FUNDAMENTALS OF MICROBIOLOGY

UNIT 1

INTRODUCTION AND TAXONOMY OF MICROORGANISMS

THALLOPHYTES

Thallophytes are a diverse group of primitive, non-vascular plants that lack true stems, roots, and leaves. These organisms are predominantly simple and primarily include algae, fungi, and lichens. They were historically classified under the plant kingdom but are now placed in various taxonomic groups based on modern classification systems.

Characteristics of Thallophytes:

Thallus Structure: The body is a thallus, meaning it is not differentiated into true roots, stems, and leaves.

Vascular System: They lack a vascular system (xylem and phloem) for water and nutrient transport.

Reproduction: They reproduce both sexually and asexually.

Asexual reproduction occurs via spores, fragmentation, or binary fission.

Sexual reproduction involves gametes, which may be isogamous, anisogamous, or oogamous.

Habitat: They are primarily aquatic (algae), terrestrial (fungi), or symbiotic (lichens).

Nutrition: Algae are autotrophic, performing photosynthesis.

Fungi are heterotrophic, either saprophytic or parasitic.

Lichens exhibit a mutualistic association between algae and fungi.

Cell Wall: The cell wall is present, composed of cellulose in algae and chitin in fungi.

SUB GROUPS OF THALLOPHYTES

Algae: Photosynthetic organisms found in freshwater, marine, or moist terrestrial habitats.

- Examples: Chlamydomonas, Spirogyra, and Ulva.

Fungi: Non-photosynthetic organisms that obtain nutrients through absorption.

- Examples: Penicillium, Aspergillus, and Saccharomyces.

Lichens: Symbiotic associations between fungi and algae or cyanobacteria.

- Examples: Cladonia and Parmelia.

Modern Classification:

With advancements in molecular biology and genetics, the term "Thallophytes" is now considered obsolete in strict taxonomy. Organisms once grouped as Thallophytes are now classified under different kingdoms:

Algae in **Kingdom Plantae** or **Kingdom Protista**.

Fungi in **Kingdom Fungi**.

Lichens as symbiotic entities involving members from multiple kingdoms.

GENERAL CHARACTERISTICS OF ALGAE

Algae are a diverse group of photosynthetic organisms that are primarily aquatic. They can be unicellular or multicellular, and their sizes range from microscopic forms to large seaweeds. Algae are classified as autotrophs, meaning they can produce their own food through photosynthesis.

Key Characteristics

Habitat:

- Predominantly aquatic (found in freshwater, marine, and brackish environments).
- Some species are terrestrial and grow in moist soil, rocks, or tree bark.

Thallus Structure:

- The body of algae is called a *thallus* and lacks true roots, stems, and leaves.
- It can be unicellular (e.g., *Chlamydomonas*), colonial (e.g., *Volvox*), filamentous (e.g., *Spirogyra*), or complex multicellular (e.g., *Ulva* and *Kelp*).

Photosynthetic Pigments:

Contain chlorophyll (types a, b, c, or d) and accessory pigments like carotenoids, xanthophylls, and phycobilins.

The pigment composition varies depending on the group of algae.

Nutrition:

Mostly autotrophic, synthesizing their own food via photosynthesis.

Some are mixotrophic (e.g., *Euglena*), capable of both autotrophy and heterotrophy.

GENERAL CHARACTERISTICS OF ALGAE (KEY CHARACTERISTICS)

Reproduction:

- **Asexual reproduction**: By binary fission, fragmentation, or spore formation.
- **Sexual reproduction**: Involves gametes that may be isogamous (similar), anisogamous (dissimilar), or oogamous (large immobile egg and small motile sperm).
- **Cell Wall**: Composed of cellulose, pectin, or polysaccharides. Some algae, such as diatoms, have cell walls made of silica (forming a frustule).
- **Storage Products**: Store food as starch, laminarin, mannitol, or oils, depending on the group.
- **Movement**: Some unicellular algae have flagella for motility (e.g., *Chlamydomonas*). Others are non-motile and depend on water currents for dispersal.

Ecological Role: Primary producers in aquatic ecosystems. Contribute to oxygen production through photosynthesis. Serve as the base of the food chain in marine and freshwater systems.

