UNIT –II

Algae (UK: /ˈælgiː/ *AL-ghee*, US: /ˈældʒiː/ *AL-jee*;[3] sg.: **alga** /ˈælgə/ *AL-gə*) are any of a large and diverse group of photosynthetic, eukaryotic organisms. The name is an informal term for a polyphyletic grouping that includes species from multiple distinct clades. Included organisms range from unicellular microalgae, such as *Chlorella*, *Prototheca* and the diatoms, to multicellular forms, such as the giant kelp, a large brown alga which may grow up to 50 metres (160 ft) in length. Most are aquatic and lack many of the distinct cell and tissue types, such as stomata, xylem and phloem that are found in land plants. The largest and most complex marine algae are called seaweeds. In contrast, the most complex freshwater forms are the *Charophyta*, a division of green algae which includes, for example, *Spirogyra* and stoneworts. Algae that are carried by water are plankton, specifically phytoplankton.

Algae constitute a polyphyletic group[4] since they do not include a common ancestor, and although their plastids seem to have a single origin, from cyanobacteria,[5] they were acquired in different ways. Green algae are examples of algae that have primary chloroplasts derived from endosymbiotic cyanobacteria. Diatoms and brown algae are examples of algae with secondary chloroplasts derived from an endosymbiotic red alga.[6] Algae exhibit a wide range of reproductive strategies, from simple asexual cell division to complex forms of sexual reproduction.[7]

Algae lack the various structures that characterize land plants, such as the phyllids (leaf-like structures) of bryophytes, rhizoids of non-vascular plants, and the roots, leaves, and other organs found in tracheophytes (vascular plants). Most are phototrophic, although some are mixotrophic, deriving energy both from photosynthesis and uptake of organic carbon either by osmotrophy, myzotrophy, or phagotrophy. Some unicellular species of green algae, many golden algae, euglenids, dinoflagellates, and other algae have become heterotrophs (also called colorless or apochlorotic algae), sometimes parasitic, relying entirely on external energy sources and have limited or no photosynthetic apparatus.[8][9][10] Some other heterotrophic organisms, such as the apicomplexans, are also derived from cells whose ancestors possessed plastids, but are not traditionally considered as algae. Algae have photosynthetic machinery ultimately derived from cyanobacteria that produce oxygen as a by-product of photosynthesis, unlike other photosynthetic bacteria such as purple and green sulfur bacteria. Fossilized filamentous algae from the Vindhya basin have been dated to 1.6 to 1.7 billion years ago.[11]

Because of the wide range of algae types, they have increasingly different industrial and traditional applications in human society. Traditional seaweed farming practices have existed for thousands of years and have strong traditions in East Asia food cultures. More modern algaculture applications extend the food traditions for other applications, including cattle feed, using algae for bioremediation or pollution control, transforming sunlight into algae fuels or other chemicals used in industrial processes, and in medical and scientific applications. A 2020 review found that these applications of algae could play an important role in carbon sequestration to mitigate climate change while providing lucrative value-added products for global economies.[12]

