Algae is an extremely diverse group consisting predominantly of aquatic plants showing relatively little differentiation of tissues and organs as compared to bryophytes and tracheophytes. It includes both prokaryotic and eukaryotic photosynthetic organisms with chlorophyll *a* and other photosynthetic pigments, releasing O_2. Algal plant body ranges from unicellular to colonial, filamentous, siphonous, and even parenchymatous, and never contains roots, stems or leaves. Plant body may be as small as unicellular (e.g. *Chlamydomonas*, *Chlorella*; 0.5–8 μm) to as large as 50 meter or more in length (e.g. *Macrocystis*). As in morphology, algae also demonstrate great variation in reproduction. They reproduce by vegetative, asexual and sexual processes. Sex organs in algae are usually unicellular or multicellular with all cells fertile (except *Charales*). The zygote does not develop into a multicellular embryo within the female sex organ. Several algae show alternation of generations. Sexual reproduction, however, is absent from prokaryotic members. A feature that distinguishes algae from other cryptogams is the absence of a multicellular wall around the sporangia or gametangia (with the exception of *Charales*). Adaptation to an aquatic environment has led to the development of many distinctive biochemical traits in algae.

From the physiological and biochemical point of view, algae are more or less similar to other plants in many respects. Algae possess almost the same biochemical pathways as of higher plants. Resembling the higher plants, all algae possess chlorophyll *a* and have almost the same carbohydrate and protein end products. Due to these characteristics, algae are ideal experimental organisms to study several biochemical and physiological processes.

From the long fossil records of both prokaryotic and eukaryotic algal forms, it is evident that the prokaryotic algae were the first photosynthetic cellular plants. It is now

generally agreed amongst botanist that algae are the group from which all subsequent groups of cryptogamic plants, and finally the flowering plants, arose on the earth during the course of evolution.

The word "algae" (singular "alga") is derived from a Latin word "alga" (means seaweeds). The science that deals with their study is called *algology*. The Greek word for algae is *phykos*, and therefore their study is called *phycology* (Gr. *phykos*, sea-weeds; *logos*, study or discourse).

Laymen have variously named algae as "pond scums", "frog spittle", "water mosses", or simply "seaweeds".

1.3 DEFINITIONS

To give a precise definition of algae is very difficult, mainly owing to the varied nature of the plants comprising the group. Because of this, Bold and Wynne (1978) have rightly stated that sometimes "even the professional botanist and biologist find algae embarrasingly elusive of definition."

In spite of this, the definitions of algae, given earlier by some phycologists, are as follows:

1. *F.E. Fritsch (1935)*
   Unless purely artificial limits are drawn, the designation alga must include all holophytic organisms (as well as their numerous colourless derivatives) that fail to reach the higher level of differentiation characteristic of the archegoniate plants.
2. *G.M. Smith (1955)*
   Simple plants with an autotrophic mode of nutrition.
3. *V.J. Chapman (1962)*
   These plants (seaweeds of the seashore and green skeins in stagnant freshwater ponds and pools) which are among the simplest in the plant kingdom, belong to the group known as algae.
4. *G.W. Prescott (1969)*
   The algae are those chlorophyll-bearing organisms (and their colourless relatives) which are thalloid, i.e., having no true roots, stems and leaves or leaf-like organs.
5. *R.N. Singh (1974)*
   The algae are by and large simple plants which display a spectrum of photosynthetic pigments and evolve oxygen during the process of photosynthesis.
6. *The author of this book defines the algae as under:*
   The algae, variously ranked as an order[5], a class[6], a division[7] or a group[8] in different systems of classification, is an assemblage of chlorophyll-bearing autotrophic Thallophytes, bounded by a cell wall, made up of pure or mixed carbohydrates.

