Algae: Definition, Characteristics and Structure

Introduction to Algae:

The term algae (Latin — seaweeds) was first introduced by Linnaeus in 1753, meaning the Hepaticeae. The algae comprise of a large heterogeneous assemblage of plants which are diverse in habitat, size, organisation, physiology, biochemistry, and reproduction.

It is an important group of Thallophyta (Gr. Thallos — a sprout; phyton — a plant), the primitive and simplest division of the plant kingdom. The orderly systematic study of algae is called Phycology (Gr.phycos — seaweeds; logos — study or discourse).

The algae are chlorophyll-containing primitive plants, both prokaryotic and eukaryotic, with wide range of thaifi starting from unicellular to multicellular organisations. Autophytic (which can manufacture their own food) and thalloid plant bodies are also found in Bryophytes.

But the sharp demarcation between the two groups can be drawn by the following characters:

1. The sex organs, especially of female sex organ in algae are unicellular.

2. There is no embryo formation in algae.

However, the reproductive structures of some groups of algae (e.g., Chlorophyceae) are apparently multicellular and the sterile tissue is generally considered as vegetative. Bryophytes onwards in the scale of evolution have the uniform multicellular sex organs, the archegonia, which are not found in algae. For that reason briophytes are usually called archegoniate plants.

Characteristics of Algae:

1. Algae are chlorophyll-bearing autotrophic thalloid plant body.

2. Almost all the algae are aquatic.

3. The plant body may be unicellular to large robust multicellular structure.

4. The multicellular complex thalli lack vascular tissue and also show little differentiation of tissues.

5. The sex organs are generally unicellular but, when multicellular, all cells are fertile and in most cases the entire structure does not have any protection jacket.

6. The zygote undergoes further development either by mitosis or meiosis, but not through embryo formation.

7. Plants having distinct alternation of generations. Both gametophyte and sporophyte generations — when present in the life cycle are independent.

Occurrence of Algae:
The algae are ubiquitous (present everywhere) in distribution, i.e., they are found in fresh water as well as marine water, on soil, on rock, as epiphytes or parasites on plants and animals, in hot springs, in desert, on permanent snow-fields etc. But they mainly dwell in aquatic environments.

Based on habitat the algae may be categorized as:
1. Aquatic algae.

2. Terrestrial algae, and

3. Algae of remarkable habitats.

1. Aquatic Algae:
Aquatic algae may be fresh water (when salinity is as low-as 10 ppm) or marine (when salinity is 33-40%). Again, certain algae grow in brackish water which is unpalatable for drinking, but less salty than sea water. The fresh water algae usually grow in ponds, lakes, tanks, ditches etc.

The very common fresh water algae are Chlamydomonas, Volvox, Ulothrix, Chara, Oedogonium, Spirogyra, Nostoc, Oscillatoria etc. Some of the very common marine algae are Sargassum, Laminaria, Ectocarpus, Polysiphonia, Caulerpa, Bangia, Padina etc.

Fresh water algae may be termed as planktonic when they grow and remain suspended on the upper part of water (e.g., Volvox, diatom), while the benthic algae are bottom-dwellers. The algae that grow at air-water interface are called neustonic. The benthic algae may be epilithic, that grow on stones; epipelic attached to sand or mud; epiphytic — growing on plants; and epizoic — growing on animal body surface.

The marine algae may be supralittoral or sub- aerial, as they grow above the water level and in the spray zone. The intertidal algae grow in such a depth so that they are exposed periodically due to tides. Other marine algae are sublittoral, meaning hat they are constantly submerged at depths as great as 30-60 metres (100-200 ft).

Again, the supralittoral algae may be edaphic— that grow in and on the soil, epilithic— growing on stones, epiphytic — growing on plants, epizoic— growing on animal body surface, and corticolous — growing on tree barks and parasitic on plants and animals. Some algae (e.g., Chlorella) live endozoically in various protozoa, coelenterates, molasses etc.

2. Terrestrial Algae:
Some algae are found to grow in terrestrial habitats like soils,' rocks, logs etc. The algae that grow on the surface of the soil are known as saprophytes. Many blue-greens, on the other hand, grow under the surface of the soil, and are called cryptophytes.

The algae growing in the desert soil may be typified as endedaphic (living in soil), epidaphic (living on the soil surface), hypolithic (growing on the lower surface of the stones on soil), chasmolithic (living in rock fissures) and endolithic algae (which are rock penetrating).

The common terrestrial members are Oscillatoria sancta, Vaucheria geminata, Chlorella lichina, Euglena sp., Fritschiella sp. and Phormidium sp.

3. Algae of Remarkable Habitats:
In addition to above mentioned habitats, some algae also occur in uncommon habitats and termed as:
1. Halophytic Algae (or Eurhaline):
They grow in the highly concentrated salt lakes, and include Chlamydomonas ehrenbergli, Dunaliella and Stephanoptera sp.

2. Symbiotic Algae:
They grow in association with fungi, bryophytes, gymnosperms or angiosperms. The best examples of symbiotic algae found in association with fungi are Nostoc,

Gloeocapsa, Rivularia; the members of Cyanophyceae and Chlorella, Cytococcus, Pleurococcus; the members of Chlorophyceae.

This symbiotic association consisting of algae and fungi is called lichen. Nostoc may also associate with Anthoceros and Anabaena associates with the roots of Cycas to form coralloid roots.

3. Cryophytic Algae:
This group of algae growing on ice or snow provides attractive colours to snow-covered mountains. The alpine and arctic mountains become red due to the growth of the Haemotococcous nivalis; green snow in Europe is due to the growth of Chlamydomonas yellowstonensis.