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Etymology and study

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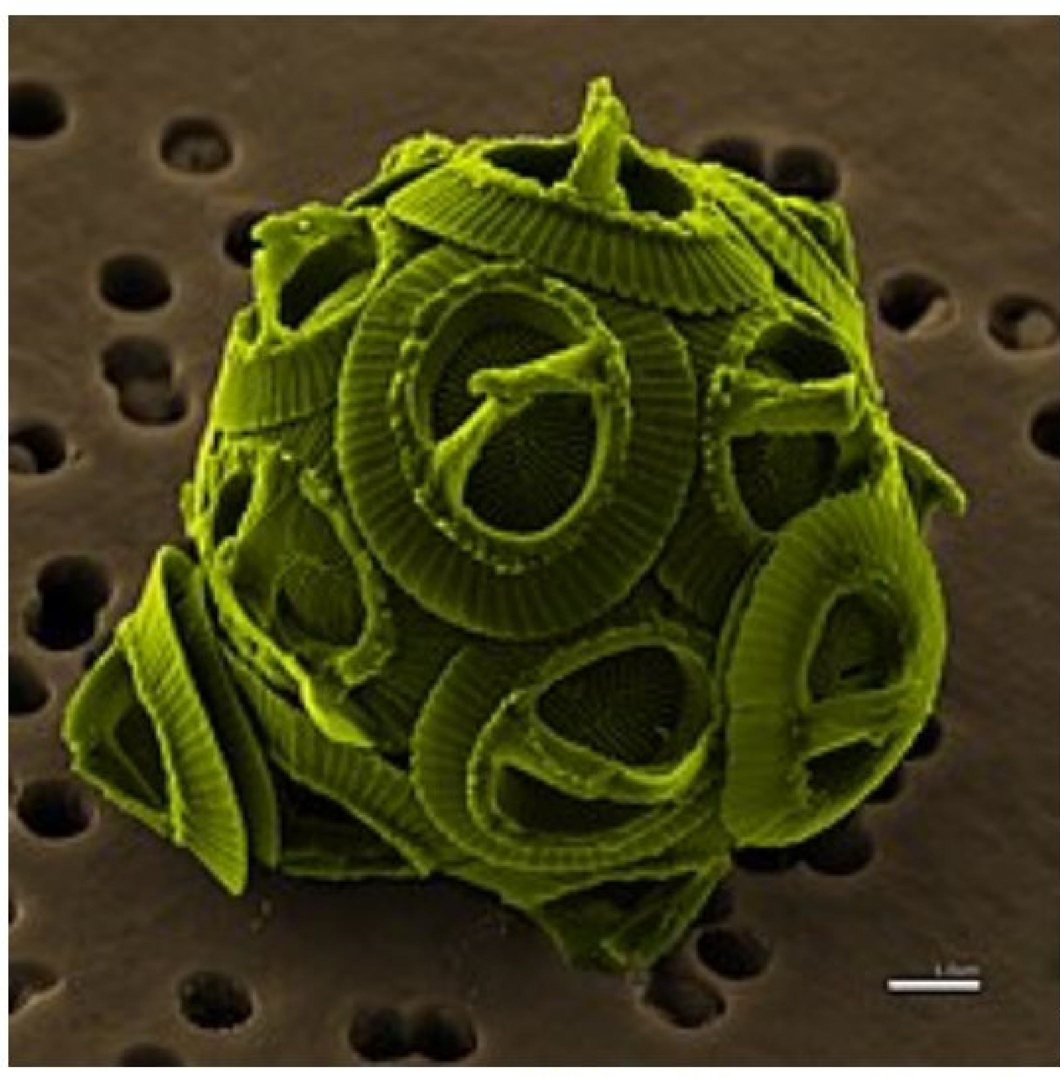
The singular *alga* is the Latin word for 'seaweed' and retains that meaning in English.[13] The etymology is obscure. Although some speculate that it is related to Latin *algēre*, 'be cold',[14] no reason is known to associate seaweed with temperature. A more likely source is *alliga*, 'binding, entwining'.[15]

The Ancient Greek word for 'seaweed' was φῦκος (*phŷkos*), which could mean either the seaweed (probably red algae) or a red dye derived from it. The Latinization, *fūcus*, meant primarily the cosmetic rouge. The etymology is uncertain, but a strong candidate has long been some word related to the Biblical פוך (*pūk*), 'paint' (if not that word itself), a cosmetic eye-shadow used by the ancient Egyptians and other inhabitants of the eastern Mediterranean. It could be any color: black, red, green, or blue.[16]

The study of algae is most commonly called phycology (from Greek *phykos* 'seaweed'); the term algology is falling out of use.[17]

Classifications

[edit]



False-color scanning electron micrograph of the unicellular coccolithophore *Gephyrocapsa oceanica*

One definition of algae is that they "have chlorophyll as their primary photosynthetic pigment and lack a sterile covering of cells around their reproductive cells".[18] On the other hand, the colorless *Prototheca* under ***Chlorophyta*** are all devoid of any chlorophyll. Although cyanobacteria are often referred to as "blue-green algae", most authorities exclude all prokaryotes, including cyanobacteria, from the definition of algae.[4][19]

The algae contain chloroplasts that are similar in structure to cyanobacteria. Chloroplasts contain circular DNA like that in cyanobacteria and are interpreted as representing reduced endosymbiotic cyanobacteria. However, the exact origin of the chloroplasts is different among separate lineages of algae, reflecting their acquisition during different endosymbiotic events. The table below describes the composition of the three major groups of algae. Their lineage relationships are shown in the figure in the upper right. Many of these groups contain some members that are no