1. **Economic Importance**: Source of food (e.g., *Porphyra*, *Laminaria*). Used in the production of agar, alginates, and carrageenan, Biofuel production from algal biomass, Nutraceuticals, cosmetics, and fertilizers.

CLASSIFICATION OF ALGAE

Based on pigmentation, habitat, and cellular organization, algae are classified into different groups:

Chlorophyceae (Green algae):Contain chlorophyll a and b.

- Examples: *Chlamydomonas*, *Spirogyra*, *Ulva*.

Phaeophyceae (Brown algae):Contain chlorophyll a, c, and fucoxanthin.

- Examples: *Fucus*, *Laminaria*, *Sargassum*.

Rhodophyceae (Red algae):

- Contain chlorophyll a and phycoerythrin. Examples: *Polysiphonia*, *Gelidium*, *Gracilaria*.
- Diatoms:
- Unicellular algae with silica-based cell walls.
- Examples: *Navicula*, *Coscinodiscus*.

Dinoflagellates:

- Flagellated algae with cellulose plates.
- Examples: *Noctiluca*, *Ceratium*.

Euglenophyceae (Euglenoids):

- Mixotrophic algae with flexible pellicles.
- Example: *Euglena*.

OUTLINES OF VARIOUS CLASSIFICATIONS

1. Fritsch’s Classification (1945)

A widely used traditional classification based on pigmentation, thallus structure, reproduction, and storage products.

Class 1: *Chlorophyceae* (Green algae)

- Pigments: Chlorophyll a and b.
- Storage: Starch.
- Examples: *Spirogyra*, *Chlamydomonas*.

Class 2: *Phaeophyceae* (Brown algae)

- Pigments: Chlorophyll a, c, and fucoxanthin.
- Storage: Laminarin, mannitol.
- Examples: *Sargassum*, *Laminaria*.

Class 3: *Rhodophyceae* (Red algae)

- Pigments: Chlorophyll a, phycoerythrin.
- Storage: Floridean starch.
- Examples: *Gelidium*, *Gracilaria*.

OUTLINES OF VARIOUS CLASSIFICATIONS

Class 4: *Xanthophyceae* (Yellow-green algae)
- Pigments: Chlorophyll a, c, and xanthophylls.
- Storage: Oil, leucosin.
- Examples: *Vaucheria*, *Tribonema*.

Class 5: *Bacillariophyceae* (Diatoms)
- Pigments: Chlorophyll a, c, and carotenoids.
- Storage: Oil, chrysolaminarin.
- Examples: *Navicula*, *Coscinodiscus*.

Class 6: *Dinophyceae* (Dinoflagellates)
- Pigments: Chlorophyll a, c, and peridinin.
- Examples: *Ceratium*, *Noctiluca*.

Class 7: *Euglenophyceae* (Euglenoids)
- Mixotrophic.
- Examples: *Euglena*.

OUTLINES OF VARIOUS CLASSIFICATIONS

2. Lee’s Modern Classification (1989)

Based on cellular organization and molecular characteristics, algae were grouped into **divisions** within the *Kingdom Protista* and *Kingdom Plantae*.

Kingdom: Protista

- **Division Chlorophyta** (*Green algae*): *Chlamydomonas*, *Ulva*.
- **Division Chromophyta** (*Brown algae and Diatoms*): *Fucus*, *Navicula*.
- **Division Rhodophyta** (*Red algae*): *Porphyra*, *Gelidium*.
- **Division Dinophyta** (*Dinoflagellates*): *Ceratium*, *Noctiluca*.
- **Division Euglenophyta** (*Euglenoids*): *Euglena*.

3. Bold and Wynne’s Classification (1985)

Based on evolutionary trends in algae, it groups them as **phyla**.

- **Phylum Chlorophyta** (*Green algae*): *Chlamydomonas*, *Spirogyra*.
- **Phylum Rhodophyta** (*Red algae*): *Gracilaria, Gelidium*.
- **Phylum Phaeophyta** (*Brown algae*): *Sargassum*, *Laminaria*.
- **Phylum Chrysophyta** (*Golden algae*): *Vaucheria*, *Synura*.
- **Phylum Bacillariophyta** (*Diatoms*): *Navicula*, *Pinnularia*.
- **Phylum Dinophyta** (*Dinoflagellates*): *Ceratium*, *Noctiluca*.
- **Phylum Euglenophyta** (*Euglenoids*): *Euglena*.