Scotiella nivalis and Raphidonema brevirostri cause black colouration of snow, whereas Ancyclonema nordenskioldii is responsible for brownish purple colouration.

4. Thermophytes or Thermal Algae:
This group of algae occurs in hot water springs (50- 70°C) where normal life is not possible. Many blue-greens (e.g., Oscillatoria brevis, Synechococcus elongates, Heterohormogonium sp.) are grown in such hot springs.

5. Lithophytes:
They grow on the moist surface of stones and rocks, e.g., Nostoc,. Gloeocapsa, Enteromofpha, Batrachospermum etc.

6. Epiphytic Algae:
They grow on other plants including other algal members.

These are:
a. Algae on Algae:
i. Ptilota plumosa and Rhodymenia pseudopalmatta on Laminaria hyperborean, ii. Diatoms on Oedogonium, Spirogyra etc.

b. Algae on Bryophytes:
Blue-green algae like Nostoc, Oscillatoria, diatoms like Achnanthes etc. grow on different bryophytes.

c. Algae on Angiosperms:
Algae like Cocconis, Achnanthes etc. grow epiphytically on Lemna, an aquatic angiosperm. Alga like Trentepohlia grows on the barks of different angiospermic plants, and is very common in Darjeeling (India).

7. Epizoic Algae:
The algae growing on animals like fish, snail etc. are called as epizoic, e.g., Stigeoclonium are found in the gills of fishes.

8. Endozoic Algae:
They grow in the tissues of animals, e.g., Zoochlorella sp. is found in Hydra viridis.

9. Parasitic Algae:
Some algae grow parasitically on different plants and animals.

These are:
a. Cephaleuros (Chlorophyceae) is parasitic and grows on the leaves of various angiosperms, such as tea (Camellia sinensis), coffee (Coffea arabica), Rhododendron, Magnolia and pepper (Piper nigrum). The most important one is Cephaleuros virescens, which causes Red rust of tea.

b. Rhodochytrium (Chlorophyceae) grows on ragweed (Ambrosia) leaves.

c. Phyllosiphon (Chlorophyceae) grows on the leaves of Arisarum vulgare.

d. Ceratocolax (Rhodophyceae) grows in Phyllophora thallus.

10. Psammon:
The algae which grow in sandy beaches are called psammon, e.g., Vaucheria, Phormidium etc.

Thallus Organisation in Algae:
Thalli of algae show a range of organisation starting from unicellular form to highly organised multicellular habit where the plant body is differentiated into root-like, stem-like, and leaf like structures giving a higher plant-like appearance. Their size ranges from a few micron to several metres.

The algal thalli are grouped into the following, based on their organisation:
A. Unicellular Algae:
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 rhizopodial 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 function as the organ of locomotion varying in number 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.

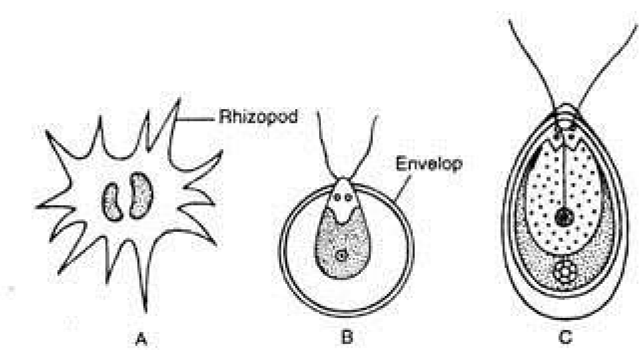

Fig. 3.1 : Unicellular motile algae : A. *Chrysamoeba*, B. *Phacotus*, and C. *Chlamydomonas*

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).

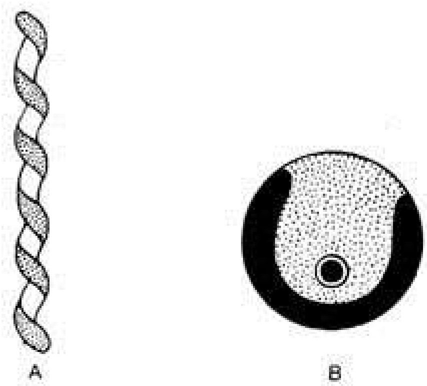

Fig. 3.2 : Unicellular non-motile algae. A. *Spirulina*, and B. *Chlorella*

B. Multicellular Algae:

1. Colonial:

The colonial habit is achieved by loose aggregation of cells within a common mucilaginous investment. The cells of these usually remain connected with each other by cytoplasmic threads.

a. Coenohium:

When a colony has a definite number of cells with a definite shape and arrangement, it is called coenobium.

Coenobium may be:

i. Motile, or

ii. Non- motile.

i. In motile form, cells are flagellated and whole coenobium can move by the organised beating action of flagella, e.g., Volvox (Fig. 3.3A), Pandorina (Fig. 3.3B), Eudorina etc. In Volvox the coenobium is a hollow sphere.

