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1. Classification of plants according to Eichler's grouping of 1883:

DIVISION	CLASS
Thallophyta	Phycotinae (Algae) Mycotinae (Fungi)
Bryophyta	Hepaticae (Liverworts) Musci (Mosses)
Pteridophyta	Psilotinate (Psilotum) Lycopodinae (Lycopodium, Selaginella) Equisetinae (Horsetails) Filicinae (Ferns)
Spermatophyta	Gymnospermae (Gymnosperms) Angiospermae (Angiosperms)

2. **Importance of Algae to man**

The nineteen most useful aspects of algae for human being are mentioned below:

a. *Food for sea animals and fishes:*

The algae are used as a direct source of food by several sea animals and fishes.

The marine algae are rich in iodine and several other important minerals. This makes the fundamental source of food for all marine animals and in this respect sea is the richest food producing area.

Image Curtsey: http://blogsimages.forbes.com/amywestervelt/files/2012/05/AuroraAlgae.jpg

Marine planktonic diatoms together with Dinoflagellata are of fundamental biological importance since all life of sea is dependent upon them.

b. Mineral contents:

High mineral content, up to five percent of the wet material, in which all the mineral elements important in human and animal physiology are found, makes sea weeds a unique supplement for a well balanced diet. Potassium, sodium and chloride are found in the ionic form in sea weeds (Pillai 1956).

According to Black (1953), the significance of iodine, as a constituent of food, is that besides being present in organic combination it is also available in part in the readily available form of the precursor of thyroxine, and hence this source of iodine surpasses mineral iodine in drinking water and iodized table salt.

The another micronutrients besides iodine which are important in human metabolism are iron, copper, manganese and zinc, and all of them are present as the trace elements of sea weeds. The highest copper content is found in Sarconema fur eellatum and Acanthophora spicifera.

At the present time, iodine is produced from brown seaweeds in Japan, France, Norway and Java. However, in Russia it is obtained from a red alga of the Black Sea, Phyllophora nervosa which contains from 0.2 to 0.5 percent on the dry matter. About 80 percent of the world's supply comes from nitrate mines in Chile.

c. Direct use of algae as food for man:

Since the pre-historic times, several sea weeds have been used as direct source of food to human beings. Several fresh water algae have also been utilised in the preparation of various kinds of vitaminized food. As we know well that the fundamental food of sea living stock are algae and they are used as food by human beings.

Since the algae are rich in vitamins and minerals, all the deficiencies are over run by the use of algae as food. The algae (sea weeds) form the most important part of the diet of Japan and China. And some people think that the artistic taste and cultural development of the people of Japan is because of the use of the sea weeds as food. In our country, a few species of Spirogyra and Oedogonium are utilised as food in South India.

Several preparations of algae are used in various countries. Of course Japan tops the list. Suimono is a Japanese preparation of dried fish and several sea weeds. Mitsu is another Japanese preparation which contains sea weeds, fruits, sugars and dried kidney beans. Dulse is an English dish of algae prepared from Rhodymenia. Seatron is prepared from Nereocystis in United States. Laver or Norl is prepared in Japan from Porphyra. Green Laver is prepared in South India from Spirogyra and Oedogonium. Kompu is the product of many Laminariales.

Apart from China and Japan, in Malaya, Indonesia, Myanmar and Thailand, the sea weeds are used as food. Ulva lactuca was used in Scotland for the preparation of salad and soups. Laminaria saccharina, Rhodymenia palmata have been used as food in parts of Scotland and Ireland and Porphyra is considered to be a tasteful culinary dish in many parts of England.

Among the more important algal food industries may be mentioned carrageen. This is a product of several sea weeds but principally Chondrus crispus. Carrageen is used by soaking it in water and mixing it with milk. Carrageen possesses the properties of gelling which is one of the factors which enhances its usefulness. Fruit juice may also be mixed with it forming fruit jelly. It is also employed in the preparation of ice creams and in the confectionery industry.

