UNIT 7

ALGAE

Structure

7.1 INTRODUCTION

In this unit, you will learn about algae (*singular* alga), a member of **thallophyta**, are a group of chlorophyll-bearing photosynthetic plant-like organisms which form a **thallus**, i.e., they do not have differentiated true tissues, and lack transport system for fluids. They include pond scums, stoneworts, and seaweeds. As per recent estimates, 72,500 algal species are known to be existent across the globe. Online taxonomic database of algae can be accessed at http://www.algaebase.org. Ecological significance of algae is evident by the fact that they contribute 30-50% of total oxygen produced in the biosphere. The small floating algae in aquatic (water) systems known as '**phytoplankton**' contribute 40% of the global photosynthesis, and is an important component of food web of aquatic ecosystem. The term algae are now restricted as eukaryotic organisms and Cyanobacteria, commonly known as blue-green algae (previously considered as algae), are now studied separately as bacteria. Therefore, cyanobacteria are not described in this chapter.

Expected Learning Outcomes

After studying this unit, you should be able to:

- ❖ understand how did science of studying algae progressed with time;
- ❖ describe important habitat (living place) of these algal forms;
- ❖ explain basic features and ultrastructure of algae;
- ❖ get introduced with different classes of algae;
- ❖ write about the mechanism of reproduction of algae; and
- ❖ explain the economic importance of various algae.

7.2 HISTORY OF PHYCOLOGY

The study of algae is called algal biology or **phycology** (Greek*phycos*-seaweed, *logos*-study of). Algae have been used since time immemorial as a food source in Rome, China (called them as ***Tsao***), and a source of manure in France. The ancient *Hawaiians* called it ***Limu*** and used as food. The systemic study of algae started after an invention of the microscope. Carl Linnaeus, a Swedish botanist, coined term 'algae' for the first time in 1754. Several scientists including H.E. Link, Roth, C.A. Agardh, J. Agardh, Kuetzing, Hassall, Pringsheim, Strassburger, and others made a significant contribution in characterizing various algal species. Indian scientists have also beenthe pioneers in algal research and carried out studies on several algal species. M.O.P. Iyengaris regarded as Father of modern algology of India. Other important phycologists from India include Balakrishnan, Desikachary, Bhardwaj, R.N. Singh, and G.S. Venkatraman. Some of thetimelines of algal studies are briefly summarized in Table 7.1.

Table 7.1: Important landmarks in the history of phycology.

Year	Description
1754	C. Linnaeus used term algae for the first time and classified as thePlant Kingdom
1789	A. L. de Jussieu Delimited algae as known to us at present
1775-1800	Description of four algal genera namely*Fucus, Ulva, Conferva,* and *Corallina*
1797-	Discovery of *Hydrodictyon, Batrachospermum,* and *Rivularia*by

1805	Roth.
1802	Description of fertilization in *Fucus* by D. Turner
1820-1833	H.E. Link studied algae of Germany and described *Tetraspora*, *Oedogonium*, and *Spyrogyra*.
1824	C.A. Agardh and Greville described various algal species including *Mougeotia, Zygnema, Polysiphonia,etc.* J. Agardh described reproduction of several algae including *Fucus, Bryopsis, Griffithsia,* and*Conferva.*
1835-1855	Hassal worked taxonomy and development of *Chara* and described sexual reproduction in Charales.
1905	Oltman's work on morphology of algae
1922-1939	V. Czurda investigated morphology, physiology, and cytology of Zygnemaceae
1977	Description of algal genetics
2004	Genome sequence of the ultrasmall unicellular red alga *Cyanidioschyzonmerolae*
2017	Genome sequence of fuel-producing alga *Botryococcusbraunii* announced

7.3 OCCURRENCE

Algae are present in diverse regions including extreme conditions. However, they are predominantly found in marine and freshwater such as ponds, lakes, slow flowing and water reservoirs. They may be free-floating, swimming or attached to the bottom in shallow water. On land, their presence can be visualized on damp soil, sides of trees, or walls. Based on their occurrence they can be categorized as:**aquatic** (living in water),**terrestrial** (on lands), **epiphytes** (on plants), **epizoic** (on animals such as shells of molluscs and turtles, fins of fishes etc.), **endozoic** (inside body of animals), **aerophytes** (adapted to live aerial mode of life occurring on tree trunk, walls, rocks, flower pots, fencing wire etc.), and**symbiotic** (mutualistic relationship with other organisms such as fungi, plants or animals). Some of them also survive high temperature (**Thermophytes**), and high salt concentration (**halophytes**).**Cryophytes** are algae which are foundin ice and snow. These algal forms cause red snow, green snow, yellow snow, yellowish green snow and violet snow. Some algae are also known to be **parasitic** and cause damages to plants and animals. Examples of such algae are given in Table 7.2.

Table 7.2: Examples of algae living in different habitats.

Types	**Examples**
Aquatic	Stagnant fresh water: *Chlamydomonas, Volvox, Hydrodictyon* Slow running water: *Cladospora, Oedogonium, Ulothrix* Marine water: *Microcystis, Chlamydomonas, Scenedesmus, Cosmarium, Zygnema, Oedogounium, Cladophora, Cylindrospermum*
Terrestrial	Soil surface (Saprophytes): *Vaucheria, Botrydium, Fritschiella, Oedogonium* Under the earth surface: *Euglena*
Aerophytes	*Trentepohlia, Phermidium, Scyytonema*
Cryophytes	*Haematococcusnevalis*(red snow), Chlamydomonasyellowstonensis, *Ankistrodesmus, Mesotenium* (green snow)
Thermophytes	*Oscillatoriabrevis, Synechococcuselongatus, Haplosiphonlignosum*
Halophytes	*Dunaliella, Stephanoptera, Chlamydomonaschrenbergii*
Lithophytes (on rocks)	*Ectocarpus, Polysiphonia*
Epiphytes	*Oedogonium, Bulbochaete, Aphaanochaete, Coelochaete* (occurs on other algae such as *Chara*and *Nitella*.
Epizoic	*Cladophora, Protoderma, Basicladia*
Endozoic	*Zoochlorella*(inside *Hydra virdis*), *Zooxanthella* (inside fresh water sponges)
Symbiotic	*Chlorella* (growing in association of *Azotobacter*bacteria)

SAQ 1

a) Tick [√] mark the correct statement:

i) Blue green algae are not considered as algae. [True/False]

ii) All algae are single cellular photosynthetic cells. [True/False]

b) Write one word for the following sentences:

i) Algae which survive in high salt concentration- halophytes

ii) Algae found in snow/ice- cryophytes

iii) Algae which survive on animals- epizoic

iv) Algae which occur inside body of animals- endozoic

7.4 CHARACTERISTIC OF ALGAE

Different algal species vary in shapes, sizes, and reproductive success but they share the same basic features**.** They all can use light energy to convert CO_2 and H_2O to synthesize carbohydrates via the process of photosynthesis.

7.4.1 Morphological Features and Thallus Organization

The algae exhibit extreme diversity regarding their appearance and organization of their body, i.e., thallus. The simplest form of algae is unicellular (single cell) such as diatoms, *Protococcus, Chlorella,* and *Chlamydomonas,* whereas many are multicellular and form varied structure. The shape of unicellular algae can be spherical, rod-shaped, club-shaped, or spindle-shaped. Several unicellular algae can group or cling together in a mucilaginous sheath which appears like multicellular forms. Most of the unicellular forms are motile and flagellated to move through the water. They can ingest solid foods through phagocytosis (ability to engulf). The multicellular forms can range from simple to complex structures.

