trace (vein)** that is not associated with a leaf gap (gap in the stele of the stem).
- **Proposed Evolution (Enation Theory):**
  - Originated as **enations** – small, superficial, vascular-less outgrowths from the stem (seen in fossil plant *Asteroxylon*).

- Xylem elements are interspersed with parenchyma, giving a *false appearance* of a pith. However, the parenchyma is of **xylary origin** (from tracheary elements) and not true ground tissue pith.
- **Example:** *Selaginella* spp.

Type 2: Siphonostele

- **Defining Feature:** The vascular tissue forms a **hollow cylinder surrounding a central pith.** The pith is **true parenchymatous ground tissue.**
- Major evolutionary advancement: Allows for increased diameter and storage.
- **Subtypes based on leaf gap morphology:**
  - **Leaf Gap:** A parenchymatous interruption in the vascular cylinder **above the point (node) where a leaf trace (vascular supply to leaf) diverges.**

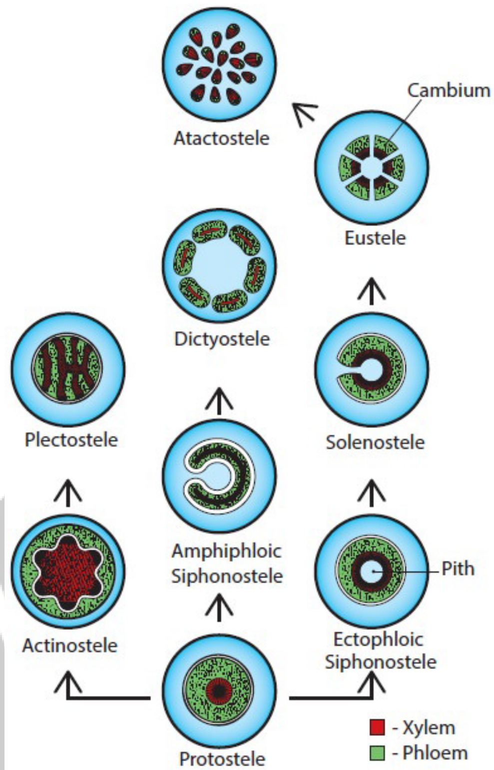


Figure 2.37: Types of Stele

A. Ectophloic Siphonostele:

- Phloem is present **only on the external side** of the xylem cylinder.
- **Example:** Stem of *Osmunda* (fern) rhizome.

B. Amphiphloic Siphonostele (Solenostele):

- Phloem is present on **BOTH sides** of the xylem cylinder (external and internal).
- Provides dual phloem pathways.
- **i. Simple Solenostele:** Uninterrupted cylinder, found in stems with widely spaced leaves (long internodes). *Example: Rhizomes of Marsilea* (fern).
- **ii. Dictyostele:** The most common type in **ferns**. Overlapping leaf gaps break the solenostele into a network of separate vascular bundles, each called a **meristele**. In cross-section, it appears as a ring of distinct bundles.
- **Example:** Most common leptosporangiate ferns (*Pteris, Adiantum*).

Type 3: Eustele

- **Defining Feature:** The vascular tissue consists of **discrete, collateral or bicollateral vascular bundles** arranged in one or more rings around a central pith. This is the result of the **break-up of the siphonostele.**
- This is the **characteristic stele of all modern gymnosperms and dicotyledonous angiosperms.**
- Bundles are separated from each other by **medullary rays** (parenchymatous interfascicular regions).
- In dicots, a **vascular cambium** develops within the bundles (fascicular cambium) and between them (interfascicular cambium) to form a continuous ring, leading to secondary growth.

Type 4: Atactostele

- **Defining Feature:** Numerous vascular bundles **appear scattered** throughout the cross-section of the stem, embedded in ground tissue. There is **no clear single ring** of bundles.
- This is the **characteristic stele of monocotyledonous angiosperms** (e.g., grasses, lilies, palms).
- **"Atacto-" means "without order"** (though patterns exist).
- The bundles are smaller and more numerous towards the periphery. There is no clear distinction between cortex and pith (**ground tissue**).

contains a primitive **actinostele** or **protostele** (a central vascular cylinder with xylem and phloem).

- **Leaves:** True leaves are **absent**. Instead, it has small, scale-like, **non-vascular** outgrowths called **enations** or **microphylls** (in the classical sense). These are arranged in spirals along the stem and are not connected to the vascular system.
- **Roots:** True roots are **absent**. The plant is anchored by a horizontally growing **rhizome** (underground stem) covered with **rhizoids** (hair-like structures) for absorption. Absorption is aided by a **mycorrhizal association** (symbiotic relationship with fungi), which is essential for nutrient uptake.
- **Vascular Tissue:** Present but primitive. The xylem consists of **tracheids** (no vessels), and phloem consists of sieve cells.

4. Reproduction

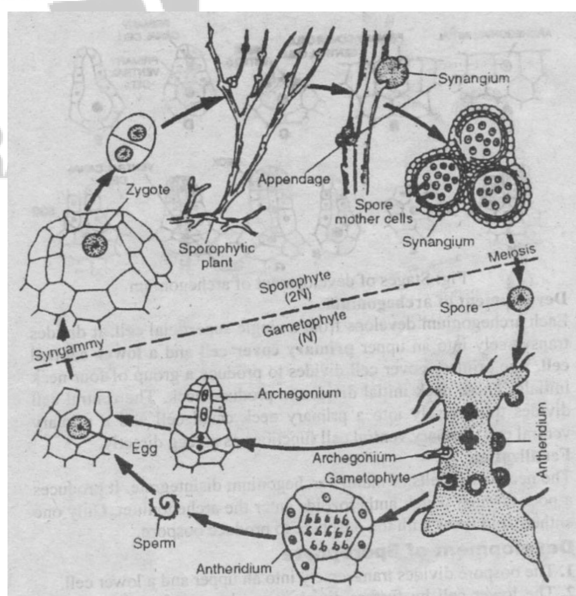
Psilotum exhibits a **heteromorphic alternation of generations** with a dominant sporophyte phase.

A. Asexual Reproduction (via Spores):

1. **Sporangia:** The reproductive structures are borne on the ends of short, lateral branches. They are **synangia** (singular: synangium) – a compound structure formed by the fusion of three **sporangia** (two in some cases). The synangium appears as a trilobed, yellowish structure.
2. **Spores:** Inside the sporangia, **sporogenous cells** undergo meiosis to produce **haploid (n), homosporous** spores (all spores are of the same type).
3. **Dispersal:** Upon maturity, the synangium splits open, releasing numerous, reniform (kidney-shaped) spores that are dispersed by wind.

B. Sexual Reproduction (via Gametophytes):

1. **Gametophyte:** The spore germinates to form a small (a few mm), cylindrical, subterranean **gametophyte**. It is non-photosynthetic, mycorrhizal, and lives saprophytically in association with fungi.
2. **Sex Organs:** The gametophyte bears both **antheridia** (male) and **archegonia** (female) on the same body, making it **monoecious**.
   - **Antheridia** produce biflagellate **spermatozoids** (antherozoids).
   - **Archegonia** have a neck and a venter containing a single **egg cell**.
3. **Fertilization:** Requires water for the sperm to swim to the archegonium. The egg is fertilized to form a diploid (2n) **zygote**.
4. **Embryo Development:** The zygote develops into a new **sporophyte** embryo, which initially derives nourishment from the gametophyte before becoming an independent plant.



5. Detailed Structure of the Sporophyte

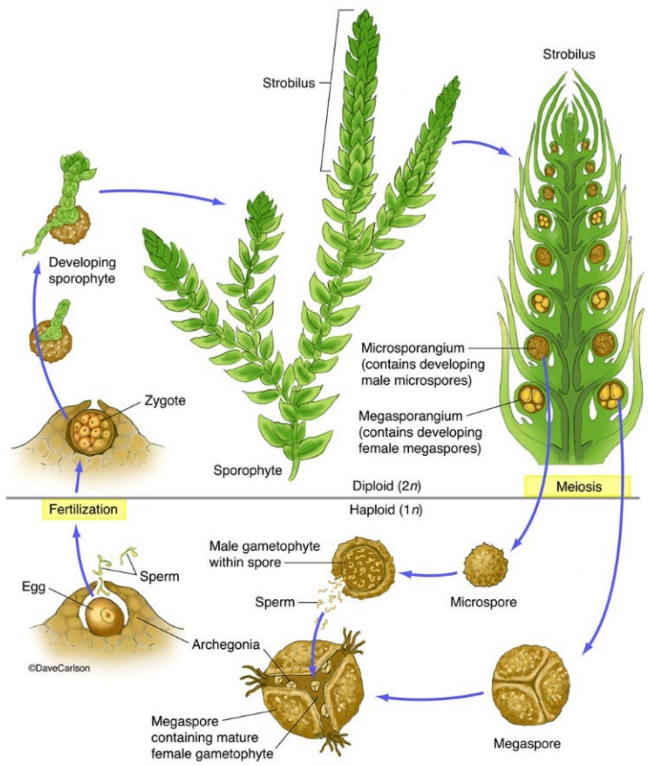
The mature sporophyte can be divided into two main parts:

A. Subterranean Rhizome System:

- Lacks roots and true leaves.
- Covered with **rhizoids** for anchorage and absorption.
- Harbors endophytic fungi (**mycorrhiza**) in the cortex, crucial for absorbing water and nutrients.
- The vascular cylinder is a simple **protostele**.

- **Male Gametophyte (Microgametophyte):** Develops from a microspore. It becomes a single **prothallial cell** and an **antheridium** that produces numerous biflagellate **spermatozoids**.

2. **Fertilization:** Released spermatozoids require a film of water to swim to the archegonia on the female gametophyte (which is often still partially enclosed within the megaspore wall on the soil). Fertilization of the egg forms a diploid **zygote**.
3. **Embryogeny:** The zygote develops into a young **sporophyte embryo** (with foot, root, stem, and leaf primordia) that is initially parasitic on the female gametophyte. It eventually establishes itself as an independent plant.



5. Detailed Structure of the Sporophyte

A. External Morphology:

- The plant body is clearly differentiated into **stem, leaves, rhizophores, and roots**.
- The branching is typically **dichotomous**.
- Leaves are **microphylls** (with a single vein) and exhibit **anisophylly** (dimorphism: dorsal vs. ventral).
- The **ligule** is a secretory structure, possibly preventing desiccation of the developing sporangium.
- **Strobili** are compact, borne terminally, and consist of spirally arranged sporophylls.

Sphenopsida (Horsetails)

I. Introduction & Evolutionary Significance

- **Sphenopsida** (or Equisetopsida) is a **class of vascular cryptogams** within the division Monilophyta (ferns and allies).

II. General Characteristics

1. **Sporophyte Plant Body:**
   - **Stems:** The most conspicuous part.
     - **Hollow, jointed, and ridged** (with longitudinal ridges and grooves).

2. **Spores:** Sporogenous tissue within the sporangia undergoes meiosis to produce numerous **haploid, homosporous**, green spores.
3. **Elaters:** A unique feature is the presence of **elaters**—hygroscopic, strap-like appendages attached to the spore. They coil and uncoil with changes in humidity, aiding in spore dispersal from the sporangium and initial crawling on the soil.
4. **Dispersal:** The strobilus matures, sporangiophores open, and spores are released by wind.

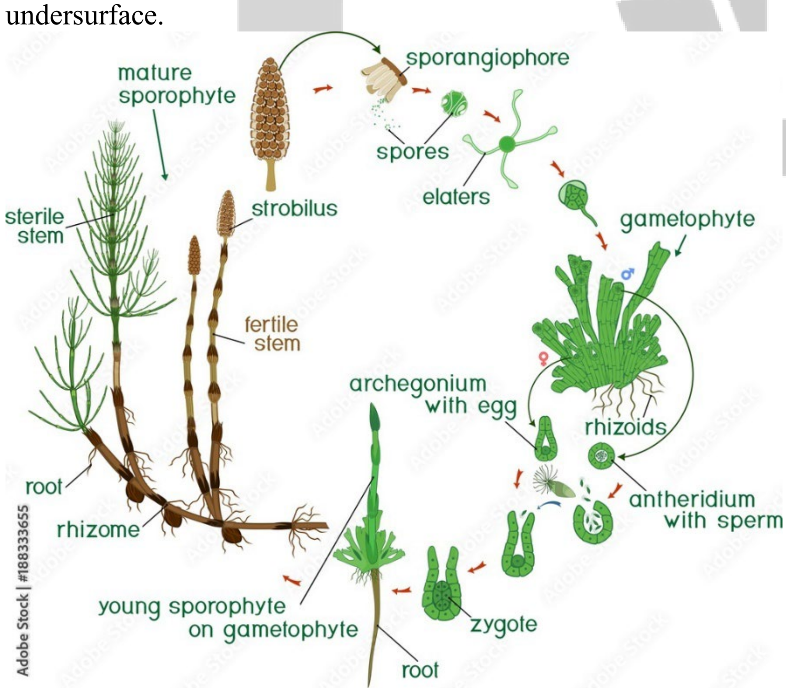
B. Sexual Reproduction (via Gametophytes):

1. **Gametophyte:** The green spore germinates to form a free-living, photosynthetic **gametophyte**. It is a lobed, thalloid structure that grows on the soil surface.
2. **Sex Organs:** The gametophytes are potentially **bisexual**, producing both **antheridia** (male) and **archegonia** (female). However, they often become functionally **unisexual** due to environmental conditions (crowding favors antheridia production).
   - **Antheridia** produce multiflagellate **spermatozoids**.
   - **Archegonia** have a neck and contain a single egg cell.
3. **Fertilization:** Requires water for the sperm to swim to the archegonium. The fertilized egg forms a diploid **zygote**.
4. **Embryogeny:** The zygote develops into an embryo and then a new **sporophyte**, which initially depends on the gametophyte.

5. Detailed Structure of the Sporophyte

A. External Morphology:

- Exhibits clear **differentiation into nodes and internodes**.
- Two forms of shoots may exist in some species (e.g., *E. arvense*):
  - **Fertile Shoot:** Non-photosynthetic, flesh-colored or brown, ephemeral, bearing a terminal strobilus. Appears in early spring.
  - **Vegetative Shoot:** Green, photosynthetic, highly branched, and appears after the fertile shoot.
- The **strobilus** is a compact cone consisting of a central axis with whorls of peltate **sporangiophores** (not sporophylls). Each sporangiophore bears 5-10 sporangia on its undersurface.



- **Pollination:** The pollen grain is transported (by wind, insects) to the **micropyle** of the ovule, **NOT to water**. This eliminates the need for external water for fertilization.
- **Pollen Tube:** In seed plants, the microgametophyte produces a **pollen tube** to deliver non-motile sperm cells directly to the egg. (In early seed plants like cycads and ginkgo, the pollen tube functions as an absorptive organ and flagellated sperm are still released inside the ovule).

Step 5: Fertilization and Seed Maturation

- **Fertilization:** Occurs **inside the ovule** on the parent plant.
- **Seed Development:** The **zygote** develops into an **embryo**. The **integument hardens into the seed coat**. The **megagametophyte tissue (or in angiosperms, the endosperm) serves as nutritive tissue**.
- The mature seed is then **dispersed as a unit**.

Pteridophytes: - MCQs

1. Pteridophytes are also known as:
A. Flowering plants
B. Vascular cryptogams
C. Non-vascular cryptogams
D. Seed plants
Correct answer: B

2. The dominant generation in pteridophytes is:
A. Gametophyte
B. Sporophyte
C. Both equally dominant
D. Zygote
Correct answer: B

3. Which of these is NOT a pteridophyte?
A. *Selaginella*
B. *Equisetum*
C. *Dryopteris*
D. *Cycas*
Correct answer: D

4. The leaves bearing sporangia are called:
A. Sporophylls
B. Microphylls
C. Megaphylls
D. Fronds
Correct answer: A

5. Circinate vernation is found in:
A. *Selaginella*
B. *Equisetum*
C. Ferns
D. *Psilotum*
Correct answer: C

6. Heterospory is found in:
A. *Lycopodium*
B. *Equisetum*
C. *Selaginella*
D. *Psilotum*
Correct answer: C

7. Which pteridophyte is commonly called "horsetail"?
A. *Selaginella*
B. *Equisetum*
C. *Dryopteris*
D. *Marsilea*
Correct answer: B

8. The stele type found in fern rhizomes is:
A. Protostele
B. Siphonostele
C. Dictyostele
D. Eustele
Correct answer: C

9. The gametophyte of pteridophytes is called:
A. Protonema
B. Prothallus
C. Thallus
D. Mycelium
Correct answer: B

10. Water is essential in pteridophytes for:
A. Photosynthesis
B. Fertilization
C. Spore dispersal
D. Vegetative growth
Correct answer: B

11. Groups of sporangia on fern leaves are called:
A. Strobili
B. Sori
C. Sporocarps
D. Cones
Correct answer: B

12. The protective covering over sorus is:
A. Annulus

Chapter 7

Gymnosperms

1. Introduction

Gymnosperms (from the Greek: *gymnos* = naked, *sperma* = seed) are a group of seed-producing plants that constitute one of the two major clades of seed plants, the other being the Angiosperms (flowering plants). They are known as **"naked seed plants"** because their seeds are not enclosed within a fruit or ovary wall; instead, they are typically borne on the surface of scales or leaves, often arranged in cones (strobili).

Evolutionary Significance:

- Gymnosperms first appeared in the late **Carboniferous Period** (around 319 million years ago) and became the dominant terrestrial plants during the **Mesozoic Era** (the "Age of Conifers" and Cycads).
- They represent a critical evolutionary advancement over the pteridophytes (ferns and allies) due to the development of the **seed**. The seed, containing an embryonic plant with stored food and a protective coat, was a key adaptation for survival in terrestrial environments, enabling colonization of drier habitats.
- They were the first plants to develop **pollen** for male gamete transfer, eliminating the need for free water for fertilization—a major limitation for ferns and mosses.

Diversity and Living Groups:

Modern gymnosperms are not as diverse as angiosperms but are ecologically and economically vital. They are represented by four main living groups:

1. **Coniferophyta (Conifers):** The largest and most familiar group (e.g., pines, firs, spruces, cedars, redwoods).
2. **Cycadophyta (Cycads):** Palm-like plants of tropical and subtropical regions (e.g., *Cycas*).
3. **Ginkgophyta:** Represented by a single living species, *Ginkgo biloba* (maidenhair tree).
4. **Gnetophyta:** A small but evolutionarily interesting group with three distinct genera (*Gnetum*, *Welwitschia*, *Ephedra*).

2. General Characters

A. Vegetative (Sporophytic) Characters:

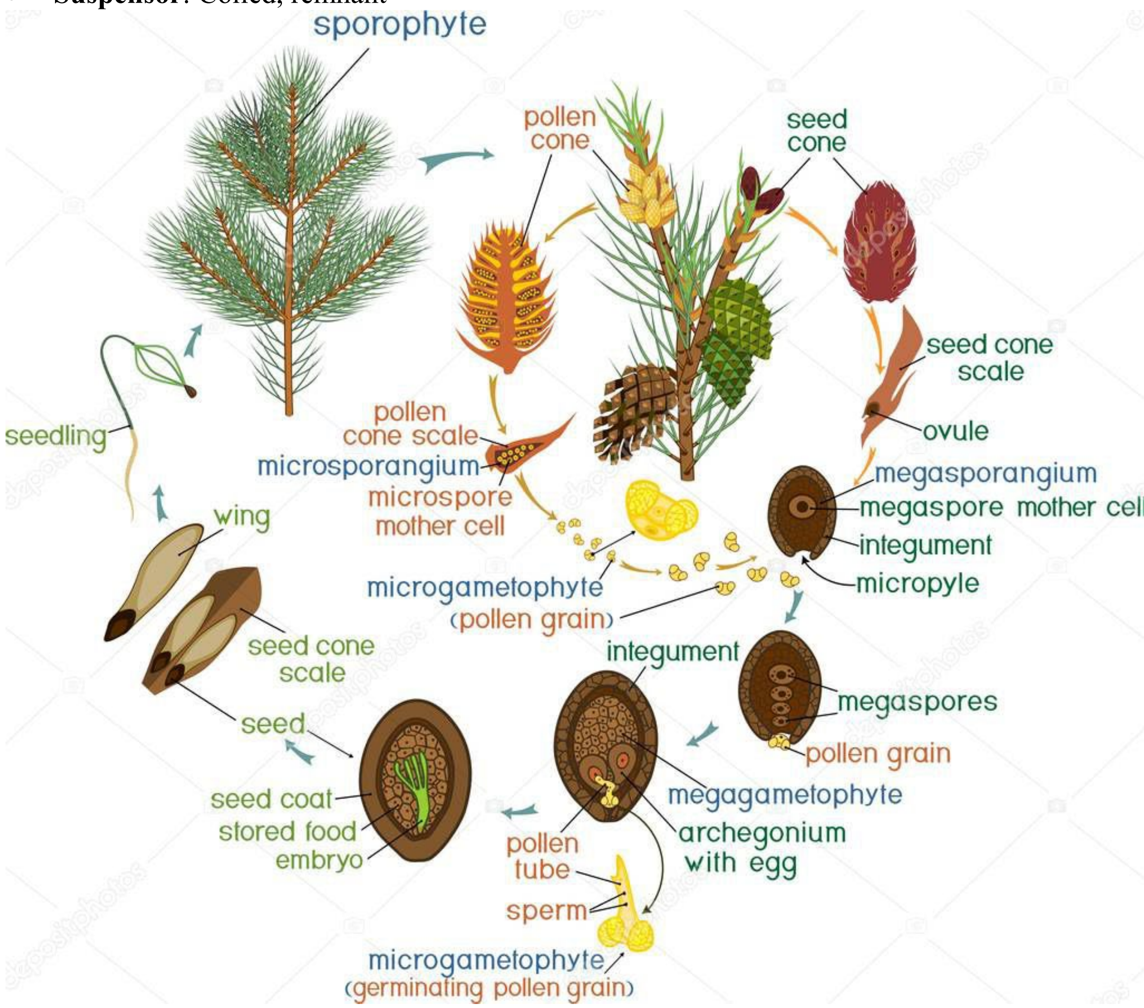
1. **Habit:** Mostly perennial, evergreen woody trees or shrubs. Rarely, they are lianas (e.g., *Gnetum*) or bizarre, turnip-like plants (*Welwitschia*).
2. **Root System:** A well-developed **tap root system**. Roots are often infected with symbiotic fungi, forming **mycorrhizae** (essential for conifers) or, in cycads, with nitrogen-fixing cyanobacteria.
3. **Stem:** Erect, branched (monopodial in conifers) or unbranched (in cycads), and woody. Possess **secondary growth** due to a well-developed vascular cambium, producing abundant secondary xylem (wood). The wood is typically **non-porous** (lacking vessel elements in most groups; tracheids conduct water) and is therefore often called "softwood."
4. **Leaves:** Show great variation.
    - **Conifers:** Leaves are simple, often needle-like (e.g., pine), scale-like (e.g., cypress), or strap-shaped (e.g., *Araucaria*). They are adapted to reduce water loss (xerophytic)—thick cuticle, sunken stomata.
    - **Cycads:** Large, compound pinnate leaves in a crown at the apex.
    - **Ginkgo:** Unique, fan-shaped, deciduous leaves with dichotomous venation.
    - **Gnetophytes:** *Gnetum* has broad, angiosperm-like leaves; *Ephedra* has scale-like leaves.

B. Reproductive Characters:

1. **Heterosporous:** They produce two distinct types of spores:
    - **Microspores:** Formed in **microsporangia** on **microsporophylls**. Develop into the male gametophyte (pollen grain).

