1. Introduction

Seaweeds or benthic marine algae are the group of plants that live either in marine or brackish water environment. Like the land plants, seaweeds contain photosynthetic pigments and with the help of sunlight and nutrient present in the seawater, they photosynthesize and produce food.

Seaweeds are found in the coastal region between high tide to low tide and in the sub-tidal region up to a depth where 0.01 % photosynthetic light is available (Fig. 1). Plant pigments, light, exposure, depth, temperature, tides and the shore characteristic combine to create different environment that determine the distribution and variety among seaweeds.

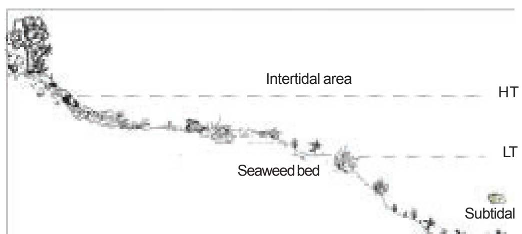
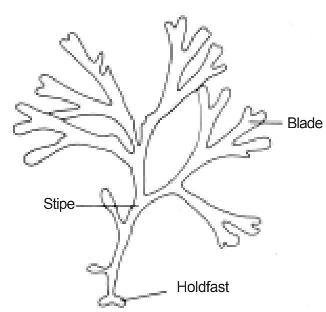


Fig. 1 Beach profile showing Intertidal and Subtidal areas

The important criteria used to distinguish the different algal groups based on the recent biochemical, physiological and electron microscopic studies are : a) photosynthetic pigments, b) storage food products, c) cell wall component, d) fine structure of the cell and e) flagella. Accordingly, algae are classified into three main groups i.e. green (Chlorophyta), brown (Phaeophyta) and red (Rhodophyta).

Seaweeds are similar in form with the higher vascular plants but the structure and function of the parts significantly differ from the higher plants. Seaweeds do not have true roots, stem or leaves and whole body of the plant is called thallus that consists of the holdfast, stipe and blade (Fig. 2).



The holdfast resembles the root of the higher plants but its function is for attachment and not for nutrient absorption. The hold fast may be discoidal, rhizoidal, bulbous or branched depending on the substratum it attaches. The stipe resembles the stem of the higher plants but its main function is for support of the blade for photosynthesis and for ab sorption of nutrients from surrounding sea water. The blade may resemble leaves of the higher plants and have variable forms (smooth, perforated, segmented, dented, etc.). The important functions of the blade are photosynthesis, absorption of nutrientThe most significant difference of seaweeds from the higher plants is that their sex organs and sporangia are usually one celled or if multi-cellular, their gametes and spores are not enclosed within a wall formed by a layer of sterile or non reproductive cells.

2. Green algae (Chlorophyta)

2.1 Morphology

Green algae are found in the fresh and marine habitats. They range from unicellular to multi-cellular, microscopic to macroscopic forms. Their thalli vary from free filaments to definetely shaped forms. The photosynthetic portion of the thalli may be moderately to highly calcified appearing in variety of forms as fan shaped segments, feather like or star-shaped branches with teeth or pinnules and clavate or globose branchlets.

2.2 Anatomy

The cell has thick and stratified cell wall consisting of an inner cellulose and outer pectin layer. The pectin layer is impregnated with calcium carbonate in all Dasycladales and in many Siphonales. The majority of the chlorophyceae have uninucleate cell and multinucleate condition occurs in Cladophorales and Siphonales during the formation of reproductive units. In some cases, cell division occurs in plane parallel to the surface and result in a distromatic or pleurostromatic paranchymatous thallus. Protoplast usually possesses a conspicuous central vacuole often traversed by cytoplasmic strands.