The multicellular algal structures include hollow spheres, filaments, or flat plate. The filamentous form may be simple (e.g., *Ulothrix, Zygnema*), or branched, or an aggregation of filaments, or a highly organized thallus of large size. In some multicellular forms, the constituent cells can perform both vegetative and reproductive functions as in *Oedogonium,* whereas other forms such as *Chara, Sargassum,* etc. can have dedicated reproductive cells or organs. Some of these algae including *Macrocystis, Sargassum,* and *Laminaria* exhibit external differentiation and have a similar structure to root, shoot, and leaves of higher plants. Several sessile (not moving) algal thalli (plural of thallus) are anchored to the surface by a root-like structure called **holdfast**. Thallus of some algae (e.g., *Macrocystis pyrifera*) are huge and tall as much as 60 meters in length.

7.4.2 Ultrastructure

The ultrastructure of typical algal cells is similar to plant cells with modifications in some species. Ultra structure of one of the most characterized unicellular alga is given in Fig. 7.1. In general, the cell walls are composed of: (i) fibrillar component such as **cellulose** in majority of algae and **mannan** in species of siphanaceous green algae, and (ii) amorphous component such as **alginic acid, fucoidin** found primarily in members of *Pheophyta* and Rhodophyta (Fig. 7.2).

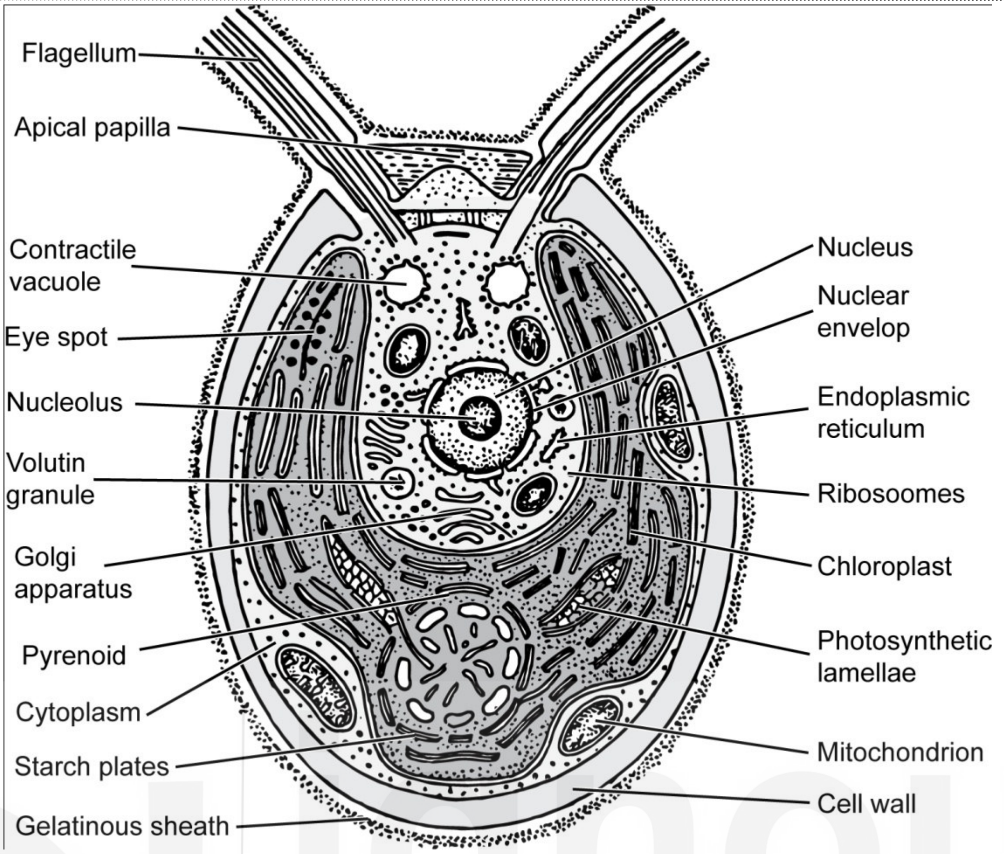


Fig. 7.1: Ultra structure of *Chlamydomonas* viewed under Electron Microscope.

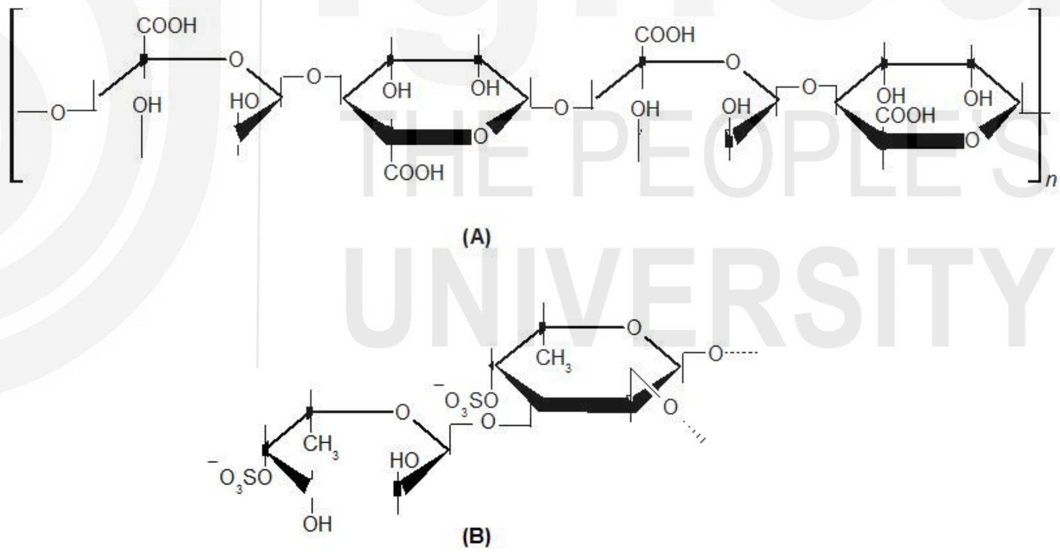


Fig. 7.2: A constituent of the amorphous component in the cell wall of certain algal species: (A) unit of alginic acid, (B) unit of fucoidin. Adopted from Phycology by R.E. Lee, 4th Ed.

The structure of chloroplast varies in different divisions of algae. Based on chloroplast structure, the algae can be grouped in three: (i) chloroplast surrounded by the two membranes of the chloroplast envelope, (ii) chloroplast surrounded by one membrane of chloroplast endoplasmic reticulum (ER), and (iii) chloroplast surrounded by two membranes of chloroplast ER. The chloroplast contains a flattened disc-like structure called **thylakoids**, which contain chlorophyll. The thylakoids may be free from one another or grouped to make thylakoid bands which may contain two or more thylakoids (Fig. 7.3).