D. Mature Embryo Structure

- **Cotyledons**: 4-15, needle-like
- **Hypocotyl**: Stem region
- **Radicle**: Root apex, at chalazal end
- **Shoot apex**: Protected by cotyledons
- **Suspensor**: Coiled, remnant



VIII. SEED DEVELOPMENT AND STRUCTURE

A. Seed Maturation Components

1. **Seed coat (testa)**: From integument (2n)
   - Outer fleshy layer (sarcotesta) - absent in most pines
   - Middle stony layer (sclerotesta)
   - Inner papery layer (endotesta)
2. **Nutritive tissue**: Female gametophyte (n) - "endosperm"
3. **Embryo (2n)**: With multiple cotyledons

B. Cone and Seed Maturation

- Female cone becomes **woody**, scales lignify
- **Cone opens** (third year) for seed dispersal
- **Seeds often winged** (from ovuliferous scale tissue)

IX. SEED DISPERSAL AND GERMINATION

A. Dispersal Mechanisms

1. **Wind**: Winged seeds (most pines)

- **Spermatogenous cell** gives rise to two sperm
- **Sperm size**: Large (70-90 µm), visible with hand lens
- **Flagella**: Thousands, arranged in spiral bands
- **Development completed** just before fertilization

VI. FERTILIZATION (ZOOLOGAMY)

A. Preparation for Fertilization

1. **Archegonial chamber forms**: By breakdown of cells above archegonia
2. **Fluid fills chamber**: Provides medium for sperm swimming
3. **Pollen tube ruptures**: Releases sperm into chamber

B. Sperm Movement and Fusion

1. **Sperm swim actively** using flagella (15-30 minutes)
2. **One sperm enters each archegonium** through neck canal
3. **Sperm nucleus fuses with egg nucleus → zygote (2n)**
4. Multiple fertilizations possible (multiple archegonia) but usually only one embryo develops

Gymnosperms: - MCQs

1. What is the primary defining characteristic of gymnosperms?
A. Presence of flowers
B. Production of fruits
C. **Seeds not enclosed in an ovary (naked seeds)**
D. Double fertilization
Correct Answer: C

2. The ovules of gymnosperms are borne on:
A. Carpels
B. **Megasporophylls**
C. In an ovary
D. Receptacle
Correct Answer: B

3. Which of the following is NOT a gymnosperm phylum?
A. Coniferophyta
B. Cycadophyta
C. Ginkgophyta
D. **Bryophyta**
Correct Answer: D

4. The most abundant and widespread group of gymnosperms is:
A. Cycads
B. **Conifers**
C. Gnetophytes
D. Ginkgoales
Correct Answer: B

5. *Pinus* is an example of a:
A. Cycad
B. **Conifer**
C. Gnetophyte
D. Fossil plant
Correct Answer: B

6. Resin canals, common in conifers, are a feature of their:
A. Xylem
B. **Mesophyll and vascular tissues**
C. Phloem only
D. Epidermis
Correct Answer: B

7. The wood of gymnosperms is commercially called 'softwood' because it lacks:
A. Tracheids
B. Fibers
C. **True vessels (in most)**
D. Parenchyma
Correct Answer: C

8. The male reproductive cone in gymnosperms is also called:
A. Ovulate cone
B. **Microsporangiate strobilus**
C. Megasporangiate strobilus
D. Seed cone
Correct Answer: B

9. In *Pinus*, microspores (pollen grains) are produced in:
A. **Microsporangia on microsporophylls**
B. Anthers
C. Megasporangia
D. Archegonia
Correct Answer: A

10. Pollination in most gymnosperms is mediated by:
A. Insects

Chapter 8

Angiosperms

Introduction

Angiosperms (division **Anthophyta/Magnoliophyta**) are the most diverse and widespread group of land plants, characterized by the production of **flowers** and **enclosed seeds** (within a fruit). They represent the culmination of plant evolution, dominating most terrestrial ecosystems.

Life Cycle (Alternation of Generations)

Angiosperms have a **diplontic life cycle with a dominant, photosynthetic sporophyte** generation. The gametophyte generation is **highly reduced** and dependent on the sporophyte.

The Sporophyte Generation of Angiosperms

The **sporophyte generation** in angiosperms is the **diploid (2n), multicellular, dominant, and photosynthetic phase** of the life cycle. It originates from the zygote and constitutes the **entire visible plant body**—from seedling to mature flowering plant. This generation is **heterotrophic only briefly during embryogenesis**, becoming autotrophic upon germination.

Key Concept: The angiosperm sporophyte is the **most complex and dominant sporophyte** in the plant kingdom, representing an evolutionary pinnacle of **structural and functional specialization**.

II. ORIGIN AND DEVELOPMENTAL TIMELINE

- **Origin:** Formed from the **zygote (2n)** following double fertilization.
- **Developmental Journey:** Zygote → Embryo (within seed) → Seedling → Juvenile Vegetative Plant → Mature Reproductive Plant (with flowers) → Senescence.
- **Duration:** Can be annual (completes in one season), biennial (two seasons), or perennial (many years).

III. STRUCTURAL ORGANIZATION OF THE SPOROPHYTE

A. VEGETATIVE (NON-REPRODUCTIVE) ORGANS

These structures support growth, nutrition, and homeostasis.

1. Root System

- **Functions:** Anchorage, water/mineral absorption, storage, hormone synthesis (e.g., cytokinins).
- **Anatomy:**
  - **Root Cap:** Protects apical meristem; secretes mucilage; contains statocytes for gravity sensing.
  - **Zone of Cell Division:** Apical meristem produces cells.
  - **Zone of Elongation:** Cells expand, driving root tip downward.
  - **Zone of Maturation/Differentiation:** Cells develop into primary tissues; root hairs form.
- **Primary Tissues (from protoderm, ground meristem, procambium):**
  - **Epidermis:** Single cell layer with root hairs.
  - **Cortex:** Parenchyma for storage; endodermis with **Casparian strip** (suberin barrier) regulating vascular cylinder entry.
  - **Stele (Vascular Cylinder):** Pericycle (lateral root origin), vascular bundles (xylem/phloem in radial arrangement).
- **Modifications:** Taproots (carrot), fibrous roots (grass), adventitious roots (prop roots of corn), storage roots (sweet potato).

2. Shoot System

- **Functions:** Photosynthesis, support, transport, reproduction.
- **Components:** Stems, leaves, buds.

a) Stem

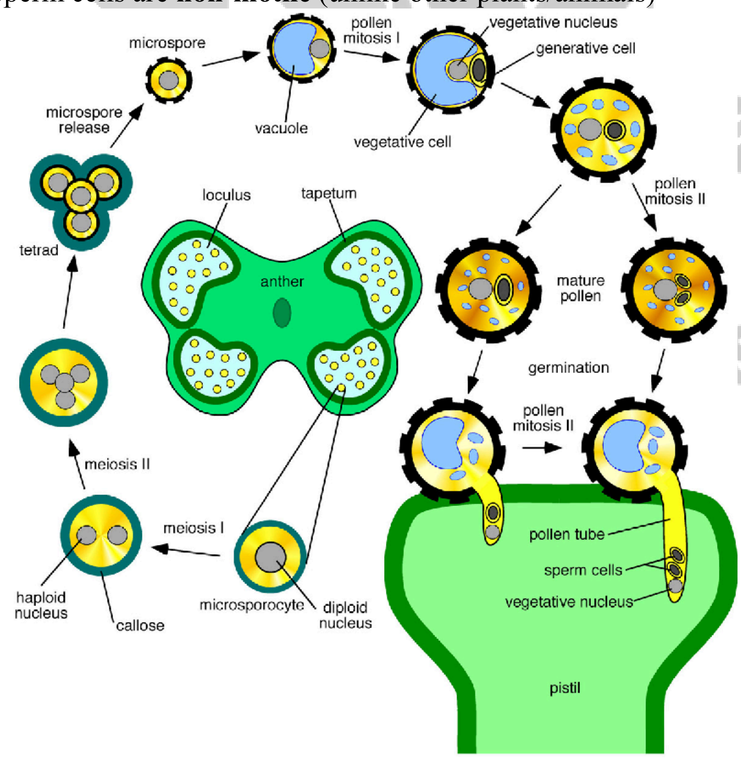
- **Anatomy:**

- Contains **vegetative cell + generative cell**
- Generative cell divides **during pollen tube growth**
- Examples: Rosaceae, Solanaceae, many dicots

- **Tricellular Pollen (≈30%):**
  - Contains **vegetative cell + two sperm cells**
  - Generative division occurs **before anther dehiscence**
  - Examples: Poaceae (grasses), Asteraceae, Brassicaceae
- **Pollen Viability:**
  - **Short-lived:** Hours to days (e.g., grasses, cereals)
  - **Long-lived:** Months to years (orchids, some trees)
  - **Storage:** Controlled by temperature, humidity

4. Pollen Ultrastructure

- **Vegetative Cell:**
  - Large nucleus with diffuse chromatin
  - Abundant **lipidic bodies** and **phytin globules**
  - **P-polysaccharide particles** (β-1,3-glucan)
  - Stored mRNA for rapid protein synthesis upon hydration
- **Generative Cell/Sperm Cells:**
  - **Enucleated during development:** Lose most organelles
  - **Minimal cytoplasm**
  - **Unique cytoskeleton** of microtubular ribbons
  - Sperm cells are **non-motile** (unlike other plants/animals)



C. Female Gametophyte (Megagametophyte/Embryo Sac) Development

1. Megaspore Selection Patterns

- **Monosporic (Polygonum Type - ≈70%):**
  - Most common

Orchids	**Legumes** (beans, peas, peanuts)
Lilies, Tulips, Onions	**Cacti**
Bananas, Ginger	**Mints, Carrots**

Angiosperms: - MCQs

1. The most distinctive feature of angiosperms is:
A. Vascular tissue
B. **Production of flowers and fruits**
C. Dominant sporophyte generation
D. Presence of seeds
Correct Answer: B

2. Double fertilization in angiosperms results in the formation of:
A. Zygote and fruit
B. **Zygote and endosperm**
C. Embryo and seed coat
D. Endosperm and fruit wall
Correct Answer: B

3. The nutritive tissue in an angiosperm seed is:
A. Haploid female gametophyte
B. **Triploid endosperm**
C. Diploid perisperm
D. Haploid nucellus
Correct Answer: B

4. The male gametophyte in angiosperms is represented by:
A. Anther
B. Pollen sac
C. **Mature pollen grain**
D. Microsporocyte
Correct Answer: C

5. Which part of the flower develops into the fruit?
A. Ovule
B. Stigma
C. **Ovary**
D. Placenta
Correct Answer: C

6. The typical embryo sac of angiosperms is:
A. Monosporic, 8-nucleate, 7-celled
B. **Monosporic, 8-nucleate, 7-celled (Polygonum type)**
C. Bisporic, 4-nucleate, 4-celled
D. Tetrasporic, 16-nucleate, 9-celled
Correct Answer: B

7. Vessels in the xylem are a characteristic feature of:
A. Pteridophytes and Gymnosperms
B. Gymnosperms only
C. **Angiosperms**
D. All vascular plants
Correct Answer: C

8. Angiosperms are divided into two main classes based on:
A. Root type
B. **Number of cotyledons**
C. Venation pattern
D. Both B and C
Correct Answer: D

9. Parallel venation is a characteristic feature of:
A. Dicot leaves
B. **Monocot leaves**
C. Gymnosperm leaves
D. Fern fronds
Correct Answer: B

10. A plant with a taproot system, net-veined leaves, and floral parts in multiples of four or five is most likely a:
A. **Dicot**
B. Monocot
C. Gymnosperm
D. Pteridophyte
Correct Answer: A

11. The androecium refers to the:
A. Female part of the flower
B. **Collective male parts (stamens)**
C. Collection of petals
D. Collection of sepals
Correct Answer: B

12. The gynoecium is made up of:
A. Stamens
B. **Carpels**
C. Sepals
D. Petals
Correct Answer: B

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

Chapter 9

Plant Morphology

Morphological Characters of the Root

1. Definition & Primary Functions:

The root is the **descending (non-green) axis** of the plant, typically growing **geotropically positive** (downwards) and **phototropically negative** (away from light). It is primarily responsible for:

- **Anchorage:** Fixing the plant firmly in the soil.
- **Absorption:** Uptake of water and dissolved mineral nutrients.
- **Conduction:** Transport of absorbed substances to the shoot system.
- **Storage:** In many plants, roots become modified for storing food reserves.

2. Distinguishing Features from Stems:

- **Nodes & Internodes: Absent** in roots.
- **Leaves & Buds: Absent** (except in adventitious buds in some species for vegetative propagation).
- **Chlorophyll:** Typically absent (non-photosynthetic).
- **Root Cap:** Present at the apex to protect the meristem.
- **Endogenous Origin:** Branch roots arise from the inner tissues (pericycle).

3. Classification of Root Systems:

A. Tap Root System

- **Origin:** Develops from the **radicle** of the seed embryo.
- **Structure:** Characterized by a single, dominant, thick **primary root** (tap root) that grows vertically downwards. It produces **lateral** (secondary) and **tertiary roots**.
- **Adaptation:** Well-suited for deep water and nutrient access, and strong anchorage.
- **Examples:**
    1. **Dicot Trees: Mango** (Aam), **Sheesham** (Shisham or Tahli), **Neem**, **Gulmohar** – all have strong, deep taproots.
    2. **Dicot Crops: Chickpea** (Channa), **Mustard** (Sarson), **Cotton** (Kapas), **Sunflower** – typical taproot systems.
    3. **Vegetables: Carrot**, **Radish** (Mooli), **Turnip** (Shaljam) – these are **modified taproots for storage**.

B. Adventitious Root System

- **Origin:** Develops from any part **other than the radicle** (e.g., stem nodes, leaves).
- **Structure:** No single dominant root. A cluster of **fibrous roots** of more or less equal size arises from the base of the stem.
- **Adaptation:** Efficient in holding topsoil, preventing erosion; common in monocots.
- **Examples:**
    1. **Staple Cereals (Monocots): Wheat** (Gandum), **Rice** (Chawal), **Maize** (Makai), **Sugarcane** (Ganna).
    2. **Lawn Grasses: Bermuda grass** (Khabbal), a common turf grass in .
    3. **Others: Onion** (Piyaz), **Garlic** (Lehsan).

4. Morphological Regions of a Young Root (From Apex Upwards):

- **Root Cap:** Protective, thimble-like structure covering the apex.
- **Region of Meristematic Activity:** A few mm behind the cap; cells are small, thin-walled, and actively dividing.
- **Region of Elongation:** Cells elongate rapidly, causing the root to lengthen.
- **Region of Maturation/Root Hair Zone:** Cells differentiate, and **root hairs** (unicellular, tubular outgrowths of epidermal cells) develop. This is the **primary site for water absorption**.

		arvensis (Field Bindweed): Sagittate/hastate base.

Application in Identification: To describe a leaf systematically, follow this sequence:
1. Complexity (Simple/Compound) → **2. Arrangement** (Phyllotaxy) → **3. Shape** → **4. Margin** → **5. Apex** → **6. Base** → **7. Venation** → **8. Surface** → **9. Petiole**.
Example for Neem: **Leaf:** Alternate, imparipinnately compound. **Leaflets:** Lanceolate, serrate margin, acuminate apex, oblique base, reticulate venation, glabrous surface.

Morphological Characters of Flowers

The flower is the **reproductive shoot** of angiosperms, a modified determinate branch (apical meristem ceases growth) bearing sporophylls (floral leaves) arranged on a condensed axis (thalamus). It is the site of sexual reproduction, culminating in fruit and seed formation.

1. PARTS OF A TYPICAL, COMPLETE, BISEXUAL FLOWER

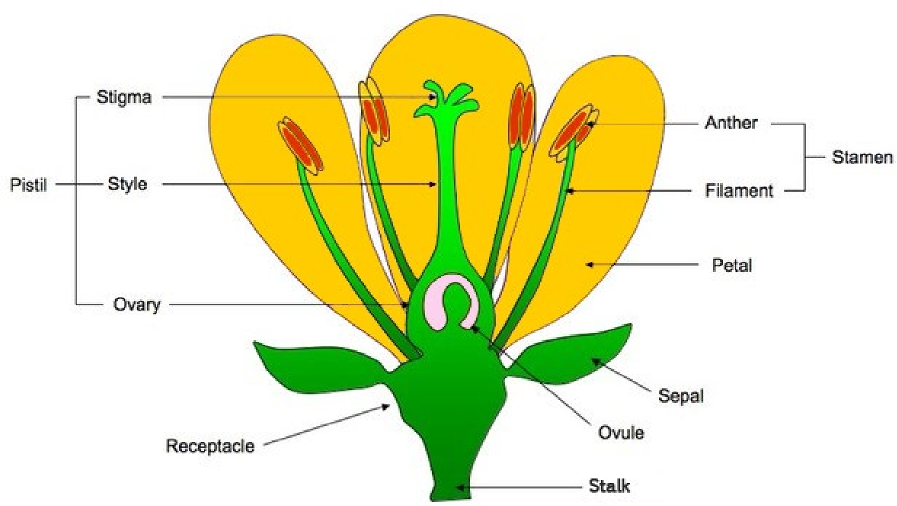
A complete flower has four whorls arranged concentrically on the thalamus.

A. Non-Essential/Accessory Whorls (Not directly involved in reproduction)

1. **Calyx:** The outermost whorl, composed of **sepals**. Usually green and protective in bud stage.
    - **Gamosepalous:** Sepals united (e.g., Cotton, Gudhal).
    - **Polysepalous:** Sepals free (e.g., Mustard, Sarson).
2. **Corolla:** Inner to calyx, composed of **petals**. Often colorful, fragrant, and attracts pollinators.
    - **Gamopetalous/Sympetalous:** Petals united (e.g., Tobacco, Potato).
    - **Polypetalous:** Petals free (e.g., Rose, Mango).

B. Essential/Reproductive Whorls

3. **Androecium:** The male reproductive unit, composed of **stamens**. Each stamen has:
    - **Filament:** The stalk.
    - **Anther:** The bilobed, pollen-bearing terminal part. The connective tissue joins the lobes.
    - **Example: Hibiscus** (Gudhal) has a prominent staminal tube with numerous stamens.
4. **Gynoecium/Pistil:** The female reproductive unit, composed of one or more **carpels**. Each carpel has:
    - **Ovary:** The swollen basal part containing **ovules**.
    - **Style:** The elongated neck.
    - **Stigma:** The receptive, often sticky or feathery tip for pollen germination.
    - **Example: Citrus** (Kino) has a multicarpellary, syncarpous ovary.



Floral Formula & Diagram are symbolic representations of flower structure, showing symmetry, whorl numbers, fusion, ovary position, etc.

B. Rice
C. Maize
D. Mustard
Correct Answer=D
5. Adventitious roots develop from:
A. Radicle
B. Stem nodes
C. Root apex
D. Root hairs
Correct Answer=B
6. The region of the root responsible for water absorption is:
A. Root cap
B. Region of elongation
C. Region of maturation
D. Meristematic region
Correct Answer=C
7. Which of the following is a modified taproot for storage?
A. Sweet potato
B. Ginger
C. Carrot
D. Potato
Correct Answer=C
8. Prop roots are found in:
A. Maize
B. Banyan tree
C. Mangroves
D. Orchids
Correct Answer=B
9. Pneumatophores are found in:
A. Deserts
B. Mangroves
C. Alpine regions
D. Grasslands
Correct Answer=B
10. Velamen tissue is present in roots of:
A. Parasitic plants
B. Epiphytic plants
C. Legumes
D. Cereals
Correct Answer=B
11. The stem develops from the:
A. Radicle
B. Plumule
C. Cotyledon
D. Endosperm
Correct Answer=B
12. Which of the following is present in stems but absent in roots?
A. Root cap
B. Nodes and internodes
C. Root hairs
D. Endogenous branching
Correct Answer=B
13. Lenticels are meant for:
A. Photosynthesis
B. Gaseous exchange
C. Water absorption
D. Food storage
Correct Answer=B
14. A stem that is herbaceous at the top and woody at the base is called:
A. Herbaceous
B. Woody
C. Suffrutescent
D. Culm
Correct Answer=C
15. Caudex is a type of:
A. Underground stem
B. Reduced aerial stem
C. Weak stem
D. Erect stem
Correct Answer=B
16. Which of the following is a culm?
A. Sugarcane
B. Mango
C. Rose
D. Cotton
Correct Answer=A
17. Tendril climbers use which structure for support?
A. Prickles
B. Twining stems
C. Coiled sensitive structures
D. Adventitious roots
Correct Answer=C
18. Which of the following is a root climber?
A. Grapevine
B. Money plant
C. Bean
D. Rose
Correct Answer=B
19. A stem that trails but does not root at nodes is called:
A. Runner
B. Stolon

Chapter 10

Plant Families

Family Ranunculaceae (Buttercup Family)

Order: Ranunculales
Family: Ranunculaceae

1. Diagnostic Characters (Morphological & Phytographical)

Vegetative Characters:

1. **Habit:** Mostly **herbaceous annuals or perennials**, rarely shrubs or climbers (e.g., Clematis).
2. **Root System:** Taproot system, sometimes tuberous (e.g., Ranunculus spp.) or rhizomatous (e.g., Caltha).
3. **Stem:** Erect, climbing, or prostrate; hollow or solid; often with **distinct nodes**.
4. **Leaves: Alternate** (rarely opposite, e.g., Clematis). **Simple to compound** (palmately or pinnately divided). **Exstipulate** but sometimes with sheathing leaf bases. Venation: Reticulate.

Floral Characters:

1. **Inflorescence:** Solitary terminal or axillary flowers, sometimes in **racemes**, **cymes**, or panicles.
2. **Flower: Actinomorphic** (radially symmetrical) or **zygomorphic** (e.g., Delphinium, Aconitum). **Bisexual** (rarely unisexual). **Hypogynous** (all floral parts inserted below the ovary).
3. **Perianth: Sepals:** 3–6, often petaloid, caducous (fall early). In some genera (e.g., Ranunculus) petals replaced by nectar-secreting structures. **Petals:** 3–many or absent; often with **nectaries** at base.
4. **Androecium:** Stamens indefinite (numerous), spirally arranged.
5. **Gynoecium: Apocarpous** (multiple free carpels), superior ovary. Carpels 1 to many. Placentation: Marginal.
6. **Fruit: Aggregate of achenes** (most common), follicles (e.g., Aconitum), or berries.
7. **Seed:** Small with copious endosperm.

2. Floral Formula

- **General Formula:**
  ♀/♂ ⚥ K3–6 C3–∞ A∞ G1–∞
- **For Ranunculus:**
  ⚥ K5 C5 A∞ G∞
- **For Delphinium (zygomorphic):**
  ⚥ K5 C4 A∞ G3–5

FLORAL DIAGRAM

4. Economic Importance

A. Ornamental Plants:

1. **Ranunculus** (Buttercup): Cultivated for bright flowers.
2. **Delphinium** (Larkspur): Popular in gardens and floral arrangements.
3. **Clematis** (Virgin's Bower): Climbers with showy flowers.
4. **Anemone** (Windflower): Grown for decorative purposes.

B. Medicinal Uses:

1. **Aconitum napellus** (Monkshood): Source of **aconite**—used in pain relief but highly toxic.
2. **Ranunculus spp.**: Poultice for joint pain in traditional medicine.

C. Poisonous Plants:

- Many species contain **ranunculin** (converts to protoanemonin, a blistering agent).
- **Aconitum** and **Delphinium** contain **alkaloids** (neurotoxic).

D. Cultural/Religious Significance:

- **Delphinium brunonianum** (Himalayan Larkspur): Used in local rituals in Gilgit-Baltistan.