2.3 Pigments

Green algae possess photosynthetic pigments such as Chlorophyll *a* & *b*, contained in the special cell structure known as chromatophores. The chloroplast are found in varying shapes and sizes. It has double membrane envelope and no chloroplast endoplasmic reticulum is present. In many forms pyrenoids are present in the chloroplast, which are the major sites of starch formation. The pyrenoids

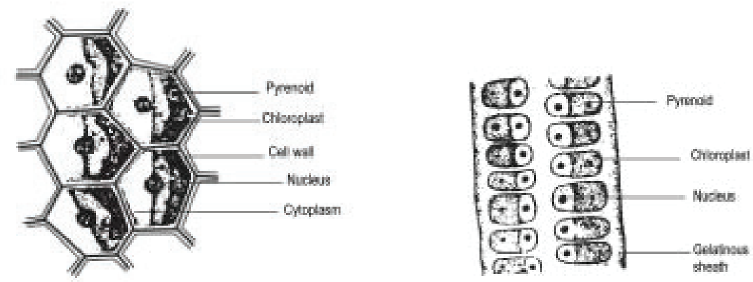


Fig. 3

of green algae are variably regarded as
masses of reserve protein and as special organelles of the cell (Fig.3). The photosynthetic product of this group is starch.

2.4 Reproduction

Reproduction in Chlorophyceae shows great diversity. Green algae can produce sexually and asexually by forming flagellate and sometimes non-flagellate spores. The vegetative propagation is achieved through fragmentation.

Sexual reproduction may be by isogamous, anisogamous or oogamous type. The simple mode of reproduction is by isogamy i.e fusion of similar gamates. In anisogamy, both the gametes are flagellated but of different size, while in oogamy the male gamete is flagellated and fuses with large non-motile female gamete to form zygote. A large number of Chlorophyceae are haploid and reduction occurs in the germinating zygote. All the oogamous type shows similar life cycles. Homologous alternation of two identical phases is known to occur in number of Ulvalaceae and Cladophoraceae, while all of Siphonales appear to be deployed.

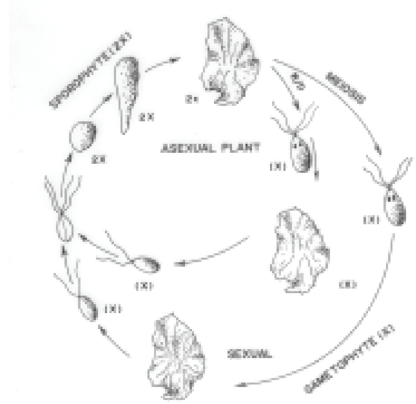


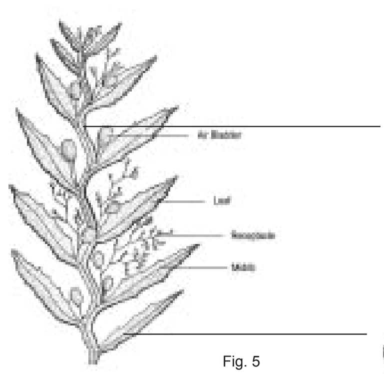
Fig. 4 Life cycle of *Ulva* sp.

Asexual reproduction by zoospores (motile) or aplanospores (non-motile) produced by vegetative cells. In many cases, the cells producing zoospores are not differentiated from vegetative cells and specialized sporangia are rare. The zoospores are formed either singly or in some numbers from the cells. The zoospores are naked and posses a more or less marked colourless beak at the anterior end from which flagella (two or four) arise. Aplanospores occur in both forms normally producing zoospores and as permanent development in many genera derived from zoosporic ancestor. Alternation of gametophytic and sporophytic generation occurs in this group (Fig. 4).

3. Brown algae (Phaeophyta)

3.1 Morphology

Brown algae are exclusively marine forms. They have different forms from simple, freely branched filaments to highly



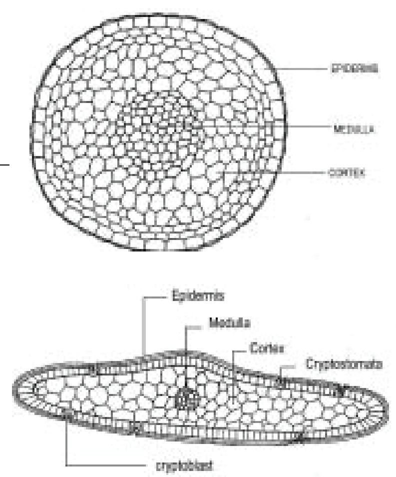


Fig. 5

differentiated forms. Branches are erect arising from prostrate basal filaments held together by mucilage forming a compact pseudo-parenchymatous aggregation of filaments into prostrate crust or erect branched axis or leaf like blades exhibiting the haplostrichous condition. Many species have large massive thalli with special air bladder, vesicles or float to make them bouyant (Fig. 5).