OUTLINES OF VARIOUS CLASSIFICATIONS

4. Whittaker’s Five-Kingdom System (1969)

Algae are distributed between **Kingdom Protista** and **Kingdom Plantae**, based on complexity.

Kingdom Protista:

- Unicellular algae: *Chlamydomonas, Euglena*.
- Colonial algae: *Volvox*.

Kingdom Plantae:

- Multicellular algae: *Ulva, Laminaria, Gelidium*.
- 5. Cavalier-Smith’s Classification (1998)
- Based on molecular data and evolutionary lineage. Algae are grouped under **Kingdom Chromista** and **Kingdom Plantae**.

Kingdom Plantae:

- *Green algae*: Chlorophyta (e.g., *Spirogyra*).
- *Red algae*: Rhodophyta (e.g., *Porphyra*).

Kingdom Chromista:

- *Brown algae*: Phaeophyta (e.g., *Fucus*).
- *Diatoms*: Bacillariophyta (e.g., *Navicula*).
- 6. Molecular Phylogenetic Classification
- Modern classifications use molecular markers like 18S rRNA and chloroplast DNA to classify algae into evolutionary lineages:

Archaeplastida (Green and Red Algae).

- **Stramenopiles** (Brown Algae, Diatoms).
- **Alveolates** (Dinoflagellates).
- **Excavates** (Euglenoids).

REPRODUCTION IN NOSTOC

Nostoc is a filamentous cyanobacterium (blue-green algae) that reproduces both **asexually** and **sexually (through genetic recombination)**. It lacks true sexual reproduction but engages in genetic material exchange.

1. Asexual Reproduction

- Asexual reproduction in Nostoc occurs through the following methods:

a. **Fragmentation**:

- The trichome (a filament of cells) breaks into smaller fragments.
- These fragments, called **hormogonia**, grow into new filaments under favorable conditions.
- Hormogonia are motile and short-lived, facilitating dispersal.

b. **Akinetes**:

- Akinetes are thick-walled, spore-like resting cells.
- Formed under unfavorable environmental conditions such as desiccation or nutrient depletion.
- They store food and have a protective wall that allows them to survive adverse conditions.
- Upon the return of favorable conditions, akinetes germinate to produce new filaments.

c. **Binary Fission**:

- Each vegetative cell divides mitotically into two daughter cells.
- This process contributes to the elongation of the filament but is not a method of dispersal.

d. Heterocysts:

- Heterocysts are specialized nitrogen-fixing cells formed under nitrogen-deficient conditions.
- While they are not directly involved in reproduction, they play a critical role in survival by supporting the growth of vegetative cells.

REPRODUCTION IN NOSTOC

2. Genetic Recombination (Analogous to Sexual Reproduction)

- Although Nostoc does not undergo true sexual reproduction, genetic material exchange occurs through processes like:

a. Conjugation-like Mechanism:

- DNA is transferred from one cell to another, similar to bacterial conjugation.
- This allows for genetic variability.

b. Transformation:

- Nostoc can take up exogenous DNA from the environment and incorporate it into its genome.

Transduction:

- Viruses (bacteriophages) can mediate the transfer of genetic material between Nostoc cells.

REPRODUCTION IN CHLAMYDOMONAS

Reproduction in Chlamydomonas

- **Chlamydomonas** is a unicellular green alga that exhibits both **asexual** and **sexual reproduction**. The mode of reproduction depends on environmental conditions, with asexual reproduction occurring during favorable conditions and sexual reproduction occurring under stress.

