

# ALGAE

## CLASSIFICATION

- For many years it has been customary to classify algae according to their colour
- Therefore we speak of green, brown, golden-brown, red algae, etc.
- All algae contain at least one type of **chlorophyll**, but they also contain **other types of pigments** and these may **mask** the colour of the chlorophyll

## **ALGAE Cont'd**

- **Unicellular motile algae** are grouped by some biologists along with **some multicellular, motile animals**, in a separate kingdom (**neither plant nor animal**, but including attributes of both) called the **Protista**

- Usually movement by algae cells is produced by the beating action against the water of one or more of the **protoplasmic extensions** from the cell called **cilia** or **flagella**

# PRIMARY CLASSIFICATION OF THE ALGAE

- Algae are basically classified into the following Divisions/Phyla:
  - ✓ Cyanophyta (Blue-green algae)
  - ✓ Chlorophyta (Green algae)
  - ✓ Bacillariophyta (Diatoms)
  - ✓ Phaeophyta (Brown algae)
  - ✓ Rhodophyta (Red algae)
  - ✓ Euglenophyta (Euglenoids)
  - ✓ Chrysophyta (Golden algae)

## CLASSIFICATION Cont'd

- In general details of vegetative structure and processes of reproduction are not particularly useful for the primary classification of algae
- Instead, the primary classification is based on five criteria of a different nature:

# CLASSIFICATION Cont'd

1. Photosynthetic pigments
2. Nature of the food reserve
3. Nature of the cell wall component
4. Types of flagella
5. Details of cell structure

- The final classification of the algae depends on a combination of several characteristics and not on any one single feature

# 1. PHOTOSYNTHETIC PIGMENTS

- Algae from the various Phyla/Divisions show striking differences in colour
- And these often afford a quick guide to the preliminary classification of an alga
- However the colour frequently varies with changes in environmental conditions

- And an accurate classification depends on the chemical analysis of the photosynthetic pigments
- The distribution of these pigments is important in algal classification

- There are three kinds of photosynthetic pigments in algae.
- These are
  - ✓ the **chlorophylls**
  - ✓ the **carotenoids**, and
  - ✓ the **biloproteins**

## **i. CHLOROPHYLLS**

- Chlorophylls extracted from different algae show different spectral properties
- On the basis of this a number of different chlorophylls have been recognized and termed **chlorophyll a, b, c, d and e**

- The distribution of these chlorophylls among various algal groups is what results in the differences in colour
- **Chlorophyll a** is present in all algae as it is in all photosynthetic organisms except the photosynthetic bacteria
- **Chlorophyll b**, the other chlorophyll of higher plants, is found in the Euglenophyta and the Chlorophyta

- They are not found in any other algal division
- **Chlorophyll c** is present in members of the Chrysophyta, Bacillariophyta, Cryptophyta and the Phaeophyta

- **Chlorophyll d** appears to be present only in the Rhodophyta
- **Chlorophyll e** has been identified in only two species of the Xanthophyta

## ii. CAROTENOIDS

- Carotenoids are of two kinds:
  - ✓ **Carotenes**, and
  - ✓ **Xanthophylls**
- **Carotenes** are linear unsaturated hydrocarbons, and
- **Xanthophylls** are oxygenated derivatives of the carotenes

# CAROTENOIDS Cont'd

- **$\beta$ -carotenes** are present in most algae although they are replaced by  **$\alpha$ -carotenes** in some members of the Chlorophyta and Cryptophyta and to a lesser extent in the Rhodophyta
- In the Chlorophyceae  **$\beta$ -carotene** is replaced by two carotenes which are characteristic of photosynthetic bacteria: **lycopene** and  **$\gamma$ -carotene**

## CAROTENOIDS Cont'd

- There are many different **xanthophylls** in algae, and since many are unique to particular algal groups, they are important diagnostic features in the classification of algae