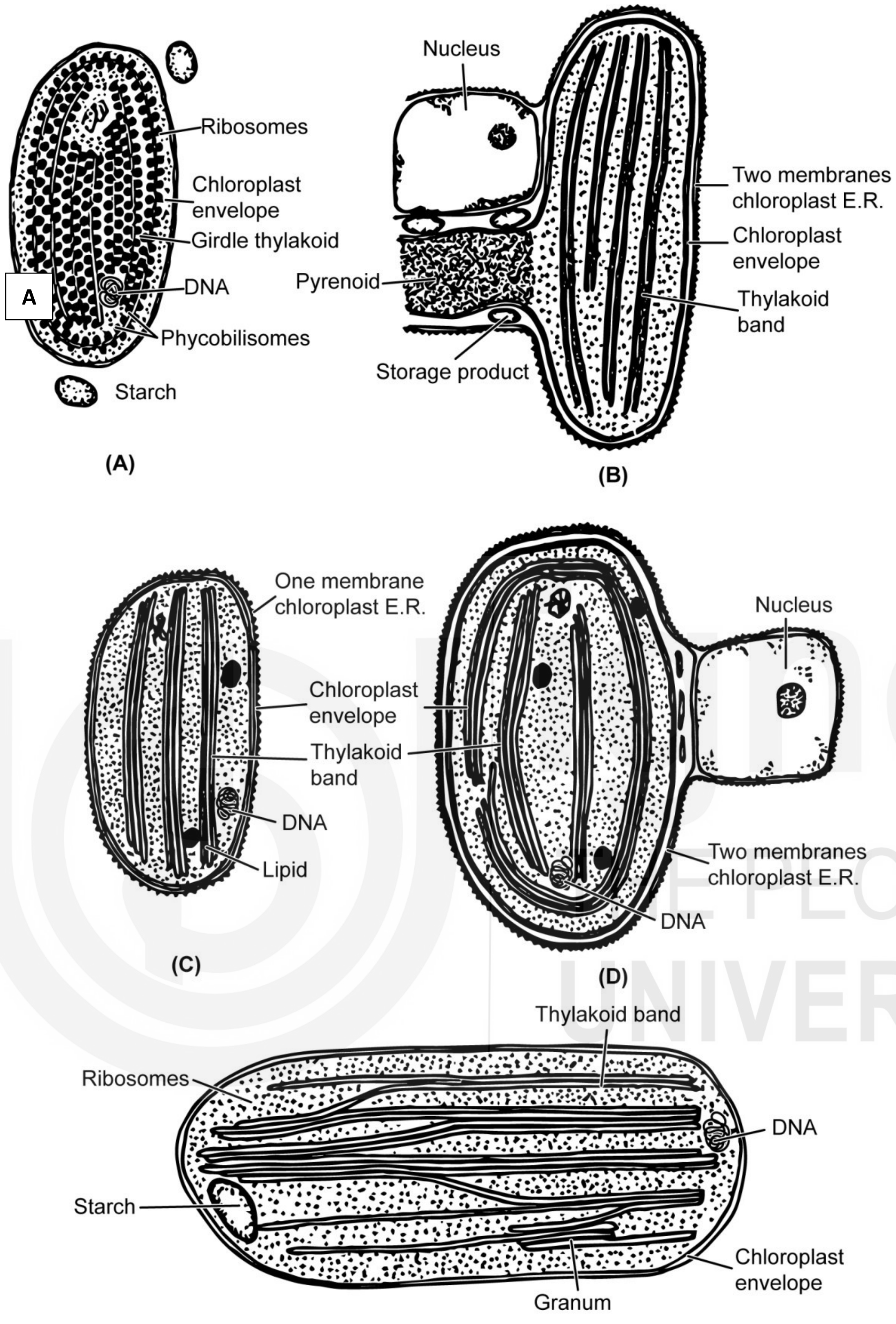


Fig. 7.3: Types of chloroplast structure in eukaryotic algae. (A) One thylakoid per band, no chloroplast endoplasmic reticulum (Rhodophyta). (B) Two thylakoids per band, two membranes of chloroplast E.R. (Cryptophyta). (C) Three thylakoids per band, one membrane of chloroplast E.R. (Dinophyta, Euglenophyta). (D) Three thylakoids per band, two membranes of chloroplast E.R. (Prymnesiophyta and Heterokontophyta). (E) Two to six thylakoids per band, no chloroplast E.R. (Chlorophyta).

7.4.3 Pigments

The algae are characterized by their colour, which in turn is dependent on the presence of one or more types of **pigments**, a coloured chemical compound. There three major classes of pigments present in algae. These are **chlorophyll**, **carotenoids**, and **phycobiloproteins** which are important light capturing compounds required for photosynthesis to take place.

Chlorophyll is composed of a pyrrophyrin-ring system that has a central magnesium atom. There are five types of chlorophylls namely chlorophyll a, b, c, d, and e out of which chlorophyll a is common in all algae whereas other types of chlorophyll have restricted distribution. For instance, chlorophyll b is found only in members of *Euglenophyta* and *Chlorophyta.*

The **carotenoids** are fat-soluble yellow or orange pigments. They are subdivided into two: (i) **carotenes**, oxygen-free hydrocarbon, and (ii) **xanthophylls** which are oxygenated derivatives of carotene.

Phycobiliproteins are water-soluble blue or red pigments. They are known as chromoproteins (coloured proteins) which are coloured due to the presence of the chomophore (which imparts colour) phycobillin, a tetrapyrrole. The examples of phycobiliproteins are **phycocyanin** and **phycoerythrin,** which are blue and red respectively.

7.4.4 Food Reserve

The food reserve accumulated in different algal forms is one of the important features to classify algae in different groups. Following polysaccharides are major food reserve stored in various algae:

(i) **Starch** and **Floridean starch** (α-1,4 linked glucans): starch composed of amylose and amylopectin, is typically found only in *Chlorophyta* and *Charophyta*, whereas Floridean starch is similar to amylopectin of higher plants and found in members of *Rhodophyta*.

(ii) **Laminarin**, **Chrysolaminarin** (**leucosin**), and **paramylon** are β-1,3 linked glucans distributed among different divisions. They are located in vesicle outside chloroplast.

(iii) **Fructosan**: It is a polymer of 1,2 linked fructose units terminated by a glucose end group which is found in some members of *Chlorophyta* (e.g., *Acetabularia*)

Apart from above-mentioned high molecular weight food reserve, some low molecular weight compounds are also stored as food reserve in some algal species. For instance, the **glycerol glycosides**, **floridoside,**and**isofloridoside**are widely distributed in the *Rhodophyta*. Similarly, **polyols** such as mannitoloccur in *Rhodophyta* and *Phaeophyta.*

7.4.5 Motility

The motile or swimming algae move with the help of flagella which can occur singly, in pairs, or in clusters at the anterior or posterior ends. There are three types of flagella namely (i) **whiplash** (cylindrical and smooth), (ii) **tinsel** (cylindrical and with hair like appendages), and (iii) ribbon or **strap-like**. The flagella on the cell may be of equal length or unequal length termed as **isokont**, and **heterokont** respectively. A single granule located at the base of flagella is called **blepharoplast**. The position, number, and type of flagella is constant for a division and can be used as a criterion for classification.

