Algae: The Plant-like Protists

Introduction

- Algae are **photosynthetic simplest eukaryotic organisms**.
- Placed in Kingdom Protista as classified by Robert H Whittaker
- They are **aquatic** (freshwater, marine, brackish) and can be **motile or non-motile**.
- Some form **colonies** known as **coenobia**.
- Plant Body: **Thalloid** (or Thallus Structure) , not differentiated into root, stem and leaves
- Nutrition: Mostly algae are **Photoautotrophic**; some forms are **Chemo-autotrophic** also.
- They possess **eukaryotic structures**: Golgi apparatus, mitochondria, endoplasmic reticulum, and a nucleus.
- Flagella: may be single, in pairs, many in no., isokont or heterokont.
- They range from **unicellular microscopic to macroscopic multicellular** forms.
- Algae are **autotrophic**, using **CO_2 as a carbon source** and light as an energy source.
- They reproduce **sexually and asexually**.
- Alternation of Generations in reproduction.

General Characteristics of Algae

1. **Cell Wall:** Varies in composition.
2. **Pigments:** Important for photosynthesis.
3. **Morphology:** Includes unicellular, colonial, and multicellular forms.
4. **Habitat:** Found in various aquatic environments.
5. **Flagella:** Varies in number and position.
6. **Reproduction:** Can be sexual or asexual.

Classification of Algae

Fritsch Classification (1945)

- Based on **pigments, flagella, and reserve food material**.
- Divided into **11 classes**:
    1. Chlorophyceae
    2. Xanthophyceae
    3. Chrysophyceae
    4. Bacillariophyceae
    5. Cryptophyceae
    6. Dinophyceae
    7. Chloromonadineae
    8. Euglenineae
    9. Phaeophyceae
    10. Rhodophyceae
    11. Myxophyceae

Modern Classifications

- **Lee (1980):** Classified algae based on **ultrastructure of organelles** into **6 divisions**.

- **Rosowski & Parker (1982):** Proposed **15 classes**.
- **Van den Hoek (1995):** Proposed **11 divisions**:
    1. Cyanophyta
    2. Prochlorophyta
    3. Glaucophyta
    4. Rhodophyta
    5. Heterokontophyta
    6. Haptophyta
    7. Cryptophyta
    8. Dinophyta
    9. Euglenophyta
    10. Chloroarachniophyta
    11. Chlorophyta

Chlorophyta (Green Algae)

- Found in **freshwater, seawater, and terrestrial environments**.
- **500 genera & ~8000 species**.
- Can be **unicellular or colonial**.
- Chloroplasts contain **chlorophyll a & b, β-carotene, and xanthophylls**.
- **Sexual and asexual reproduction**.

Examples of Green Algae

1. **Chlamydomonas** – Unicellular, motile, found in stagnant water.
2. **Volvox** – Colonial, freshwater, up to 50,000 cells.
3. **Chlorella** – Globular, non-motile, used as **Single-Cell Protein (SCP)**.
4. **Ulothrix** – Filamentous, found in flowing streams, attaches via **holdfasts**.
5. **Spirogyra** – Filamentous, contains **spiral chloroplasts**, found in **clean eutrophic water**.
6. **Chara ("Stoneworts")** – Grows in **limestone-rich waters**, has **calcium carbonate deposits**.
7. **Acetabularia:** Called "Mermaid's Wineglass" due to its shape.
    Three parts:
    Foot/base (contains nucleus)
    Stalk
    Cap

Rhodophyta (Red Algae)

- Contain **phycoerythrin**, giving them a **red color**.
- Found in **marine & freshwater**.
- Some form **coralline algae**, contributing to **reef formation**.
- **Reproduction**:
    - **Asexual**: By **monospores**.
    - **Sexual**: **Oogamous**, involving **carpogonia (female)** and **spermatia (male)**.

Economic Importance

- **Carrageenan** – Used as a stabilizer in food (e.g., ice cream).
- **Agar** – Extracted from **Gelidium** and **Gracilaria**, used in **microbiological media**.

Examples

1. **Gelidium** – Used for agar production.

2. **Gracilaria** – Used for agar and as **fish food**.

Thallus Structure of Algae

- **Undifferentiated plant body** (no roots, stems, leaves).
- Can be **simple filaments** or **branched structures**.
- **Size** varies from microscopic to several meters.

Algal Thallus Structure

1. Introduction to Thallus in Algae

- The plant body of algae is called a **thallus**.
- Unlike higher plants, algae **lack true roots, stems, and leaves**.
- The thallus can range from **unicellular** to **large, complex multicellular structures**.
- The **size** varies from a few microns to several meters.
- The thallus can be **free-floating or attached** to a substrate.