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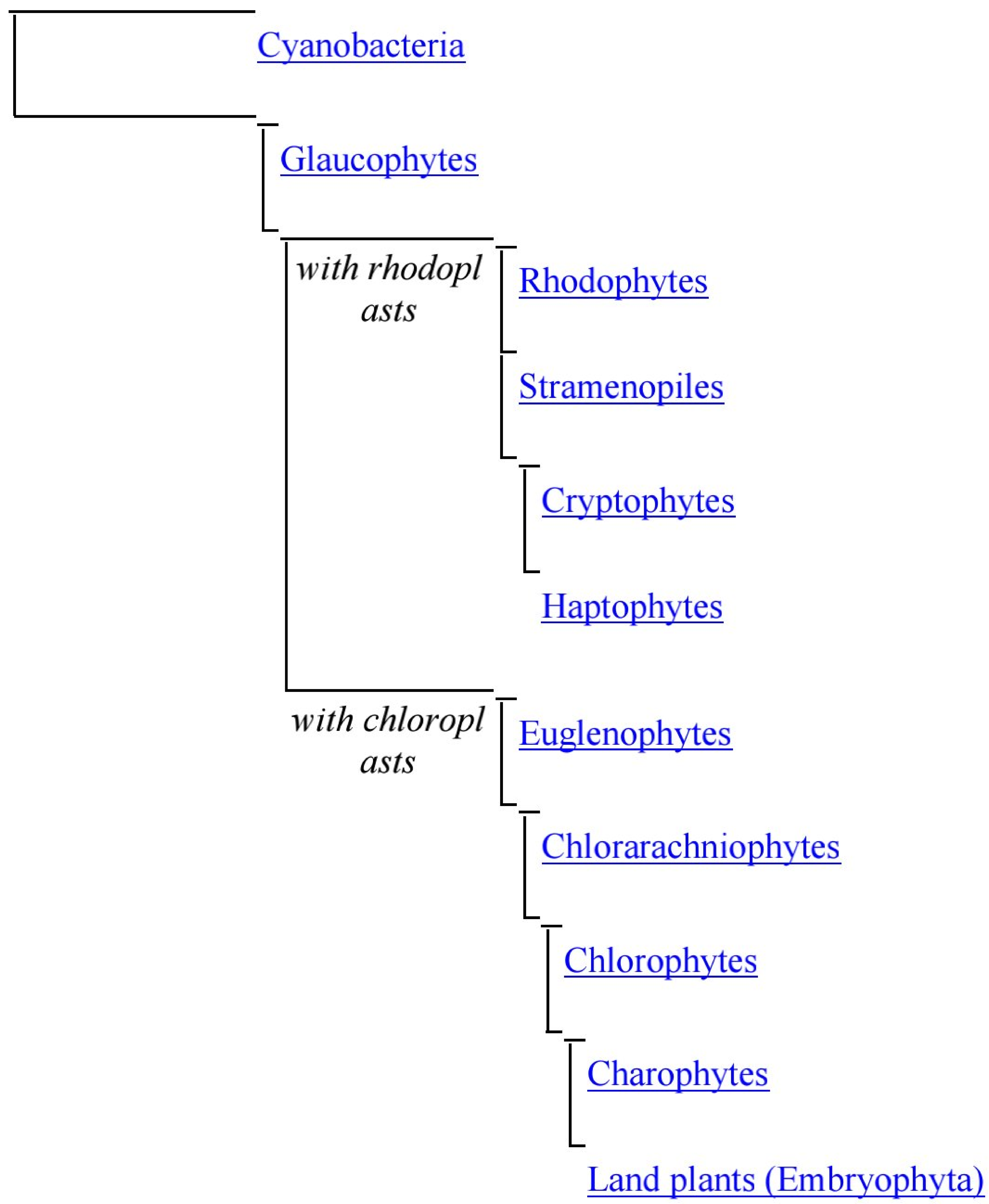
longer photosynthetic. Some retain plastids, but not chloroplasts, while others have lost plastids entirely.[20]

Phylogeny based on plastid[21] not nucleocytoplasmic genealogy:



Supergroup affiliation	Members	Endosymbiont	Summary
Primoplantae/ Archaeplastida	• Chlorophyta • Rhodophyta • Glaucophyta	Cyanobacteria	These algae have "primary" chloroplasts, i.e. the chloroplasts are surrounded by two membranes and probably developed through a single