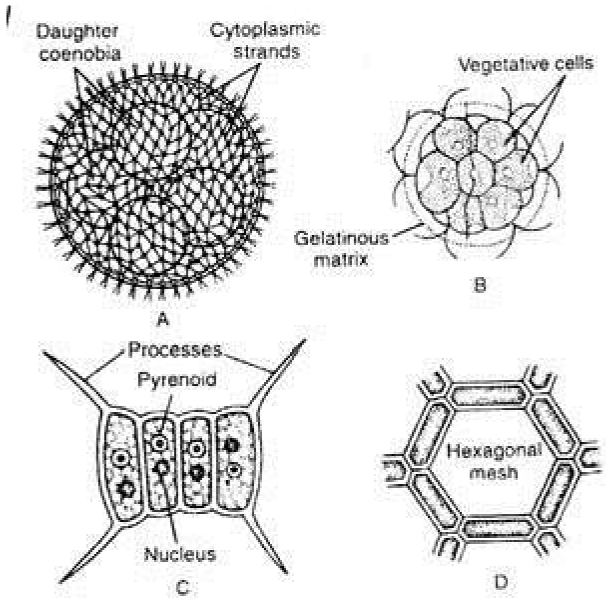

Fig. 3.3 : Colonial algae : A. *Volvox*, B. *Pandorina*, C. *Scenedesmus*, and D. *Hydrodictyon*

ii. In non-motile form, the cells are without flagella, thereby the coenobium is non-motile, e.g., Scenedesmus (Fig. 3.3C), Hydro- dictyon (Fig. 3.3D).

b. Aggregated Form:

Unlike coenobium the cells are aggregated irregularly showing a colonial mass of various size and shape.

It is of three types:

i. Palmelloid,

ii. Dendroid, and

iii. Rhizopodial.

i. Palmelloid:

In this type the non- motile cells remain embedded in an amorphous gelatinous or mucilaginous matrix. Each and every cell of the organisation is independent and can perform all the functions as an individual. Chlamydomonas and Chromulina represent palmelloid as a temporary feature in their life cycle.

But in Tetraspora (Fig. 3.4A, B) and Palmodictyon (Chlorophyceae), Gleochloris and Chlorosaccus (Xanthophyceae), Phaeocystis (Chrysophyceae) and Microcystis (Cyanophyceae), the palmelloid habit is a permanent feature.

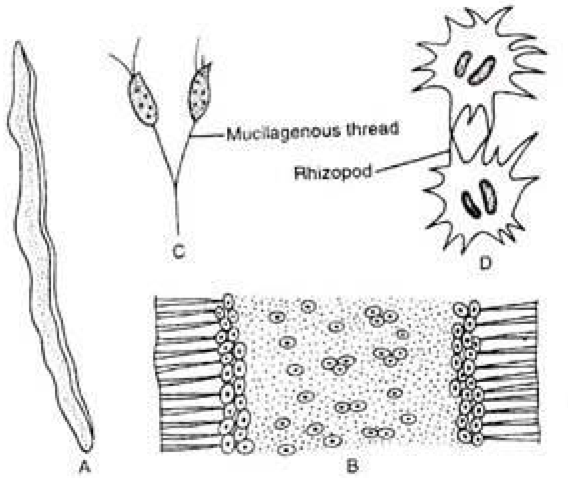

Fig. 3.4 : Aggregated form : A. *Tetraspora*, B. *Tetraspora*, (portion of a colony in T.S.), C. *Chrysodendron* and D. *Chrysidiastrum*

ii. Dendroid:

In this type the number, shape and size of the cell is variable. They look like microscopic trees (e.g., Prasinocladus, Ecballocystis, Chrysodendron, Fig. 3.4C; etc.). A mucilaginous thread is present at the base of each cell, thus showing a sort of polarity.

iii. Rhizopodial:

In this type the cells are united through rhizopodia. e.g., Chrysidiastrum (Chrysophyceae, Fig. 3.4D).

2. Filamentous:

The filamentous plant body is formed through repeated cell divisions in a single plane and in a single direction, where the cells remain firmly attached to each other — end to end forming a chain or a thread. The filaments may be unbranched or branched.

a. Unbranched Filament:

It may be free-floating (e.g., Spirogyra, Fig. 3.5A) or attached to the substratum (e.g., Ulothrix, Oedogonium, etc.). The free-floating unbranched filaments are not differentiated into basal and apical ends. All the cells in the filament are alike. But the Unbranched filaments that remain attached to the substratum are differentiated into base and apex.

All the cells of the filament are similar except the basal attachment cell that is specially modified for the purpose called holdfast or rhizoidal cell. The cell is devoid of chloroplast and only performs the function of anchorage. So certain degree of division of labour among the cells of the filament is established as rest of the cells performs photosynthetic and reproductive functions.

b. Branched Filament:
It is formed when a filament occasionally starts division in a second plane.

It is of two types:
i. Falsely branched, and

ii. Truly branched.

i. Falsely Branched:
The trichomes of blue greens may break either due to death or decay of the intercalary cells. The broken ends emerge out of the mucilaginous sheath in the form of a branch. They do not arise as lateral outgrowths, e.g., Scytonema (Fig. 3.5C).

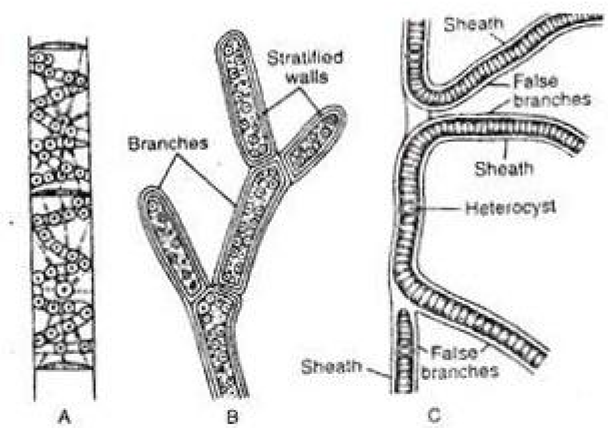

Fig. 3.5 : Filamentous type : A. *Spirogyra*, B. *Cladophora* and C. *Scytonema*

ii. Truly Branched:
When a cell in the filament occasionally starts division in a second plane, true branch is formed. Thus true branches arise as lateral outgrowths of the main filament. True branches are of the following three types: Simple filament, Heterotrichous habit, and Pseudoparenchymatous habit.