2. Types of Algal Thallus Structures

A. Unicellular Thallus

- Single cells function as complete living organisms.
- Found in all groups except **Rhodophyceae, Phaeophyceae, and Charophyceae**.
- Can be **motile or non-motile**.

Examples:

1. **Chlamydomonas** (Motile, flagellated)
2. **Chlorella** (Non-motile, globular)

B. Colonial Thallus

- Group of cells joined together, forming colonies.
- Can be **loose** or **coenobial (fixed cell number and arrangement)**.

Examples:

1. **Volvox** (Spherical colony with 50,000+ cells)
2. **Hydrodictyon** (Net-like structure)

C. Filamentous Thallus

- Cells arranged **end-to-end**, forming thread-like structures.
- Filaments can be **unbranched** or **branched**.
- Can be **free-floating** or **attached**.

Types:

1. **Unbranched Filamentous** – Simple linear arrangement (e.g., *Spirogyra*)
2. **Branched Filamentous** – Shows lateral branching (e.g., *Cladophora*)
3. **Heterotrichous Filamentous** – Differentiated into prostrate and erect systems (e.g., *Stigeoclonium*)

D. Siphonous (Coenocytic) Thallus

- **Multinucleate**, lacks cross walls.
- Thallus consists of a **single, continuous cytoplasmic mass**.

Examples:

1. **Vaucheria** (Freshwater and marine habitats)
2. **Caulerpa** (Highly developed siphonous structure)

E. Parenchymatous Thallus

- Formed by **cell division in multiple planes**, resulting in a sheet-like or tissue-like structure.
- Resembles higher plants.

Examples:

1. **Ulva (Sea Lettuce)** – Flat, two-cell-thick sheet.
2. **Laminaria (Kelp)** – Large, differentiated parenchymatous structure.

F. Pseudoparenchymatous Thallus

- Formed by **interwoven filaments**, appearing as parenchymatous tissue.
- Less organized than true parenchymatous thalli.

Examples:

1. **Polysiphonia** (Red algae, delicate branched structure)
2. **Gracilaria** (Used in agar production)

G. Complex Thallus (Macroscopic Forms)

- Large, highly differentiated algae with **specialized structures**.
- Often found in **marine environments**.

Examples:

1. **Macrocystis (Giant Kelp)** – Forms underwater forests, can grow over 60 meters.
2. **Chara (Stoneworts)** – Resembles higher plants, has nodes and internodes.

- The **thallus structure varies greatly among algae**, adapting them to different environments.
- **Simple thalli** are common in unicellular and colonial algae, while **complex forms** dominate marine ecosystems.
- Understanding algal thalli is essential for **taxonomy, ecology, and commercial applications**.

PIGMENTS IN ALGAE

Pigment Type	Examples	Color	Function	Occurrence in Algae Groups
Chlorophylls	Chlorophyll **a**, **b**, **c**, **d**, **e**, **f**	Green	Primary photosynthetic pigment; absorbs light for photosynthesis	**All algae** (Chl-a in all, Chl-b in green algae, Chl-c in brown algae, Chl-d in red algae, Chl-f in cyanobacteria)
Carotenoids	β-carotene, Xanthophylls (fucoxanthin, lutein, violaxanthin, etc.)	Yellow, Orange, Red	Accessory pigments; protect from photo-oxidation and enhance light absorption	**All algae** (Fucoxanthin in brown algae, lutein in green algae, peridinin in dinoflagellates)
Phycobilins	Phycocyanin, Allophycocyanin, Phycoerythrin	Blue, Red	Accessory pigments; absorb light and transfer energy to chlorophyll **a**	**Cyanobacteria & Red algae (Rhodophyta)** (Phycocyanin in blue-green algae, Phycoerythrin in red algae)
Phycoerythrins	C-phycoerythrin, B-phycoerythrin	Red	Absorbs green light; allows algae to photosynthesize in deep waters	**Red algae (Rhodophyta) & some Cyanobacteria**

Phycocyanins	C-phycocyanin, Allophycocyanin	Blue	Absorbs red/orange light; enhances energy capture	**Cyanobacteria (blue-green algae) & some Red algae**

This table provides a quick reference for understanding the **types, colors, functions, and distribution** of pigments in different algae groups.

Types of Algal Reproduction

Types of Algal Reproduction

1. Asexual Reproduction

Asexual reproduction in algae occurs without the involvement of gametes and results in genetically identical offspring. It includes the following methods:

- **Binary Fission:** The parent cell divides into two identical daughter cells (e.g., *Chlamydomonas* in favorable conditions).
- **Fragmentation:** Algal filaments break into smaller pieces, each developing into a new individual (e.g., *Spirogyra*).
- **Zoospore Formation:** Motile spores (zoospores) are produced and dispersed to form new individuals (e.g., *Chlamydomonas*).
- **Akinetes & Hypnospores:** Thick-walled resting spores that survive unfavorable conditions (e.g., *Nostoc*).