1. Asexual Reproduction

- Occurs during favorable conditions and involves mitotic cell division. The methods include:

a. Binary Fission:

- The parent cell divides into two daughter cells by mitosis.
- Common in smaller species of *Chlamydomonas*.

b. Zoospore Formation:

- The parent cell undergoes multiple mitotic divisions to form 2, 4, or 8 motile zoospores within the parent cell wall.
- Zoospores are released after the parent cell wall ruptures.
- Each zoospore develops into a new *Chlamydomonas* individual.

c. Aplanospore Formation:

- During unfavorable conditions, non-motile aplanospores are produced.
- Aplanospores develop into new cells upon the return of favorable conditions.

d. Palmella Stage:

- In extremely unfavorable conditions, *Chlamydomonas* cells lose their flagella and secrete mucilage to form a non-motile, multicellular colony.
- When conditions improve, the cells regain flagella and become motile.

REPRODUCTION IN CHLAMYDOMONAS

2. Sexual Reproduction

- Occurs under un favorable environmental conditions (e.g., nutrient depletion, desiccation) and includes three main stages:

a. Gamete Formation:

- Haploid vegetative cells act as gametes.
- Gametes can be **isogamous** (similar in size), **anisogamous** (different in size), or **oogamous** (large immobile egg and small motile sperm) depending on the species of *Chlamydomonas*.

b. Gamete Fusion (Syngamy):

- Two compatible gametes fuse to form a **diploid zygote**.
- The zygote develops a thick wall, becoming a **zygospore**.
- The zygospore is resistant to harsh environmental conditions.

c. Germination:

- Under favorable conditions, the zygospore undergoes meiosis to produce four haploid cells.
- These haploid cells grow into new individuals.

SUMMARY OF REPRODUCTIVE METHODS IN *CHLAMYDOMONAS*:

Reproductive Type	Method	Key Features
Asexual	Binary fission, zoospores	Rapid population increase during favorable conditions.
Sexual	Gamete fusion, zygospore	Genetic recombination under stressful conditions.

REPRODUCTION IN SARGASSUM

Reproduction in Sargassum

- **Sargassum**, a genus of brown algae in the class *Phaeophyceae*, reproduces through both **asexual** and **sexual methods**. It has a complex life cycle involving the production of gametes and spores. Its mode of reproduction depends on environmental conditions.

1. Asexual Reproduction

- Asexual reproduction in *Sargassum* occurs through:

a. Fragmentation:

- The thallus (body) of the alga fragments into smaller pieces.
- Each fragment can grow into a new individual under suitable conditions.

b. Propagules:

- Special vegetative structures, called propagules, are formed.
- These structures detach from the parent and develop into new thalli.

2. Sexual Reproduction

- Sexual reproduction in *Sargassum* is **oogamous**, meaning it involves the fusion of a large, non-motile egg and a small, motile sperm. The process includes the following steps:

a. Receptacles Formation:

- Specialized reproductive structures, called **receptacles**, are formed at the tips of branches.
- Receptacles contain conceptacles, which are small chambers housing reproductive organs.

b. Development of Gametes:

- **Male organs (Antheridia)**:
  - Produce motile sperms.
- **Female organs (Oogonia)**:
  - Produce large, non-motile eggs.

REPRODUCTION IN SARGASSUM

c. Fertilization:

- Fertilization occurs in the water column when sperms are released and swim to the eggs.
- Fusion of gametes forms a **zygote**.

d. Zygote Development:

- The zygote settles on a suitable substrate and grows into a new diploid *Sargassum* individual.

3. Life Cycle of Sargassum

- *Sargassum* follows a **diplohaplontic life cycle**, but it is predominantly diploid. Key features include:
- **Dominant Diploid Sporophyte**:
  - The main thallus is a diploid sporophyte.
- **Reduced Haploid Gametophyte**:
  - Gametes are directly formed on the sporophyte, without a free-living gametophyte stage.

REPRODUCTION IN SARGASSUM

Reproductive Type	Method	Key Features
Asexual	Fragmentation, propagules	Rapid reproduction during favorable conditions.
Sexual	Oogamous (egg + sperm)	Genetic variation and adaptation under stress.

REPRODUCTION IN POLYSIPHONIA

Polysiphonia, a red alga belonging to the class Rhodophyceae, exhibits a complex life cycle involving **vegetative, asexual, and sexual reproduction**. Its reproduction is characterized by an alternation of generations, including gametophyte, carposporophyte, and tetrasporophyte phases.