Simple Filament:
In this branching system the whole thallus remain attached to the substratum by a basal cell and the branches may arise from any cell of the filament except the basal cell, e.g., Cladophora (Fig. 3.5B).

Heterotrichous Habit:
In this branching system the whole thallus is differentiated into prostrate and erect system. Both the prostrate and erect systems may be well-developed (e.g., Fritschiella, Ectocarpus, Fig. 3.6A). Progressive elimination of the prostrate system is observed in Draparnaldiopsis (Fig. 3.6B), Stigoclonium, oi of the erect system as in Coleochaete (Fig. 3.6C).

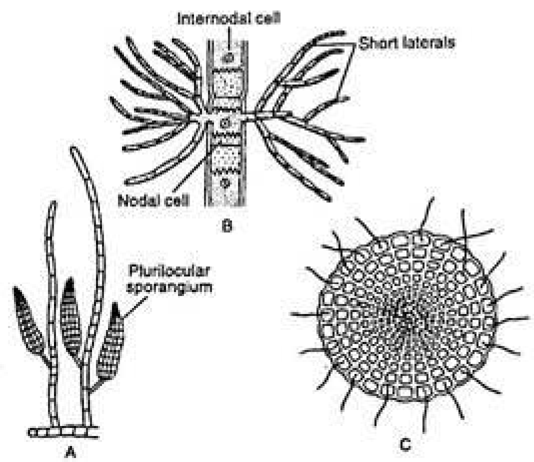

Fig. 3.6 : Branched filament showing heterotrichous habit : A. *Ectocarpus*, B. *Draparnaldiopsis*, and C. *Coleochaete*

Pseudoparenchymatous Habit:
If one or more central or axial filaments together with their branches fuse to form a parenchymatous structure, it is called pseudoparenchymatous. thallus. Again, if it is formed by the branches of a single filament it is known as uniaxial (e.g., Batrachospermum, Fig. 3.7A, B), or it may be multiaxial where more than one filament are involved (e.g., Polysiphonia, Fig. 3.7C).

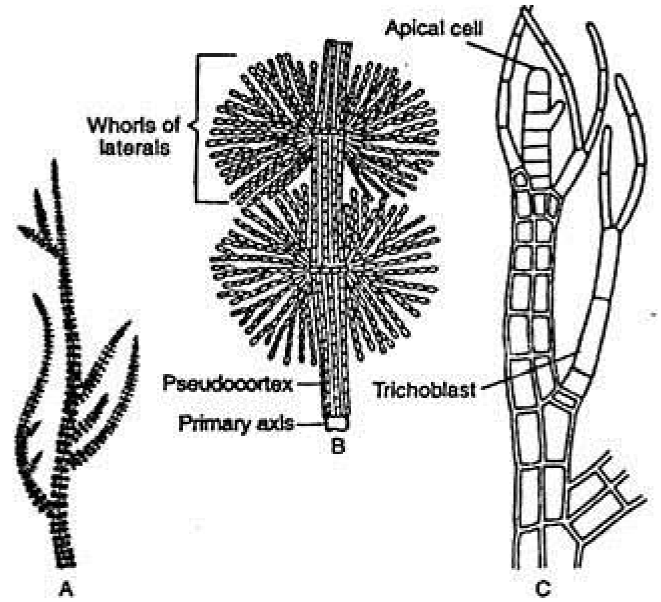

Fig. 3.7 : Pseudoparenchymatous habit : A. *Batrachospermum*, B. *Batrachospermum* (portion of the plant body), and C. *Polysiphonia*

3. Siphonaceous Forms:

In this form the thallus is aseptate and multinucleate i.e., a coenocyte. It may be simple branched (e.g., Vaucheria, Fig. 3.8A) or may be very elaborate with clear division of labour, differentiated into aerial and subterranean portions (e.g., Botrydium, Fig. 3.8B).

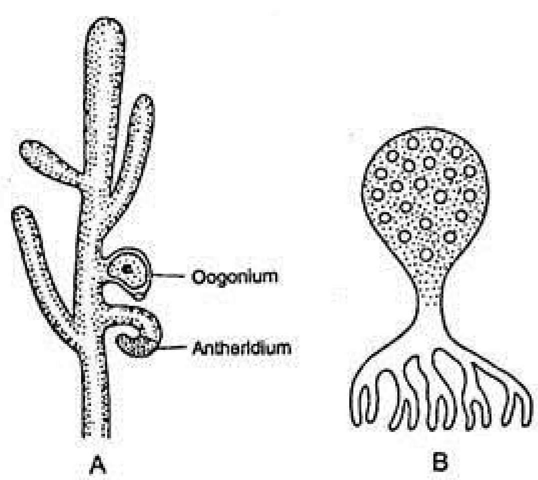

Fig. 3.8 : Siphonaceous algae : A. *Vaucheria*, and B. *Botrydium*

4. Parenchymatous Forms:

When the cells of a filament divide in multidirectional planes, it results the formation of a parenchymatous thallus and ultimately becoming foliose and flat (e.g., Ulva, Fig.