2. Sexual Reproduction

Sexual reproduction in algae involves the fusion of gametes, leading to genetic variation. It occurs through different mechanisms:

- **Isogamy:** Fusion of identical motile gametes (e.g., *Ulothrix*).
- **Anisogamy:** Fusion of dissimilar motile gametes, where one is slightly larger (e.g., *Eudorina*).
- **Oogamy:** Fusion of a large, non-motile egg with a small, motile sperm (e.g., *Volvox*).

3. Vegetative Reproduction

Some algae reproduce through simple vegetative propagation without producing specialized reproductive cells:

- **Cell Division:** In unicellular algae, mitotic division leads to new individuals (e.g., *Chlorella*).
- **Fragmentation:** Algal filaments break and grow into new individuals (e.g., *Spirogyra*).

1. Vegetative Reproduction

Vegetative reproduction occurs without the formation of specialized reproductive cells. It involves the following methods:

- **Fragmentation:** The parent body breaks into smaller fragments, each growing into a new individual. Common in filamentous algae like *Spirogyra*.
- **Fission:** A single cell divides into two daughter cells. Seen in unicellular algae such as *Chlamydomonas* and *Diatoms*.
- **Tuber Formation:** Some algae form underground storage structures (tubers), which grow into new individuals.
- **Adventitious Structures:** Specialized structures that develop into new algal individuals.
- **Hormogonia Formation:** Short filamentous fragments separate and develop into new individuals, common in cyanobacteria like *Nostoc*.
- **Budding:** A small outgrowth or bud forms on the parent body and eventually detaches to grow into a new organism. Example *Saccharomyces*

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2. Asexual Reproduction

Asexual reproduction involves the formation of specialized reproductive spores without gamete fusion. It includes:

- **Zoospores:** Flagellated, motile spores that swim to new locations and develop into new individuals (e.g., *Chlamydomonas*).
- **Aplanospores:** Non-motile spores that develop under unfavorable conditions and germinate when conditions improve.
- **Akinetes:** Thick-walled, dormant cells that help algae survive harsh conditions, found in *Anabaena*.
- **Hypnospores:** Highly resistant spores that can endure extreme environmental conditions.
- **Tetraspores:** Four non-motile spores produced by certain red algae for reproduction.
- **Autospores:** Non-motile spores that resemble the parent cell and develop into new individuals.

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3. Sexual Reproduction

Sexual reproduction involves the fusion of gametes, leading to genetic recombination and increased diversity. It occurs through:

- **Isogamy:** Fusion of morphologically similar motile gametes (e.g., *Ulothrix*).
- **Anisogamy:** Fusion of gametes that are morphologically different in size but both are motile.
- **Oogamy:** Fusion of a large, non-motile egg with a small, motile sperm (e.g., *Volvox*).
- **Hologamy:** The entire vegetative cells act as gametes and fuse to form a new individual.
- **Autogamy:** Self-fertilization within a single cell, where gametes from the same organism fuse.

Advantages of Sexual Reproduction

- Increases **genetic variation**.
- Helps in **DNA repair and adaptation**.
- More beneficial in **large populations**.

Environmental Factors Affecting Sexual Reproduction

- **Light intensity**.
- **pH value**.
- **Temperature**.

Life Cycle in Algae

1. Introduction to Life Cycle in Algae

A life cycle refers to the sequence of distinct morphological and cytological stages an organism passes through, from one generation's zygote to the next. It includes both haploid and diploid phases, depending on the type of life cycle.

Alternation of generations is a life cycle pattern in algae where organisms alternate between two distinct multicellular stages:

Gametophytic (Haploid, n) Generation – Produces gametes via mitosis.

Sporophytic (Diploid, 2n) Generation – Produces spores via meiosis.

This cycle can be isomorphic (both generations look similar) or heteromorphic (generations appear different).

2. Five Types of Life Cycles in Algae

1. **Haplontic Life Cycle**
2. **Diplontic Life Cycle**
3. **Haplodiplontic Life Cycle**
4. **Diplohaplontic Life Cycle**
5. **Haplo-diplobiontic Life Cycle**

3. Types of Life Cycles

A. Haplontic Life Cycle

- The plant body is haploid (gametophyte), while the diploid phase (sporophyte) is limited to the zygote.

