CHAPTER 40
Classification of Algae with Special Reference to Seaweed

Algae are photosynthetic organisms that occur in most habitats, ranging from marine, brackish water, freshwater to desert sands and from hot boiling springs to snow and in polar ice. They vary from small, single-celled to complex multicellular forms, The microscopic algae are called as phytoplankton whereas large benthic algae are called as macro algae. Some of the algae like giant kelps of the eastern Pacific that grow to more than 60 meters in length and form dense marine forests. Algae are found in the fossil record dating back to approximately 3 billion years in the Precambrian.

Taxonomy of algae is being modified from 1935 till date. Earlier classification was based on five important characteristics 1.type of pigments 2. nature of reserve food material, 3. type of cell wall material 4. Type, number and attachment of flagella and 5. cell structure. Fritsch (1935) divided the algae into 11 classes based on pigmentation, types of flagella, assimilatory products, thallus structure and methods of reproduction which was very well explained in his book entitled “Structure and reproduction of Algae”.

1.Chlorophyceae
2. Xanthophyceae
3.Chrysophyceae
4.Bacillariophyceae
5.cryptophyceae
6.Dinophyceae
7.Chloromonadineae
8.Euglenineae
9.Phaeophyceae
10.Rhodophyceae
11. Myxophyceae.

G.M. Smith (1950) classified algae into seven divisions. These divisions based on colour, storage food and cell wall composition. He included certain algae of uncertain position into Chloromonadales & Cryptophyceae.

1.Chlorophyta: Chlorophyceae & Charophyceae
2.Chrysophyta: Chrysophyceae, Xanthophyceae & Bacillariophyceae
3. Pyrophyta: Dinophyceae & Desmophyceae
4. Euglenophyta
5. Phaeophyta
6. Rhodophyta
7. Cyanophyta

Further Round (1973) has classified algae in two groups like Prokaryota & Eukaryota keeping Cyanophyta under Prokaryota and all other like Chlorophyta Euglenophyta Charophyta Parsinophyta Xanthophyta Haptophyta Dinophyta Bacillariophyta Chrysophyta Phaeophyta Rodhophyta Cryptophyta under Eukaryota.

Papenfuss (1946) included the suffix 'phyco' to the divisions of algae and named chlorophyta as Chlorophycophyta. The name green alga is given because of the presence of dominant pigments like Chlorophylls a and b over the carotenoids and xanthophylls.

Bold and Wynne (1978, 1985) recognized ten divisions of algae retaining the nomenclature given by Papenfuss (1946), except for blue green algae. They considered Cyanophyceae as a division and called it Cyanochloronta whereas Papenfuss had included it in phylum Schizophyta as a class.

1. Cyanophyta (Blue Green Algae)
2. Prochlorophyta (Single genus: Prochloron)
3. Chlorophyta (Green algae)
4. Charophyta (Stone worts)
5. Euglenophyta
6. Phaeophyta (Brown algae)
7. Chrysophyta (Golden and yellow green algae)
8. Pyrrhophyta (Dinoflagellates)
9. Cryptophyta
10. Rhodophyta (Red algae)

Robert Edward Lee's Classification (1989) divided the algae based on evolution and formed 4 evolutionary groups of algae which are further divided into 15 divisions.

1. Prokaryotic algae (Cyanophyta)
2. Eukaryotic algae with chloroplast surrounded by the two membranes
    - Glaucophyta,
    - Rhodophyta
    - Chlorophyta
3. Eukaryotic algae with chloroplast surrounded one membrane of chloroplast endoplasmic reticulum
    - Euglenophyta
    - Dinophyta
4. Algae which have two membranes of chloroplast endoplasmic reticulum
    - Cryptophyta
    - Heterokontophyta

Graham and Wilcox (2008) again classified algae based on the photosynthetic pigments, storage food and cell wall. He divided alga into 9 division such as