3.9A), tubular (e.g., Enteromorpha, Scytosiphon) or complex (e.g., Sargassum, Fig. 3.9B) structure.

Growth of the parenchymatous thalli may be diffused (when all the cells can divide), intercalary (when the dividing region remain in the intercalary position) e.g., Laminaria (Fig. 3.9C), trichothallic (growth by a specialised intercalary meristem at the base of a terminal hair) e.g., Porphyra or apical (when one or more well-defined apical cells divide to produce the remainder of the thallus), e.g., Fucus.

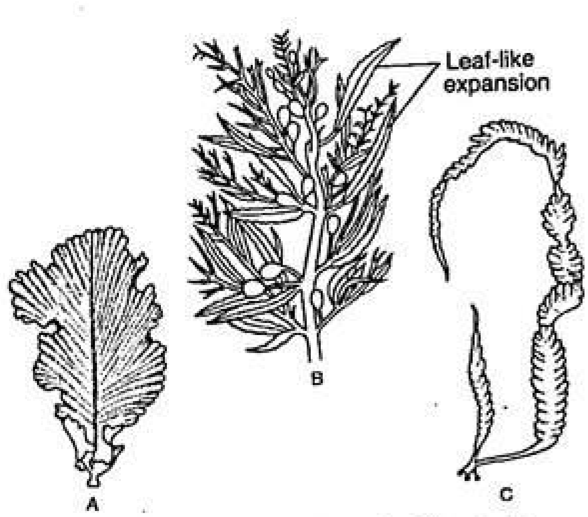

Fig. 3.9 : Parenchymatous algae : A. *Ulva*, B. *Sargassum*, and C. *Laminaria*

Occurrence of Algae:

Algae are commonly presumed to be occurring in water and moist places but algae are found in a variety of habitats.

The common places of occurrence of algae are as follows:

(i) Aquatic Algae:

Aquatic algae can be:

(a) Fresh water forms

(b) Marine forms.

(a) Fresh water forms:

Fresh water forms are found in water of low salinity such as in ponds, lakes, rivers, ditches etc. Cladophora, Vaucheria, Chara and some algae found in slow running water while Spirogyra, Chlamydomonas, Hydrodictyon and Volvox are found in stagnant water.

(b) Marine forms:
The algae found in sea water are called marine algae. Such algae grow in water of high salinity. Marine algae can be macroscopic and very large in size e.g., Macrocystis (70 meters) and Nereocystis (100 meters).

Some other examples of marine algae are:
Enteromorpha, Sargassum, Fucus, Polysiplionia, Gelidium and Gracilaria etc.

(ii) Terrestrial Algae:
Algae growing on moist soil surface, stones and rocks are terrestrial algae. The algae growing on surface of soil are called saprophytes and the algae growing under the surface of soil are called cryptophytes. Some terrestrial algae grow on moist walls and barks of trees. These algae absorb CO_2 and water from atmosphere.
Some common terrestrial algae are:
Fritschiella, Vaucheria, Chlorella, and Oscillatoria.

(iii) Lithophytic Algae:
Algae growing on surface of rocks and stones are lithophytic e.g., Nostoc, Gloeocapsa.

(iv) Halophytic Algae:
Algae growing in water of high concentration of salts as in salt lakes are halophytic algae e.g., Chlamydomonas ehrenbergii and Dunaliella.

(v) Thermophytic Algae:
The thermophytic algae grow in water of high temperature where other plant forms cannot grow. Some blue green algae are capable of growing at very high temperature because of unorganized nucleus. The thermal algae found in hot water springs are Oscillatoria terebriformis, Heterohormogonium, Synechococcus, Scytonema etc.

(vi) Cryophytic Algae:
Algae occurring in snow and ice are cryophytic algae. These algae impart special colours to snow due to their pigments. Red snow is caused by Haematococcus nivalis and Chlamydomonas nivalis. Green snow is caused by Chlamydomonas yellowstonensis.

Purple brown snow is caused by Ancyclonema nordenskliolдii. Black snow is caused by Raphidonema.

(vii) Epiphytic Algae:

Algae growing on other algae and plants are called epiphytic algae e.g., Polysiphonia, Oedogonium are found growing on other algae, bryophytes and aquatic angiosperms.

(viii) Epizoic Algae:

Algae growing on other animals are called epizoic algae e.g., Cladophora crisposa grows on snails, Stigeoclonium grows on gills of fishes.

(ix) Endophytic Algae:

Algae growing inside other plants are called endophytic algae e.g., Nostoc is found in thallus of Anthoceros, Anabaena cycadearum is found in coralloid root of Cycas, Anabaena azollae is found in Azolla.

(x) Endozoic Algae:

Algae found inside the body of animals are endozoic algae e.g., Zoo chlorella is found in Hydra and sponges. Some blue green algae are found in respiratory and digestive tracts of animals.

(xi) Parasitic Algae:

Some algae can be found as parasites on plants and animals e.g., Cephaleuros is found on leaves of tea, coffee and mango plants and causes red rust. Polysiphonia fastigiate is semi-parasitic on algae Ascophyllum.

(xii) Symbiotic Algae:

Some algae of Chlorophyceae and Cyanophyceae are found in symbiotic association with other plants. Nostoc and Anabaena make symbiotic association with Anthoceros and coralloid roots of Cycas. Lichens are symbiotic association of algae and fungi.

(xiii) Planktons:

Algae growing on surface of water and found as free floating on surface of water are called planktons. Planktonic algae are mainly members of Chlorophyceae, Cyanophyceae and Bacillariophyceae. When planktonic algae grow fast and increase enormously in number, these algae form water blooms.