Order: Malpighiales
Family: Euphorbiaceae
1. Diagnostic Characters (Morphological & Phytographical)
Vegetative Characters:

1. **Habit:** Extremely diverse - **herbs** (Euphorbia hirta), **shrubs** (Jatropha), **trees** (Hevea), **succulents** (cactus-like Euphorbias), and **vines**
2. **Latex:** Most species contain **white or colored latex** (milky sap) in specialized laticifers
3. **Stem:** Variable; succulents often have **photosynthetic stems**; some with **phylloclades** (flattened stem segments)
4. **Leaves:**
    - Usually **alternate**, sometimes opposite or whorled, **Simple** (rarely compound), **Stipulate** (stipules often modified into spines or glands), Leaves may be reduced or absent in succulents. Often with **glands** at base or on margin

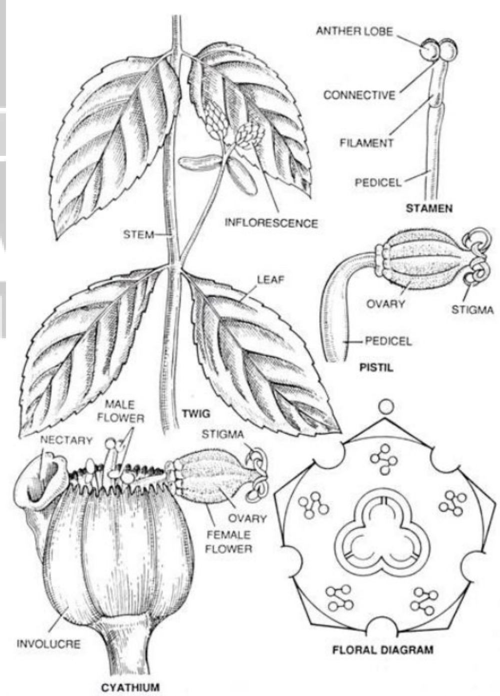
Floral Characters:

1. **Inflorescence:** Highly specialized:
    - **Cyathium** in Euphorbia (unique pseudanthium resembling a single flower)
    - Raceme, spike, panicle, or cyme in other genera
2. **Flower:**
    - **Unisexual** (monoecious or dioecious), extremely reduced
    - **Actinomorphic**
    - **Hypogynous**
    - Often **naked** (without perianth) or with small perianth
3. **Male Flower:**
    - Single stamen or few stamens, Often with jointed filament, Perianth reduced or absent
4. **Female Flower:**
    - Tricarpellary, syncarpous, superior ovary, Usually 3 styles, each often bifid, **Axile placentation**, Ovules 1-2 per locule
5. **Fruit: Regma** (schizocarpic capsule) splitting into 3 cocci (mericarps), sometimes drupe or berry
6. **Seed:** Often with **caruncle** (fleshy outgrowth near hilum); endosperm present; embryo straight

2. Floral Formula

- **General Formula for unisexual flowers:**
    - **Male:** ♂ P0-5 A1-∞
    - **Female:** ♀ P0-5 G(3)
- **For Euphorbia (Cyathium):** Represented as pseudanthium with multiple male flowers surrounding one female flower
- **For Ricinus:** ♂ K3-5 C0 A∞ and ♀ K3-5 C0 G(3)

3. Floral Diagram

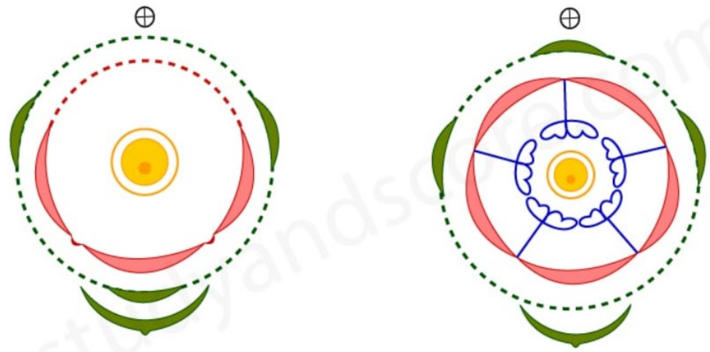


4. Economic Importance
A. Food & Nutrition:

1. **Cassava/Tapioca:** Manihot esculenta - Major staple in tropics (must be processed to remove cyanide)
2. **Vegetable:** Sauropus androgynus (Sweet leaf bush) - Leafy vegetable in Southeast Asia

B. Oilseed Crops:

1. **Castor Bean:** Ricinus communis - Castor oil (industrial lubricant, medicinal)



Floral Diagram of Ray floret

Floral formula: Br % ♀ $K_{(2\text{-}3)\,(pappus)}$ $C_{(3\text{-}5)}$ A_0 $\overline{G}_{(2)}$

Floral Diagram of Disc floret

Floral formula: Br ⊕ ⚥ $K_{2\text{-}3\,(pappus)}$ $C_{(5)}$ A_5 $\overline{G}_{(2)}$

4. Economic Importance

A. Food Crops:

1. **Leafy Vegetables:**
    - Lactuca sativa (Lettuce)
    - Cichorium endivia (Endive)
    - Cichorium intybus (Chicory)
2. **Root Vegetables:**
    - Helianthus tuberosus (Jerusalem artichoke)
    - Scorzonera hispanica (Black salsify)
3. **Oilseeds:**
    - Helianthus annuus (Sunflower) - Major oilseed crop
    - Carthamus tinctorius (Safflower) - Oil and dye
4. **Edible Seeds:**
    - Cynara scolymus (Artichoke) - Flower heads
    - Tragopogon porrifolius (Salsify) - Roots

B. Medicinal Plants:

1. Artemisia annua (Sweet wormwood) - Source of artemisinin (malaria treatment)
2. Calendula officinalis (Marigold) - Wound healing, anti-inflammatory
3. Echinacea purpurea (Coneflower) - Immune system stimulant
4. Matricaria chamomilla (Chamomile) - Sedative, digestive aid
5. Taraxacum officinale (Dandelion) - Diuretic, liver tonic
6. Silybum marianum (Milk thistle) - Liver protection

C. Ornamental Plants:

1. **Cut Flowers:**
    - Chrysanthemum spp. (Chrysanthemums)
    - Dahlia spp. (Dahlias)
    - Gerbera jamesonii (Gerbera daisy)
    - Zinnia elegans (Zinnia)
2. **Garden Plants:**
    - Aster spp. (Michaelmas daisies)
    - Rudbeckia hirta (Black-eyed Susan)
    - Coreopsis spp. (Tickseed)
    - Gaillardia spp. (Blanket flower)

D. Industrial Uses:

1. **Insecticides:** Pyrethrum from Tanacetum cinerariifolium
2. **Rubber:** Parthenium argentatum (Guayule) - Rubber source

Fruit Type	Utricle/Achene	Pepo	Berry/Capsule	Schizocarp (4 nutlets)	Cypsela	Schizocarp (2 mericarps)	Capsule/ Berry	Caryopsis (grain)
Special Features	Mealy covering, bladder hairs	Tendrils, pepo fruit	Oblique septum	Square stem, gynobasic style	Composite head, pappus	Sheathing leaf base, stylopodium	Bulbs/rhizomes, showy flowers	Spikelets with glumes/lemmas

Plant Families: - MCQs

Family: Fabaceae (Leguminosae)

1. The floral formula % K(5) C1+2+(2) A(9)+1 G1 is characteristic of which family?
A. Solanaceae
B. Fabaceae
C. Liliaceae
D. Brassicaceae
Correct Answer= B

2. Which of the following is a diagnostic feature of the subfamily Papilionoideae (Faboideae) of Fabaceae?
A. Zygomorphic flower with vexillum, alae, and carina
B. Actinomorphic flower
C. Flowers in hypanthodium
D. Epigynous flower
Correct Answer= A

3. The fruit in Fabaceae is typically a:
A. Capsule
B. Siliqua
C. Legume or pod
D. Caryopsis
Correct Answer= C

4. Which of these is a major pulse crop obtained from Fabaceae?
A. Triticum aestivum
B. Cajanus cajan (Pigeon pea)
C. Oryza sativa
D. Zea mays
Correct Answer= B

5. The root nodules of Fabaceae plants contain bacteria that help in:
A. Phosphate solubilization
B. Nitrogen fixation
C. Potassium uptake
D. Cellulose degradation
Correct Answer= B

Family: Solanaceae

6. The floral formula K(5) C(5) A5 G(2) is representative of:
A. Brassicaceae
B. Solanaceae
C. Malvaceae
D. Asteraceae
Correct Answer= B

7. A persistent calyx that remains attached to the fruit is a feature seen in many members of:
A. Fabaceae
B. Poaceae
C. Solanaceae
D. Liliaceae
Correct Answer= C

8. Which of the following is a fruit type characteristic of Solanaceae?
A. Legume
B. Siliqua
C. Berry or Capsule
D. Cypsela
Correct Answer= C

9. Which of these economically important plants belongs to Solanaceae?
A. Potato (*Solanum tuberosum*)
B. Pea (*Pisum sativum*)
C. Rice (*Oryza sativa*)
D. Cotton (*Gossypium*)
Correct Answer= A

10. Which of the following is a deadly poisonous plant from Solanaceae, also used medicinally in minute doses?
A. *Mentha*
B. *Datura stramonium*
C. *Catharanthus*
D. *Azadirachta*
Correct Answer= B

Family: Liliaceae

Chapter 11

Plant Anatomy

Plant Cell Wall: Structure and Chemical Composition

The plant cell wall is a **highly ordered, dynamic extracellular composite material**. It is not an inert shell but a metabolically active **apoplastic compartment** that defines cell shape, mediates growth, and integrates environmental signals.

Primary vs. Secondary Wall

- **Primary Cell Wall (PCW):**
  - **When:** Deposited during cell growth and expansion.
  - **State:** Relatively thin, hydrated, and **plastic/extensible**.
  - **Function:** Governs directional growth, cell-cell adhesion, and defense signaling.
  - **Presence:** In all plant cells. Some cells (e.g., parenchyma) possess only a PCW.
- **Secondary Cell Wall (SCW):**
  - **When:** Deposited **inside** the PCW **after** cell expansion has ceased.
  - **State:** Thick, layered, and often **rigid and hydrophobic** due to lignification.
  - **Function:** Provides mechanical strength, hydrophobicity for water transport, and decay resistance.
  - **Presence:** Specialized cells only (e.g., tracheary elements, fibers, sclereids).

MACRO-ARCHITECTURE: THE LAYERED STRUCTURE

A. The Middle Lamella (ML)

- **Position:** The outermost layer, **shared between** adjacent cell walls.
- **Nature:** A gel-like, pectin-rich matrix.
- **Primary Composition:** Predominantly **Calcium-Pectate** (gels of de-esterified homogalacturonan cross-linked by Ca^{2+} ions).
- **Function:** Acts as an **intercellular cement**, binding neighboring cells together. The first line of defense against pathogen ingress; pectin-degrading enzymes cause tissue maceration.

B. The Primary Cell Wall (PCW)

- **Position:** Deposited between the plasma membrane and the middle lamella.
- **Architectural Model:**
  1. **Tethered Network Model (Classic Model for Dicots & Non-Grass Monocots):**
     - Cellulose microfibrils form a scaffold.
     - They are **covalently cross-linked** by hemicellulosic tethers (mainly xyloglucan).
     - This cellulose-hemicellulose network is embedded in a **pectin gel matrix**.
  2. **Grass Model (Poaceae):**
     - **Cellulose microfibrils** are cross-linked primarily by **glucuronoarabinoxylans (GAX)**.
     - **Mixed-Linkage Glucans (MLGs)** are abundant during rapid growth but decrease upon maturation.
     - **Pectin content is significantly lower**, and structural proteins differ (more hydroxycinnamic acids like ferulic acid).

C. The Secondary Cell Wall (SCW)

- **Position:** Internal to the primary wall. Often has three distinct sub-layers (S1, S2, S3) with differing microfibril orientations for maximum tensile strength.
- **Key Feature: Lignification** – the impregnation of the polysaccharide matrix with the phenolic polymer **lignin**.
- **Composition Shift:** Dramatic increase in **cellulose** content (up to 50%), high hemicellulose (xylan or mannan), and lignin. Pectins and structural proteins are minimal or absent.

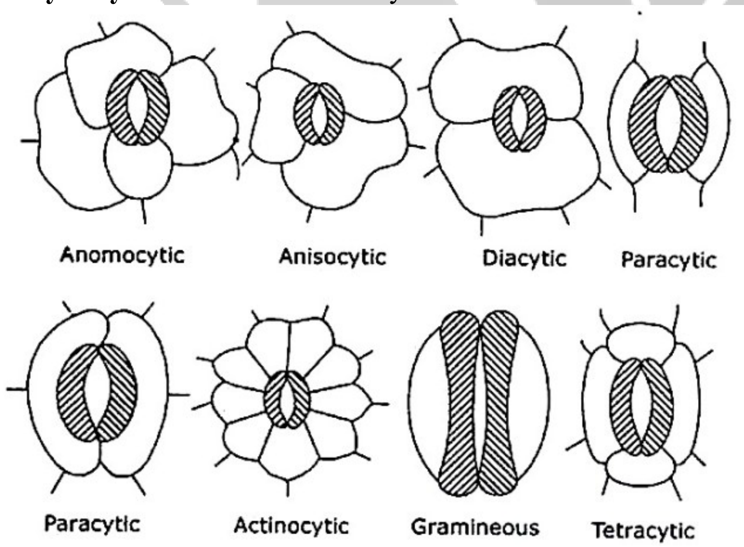
3. K^+ influx via K^+ in channels
4. Malate^{2-} synthesis from starch (via PEP carboxylase)
5. Cl^- uptake via H^+/Cl^- symport
6. Osmotic potential decreases → water influx → turgor increase → pore opens

- **Closing Sequence (ABA Pathway):**
  1. ABA binds to receptors
  2. Inhibits PP2Cs → activates SnRK2s
  3. Phosphorylation of ion channels
  4. Ca^{2+} influx
  5. Activation of anion channels → depolarization
  6. K^+ efflux via GORK
  7. Osmotic potential increases → water efflux → turgor decrease → pore closes

C. Stomatal Classification Systems

1. Based on Subsidiary Cell Arrangement (Metcalfe & Chalk)

- **Anomocytic (Ranunculaceous):** No subsidiary cells (e.g., Ranunculus)
- **Anisocytic (Cruciferous):** 3 unequal subsidiary cells (e.g., Brassica)
- **Paracytic (Rubiaceous):** 2 parallel subsidiary cells (e.g., Rubiaceae)
- **Diacytic (Caryophyllaceous):** 2 perpendicular subsidiary cells (e.g., Caryophyllaceae)
- **Actinocytic:** Radiating subsidiary cells
- **Cyclocytic:** Circle of subsidiary cells



TRICHOMES

Morphogenesis

- **Tip growth** (root hair-like) for unicellular trichomes
- **Controlled cell division planes** for multicellular types
- **Cytoskeletal control:** Microtubules determine branching patterns

Classification

1. Non-Glandular (Protective) Trichomes

- **Unicellular:**
  - Simple (linear): Cotton fibers (up to 5 cm!)
  - Branched: Star-shaped (stellate) in *Quercus*
- **Multicellular:**
  - Unbranched: 2-8 cells in row
  - Branched:

- **Pollination-induced:** Pollen tube growth provides hormones without fertilization (e.g., some orchids).
- **Hormone-induced:** Application of **auxins, gibberellins, or cytokinins** to the ovary/pistil can initiate fruit set. Common in tomatoes, cucumbers, and eggplants under protected cultivation.

- **Mechanism:** Fertilization normally provides hormones (especially auxin) that trigger ovary wall development into pericarp (fruit flesh). In parthenocarpy, the ovary either produces these hormones autonomously or receives them from an external source (pollen tube, applied hormones).

Plant Anatomy: - MCQs

Plant Cell Wall & Pits

1. The primary cell wall is characterized by being:
A. Thick, rigid, and lignified
B. Thin, hydrated, and extensible
C. Suberized and impermeable
D. Composed mainly of lignin
Correct Answer= B

2. Which component is the main structural framework of the cell wall?
A. Pectin
B. Hemicellulose
C. Cellulose
D. Lignin
Correct Answer= C

3. The middle lamella is primarily composed of:
A. Cellulose microfibrils
B. Calcium pectate
C. Lignin
D. Suberin
Correct Answer= B

4. In grasses (Poaceae), the primary cell wall cross-links are mainly formed by:
A. Xyloglucan
B. Glucuronoarabinoxylan (GAX)
C. Homogalacturonan
D. Extensin
Correct Answer= B

5. Lignin, a hydrophobic filler, is a characteristic component of the:
A. Primary cell wall
B. Middle lamella
C. Secondary cell wall
D. Plasma membrane
Correct Answer= C

6. The "egg-box" structure in the cell wall is formed by calcium bridging of:
A. Cellulose chains
B. De-esterified homogalacturonan
C. Xyloglucan molecules
D. Lignin polymers
Correct Answer= B

7. A pit is defined as a region where:
A. The secondary wall is thickened
B. Only the middle lamella is present
C. The secondary wall is absent, leaving the primary wall and middle lamella
D. The cell lumen is completely open to the adjacent cell
Correct Answer= C

8. A pit-pair where one side is bordered and the other is simple is called a:
A. Blind pit
B. Half-bordered pit
C. Compound pit
D. Scalariform pit
Correct Answer= B

9. The torus-margo membrane, an embolism safety mechanism, is characteristic of bordered pits in:
A. Angiosperm vessels
B. Conifer tracheids
C. Parenchyma cells
D. Phloem sieve tubes
Correct Answer= B

10. Pits that face an intercellular space rather than another cell are called:
A. Simple pits
B. Bordered pits
C. Blind pits
D. Alternate pits
Correct Answer= C

Plant Tissues: Meristems & Simple Tissues

11. Which meristem is responsible for the increase in length of roots and shoots?
A. Lateral meristem
B. Intercalary meristem

Chapter: 12

Cell Biology

Introduction

Cell biology (cytology) is the interdisciplinary study of cell structure, function, and behavior, integrating microscopy, biochemistry, genetics, and computational biology. The **cell** is the smallest unit capable of performing all activities associated with life and serves as the fundamental **structural and functional unit** of all living organisms. While the components of a cell cannot survive independently, the cell operates as an integrated system, and groups of cells form tissues, organs, and organisms, demonstrating biological complexity.

Cell Theory

The **Cell Theory** is the foundational principle of modern biology, formalized by **Matthias Schleiden** (1838), **Theodor Schwann** (1839), and **Rudolf Virchow** (1855). **August Weismann** later contributed the concept of common descent.

Salient Features of Modern Cell Theory:

- All living organisms are composed of one or more cells.
- The cell is the basic unit of structure, function, and organization in all organisms.
- All cells arise from pre-existing cells through cell division (**Principle of Biogenesis**).
- Cells contain hereditary material (DNA) passed from parent to daughter cells.
- All cells are fundamentally similar in chemical composition and core metabolic processes.
- The total activity of an organism is the sum of the activities of its independent cells.

Historical Development and Validation of Cell Theory

- **Robert Hooke (1665):** Coined the term "cell" after observing the honeycomb structure of dead cork tissue under a primitive microscope. He observed cell walls, not living content.
- **Anton van Leeuwenhoek (1670s):** First to observe and describe living, moving cells ("animalcules") like bacteria, protozoa, and spermatozoa using superior, self-made lenses.
- **Robert Brown (1831):** Discovered the **nucleus** within plant cells, identifying a constant internal structure.
- **Matthias Schleiden (1838) & Theodor Schwann (1839):** Formally proposed the Cell Theory. Schleiden concluded plants are composed of cells, and Schwann extended this to animals, stating cells are the universal building blocks of life.
- **Rudolf Virchow (1855):** Articulated **"Omnis cellula e cellula"** ("All cells come from cells"), refuting the theory of spontaneous generation for cellular life.
- **Louis Pasteur (1862):** Provided definitive experimental proof for biogenesis using his famous swan-neck flask experiment, demonstrating that microorganisms arise only from pre-existing ones.
- **August Weismann (1880):** Added that all living cells trace their ancestry back to ancient cells, establishing the principle of **common descent**, supported by universal biochemical similarities.

Advanced Microscopy: Principles and Techniques

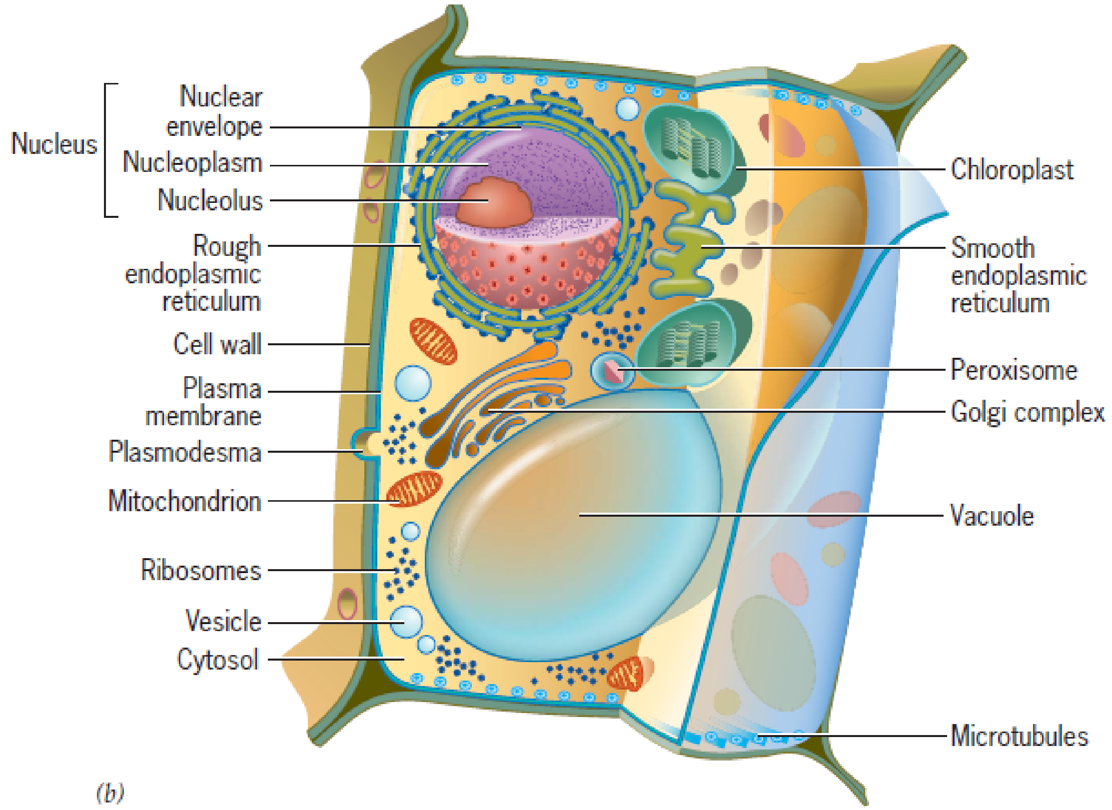
Microscopy overcomes the limited **resolution** of the human eye (~0.1 mm). **Resolution (Resolving Power)** is the minimum distance between two points that can be distinguished as separate. **Magnification** is the increase in an object's apparent size. High magnification without sufficient resolution results in empty magnification (a blurry, enlarged image).

Light Microscopy (LM)

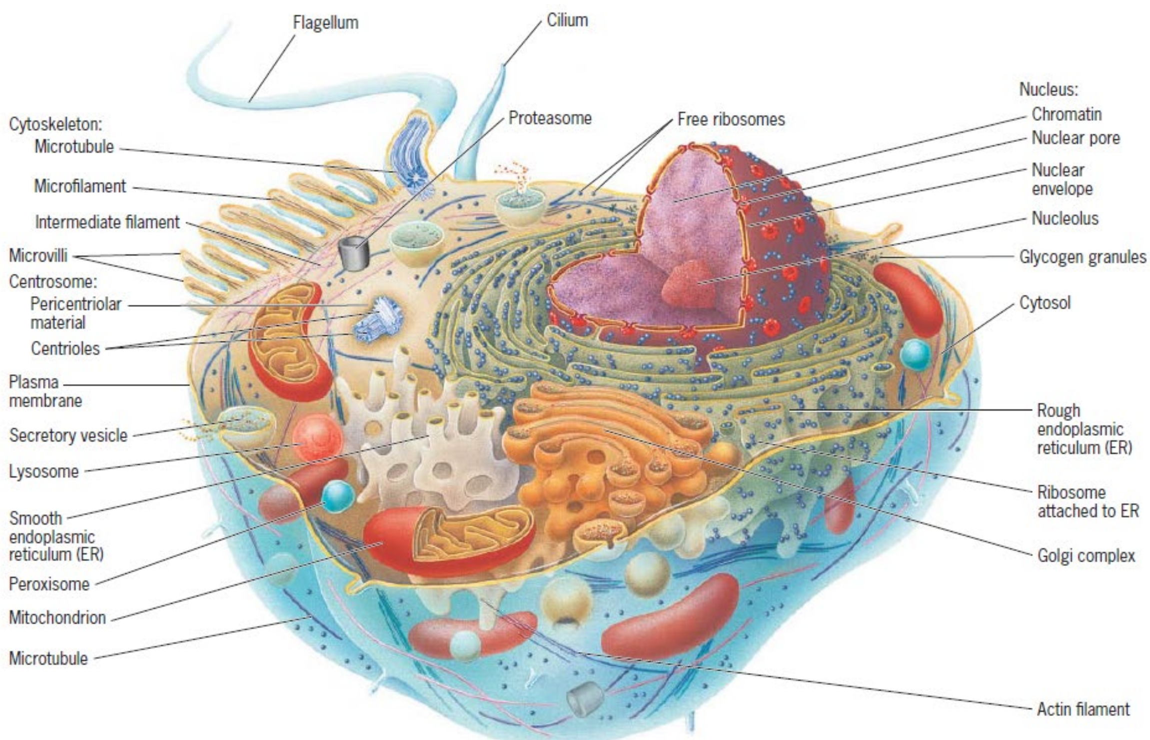
Utilizes visible light (400-700 nm wavelength) and a system of glass lenses.

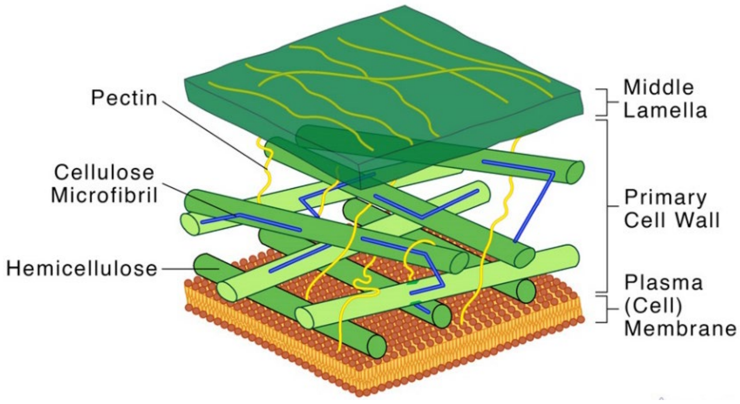
- **Maximum Theoretical Resolution:** ~200 nm (0.2 µm), limited by the wavelength of light (Abbe's Law).
- **Maximum Useful Magnification:** ~1000X to 1500X.
- **Key Techniques:**

Plant Cell



Animal Cell





Extracellular Matrix (ECM) of Animal Cells
A complex meshwork secreted by the cells.