Phylum	Pigment constituents	Storage food	Cell wall
Cyanobacteria	Chl a, phycocyanin, allophycocyanin, phycoerythrin, β carotene and Xanthophyll	Cyanophycean starch, granules and glocogen	Peptidoglycan
Glaucophyta	Chl*a*, phycocyanin, allophycocyanin, β carotene and Xanthophyll	Starch	Cellulosic
Euglenophyta	Chl *a*,b β carotene, other carotenoid and Xanthophyll	paramylon	Proteinaceous pellicle beneath plasma membrane
Cryptophyta	Chl *a*,c, phycocyanin, phycoerythrin, α & β carotene and Xanthophylls	Starch	Proteinaceous periplast beneath plasma membrane
Haptophyta	Chl *a*,c, β carotene and Xanthophylls	Chrysolaminaran	Mostly calcified
Dinophyta	Chl *a*,c, β carotene and Xanthophylls	Starch	Cellulosic plate in vesicles beneath plasma membrane
Ochrophyta	Chl *a*, α & β carotene and Xanthophylls	Chrysolaminaran & lipid	Some naked, some with silica organic scales, cellulose, some having alginate
Rhodophyta	Chl*a*, phycocyanin, allophycocyanin, α & β carotene and Xanthophyll	Floridean starch	Cellulose, sulphated polysaccharides, some are calcified
Chlorophyta	Chl *a*,b, α & β carotene, other carotenoids and Xanthophyll	Starch	Cellulose, some are naked some are calcified

Cavalier-Smith, 2007 explained seaweed are not having a single taxonomic entity. Molecular phylogeny show they belong to three kingdom like Plantae (Which include Chlorophyta and Rhodophyta), the kingdom Chromista (includes Phaeophyta, dinoflagellates and diatoms) and the kingdom Bacteria (includes cyanophyta or blue green algae). Diatoms are the largest group of algae perhaps more than 25000 species described till date. Around 7000 species of red algae, 2000 species of brown, 1800 species of green and 1500 species of blue green are recorded so far.

Seaweeds are classified into three major groups based on their pigmentation like brown algae (Phaeophyceae), green algae (Chlorophyta), and red algae (Rhodophyta).

	Chlorophyta	Phaeophyta	Rhodophyta
Habitat	Marine, Freshwater & Terrestrial	Marine	Mostly marine & few freshwater
Pigments	Chl a & b , carotenoid	Chl a & c, Xanthophyll, Fucoxanthin & carotenoid	Chl a & d , carotenoid, Phycobiloprotein
Cell wall	cellulose	Cellulose	cellulose
Stored food	starch	Alginic acid, Laminarin, Mannitol	Agar, carrageenan
Species	*Ulva, Enteromorpha, Caulerpa*	*Sargassum, Turbinaria,Padina*	*Gracilaria, Gelidiellla,Hypnea, Kappaphycus*

Seaweeds are nothing but marine macroalgae found from the intertidal area to deep Ocean. Seaweeds are not grouped with the true plants because they lack a specialized vascular system like xylem, phloem, roots, stems, leaves, and enclosed reproductive structures like flowers and cones. They are simple thallus and the whole plant are responsible to do all the activities like photosynthesis, reproduction, fluid transport and respiration. Like true plants, seaweeds are photosynthetic, they convert solar energy to chemical energy and produce carbohydrate with the help of pigment systems present in each cell of the thallus. Within their cells seaweeds have the green pigment chlorophyll, which absorbs the sunlight they need for photosynthesis. Chlorophyll is also responsible for the green colouration of many seaweeds. In addition to chlorophyll some seaweeds contain other light absorbing pigments. These pigments can be red, blue, brown, or golden, and are responsible for the beautiful colouration of red and brown algae. In Chlorophyll Chl a is responsible for light reaction in the photosystem where as other chlorophyll pigments like chl b, c, d are accessories pigments which channel the solar energy photon to chla. Similarly other pigments like xanthophyll, phycobiloprotein also present in seaweed and these pigments provides beautiful colors for seaweed. Despite of the undeserved negative connotation associated with such a name, seaweeds play a fundamental role marine ecosystems, where they have a multitude of beneficial effects.