The structure of a flagellum is characterized by the presence of a central filament called **axoneme** surrounded by cytoplasmic membrane or **sheath** which terminates short at apex. The naked portion of axoneme is called **end piece**. The transverse section of a flagellum shows two central singlet fibrils surrounded by nine peripheral doublet fibrils (Fig. 7.4).

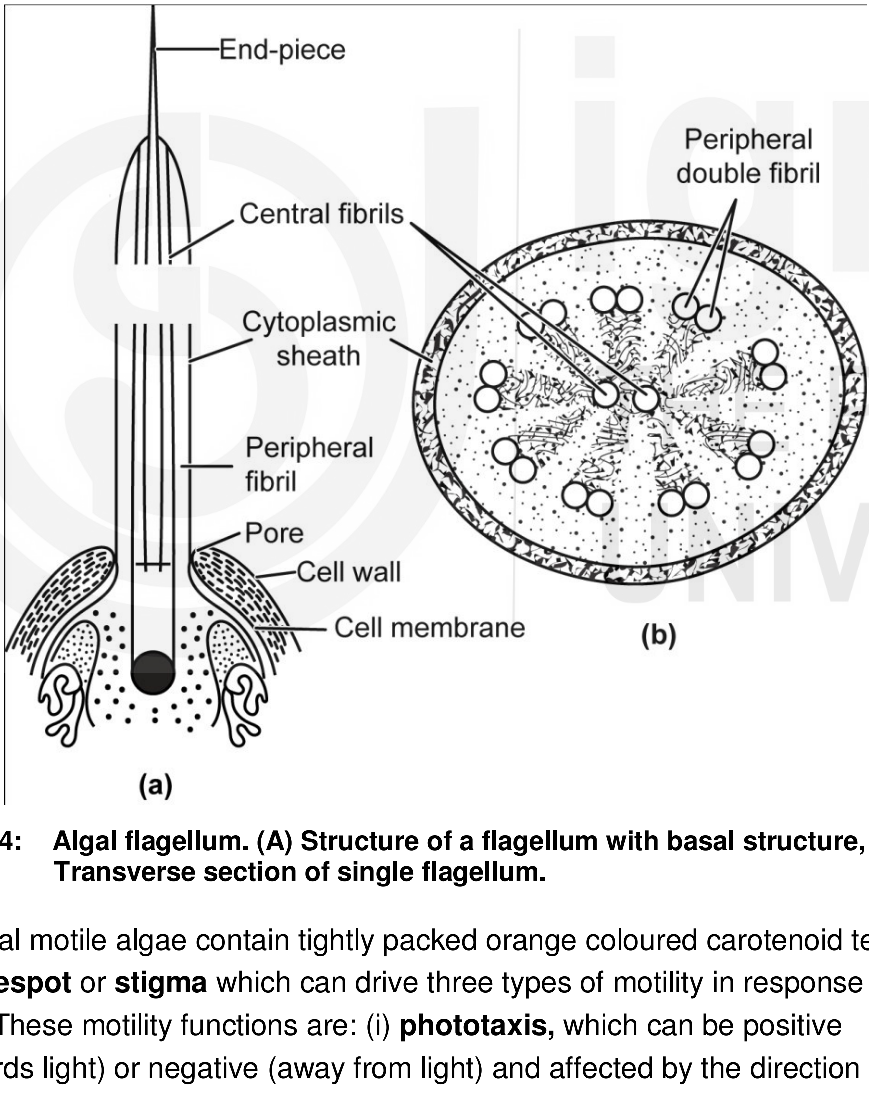


Fig. 7.4: Algal flagellum. (A) Structure of a flagellum with basal structure, (B) Transverse section of single flagellum.

Several motile algae contain tightly packed orange coloured carotenoid termed as **eyespot** or **stigma** which can drive three types of motility in response to light. These motility functions are: (i) **phototaxis,** which can be positive (towards light) or negative (away from light) and affected by the direction and intensity of light, (ii) **photophobia,** i.e. change in the direction of movement caused by rapid change in intensity of light, and (iii) **gliding**. In phototaxis and photophobia, cells move by beating the flagella whereas in light-driven gliding, the cells glide over the surface with one flagellum actively leading and the other passively trailing (Fig. 7.5).

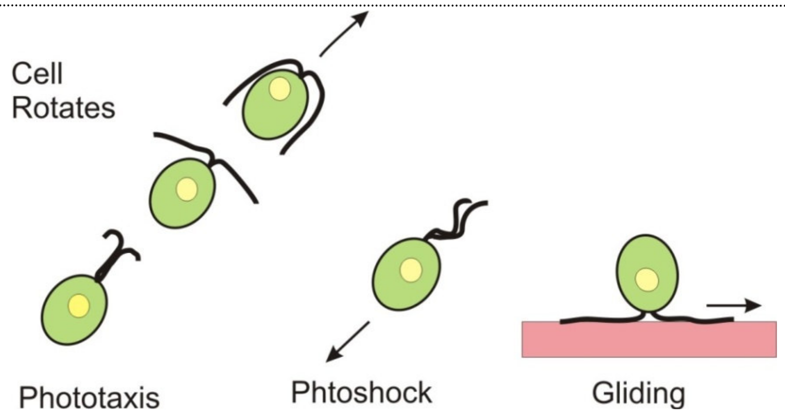


Fig. 7.5: Light-driven motility mediated by eyespot.

7.4.6 Reproduction

The reproductive process in algae is quite diverse and range from simple vegetative process to complex sexual processes. The reproduction of algae can be asexual and sexual.

Asexual reproduction: Many simple or primitive algal forms divide simply by **cell fission** where the cells grow and divide into two (as in bacteria). Others can reproduce through the process of **fragmentation** where even a fragment of old algae can form a new algal colony. Asexual reproduction in several algae is more complex and involves the formation of specialized cells called **spores**. The spores can be motile (**zoospores**), or non-motile (**aplanospores**). In general, zoospores are formed by aquatic algae whereas aplanosporesare found in terrestrial (growing on land) forms.

Sexual reproduction: Higher forms of algae reproduce sexually which involves fusion of **gametes** (specialized sex-cells) to form **zygote** in which nucleus from two gametes blend to form new genetic combination. The fusion is called **isogamous** when the two fusing gametes are identical whereas **anisogamous** or **heterogamous** when two gametes differing in size and behaviour (referred as male and female) fuse. In some of the higher forms of algae, sex cells are more specialized and referred typically as **ovum** (female gamete) and **sperm** (male gamete). The sperm cells are small and actively motile whereas the ovum is large and non-motile. The fusion of ovum and sperm is termed as **oogamy**. The male and female gametes can be produced by separate thalli or by thesamethallus. The plants producing only one type of sex cells (either male or female) is called **dioecious** (Greekdiakoia- two household), and the plants producing both sex cells are termed as **monoecious**.

SAQ 2

a) Name three major pigments found in algae.

b) Name three types of food reserves found in algae.

c) Define the following:

i) Phototaxis-…………………………………………….

ii) Photophobia-………………………………………..

iii) Aplanospores- ………………………………………

7.5 CLASSIFICATION

Though the criteria for classifying algae is not fixed, several features including nature and properties of pigments, type of food reserve and assimilatory product of photosynthesis, cell walls, cellular and thallus morphology, and life cycle have been used for classifying them. According to Whittaker's five kingdom concept, algae has seven divisions out of which five of them namely *Chrysophyta*, *Euglenophyta*, *Pyrrophyta*, *Charophyta*, and *Chlorophyta* belong to kingdom Protista whereas *Pheophyta* and *Rhodophyta* belong to kingdom Plantae. Basic features of the members belonging to these divisions are briefly described below.