- **Components: Collagen** (provides tensile strength), **Elastin** (elasticity), **Proteoglycans** (protein cores with long GAG chains; form a hydrated gel resisting compression), **Glycoproteins** (e.g., **Fibronectin**, Laminin - facilitate adhesion).
- **Integrins:** Transmembrane receptor proteins. Their extracellular domains bind to ECM components (e.g., fibronectin); their intracellular domains link to the **cytoskeleton** (via talin, vinculin) and signaling molecules. Mediate **mechanotransduction** (converting mechanical force into biochemical signals) and **outside-in/inside-out signaling**.

Comparison of Animal and Plant Cells
Animal vs. Plant Cell

Feature	Animal Cell	Plant Cell
Cell Wall	Absent	Present (Cellulose)
Plastids	Absent	Present (Chloroplasts, etc.)
Centrioles	Present	Absent
Vacuoles	Small, numerous	Single, large central vacuole
Lysosomes	Present	Usually absent
Shape	Irregular, round	Fixed, rectangular
Storage Product	Glycogen	Starch
Mode of Nutrition	Heterotrophic	Autotrophic (primarily)

CELL BIOLOGY MCQs

1. Which scientist first coined the term "cell" after observing cork under a microscope?
A) Anton van Leeuwenhoek
B) Robert Brown
C) Matthias Schleiden
D) Robert Hooke
Answer: Robert Hooke

2. The principle "Omnis cellula e cellula" (all cells come from cells) was proposed by:
A) Rudolf Virchow
B) Louis Pasteur
C) Theodor Schwann
D) August Weismann
Answer: Rudolf Virchow

3. Which of the following is NOT a tenet of modern cell theory?
A) All living organisms are composed of one or more cells.
B) All cells arise from pre-existing cells.
C) All cells contain a membrane-bound nucleus.
D) Cells contain hereditary material (DNA) passed to daughter cells.
Answer: All cells contain a membrane-bound nucleus.

4. The maximum theoretical resolution of a standard light microscope is approximately:
A) 0.2 nm
B) 200 nm
C) 2 µm
D) 0.2 mm
Answer: 200 nm

Chapter 13

Cell Cycle

Introduction to Cell Division

Cell division is the fundamental process where a parent cell divides into two or more daughter cells. Essential for:

- **Growth & Development**
- **Tissue Repair & Renewal**
- **Reproduction** (asexual & sexual)

Two main types in eukaryotes:

- **Mitosis:** Produces genetically identical somatic cells
- **Meiosis:** Produces genetically diverse gametes

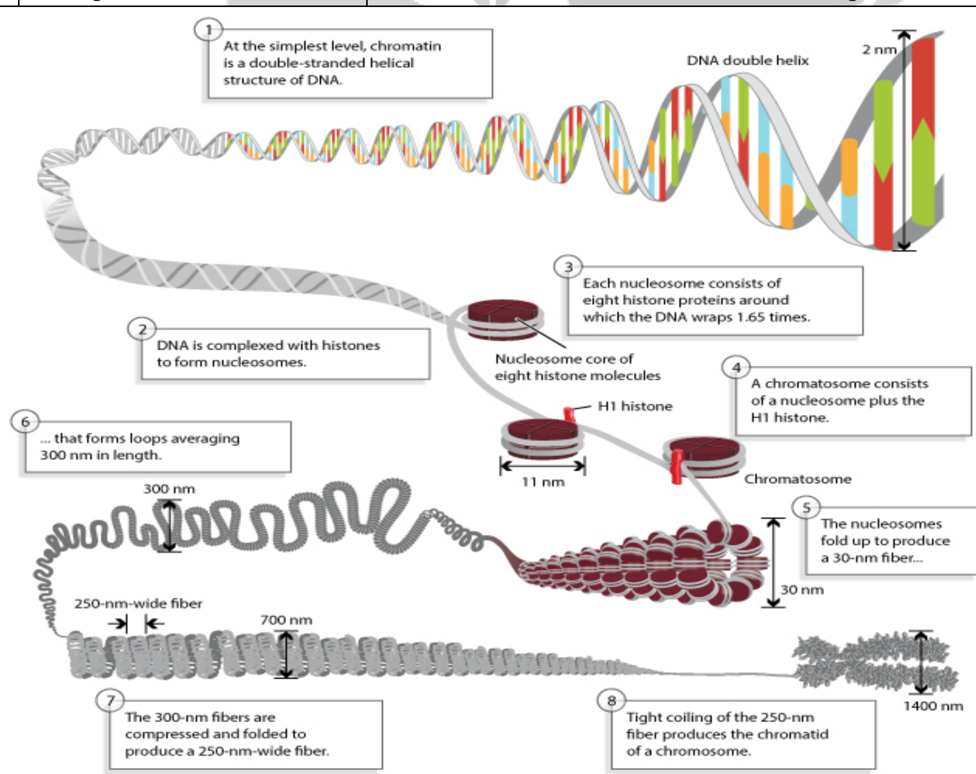
Eukaryotic Chromosome Structure & Packaging

Chromosome Composition

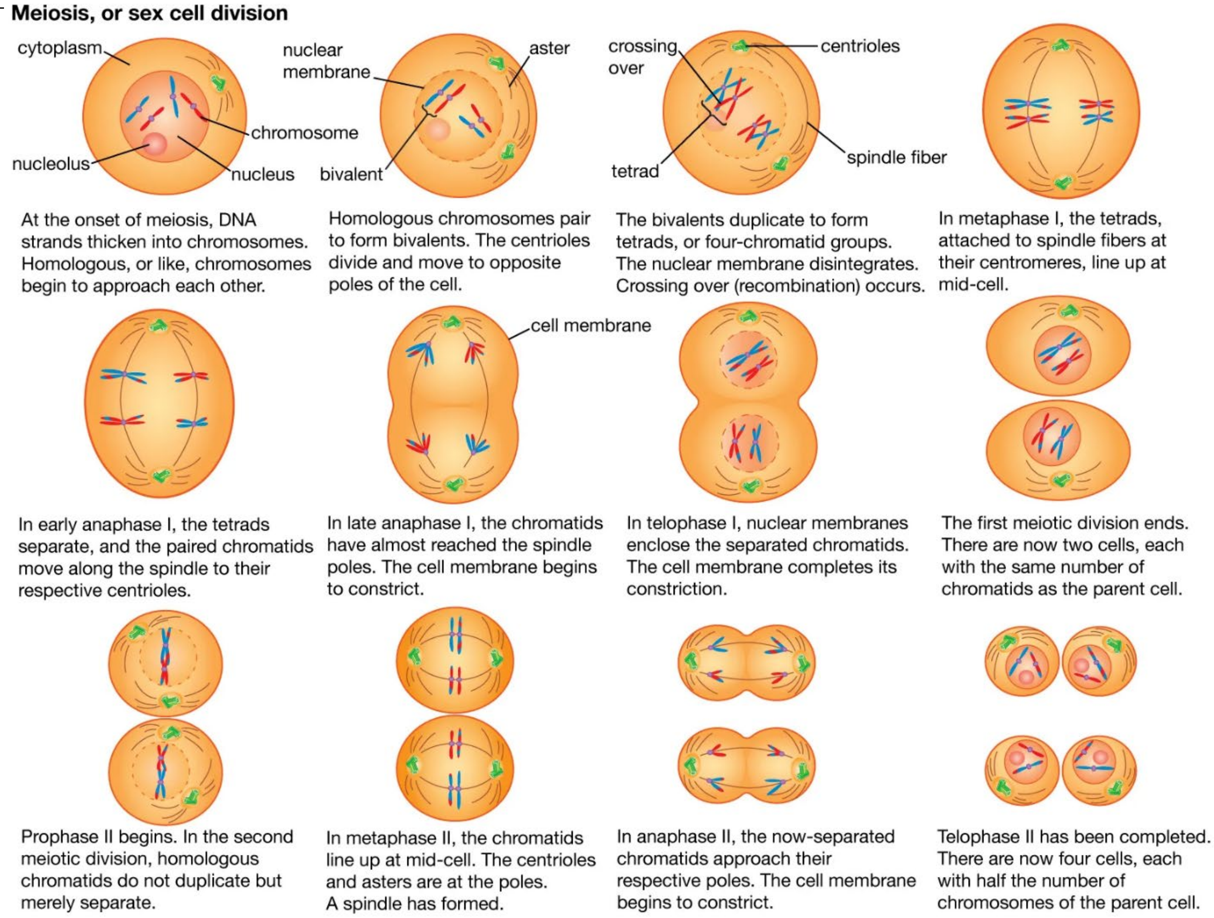
- Made of **chromatin** = DNA + proteins (histones & non-histones)
- **Histones** (H2A, H2B, H3, H4): Positively charged proteins for DNA wrapping
- **Non-histone proteins:** Structural & regulatory functions

Levels of Chromatin Packaging

Level	Structure	Description
1°	Nucleosome	146 bp DNA wrapped around histone octamer (2 each: H2A, H2B, H3, H4)
2°	30-nm Fiber	Nucleosomes packed with linker histone H1
3°	Looped Domains	30-nm fibers form loops attached to protein scaffold
4°	Metaphase Chromosome	Maximum condensation via **condensin** proteins



Chromosome Terminology



Regulation of Cell Division

Cell Cycle Checkpoints

Checkpoint	Location	Checks For	Key Proteins
G_1/S (Restriction)	Late G_1	Size, nutrients, GF, DNA damage	p53, Rb, CDKs
G_2/M	End G_2	Complete replication, DNA damage	CDK1/Cyclin B
Spindle Assembly	Metaphase	Chromosome attachment	Mad2, BubR1
Post-replication	S phase	Replication errors	ATR, Chk1

Molecular Regulators

Cyclin-CDK Complexes:

Complex	Cyclin	CDK	Function
G_1-CDK	Cyclin D	CDK4/6	Early G_1 progression
G_1/S-CDK	Cyclin E	CDK2	G_1/S transition
S-CDK	Cyclin A	CDK2	DNA replication initiation
M-CDK (MPF)	Cyclin B	CDK1	Mitotic entry & events

Comparison: Mitosis vs Meiosis

Aspect	Mitosis	Meiosis I	Meiosis II

A) G_1 phase
B) G_2 phase
C) M phase
D) S phase
Answer: S phase

3. Which protein forms a contractile ring during cytokinesis in animal cells?
A) Tubulin
B) Actin
C) Keratin
D) Collagen
Answer: Actin

4. What is the term for the paired maternal and paternal chromosomes that carry the same genes?
A) Sister chromatids
B) Homologous chromosomes
C) Sex chromosomes
D) Recombinant chromosomes
Answer: Homologous chromosomes

5. The point of constriction on a chromosome that holds sister chromatids together is called the:
A) Kinetochore
B) Telomere
C) Centromere
D) Centrosome
Answer: Centromere

6. Which of the following is a key feature of prophase I of meiosis that does NOT occur in mitosis?
A) Chromosome condensation
B) Breakdown of the nuclear envelope
C) Synapsis and crossing over
D) Formation of the mitotic spindle
Answer: Synapsis and crossing over

7. What is the haploid (n) number of chromosomes in a human somatic cell?
A) 23
B) 46
C) 92
D) 2
Answer: 23

8. The enzyme that adds DNA sequences to telomeres to counteract shortening is:
A) DNA polymerase
B) Telomerase
C) Ligase
D) Primase
Answer: Telomerase

9. Which checkpoint ensures that all chromosomes are properly attached to the spindle before anaphase?
A) G_1/S checkpoint
B) G_2/M checkpoint
C) Spindle assembly checkpoint
D) Post-replication checkpoint
Answer: Spindle assembly checkpoint

10. What is the correct order of the mitotic phases?
A) Prophase, Metaphase, Anaphase, Telophase, Prometaphase
B) Prophase, Prometaphase, Metaphase, Anaphase, Telophase
C) Interphase, Prophase, Metaphase, Anaphase, Telophase
D) Prophase, Anaphase, Metaphase, Telophase, Cytokinesis
Answer: Prophase, Prometaphase, Metaphase, Anaphase, Telophase

11. Binary fission in bacteria is most similar to which eukaryotic process?
A) Mitosis
B) Meiosis I
C) Meiosis II
D) Cytokinesis
Answer: Mitosis

12. Which protein complex holds sister chromatids together after DNA replication?
A) Condensin
B) Cohesin
C) Kinetochore
D) Securin
Answer: Cohesin

13. What is the primary source of genetic variation during meiosis?
A) DNA replication
B) Cytokinesis
C) Independent assortment and crossing over
D) Mitotic spindle formation
Answer: Independent assortment and crossing over

14. A cell that has completed mitosis but not cytokinesis would contain:
A) One nucleus with half the chromosomes
B) Two nuclei within a single cell
C) Four haploid nuclei
D) No nucleus
Answer: Two nuclei within a single cell

Chapter 14

Classical Genetics

Introduction to Genetics

- **Genetics** is the scientific study of **heredity** (transmission of traits from parents to offspring) and **variation** (differences among individuals).
- **Inheritance**, the process encompassing both heredity and variation, is crucial for evolution and speciation.
- Since **genes** control heredity and variation, genetics is fundamentally the study of genes.
- **Molecular Basis:** A gene is a specific DNA sequence that codes for a polypeptide via **transcription** (DNA to mRNA in nucleus) and **translation** (mRNA to protein at ribosome).

Fundamental Genetic Concepts

- **Gene** – Basic unit of heredity; a segment of DNA coding for a polypeptide/trait. *(Example: The gene for flower color in peas.)*
- **Allele** – Alternative form of a gene at the same locus. *(Example: The alleles for purple (P) or white (p) flowers.)*
- **Locus** – Specific position of a gene on a chromosome.
- **Genotype** – Genetic makeup of an individual. *(Example: PP, Pp, or pp.)*
- **Phenotype** – Observable expression of a trait. *(Example: Purple or white flowers.)*
- **Homozygous** – Having two identical alleles for a gene. *(Example: PP or pp.)*
- **Heterozygous** – Having two different alleles for a gene. *(Example: Pp.)*
- **Hemizygous** – Having only one allele for a gene (e.g., X-linked genes in males).
- **Wild type** – Most common phenotype in natural populations.
- **Mutant phenotype** – Trait alternative to wild type.
- **Gene Pool** – All alleles present in a breeding population at a given time.

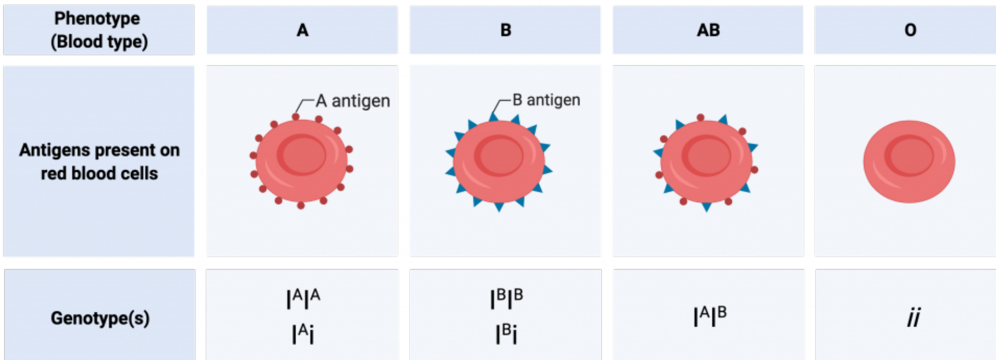
Mendelian Principles & Crosses

- **Law of Segregation (Principle of Segregation)** – Alleles separate during gamete formation. *(Mendel's pea plant experiments.)*
- **Law of Independent Assortment** – Genes for different traits assort independently during gamete formation.
- **P generation** – Parental generation.
- **F_1 generation** – First filial generation.
- **F_2 generation** – Second filial generation.
- **True-breeding (Pure breeding)** – Organisms that produce identical offspring when self-fertilized.
- **Monohybrid cross** – Cross involving one trait. *(Example: Crossing pure-breeding tall and dwarf pea plants.)*
- **Dihybrid cross** – Cross involving two traits. *(Example: Crossing plants differing in seed shape and color.)*
- **Testcross** – Cross between an individual with unknown genotype and a homozygous recessive individual.

Extensions to Mendelian Genetics

- **Complete Dominance** – One allele completely masks the other. *(Example: Mendel's pea traits.)*
- **Incomplete dominance** – Heterozygote shows an intermediate phenotype. *(Example: Pink flowers from red and white snapdragons.)*
- **Codominance** – Both alleles are fully expressed in the heterozygote. *(Example: AB blood type; speckled chicken feathers.)*

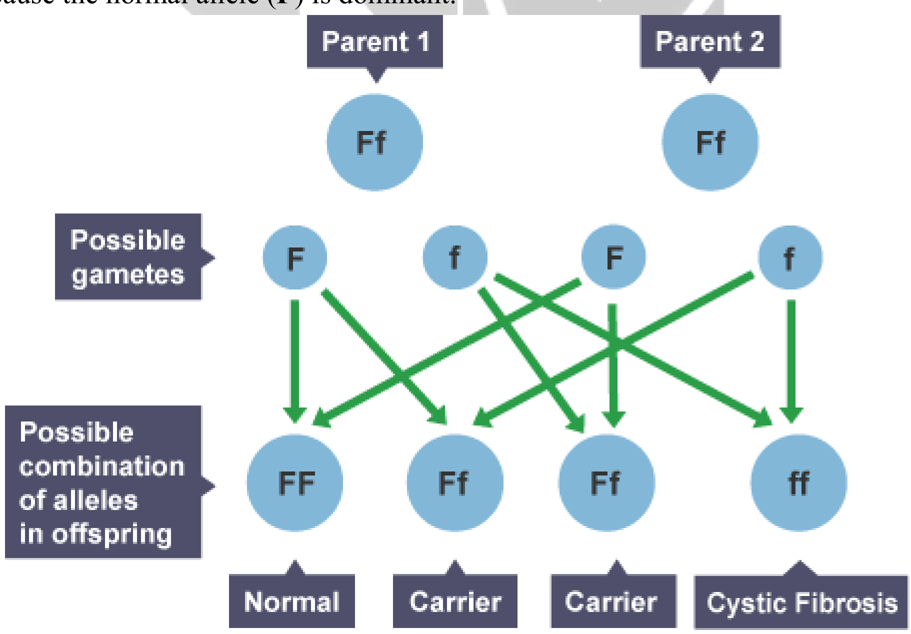
- **Example**: In human blood type inheritance, the A (I^A) and B (I^B) alleles are co-dominant. If a person inherits one A allele and one B allele (I^A I^B), both A and B antigens will be present on the surface of red blood cells, resulting in **AB blood type**.
- **Genotypic Ratio**: 1 I^A I^A : 2 I^A I^B : 1 I^B I^B
- **Phenotypic Ratio**: AB : AA : BB



d) Recessive Alleles

In **recessive inheritance**, the recessive allele only manifests its trait when an individual inherits two copies of it (homozygous recessive). If only one copy of the recessive allele is present (heterozygous), the dominant allele will express its trait, and the recessive allele will be masked.

- **Example**: In humans, cystic fibrosis is caused by a recessive allele (f). A person with the genotype **ff** will have cystic fibrosis, while individuals with **Ff** or **FF** will not show the disease because the normal allele (**F**) is dominant.



e) Multiple Alleles

Some traits are controlled by **multiple alleles**, more than the typical two alleles (one from each parent). Multiple alleles can exhibit a variety of dominance relationships, including complete dominance, incomplete dominance, or co-dominance.

Primary Cause	**Autoimmune destruction** of pancreatic β-cells → absolute insulin deficiency.	**Insulin resistance** in peripheral tissues + relative insulin deficiency.
Genetic Basis	**Polygenic susceptibility.** Strong association with **HLA class II genes** (esp. DR3/DR4). Environmental triggers (e.g., viruses).	**Strong polygenic & multifactorial basis.** Multiple genes involved in insulin secretion, action, obesity. Major environmental factors (obesity, sedentary lifestyle).
Inheritance Pattern	Complex; increased risk in siblings (5-10%).	Complex; stronger familial clustering.
Special Subtype	-	**MODY (Maturity Onset Diabetes of the Young):** Monogenic, autosomal dominant form with early onset.

Classical Genetics: - Practice MCQs

1. **What is the basic unit of heredity that codes for a functional product like a protein?**
A) Allele
B) Locus
C) Gene
D) Chromosome
Answer: Gene
2. **The specific physical location of a gene on a chromosome is called its:**
A) Allele
B) Genome
C) Locus
D) Phenotype
Answer: Locus
3. **Alternative forms of the same gene that occupy corresponding loci on homologous chromosomes are known as:**
A) Genotypes
B) Phenotypes
C) Alleles
D) Linkage groups
Answer: Alleles
4. **The complete set of all alleles present in all individuals of a breeding population at a given time is the:**
A) Genome
B) Karyotype
C) Gene pool
D) Genotype frequency
Answer: Gene pool
5. **The genetic constitution of an organism for a particular trait is its:**
A) Phenotype
B) Allele
C) Genotype
D) Karyotype
Answer: Genotype
6. **The observable characteristics resulting from genotype and environment define the:**
A) Genotype
B) Allele
C) Phenotype
D) Locus
Answer: Phenotype
7. **An individual with two identical alleles at a given locus is said to be:**
A) Heterozygous
B) Hemizygous
C) Homozygous
D) Homogametic
Answer: Homozygous
8. **An allele that expresses its phenotypic effect even in a heterozygous state is termed:**
A) Recessive
B) Codominant
C) Dominant

Chapter 15

Molecular Genetics

Nucleic Acids: Fundamental Units of Heredity

- **Nucleic acids** are linear, unbranched polymers of nucleotides that serve as the primary information-carrying molecules in all living organisms and viruses.
- They constitute the **chemical basis of heredity** and direct cellular metabolism.
- **Historical Perspective:** Initially, proteins were favored as genetic material due to their chemical complexity. The series of key experiments established DNA as the universal genetic material.

Landmark Experiments Proving DNA as Genetic Material

Experiment (Year)	Scientists	Key Organism/System	Method & Findings	Conclusion
Transformation (1928)	Frederick Griffith	*Streptococcus pneumoniae* strains (S-virulent, R-avirulent)	Heat-killed S + live R → mice died; live S recovered.	A **"transforming principle"** transferred genetic traits.
Identification of Transforming Principle (1944)	Oswald Avery, Colin MacLeod, Maclyn McCarty	*S. pneumoniae*	Purified components; only DNA fraction caused transformation; DNase destroyed activity.	**DNA is the transforming substance and hereditary material** in bacteria.
Hershey-Chase (1952)	Alfred Hershey, Martha Chase	Bacteriophage T2 & *E. coli*	Radioactive labeling: ^{32}P (DNA) entered bacteria; ^{35}S (protein) remained outside.	**DNA, not protein, is the genetic material** that enters host cells.
Chargaff's Rules (1949)	Erwin Chargaff	Multiple species	Chemical analysis of DNA base composition.	**A=T, G=C**; (A+G)=(T+C); base ratios are species-specific.
X-ray Diffraction (1950-53)	Rosalind Franklin, Maurice Wilkins	DNA fibers	Produced "Photo 51": helical structure, 2 nm diameter, 3.4 nm repeat, 0.34 nm between bases.	Provided critical data for double helix model.
Double Helix Model (1953)	James Watson, Francis Crick	N/A	Combined Chargaff's rules and Franklin's X-ray data to build a molecular model.	Proposed the **antiparallel double helix** with specific **A-T and G-C pairing**.

Central Dogma of Molecular Biology

Original Concept (Crick, 1958): DNA → RNA → Protein

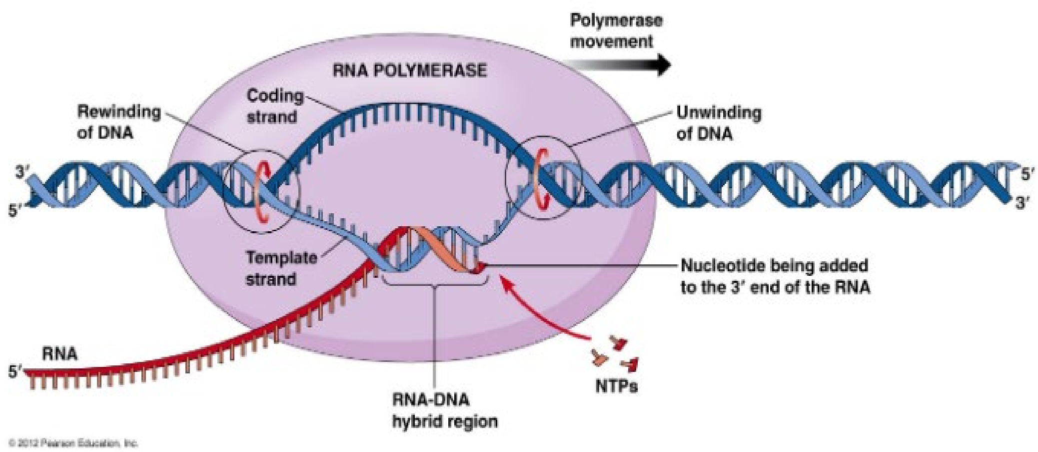
Revised Concept: Includes exceptions:

- **Reverse transcription** (RNA → DNA) by retroviruses (e.g., HIV)

- **Epigenetic Memory:** Stable transcription patterns can be maintained through cell division via epigenetic marks (e.g., DNA methylation, histone modifications), allowing cells to "remember" their specialized identity.