1.4 GENERAL CHARACTERS OF ALGAE

1. The group algae is represented by about 1560 genera and 17 535 species[9,10,11] (Smith 1955). Alexopoulos and Bold (1967) mentioned 1800 genera and 21 000 species in algae. The members are distributed in nearly all parts of the world and occur[12] in nearly all kinds of habitats.
2. Thallus organization[13] in algae varies greatly and shows a clear range. In brief, they are represented by the following habits:
   i. Motile unicellular, e.g. *Chlamydomonas* and *Phacus;*
   ii. Motile colonial, e.g. *Volvox*, *Pleodorina*, *Eudorina* and *Pandorina*;
   iii. Palmelloid, e.g. *Chlamydomonas*, *Tetraspora*, *Chlorosaccus* and *Palmella*;
   iv. Dendroid, e.g. *Ecballocystis* and *Prasinocladus*;
   v. Coccoid, e.g. *Chlorella*, *Hydrodictyon* and *Pediastrum;*
   vi. Filamentous, e.g. *Spirogyra*, *Zygnema*, *Ulothrix*, *Nostoc*, *Oedogonium*, *Oscillatoria*, *Lyngbya*, *Anabaena*, *Tribonema*, *Cladophora*, *Pithophora* and *Bulbochaete;*
   vii. Heterotrichous, e.g. *Fritschiella*, *Draparnaldiopsis*, *Ectocarpus* and *Stigeoclonium;*
   viii. Siphonaceous, e.g. *Vaucheria*, *Botrydium*, *Bryopsis* and *Codium;*
   ix. Uniaxial, e.g. *Batrachospermum*;
   x. Multiaxial, e.g. *Polysiphonia*;
   xi. Parenchymatous, e.g. *Ulva*, *Enteromorpha* and *Sargassum.*

3. The size of the algae also varies greatly. Most of them are microscopic and many are even unicellular (*Chlamydomonas*, *Dunaliella*, etc.) attaining a maximum size of 0.5 μ in diameter. *Micromonas pusilla* (1 × 1.5 μm) and species of *Chlorella* (5–8 μm) are also very small in size. On the other hand, there are large macroscopic genera attaining a size of 30 m or even more, e.g. *Macrocystis*. Regarding *Macrocystis pyrifera* Prescott (1969) reported "one unsubstantiated record claims a specimen to have been 700 feet (i.e. 213 m)—the longest plant in the world". All the other members come in between these limits.
4. Each cell[14] is bound by a typical cell wall, with a few exceptions like *Euglena* and *Gymnodinium* where a cytoplasmic membrane, called *pellicle*, is present.

   The cell wall is bilayered in most of the algal members and composed mainly of cellulose and partly of other substances like pectin, chitin, algin and fucoidin[15]. In some genera, the cell wall is impregnated with inorganic substances such as calcium, silica and magnesium carbonate.
5. Motile members, zoospores (Plate IA) and gametes of many representatives of algae, bear flagella which are the means of motility. Electron-microscopic studies have shown that in a cross-section, a flagellum consists of 2 central tubules, surrounded by 9 peripheral tubules, all enclosed by a membrane (Fig. 1.1).

   Flagella may be equal (Fig. 1.2 A) or unequal (Fig. 1.2 B), inserted apically (Fig. 1.2 A, B) or laterally (Fig. 1.2 E), and may be of tinsel (Fig. 1.2 C) or whiplash (Fig. 1.2 D) types. The whiplash type is smooth and regular throughout its length, whereas the tinsel type has small outgrowths throughout the length and appears like a feather.
6. In the cytoplasm are present structures like contractile vacuoles, mitochondria, eyespot, chloroplast, nucleus, pyrenoids, chondriosomes, Golgi bodies, various types of pigments, etc. In prokaryotic cells, however, structures such as mitochondria, Golgi bodies, endoplasmic reticulum and a definite nucleus, are absent.
7. Important pigments are chlorophyll-a, chlorophyll-b, β-carotene and xanthophylls, such as lutein, violaxanthin[16], fucoxanthin[17] and neofucoxanthin. Xanthophylls of Myxophyceae are myxoxanthin and myxoxanthophyll. Phycobilins are mainly present in Rhodophyceae and Myxophyceae.