7.5.1 *Chrysophyta*

The organisms belonging to this division are majorly unicellular and flagellated. Some are amoeboid having pseudopodia (false feet) like extension. However, colonial and filamentous forms are also found. Members of this division vary regarding pigment, cell wall, and flagella. They are found in both freshwater and marine ecosystems and include (i) diatoms (class *Bacillariophyta*), (ii) golden/golden-brown algae (class *Chrysophyceae*), and (iii) yellow-green algae (class *Xanthophyceae*). They store **chrysolaminarin** as food storage instead of starch found in green algae. The cell walls of these members constitute cellulose, silica, chitin, and calcium carbonate. They reproduce asexually and possess chlorophyll a, c1/c2 along with accessory pigments.

The sea in Tasmania's Preservation Bay has been glowing bright blue, which is caused by dinoflagellate Noctilucascintillans, which illuminate when waves or currents disturb them. (Courtesy: Image courtesy of Brett Chatwin - Facebook

Diatoms are a major group of microalgae which can be unicellular or can group to form colonies in the form of filaments (e.g. *Fragilaria*), fans (e.g. *Meridion*), zigzags (e.g. *Tabellaria*), or stars (e.g. *Asterionella*) (Fig. 7.6).The diatom cells are unique in having a cell wall made of silica called **frustules**. The deposits of these shells of diatoms are known as diatomaceous earth used for several commercial purposes.

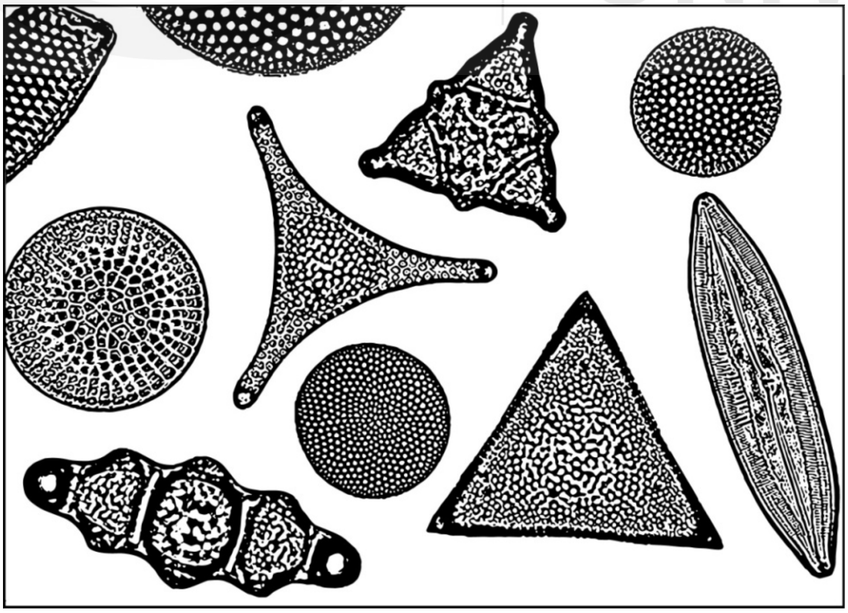
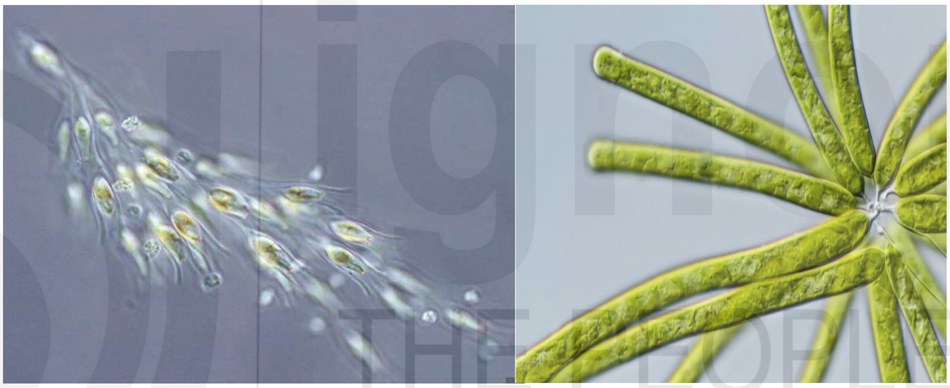


Fig. 7.6: Myriad shapes of diatoms. Magnification 400X. (Adopted from web images).

Golden brown-algae is called so because of their appearance due to the presence of a brown pigment called fucoxanthin and other pigments. They belong to the group **Heterokontophyta,** which possesses chloroplast surrounded by four membranes. Most of them are biflagellates having two specialized flagella (Fig. 7.7A).Many golden algae are surrounded by silica forming a cyst (sac-like structure) called **statospore** or **statocyst.** They usually reproduce asexually by forming amotile and non-motile spore.

Yellow-green algae, also belong to **heterophytokonta** group, are found more frequently in the temperate region of freshwater and marine water. They appear yellow-green because of **beta-carotene** and **xanthins**, such as **vaucheriaxanthin, diatoxanthin, diadinoxanthin**, and **heteroxanthin** (but not fucoxanthin). They can be unicellular or form branched and unbranched filaments (Fig. 7.7 B). Some of the filaments are coenocytic, i.e., single cells containing multiple nuclei. Their cell wall is composed of cellulose and pectin. Most of the members of this class are non-motile, but some reproduce asexually by **zoospores**.



(A) (B)

Fig.7.7: Representative members of golden algae and yellow-green algae. (A) *Denobryan*, a genus of golden algae, and (B) light micrograph of freshwater yellow-green algae *Ophiocytium* sp.

7.5.2 *Euglenophyta*

The members of this division are unicellular, flagellated, and actively motile. They share features of both plants and animals. They are widely distributed in soil and water where they form bloom. The cell of *Euglena* lacks cell walls and contain a defined outer membrane (called as **periplast** or **pellicle**) made of proteins (microtubule) instead. The chloroplast of genus *Euglena* contains **pyrenoids** which are a precursor of paramylon which in turn act as an energy storage enabling *Euglena* to survive in the absence of light deprivation. All euglenoids have two flagella (one long and another very short) emerging from **basal bodies** located in a small reservoir at the front of the cell. Some of the euglenoids have a red **eyespot**, an organelle composed of carotenoid pigment granules. The red spot permits the *Euglena* to find the light and move toward it (a process is known as **phototaxis**). The presence of contractile vacuole at one end of a cell helps euglena cells expel excess water absorbed by the cell from its freshwater environment (Fig. 7.8).