- Zygote undergoes meiosis to form haploid meiospores, which grow into haploid plants.
- Found in **Chlamydomonas, Ulothrix, Oedogonium, Spirogyra, Chara**, and **Xanthophyceae members**.

B. Diplontic Life Cycle

- The plant body is diploid (sporophyte), and haploid gametes are formed by meiosis.
- Gametes fuse to form a zygote, which directly develops into a diploid sporophyte.
- Found in certain algae groups.

C. Diplohaplontic Life Cycle

- Both haploid and diploid phases are equally prominent and represented by distinct individuals.
- Gametophyte reproduces sexually, while sporophyte reproduces asexually.
- Alternation of generations occurs through sporogenic meiosis and gamete fusion.

D. Haplo-diplobiontic Life Cycle

- Features two well-developed haploid phases.
- Diploid phase is represented only by the zygote.
- First haploid phase: gametophytic plant, sex organs, and gametes.
- Second haploid phase: gonimoblast filaments, carposporangia, carpospores, and chantransia stage.
- Found in **Batrachospermum** and **Nemalion**.

4. Triphasic Life Cycle

A. Haplobiontic Type

- Gametophytic (haploid) phase is dominant, while the sporophytic (diploid) phase is short-lived.
- Example: **Batrachospermum, Nemalion** (primitive **Rhodophyceae** members).
- Gametophytic plant produces gametes that fuse to form a zygote.
- Zygote undergoes meiosis to form a haploid carposporophyte, which produces carpospores that grow into a new gametophyte.

B. Diplobiontic Type

- One gametophytic phase and two sporophytic phases.
- Sporophytic phase is dominant.
- Example: **Polysiphonia** (**Rhodophyceae** member).
- Gametophytes produce gametes, forming a zygote that develops into a diploid carposporophyte.
- Carposporophyte forms diploid carpospores that develop into a diploid tetrasporophytic plant.
- Tetrasporangia produce haploid tetraspores, which form male and female gametophytes.

5. Examples of Algae with Different Life Cycle Patterns

Life Cycle Type	Examples
Haplontic	Chlamydomonas, Ulothrix, Oedogonium, Spirogyra, Chara
Diplontic	Fucus, Sargassum
Diplohaplontic	Ectocarpus, Laminaria
Haplo-diplobiontic	Batrachospermum, Nemalion
Triphasic (Haplobiontic)	Batrachospermum, Nemalion
Triphasic (Diplobiontic)	Polysiphonia

Algae play a significant role in the global economy across various industries. Here are some key areas where algae have economic importance:

1. Food Industry

- **Human Consumption**: Edible algae like *Spirulina*, *Chlorella*, *Nori*, and *Kombu* are rich in proteins, vitamins, and minerals.
- **Thickening Agents**: Alginates, carrageenan, and agar (extracted from algae) are used in dairy, bakery, and processed food products.

2. Pharmaceutical & Nutraceutical Industry

- **Bioactive Compounds**: Algae produce antioxidants, anti-inflammatory, and antimicrobial compounds used in medicines.
- **Omega-3 Fatty Acids**: Microalgae like *Schizochytrium* and *Crypthecodinium* provide DHA and EPA, used in dietary supplements.

3. Biofuel Production

- **Biodiesel & Bioethanol**: Algae, especially microalgae, are explored as a renewable source of biofuels due to their high lipid content.
- **Sustainability**: Algae-based biofuels can reduce dependency on fossil fuels and lower carbon emissions.

4. Wastewater Treatment

- **Bioremediation**: Algae help remove heavy metals, nitrogen, and phosphorus from wastewater.
- **CO_2 Sequestration**: Algae absorb CO_2, contributing to carbon capture and climate change mitigation.

5. Agriculture & Fertilizers

- **Biofertilizers**: Algal extracts improve soil fertility and crop productivity.

- **Animal Feed**: Algae-based feeds enhance livestock growth, immune function, and nutrition.

6. Cosmetics & Skincare

- **Anti-aging & Hydrating Agents**: Algal extracts are used in creams, lotions, and sunscreens.
- **UV Protection**: Some algae-derived compounds protect skin from UV radiation.

7. Textile & Paper Industry

- **Dyes & Pigments**: Algal pigments (phycocyanin, chlorophyll, etc.) are used as natural colorants.
- **Paper Coating & Additives**: Alginates improve paper quality and durability.

8. Bioplastics & Packaging

- **Sustainable Alternatives**: Algae-based bioplastics are biodegradable and reduce plastic pollution.

9. Aquaculture & Fisheries

- **Fish & Shrimp Feed**: Algae are a vital feed source for aquaculture species.
- **Larval Growth Enhancement**: Microalgae like *Dunaliella* and *Isochrysis* boost aquaculture productivity.