Reproduction in Algae:

1. Vegetative Reproduction:

In this type, any vegetative part of the thallus develops into new individual. It does not involve any spore formation and there is no alternation of generations. It is the most common method of reproduction in algae.

The vegetative reproduction in algae is of the following types:

a. Cell division or fission:

It is the simplest method of reproduction. The unicellular forms of algae commonly reproduce by this simple process, often called binary fission as found in Chlamydomonas, Synechococcus (Fig. 3.16A), diatoms etc. In this method the vegetative cell divides mitotically into two daughter cells, those finally behave as new individual.

b. Fragmentation:

In this method, the multicellular filamentous thallus breaks into many-celled fragments, each of which gives rise to a new individual. The fragmentation may be accidental or by the formation of separation discs or by some other mechanical force or injury. It is found in Spirogyra, Ulothrix, Oedo- gonium, Zygnema, Cylindospermum (Fig. 3.16B) etc.

c. Hormogonia:

This method of vegetative reproduction is found in blue-green algae. The trichomes of blue-green algae break up within the sheath into many-celled segments called hormogonia or hormogones. They remain delimited by the formation of heterocysts, separation discs or necridia or by the death and decay of intercalary cells of the trichome. Hormogonia are commonly found in Nostoc, Oscillatoria, Cylindosporium etc.

d. Formation of Adventitious Branches:

Adventitious branches are formed in different large thalloid algae, which, when detached from the plant body, develop into new individuals (e.g., Fucus, Dictyota). Protonema-like adventitious branches are formed from the internodes of Chara, stolons of Cladophora glomareta etc.

e. Bulbils:

Tuber-like outgrowths are developed due to storage of food at the tip of rhizoids and on the lower nodes of Chara, called bulbils (Fig. 3.16C). After detachment from the plant body, bulbils grow into new plants.

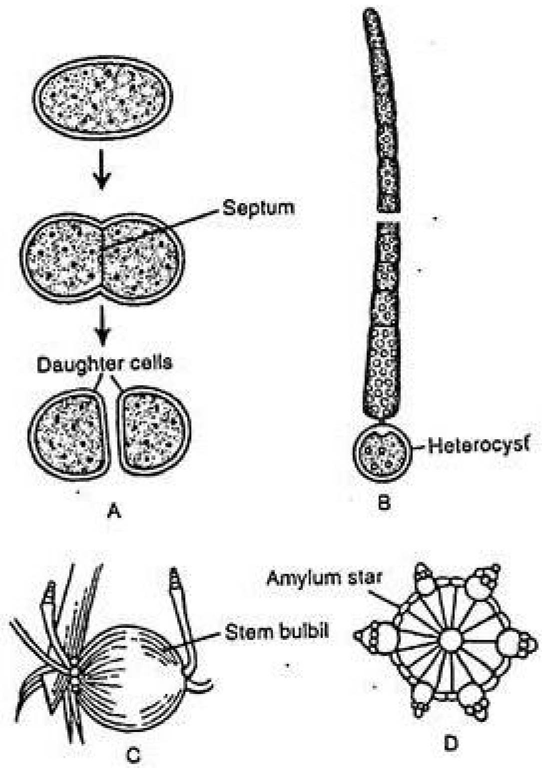

Fig. 3.16 : Vegetative reproduction in algae : A. Cell division (*Synechococcus* sp.) B. Fragmentation of filament (*Cylindrospermum* sp.) C. Stem bulbil (*Chara* sp.) and D. Amylum star (*Chara* sp.)

f. Amylum stars:

Star-shaped aggregation of starch containing cells develops on the lower nodes of Chara. These structures are called amylum stars (Fig. 3.16D). When detached from the plant body, they grow into new plants.

g. Budding:

In Protosiphon bud-like structures are formed due to proliferation of vesicles delimited from the parental body by a septum, which, after detachment, grow into a new plant.

2. Asexual Reproduction:

Asexual reproduction involves the formation of certain type of spores — either naked or newly walled. It is a process of rejuvenation of the protoplast without any sexual fusion. Each and every spore germinates into a new plant. In this method, there is no alternation of generations.

The asexual spores may be of various types:

a. Zoospores:

These are motile naked spores provided with two, four or many flagella and called as bi-, quadri- or multiflagellate zoospores, respectively. Biflagellate zoospores are found in Chlamydomonas, Ulothrix (Fig. 3.17A) Ectocarpus etc., quadriflagellate zoospores are found in Ulothrix (Fig. 3.17B) and multiflagellate zoospores are found in Oedogonium (Fig. 3.17C).

But the multinucleate and multiflagellate zoospores as found in Vaucheria (Fig. 3.17D) are called synzoospores. Each zoospore has a chloroplast and an eye spot. The zoospores may be either haploid or diploid.