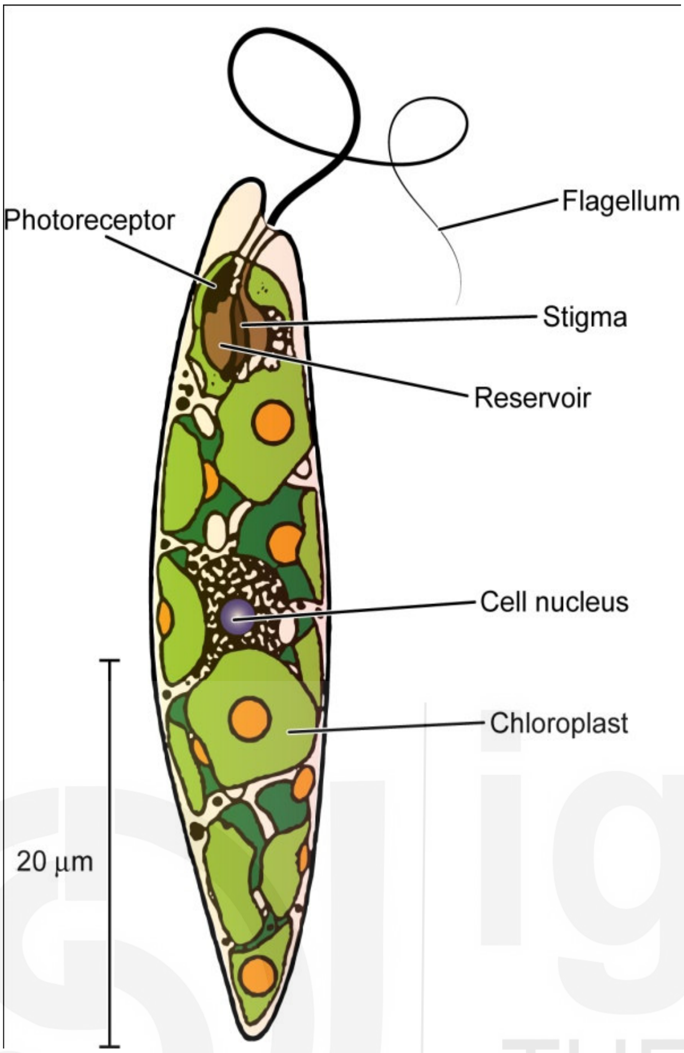


Fig. 7.8: Structure of *Euglena.*

7.5.3 *Pyrrophyta*

Pyrrophytes are unicellular algae majorly present in marine water. They are classifiedin two groups namely **dinoflagellates** and **Cryptomonads**. Similar to *Euglenophyta*, they also share features of both plants and animals.

Many dinoflagellates are autotrophic whereas a large number of them are **mixotrophs** having the ability to synthesize their food as well as to live heterotrophically by ingesting prey (**phagotrophy**). Certain species such as *Symbiodinium*sp exists as endosymbiont (living inside) of corals, where it can act as mutualist (helping each other regarding nutrition) or parasite (harming the host). Other dinoflagellates are unpigmented and feed upon other protozoa, and a few forms are parasitic (e.g., *Oodinium, Pfiesteria*).**Starch** and **glucan** serve as a food reserve. They also produce a neurotoxin that can impair muscle function.

The dinoflagellate cells are a flattened structure having a transverse constriction, the **girdle**, around the cell (Fig. 7.9).They exhibit the unique arrangement of flagella which are inserted in the girdle where one of them encircle the cell and another trail. Hairs project from the flagellar surface.

> ***Amazing fact***
> *Dinoflagellates can move a distance 1000 times their own length each second.*

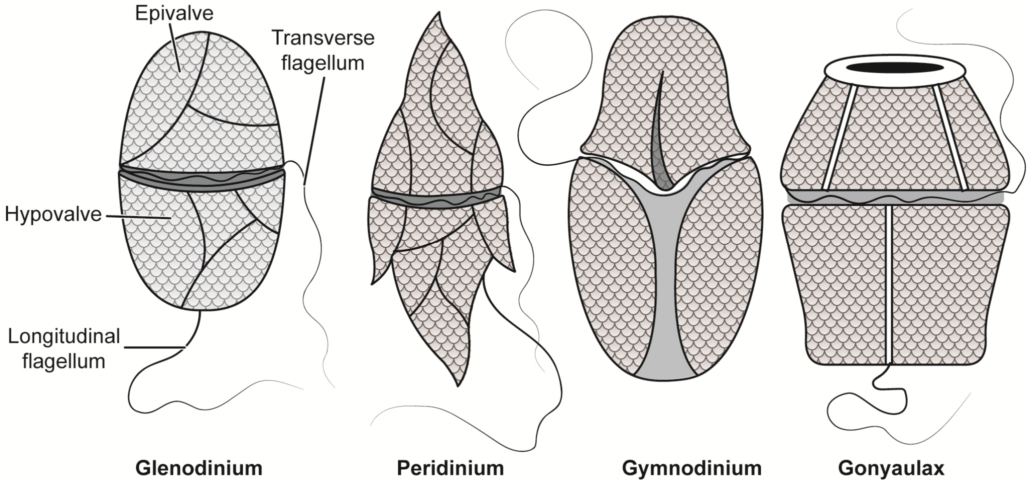


Fig. 7.9: Structure of different types of dinoflagellates.

Cryptomonads are similar to dinoflagellates,and they may be responsible for causing algal blooms, which turns the water to have a red or dark brown appearance.

> ***Why are stoneworts called so?***
> *The cell walls of stoneworts accumulate calcium carbonate which gives it a stony appearance. This is the reason they called so.*

7.5.4 *Charophyta*

Members of this division are commonly known as stoneworts, which are distributed worldwide. They occur usually attached to the muddy bottom of afresh or brackish river or lakes. They superficially resemble higher plants in having root-like rhizoids, whorls of branches at regular intervals, and a straight cylindrical axis covered with a sheath of small cells (Fig. 7.10A). Some charophytes, termed as **desmids** (e.g.,*Closterium*), are unicellular, non-flagellated algae having cells divided into two symmetrical compartments separated by a narrow bridge or **isthmus**, wherein the spherical nucleus is located. Each semi-cell houses a large, often folded chloroplast for photosynthesis (Fig. 7.10B). They reproduce sexually where **oogonium**, a female sex organ, contains one large immobile egg, and **antheridium**, a male sex organ produces one small biflagellate sperm. An envelope of sterile cells surrounds the reproductive structures. It lacks motile spores.

The watermelon snow is caused by a green algae Chlamydomonasnovalis which gives it pink colour due to presence of red catotenoid pigment astaxanthin.

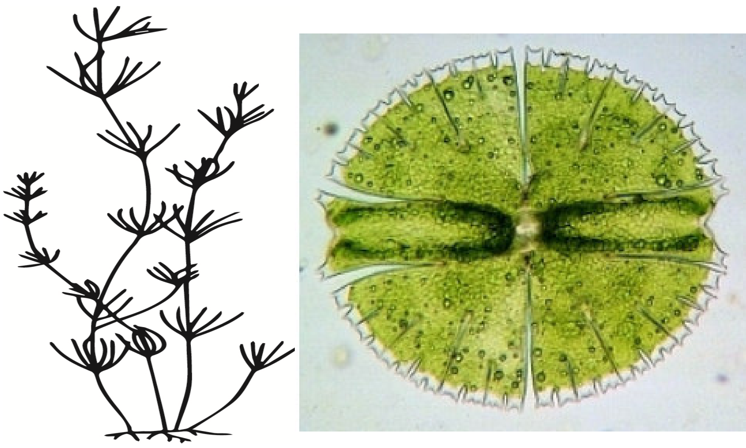
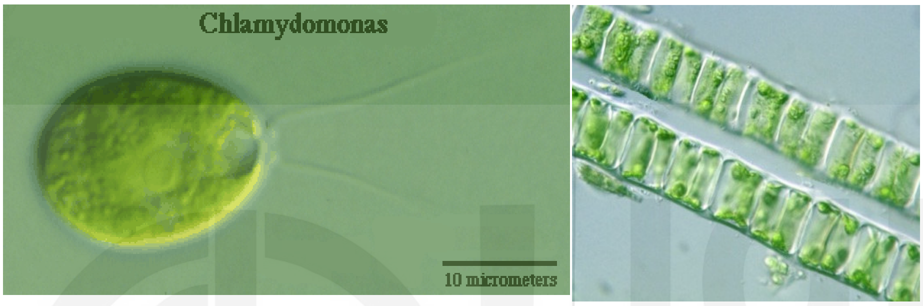


Fig. 7.10: Examples of *Charophytes* or stoneworts. (A) *Chara* (B) Desmid.