Disease and Medicine

- **Dysregulation Leads to Disease:** Errors in transcriptional regulation are a root cause of many diseases.
    - **Cancer:** Oncogenes (overexpressed) and tumor suppressor genes (silenced).
    - **Developmental Disorders:** Mutations in transcription factors (e.g., in *PAX6* causes aniridia).
    - **Metabolic & Immune Diseases.**
- **Therapeutic Target:** Many drugs act by modulating transcription (e.g., hormone receptors, anti-inflammatory steroids). New technologies aim to correct faulty gene expression.



TRANSLATION: PROTEIN SYNTHESIS

1. Introduction

Definition of Translation

Translation is the biological process in which the **sequence of codons** in a messenger RNA (mRNA) molecule is **decoded** to specify the **sequence of amino acids** in a polypeptide chain (protein). It is the **second stage of gene expression**, following transcription, where the genetic information encoded in nucleic acids is converted into the functional molecules of life.

Role of Translation in Gene Expression

- **Execution Phase:** Translation is the **executive step** where the genetic blueprint (mRNA) is used to synthesize the actual functional products—proteins.
- **Regulation Point:** While transcription is the primary control point, translation is also **highly regulated**, allowing cells to rapidly fine-tune protein production in response to immediate needs (e.g., stress, signals) without altering mRNA levels.
- **Protein Homeostasis:** Controls the **quantity, location, and timing** of protein synthesis, which is critical for all cellular processes, from metabolism and structure to signaling and defense.

Central Dogma of Molecular Biology

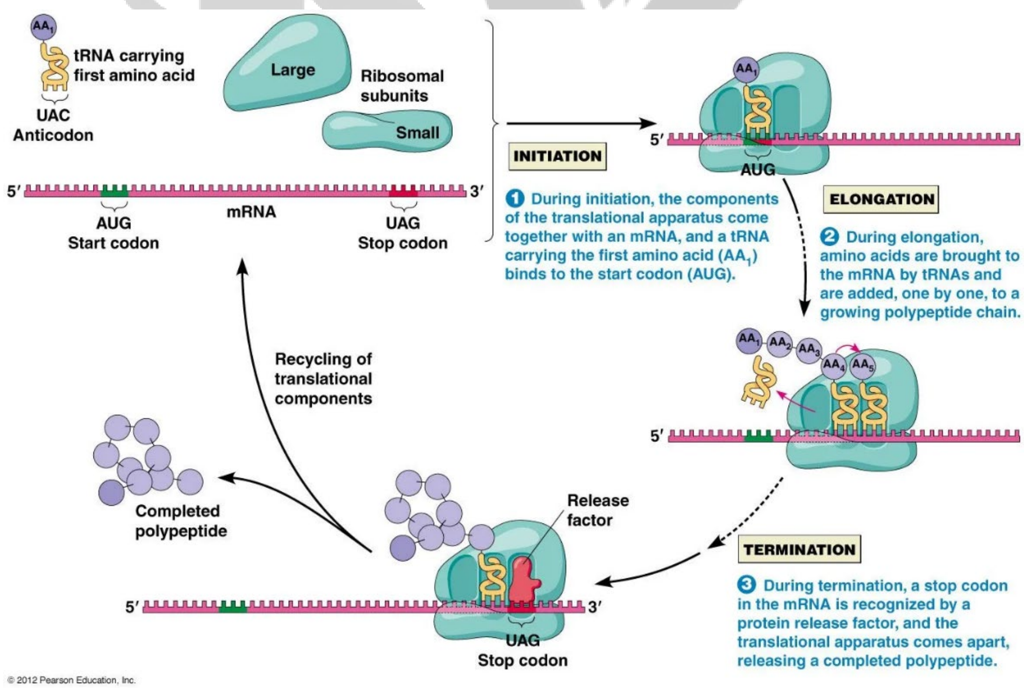
Translation is the final step in the core flow of genetic information:

DNA → (Transcription) → RNA → (Translation) → Protein

- **DNA** stores the genetic information.
- **Transcription** copies this information into a mobile RNA format (mRNA).
- **Translation** interprets the RNA code to assemble a specific protein. This flow is **unidirectional** under normal cellular conditions.

2. Basic Features of Translation

Inhibitor	Target Organism	Site of Action / Mechanism	Effect
Streptomycin	**Prokaryotes**	**30S subunit.** Binds near the decoding center (16S rRNA).	Causes **misreading of the genetic code** (incorporation of wrong amino acids) and inhibits initiation complex formation.
Tetracycline	**Prokaryotes**	**30S subunit.** Binds near the A site.	**Blocks entry of aminoacyl-tRNA** into the A site, preventing elongation.
Chloramphenicol	**Prokaryotes**	**50S subunit.** Binds near the **peptidyl transferase center** (23S rRNA).	**Inhibits peptide bond formation.**
Erythromycin	**Prokaryotes**	**50S subunit.** Binds near the **exit tunnel**.	**Blocks translocation** of the ribosome, trapping peptidyl-tRNA.
Cycloheximide	**Eukaryotes**	**60S subunit.** Binds to the **E site**.	**Inhibits translocation** in eukaryotic ribosomes. (Used in lab research).
Puromycin	**Both**	**Mimics aminoacyl-tRNA.** Enters A site and accepts the growing chain.	Causes **premature chain termination** by forming a peptidyl-puromycin that dissociates. (Research tool).



MUTATIONS AND DNA REPAIR

Classification of Mutations

Basis of Classification	Types	Description & Examples

DNA Sequencing	**Sanger:** Chain termination with ddNTPs. **NGS:** Massively parallel sequencing (Illumina, Nanopore).	Whole genome sequencing, phylogenomics, SNP discovery.
Hybridization Techniques	**Southern blot** (DNA), **Northern blot** (RNA), **FISH** (chromosomal localization).	Gene mapping, chromosomal abnormalities, gene expression.
Recombinant DNA Technology	Restriction enzymes, ligation, cloning vectors (plasmids, BACs, YACs).	Gene cloning, transgenic animal production.
CRISPR-Cas9	RNA-guided DNA endonuclease for targeted genome editing.	Gene knockout/knockin in model organisms, functional genomics.
DNA Barcoding	Sequencing standardized gene region (e.g., COI for animals) for species identification.	Biodiversity assessment, cryptic species discovery.
RNA-seq	NGS of cDNA from RNA population.	Transcriptome analysis, differential gene expression, non-coding RNA discovery.

Molecular Genetics: - MCQs

1. Which nitrogenous base is found in RNA but not in DNA?
A) Adenine
B) Guanine
C) Thymine
D) Uracil
Answer: Uracil

2. The Meselson-Stahl experiment demonstrated that DNA replication is:
A) Conservative
B) Dispersive
C) Semiconservative
D) Non-conservative
Answer: Semiconservative

3. Which enzyme is responsible for synthesizing RNA primers during DNA replication?
A) DNA polymerase I
B) DNA polymerase III
C) Primase
D) Ligase
Answer: Primase

4. In the Watson-Crick model of DNA, adenine pairs with:
A) Guanine
B) Cytosine
C) Thymine
D) Uracil
Answer: Thymine

5. Which type of RNA carries amino acids to the ribosome during translation?
A) mRNA
B) tRNA
C) rRNA
D) snRNA
Answer: tRNA

6. The condition characterized by trisomy 21 is:
A) Turner syndrome
B) Klinefelter syndrome
C) Down syndrome
D) Cri-du-chat syndrome
Answer: Down syndrome

7. Which of the following is a purine base?
A) Cytosine
B) Thymine
C) Uracil
D) Adenine
Answer: Adenine

Chapter 16

Regulation of Gene Expression

1. Introduction

Definition of Gene Expression

Gene expression is the **process by which the information encoded in a gene is used to direct the synthesis of a functional gene product**, typically a protein or functional RNA molecule (like tRNA or rRNA). It involves two main stages:

1. **Transcription:** The synthesis of an RNA molecule (mRNA) from a DNA template.
2. **Translation:** The synthesis of a polypeptide chain (protein) using the information in mRNA.

The **Central Dogma of Molecular Biology** outlines this flow: **DNA → RNA → Protein**.

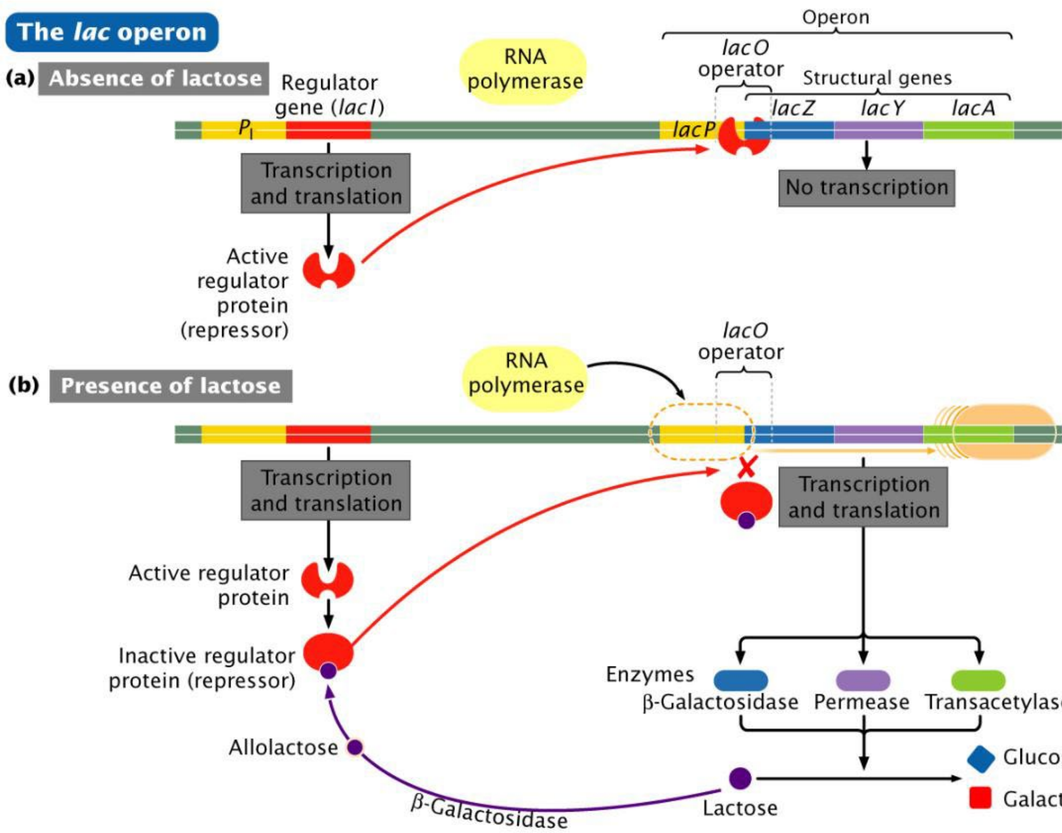
Need for Regulation of Gene Expression

Regulation is essential for cellular economy, development, adaptation, and specialization. Without it, cells would waste energy and resources, and complex multicellular life would be impossible.

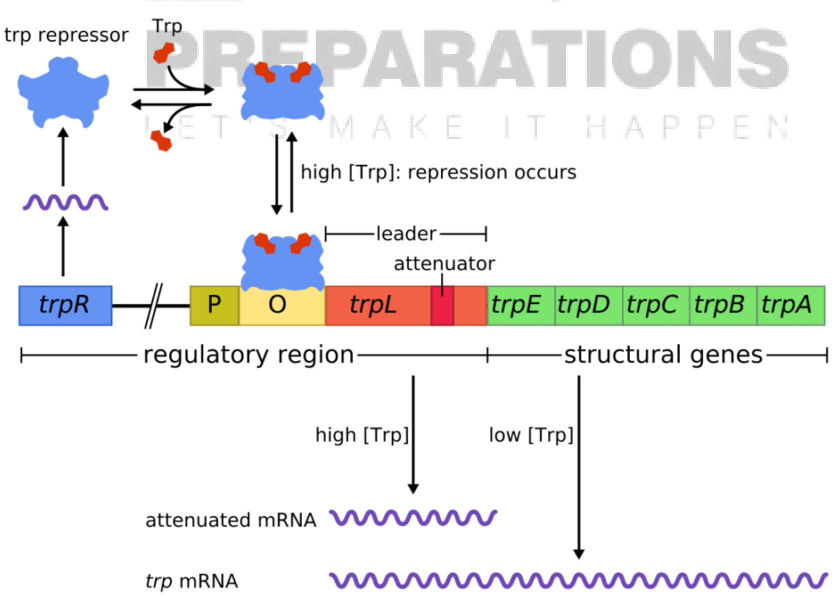
Reason for Regulation	Explanation	Example
1. Cellular Economy	Not all proteins are needed at all times. Producing unnecessary proteins wastes energy (ATP), building blocks (amino acids), and cellular machinery.	*E. coli* only produces lactose-metabolizing enzymes when lactose is present.
2. Adaptation to Environment	Cells must respond to changing external conditions (nutrients, temperature, toxins, stress).	Heat shock proteins are produced only during high-temperature stress.
3. Cellular Differentiation	In multicellular organisms, different cell types express different sets of genes despite having identical genomes.	A liver cell expresses albumin genes; a neuron expresses neurotransmitter genes.
4. Development & Morphogenesis	Precise temporal and spatial control of gene expression guides embryonic development, growth, and tissue organization.	Hox genes determine body plan and segment identity in animals.
5. Homeostasis & Response	Regulation maintains internal balance and coordinates responses to signals (hormones, growth factors).	Insulin regulates glucose metabolism by altering expression of metabolic enzymes.
6. Cell Cycle Control	Specific genes must be expressed at precise times during cell division (e.g., cyclins).	Cyclin expression peaks at specific phases of the cell cycle.

Constitutive vs. Inducible Genes

Characteristic	Constitutive (Housekeeping) Genes	Inducible/Repressible Genes
Expression Pattern	**Constantly expressed** at relatively constant levels.	**Expression changes** in response to signals.
Function	Encode products required for **basic cellular maintenance** and survival in all conditions.	Encode products needed only under **specific conditions** or in **specific cell types**.
Regulation	**Minimal regulation;** promoter is always accessible to RNA polymerase.	**Tightly regulated** by activators/repressors responding to environmental or internal cues.



C. Trp Operon (Repressible Operon)
The classic model of **negative repressible control**. It regulates genes for **tryptophan biosynthesis**.
Structural Genes & Their Functions
The operon contains five structural genes (*trpE, trpD, trpC, trpB, trpA*) encoding enzymes that catalyze the multi-step biosynthesis of the amino acid **tryptophan**.



Regulatory Protein	**Lac Repressor** (binds operator alone)	**Trp Repressor** (binds operator **only** with corepressor)
Positive Control	Yes (CAP-cAMP)	No
Fine-Tuning	No	Yes (Attenuation)
Energy Efficiency	Prevents synthesis of unneeded catabolic enzymes.	Prevents synthesis of unneeded anabolic enzymes.

MCQs

1. The process by which the information in a gene is used to synthesize a functional product like a protein is called:
A. DNA replication
B. Gene expression
C. Genetic recombination
D. Mutation
Correct Answer= B

2. According to the Central Dogma, the flow of genetic information is:
A. RNA → Protein → DNA
B. DNA → Protein → RNA
C. DNA → RNA → Protein
D. Protein → RNA → DNA
Correct Answer= C

3. Which of the following is NOT a primary reason for the regulation of gene expression?
A. Cellular economy
B. Cellular differentiation
C. Keeping all genes active at all times
D. Adaptation to the environment
Correct Answer= C

4. Genes that are constantly expressed at relatively stable levels to maintain basic cellular functions are called:
A. Inducible genes
B. Repressible genes
C. Constitutive (housekeeping) genes
D. Silent genes
Correct Answer= C

5. Which of the following is an example of a constitutive gene product?
A. Lactose-digesting enzymes in E. coli
B. Ribosomal RNA (rRNA)
C. Heat shock proteins
D. Insulin
Correct Answer= B

6. The most common and energy-efficient point for controlling gene expression is at the level of:
A. Transcription
B. Translation
C. Post-translation
D. DNA replication
Correct Answer= A

7. In eukaryotic cells, DNA is typically packaged as transcriptionally silent chromatin. Which modification is generally associated with increased transcription?
A. DNA methylation
B. Histone deacetylation
C. Histone acetylation
D. Cytosine methylation
Correct Answer= C

8. Alternative splicing is a form of post-transcriptional regulation that allows:
A. A single gene to code for multiple different proteins
B. Direct editing of the DNA sequence
C. Global shutdown of translation
D. Rapid degradation of mRNA
Correct Answer= A

9. The half-life of an mRNA molecule, which determines how long it persists in the cell, is a key aspect of regulation at which level?
A. Transcriptional
B. Post-transcriptional
C. Translational
D. Post-translational
Correct Answer= B

10. RNA interference (RNAi) involves small non-coding RNAs that guide a complex to target mRNA, leading to its:
A. Enhanced translation
B. Degradation or translational repression
C. Alternative splicing
D. Transport to the nucleus
Correct Answer= B

11. Phosphorylation of the eukaryotic initiation factor eIF2α under stress conditions

Chapter 17

Biotechnology

1. Introduction to Biotechnology

Definition of Biotechnology

Biotechnology is a multidisciplinary field that utilizes biological systems, living organisms, or derivatives thereof to develop or modify products and processes for specific uses.

It merges principles from **biology, chemistry, genetics, molecular biology, engineering, and computer science** to innovate in areas ranging from healthcare to environmental management.

- **Broadly defined**: Any technological application that uses biological systems to make or modify products.
- **Modern context**: Often involves deliberate manipulation of DNA, cells, and biological processes at the molecular level.

Traditional vs. Modern Biotechnology

Aspect	Traditional Biotechnology	Modern Biotechnology
Time Period	Ancient to early 20th century	Late 20th century – present
Basis	Empirical knowledge, natural processes	Understanding of molecular biology and genetics
Techniques	Fermentation, selective breeding, hybridization	Genetic engineering, recombinant DNA, cell culture, CRISPR, omics
Precision & Control	Low; relies on natural variation	High; specific genetic modifications
Examples	Beer, bread, cheese making; animal domestication; crop rotation	Insulin from GM bacteria, Bt cotton, gene therapy, mRNA vaccines
Scale & Speed	Slow, often small-scale	Rapid, scalable, industrially applicable
Regulation & Ethics	Minimal concern	Highly regulated; raises ethical, social, and safety debates

Key Transition: The 1973 discovery of **recombinant DNA technology** (Cohen & Boyer) marked the shift from traditional to modern biotechnology.

2. Historical Background

Early Uses of Biotechnology

- **~10,000 BCE**: Selective breeding of plants and animals for desirable traits.
- **~6000 BCE**: Fermentation for beer (Sumerians, Babylonians), wine (ancient Egypt, China), and leavened bread (using yeast).
- **~500 BCE**: Use of moldy soybean curd (antibiotic-like) in ancient China.
- **1860s**: Louis Pasteur's germ theory and fermentation studies laid scientific foundations.
- **1917**: Karl Ereky coined the term "biotechnology" (German: *Biotechnologie*), referring to using living organisms to produce products.

Development of Recombinant DNA Technology

- **1953**: Watson & Crick discover DNA double helix structure.
- **1970s**:
    - **1970**: Discovery of restriction enzymes (Arber, Smith, Nathans).
    - **1972**: Paul Berg creates first recombinant DNA molecule (SV40 virus + lambda phage).
    - **1973**: Herbert Boyer & Stanley Cohen successfully clone recombinant DNA into *E. coli*—birth of genetic engineering.
- **1976**: First biotech company, **Genentech**, founded; produced human insulin using rDNA by 1978.

Milestones in Biotechnology

Bioremediation	**Oil-degrading bacteria** (e.g., *Alcanivorax*) **Heavy metal accumulators** **PCB/Dioxin degraders**	**Phytoremediation plants** (Metal accumulators) **Plants degrading TNT/explosives**	Limited application (Mosquitoes for disease control)
Pollution Control	**Wastewater treatment microbes**	**Plants for soil stabilization**	Not applicable
Conservation	Not primary application	**Disease-resistant trees** (e.g., American chestnut)	**Gene drives** to control invasive species (controversial)
Biosensing	**Bacteria with reporter genes** for toxin detection	**Plants that change color** with pollutants/explosives	Not applicable
OTHER APPLICATIONS			
Biocontrol	**Frost-preventing bacteria** (*Pseudomonas syringae*) **Insect pathogens**	Not primary application	**Sterile insect technique** mosquitoes
Cosmetics	**Hyaluronic acid** production	**Plant oils** for cosmetics **Aloe vera** with enhanced compounds	**Collagen** from transgenic sources

MCQs

1. What is the broad definition of biotechnology?
   A. Use of computers in biology
   B. Any technological application using biological systems
   C. Only genetic engineering
   D. Study of ecosystems
   Correct Answer = B
2. Which discovery marked the shift from traditional to modern biotechnology?
   A. PCR
   B. Recombinant DNA technology
   C. DNA sequencing
   D. Monoclonal antibodies
   Correct Answer = B
3. Which of the following is an example of traditional biotechnology?
   A. mRNA vaccines
   B. Beer brewing
   C. CRISPR therapy
   D. GM crops
   Correct Answer = B
4. Who coined the term “biotechnology”?
   A. Louis Pasteur
   B. Karl Ereky
   C. Herbert Boyer
   D. Stanley Cohen
   Correct Answer = B
5. The first recombinant DNA molecule was created by:
   A. Kary Mullis
   B. Paul Berg
   C. Watson & Crick
   D. Doudna & Charpentier
   Correct Answer = B
6. The first approved GM product for human use was:
   A. Bt cotton
   B. Human insulin (Humulin)
   C. Flavr Savr tomato
   D. Dolly the sheep
   Correct Answer = B
7. Which branch deals with medical applications?
   A. Green biotechnology

Chapter 18

Viruses

Introduction

- **Acellular entities** are infectious agents that **lack a cellular structure** (no cytoplasm, organelles, or metabolism). They include **viruses, viroids, and prions**.
- They are **obligate intracellular parasites**, meaning they **can only replicate inside a living host cell** by hijacking its metabolic machinery.
- They are major pathogens causing significant global economic losses and health impacts in plants, animals, and bacteria.

History and Discovery of Viruses

- **Term Origin:** The word **virus** is derived from Latin for "poison" or "venom."
- **1884 (Charles Chamberland):** Found that the causative agent of rabies could pass through a porcelain filter that trapped bacteria, suggesting a filterable agent smaller than bacteria.
- **1892 (Dmitri Ivanowsky):** Demonstrated that the sap from tobacco plants with **Tobacco Mosaic Disease (TMD)** remained infectious after bacterial filtration, proposing it was caused by a filterable agent or a "bacterial toxin."
- **1898 (Martinus Beijerinck):** Conducted critical experiments showing the infectious agent in filtered sap could **replicate** only within a living host. He coined the term **"contagium vivum fluidum"** (living contagious fluid) and is credited with conceptualizing the virus.
- **1935 (Wendell Stanley):** Crystallized the **Tobacco Mosaic Virus (TMV)**, proving viruses could exist as non-living, infectious particles.
- The invention of the **electron microscope** later allowed direct visualization of viruses. The study of viruses is called **virology**.

Status of Viruses: Living or Non-Living?