### iii. BILOPROTEINS

- Chlorophylls and carotenoids are soluble in lipid solvents and cannot be extracted in aqueous solution
- However, water soluble pigments can be extracted from some types of algae
- These were called **phycobilins**
- During the extraction procedure the free pigment cannot be separated from the protein part

## BILOPROTEINS Cont'd

- And the name of the pigment was therefore changed from **phycobilins** to **biloproteins** to indicate the existence of the pigment-protein complex
- **Biloproteins** are present in only three algal divisions:
  - ✓ the Cyanophyta
  - ✓ the Rhodophyta, and
  - ✓ the Cryptophyta

## **BILOPROTEINS Cont'd**

- Analysis of the spectral properties of these pigments shows that there are two kinds of **biloproteins**:  
**Phycocyanin** and **Phycoerythrin**
- Each of these biloproteins shows differences among the three groups of algae

## BILOPROTEINS Cont'd Cont'd

- In general those of the Cyanophyta are of the **C-type**
- Those of the Rhodophyta are of the **R-type**, and
- Those of the Cryptophyta are of a third type
- The proportion of one kind of photosynthetic pigment to the other is variable

## **PHOTOSYNTHETIC PIGMENTS Cont'd**

- The proportion of one kind of photosynthetic pigment to the other is variable
- For example cells of the Chlorophyta and Euglenophyta appear green because of an excess of chlorophylls over carotenoids

## **PHOTOSYNTHETIC PIGMENTS Cont'd**

- Whereas the yellow-brown colour of groups such as the Pyrrophyta, Chrysophyta, Cryptophyta, Phaeophyta, etc. and the yellow-green colour of the Xanthophyta reflects an excess of carotenoids compared with chlorophylls
- Also, the characteristic colour of the Cyanophyta (blue-green) and the Rhodophyta (red) are due to an excess of the appropriate biloproteins

## **PHOTOSYNTHETIC PIGMENTS Cont'd**

- However the proportion of one type of pigment to the other can vary considerably with changes in the environmental conditions
- And it is difficult to justify its use as a taxonomic feature

## 2. FOOD STORAGE

- The initial stages of **CO<sub>2</sub> fixation** are probably the same in all photosynthetic organisms
- Thus the primary products of photosynthesis are the same in all algae
- However the insoluble products which accumulate over a longer period of time are more variable and they afford useful taxonomic criteria

## FOOD STORAGE Cont'd

- The compounds which are most widespread and most useful in the primary classification of algae are various polysaccharides
- **“True” starch**, similar to that found in higher plants, is only found in one algal division, the Chlorophyta
- Two other divisions, the Rhodophyta and the Cyanophyta, accumulate characteristic starches:

## FOOD STORAGE Cont'd

- ✓ **Floridean starch** and **Myxophycean starch** respectively
- Both are **polyglucose molecules** identical to the **amylopectin** part of higher plant starch
- In some other algae such as the Phaeophyta, the storage carbohydrate is **Laminarin**
- **Paramylum** is present in the Euglenophyta

### 3. CELL WALL COMPONENT

- When a cell wall is present in an alga its chemical constituent varies from one group to the other
- And these are sometimes important indications of the taxonomic position of the particular alga
- The cell wall is generally made up of two kinds of materials:
  - ✓ an **inner water insoluble material**, and
  - ✓ an **outer pectic or mucilageneous substance** soluble in boiling water

## CELL WALL COMPONENT Cont'd

- Although both inner and outer wall materials are mainly **polysaccharides**, **lipid** and **proteinaceous** materials are also present

## CELL WALL COMPONENT Cont'd

- The commonest water insoluble polysaccharide of the inner layer is **cellulose**
- And this is present in walled species of all divisions except the Chrysophyta
- Other characteristic components of the cell wall includes **polyuronic acid** and **alginic acid**

## **4. TYPE OF FLAGELLA**

- Apart from the Cyanophyta and the Rhodophyta flagella are found in other divisions of the algae
- And their nature, number and position are important characters for the primary classification of the algae