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			endosymbiotic event. The chloroplasts of red algae have chlorophylls *a* and *c* (often), and phycobilins, while those of green algae have chloroplasts with chlorophyll *a* and *b* without phycobilins. Land plants are pigmented similarly to green algae and probably developed from them, thus the Chlorophyta is a sister taxon to the plants; sometimes the Chlorophyta, the Charophyta, and land plants are grouped together as the Viridiplantae.
Excavata and Rhizaria	• Chlorarachniophytes • Euglenids	Green algae	These groups have green chloroplasts containing chlorophylls *a* and *b*.[22] Their chloroplasts are surrounded by four and three membranes, respectively, and were probably retained from ingested green algae. **Chlorarachniophytes**, which belong to the phylum Cercozoa, contain a small nucleomorph, which is a relict of

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			the algae's nucleus. **Euglenids**, which belong to the phylum Euglenozoa, live primarily in fresh water and have chloroplasts with only three membranes. The endosymbiotic green algae may have been acquired through myzocytosis rather than phagocytosis.[23] (Another group with green algae endosymbionts is the dinoflagellate genus **Lepidodinium**, which has replaced its original endosymbiont of red algal origin with one of green algal origin. A nucleomorph is present, and the host genome still have several red algal genes acquired through endosymbiotic gene transfer. Also the euglenid and chlorarachniophyte genome contain genes of apparent red algal ancestry)[24][25][26]
Halvaria and Hacrobia	• Heterokonts • Dinoflagellates • Haptophyta • Cryptomonads	Red algae	These groups have chloroplasts containing chlorophylls *a* and *c*, and phycobilins. The

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shape can vary; they may be of discoid, plate-like, reticulate, cup-shaped, spiral, or ribbon shaped. They have one or more pyrenoids to preserve protein and starch. The latter chlorophyll type is not known from any prokaryotes or primary chloroplasts, but genetic similarities with red algae suggest a relationship there.[27]

In the first three of these groups (Chromista), the chloroplast has four membranes, retaining a nucleomorph in cryptomonads, and they likely share a common pigmented ancestor, although other evidence casts doubt on whether the heterokonts, Haptophyta, and cryptomonads are in fact more closely related to each other than to other groups.[28][29]

The typical dinoflagellate chloroplast has three membranes, but considerable diversity exists in chloroplasts within the group, and a number of

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endosymbiotic events apparently occurred.[5] The Apicomplexa, a group of closely related parasites, also have plastids called apicoplasts, which are not photosynthetic, but appear to have a common origin with dinoflagellate chloroplasts.[5]


HISTORIA
FVCORVM
AVCTORE
SAMVEL GOTTLIEB GMELIN,

PETROPOLI
EX TYPOGRAPHIA ACADEMIAE SCIENTIARVM

Title page of Gmelin's *Historia Fucorum*, dated 1768

Linnaeus, in *Species Plantarum* (1753),[30] the starting point for modern botanical nomenclature, recognized 14 genera of algae, of which only four are currently considered among algae.[31] In *Systema Naturae*, Linnaeus described the genera *Volvox* and *Corallina*, and a species of *Acetabularia* (as *Madrepora*), among the animals.

In 1768, Samuel Gottlieb Gmelin (1744–1774) published the *Historia Fucorum*, the first work dedicated to marine algae and the first book on marine biology to use the then new binomial nomenclature of Linnaeus. It included elaborate illustrations of seaweed and marine algae on folded leaves.[32][33]

W. H. Harvey (1811–1866) and Lamouroux (1813)[34] were the first to divide macroscopic algae into four divisions based on their pigmentation. This is the first use of a biochemical criterion in plant systematics. Harvey's four divisions are: red algae (Rhodospermae), brown algae (Melanospermae), green algae (Chlorospermae), and Diatomaceae.[35][36]

At this time, microscopic algae were discovered and reported by a different group of workers (e.g., O. F. Müller and Ehrenberg) studying the Infusoria (microscopic

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organisms). Unlike macroalgae, which were clearly viewed as plants, microalgae were frequently considered animals because they are often motile.[34] Even the nonmotile (coccoid) microalgae were sometimes merely seen as stages of the lifecycle of plants, macroalgae, or animals.[37][38]

Although used as a taxonomic category in some pre-Darwinian classifications, e.g., Linnaeus (1753),[39] de Jussieu (1789),[40] Lamouroux (1813), Harvey (1836), Horaninow (1843), Agassiz (1859), Wilson & Cassin (1864),[39] in further classifications, the "algae" are seen as an artificial, polyphyletic group.[41]