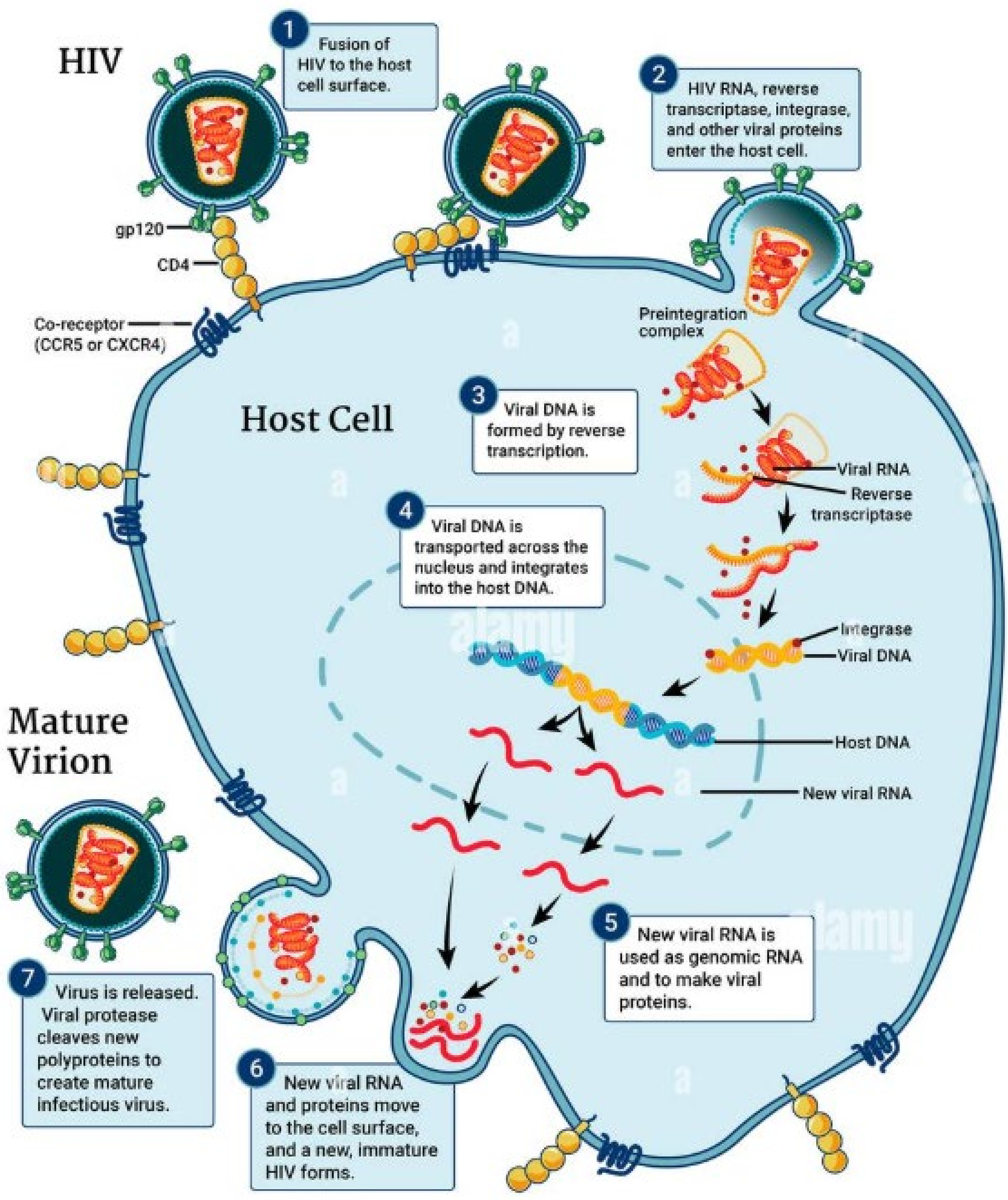
Viruses exist in a gray area, exhibiting characteristics of both living and non-living entities.

Living Characteristics	Non-Living Characteristics
1. Possess genetic material (DNA or RNA) capable of **mutation**.	1. **Acellular**; lack cellular organization, metabolic enzymes, and energy-generating systems (cannot make ATP).
2. Capable of **reproduction** (using host machinery).	2. Can be **crystallized** and stored like chemicals.
3. Show **specificity** and variation (exist in different strains).	3. Outside a host, they are **inert**, non-living particles.
4. Act as **obligate intracellular parasites**, causing disease.	4. Do not grow, respire, or carry out independent metabolic activities.
5. Susceptible to destruction by agents like heat and UV radiation.	5. Assemble spontaneously from pre-made components; do not divide.

- **Conclusion:** Most biologists consider viruses **non-living** because they cannot carry out life processes independently. They lead a **"borrowed life."**

Structure of Viruses

- **Prevention:** Safe sexual practices, sterile needles, screening of blood products, prevention of mother-to-child transmission (PMTCT). **Not transmitted** by casual contact, mosquitoes, or sharing food.



Viral Diseases - Examples

Disease	Causative Agent (Virus)	Primary Transmission	Key Features/Treatment
Hepatitis A	Hepatitis A Virus (HAV)	Fecal-oral route	Acute infection; **Vaccine** available; Supportive care.

- **Significance:** Caused **devastating pandemics** in Africa since the 1990s, threatening food security. Spread by **whiteflies**.

9. Barley Yellow Dwarf Virus (BYDV)
- **Virus:** *Luteovirus* (spherical, single-stranded RNA).
- **Host:** Cereals and grasses (barley, wheat, oats, rice).
- **Disease & Symptoms:**
  - **Yellowing and reddening** of leaf tips, especially in older leaves.
  - **Stunted plants with reduced tillering.**
  - **Heads remain upright** and produce small, shriveled grains.
- **Significance:** The **most widespread and economically damaging** viral disease of cereal crops globally. Spread by aphids.

10. Cauliflower Mosaic Virus (CaMV)
- **Virus:** *Caulimovirus* (spherical, double-stranded DNA).
- **Host:** Crucifers (cauliflower, cabbage, turnip).
- **Disease & Symptoms:**
  - **Mosaic mottling, vein clearing.**
  - **Stunted curd** formation in cauliflower and broccoli.
- **Significance:** Historically important as the **first plant virus shown to have DNA as its genetic material**. Its **CaMV 35S promoter** is **ubiquitously used in plant genetic engineering** to drive gene expression. Spread by aphids.

Applied Virology
- **CRISPR-Cas Technology:** Derived from bacterial immune systems, now a revolutionary tool for **genome editing**.
- **Viral Vectors:** Used in **gene therapy** and **vaccine development** (e.g., adenovirus vectors in some COVID-19 vaccines).
- **Phage Therapy:** Use of bacteriophages to treat antibiotic-resistant bacterial infections.
- **Antiviral Drugs:** Target specific viral processes (e.g., Oseltamivir/Tamiflu inhibits neuraminidase in influenza; Acyclovir inhibits herpes DNA polymerase).

Viruses: - MCQs
1. What is the primary structural component that surrounds the viral genome?
A) Envelope
B) Capsid
C) Capsomere
D) Nucleoid
Answer: Capsid

2. Who first crystallized a virus, proving it could exist as a non-living particle?
A) Dmitri Ivanowsky
B) Martinus Beijerinck
C) Wendell Stanley
D) Adolf Mayer
Answer: Wendell Stanley

3. Which characteristic is NOT shared by all viruses?
A) Genetic material
B) Protein coat
C) Independent metabolism
D) Obligate intracellular parasitism
Answer: Independent metabolism

4. The protein subunits that assemble to form a viral capsid are called:
A) Protomers
B) Capsomeres
C) Envelopes
D) Spikes
Answer: Capsomeres

5. A virus that infects bacteria is specifically termed a:
A) Retrovirus
B) Bacteriophage
C) Viroid
D) Prion
Answer: Bacteriophage

6. Which viral structure is derived from the host cell's membrane?
A) Capsid
B) Core

Chapter 19

Bacteria and Archaea

INTRODUCTION TO PROKARYOTES

Prokaryotes are unicellular organisms that constitute the domains **Bacteria** and **Archaea**. They are the most abundant and widespread life forms on Earth, found in virtually every habitat. Key defining features include:

- **Lack of a membrane-bound nucleus.** Genetic material is located in a region called the **nucleoid**.
- **Absence of membrane-bound organelles** (e.g., mitochondria, chloroplasts).
- Generally smaller (0.5–5.0 µm) and structurally simpler than eukaryotic cells.
- Possess a rigid **cell wall** (with exceptions like *Mycoplasma*).
- Exhibit extraordinary **metabolic diversity**, enabling survival in extreme environments.

Despite their simplicity, they are highly evolved, having existed for over 3.5 billion years. While a minority are pathogens, most play crucial ecological roles in nutrient cycling, decomposition, and symbiotic relationships.

HISTORICAL DISCOVERY AND FOUNDATIONS

- **Antonie van Leeuwenhoek (1673):** First to observe and describe bacteria ("animalcules") using a simple microscope.
- **Louis Pasteur (19th Century):**
  - Disproved spontaneous generation.
  - Developed **germ theory of disease**.
  - Created vaccines (anthrax, rabies).
  - Developed the **pasteurization** process.
- **Robert Koch (19th Century):** Established the definitive link between specific microbes and specific diseases using **Koch's Postulates**.
  1. The pathogen must be present in all diseased individuals and absent in healthy ones.
  2. The pathogen must be isolated and grown in pure culture.
  3. The cultured pathogen must cause the same disease when inoculated into a healthy host.
  4. The pathogen must be re-isolated from the experimentally infected host.

TAXONOMY AND PHYLOGENETIC POSITION

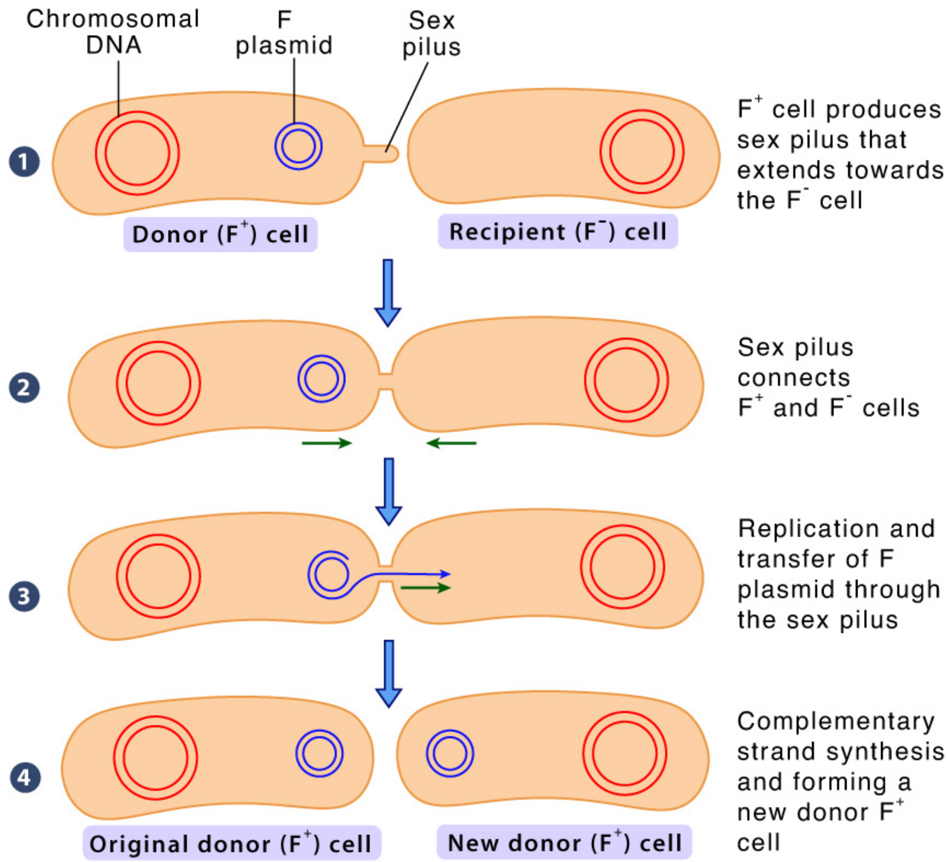
- **Historical Classification:** All prokaryotes were initially placed in the kingdom **Monera**.
- **The Three-Domain System (Carl Woese, 1977):** Based on comparisons of **small-subunit ribosomal RNA (rRNA)** gene sequences, life is divided into three domains:
  1. **Bacteria (Eubacteria):** "True bacteria."
  2. **Archaea (Archaebacteria):** A distinct lineage sharing some features with eukaryotes.
  3. **Eukarya:** All eukaryotic organisms.
- This system revealed that **Archaea are more closely related to Eukarya than to Bacteria**. The last common ancestor of Bacteria and Archaea was likely a **hyperthermophile**.

STRUCTURE OF BACTERIA

Size of Bacteria

Bacteria are **microscopic, prokaryotic** organisms. Their size is measured in micrometers (µm).

- **Typical Range:** 0.5 – 5.0 µm in length or diameter.
- **Examples:**
  - *Escherichia coli* (rod): ~**2.0 µm** long, ~**0.5 µm** in diameter.
  - *Staphylococcus aureus* (coccus): ~**1.0 µm** in diameter.
  - *Mycoplasma* (smallest known bacteria): ~**0.2 – 0.3 µm** (at the limit of light microscopy).



TRANSFORMATION IN BACTERIA

I. OVERVIEW

Bacterial transformation is a **horizontal gene transfer (HGT)** mechanism where bacteria take up **free, naked DNA** from their environment and incorporate it into their genome. This is a **natural genetic engineering** process that does not require cell-to-cell contact.

- **Historical Significance:** Discovered by **Frederick Griffith (1928)** in *Streptococcus pneumoniae* (the "Griffith experiment"), providing the first evidence that DNA is genetic material (later confirmed by Avery, MacLeod, and McCarty in 1944).
- **Key Concept:** Bacteria must be **competent** – physiologically able to take up DNA.
- **Significance:** Natural mechanism for genetic diversity, used extensively in molecular biology/cloning.

II. KEY TERMINOLOGY

A. Competence

The physiological state allowing a bacterium to take up exogenous DNA.

- **Natural Competence:** Genetically programmed ability (species-specific).
- **Artificial/Induced Competence:** Created in lab via chemical/electrical methods.

B. Transformasome/Competence Apparatus

Multiprotein complex spanning the cell envelope for DNA uptake and processing.

C. Transforming DNA

- **Chromosomal DNA fragments** from lysed cells.
- **Plasmid DNA** (must be circular to replicate autonomously).

- **Microscopic Structure:** The colony is composed of **unbranched filaments** called **trichomes**, all embedded in a common, firm **gelatinous matrix** or sheath.
- **Trichome Composition:**
  - **Vegetative Cells:** Spherical or barrel-shaped, **photosynthetic**. Contain **chlorophyll-a**, **phycobiliproteins** (phycocyanin - blue, phycoerythrin - red), and carboxysomes for carbon fixation.
  - **Heterocysts:** Larger, thick-walled, pale yellow cells. **Specialized for nitrogen fixation**. They have:
    - A thickened cell wall to limit O_2 diffusion.
    - Loss of Photosystem II (stops O_2 production).
    - Presence of **nitrogenase enzyme** (O_2-sensitive).
    - **Regular, interspaced arrangement** along the trichome (singly or in pairs). They provide fixed nitrogen to neighboring vegetative cells.
  - **Akinetes (Resting Spores):** Large, thick-walled, dormant cells formed under unfavorable conditions (cold, desiccation). They store nutrients and germinate when conditions improve. Usually located adjacent to heterocysts.

4. Reproduction

- **Asexual Only** (typical for cyanobacteria).
  1. **Colony Fragmentation:** The primary method. Pieces of colony break off and grow into new colonies.
  2. **Hormogonia Formation:** Short, motile fragments of trichomes break free from the main filament, glide away, lose motility, and develop into new filaments/colonies.
  3. **Akinetes:** Germinate to form new filaments when conditions become favorable.

5. Physiology & Metabolism

- **Oxygenic Photosynthesis:** Uses **Photosystem I & II**, with H_2O as the electron donor, producing O_2. Performed by vegetative cells.
- **Nitrogen Fixation:** Performed exclusively by **heterocysts**. Converts atmospheric N_2 into ammonia (NH_3/NH_4^+) using the enzyme **nitrogenase**.
  - **Chemical Equation:** $N_2 + 8H^+ + 8e^- + 16\ ATP \rightarrow 2NH_3 + H_2 + 16ADP + 16Pi$
- **Carbon Fixation:** Via the **Calvin Cycle** in vegetative cells.
- **Desiccation Tolerance:** Can survive extreme drying for long periods (anhydrobiosis), reviving quickly upon rehydration.

6. Ecological & Economic Importance

- **Primary Production:** Contributes to carbon fixation in aquatic and terrestrial ecosystems.
- **Nitrogen Fertilization:** As a **free-living** organism, it enriches soils and water bodies with fixed nitrogen. As a **symbiont**, it provides nitrogen directly to host plants, reducing/eliminating their need for soil nitrogen.
  - The **Azolla-Nostoc** symbiosis is a critical natural biofertilizer in rice paddies.
- **Pioneer Species:** Colonizes bare rocks and poor soils, initiating soil formation.
- **Food Source:** Historically consumed in Asia ("fa cai" in China, "nostoc" soup). Rich in proteins and nutrients.
- **Biotechnological Potential:** Source of bioactive compounds (antiviral, antibacterial), biofuels, and natural fertilizers.
- **Blooms:** Under eutrophic conditions, some *Nostoc* species can form blooms, but they are generally less toxic than other cyanobacteria (e.g., *Microcystis*).

Nostoc vs. Anabaena vs. Oscillatoria

A comparative table highlighting the key differences and similarities between these three common and important genera of filamentous cyanobacteria.

Feature	*Nostoc*	*Anabaena*	*Oscillatoria*

		hepatotoxins). A **common cause of toxic algal blooms.**	associated with poisoning than *Anabaena*.
12. Key Distinguishing Feature	**Macroscopic gelatinous colony.**	**Planktonic, free filaments with heterocysts, often toxic.**	**Gliding motility, disc-shaped cells, no heterocysts.**

Bacteria & Archaea: - MCQs

1. Which scientist first observed bacteria using a homemade microscope?
A) Louis Pasteur
B) Robert Koch
C) Antonie van Leeuwenhoek
D) Christian Gram
Answer: Antonie van Leeuwenhoek

2. The domain Archaea differs from Bacteria in having:
A) Peptidoglycan in cell wall
B) Ester-linked membrane lipids
C) Ether-linked membrane lipids
D) Circular chromosome
Answer: Ether-linked membrane lipids

3. Gram-positive bacteria stain purple due to:
A) Thin peptidoglycan layer
B) Outer lipopolysaccharide membrane
C) Thick peptidoglycan layer retaining crystal violet
D) Presence of periplasmic space
Answer: Thick peptidoglycan layer retaining crystal violet

4. Which of the following is a photosynthetic prokaryote?
A) Escherichia coli
B) Streptococcus pneumoniae
C) Nostoc
D) Staphylococcus aureus
Answer: Nostoc

5. Koch's postulates are used to:
A) Classify bacteria based on shape
B) Prove causal relationship between microbe and disease
C) Identify antibiotic resistance
D) Stain bacterial capsules
Answer: Prove causal relationship between microbe and disease

6. Bacteria that require oxygen for growth are called:
A) Obligate anaerobes
B) Facultative anaerobes
C) Obligate aerobes
D) Microaerophiles
Answer: Obligate aerobes

7. The rigid spiral-shaped bacteria are known as:
A) Vibrio
B) Spirillum
C) Spirochete
D) Coccus
Answer: Spirillum

8. Which structure is involved in bacterial conjugation?
A) Flagella
B) Pili
C) Capsule
D) Endospore
Answer: Pili

9. The process of taking up free DNA from the environment is:
A) Transduction
B) Conjugation
C) Transformation
D) Binary fission
Answer: Transformation

10. Which of the following bacteria produce endospores?
A) Escherichia coli
B) Bacillus anthracis
C) Neisseria gonorrhoeae
D) Vibrio cholerae
Answer: Bacillus anthracis

11. Plasmids are best described as:
A) Essential for bacterial growth
B) Circular, double-stranded extrachromosomal DNA
C) Part of the bacterial chromosome
D) Involved in protein synthesis
Answer: Circular, double-stranded extrachromosomal DNA

Chapter: 20

Plant Physiology I

Imbibition in Plants

1. Core Definition & Basic Concept

Imbibition is a **special type of diffusion** and a **physical process** in which water (or any other liquid) is **adsorbed** by the solid-colloidal particles of a substance, resulting in an **enormous increase in volume**.

- **Key Analogy:** It is like a dry sponge soaking up water, swelling, and becoming rigid.
- **Biological Context:** It is the **first step in seed germination** and is crucial for the hydration of plant tissues before other physiological processes (like osmosis and metabolic activation) can begin.
- **Energy Involved:** It is an **exothermic process**—heat energy (termed *heat of wetting*) is released during imbibition.

Essential Characteristics of an Imbibant

For a substance to undergo imbibition, it must have:

1. **Hydrophilic Colloids:** The substance must contain colloids like cellulose, pectin, lignin, starch, or proteins.
2. **Water Potential Gradient:** There must be a difference in water potential between the imbibant and the liquid. The drier the imbibant, the steeper the gradient and the faster the initial rate.
3. **Porosity:** The material must be porous to allow water to penetrate its structure.
4. **Temperature:** Rate increases with temperature (increases kinetic energy of water molecules).

Osmosis in Plants

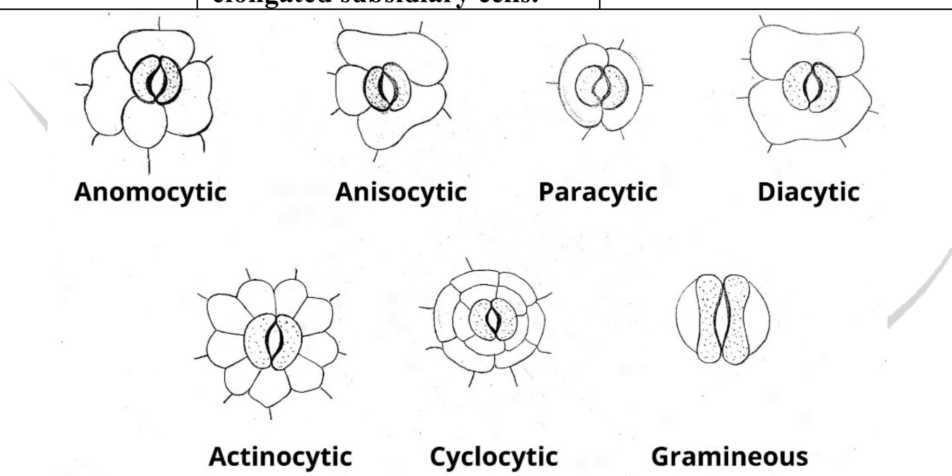
I. Fundamental Concept of Osmosis

- **Definition:** Osmosis is the **net movement of water molecules** across a **selectively permeable membrane** (semi-permeable membrane) from a region of **higher water potential** (dilute solution, low solute concentration) to a region of **lower water potential** (concentrated solution, high solute concentration).
- **Driving Force:** The movement is driven by the **chemical potential of water**, striving to equalize solute concentrations on both sides of the membrane. It is a passive process (does not require direct energy input from the cell).

II. Core Terminology & Concepts in Plant Water Relations

1. **Water Potential (Ψ, psi):** The fundamental concept that predicts the direction of water movement. It is expressed in units of pressure (Megapascals, MPa, or bars).
    - **Formula: $\Psi = \Psi s + \Psi p + \Psi g + \Psi m$**
        - **Ψs (Solute Potential or Osmotic Potential):** Always **negative** (or zero for pure water). The reduction in water potential due to the presence of solutes. More solutes = more negative Ψs.
        - **Ψp (Pressure Potential):** The physical pressure exerted on the water. In plant cells, it is usually **positive** (turgor pressure). It can be negative in xylem vessels under tension.
        - **Ψg (Gravitational Potential):** Important in tall trees; positive as height increases. Often negligible at cellular level.
        - **Ψm (Matric Potential):** The potential due to adhesion of water to surfaces (e.g., in cell walls, soil particles). It is **negative** and very important in soil and cell wall water retention.
    - **Water always moves from an area of higher (less negative) Ψ to an area of lower (more negative) Ψ.**
2. **Tonicity (in a plant context):**

Anomocytic (Ranunculaceous)	**No subsidiary cells.** Guard cells surrounded by ordinary epidermal cells.	Dicots like *Ranunculus* (buttercup), *Brassica*.
Anisocytic (Cruciferous)	**Three subsidiary cells of unequal size;** one is distinctly smaller.	Many dicots like *Solanum* (tomato, potato).
Paracytic (Rubiaceous)	**One or more subsidiary cells flank the guard cells, parallel to the pore axis.**	*Rubia*, *Hibiscus*, *Mangifera* (mango).
Diacytic (Caryophyllaceous)	**Two subsidiary cells arranged perpendicular to the guard cells.**	*Dianthus* (carnation), *Ocimum* (basil).
Gramineous (Monocot Type)	**Two dumbbell-shaped guard cells flanked by two parallel, elongated subsidiary cells.**	All grasses and cereals (wheat, rice, maize).



Theories of Stomatal Movement

I. Historical Context and Early Observations

- **First description:** Malpighi (1675) observed stomata but didn't understand function.
- **Function hypothesized:** von Mohl (1856) correctly proposed stomata control transpiration and gas exchange.
- **Critical discovery:** Guard cells contain chloroplasts (von Mohl, 1856) – unique among epidermal cells.

II. Major Theories in Chronological Development

1. Classical Starch-Sugar Interconversion Theory (Sayre, 1926; Scarth, 1932)

Core Hypothesis: Stomatal movements result from **osmotic changes** caused by interconversion of starch to glucose in guard cell chloroplasts.