1. Vegetative Reproduction

- **Fragmentation**: The thallus can break into fragments, and each fragment can grow into a new individual.
- This is a less common method of reproduction.

2. Sexual Reproduction

- Polysiphonia is **dioecious**, with separate male and female plants.
- Sexual reproduction is **oogamous**, involving non-motile female gametes and motile male gametes.

Male Reproductive Structures

- The male gametophyte produces **spermatangia** in clusters at the tip of branches.
- Spermatangia release **spermatia** (non-flagellated male gametes) into the water.

Female Reproductive Structures

- The female gametophyte bears **carpogonia** (specialized reproductive organs).
- The carpogonium consists of:
    - **Basal part**: Contains the egg cell.
    - **Trichogyne**: A long hair-like projection for capturing spermatia.

Fertilization

- Spermatia adhere to the trichogyne and fertilize the egg.
- The zygote develops into a **carposporophyte**, which remains attached to the female gametophyte.

REPRODUCTION IN POLYSIPHONIA

3. Asexual Reproduction

- The carposporophyte produces **carpospores**, which are diploid.
- Carpospores are released into the water and grow into a diploid tetrasporophyte.
- **Tetrasporophyte Phase**
- The tetrasporophyte is morphologically similar to the gametophyte.
- It produces **tetrasporangia**, which undergo meiosis to form **haploid tetraspores**.
- Tetraspores germinate to form new male and female gametophytes, completing the life cycle.

Key Features of the Life Cycle

1. **Triphasic Life Cycle**:
    1. Gametophyte (haploid).
    2. Carposporophyte (diploid, parasitic on the female gametophyte).
    3. Tetrasporophyte (diploid, free-living).
2. **Alternation of Generations**:
    1. Involves both haploid (n) and diploid (2n) phases.
3. **Non-motile Gametes**:
    1. Typical of red algae.

LIFE CYCLE AND ECONOMIC IMPORTANCE OF NOSTOC

1. Nostoc (Cyanobacteria)

Life Cycle:

- Nostoc exhibits a **haplontic life cycle**, meaning the dominant stage is **haploid** (n).
- It reproduces **asexually** through:
  - **Fragmentation**
  - **Heterocyst formation** (for nitrogen fixation)
  - **Akinetes** (thick-walled dormant spores for survival in harsh conditions)
- Sexual reproduction is absent.

Economic Importance:

- **Nitrogen Fixation**: Converts atmospheric nitrogen into ammonia, enriching soil fertility (used in rice paddies).
- **Biofertilizer**: Used in agriculture to improve crop yield.
- **Edible**: Some species are consumed in China and other Asian countries.
- **Pharmaceutical Uses**: Produces bioactive compounds with antimicrobial and anticancer properties.
- **Pollution Control**: Helps in wastewater treatment by removing heavy metals and excess nutrients.

LIFE CYCLE AND ECONOMIC IMPORTANCE OF CHLAMYDOMONAS

Chlamydomonas (Green Algae)

Life Cycle:

- Chlamydomonas has a **haplontic life cycle** with a dominant **haploid (n) phase**.
- Reproduces **asexually** via:
  - **Binary fission**
  - **Zoospore formation**
- **Sexual reproduction** occurs under unfavorable conditions:
  - **Isogamy** (similar gametes), **Anisogamy** (unequal gametes), or **Oogamy** (large immobile egg, small motile sperm).
  - The zygote (2n) undergoes meiosis to restore the haploid phase.

Economic Importance:

- **Biofuel Production**: Used in biodiesel production due to its high lipid content.
- **Oxygen Production**: Contributes to atmospheric oxygen via photosynthesis.
- **Bioremediation**: Used to remove heavy metals and pollutants from wastewater.
- **Food Supplement**: Rich in proteins and antioxidants, potential in nutritional supplements.
- **Genetic Research**: A model organism for studying photosynthesis and flagellar movement.

LIFE CYCLE AND ECONOMIC IMPORTANCE OF SARGASSUM

Sargassum (Brown Algae)

Life Cycle:

- Sargassum exhibits a **diplohaplontic life cycle** with **alternation of generations**.
- It has a **dominant diploid (2n) sporophyte stage**, while the haploid (n) gametophyte is reduced.
- **Asexual reproduction** occurs through fragmentation.
- **Sexual reproduction**:
  - Oogamous (large egg, small motile sperm).
  - Fertilization occurs in water, forming a diploid zygote that develops into a sporophyte.

