# TAXONOMY OF ALGAE WITH SPECIAL REFERENCE TO SEAWEED

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**What are Algae?**

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. Around 7000 species of red algae, 2000 species of brown, 1800 species of green and 1500 species of blue green are recorded so far. They vary from small, single-celled to complex multicellular forms.The microscopic algae are called as phytoplankton whereas large benthic algae are called as macroalgae or seaweed. The life history of algae is complicated, and this is what really differentiates them from plants. In fact, macroalgae can pass through life stages so distinct that, in the past, they have been mistaken for separate species. Algae are found in the fossil record dating back to approximately 3 billion years in the Precambrian. 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.

**What are Seaweeds?**

Seaweeds are nothing but marine macroalgae found from the intertidal area to deep Ocean. The life history of algae is complicated, and this is what really differentiates them from plants. In fact, macroalgae can pass through life stages so distinct that, in the past, they have been mistaken for separate species. 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. Seaweed reproduction can involve either exclusively sexual or asexual phases, while some species display an alternation of generations that involves both in succession. In the former, the seaweed produces gametes (egg and sperm cells) with a single set of chromosomes and, in the latter, spores containing two sets of chromosomes. Some species can also reproduce asexually by fragmentation. 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 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 chl *a*. Similarly other pigments like xanthophyll, phycobiloprotein also present in seaweed and these pigments provides beautiful colours for seaweed.

The red macroalgae normally grow at the greatest depths, typically as far as 30 meters down, the green macroalgae thrive in shallow water, and the brown algae in between. This distribution of species according to the depth of the water is somewhat imprecise, however; a given species can be found at a location where there are optimal conditions with respect to substrate, nutritional elements, temperature, and light. In exceptionally clear water, one can find seaweeds growing as far as 250 meters below the surface of the sea. It is said that the record is held by a calcareous red alga that was found at a depth of 268 meters, where only 0.0005 percent of the sunlight penetrates. Even though the waters at that depth may appear pitch-dark to human eyes, there is still sufficient light to allow the alga to photosynthesize. In turbid waters, seaweeds grow only in the top, well-lit layers of water. Despite of the undeserved negative connotation associated with such a name, seaweeds play a fundamental role in marine ecosystems, where they have a multitude of beneficial effects.

**Classification of algae**

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

**Papenfuss (1946)** included the suffix 'phyco' to the divisions of algae and named chlorophyta as Chlorophycophyta

**G.M. Smith (1950)** classification based on the morphology and physiological structure of algae and the classes reduced to seven combining Chlorophyceae and Charophyceae in one group like chlorophyta Similarly Xanthophyceae, Chrysophyceae and Bacillariophycear under Chrysophyta mostly based on the pigmentation thus the classes are 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 and Eukaryota keeping Cyanophyta under Prokaryota and all other like Chlorophyta Euglenophyta Charophyta Parsinophyta Xanthophyta Haptophyta Dinophyta Bacillariophyta Chrysophyta Phaeophyta Rodhophyta Cryptophyta under Eukaryota

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

**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.

- Prokaryotic algae (Cyanophyta)
- Eukaryotic algae with chloroplast surrounded by the two membranes: Glaucophyta, Rhodophyta, Chlorophyta
- Eukaryotic algae with chloroplast surrounded one membrane of chloroplast endoplasmic reticulum: Euglenophyta, Dinophyta
- 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 divisions.

| Phylum | Pigment constituents | Storage food | Cell wall |
|---|---|---|---|
| **Cyanobacteria** | Chl a, phycocyanin, allophycocyanin, phycoerythrin, β carotene and Xanthophyll | Cyanophycean starch, granules and glocogen | Peptidoglycan |
| **Glaucophyta** | Chla, 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** | Chla, phycoerythrin 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 (Phaeophyta), 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 |

**Brown algae (Phaeophyta)*:***

- It is a large group of algae consisting of 240 genera and over 1,800 species
- 32 genera and 93 species are reported from India.
- About 99.7% members are marine and a few grow in fresh water.
- They range from simple microscopic heterotrichous filament (Ectocarpus) to largest alga like *Macrocystis pyrifera*, which attains a length of 60-90 meters.