The sea weeds are also used as food in the regions of Far East and Australia. The inhabitants of the Hawaii Island consume large quantities of sea weeds. The indigenous people of Chile use large quantities of Durvillea Antarctica and some species of Ulva. The natives of New Zealand use certain green sea weeds in preparation of salad and soups.

The people of China and Japan consume the sea weeds on large scale. The people living on the sea coasts in these countries commonly use fresh sea weeds as food. In Japan, Porphyra tenera happens to be one of the most important edible alga and a product by the name of Amanori and Asakusa-Nori are made from it.

d. As a source of vitamins.

The marine algae are the richest source of vitamins. The vitamins A, B and E are found abundantly in sea weeds. The vitamin B essentially required for the development of human body is found in great abundance in almost all Phaeophyceae. The cod liver oil is the rich source of vitamin A, which is acquired from sea weeds. Vitamin E is equally important for human beings which are found in many marine algae.

According to Lundin and Ericson (1956), in the sea weeds of Sweden maximum amount of vitamin B_{12} and folic acid are found in spring and summer and niacin and folic acid in winter. Vitamin B_{12} content and also that of B_1 are higher in green and red algae than in brown algae and that the niacin and vitamin C content appear to be about the same in the above three groups of marine algae. Several vitamins except ascorbic acid have been reported from Chlorella. The vitamins found in Chlorella are – thiamin, riboflavin, niacin, pyridoxine, pantothenic acid, chlorine, biotin, vitamin B_{12} and lipoic acid.

e. As a source of agar:

The best agar is manufactured from Gelidium of Rhodophyceae, which is also called vegetative agar; Japan produces the largest quantity of agar. It produces 95% of the World production. Agar is also obtained from several other marine algae, the yield of agar, setting temperature and gel strength of the product from ten species belonging to Gelidium, Sarconema, Hypnea and Gracilaria were obtained by Thivy (1951). Japan is the chief agar producing country and it exports agar to most of the countries of the world.

The agar is used in several ways. It is employed in the preparation of ice cream, jellies, desserts, etc., in sizing the textiles and clearing many liquids. It is also used in preparing shaving creams, cosmetics and shoe polishes. The agar has constantly been used in biological laboratories for media preparation.

In India, agar resources, as annual yield of dry sea weeds of Chilka Lake have been estimated by Mitra (1946) to be about 4.06-5.08 metric tons, of Cape Comorin by Koshy and John (1948). Thivy (1957) about one metric ton, and of the Pamban area as estimated by Thivy (1957) about seven metric tons. Other large quantities are in Kathiawar Peninsula end estuaries, the resources of the Andamans are believed to be considerable.

f. Medicines and minerals:

Several diseases caused by vitamin deficiency such as vitex, asthma, tooth decay, etc., may be eradicated, if flour of the sea weeds is added to the food. According to Dr.

Weston, iodine is the most important element to enable the thyroid glands to secrete the thyrosin which contains 60% iodine. It controls the general development of the animal. Sea weeds are the best source of iodine for human beings.

Several important sea weed medicinal preparations are prepared in various countries, i.e., Kelpeck is prepared from kelps in Chicago; Burbank Vegetable tablets are sea weed preparations from United States. Kelpamalt is a sea weed medicinal preparation from New York (U.S.A.); Isokelp is prepared in California; Parakelp and Manamar are other medicinal sea weed American preparations. An antibiotic drug Chlorellum is also obtained from algae.

About forty-five elements are found in a sea weed Macrocystis pyrifera. In addition to these elements, vitamins are also found. No other food contains such a great abundance of minerals and vitamins.

Marine algae are specially rich in vitamins A, B, C and E. The diatom Nitzschia is very rich in vitamin A and possibly this is the main source of vitamin A that is found in liver oils of many fishes. Vitamin B is also found in certain algae, for example, Ulva, Porphyra, etc., and Alaria valida is rich in Vitamin C, while some Fucoids and Porphyra are even richer.