## FLAGELLA Cont'd

- The detailed fibrillar structure of the algal flagella in transverse section resembles that of cilia and flagella of other organisms in showing a typical **9+2 pattern of component fibrils**

## FLAGELLA Cont'd

- Each flagellum is bounded by an extension of the **plasmalemma**
- Within the plasmalemma there is a **ring of nine pairs of fused fibrils/tubules** and a **pair of unfused fibrils/tubules** at the centre
- This is the basic pattern of plant and animal flagella

## FLAGELLA Cont'd

- The macrostructure of the flagellum does not however show such uniformity
- For a long time algal flagella were thought to be of two kinds:
  - ✓ the **acronematic** (smooth), and
  - ✓ the **pantonematic/pleuronematic** (**flimmer**)

## FLAGELLA Cont'd

- The **acronematic type** is smooth and whiplike
- While the **pantonematic/pleuronematic type** has longitudinal rows of fine hairs (**flimmers** or **mastigonemata/mastigonemes**) arranged along the axis of the flagella

## FLAGELLA Cont'd

- More recent work with the electron microscope has revealed one other type of flagella in which the flagella surface is covered with **minute hairs** (different from those of the pantonematic/pleuronematic flagella) **and scales**

## 5. DETAILS OF CELL STRUCTURE

- The important structural features of the cell of various algae normally are uniform throughout the division
- In most texts particularly on the Chlorophyta, **chloroplast** runs throughout the entire division while **chromatophores** are found in others

## CELL STRUCTURE Cont'd

- The distinction between these two pigments is generally based on the differences of pigmentation
- The term **chloroplast** is used in species of algae possessing **chlorophylls a** and **b** (as in higher plants)
- And the term **chromatophore** is applied to algal species not having **chlorophyll b**, but having an **excess of carotenoids** over chlorophylls

## CELL STRUCTURE Cont'd

- The position of chloroplast in the cell is very important
- They are termed **parietal** when located towards the periphery of the cell, and **axiel** when located towards the centre
- A further feature of the chloroplast which is emphasized is the presence or absence of a deeply staining area of the chloroplast generally associated with deposits of reserved products, the **pyrenoid**

## **CELL STRUCTURE Cont'd**

- The cells of archegonate plants (bryophytes) normally have numerous discoid chloroplasts, and the possession of such a feature by some algal cells is therefore emphasized

# MORPHOLOGIC DIVERSITY OF THE ALGAE

- The body of an alga is a **thallus**
- Algae range in form from **Unicellular** through **Colonial, Filamentous, Siphonaceous**, to the complex **Parenchymatous thalli** of the larger seaweeds

# UNICELLULAR FORMS

- Unicellular forms are among all groups of algae except the Rhodophyta and Phaeophyta, although even among these two groups unicellular stages are produced at various points in their life history
- The unicellular species may be **motile** (flagellated), **non-motile** (coccoid) or **amoeba-like**

## UNICELLULAR FORMS Cont'd

- Flagellated solitary cells are considered primitive in most groups of **eukaryotic algae** and are believed to have given rise to the other types
- They vary in the number and arrangement of the flagella

# **MULTICELLULAR FORMS**

# 1. COLONIAL FORMS

- The association of organisms into groups of cells or colonies probably originated as it does in **ontogeny** (development of the individual)
- ✓ by the failure of the cells to separate after cell division

## **i. COENOBIAL**

- In this type of thallus the cells are either embedded in mucilaginous matrix or united by a more localized production of mucilage
- It is not merely an irregular aggregation of cells but it is a well defined colony with important reproductive features

## COENOBIAL Cont'd

- The **coenobium** (colony) is of constant size and shape for any given species and the cells show no vegetative division
- Thus the number of cells of a coenobium is determined at its formation and does not increase during growth of the colony