7.5.5 *Chlorophyta*

Chlorophytes, the most abundant algal forms, are primarily the freshwater (more than 90%) algae and popularly known as green algae. They have chlorophylls a and b, and form starch as food reserve on **pyrenoids** (protein rich site for carbon fixation and starch synthesis), a micro-compartment within the chloroplast. Thus the food reserves are within the chloroplast which makes them different from other algae. This division contains both motile unicellular (eg.,*Chlamydomonas, Chlorella,*etc.) and multicellular forms (Fig. 7.11). Their colonial types occur as filaments (e.g.*, Ulothrix*), spheres (e.g.,*Volvox*), or plates. The cell walls of most of the chlorophytes are made up of cellulose with few exceptions. For instance, the cell wall of Volvocalesis made of glycoproteins.

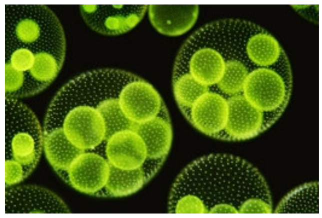


(A) (B)

Fig. 7.11: Micrographs of (A) unicellular green alga *Chlamydomonas* and (B) a multicellular filamentous green alga *Ulothrix.*

They exhibit both asexual and sexual mode of reproduction. Asexual reproduction takes place through **fission**, **fragmentation**, **zoosporogenesis** (formation of bi-or quadri-flagellated motile zoospore), and other asexual methods. All three types of sexual reproduction namely **isogamy** (in some species of *Chlamydomonas* and *Zygnema*), **anisogamy** (in species of *Spirogyra*), and **oogamy** are present in different members of this division. Reproduction by isogamy is most common.

Interesting organism: Volvox



Colonial form made of 500 to 5000 cells which coordinately act to propel the sphere in water. The flagella are oriented outside the sphere, and beat in unison in particular orientation to form coordination within themselves, ultimately leading to locomotion. Interestingly, the colony can change its direction as per the requirement.

Isogamy is the fusion of male and female gametes which are similar in size. Anisogamy is the fusion of male and female gametes which are dissimilar in size. Here, either both the gametes are motile or both are non-motile. Oogamy is the fusion of a large non-motile female gamete with a smaller motile male gamete.

7.5.6 *Phaeophyta*

The members of this division are known as brown algae due to the presence of a golden brown pigment fucoxanthin in their **chromatophore**. They are mostly marine, and their plant body is immobile and multicellular. They include *Laminaria,* commonly known as kelp, is used as food for humans, other animals, and fish; in medicinal preparations; in fertilizers; and as a source of iodine and mineral salts (Fig. 7.12). Their complex thalli are tough, leathery or rubbery in texture and produce abundant mucilage. They have **holdfast**, a **stripe**, and an expanded **blade.** Some of them have **air bladder** which gives them buoyancy. The phaeophytes reproduce asexually by zoospores, and sexually both by iso- and anisogamous.

Fig. 7.12: Representative member of brown algae. *Laminaria* or kelp.

7.5.7 *Rhodophyta*

They are commonly known as red algae due to their appearance which results from the presence of phycobiliprotein (water soluble) pigments **phycoerythrin** and **phycocyanin**. They are found in both marine and freshwater environments. Almost all red algae are multicellular macroscopic thallus which is diverse in their forms ranging from filamentous (e.g., *Polysiphonia*) to ribbon-like or plate-like structures (e.g., *Porphyra*) (Fig. 7.13). Some species are **epiphytes** growing on other algae, or **epizoic** growing on sponges, hydroids, and mollusks. The deposition of lime from some red algae helps in theformation of thealgal reef.

The red algal cells lack flagella and centrioles, their chloroplasts lack external endoplasmic reticulum and; contain unstacked (stoma) thylakoids. They consist of highly branched amylopectin without amylose as food reserves outside their plastids. Some of the red algae such as *Lomentaria* have **pits** on cell walls of adjacent cells. These pits help in the maintenance of protoplasmic continuity between these cells.

The red algae reproduce both sexually and asexually. The asexual reproduction process includes theformation of non-motile spores whereas they reproduce sexually with the unison of **spermatia** (male germ cells), and **carpogonia** (female sex organ).

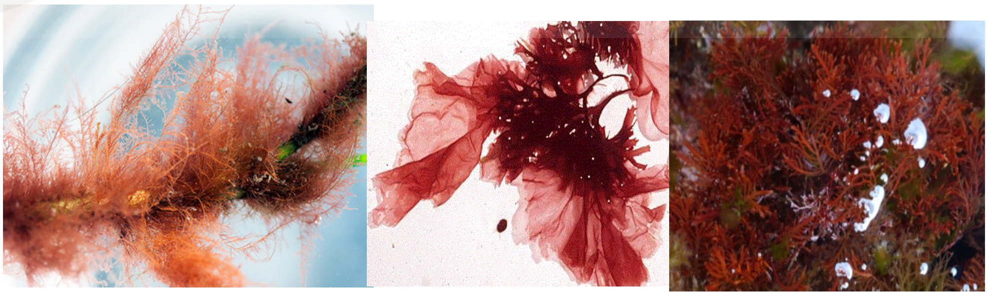


Fig. 7.13: Representative genera of red algae. (A) Filamentous *Polysiphonia,* (B) Plate-like *Porphyra,* and (C) *Gelidium.*

7.6 ECONOMIC IMPORTANCE

Algae impart a great biological significance being a major primary producer in aquatic environments and contribute a huge amount of total oxygen in the biosphere. Moreover, it is a major food source for several aquatic organisms. Apart from their biological significance, the algae can be exploited for various purposes. Some of them are described briefly in Table 7.3.