Besides these several other marine forms are quite rich in minerals and vitamins. Several tribes using the sea weeds directly as food have their people handsome and sturdy.

g. Manufacture of iodine:

The World's iodine supply is fulfilled from the sea weeds. Since a century back the iodine manufacture is in progress. Iodine is used in several ways.

h. Alginic acid, algin and mannitol:

The alginic acid is manufactured from the cell wall of Phaeophyceae. It is insoluble in water and hard when dry. Sodium alginate is used in sizing material for water proof material, dyes, buttons, handles, combs and many of such things. This is also used as a sterilizer in daily use.

The algin is found in the form of calcium alginate and alginic acid. The Fucaceae are the chief source of algin in India. Yields of algin varying from 15.6 to 19.2 percent on air dry matter were estimated for Fucaceae and 10.4 percent for Padina.

A yield of 9.4 percent of mannitol from Sargassum tenerrimum and 73% from S. wightii have been reported.

i. *Manufacture of soaps and alums:*

By burning sea weeds on the sea coast, the alkalies are prepared from sea weed ashes. These alkalies are employed in the manufacture of soaps and alums.

j. *As a fodder for hens and milk cattle:*

By feeding the milk cattle and hens with sea weeds, iodine quantity of the milk and eggs may sufficiently be increased. In Scotland, New Zealand, Norway, France and United States several sea weeds are utilized for feeding hens and young livestock.

Some countries have even factories to Process Sea weeds into suitable cattle feed. The manufacture of cattle feed from sea weeds is made principally from brown algae and the processed food is fed to cattle, poultry and even pigs. It has been recorded that dried sea weeds served as cattle food have enhanced the milk-yielding and egg-laying capacity of cattle and poultry respectively.

k. *Manufacture of potash:*

Species of Macrocystis and Nereocystis (Phaeophyceae) possess 30% of potash in their dry weight.

l. *Used as fertilizers:*

Due to the presence of potassium chloride (KC1) in sea weeds, they are used as fertilizers in many countries, such as Japan, France, United States, England and South India.

Sea weeds are a store-house of the important potash, ionic sulphate, trace elements and growth substances, besides having every other element and radical required by plants. Sea weed manure seems to increase resistance to disease. Most of the nutrients including nitrogen compounds are in ionic form and a quick absorption by crops takes place and relatively little is left to be broken down by soil microflora, thus preventing acid conditions of the soil arising from the fermentation.

In general, the minerals diffuse out from the sea weed thallus rapidly. Yet another, feature is that sea weed manure holds water and air at the same time and improves the soil in both respects. Like other manures sea weeds have a similar role but also contribute the required potassium, sulphur, phosphorus and calcium.

m. *Manufacture of light weight buildings:*

Germany has discovered a process, in which the sea weeds are mixed with cement to make buildings light in weight and good heat resistant.

n. *Manufacture of paper:*

It is probably thought that a rough quality of paper may be manufactured from sea weeds; as yet it is not practised.

o. *Ornamental uses:*

Some algae like Botrydium and Spirogyra are grown in the garden ponds for their good looking habit.

p. *Diatomin earth:*

In the beds of oceans, diatom earth is found. During millions of years, immense rocks of diatomaceous earth have been formed. At Lompoc and California, the deposits are several hundred feet deep, i.e., 700 feet. At St. Maria oil fields California, the deposits are 3,000 feet deep and miles in length. Diatomaceous earth is very important commercial product and used in several ways. America is the largest producer of diatomaceous earth.

This is employed as an absorbent in the manufacture of dynamite. It is used in the filtration of liquid in sugar industry. This earth can resist very high temperatures upto 1,500°C, and used in the manufacture of fire bricks. These bricks are used in the inner lining of the blast furnaces.

This is also added in the cement to increase its cementing power. It is used as a mild abrasive for metal polishes. It is also used in the manufacture of tooth pastes and car polishes. It acts as a catalyst carrier in the hydrogenation of vegetable oil. In the manufacture of paints, lipsticks and other cosmetics, it is used in many ways.

q. Nitrogen fixation by blue green algae (cyanobacteria):

Many members of blue green algae have the ability to fix the atmospheric nitrogen in the soil. Soil is a living mass and apart from soil particles there are in it a number of bacteria, fungi, algae and protozoa. According to Russel, algae occupy a volume three times that of the bacteria.