8. *Reserve food* material is in the form of starch. But in the members of Bacillariophyceae, Xanthophyceae and Dinophyceae, fats and oils are present. Laminarin and mannitol are the reserve products in the members of Phaeophyceae, whereas in Rhodophyceae floridian starch, floridoside and mannoglycerate are the chief reserve products. In Myxophyceae, myxophycean starch and cyanophycin are the reserve products.
9. Sitosterol is the main sterol in the members of Chlorophyceae, whereas fucosterol is present in Phaeophyceae, Bacillariophyceae, Chrysophyceae and Rhodophyceae.
10. Hamana and Matsuzaki (1982) analysed the diamine and polyamine contents of Rhodophyta, Pyrrophyta, Chrysophyta, Phaeophyta, Euglenophyta, Chlorophyta and Charophyta. They detected putrescine and spermidine in all the studied algae of these seven groups.
11. *Growth* is controlled by the hormones or hormone-like growth regulators present within the cell. Growth in multicellular members may be of the following types:
    a. *Generalized growth* takes place throughout the body. All the cells of the organism divide. So, there is an overall increase in size of the plant, e.g. *Ulva*.
    b. *Localized growth* takes place by cell division in only certain restricted parts of the plant. The localized growth may be of any of the following three categories:
        (i) *Apical growth*: It is restricted only up to the extremities or tips of the plant, as in *Cladophora*, *Dictyota*.
        (ii) *Basal growth*: It is seen only in the basal parts, as in *Bulbochaete*.
        (iii) *Intercalary growth*: It is seen in one or many intercalary regions, and restricted neither at the base nor at the apex, as in *Oedogonium*.

12. Reproduction[18] in algae takes place by all the three means, i.e. vegetative[19], asexual and sexual.
13. Various means of vegetative reproduction are fragmentation, fission, akinete, tuber, hormogonia, formation of adventitious thalli, etc.
14. Asexual reproduction is a process in which the protoplast (or protoplasts) is released from the cell. This protoplast germinates into a new plant. It takes place by the formation of various types of spores like zoospore, synzoospore, aplanospore, hypnospore, autospore, auxospore, carpospore, tetraspore, cyst, etc.
    i. *Zoospores* (Plate IA) are flagellated, asexual reproductive bodies, usually each having an eyespot, e.g. *Chlamydomonas*, *Ulothrix* and *Cladophora*. Zoospores in *Chlamydomonas* are biflagellate; in *Cladophora* and *Ulothrix*, they may be biflagellate as well as quadriflagellate; and in *Oedogonium*, they are multiflagellate having a ring of paired flagella.
    ii. *Synzoospore* is a multinucleate and multiflagellated zoospore as in *Vaucheria*. It is also called *compound zoospore*.
    iii. *Aplanospore* is a non-motile, thin-walled zoospore formed by the cleavage of protoplast within a cell, e.g. *Vaucheria*, *Chlamydomonas*, *etc.*
    iv. *Hypnospore* is a thick-walled aplanospore, e.g. *Vaucheria*.

v. *Autospores* are the replicas of the parent cell and formed by the cell division., e.g. *Chlorella*, *Oocystis*.

vi. *Tetraspores* are haploid, thin-walled, non-motile spores formed after reduction division in diploid tetrasporangia of many Rhodophyta and also in some Phaeophyta (e.g. *Dictyota*)

15. *Sexual reproduction* takes place by the union of cytoplasm and nuclear material of two gametes of two organisms of the same species. It is of the following three types:

a. *Isogamy*: When two fusing gametes are morphologically identical, they are called *isogametes* and the process of their fusion (plasmogamy and karyogamy) is known as isogamy, e.g. *Chlamydomonas eugametos* (Fig. 24.16 A).

b. *Anisogamy*: When two fusing motile gametes are morphologically dissimilar, i.e. one is smaller and the other is larger, the gametes are called *anisogametes* and the process of their fusion is called anisogamy, as in *Chlamydomonas braunii* (Fig. 24.19 A–C).

c. *Oogamy*: In oogamy, one gamete becomes immobile. This functions as the female gamete. The male gamete is comparatively very small and motile. These gametes are called *oogametes* and their fusion process is known as oogamy. It takes place in many algal genera including *Chlamydomonas*, *Volvox*, *Fucus*, *Oedogonium*, *Vaucheria*, *etc.*