- 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
- The brown colour of the algae due to the dominance of xanthophyll pigments like fucoxanthin
- It masks the other pigment like chl a & c (no chl b in phaeophyta), β carotene and other xanthophylls.
- It 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 harvested biomass (wild and farmed) comes from few number of *Laminariales* & *Fucales*

**Fritsch (1935, 45) classified the Class. Phaeophyceae into 9 orders.**

1.Ectocarpales :*Ectocarpus, Haiothrix*.
2. Tilopteridales : *Ptilopteris*.
3. Cutleriales :*Cutleria*
4. Sporochnales : *Sporochnus.*
5. Desmarestiales :*Desmarestia..*
6. Laminariales :*Laminaria*.
7. Sphacelariales :*Sphacelaria*.
8. Dictyotales :*Dictyota*.
9. Fucales :Sargassum


*Ptilopteris*


*Ectocarpus* *Sphacelaria* *Desmarestia*

*Macrocystis pyrifera*

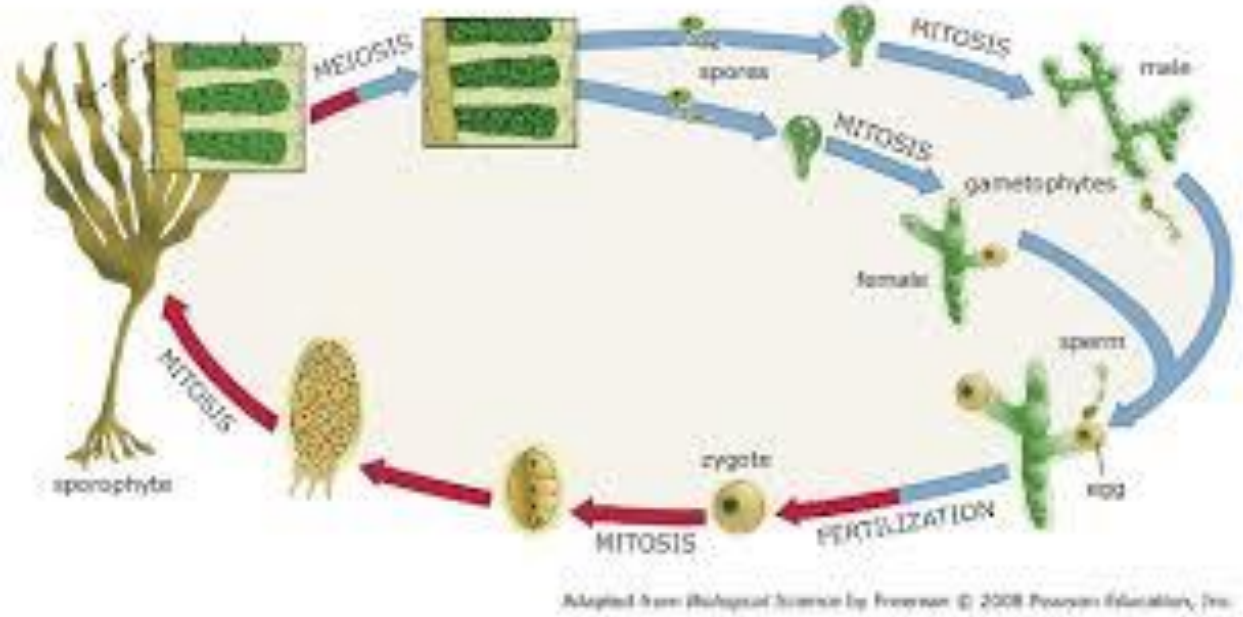
*Sargassum wightii*

*Laminaria digitata*

*Sargassum longifollium*

*Padina tetrastromatica*

*Turbinaria ornata*

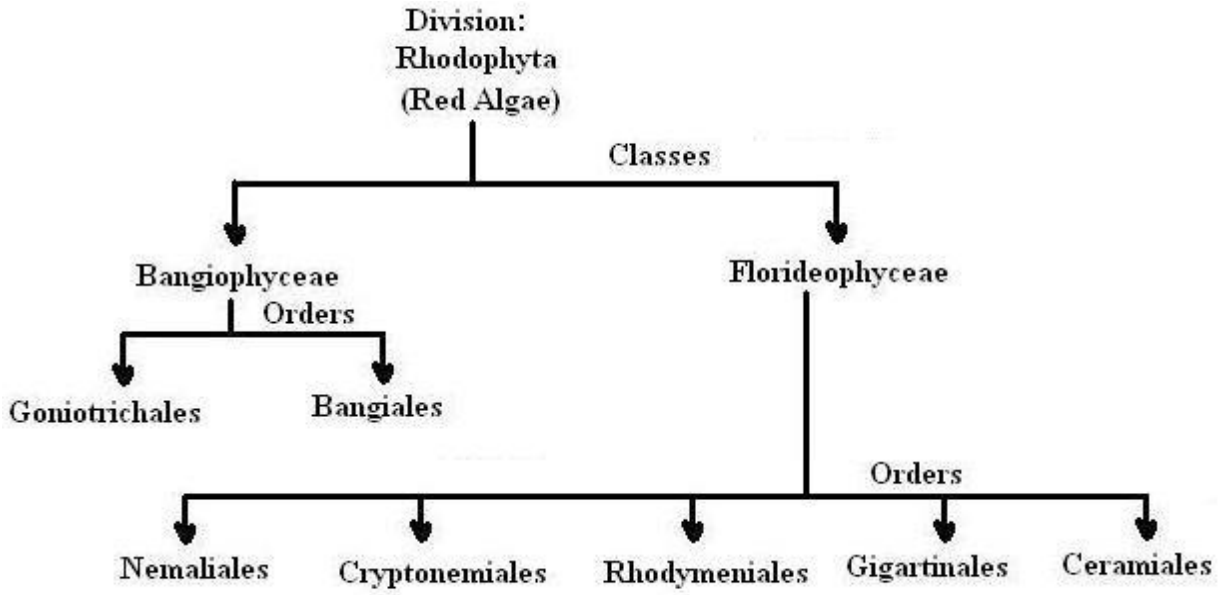



**Life cycle of *Laminaria* Courtesy: Adapted by Biological Sciences Freeman 2008**

**Red algae (Rhodophyta)**

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.