For a long time, it was felt that these are the bacteria in the sheath of blue-green algae which fix nitrogen. P. K. De (1939) conclusively proved that blue-green algae (now called cyanobacteria) are the main agents for nitrogen fixation in rice fields, and the part played by other bacteria is relatively unimportant.

Watanabe (1951) made a far reaching research and proved that Tolyporthrix tenuis is a strong nitrogen fixer, and it was also reported that it could fix as much as 780 lbs. of nitrogen per acre per year. Allen (1955) found that Anabaena cylindrica fixes 2,900 lb. of nitrogen per acre per year.

The work on this problem has been undertaken at I. A. R.I. New Delhi by GS. Venkataraman and N. Dutta (1958). They have concluded that many blue green algae (cynobacteria) are capable of fixing atmospheric nitrogen in the soil. The dominance of the blue green algae, possessing the ability for nitrogen fixation particularly in the tropics, suggests that these organisms are of considerable importance in maintaining soil fertility. By increasing and strengthening the local blue green algal flora of a given habit, it may be possible to increase the fertility of these soils.

r. Reclamation of alkaline usar soils by blue-green algae (cyanobacteria):

It has been found that some blue green algae form a thick stratum on the surface of saline usar soils during the rainy season when other plants including crop fail to grow. Various species of Nostoc, Scytonema, Anabaena, etc., have been found to be plentifully growing on usar soils during the rains. According to Dr. R.N. Singh (1950), these algae (cynobacteria) can be of use in the reclamation of usar lands.

There is successive growth of the algal crop on such soils in a water-logged condition. After a year of such reclamation, it has been possible to grow transplanted paddy crop with a yield of as much as 1576-2000 lb. per acre. It has been found that the pH of the soil experimented upon in this matter fell from 9.7 to 7.6. Moreover, there was an improvement in the tilth and exchangeable calcium by about 20 to 33 percent. The water holding capacity increased by about 40 percent.

s. Utilization or Chlorella:

In recent years, the alga Chlorella has assumed great importance and it is likely to become even more important in the future. Chlorella is rich in proteins, fats and vitamins, and in the presence of nutrients, CO_2 and sunlight, multiplies at an enormous rate. Several countries have been experimenting with the mass production of Chlorella. Pilot scale Chlorella farms have already been established in America, Japan, Holland, Germany and Israel.
Such farms do not require excessive amounts of water and hence would be invaluable to augment food supplies in arid areas. Such 'farms' on a smaller scale could also be used to supply food in space stations of the future and even in the large ships.

Chlorella is also being increasingly used as means of purifying sewage when it is present in large, shallow tanks of effluent (after primary sedimentation of solids) the rapid photosynthesis produces abundant oxygen which is then used by the bacteria responsible for destroying the remaining organic matter. A number of sewage works using Chlorella now exist in the U.S.A. and at present largest in the world is opening at Auckland in New Zealand. It would seem that this cheap and effective means of sewage purification is likely to extend in the future.

Chlorella has the distinction of being the most widely studied alga as a potential food source for the world's expanding population. Each quart of a moderately thin suspension of Chlorella contains twenty billion cells of the alga. Arthur D. Little has produced Chlorella at the rate of 20 grams per square metre per day in his pilot plant established at Massachusetts. This way 17.5 tons of Chlorella may be produced per acre per year.

Chlorella has been largely used for studies on photosynthesis because it is easy to grow in various, environments and because the chlorophyll and end products, obtained during pho¬tosynthesis are quite similar to those found in higher plants. In newly grown cultures of Chlorella, large amount of protein is formed, but as the culture gets older the fats and carbohydrates are produced abundantly. The nutritional value of Chlorella is not only based on its high protein content but also on the fact that it contains the essential amino acids.

Chlorella contains most of the known vitamins such as thiamin, riboflavin, niacin, pyridoxine, pantothenic acid, choline, biotin, vitamin B_{12} and lipoic acid. Phytoplankton is the basic source of vitamins for fish, and makes the basis of food and vitamins for human beings. This has been calculated that a quarter pound of Chlorella will

3. Unicellular Form of Algae:

Chlamydomonas represents the unicellular and motile forms of green algae.