Turbinaria

Brown algae: *Sargassum, Padina, Stoechospermum, Turbinaria, Fucus, Laminaria* etc . It is a large group of algae consisting of 240 genera and over 1,800 species out of which 32 genera and 93 species are reported from India. About 99.7% members are marine and a few grow in freshwater. They range from simple microscopic heterotrichous filament (Ectocarpus) to largest alga like *Macrocystis pyrifera*, which attains a length of 60-90 meters. The brown colour of the algae due to the dominance of xanthophyll pigments like fucoxanthin which masks the other pigment like chl a & c (there is no chl b in phaeophyta), β carotene and other xanthophylls. There is no unicellular or colonial form in brown algae, They are branched, filamentous. Most of the plant are having a hold fast. Some of the higher brown algae are having stipe and lamina and is the only alga having tissue differentiation into conducting tissues but there is no true xylem or phloem found as in higher plants. In general they are larger in size and mostly found in temperate waters. Worldwide biomass harvested (from wild and farmed) comes from relatively few number of species from Laminariales and Fucales.

Sargassum

Fritsch (1935, 45) classified the Class. Phaeophyceae into nine orders. This was also followed by Mishra (1966).

1. Ectocarpales e.g., Ectocarpus, Haiothrix.
2. Tilopteridales e.g., Ptilopteris.
3. Cutleriales e.g., Cutlria.
4. Sporochnales e,g. Sporochnus.
5. Desmarestiales e.g., Desmarestia.
6. Laminariales e.g., Laminaria.
7. Sphacelariales e.g., Sphacelaria.
8. Dictyotales e.g., Dictyota.

9. Fucales e.g., Sargassum.

Padina

Ulva

The green algae represent a very diverse group distributed not only in the sea, but also in freshwater and terrestrial habitats. In recent years, based on DNA sequence data green algae do not form a homogeneous and coherent entity.

Enteromorpha

They are part of a larger group called Viridiplantae, in which the land plants are also included (Lewis & McCourt, 2004). However, all marine green algae are classified in a common class, called Ulvophyceae. The Ulvophyceae are a very diverse group and include about 920 species, which are distributed in all seas of the world. In the green seaweeds, the body of the alga shows a great range of variation in morphology but usually its morphology . It may be very thin filamentous as found in *Cladophora* and *Chaetomorpha* or in the form of sheets in *Ulva* or siphonaceous like *Caulerpa.* Species of this genus consist of a creeping stolon (that grows attached to the rocky bottom), from which numerous erect frond of variable shape arise. Siphonalean green algae are classified in two orders, Bryopsidales and Dasycladales, and are among the most ecologically successful seaweeds. The body of these algae is formed by one single giant cell, which contains numerous nuclei. There are few green algae which are calcareous like *Halimeda.*

Caulerpa

The red algae are one of the most ancient groups of eukaryotic algae. Fossil record of 1.2 billion years old was found for Bangiomorpha sps. Red algae lacks flagella in any stage of their life history as found in other algae. They have a complex life history, which usually involves the alternation of three generations like gametophyte, carposporophyte and tetrasporophyte. Saunders & Hommersand (2004) and Yoon et al(2006) emphasized based on the molecular data produced in the last two decades which revolutionise the classification of red algae belonging to a single phylum (Rhodophyta) which subdivided in two subphyla (Cyanidiophytina and Rhodophytina), seven classes (Cyanidiophyceae, Bangiophyceae, Compsopogonophyceae, Florideophyceae, Porphyridiophyceae, Rhodellophyceae and Stylonematophyceae)and 33 orders. The red algae show wide morphological variation from the simplest single cells *Porphyridium* to thin filaments in *Bangia*. The habit of expanded blades is found in many generasuch as *Delesseria Polyneura, Porphyra* and *Halymenia*. There are certain coralline algae attached to rocky substratum where the cell wall accumulate calcium carbonate. A typical example is represented by species of the order Corallinales, in which the cell walls accumulate calcium carbonate in the form of aragonite such as *Lithophyllum*, *Lithothamnion* and *Phymatolithon*, look like pink or red calcified crusts. Many branched species of red algae are found in the intertidal rocky shore. They are *Chondrus, Geledium, Gracilaria, Hypnea, Laurencia* & *Kappaphycus.*

Most of the red algae are having sulphated polysaccharides like agar-agar & carrageenan and for this purpose they are farmed on large scale in tropical regions.

Acanthophora

Kappaphycus

Hypnea