3.2 Anatomy

The cell wall is two layered. Outer layer is mucilaginous and sticky due to the presence of alginate. The inner layer is of cellulose (microfibrils). The cell is uninucleate with one or two nucleoli. The nuclei of Phaeophyta are usually large and possess a large and readily stained nucleolus with a delicate network having little chromatic material. The chromosomal organization is much advanced. The chromo centers on the chromosome of unknown function are characteristic of Phyaeophyta. Cytoplasm contains organelles like mitochondria, golgi bodies, ER, chromatophores, vacuoles and fucosan vesicles. The chromatophores are invariably parietal. The photosynthetic cells in the majority of brown algae contain numerous small discoid chromatophores. Chromatophores show movement to changes in the intensity and direction of illumination.

3.3 Pigments

Brown algae vary in colouration from olive –yellow to deep brown. The colouration is due to the accessory carotenoid pigment and fuxoxanthin. The amount of fucoxanthin varies in different species of brown algae. Dictyota, Ectocarpus, Laminaria etc. are rich in fucoxanthin, while species of Fucus are poor in fucoxanthin. Most of the littoral brown algae are rich in xanthophylls and fucoxanthin.

The algae rich in fucoxanthin exhibit a much higher rate of phytosynthesis in blue light than the algae with poor fucoxathin.

The other photosynthetic pigments of the brown algae are Chlorophyll *a* & *c*, B-carotene and xanthophylls. The photosynthetic products of the brown algae are Laminarian and Manitol. Laminarian is dextrin like polysaccharide, a food reserve, arise from the simple sugar of photosynthesis. Manitol appears to be non widely distributed and presence of such alcohols may account for extreme scarcity of free sugars as they undergo immediate conversion into alcohol and polysaccharides.

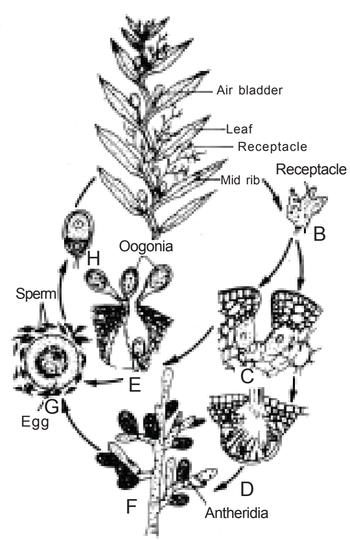


Fig. 6 Life cycle of *Sargassum* sp.

3.4 Reproduction

This group reproduces sexually and asexually. Several species of this group reproduce vegetatively by fragmentation. Members of this group produce biflagellate neutral spores found with in one celled or many celled reproductive organs.

The asexual reproduction is by the formation of zoospores in the unilocular or pleurilocular sporangia except in Dictyotales, Tilopteridales and Fucales. Unilocur sporangia produce haploid gamatophytic stage, while, pleurilocular sporangia produce diploid phase. The zoospores are asymmetric or bean shaped with two lateral or sub apical flagella. Zoospores are formed in the single celled unilocular sporangia by meiosis and gives rise to gametophytes.

Sexual reproduction is by isogamy, anisogamy and oogamy. In oogamous type of reproduction, the male sex organ (antheridium) and the female sex organ (oogamium) may be produced on the same plant or on different plants (Fig. 6). Alternation of gametophytic and sporophytic generations occurs in this group except in the members of Fucales.

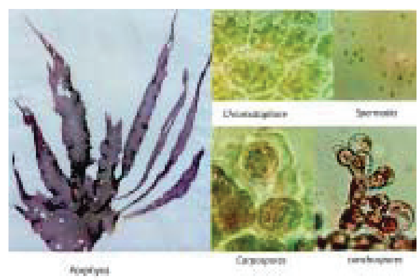


Fig. 7

4. Red algae (Rhodophyta)

4.1 Morphology

Except for few species they are exclusively marine. They vary in size and shape. They are either epiphytes, grows as crust on the rocks or shells as a large fleshy, branched or blade like thalli (Fig 7). The thallus is basically filamentous, simple or branched, free or compacted to form pseudoparenchyma with uni or multiaxial construction. They inhabit intertidal to subtidal to deeper waters.