## ii. AGGREGATIONS

- Unlike the **coenobium** an **aggregation** of cells is not of constant size and shape
- Moreover vegetative cell division takes place so there is an increase in cell number during growth
- The most common type of aggregation is the **palmelloid** form in which the cells are embedded in an irregular mass of mucilage

## AGGREGATION Cont'd

- The **dendroid** colony consists of cells which are united by localized production of mucilage to form a tree-like structure
- Another kind is the **rhizopodial** form of aggregation consisting of variable number of amoeboid cells joined together by a number of **cytoplasmic processes**

## 2. FILAMENTOUS FORMS

- Filamentous forms are also characterized by vegetative cell division but unlike the irregular aggregations the cells are arranged in linear rows with adjacent cells sharing a common cross wall
- Cytoplasmic connections (**plasmodesmata**) may extend through the cross walls

## FILAMENTOUS FORMS Cont'd

- In **uniseriate filaments** the cells are arranged in a single series
- **Multiseriate filaments** have more than one series of cells but still retain a thread-like appearance

## FILAMENTOUS FORMS Cont'd

- Filaments may be **branched** or **unbranched**
- More complex filamentous algae may show differentiation among the branches
- **Heterotrichous** filaments have a distinct system of prostrate branches growing attached to the substrate and an erect system of more open branches extending free of the substrate

## **FILAMENTOUS FORMS Cont'd**

- In the **pseudoparenchymatous** thalli the branches do not spread apart in an open branching pattern but form a compact mass that makes individual branches difficult to see
- Such a structure is the basis of all larger members of the Rhodophyta

### 3. SIPHONEOUS/SIPHONACEOUS FORMS

- In this kind the thallus is multinucleate but is not divided into cells apart from those associated with reproduction
- The thallus can be extremely elaborate and is generally considered more desirable to refer to such a thallus as **acellular** and not **unicellular**

## 4. PARENCHYMATOUS FORMS

- Vegetative cell division in filamentous forms occurs in one plane only so that a single row of cells is formed
- When cells divide in more than one plane a parenchymatous construction is produced
- Cell divisions in three dimensions produce a solid mass of cells rather than the threadlike linear arrangement of a filament

## **PARENCHYMENTOUS Cont'd**

- Parenchymatous thalli may be blades, branching cylinders or hollow tubes
- The parenchymatous construction which is also characteristic of bryophytes and vascular plants is the most advanced form

## PARENCHYMENTOUS Cont'd

- Growth of the filamentous and parenchymatous thalli can be:
- **Diffused** ie. all the cells are capable of division
- **Intercalary** ie. well defined dividing regions are not located terminally

## **PARENCHYMENTOUS Cont'd**

- **Trichothallic** ie. a specialized meristematic region at the base of branches or filaments, or
- **Apical** ie. one or more well defined apical cells dividing to give the remainder of the thallus

# **METHODS OF REPRODUCTION IN THE ALGAE**

- A particular plant may take to one or more of the three methods of reproduction i.e
  - ✓ Vegetative
  - ✓ Asexual, or
  - ✓ Sexual

# **1. VEGETATIVE REPRODUCTION**

- Vegetative reproduction commonly takes place by cell division or by fragmentation
- Many filamentous algae reproduce vegetatively by the fragmentation of the filament to liberate small pieces
- Among filamentous members of the Cyanophyta this is a specialized process and a number of short motile lengths of filaments are formed

## VEGETATIVE REPRODUCTION Cont'd

- These entities are referred to as **hormogonia**
- They are short segments from the ends of the filaments that form when the walls between the cells split or when the cell in between dies

## 2. ASEXUAL REPRODUCTION

- Asexual reproduction involves the formation of reproductive cells that develop directly into new individuals (**without sexual fusion**)
- This is normally achieved by the formation of **spores** of various kinds
- Most groups except the Cyanophyta and Rhodophyta produce **zoospores** which are **motile unicells**