Mechanism:

Light
↓
Starch + H_2O → Glucose-1-Phosphate (via phosphorylase)
↓
6-8 glucose molecules produced per starch molecule
↓
Osmotic concentration increases (2-3x)
↓

A. Wilting of leaves
B. Rising of mercury in a barometer
C. Breaking of seed coats during germination
D. Guttation
Correct Answer: Breaking of seed coats during germination

4. Imbibition is a type of:
A. Diffusion
B. Osmosis
C. Adsorption
D. Active transport
Correct Answer: Adsorption

5. The swelling of wooden doors during rainy season is due to:
A. Osmosis
B. Imbibition
C. Capillarity
D. Transpiration pull
Correct Answer: Imbibition

6. Imbibition pressure is also known as:
A. Wall pressure
B. Turgor pressure
C. Matric potential
D. Osmotic pressure
Correct Answer: Matric potential

7. The process of water loss from the aerial parts of plants in the form of vapour is called:
A. Evaporation
B. Transpiration
C. Guttation
D. Exudation
Correct Answer: Transpiration

8. More than 90% of transpiration in plants occurs through:
A. Lenticels
B. Stomata
C. Cuticle
D. Hydathodes
Correct Answer: Stomata

9. Cuticular transpiration is generally higher in:
A. Xerophytes
B. Mesophytes
C. Hydrophytes
D. Halophytes
Correct Answer: Mesophytes

10. The stomatal transpiration is regulated by:
A. Guard cells
B. Subsidiary cells
C. Epidermal cells
D. All of these
Correct Answer: Guard cells

11. The instrument used to measure the rate of transpiration is:
A. Potometer
B. Porometer
C. Hygrometer
D. Photometer
Correct Answer: Potometer

12. Transpiration is considered a necessary evil because:
A. It causes wilting
B. It causes water loss but helps in mineral absorption and ascent of sap
C. It leads to stomatal closure
D. It increases respiration
Correct Answer: It causes water loss but helps in mineral absorption and ascent of sap

13. The process responsible for guttation is:
A. Root pressure
B. Transpiration pull
C. Imbibition
D. Capillarity
Correct Answer: Root pressure

14. Water droplets exuded from hydathodes contain:
A. Pure water
B. Water with dissolved minerals and sugars
C. Water with resins
D. Water with latex
Correct Answer: Water with dissolved minerals and sugars

15. Stomatal opening is influenced by:
A. Light intensity
B. CO_2 concentration
C. Potassium ion influx
D. All of these
Correct Answer: All of these

16. The ion that plays a key role in stomatal opening is:
A. Ca^{2+}
B. K^+
C. Cl^-
D. Na^+
Correct Answer: K^+

17. Stomata close when guard cells are:
A. Turgid
B. Flaccid
C. Dividing

Chapter: 21

Plant Physiology II

BIOLOGICAL NITROGEN FIXATION

Biological nitrogen fixation (BNF) is the process by which certain prokaryotic microorganisms convert atmospheric nitrogen (N_2) into ammonia (NH_3), making it biologically available for incorporation into organic compounds.

Global Significance

- **Nitrogen paradox:** N_2 constitutes 78% of atmosphere but is chemically inert
- **Biological limitation:** Most organisms cannot use N_2 directly
- **BNF contribution:** ~65% of biologically fixed nitrogen globally (~150 million tons/year)

Fundamental Chemistry

Reaction: $N_2 + 8H^+ + 8e^- + 16ATP \rightarrow 2NH_3 + H_2 + 16ADP + 16Pi$

ORGANISMS CAPABLE OF NITROGEN FIXATION

Classification by Lifestyle

A. Free-Living Nitrogen Fixers

1. **Aerobic:**
   - *Azotobacter* (heterotrophic)
   - *Klebsiella pneumoniae* (facultative)
   - Cyanobacteria: *Anabaena*, *Nostoc*, *Trichodesmium* (marine)
2. **Anaerobic:**
   - *Clostridium pasteurianum* (obligate anaerobe)
   - Purple sulfur bacteria (*Chromatium*)
   - Green sulfur bacteria (*Chlorobium*)
3. **Facultative anaerobes:**
   - *Klebsiella*
   - *Bacillus polymyxa*

B. Symbiotic Nitrogen Fixers

1. **Legume-Rhizobia symbiosis:**
   - *Rhizobium*, *Bradyrhizobium*, *Sinorhizobium*, *Mesorhizobium*
   - Infect legumes (Fabaceae): soybeans, peas, clover, alfalfa
2. **Actinorhizal symbiosis:**
   - *Frankia* (actinobacteria)
   - Infects 25 genera across 8 plant families (non-legumes)
   - Examples: Alder (*Alnus*), Bayberry (*Myrica*), Casuarina
3. **Cyanobacterial symbioses:**
   - *Anabaena* with aquatic fern *Azolla* (rice paddies)
   - *Nostoc* with cycads, *Gunnera*
4. **Associative symbiosis:**
   - *Azospirillum* with grasses (wheat, maize)

C. Archaeal Nitrogen Fixers

- Methanogenic archaea: *Methanococcus*, *Methanosarcina*
- Extreme environments: Hot springs, deep-sea vents

ASYMBIOTIC NITROGEN FIXATION

Asymbiotic nitrogen fixation (also called free-living or non-symbiotic fixation) refers to biological nitrogen fixation carried out by prokaryotic organisms that function **independently** of any plant host association. These organisms fix atmospheric N_2 for their own metabolic needs, with excess nitrogen eventually released into the environment upon cell death or excretion.

Key Distinction from Symbiotic Fixation

- **Fruit ripening**
- **Pollen development**
- **Senescence**

H. STRIGOLACTONES (SLs)

Discovery & Functions:

- Originally identified as seed germination stimulants for parasitic plants
- **Endogenous roles**:
  - Inhibit shoot branching (branching hormone)
  - Root architecture modulation
  - Arbuscular mycorrhizal symbiosis promotion

4. Hormone Interactions & Cross-Talk

Key Antagonistic/Synergistic Relationships:

1. **Auxin:Cytokinin**:
   - Ratio determines root/shoot differentiation
   - High auxin:ck → root formation
   - High ck:auxin → shoot formation
2. **Gibberellin:Abscisic Acid**:
   - GA promotes germination; ABA inhibits
   - Balance controls seed dormancy
3. **Ethylene:Auxin**:
   - Auxin induces ethylene biosynthesis
   - Synergistic in abscission, root inhibition
4. **Brassinosteroids:Auxin**:
   - Synergistic in cell elongation
   - Shared downstream targets

Signaling Integration:

- **Network hubs**: DELLA proteins (GA signaling) integrate multiple hormones
- **Shared components**:
  - Proteasome degradation (auxin, GA, JA)
  - Phosphorelays (cytokinin, ethylene)
  - Secondary messengers (Ca^{2+}, ROS)

6. **Summary Table of Major Hormones**

Hormone	Biosynthesis Site	Transport	Primary Functions	Key Applications
Auxin	Shoot tips, young leaves	Polar (PAT)	Cell elongation, tropisms, apical dominance	Rooting powders, herbicides
Gibberellin	Young leaves, seeds	Xylem/phloem	Stem elongation, germination, flowering	Malt production, fruit growth
Cytokinin	Root tips, seeds	Xylem (root→shoot)	Cell division, shoot initiation, delays senescence	Tissue culture, anti-aging
Abscisic Acid	Leaves, roots (stress)	Xylem/phloem	Stomatal closure, dormancy, stress response	Anti-transpirants
Ethylene	Most tissues (aging/stress)	Diffusion	Ripening, senescence, abscission	Fruit ripening control
Brassinosteroid	All tissues	Phloem?	Cell expansion, differentiation, stress	Potential yield enhancement

COMPARATIVE TABLE: MOVEMENT TYPES

Movement Type	Stimulus Direction	Speed	Reversibility	Primary Mechanism	Example
Phototropism	Directional	Hours	No	Differential growth	Sunflower stem
Gravitropism	Directional	Hours	No	Differential growth	Root curvature
Thigmotropism	Directional	Hours-days	No	Differential growth	Tendril coiling
Nyctinasty	Non-directional	Minutes-hours	Yes	Turgor changes	Bean leaf sleep
Seismonasty	Non-directional	Seconds-minutes	Sometimes	Turgor changes	*Mimosa* leaf
Thigmonasty	Non-directional	Milliseconds-seconds	Sometimes	Snap buckling	Venus flytrap
Circumnutation	Autonomous	Hours	Continuous	Growth oscillations	Twining stems
Thermonasty	Non-directional	Minutes-hours	Yes	Differential expansion	Tulip flower
Chemotaxis	Directional	Variable	No	Motile cell movement	Fern sperm

Important MCQs

1. Which plant hormone is primarily synthesized in the shoot apices and is crucial for cell elongation?
   A. Cytokinin
   B. Gibberellin
   C. **Auxin**
   D. Abscisic Acid
   Correct Answer: C
2. The most common natural auxin found in plants is:
   A. NAA
   B. 2,4-D
   C. Kinetin
   D. **IAA (Indole-3-acetic acid)**
   Correct Answer: D
3. Stem elongation and the breaking of seed dormancy in some species are promoted by:
   A. Cytokinins
   B. **Gibberellins**
   C. Ethylene
   D. Jasmonates
   Correct Answer: B
4. Cell division in plants is primarily stimulated by hormones synthesized in the root tips called:
   A. Auxins
   B. **Cytokinins**
   C. Brassinosteroids
   D. Abscisic Acid
   Correct Answer: B
5. The primary plant stress hormone that induces stomatal closure during water deficit is:
   A. Ethylene
   B. Gibberellin
   C. **Abscisic Acid (ABA)**
   D. Auxin
   Correct Answer: C
6. A gaseous hormone that promotes fruit ripening and leaf senescence is:
   A. Carbon dioxide
   B. **Ethylene**
   C. Nitric oxide
   D. Methane
   Correct Answer: B
7. Apical dominance in a plant is maintained by the action of:
   A. Gibberellin
   B. **Auxin**

Chapter: 22

Plant Physiology III

Bioenergetics

Bioenergetics is defined as the study of energy transduction in living organisms, encompassing the capture of light energy and its storage as chemical bond energy, as well as the utilization of energetic compounds through processes such as aerobic respiration.

Photosynthesis

1. Introduction to Photosynthesis

A. Definition

Photosynthesis is the fundamental **biochemical process** by which **photoautotrophs**—primarily plants, algae, and certain bacteria (like cyanobacteria)—captain and convert **light energy** from the sun into **stable chemical energy** stored in the bonds of organic molecules (e.g., glucose). This process transforms inorganic carbon (from atmospheric carbon dioxide) and water into energy-rich carbohydrates, releasing oxygen as a byproduct.

B. Overview of the Process

At its core, photosynthesis is a two-stage process occurring within specialized organelles called **chloroplasts**:

1. **Light-Dependent Reactions:** Occur in the **thylakoid membranes**. Light energy is captured by pigments like chlorophyll and used to split water molecules (**photolysis**), releasing oxygen. This energy is converted into short-term energy carriers (**ATP** and **NADPH**).
2. **Light-Independent Reactions (Calvin Cycle):** Occur in the **stroma** of the chloroplast. The chemical energy from ATP and NADPH is used to fix atmospheric carbon dioxide (**CO_2**) into organic sugars, like glucose. This stage does not require light directly but depends on the products of the light reactions.

2. The General Equation

The overall chemical equation summarizes the net input and output of the complex process:

$6CO_2 + 6H_2O + \text{Light Energy} \rightarrow C_6H_{12}O_6 + 6O_2$

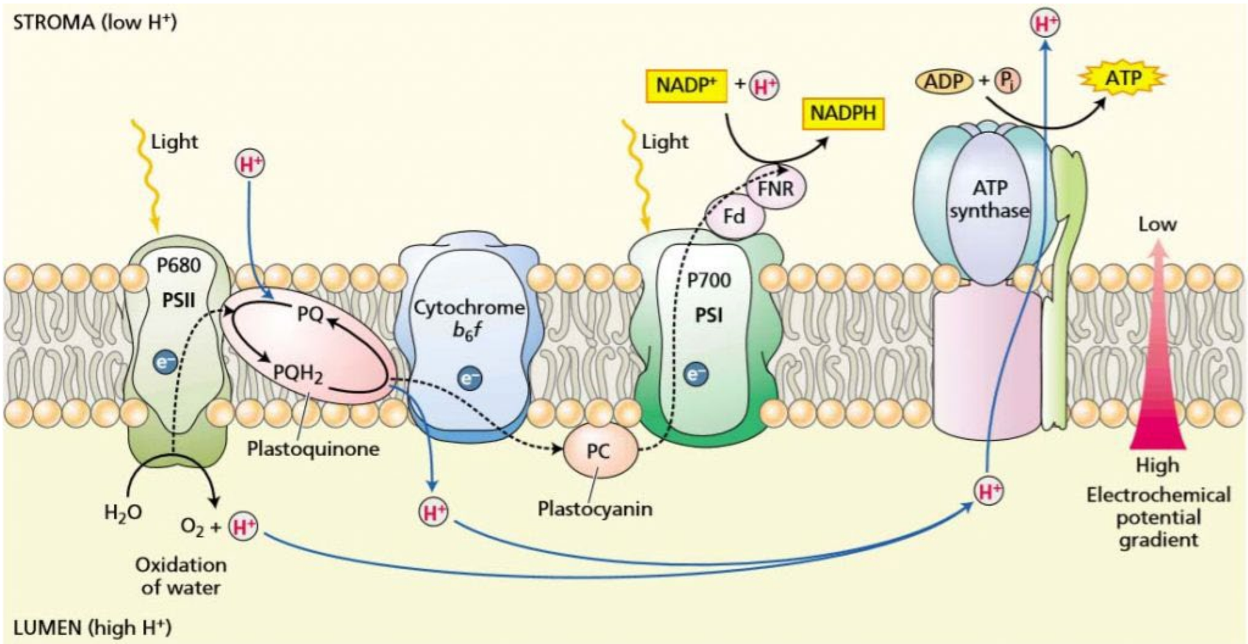
- **Reactants: Carbon Dioxide (CO_2)** from the air and **Water (H_2O)** from the soil.
- **Products: Glucose ($C_6H_{12}O_6$)**, a simple sugar used for energy and structure, and **Molecular Oxygen (O_2)**, released into the atmosphere.

The Chloroplast: Structure and Function

The **chloroplast** is a double-membrane-bound organelle.

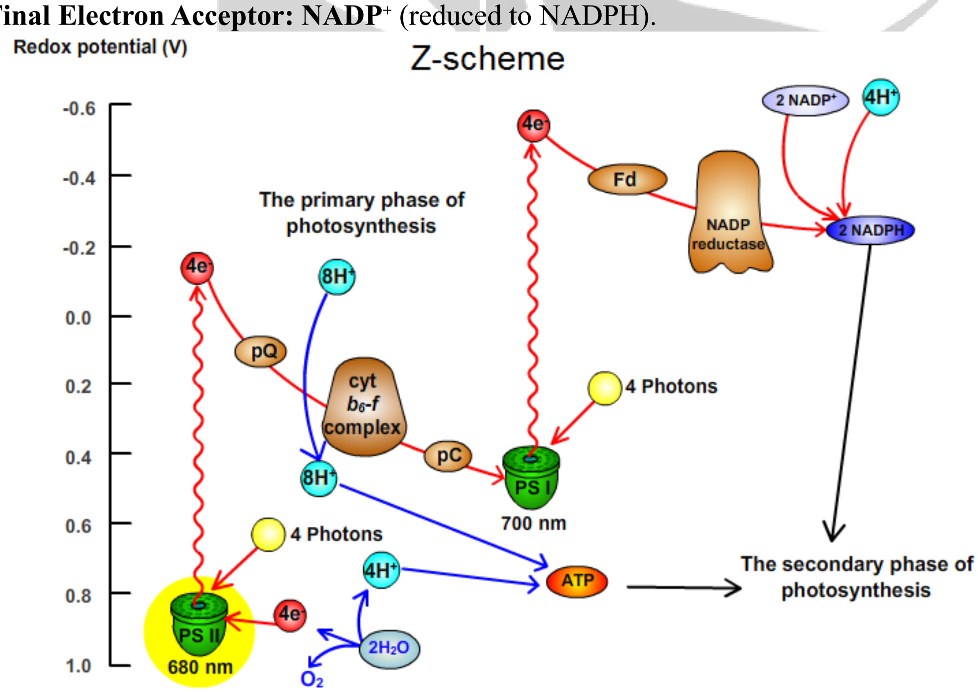
Structure	Description & Function
Outer & Inner Membrane	Envelope the organelle. The inner membrane is selectively permeable.
Intermembrane Space	Narrow space between the two membranes.
Stroma	**Viscous fluid filling the chloroplast.** Site of the **light-independent reactions (Calvin Cycle)**. Contains enzymes, DNA, ribosomes, and starch grains.
Thylakoids	A system of interconnected, flattened, membranous sacs.
Grana (sing. granum)	Stacks of thylakoids (like a stack of coins).
Lumen	The interior space of a thylakoid.
Chlorophyll & Accessory Pigments	Embedded in the **thylakoid membranes**. Arranged in **photosystems** (I & II) to form light-harvesting complexes.
Function Summary:	**Thylakoids** = Site of **light-dependent reactions** (produce ATP, NADPH, O_2). **Stroma** = Site of **light-independent reactions** (use ATP & NADPH to fix CO_2 into sugar).

- The high-energy electron from PSI is passed through the soluble protein **Ferredoxin (Fd)**.
- The enzyme **NADP⁺ Reductase** then uses **2 electrons** and **1 H⁺ from the stroma** to reduce **NADP⁺** to **NADPH**.



Summary of Electron Source & Sink:

- **Initial Electron Donor: H_2O** (oxidized to O_2).
- **Final Electron Acceptor: NADP⁺** (reduced to NADPH).



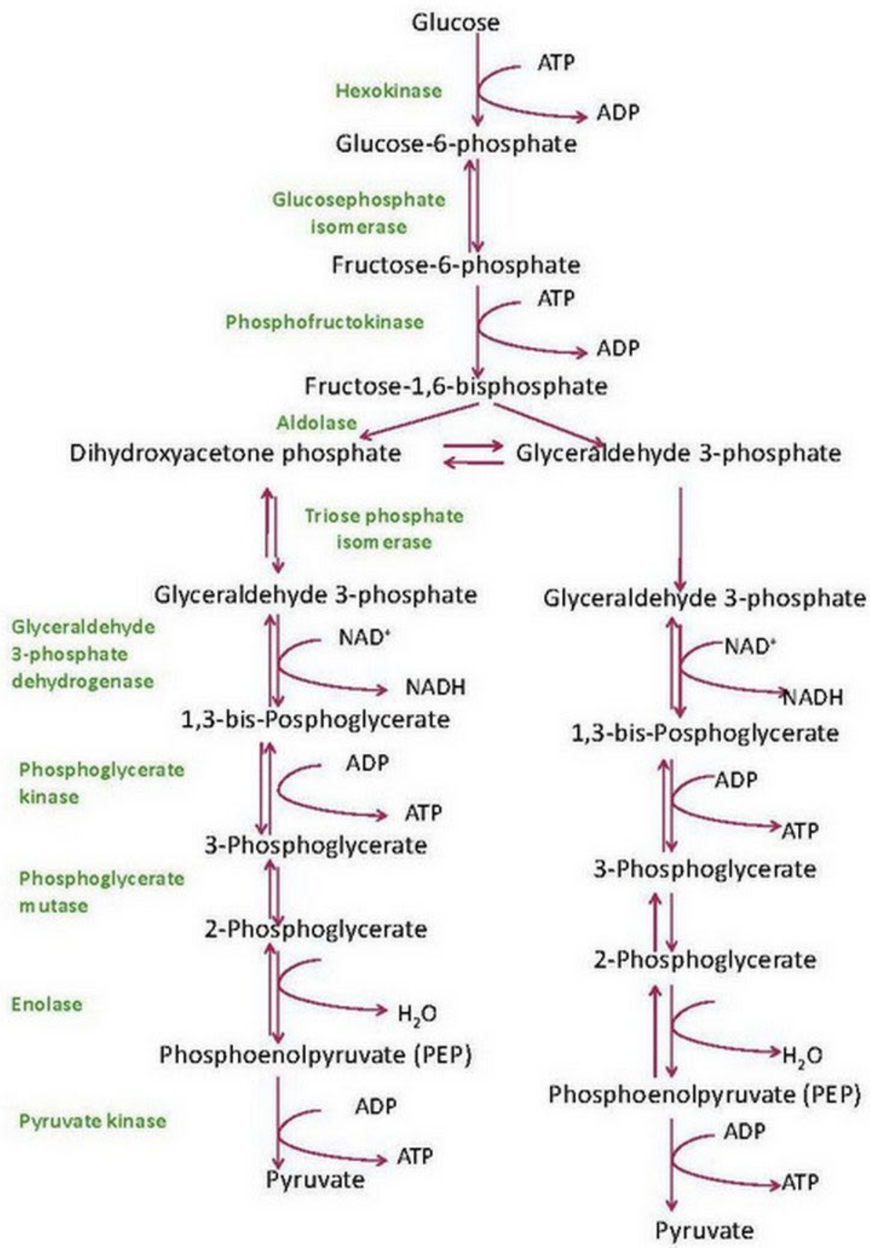
cyt = cytochrome; Fd = ferredoxin; pC = plastocyanin; pQ = plastoquinone; PS = photosystem

IV. Chemiosmosis & ATP Synthesis (Photophosphorylation)

This couples the electron flow to ATP production.

1. Building the Proton Gradient (Proton Motive Force):

- Protons (H⁺) accumulate in the **thylakoid lumen** from:



Fate of Pyruvate (Branch Points)

A. Aerobic Conditions: Complete Oxidation

1. **Pyruvate → Acetyl-CoA**
   - Enzyme: Pyruvate dehydrogenase complex (PDC)
   - Location: Mitochondrial matrix
   - Produces: 1 NADH, 1 CO_2, 1 acetyl-CoA per pyruvate
   - Acetyl-CoA enters TCA cycle → total ~30 ATP/glucose

B. Anaerobic Conditions: Fermentation

Purpose: Regenerate NAD^+ from NADH to sustain glycolysis

1. **Lactic Acid Fermentation (Animals, some bacteria)**
   - Enzyme: Lactate dehydrogenase (LDH)
   - Reaction: Pyruvate + NADH + H^+ ⇌ Lactate + NAD^+

High-carb diet: RQ → 1.0
High-fat diet: RQ → 0.70
RQ During Different Activities
Resting Conditions:

- Sedentary individual: RQ ≈ 0.82
- After carbohydrate meal: RQ ↑ (up to 1.0)
- After fat meal: RQ ↓ (toward 0.70)

SUMMARY TABLE: Key RQ Values

Condition/Substrate	RQ Value	Interpretation
Pure glucose	1.00	Complete carbohydrate oxidation
Pure fat	0.70-0.71	Complete fat oxidation
Pure protein	~0.82	Average amino acid oxidation
Mixed diet	0.82-0.85	Typical human metabolism
Starvation	0.70-0.73	Fat and ketone oxidation
Postprandial	0.85-1.00	Carbohydrate utilization
Lipogenesis	>1.00	Net conversion of carbs to fat
Anaerobic	>1.00	Lactate buffering produces CO_2
Malate oxidation	1.33	Organic acid metabolism in plants

Most Important MCQs

1. The primary source of energy for most living organisms is:
A. Glucose
B. ATP
C. Sunlight
D. Heat
Correct Answer: Sunlight

2. The process by which plants convert light energy into chemical energy is called:
A. Respiration
B. Photosynthesis
C. Transpiration
D. Fermentation
Correct Answer: Photosynthesis

3. The overall chemical equation for photosynthesis is:
A. C6H12O6 + 6O2 → 6CO2 + 6H2O + energy
B. 6CO2 + 6H2O → C6H12O6 + 6O2
C. C6H12O6 → 2C2H5OH + 2CO2
D. 6CO2 + 12H2O → C6H12O6 + 6O2 + 6H2O
Correct Answer: 6CO2 + 12H2O → C6H12O6 + 6O2 + 6H2O

4. The organelles where photosynthesis takes place are:
A. Mitochondria
B. Ribosomes
C. Chloroplasts
D. Leucoplasts
Correct Answer: Chloroplasts

5. The main photosynthetic pigment in green plants is:
A. Chlorophyll a
B. Chlorophyll b
C. Xanthophyll
D. Carotene
Correct Answer: Chlorophyll a

6. Which part of the chloroplast contains the photosynthetic pigments?
A. Stroma
B. Granum
C. Thylakoid membrane
D. Inner membrane
Correct Answer: Thylakoid membrane

7. The light-independent reactions of photosynthesis occur in the:
A. Thylakoid lumen
B. Stroma
C. Grana
D. Intermembrane space
Correct Answer: Stroma

8. During the light reactions of photosynthesis, the initial electron donor is:
A. NADP+
B. Water
C. Oxygen
D. Carbon dioxide
Correct Answer: Water

Chapter: 23

Plant Ecology

Core Definitions

- **Ecology**: Scientific study of interactions between organisms and their biotic and abiotic environment. Coined by Ernst Haeckel from Greek *oikos* (household) + *logy* (study).
- **Ecosystem**: Dynamic complex of biotic communities and their abiotic environment interacting as a functional unit through energy flows and biogeochemical cycles. Coined by Arthur Tansley (1935) to emphasize interconnectedness.
- **Environment**: All abiotic (non-living: climate, soil, water) and biotic (living: plants, animals, microbes) factors influencing an organism.
- **Biosphere**: Thin, life-supporting layer of Earth where all ecosystems exist.