Throughout the 20th century, most classifications treated the following groups as divisions or classes of algae: cyanophytes, rhodophytes, chrysophytes, xanthophytes, bacillariophytes, phaeophytes, pyrrhophytes (cryptophytes and dinophytes), euglenophytes, and chlorophytes. Later, many new groups were discovered (e.g., Bolidophyceae), and others were splintered from older groups: charophytes and glaucophytes (from chlorophytes), many heterokontophytes (e.g., synurophytes from chrysophytes, or eustigmatophytes from xanthophytes), haptophytes (from chrysophytes), and chlorarachniophytes (from xanthophytes).[*citation needed*]

With the abandonment of plant-animal dichotomous classification, most groups of algae (sometimes all) were included in Protista, later also abandoned in favour of Eukaryota. However, as a legacy of the older plant life scheme, some groups that were also treated as protozoans in the past still have duplicated classifications (see ambiregnal protists).[*citation needed*]

Some parasitic algae (e.g., the green algae *Prototheca* and *Helicosporidium*, parasites of metazoans, or *Cephaleuros*, parasites of plants) were originally classified as fungi, sporozoans, or protistans of *incertae sedis*,[42] while others (e.g., the green algae *Phyllosiphon* and *Rhodochytrium*, parasites of plants, or the red algae *Pterocladiophila* and *Gelidiocolax mammillatus*, parasites of other red algae, or the dinoflagellates *Oodinium*, parasites of fish) had their relationship with algae conjectured early. In other cases, some groups were originally characterized as parasitic algae (e.g., *Chlorochytrium*), but later were seen as endophytic algae.[43] Some filamentous bacteria (e.g., *Beggiatoa*) were originally seen as algae. Furthermore, groups like the apicomplexans are also parasites derived from ancestors that possessed plastids, but are not included in any group traditionally seen as algae.[*citation needed*]

Evolution

[edit]

Algae are polyphyletic thus their origin cannot be traced back to single hypothetical common ancestor. It is thought that they came into existence when photosynthetic coccoid cyanobacteria got phagocytized by a unicellular heterotrophic eukaryote (a protist),[44] giving rise to double-membranous primary plastids. Such symbiogenic events (primary symbiogenesis) are believed to have occurred more than 1.5 billion years ago during the Calymmian period, early in Boring Billion, but it is difficult to track the key events because of so much time

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gap.[45] Primary symbiogenesis gave rise to three divisions of archaeplastids, namely the Viridiplantae (green algae and later plants), Rhodophyta (red algae) and Glaucophyta ("grey algae"), whose plastids further spread into other protist lineages through eukaryote-eukaryote predation, engulfments and subsequent endosymbioses (secondary and tertiary symbiogenesis).[45] This process of serial cell "capture" and "enslavement" explains the diversity of photosynthetic eukaryotes.[44]

Recent genomic and phylogenomic approaches have significantly clarified plastid genome evolution, the horizontal movement of endosymbiont genes to the "host" nuclear genome, and plastid spread throughout the eukaryotic tree of life.[44]

Relationship to land plants

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Fossils of isolated spores suggest land plants may have been around as long as 475 million years ago (mya) during the Late Cambrian/Early Ordovician period,[46][47] from sessile shallow freshwater charophyte algae much like *Chara*,[48] which likely got stranded ashore when riverine/lacustrine water levels dropped during dry seasons.[49] These charophyte algae probably already developed filamentous thalli and holdfasts that superficially resembled plant stems and roots, and probably had an isomorphic alternation of generations. They perhaps evolved some 850 mya[50] and might even be as early as 1 Gya during the late phase of the Boring Billion.[51]

Chlorophyceae

The **Chlorophyceae** are one of the classes of green algae, distinguished mainly on the basis of ultrastructural morphology.[2] They are usually green due to the dominance of pigments chlorophyll a and chlorophyll b. The chloroplast may be discoid, plate-like, reticulate, cup-shaped, spiral- or ribbon-shaped in different species. Most of the members have one or more storage bodies called pyrenoids located in the chloroplast. Pyrenoids contain protein besides starch. Some green algae may store food in the form of oil droplets. They usually have a cell wall made up of an inner layer of cellulose and outer layer of pectose.

General characteristics

[edit]

This section may **require cleanup** to meet Wikipedia's quality standards. The specific problem is: **The whole section is a bulleted list.** Please help improve this section if you can. *(October 2013)* (*Learn how and when to remove this message*)

- The body may be unicellular, colonial, filamentous or multicellular.

