

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

- **β -carotenes** are present in most algae although they are replaced by **α -carotenes** in some members of the Chlorophyta and Cryptophyta and to a lesser extent in the Rhodophyta
- In the Chlorophyceae **β -carotene** is replaced by two carotenes which are characteristic of photosynthetic bacteria: **lycopene** and **γ -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. BIOPROTEINS

- 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_2 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. SIPHONOUS/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 **isogametes**
- Gametes that are **flagellated** but **differ in size** are known as **anisogametes**
- **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**