Levels of Ecological Organization

1. **Organism**: Individual living entity.
2. **Population**: Group of interbreeding individuals of the same species in a specific area.
3. **Community**: Assemblage of different populations living and interacting in a defined area.
4. **Ecosystem**: Community + physical environment, interacting through nutrient cycling and energy flow.
5. **Biome**: Large geographical region with distinct climate and characteristic community.
6. **Biosphere**: All ecosystems collectively.

Key Ecological Concepts

- **Habitat**: Physical space where an organism lives.
- **Ecological Niche**: Multidimensional concept describing the functional role of a species (resources used, conditions tolerated).
  - *Fundamental Niche*: Full range theoretically usable.
  - *Realized Niche*: Actual range occupied due to interspecific interactions.
- **Metapopulation**: Set of local populations linked by immigration/emigration. The **Glanville fritillary butterfly** in Finland exists as scattered local populations in dry meadows, connected by occasional migration.
- **Symbiosis**: Close, long-term biological interaction between two different species (parasitic, mutualistic, or commensal).
- **Mutualism**: Clownfish and sea anemones.
- **Parasitism**: Tapeworms in mammals.
- **Commensalism**: Barnacles on whales.

History of Plant Ecology

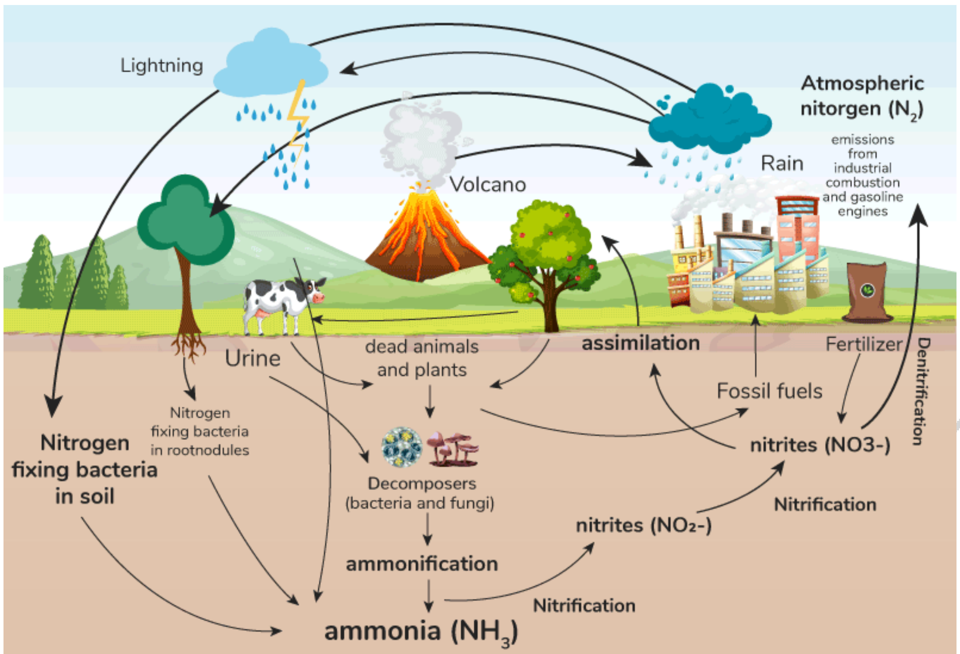
I. Pre-Scientific Foundations & Early Observations

- **Ancient & Indigenous Knowledge (Pre-18th Century):**
  - **Philosophical Foundations:** Theophrastus (c. 371–287 BC), a student of Aristotle, wrote *"Historia Plantarum,"* describing plant habits, distribution, and responses to environment—considered a precursor to botany and ecology.
  - **Herbalists & Naturalists:** Renaissance herbals (e.g., by Brunfels, Fuchs) included habitat notes. John Ray (1627–1705) advanced plant classification and observed plant distributions.

II. The Birth of Plant Ecology (18th - Mid-19th Century)

by *Nitrosomonas* → NO_3^- by *Nitrobacter*), **assimilation**, **ammonification**, **denitrification** (by *Pseudomonas*), and **anammox** (anaerobic ammonium oxidation).

- **Key Compounds:** Reactive nitrogen forms: **Ammonia** (NH_3), **Ammonium** (NH_4^+), **Nitrite** (NO_2^-), **Nitrate** (NO_3^- – highly leachable), **Nitrous oxide** (N_2O – 265x CO_2 potency), and NO_x gases.
- **Human Impact:** Human creation of reactive N **exceeds natural fixation**; **nitrate pollution** in groundwater (>10 mg/L is unsafe); N-based smog and aerosols; **biological magnification** not significant for N.
- **Ecological Role:** Limiting nutrient in most terrestrial/marine systems; determines primary productivity; **legume-rhizobium symbiosis** is classic mutualism.



Phosphorus Cycle

- **Major Reservoirs: Sedimentary rocks** (apatite – primary source), soil (bound to Fe, Al, Ca ions), ocean sediments, living biomass.
- **Core Processes: Geological uplift & weathering** (slow, limiting step), **mineralization** (by decomposers), **plant uptake**, **immobilization** (into microbial biomass), **sedimentation**, and **no gaseous loss phase**.
- **Key Compounds: Orthophosphate** ($H_2PO_4^-/HPO_4^{2-}$ – plant available), **organic phosphates** (in DNA, ATP, phospholipids), and **insoluble mineral phosphates**.
- **Human Impact: Mined for fertilizers** (guano, rock phosphate); **runoff causes cultural eutrophication** (P is typical **limiting factor in freshwater**); detergent phosphates banned in many regions.
- **Ecological Role:** Component of **ATP** (energy currency), **nucleic acids**, **phospholipid bilayers**, and bones/teeth (apatite).
- **MCQ Points:** Cycle is **slowest and mostly sedimentary**; **Mycorrhizal fungi** massively increase plant P uptake; **P availability is pH-dependent** (max at pH 6.5); **N:P Redfield Ratio** in oceans is 16:1.

5. **Solutions require integrated approach:** Engineering + agronomic + policy + community participation.
6. **Social justice dimension:** Smallholders most vulnerable, need targeted support.

Key Institutions Working on Salinity in Pakistan:

- **PCRWR** (Pakistan Council of Research in Water Resources)
- **WAPDA** (Water and Power Development Authority)
- **NARC** (National Agricultural Research Centre)
- **SAU** (Sindh Agriculture University)
- **UAF** (University of Agriculture Faisalabad)
- **Soil Survey of Pakistan**

Stress Factor	Core Problem	Key Plant Response	Primary Reclamation Focus
Aridity	**Absolute water deficit** (Low P, High PET)	Drought avoidance/tolerance (xeromorphy)	**Water Conservation & Harvesting**
Water Logging	**Oxygen deficit** in root zone (Anaerobic soil)	Root hypoxia, toxin accumulation	**Drainage** (Surface & Subsurface)
Salinity	**Osmotic & ionic stress** (High salt concentration)	Osmotic adjustment, ion exclusion/sequestration	**Leaching & Chemical Amendments** (requires drainage)

These three abiotic stresses are often interconnected (e.g., irrigation in **arid** areas can cause **water logging**, which leads to **salinity**), requiring integrated management approaches.

EROSION

1. Definition

- **Erosion**: The process by which soil, rock, or dissolved material is **worn away, transported, and deposited** from one location to another by natural agents (water, wind, ice, gravity).
- **Accelerated Erosion**: Human activities that significantly increase natural erosion rates.
- **Distinction from Weathering**: Weathering is the *in-situ* breakdown of rocks; erosion involves *transport* of weathered material.

2. Causes of Erosion

A. Natural (Geological) Erosion

1. **Water Erosion**:
    - **Raindrop Impact**: Dislodges soil particles.
    - **Sheet Erosion**: Thin, uniform removal of soil surface.
    - **Rill Erosion**: Small channels (<30 cm deep).
    - **Gully Erosion**: Larger channels (>30 cm deep, cannot be removed by tillage).
    - **Stream/River Erosion**: Bank cutting, scouring.
    - **Coastal Erosion**: Wave action, tidal currents.
2. **Wind Erosion**:
    - **Saltation**: Bouncing of medium-sized particles.
    - **Suspension**: Fine particles carried long distances.
    - **Creep**: Rolling/sliding of large particles.
3. **Glacial Erosion**:

- **Abrasion**: Rock debris dragged by glacier scrapes bedrock.
- **Plucking**: Glacier freezes onto and pulls away bedrock.

4. **Mass Movement**:
   - **Landslides, slumps, debris flows** driven by gravity.

B. Anthropogenic Causes (Accelerated Erosion)

1. **Deforestation**: Removal of vegetative cover increases surface runoff.
2. **Overgrazing**: Reduces grass cover, compacts soil.
3. **Poor Agricultural Practices**:
   - **Monocropping**: Reduces soil structure.
   - **Excessive tillage**: Breaks down soil aggregates.
   - **Farming on steep slopes** without terracing.
   - **Bare fallow periods**.
4. **Construction & Urbanization**:
   - Soil exposure, compaction, altered drainage.
5. **Mining Activities**: Exposes large areas.
6. **Fire**: Destroys vegetation cover.
7. **Improper Water Management**:
   - Poor irrigation causing channel erosion/salinization.

DESERTIFICATION

- **Desertification**: The **persistent degradation** of dryland ecosystems (arid, semi-arid, and dry sub-humid areas) due to human activities and climatic variations.
- **Key UNCCD Definition**: "Land degradation in arid, semi-arid, and dry sub-humid areas resulting from various factors, including climatic variations and human activities."
- **Not Simply Desert Expansion**: It's a process of **land degradation**, not necessarily advancing deserts.
- **Affects ~40% of Earth's land area**, home to ~2 billion people.

Practice MCQs

1. Who coined the term "ecology"?
A) Arthur Tansley
B) Ernst Haeckel
C) Charles Darwin
D) Joseph Grinnell
Answer: Ernst Haeckel

2. The term "ecosystem" was coined by:
A) Ernst Haeckel
B) Robert Paine
C) Arthur Tansley
D) Eugene Odum
Answer: Arthur Tansley

3. All the ecosystems on Earth collectively form the:
A) Community
B) Biome
C) Biosphere
D) Hydrosphere
Answer: Biosphere

4. A group of interbreeding individuals of the same species in a specific area is a:
A) Community
B) Population
C) Guild
D) Ecosystem
Answer: Population

5. The physical space where an organism lives is its:
A) Niche
B) Territory
C) Habitat

Chapter 24

Environmental Biology

Key Terms

- **Ecology:** The scientific study of the interactions between organisms and their environment.
- **Ecosystem:** A community of living organisms (biotic factors) interacting with their non-living (abiotic) physical and chemical environment.
- **Biosphere:** The global sum of all ecosystems; the zone of life on Earth (from the deep crust to the lower atmosphere).
- **Biotic Factors:** The living components of an ecosystem (e.g., plants, animals, bacteria, fungi).
- **Abiotic Factors:** The non-living physical and chemical components of an ecosystem (e.g., sunlight, temperature, water, minerals, pH).
- **Habitat:** The specific place or environment where an organism lives.
- **Niche:** The role and position a species has in its environment, including all its interactions with biotic and abiotic factors (its "ecological job").

Levels of Organization

- **Population:** A group of interbreeding individuals of the same species living in the same area.
- **Community:** All the populations of different species that live and interact in a particular area.
- **Biome:** A large geographic area with a characteristic climate and distinctive plant and animal communities (e.g., tropical rainforest, tundra, desert).

Energy Flow & Trophic Dynamics

- **Primary Producer (Autotroph):** An organism that produces its own organic compounds from inorganic sources via photosynthesis or chemosynthesis (e.g., plants, algae, some bacteria).
- **Consumer (Heterotroph):** An organism that obtains energy by consuming other organisms.
- **Trophic Level:** The position an organism occupies in a food chain (e.g., producer, primary consumer, secondary consumer).
- **Food Chain:** A linear sequence of organisms through which energy and nutrients pass.
- **Food Web:** A complex network of interconnected food chains, showing multiple feeding relationships.
- **Ecological Pyramid:** A graphical representation of the biomass, numbers, or energy at each trophic level (typically shows energy loss).
- **Biomass:** The total mass of living organic matter in a given area or trophic level.
- **Decomposer:** Organisms (like fungi and bacteria) that break down dead organic material, returning nutrients to the ecosystem.
- **Detritivore:** An organism that feeds on dead organic matter (detritus), facilitating decomposition (e.g., earthworms, woodlice).

Biogeochemical Cycles

- **Biogeochemical Cycle:** The pathway by which a chemical substance (e.g., water, carbon, nitrogen, phosphorus) moves through biotic and abiotic compartments of Earth.
- **Nitrogen Fixation:** The process by which certain bacteria convert atmospheric nitrogen (N_2) into ammonia (NH_3), making it usable by plants.
- **Eutrophication:** Excessive nutrient enrichment (often by nitrogen and phosphorus from fertilizers) of a water body, leading to algal blooms, oxygen depletion, and ecosystem degradation.

Species Interactions

- **Symbiosis:** A close, long-term interaction between two different biological organisms.
  - **Mutualism:** Both species benefit (e.g., pollinators and flowers).
  - **Commensalism:** One benefits, the other is unaffected (e.g., barnacles on a whale).

Natural Resources

1. Introduction

Natural resources are materials and components (natural assets) that occur in nature and can be used for economic gain or to support life. They form the foundation of human civilization, providing everything from food and water to energy and raw materials for industry.

Natural resources are **finite**, and their exploitation must be balanced with their renewal rates to ensure long-term sustainability.

2. Classification of Natural Resources

Resources are primarily classified based on their **rate of replenishment** relative to human consumption.

A. Renewable Resources

Resources that can be **replenished naturally** over relatively short periods (from days to decades) through natural cycles.

Characteristics:

- Can be used **indefinitely** if managed sustainably.
- Regeneration rate must exceed or equal the rate of consumption.
- Often flow-based (e.g., solar energy, wind) or biological (e.g., forests, fisheries).

Examples:

- **Solar Energy**
- **Wind Energy**
- **Hydropower (Water Flow)**
- **Geothermal Heat**
- **Biomass (Wood, Biofuels)**
- **Fresh Water** (through the hydrological cycle)
- **Forests** (if replanted)
- **Fisheries and Wildlife** (if populations are maintained)

Renewable resources can become **depleted or degraded** if used at a rate faster than they can renew (e.g., deforestation, overfishing, aquifer depletion). Their renewability is **conditional** on sustainable management.

B. Non-Renewable Resources

Resources that exist in a **fixed quantity** on Earth or that regenerate over **geological timescales** (millions of years), making them effectively finite for human use.

Characteristics:

- **Stock-limited:** Once consumed, they are gone for practical purposes.
- Formation rate is **negligibly slow** compared to consumption.
- Often involve **high extraction costs** and significant environmental impact.

Subcategories and Examples:

Category	Description	Examples
Fossil Fuels	Formed from ancient organic matter under heat and pressure over millions of years.	**Coal, Petroleum (Crude Oil), Natural Gas.**
Metallic Minerals	Ores containing metals, extracted and refined.	**Iron, Copper, Aluminum, Gold, Rare Earth Elements** (used in electronics, magnets).
Non-Metallic Minerals	Industrial rocks and minerals.	**Limestone** (cement), **Phosphate Rock** (fertilizer), **Sand & Gravel** (construction), **Potash.**
Nuclear Fuels	Elements that undergo fission to release energy.	**Uranium-235, Thorium.**

3. Major Greenhouse Gases (GHGs)

Gas	Chemical Formula	Primary Anthropogenic Sources	*Global Warming Potential (GWP) over 100 years*	Atmospheric Lifetime	Contribution to Warming
Carbon Dioxide	CO_2	**Fossil Fuel Combustion** (coal, oil, gas), **Deforestation**, Cement production.	**1** (The Baseline)	**Centuries** (20-2000 yrs, some permanent)	**~76%** of total forcing (Dominant driver)
Methane	CH_4	Agriculture (livestock digestion, rice paddies), Fossil fuel extraction (leaks), Landfills, Wastewater.	**27-30** (27-30x more potent than CO_2)	**~12 years**	**~16%** (Potent short-term forcer)
Nitrous Oxide	N_2O	Agricultural soils (synthetic fertilizers), Industrial processes, Fossil fuel combustion, Biomass burning.	**273** (273x more potent than CO_2)	**~121 years**	**~6%** (Long-lived & potent)
Fluorinated Gases (F-gases)	HFCs, PFCs, SF_6, NF_3	Refrigerants, Aerosols, Solvents, Electrical insulation.	**Thousands to tens of thousands** (e.g., SF_6 = 23,500)	**Decades to millennia**	**~2%** (Extremely potent, small but growing)
Water Vapor	H_2O	**Feedback agent, not a primary driver.** Evaporation increases in response to warming caused by other GHGs (positive feedback loop).	Variable	**~9 days**	Major amplifier, not an initial trigger.

4. Human Activities Intensifying the Greenhouse Effect

A. Fossil Fuel Combustion (The #1 Contributor)

- Burning **coal, oil, and natural gas** for **energy, electricity, and transportation** releases **billions of tons of CO_2** stored underground for millions of years into the atmosphere in decades.
- Accounts for **~65%** of all human-caused GHG emissions.

B. Deforestation and Land Use Change

- Forests are **carbon sinks**. Cutting/burning them:
  1. Releases stored carbon as CO_2.
  2. Removes future CO_2 absorption capacity.
- Responsible for **~11%** of global GHG emissions (mostly CO_2, some CH_4 from burning).

C. Agriculture

- **Methane** from enteric fermentation in livestock (cattle, sheep) and flooded rice paddies.
- **Nitrous Oxide** from microbial processes in soils over-fertilized with nitrogen.

D. Industrial Processes

- Cement production (releases CO_2 from limestone), chemical manufacturing, and leaks of F-gases.

5. Observed Impacts of the Enhanced Greenhouse Effect

Unequivocal Evidence:

- **Global Temperature Rise:** The last decade (2014-2023) was the **hottest on record**. Earth is now **~1.2°C warmer** than pre-industrial (1880) levels.
- **Changing Precipitation Patterns:** Wet regions get wetter (more intense rainfall, flooding), dry regions get drier (more severe droughts).

Past Papers MCQs

1. Ornithology is the study of:
A. Insects
B. Bee keeping
C. Birds
D. Fossils
Correct Answer= C
2. Study of life in outer space is called:
A. Exobiology
B. Eugenics
C. Ethology
D. Anthropology
Correct Answer= A
3. Chlorophyll is a/an molecule:
A. Inorganic
B. Cationic
C. Anionic
D. Organic
Correct Answer= D
4. Taking in of liquid material into the cells is known as:
A. Phagocytosis
B. Pinocytosis
C. Exocytosis
D. None of these
Correct Answer= B
5. The type of plastids which help in pollination is:
A. Chromoplasts
B. Leukoplasts
C. Chloroplasts
D. All of these
Correct Answer= A
6. Cycas & Adiantum resemble each other in having:
A. Cambium
B. Vessels
C. Seeds
D. Motile sperms
Correct Answer= D
7. In chlorophyceae, the mode of sexual reproduction is:
A. Isogamy
B. Anisogamy
C. Oogamy
D. All of these
Correct Answer= D
8. Which of the following is known as resurrection plant?
A. Rafflesia
B. Selaginella
C. Chlorella
D. Welwitschia
Correct Answer= B
9. Meiosis in Dryopteris takes place during:
A. Spore formation
B. Gamete formation
C. Sperm formation
D. Spore germination
Correct Answer= A
10. Ectophloic siphonostele is found in:
A. Adiantum
B. Marsilea
C. Osmunda
D. All of these
Correct Answer= C
11. Cuscuta is:
A. Partial stem parasite
B. Total stem parasite
C. Epiphyte
D. Total root parasite
Correct Answer= B
12. Fibrous roots develop in maize from:
A. Lower nodes
B. Upper nodes
C. Lower internodes
D. Upper internodes
Correct Answer= A
13. Roots of Dahlia are:
A. Naphthol
B. Fasciulated
C. Fibrous
D. Assimilatory
Correct Answer= B
14. Vegetative reproduction in Colocasia takes place through:
A. Sucker
B. Rhizome

C. Offset
D. Corm
Correct Answer= D
15. Zigzag development of inflorescence axis is an example of:
A. Heliocarpus
B. Verticillaster
C. Scorpidium
D. Spadix
Correct Answer= B
16. Smallest flower is of:
A. Wolfia microscopic
B. Rafflesia arnoldii
C. Carica Papaya
D. Colocasia antiquorum
Correct Answer= A
17. In Bougainvillea, the large coloured structures are:
A. Epidermis
B. Coloured Sepals
C. Coloured petals
D. Petaloid bracts
Correct Answer= D
18. Gynobasic style is found in:
A. Ranunculus
B. Ocimum
C. Coleus
D. Centella
Correct Answer= B
19. In Ruellia tuberosa seeds are dispersed by:
A. Parachute mechanism
B. Censor mechanism
C. Jaculator mechanism
D. None of these
Correct Answer= C
20. Pappus helps in seed dispersal in:
A. Brassicaceae
B. Asteraceae
C. Malvaceae
D. Solanaceae
Correct Answer= B
21. Plants capable of growing in nitrogen deficient soil is:
A. Orchids
B. Ferns
C. Insectivorous plants
D. None of these
Correct Answer= C
22. Gray spots of oat are caused by deficiency of:
A. Cu
B. Fe
C. Zn
D. Mn
Correct Answer= D
23. Which of the following is correct set of micronutrient for plants?
A. Mg, Si, Fe, Cu, Ca
B. Cu, Fe, Zn, B, Mn
C. Mg, Fe, Zn, B, Mn
D. Mn, Zn, Cl, Mg, Ca
Correct Answer= B
24. The assimilatory power in photosynthesis is:
A. ATP
B. NADPH
C. ATP & NADPH
D. ATP, NADPH & CO_2
Correct Answer= C
25. Photosynthesis will proceed upto:
A. Limit of temperature
B. Limit of wind
C. Limit of light
D. Limit of moisture
Correct Answer= C
26. Krantz type of anatomy is found in:
A. C_2 plants
B. C_3 plants
C. C_4 plants
D. CAM plants
Correct Answer= C
27. Munch mass flow hypothesis explains:
A. Transcription
B. Translocation
C. Transpiration
D. Translation
Correct Answer= B
28. A plant requires magnesium for:
A. Chlorophyll synthesis
B. Protein synthesis
C. Cell development
D. Holding cells together
Correct Answer= A

E. Protostele
Correct Answer= E
352. Higher gymnosperms differ from pteridophytes in having well-defined
A. Primary growth
B. Secondary growth
C. Re-growth
D. Retrospective growth
E. Progressive growth
Correct Answer= B
353. The seed formation in gymnosperms occur due to permanent retention of
A. Microspore
B. Megaspore
C. Nanospore
D. Statospore
E. Hypnospore
Correct Answer= B
354. Point of attachment of seed inside ovary is called
A. Locule
B. Placenta
C. Receptacle
D. Funiculus
E. Follicle
Correct Answer= D
355. The ending suffix for orders is
A. --ya
B. --ceae
C. --dae
D. --ale
E. --cota
Correct Answer= D
356. Phylogenetic system of classification is based on:
A. Morphological relationships of organisms
B. Evolutionary relationship of organisms
C. Cytological relationship of organisms
D. Chromosomal relationship of organisms
E. Biochemical relationship of organisms
Correct Answer= B
357. The stems with hollow internodes are known as
A. Jointed stems
B. Cylindrical stems
C. Herbaceous stems
D. Flattened stems
E. Fistulary stems
Correct Answer= E
358. Two major products of light reaction of photosynthesis are
A. ATP & NADH
B. ATP & $FADH_2$
C. ATP & CoA
D. ATP & NADPH
E. NADPH & CoA
Correct Answer= D
359. The compound acting as chromophore in the phytochrome is
A. Phytochromeobillin
B. Phycocyanobilin
C. Phycoerythrobilin
D. Phytophaeobilin
E. Phycorhodobilin
Correct Answer= A
360. In mitochondrial electron transport chain, the oxidation of complex III and reduction of complex IV is mediated by:
A. Cytochrome a
B. Cytochrome b
C. Cytochrome c
D. Cytochrome d
E. Cytochrome f
Correct Answer= C
361. The culminating stage of plant succession in a given ecosystem is:
A. Clime
B. Climate
C. Climax
D. Cleaves
E. Connectance
Correct Answer= C
362. Function of enzyme reverse transcriptase is:
A. Synthesis of cDNA from mRNA
B. Synthesis of mRNA from DNA
C. Synthesis of tRNA from mRNA
D. Synthesis of cDNA from mRNA
E. Synthesis of cDNS from tRNA
Correct Answer= A
363. Diagnosis of a genetic condition before the appearance of symptoms is:
A. Morphological diagnosis