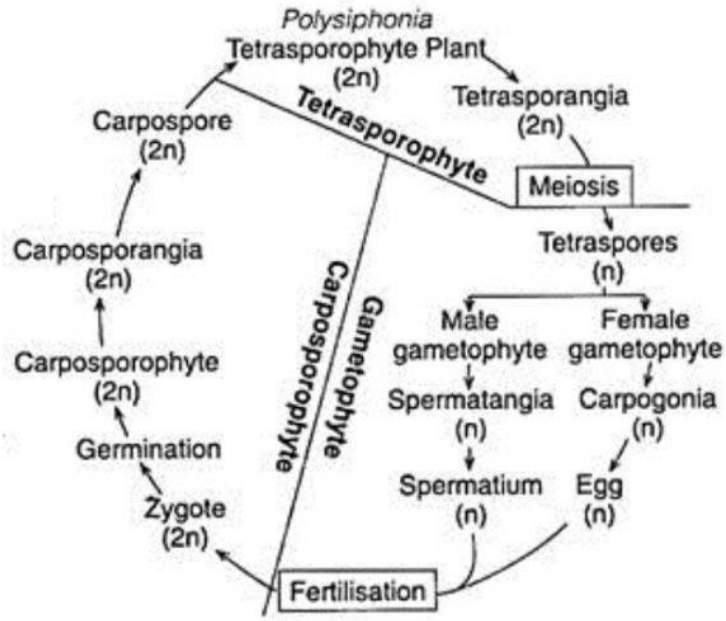

***Amphiroa*** ***Grateloupia*** ***Botryocladia*** ***Hypnea*** ***Laurencia***

*Gracilaria edulis* *G.crassa* *Sarconema filiforme*

*Kappaphycus alvarezii*

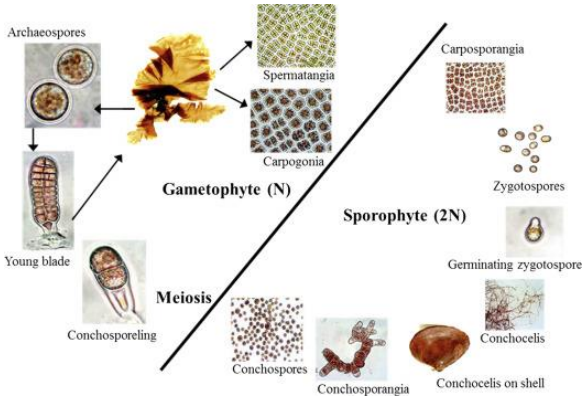
*Hypnea musciformis*

*Acanthophora spicifera*




**Triphasic Life Cycle :** Diplobiontic Type (*Polysiphonia*)

*Porphyra sp*




**Life cycle of *Porphyra***

**Chlorophyta (Green algae)**

1. Chlorophyta is having more than 7000 species present in varying habitats from freshwater to marine, land and in artic area
2. 90% of the chlorophycean algae are in freshwater.

3. In recent years, based on DNA sequence data green algae do not form a homogeneous and coherent entity.
4. They are part of a larger group called Viridiplantae, in which the land plants are also included (Lewis & McCourt, 2004).
5. However, all marine green algae are classified in a common class, called Ulvophyceae.
6. The Ulvophyceae are a very diverse group and include about 920 species, which are distributed in all seas of the world.
7. In the green seaweeds, the body of the alga shows a great range of variation in morphology but usually its morphology vary from thin filamentous as found in *Cladophora* and *Chaetomorpha* or in the form of sheets in *Ulva* or siphonaceous like *Caulerpa*
8. 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.
9. Siphonalean green algae are classified in two orders, Bryopsidales and Dasycladales, and are among the most ecologically successful seaweeds.
10. The body of these algae is formed by one single giant cell, which contains numerous nuclei.
11. There are few green algae which are calcareous like *Halimeda.*

*Enteromorpha intestinalis*

*Ulva lactuca*

*Chaetomorpha antennina*

*Codium tomentosum*

*Boergesnia forbesii*

*Halimeda gracilis*

**Life cycle of *Ulva lactuca***

**Importance of marine algae (Seaweed)**

- ✓ Seaweeds play a major role in marine ecosystems.
- ✓ As the first organism in marine food chains, they provide nutrients and energy for animals directly or indirectly by decomposition.
- ✓ Marine algae have more than 60 odd elements for health and nutritional security
- ✓ Seaweed are the souce of phycocolloids like agar,align and carrageenan. Besides mannitol, iodine and other vitamins.
- ✓ It is source for food, fodder and fertilizer, bioplastic, biofuel and cosmetic product
- ✓ It is used in pharma industries, textile, cosmetic and other industries like dairy, meat
- ✓ seaweeds as a potential climate change mitigation by sequestrating carbon dioxide.
- ✓ It also helps in bio mitigating pollution through bioremediation.
- ✓ It is the best nursery ground for fish and shellfish larvae providing very good oxygen to the young one and by reducing the temperature of the nursery ground.
- ✓ Seaweed should be used in daily diet.

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