Found in stagnant water usually along with other forms.

Flagella are the structures for mobility.

The cell is bounded by a cellulose cell wall; contains organelles e.g. nucleus, mitochondria, stigma(eyespot), cup-shaped chloroplast, pyrenoid, etc.

The nucleus carries the genetic programme of the cell;

The stigma is for photoreception.

The mitochondria meditate the elaboration of energy molecules.

Manufactured sugar is processed into starch on the pyrenoid as explained below :

Unicellular forms of algae are also called acellular algae as they function as complete living organisms. Unicellular forms are common in all the groups of algae except Rhodophyceae, Phaeophyceae and Charophyceae. The unicells may be motile or non-motile.

a. The motile unicells are either rhizopo¬dial or flagellated.

The rhizopodial forms lack rigid cell wall and have cytoplasmic projections that help them in amoeboid movement, e.g., Chrysamoeba (Chrysophyceae, Fig. 3.1 A), Rhizochloris (Xantho- phyceae).

The flagellated unicells resemble the motile gametes and zoospores. The flagella func¬tion as the organ of locomotion varying in num¬ber and type in different groups. The flagellated unicells are found in many groups of algae, e.g., Phacotus (Fig. 3.1 B) and Chlamydomonas (Fig. 3.1 C), of Chlorophyceae. Euglena of Eugleno- phyceae etc.

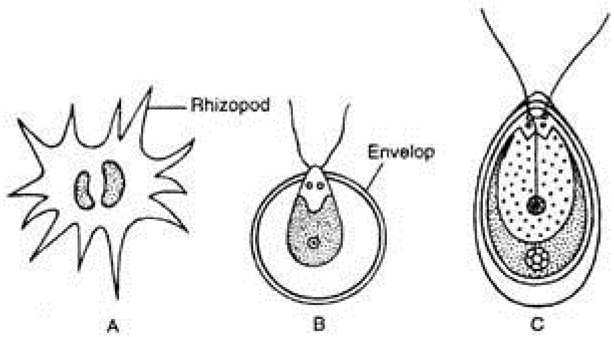


Fig. 3.1 : Unicellular motile algae : A. *Chrysamoeba*, B. *Phacotus*, and C. *Chlamydomonas*

b. The non-motile cells may be spiral filament as found in Spirulina (Cyanophyceae) (Fig. 3.2A). The coccoid unicellular algae are the simplest forms of algae found in Cyanophyceae, Chlorophyceae etc., e.g., Gloeocapsa, Chlorella (Fig. 3.2B).

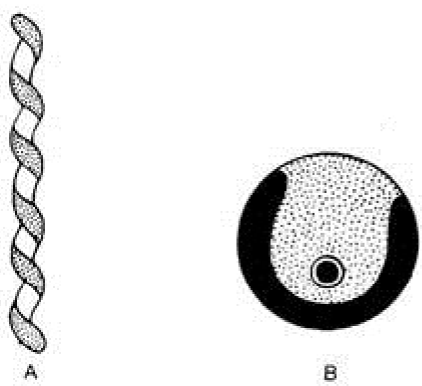


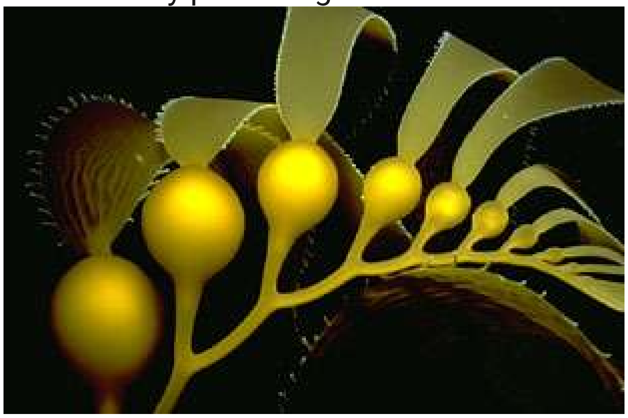
Fig. 3.2 : Unicellular non-motile algae. A. *Spirulina*, and B. *Chlorella*

4. **Reproduction of unicellular algae:**

   It can be either vegetative or sexual reproduction.