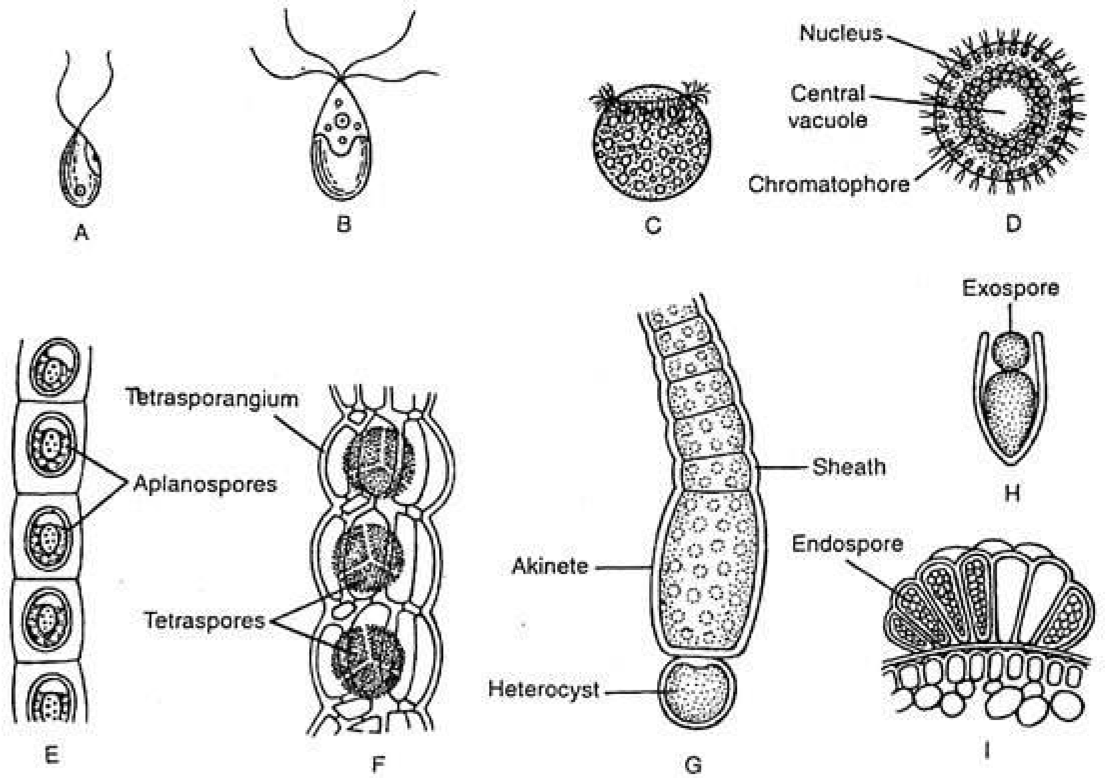

Fig. 3.17 : Asexual spores in algae : A. Biflagellate microzoospore, and B. Quadriflagellate microzoospore of *Ulothrix* sp., C. Multiflagellate zoospore of *Oedogonium* sp., D. Synzoospore of *Vaucheria* sp., E. Aplanospores of *Ulothrix* sp., F. Tetraspores of *Polysiphonia* sp., G. Akinete of *Gloeotrichia* sp., H. Exospore of *Chamaesiphon incrustans*, and I. Endospores of *Dermocarpa prasina*

They are formed within the zoosporangium. There may be single zoospore (e.g., Oedogonium) or many zoospores (e.g., Cladophora) per zoosporangium. Zoospores are either haploid or diploid depending on the nature of plant body, gametophytic or sporophytic on which it develops.

The zoospores are liberated either by the disintegration of the zoosporangial wall or by the formation of an apical pore on the zoosporangium. After liberation the zoospores swim for a while, then withdraw their flagella, encyst and ultimately germinate into new plants.

b. Aplanospores:

Aplanospores are non- motile spores. These spores are formed either singly or its protoplast may divide to form many aplanospores inside sporangium during unfavourable conditions, especially in drought (e.g., Ulothrix (f ig. 3.17E), Microspora). The aplanospores may also be formed in certain algae of semiaquatic habitat.

When they appear identical to the parent cell, they are referred to as autospores (e.g., Scenedesmus, Chlorella etc.). Aplanospores with thickened wall and abundant food reserve are known as hypnospores (e.g., Pediastram, Sphaerella etc.).

They are formed to overcome prolonged period of desiccation. With the onset of favourable condition the hypnospores either directly germinate into a new individual or their protoplasts may form zoospores. Due to deposition of haematochrome pigment in their walls, the hypnospores of Chlamydomonas nivalis are red in colour.

c. Tetraspores:
Diploid plants of some algae (e.g., Polysiphonia, Fig. 3.17F) produce a special type of haploid aplanospores, called tetraspores, formed within tetrasporangium. The diploid nucleus of a tetrasporangium divides meiotically to form four haploid nuclei which — with little amount of protoplasm — are developed into four tetraspores. After liberation the tetraspores germinate to form male and female gametophytes.

d. Akinetes:
The vegetative cells of certain filamentous algae develop into elongated thick-walled spore-like structures with abundant food reserves, called akinetes (e.g., Gloeotrichia, Fig. 3.17G). They can tide over the unfavourable conditions. With the onset of favourable condition they germinate into new individuals.

e. Exospores:
In some algae, spores are regularly cut off at the exposed distal end of the protoplast in basipetal succession, called exospores. These spores aggregate in groups and develop new colonies, e.g., Chamaesiphon (Fig. 3.17H).

f. Endospores:
These are small spores formed by the divisions of the mother protoplast. They are also called conidia or gonidia. They are set free after the dissolution of mother wail. Without taking rest, the spores germinate directly and develop into a new plant, e.g., Dermocarpa (Fig. 3.17 I).

3. Sexual Reproduction:
All algae except the members of the class Cyanophyceae reproduce sexually. During sexual reproduction gametes fuse to form zygote (Fig. 3.18). The new genetic set up can develop by the fusion of gametes coming from the different parents.