4.3 Anatomy

Cells are eukaryotic. Inner cell wall is of cellulose and outer cell wall with amorphous matrix of mucopolysaccharides (i.e agar, porphyron, furcellaran, cerrageenan) . Cells are uninucleate /multinucleate with a large centric vacuole. The cross wall separating neighbouring cells exhibit a distinct features - the pit r connection or pit plug. The cytoplasm exhibits a high degree of viscosity and there is often a very firm adhesion to the wall which penetrates to the inner most layer of the membrane. The cells of Rhodophyta are always uninucleate except in the older cells that are multinucleate. The nuclei exhibit a prominent nucleolus and a well developed network with numerous chromatin grains. The chloroplast varies from single, axial, stellate in primitive taxa to parietal and discoid forms in non advance taxa.

4.3 Pigments

The colouration of Rhodophyta is due to water-soluble pigments, the red phycoerythrin and blue phycocyanin. Other pigments present are chlorophyll *a* & *b*, carotene etc. The photosynthetic product of this group is Floridian starch. Phycoerythrin pigment is found to be in the greater quantity in seaweeds of deeper water and freely illuminated forms which also show increase ratio of phycoerythrin to chlorophyll. The accessory pigments that resemble those found in Myxophyceae are of proteins and show characteristic similar to those of globulin. Red algae carry on apparently more photosynthesis in feeble light than brown and green algae.

4.4 Reproduction

This group seldom reproduces asexually. All the members of this group produce one or more kinds of non-flagellated spores that are either sexual or asexual in nature.

Sexual reproduction is very complicated involving several structures after fusion of gametes. The male structure called antheridium produces a single spermatangia which give

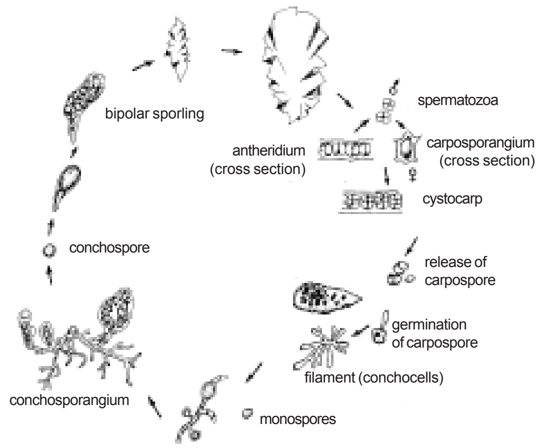


Fig. 8 Life cycle of *Porphyra* sp.

rise to non–motile spermatia. The female structure is a swollen carpogonium, which usually bears a long drawn out receptive trichogyne. The zygote is formed either by direct division as in Bangiales or after production of filamentous outgrowth called gonimoblast which give rise to number of sporangia each forming naked spore. Reduction occurs either at the first division of the zygote nucleus or is postponed and takes place in special tetrasporangia borne on individual distinct forms.

Some members of this group exhibit biphasic alternation of generation in which sexual generation (gametophyte) alternates with asexual (tetrasporophyte) generation, while others are triphasic with three generation or somatic phases (gamatophtye, caropsporophyte, tetrasporophyte) successively following one another (Fig. 8).

5. Intertidal seaweed collection procedure

The collection of seaweeds from the intertidal area is done during the low tide. It is necessary to go for collection one or two hours before the time of low tide as per tide tables. This will give more time for seaweed collection and to observe seaweeds in the natural habitat. It is important to make notes on the description of the site location, topography, associated flora and fauna and other related parameters. Although, there are number of methods for qualitative and quantitative assessment of seaweeds, we consider here two methods which are practical and easy to study.

Material necessary for seaweed collection

- Polyethylene bags
- Knife or scalpel
- Labeling materials (pen/pencil, labels, marker pens etc.)
- Rubber bands
- Field note book
- Long rope (about 50 m long)
- Quadrant 0.25 m^2 / 1 m^2
- Mono pan balance