Table 7.3: Economic importance of algae in industry, agriculture, and health

Application	**Description**
Food and Fodder	*Porphyra*known as '**Noori**' is used in thepreparation of 'shushi' a Japanese food item.
	Red algae *Chondrus, Acanthopeltis, Nemalion,* and *Eucheuma,* are eaten as vegetables or in soups or prepared as sweetened jellies.
	Several brown algae including *L. japonica,* and*Porphyra* some seaweedsare used in several diets of China.
	Porphyra(Laver), *Chondrus*(Irish moss), and *Palmaria*(dulse)are used as food in Europe and North America.
	Laver is used as snacks in the British Isles and Canada
	*Chlorella*is used as food for humans and domestic animals
	Several small algae are rich source of proteins, carbohydrates, fats, vitamins, and minerals
	*Rhodymenia palmate*is used as food for sheeps in Narvey. *Laminariasaccharina, Pelvitia, Ascophyllum*, etc. species are used as food for cattle.
Agriculture	Several floating algae can be collected, dried and used as fertilizers, soil conditioners.
Biofuel and Energy	Due to high growth rate and efficient use of CO_2, microalgae are a potential candidate for biomass production which can be used to produce biofuel (ethanol, biodiesel) and bioenergy (hydrogen).
Commercial Products	**Carrageenan**, a polymer of galactose, extracted from walls of red algae (*Chondrus, Gigartina,* and *Eucheuma*) is used as a stabilizer or emulsifier in foods such as ice cream and other milk products. It is also used as a binder in toothpaste, pharmaceutical products; as a thickening agent in shaving creams and lotions, and in soap industry; as a finishing compound in textile and paper industries.
	Agar, a solidifying agent, obtained from red algae *Gelidium and Gracilaria*is used in food industry for preparing processed cheese, mayonnaise, puddings, jellies,etc.

	Alginic acid and its salt derivatives obtained from walls of brown algae such as *Macrocystis, Agarum, Laminaria, Fucus,*and *Ascophyllum,* is used in food products such as ice cream, cheeses, and bakery products; paper manufacturing; printing of fabrics and; paint thickening. Alginate material is used by dentists to make impressions of the teeth for crowns.
	Diatomaceous earth is used for filters or filter aids. It is also used for polishing delicate surfaces.
	Laminaria, Ecklonia, Eisenia, etc. are used for preparation of Iodine
Antibiotic and medicine	Chlorellin, an antibiotic, prepared from *Chlorella* is effective against some pathogenic bacteria.
	Extracts from *Cladophora*, *Lyngbya* can kill pathogenic *Pseudomonas* and *Mycobacterium*.
	*Laminaria*is used as one of the modern tools for abortion.
	Seaweeds have a beneficial effect on gall bladders, pancreas, kidneys, uterus and thyroid glands.

SAQ 3

a) Tick mark the correct answer:

i) Yellow-green algae belong to heterophytokonta group. [True/False]

ii) Red algae are member of division chlorophyta. [True/False]

iii) Euglena shares feature of both plant and animals. [True/False]

b) Fill in the blanks with appropriate words:

i) Chlorophyta are also termed as……………………..

ii) Agar-agar used for solidification of culture media is obtained from …………………

iii) Dinoflagellates are member of division………………………

iv) The uniqueness of diatoms include presence of ………….in their cell wall

v) A root like structure which helps thallus of some algal species to anchoring to surface is called………………

7.7 SUMMARY

- Algae are plant-like photosynthetic organisms which do not have true-differentiated tissues.
- Majority of algal forms are aquatic, however they can also be found on soil, rocks, surface of plants, surface of animals and in the interior of plant or animals. Some of them grow in extremity like high or low temperature.
- They are diverse in size, shape, and structure. They can be unicellular, colonial, or multicellular.
- The ultrastructure of typical algal cells is similar to that of plant cells with modifications in some species such as presence of mannan, alginic acid, or fucoidin in cell wall and diversity in organization of thylakoids in chloroplast.
- They show diversity in pigments and storage compounds present therein which are also used to classify the algal species.
- The reproductive process in algae is quite diverse and include asexual reproduction through fission, fragmentation, asexual spores (aplano- and zoospore) range from simple vegetative process to complex sexual processes. Higher forms of algae reproduce sexually where female gamete and male gamete fuse to form zygote.
- According to Whittaker's five kingdom concept, algae has seven divisions namely *Chrysophyta*, *Euglenophyta*, *Pyrrophyta*, *Charophyta*, *Chlorophyta, Pheophyta,* and *Rhodophyta.*
- Algae have both ecological and economical significance. They are major primary producer in marine ecosystem. Several algae can be used as food source, antibiotic, solidifying agent, filter material, and in agriculture.

7.8 TERMINAL QUESTIONS

1. How do xanthophylls differ from carotenes?
2. How do algal cells reproduce asexually?
3. What are desmids?
4. Why are stoneworts called so?
5. What are pyrenoids and what is it important?
6. How are chlorophytes different from others regarding food storage?
7. Describe the ultra structure of algal chloroplast with suitable diagram.
8. Discuss the salient feature of Charophyta?
9. Write the economic importance of algae.

7.9 ANSWERS

Self-Assessment Questions

1. a) i) True

ii) False

b) i) Halophytes

ii) Cryophytes

iii) Epizoic

iv) Endozoic

2. a) Chlorophyll, carotenoids, and phycobiloproteins

b) Starch and Floridean starch, Laminarin, Chrysolaminarin (leucosin) and paramylon and Fructosan

c) i) Phototaxis: motility which can be positive (towards light) or negative (away from light) and affected by the direction and intensity of light.

ii) Photophobia: change in the direction of movement caused by rapid change in intensity of light.

iii) Aplanoapores: non motile spores.

3. a) i) True

ii) False

iii) True

b) i) Green algae

ii) *Gelidium* or *Gracilaria*

iii) Pyrrophyta

iv) Silica

v) Holdfast

Terminal Questions

1. Both carotenes and xanthophylls are fat-soluble yellow or orange pigments known as **carotenoids**. X**anthophylls** are oxygenated derivatives of carotene.

2. Algal cells reproduce asexually by cell fission, fragmentation or through spores.

3. Desmids belong to charophytes and are unicellular, non-flagellated algae having cells divided into two symmetrical compartments separated by a narrow bridge or **isthmus**, wherein the spherical nucleus is located, fro example *osterium*.

4. Stoneworts are so called because of accumulation of calcium carbonate in their cell wall giving them stone like appearance.

5. Pyrenoids are the protein rich sites surrounded by starch sheath present in the algal chloroplast. These are involved in carbon fixation and starch synthesis and store energy enabling the organism to survive in the absence of light.

6. Chlorophytes, are primarily the freshwater algae and popularly known as green algae. They have chlorophylls a and b, and form starch as food reserve on **pyrenoids** (protein rich site for carbon fixation and starch synthesis), a micro-compartment within the chloroplast. Thus the food reserves are within the chloroplast which makes them different from other algae.

7. The structure of chloroplast varies in different divisions of algae. Based on chloroplast structure, the algae can be grouped in three: (i) chloroplast surrounded by the two membranes of the chloroplast envelope, (ii) chloroplast surrounded by one membrane of chloroplast endoplasmic reticulum (ER), and (iii) chloroplast surrounded by two membranes of chloroplast ER. The chloroplast contains a flattened disc-like structure called **thylakoids**, which contain chlorophyll. Please refer to the section 7.4.2 for more details.

8. Charophytes are commonly known as stoneworts, which occur usually attached to the muddy bottom of a fresh or brackish river or lakes. They superficially resemble higher plants in having root-like rhizoids, whorls of branches at regular intervals, and a straight cylindrical axis covered with a sheath of small cells. Please refer to the section 7.5.2 for more details.

9. Algae find many uses of economic importance industry, agriculture, and health which are described in section 7.6.