Economic Importance:

- **Food Source**: Edible in some Asian countries.
- **Pharmaceutical Uses**: Contains bioactive compounds with antioxidant, anticancer, and antimicrobial properties.
- **Alginate Production**: Used in the food, textile, and pharmaceutical industries as a thickener and stabilizer.
- **Fertilizers & Animal Feed**: Used as organic manure and livestock feed.
- **Coastal Protection**: Forms floating mats in oceans, providing habitats for marine life.

LIFE CYCLE AND ECONOMIC IMPORTANCE OF POLYSIPHONIA (RED ALGAE)

Polysiphonia (Red Algae)

Life Cycle:

- Polysiphonia follows a **triphasic (diplohaplontic) life cycle**, with three generations:
  - **Gametophyte (n)** – Produces gametes.
  - **Carposporophyte (2n)** – Develops after fertilization and produces carpospores.
  - **Tetrasporophyte (2n)** – Produces tetraspores by meiosis, which grow into gametophytes.
- **Asexual reproduction** occurs via carpospores and tetraspores.

Economic Importance:

- **Agar Production**: Used in microbiology, pharmaceuticals, and food industries.
- **Carrageenan Source**: Used as a thickening agent in dairy and cosmetic products.
- **Anticancer and Antiviral Properties**: Contains bioactive compounds beneficial for medicine.
- **Marine Ecology**: Forms part of the marine food chain and provides habitat for aquatic organisms.

COMPARISON OF LIFE CYCLES

Organism	Type of Life Cycle	Dominant Phase	Asexual Reproduction	Sexual Reproduction	Special Features
Nostoc	Haplontic	Haploid (n)	Fragmentation, Heterocysts, Akinetes	Absent	Nitrogen fixation
Chlamydomonas	Haplontic	Haploid (n)	Binary fission, Zoospores	Isogamy, Anisogamy, Oogamy	Model organism
Sargassum	Diplohaplontic	Diploid (2n) Sporophyte	Fragmentation	Oogamous	Alginate production
Polysiphonia	Triphasic (Diplohaplontic)	Alternating	Carpospores, Tetraspores	Oogamous	Agar and carrageenan source

GENERAL CHARACTERISTICS OF FUNGI

Fungi are a diverse group of eukaryotic organisms that include **molds, yeasts, and mushrooms**. They belong to the kingdom **Fungi** and exhibit unique structural, reproductive, and physiological characteristics.

1. General Features

- **Eukaryotic**: Possess a well-defined nucleus and membrane-bound organelles.
- **Heterotrophic**: Obtain nutrients by absorbing organic matter (saprophytic, parasitic, or symbiotic).
- **Cell Wall**: Composed mainly of **chitin** (different from plant cell walls made of cellulose).
- **Unicellular or Multicellular**:
  - **Yeasts** are unicellular.
  - **Molds and mushrooms** are multicellular, forming networks of filaments.

2. Structural Characteristics

- **Body Structure**:
  - **Hyphae**: Thread-like filaments that form the fungal body.
  - **Mycelium**: A network of hyphae, which is the vegetative part of the fungus.
  - **Septate or Coenocytic Hyphae**:
    - **Septate hyphae** have cross-walls (septa) with pores.
    - **Coenocytic hyphae** lack septa, forming a continuous multinucleated structure.

GENERAL CHARACTERISTICS OF FUNGI

3. Reproduction

- Fungi reproduce by both **asexual and sexual** methods.
- **Asexual Reproduction (Most Common)**
- **Fragmentation**: Hyphae break into pieces and grow into new fungi.
- **Budding**: Small outgrowth forms on the parent cell (e.g., yeast).
- **Spore Formation**:
  - **Conidia** (asexual spores) are formed at the tip of hyphae.
  - **Sporangiospores** are produced inside a sac-like **sporangium**.
- **Sexual Reproduction**
- Occurs under unfavorable conditions.
- Involves the fusion of compatible hyphae or gametes.
- Produces sexual spores like **Zygospores, Ascospores, and Basidiospores**.