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- They are usually green due to the presence of chlorophyll a, chlorophyll b and beta-carotene.
- The chloroplast may be discoid, cup-shaped (e.g. *Chlamydomonas*), spiral or ribbon shaped[example needed]
- Most chlorophytes have one or more storage bodies called pyrenoids (central proteinaceous body covered with a starch sheath) that are localised around the chloroplast.
- The inner cell wall layer is made of cellulose and the outer layer of pectose.
- Asexual reproduction is by zoospores. They are flagellates produced from the parent cells by mitosis. Also by aplanospores, hypnospores, akinetes, Palmella stage, etc.
- Sexual reproduction of Chlorophyceae is isogamous, anisogamous or oogamous.
- The chlorophycean CW clade, and chlorophycean DO clade, are defined by the arrangement of their flagella. Members of the CW clade have flagella that are displaced in a "clockwise" (CW, 1–7 o'clock) direction e.g. Chlamydomonadales. Members of the DO clade have flagella that are "directly opposed" (DO, 12–6 o'clock) e.g. Sphaeropleales.[3]

Reproduction

[edit]

Vegetative reproduction usually takes place by fragmentation. Asexual reproduction is by flagellated zoospores. And haplospore, perennation (akinate and palmella stage). Asexual reproduction by mitospore absent in spyrogyra. Sexual reproduction shows considerable variation in the type and formation of sex cells and it may be isogamous e.g. *Chlamydomonas, Ulothrix*, anisogamous e.g. *Chlamydomonas, Eudorina* or Oogamous e.g. *Chlamydomonas, Volvox*. *Chlamydomonas* has all three types of sexual reproduction.

They share many similarities with the higher plants, including the presence of asymmetrical flagellated cells, the breakdown of the nuclear envelope at mitosis, and the presence of phytochromes, flavonoids, and the chemical precursors to the cuticle.[4]

The sole method of reproduction in *Chlorella* is asexual and azoosporic. The content of the cell divides into 2,4 (B), 8(C) sometimes daughter protoplasts. Each daughter protoplast rounds off to form a non-motile spore. These autospores (spores having the same distinctive shape as the parent cell) are liberated by the rupture of the parent cell wall (D). On release each autospore grows to become a new individual. The presence of sulphur in the culture medium is considered essential for cell division. It takes place even in the dark with sulphur alone as the source material but under light conditions nitrogen also required in addition. Pearsall and Loose (1937)[5] reported the occurrence of motile cells in *Chlorella*. Bendix (1964)[6] also observed that *Chlorella* produces motile cells which might be gametes. These observations have an important bearing on the concept of the life cycle of *Chlorella,* which at present is considered to be strictly asexual in character.

Asexual reproduction in *Chlorella ellipsoides* has been studied in detail and the following four phases have been observed during the asexual reproduction.

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1. Growth phase - During this phase the cells grow in size by utilizing the photosynthetic products.
2. Ripening phase - In this phase the cells mature and prepare themselves for division.
3. Post ripening phase - During this phase, each mature cell divides twice either in dark or in light. The cells formed in dark are known as dark to light phase, cells again grow in size.
4. Division phase - During this phase the parent cell wall ruptures and unicells are released.

Orders

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As of May 2023, AlgaeBase accepted the following orders in the class Chlorophyceae:

- Chaetopeltidales C.J.O'Kelly, Shin Watanabe, & G.L.Floyd – 16 species
- Chaetophorales Wille – 225 species
- Chlamydomonadales F.E.Fritsch (also known as Volvocales) – 1793 species
- Oedogoniales Heering – 792 species
- Sphaeropleales Luerssen – 941 species

Along with these genera, AlgaeBase recognizes several taxa that are incertae sedis (i.e. unplaced to an order):

- Dangeardinellaceae Ettl - 1 species

Other orders that have been recognized include:

- Dunaliellales – *Dunaliella* and Dunaliellaceae are placed in Chlamydomonadales by AlgaeBase[7]
- Chlorococcales – *Chlorococcum* and Chlorococcaceae are placed in Chlamydomonadales by AlgaeBase[8]
- Microsporales – *Microspora* and Microsporaceae are placed in Sphaeropleales by AlgaeBase[9]
- Tetrasporales – *Tetraspora* and Tetrasporaceae are placed in Chlamydomonadales by AlgaeBase[10]

In older classifications, the term Chlorophyceae is sometimes used to apply to all the green algae except the Charales, and the internal division is considerably different.[*citation needed*]

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