## **ASEXUAL REPRODUCTION Cont'd**

- **Non-motile asexual spores** are also produced and these are called **aplanospores**
- When the non-motile asexual spores appear identical to the parent cell (ie. similar in form but a miniature of the parent cell) they are referred to as **autospores**

## **ASEXUAL REPRODUCTION Cont'd**

- And if they acquire a thick wall around them they are referred to as **hypnospores**
- The term “**swarmer**” is commonly used for any motile cell formed when a vegetative cell reproduces and it indicates that it is unknown whether the swarmer behaves as a gamete or a zoospore

## ASEXUAL REPRODUCTION Cont'd

- Among multicellular forms the spore may be formed in all vegetative cells or their formation may be restricted to well-defined **sporangia**
- In the Phaeophyta two specialized kinds of sporangia can be recognized
- These are the **plurilocular** and the **unilocular** sporangia

## ASEXUAL REPRODUCTION Cont'd

- The **plurilocular** consists of an enlarged vegetative cell which divides into a number of compartments and the content of each compartment develops into a swarmer

## **ASEXUAL REPRODUCTION Cont'd**

- In the **unilocular type** contents of the enlarged vegetative cell divide to form a number of swarmers without any previous division of the parent cell into a number of compartments
- **Swarmers** from the **unilocular type** are always asexual whereas either **gametes or zoospores** can be liberated from the **plurilocular sporangia**

### 3. SEXUAL REPRODUCTION

- In sexual reproduction the cells released by the parents are **gametes**
- Pairs of compatible gametes fuse to form a **zygote**
- Sexual reproduction is achieved by three basic means:
  - ✓ Isogamy
  - ✓ Anisogamy, and
  - ✓ Oogamy

## SEXUAL REPRODUCTION Cont'd

- If both gametes of a pair are **flagellated** and **similar in size** they are **isogamates**
- Gametes that are **flagellated but differ in size** are known as **anisogamates**
- **Isogamy** involves the fusion of two identical gametes and **anisogamy** is the fusion of two morphologically dissimilar gametes

## SEXUAL REPRODUCTION Cont'd

- Sometimes morphologically identical gametes behave differently and so show **physiological anisogamy**
- In **oogamy** only one gamete (**the sperm**) is flagellated and it fuses with a larger **non-flagellated gamete (the egg)**

## SEXUAL REPRODUCTION Cont'd

- **Oogamy** also differs from anisogamy in that the female gamete (the egg) is not liberated prior to fertilization but is fertilized while within the **oogonium**

## GERMINATION OF THE ZYGOTE

- The zygote formed by the three methods of sexual reproduction has an independent existence for a variable length of time
- Upon germination the content of the zygote divides to form a number of **zoospores**

## ZYGOTE GERMINATION Cont'd

- These are liberated and after a period of swimming they germinate into a parent plant
- More seldom the zygote germinates directly into the adult plant
- During growth an alga passes through a number of distinct phases and the sequence of these is known as its **life history**

## ZYGOTE GERMINATION Cont'd

- The life history has two aspects
  - ✓ the **somatic** or morphological, and
  - ✓ the **cytological**
- The somatic or morphological aspect involves whether in the life history the vegetative stages are morphologically alike or not

## ZYGOTE GERMINATION Cont'd

- The cytological aspect is usually concerned with the chromosome number of each particular stage
- The type of life history thought to be **most primitive** is that in which the **only vegetative stage is haploid** and the zygote represents the only diploid stage

## ZYGOTE GERMINATION Cont'd

- The opposite extreme is that in which the **vegetative stage is diploid** and in which the gametes represent the only haploid stage
- Intermediate between the two extremes are those life histories in which there is an **alternation between two vegetative stages, one haploid and the other diploid**

## ZYGOTE GERMINATION Cont'd

- When the two stages are morphologically similar the alternation is **isomorphic**, and
- When they are morphologically different the alternation is **heteromorphic**