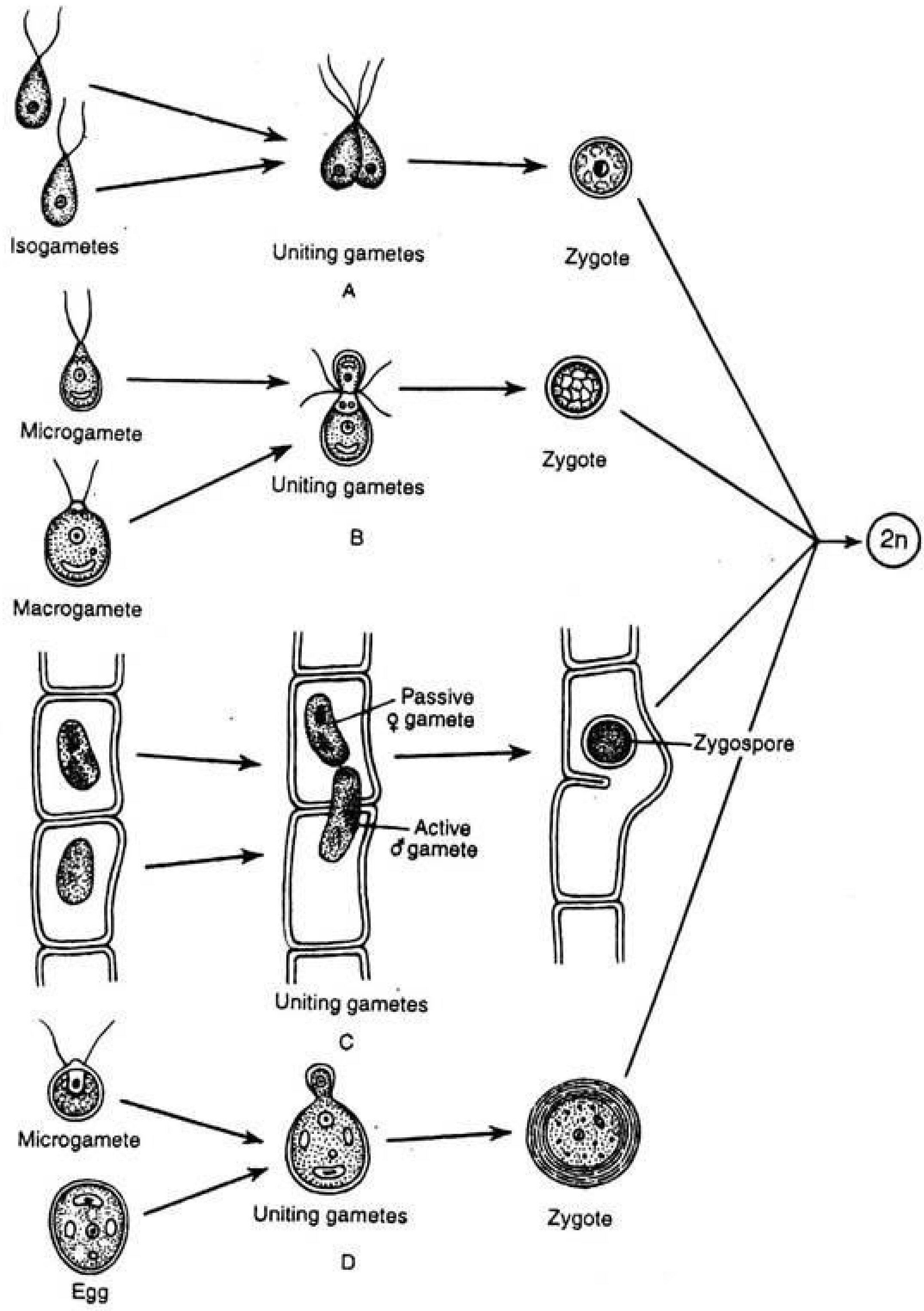

Fig. 3.18 : Types of sexual reproduction in algae : A. Isogamy in *Chlamydomonas* sp., B. Anisogamy in *Ectocarpus* sp. C. Physiological anisogamy in *Spirogyra* sp., and D. Oogamy in *Chlamydomonas* sp.

Depending on the structure, physiological behavior and complexity of sex organs, sexual reproductions are of the following five types:

a. Autogamy:

In this process the fusing gametes are developed from the same mother cell and after fusion they form zygote. For the above, plant developed through autogamy does not show the introduction of any new characteristic, e.g., Diatom (Amphora normani).

b. Hologamy:

In some unicellular member the vegetative cells of different strains (+ and -) behave as gametes and after fusion they form zygote. It is an inefficient process considering the point of multiplication, but new genetic combinations are developed by this process, e.g., Chlamydomonas.

c. Isogamy:

It is the process of union, between two gametes which are morphologically and physiologically similar — after fusion they form zygote. The gametes are called isogametes. Usually they are flagellate, e.g., Chlamydomonas eugametos, Ulothrix etc.

d. Anisogamy:

In this process the uniting gametes are morphologically and physiologically different. The smaller and more active one is the microgamete (male), whereas the larger and less active one is the macrogamete (female), e.g., Chlamydomonas braunii.

Deviating from the typical anisogamy, when the uniting gametes show morphological similarity with physiological difference, it is called physiological anisogamy. e.g., Zygnema, Spirogyra etc.

e. Oogamy:

It is an advanced process where fertilisation takes place between a small motile (non-motile in Rhodo- phyceae) male gamete (sperm or antherozoides) with a large non-motile female gamete (egg or ovum). Male gametes develop within antheridium, whereas the female gamete within the oogonium, e.g., Oedogonium, Vaucheria, Chara, Laminaria, Sargassum, Polysiphonia, Batrachospermum etc.