GENERAL CHARACTERISTICS OF FUNGI

4. Nutrition and Metabolism

- **Saprophytic**: Decompose dead organic matter (e.g., *Rhizopus*, *Aspergillus*).
- **Parasitic**: Live on a host, sometimes causing diseases (e.g., *Candida albicans*).
- **Symbiotic**: Form mutualistic associations (e.g., Lichens – fungi + algae, Mycorrhizae – fungi + plant roots).
- **Absorptive Nutrition**: Secrete digestive enzymes to break down food externally and absorb nutrients.

5. Habitat and Distribution

- Found in **terrestrial and aquatic** environments.
- Thrive in warm, moist conditions but can also survive in extreme environments.
- Many are **decomposers**, playing a key role in ecosystems by recycling nutrients.

6. Classification of Fungi

- Fungi are classified into major groups based on their reproductive structures:

GENERAL CHARACTERISTICS OF FUNGI

Group	Characteristics	Example
Zygomycota	Form zygospores, coenocytic hyphae	*Rhizopus* (bread mold)
Ascomycota	Produce ascospores inside an ascus (sac fungi)	*Saccharomyces*, *Penicillium*
Basidiomycota	Form basidiospores on basidia (club fungi)	Mushrooms, *Agaricus*
Chytridiomycota	Primitive fungi with flagellated spores	*Batrachochytrium*
Glomeromycota	Form mycorrhizal associations with plant roots	*Glomus*

GENERAL CHARACTERISTICS OF FUNGI

- **7. Economic Importance of Fungi**
- **Beneficial Roles**
- **Food Production**: Used in bread (*Saccharomyces*), cheese, and soy sauce fermentation.
- **Medicine**: Source of antibiotics (e.g., *Penicillium* produces penicillin).
- **Biotechnology**: Used in enzyme production, bioremediation, and biofuel generation.
- **Agriculture**: Mycorrhizal fungi help plants absorb nutrients.
- **Harmful Roles**
- **Pathogens**: Cause plant (*Puccinia* – wheat rust) and human diseases (*Candida*, *Aspergillus*).
- **Food Spoilage**: Contaminate stored food with toxins (*Aspergillus flavus* produces aflatoxins).

Classification of Fungi

- **Classification of Fungi**
- Fungi are classified based on their mode of reproduction, structure, and spore formation. The major groups of fungi include **Zygomycota, Ascomycota, Basidiomycota, Chytridiomycota, and Glomeromycota**.
- **1. Zygomycota (Zygomycetes - Conjugation Fungi)**
- **Characteristics:**
- Mostly **saprophytic**, found in soil and decaying organic matter.
- **Coenocytic hyphae** (multinucleated without septa).
- Reproduce **asexually** by **sporangiospores** and **sexually** by **zygospores** (thick-walled resistant spores).
- Example: *Rhizopus stolonifer* (bread mold), *Mucor* (soil fungi).

- **2. Ascomycota (Ascomycetes - Sac Fungi)**
- **Characteristics:**
- Largest fungal group, includes unicellular **yeasts** and multicellular molds.
- **Septate hyphae** (hyphae with cross-walls).
- Reproduce **asexually** by **conidia** and **sexually** by **ascospores** formed inside an **ascus** (sac-like structure).
- Some are beneficial (fermentation, antibiotics), while others are pathogenic.
- Example: *Saccharomyces cerevisiae* (yeast), *Penicillium* (antibiotic production), *Aspergillus* (food fermentation and toxins), *Claviceps purpurea* (ergot disease).
- **3. Basidiomycota (Basidiomycetes - Club Fungi)**
- **Characteristics:**
- **Multicellular fungi** with **septate hyphae**.
- Reproduce sexually by **basidiospores**, produced on **basidia** (club-shaped structures).
- Many form **mushrooms, puffballs, and bracket fungi**.
- Includes both **saprophytic** and **pathogenic** species.
- Example: *Agaricus bisporus* (edible mushroom), *Puccinia* (rust fungi), *Ustilago* (smut fungi).