Vegetative reproduction: is the production of progeny without the union of cells or nuclear material. Many small algae reproduce asexually by ordinary cell division or by fragmentation, whereas larger algae reproduce by spores. Some red algae produce monospores (walled, nonflagellate, spherical cells) that are carried by water currents and upon germination produce a new organism. Some green algae produce nonmotile spores called aplanospores, while others produce zoospores, which lack true cell walls and bear one or more flagella. These flagella allow zoospores to swim to a favourable environment, whereas monospores and aplanospores have to rely on passive transport by water currents.

Sexual reproduction: is characterized by the process of meiosis, in which progeny cells receive half of their genetic information from each parent cell. Sexual reproduction is usually regulated by environmental events. In many species, when temperature, salinity, inorganic nutrients (e.g., phosphorus, nitrogen, and magnesium), or day length become unfavourable, sexual reproduction is induced. A sexually reproducing organism typically has two phases in its life cycle. In the first stage, each cell has a single set of chromosomes and is called haploid, whereas in the second stage each cell has two sets of chromosomes and is called diploid. When one haploid gamete fuses with another haploid gamete during fertilization, the resulting combination, with two sets of chromosomes, is called a zygote. Either immediately or at some later time, a diploid cell directly or indirectly undergoes a special reductive cell-division process (meiosis). Diploid cells in this stage are called sporophytes because they produce spores. During meiosis the chromosome number of a diploid sporophyte is halved, and the resulting daughter cells are haploid. At some time, immediately or later, haploid cells act directly as gametes. In algae, as in plants, haploid cells in this stage are called gametophytes because they produce gametes.



giant kelp The giant kelp species *Macrocystis pyrifera* reproduces sexually and has distinct haploid and diploid stages. The reproductive behaviour of *M. pyrifera* is heavily influenced by water temperature and the availability of nutrients.*Copyright Richard Herrmann*

5. Differences between the two types of colonial form of algae are:

- Pandorina has a unicellular motile thallus while volvox has a multicellular motile thallus.
- Pandorina has a sexual reproduction which is anisogamous while volvox has a sexual reproduction which is monogamous.
- Pandorina has 16 cells attached to one another while volvox has more cells in the colony which may run into thousands with cytoplasmic strands that run through the cells.

6. Description of Fucus:

It's a genus of brown algae whose species are often found on rocks in the inter tidal zones of the sea shores. The plant body is a flattened, dichotomously-branched phallus with a mid rib a vegetative apex, a reproductive apex at maturity) and a multicellular disk (hold fast) with which plant is attached to rock surface. The plant body also has air bladders which is believed to aid the plant to float on the water. Various species of *fucus* exist; vary in size from a few centimetres to about 2metres in length.

They also vary in terms of whether the sex cells are found in the same sexual chamber or in different sexual chambers on different plant bodies.

Sexual reproduction is monogamous, sex cells are produced in conceptacles which have openings (ostioles) on the surface of the phallus. In the male conceptacles, one of the diploid cells from outgrowth of the wall of the conceptacles undergoes meiosis, the amniotic product undergo many mitotic divisions to produce antheridium having 64 cells of which each cell develops into a biflagellate sperm that swims out of the conceptacles through the ostiole.

In the female conceptacle, similar to the situation in the Male conceptacle, leads to the production of an 8 celled oogonium – each becomes an egg which is the female sex cell.

Motile sperm cell from the antheridium move through the ostiole into the female conceptacle where the eggs are fertilised and diploid zygote are produced. Apart from the antheridia and oogonium, sterile multicellular filaments (paraphyses) are also produced in the conceptacles which are dispersed among the antheridial and oogonial outgrowths and at the entrance into the conceptacles. The diploid zygote germinates into a new diploid *Fucus* plant making the diploid the dominant generation.