UNIT 3 COMPARATIVE MORPHOLOGY AND CELL STRUCTURE IN ALGAE

Structure

3.1 INTRODUCTION

In the previous block you have learnt that algae are placed in Kingdom Protista along with protozoa. Earlier they were classified with plants as they are photosynthetic autotrophs - possess chlorophyll and chloroplasts and superficially appear like plants. Since their gametes do not have protective cells around them they are no longer classified with plants.

Traditionally, on the basis of physical features, Plant Kingdom is divided into four groups or divisions - Thallophyta, Bryophyta, Pteridophyta, Spermatophyta. The first three divisions are collectively called *Cryptogames* or flowerless or seedless plants as they never bear flowers. The last division spermatophyta in known as *Phanerogames* or flowering plants.

In this first unit on algae you will study the morphology and cell structure of algae and also of cyanobacteria (commonly known as blue-green algae). Algae are widely distributed in nature wherever there is plenty of water and sunshine. They even inhabit harsh habitats. Although simple in structure, lacking differentiation, algae exhibit great diversity in size and appearance. Their size ranges from simple microscopic to giant thallus extending several metres in length as in kelps. Algal morphology varies from simple unicellular form to complex thallus as found in seaweed. While studying the morphology of representative genera included here you will note the various stages in the evolution of multicellular thallus that led to the development of first land plants.

The kelps have fronds as large as 100 metres and grow at a rate of about 60 cm per day.

The study of their cell structure under electron microscope has revealed one major fact that blue-green algae have prokaryotic type of cell like that of bacteria and hence they are more related to them than to other algae with which they were traditionally grouped. All other algae have eukaryotic type of cell.

The reproductive processes found in algae are discussed in the subsequent unit. Algae are widely distributed in nature and are diverse in habitat. We have given in unit 6 a detailed account of habitats and distribution particularly in India.

Objectives

After studying this unit you will be able to:

- describe the basic types of thallus in algae,
- compare the morphology of unicellular, colonial, filamentous, heterotrichous, thalloid and polysiphonoid forms of algae,
- draw the morphology of *Anacystis, Chlamydomonas, Microcystis, Volvox, Nostoc, Ulothrix, Oedogonium, Draparnaldiopsis, Coleochaete, Ectocarpus, Ulva, Fucus* and *Polysiphonia* and describe their special features,
- draw and label the parts as seen in ultrastructure of cells of prokaryotic and eukaryotic algae and list their distinguishing features,
- describe briefly the basic features of various cell organelles present in prokaryotic and eukaryotic algae and
- explain the evolution of thallus in algae.

3.2 ALGAL MORPHOLOGY

The science or study of algae is called 'Phycology'. One who specialises in the study of algae is called 'Phycologist' or 'Algologist'.

The body of an alga is called thallus. In unicellular algae it is simple consisting of a single cell. All multicellular organisms start their life as single cells. When a cell divides and the daughter cells form a packet enclosed in a mucilaginous mass, a colony is formed. While the division of a cell continuously in the same plane, with the daughter cells sticking together, results in a row of cells forming a filament. Some of the cells of a filament divide only once by a vertical plane followed by transverse divisions repeatedly and thus produce filamentous-branched thallus. Further, when all the cells of a filament undergo divisions in cross and vertical planes it results in a sheet of one or more cells in thickness. Such multicellular thallus may show complicated differentiation as in seaweed. All multicellular algae show the above stages during their development.

In the following account you will study the specific examples of the above basic types of thallus in algae. It is to be noted that all the above forms may not be found in all algal divisions but some are predominently multicellular, some filamentous and some include only unicellular forms. A gradual complexity in form also indicates how the evolution of thallus has taken place, in algae.

Morphologically algae can be distinguished as unicellular, colonial, filamentous, heterotrichous, thalloid and polysiphonoid forms. Each of these type is described below.

3.2.1 Unicellular Forms

Anacystis

Single cells, cylindrical, short or long; sometimes very long snake forms (Fig. 3.1 A). Cells divide by constriction, the two daughter cells get separated, rarely they remain together to form a 2-celled filament.

Individual single cells may have their own mucilagenous cover around them. Several such cells may be enclosed in common colourless mucilage giving the impression of a colony.

Chlamydomonas

This single celled alga contains a nucleus, a cup-shaped chloroplast in which one **pyrenoid** is commonly present (Fig. 3.1 B and Fig. 3.8 B). The chloroplast on the anterior side shows 2 to 3 rows of fatty red coloured granules. This is known as **eyespot** or **stigma** which is helpful for the alga to respond to light. The cell wall is firm and distinct. A small contractile vacuole is found at the base of each flagellum.

Chlamydomonas cells under partially dry conditions divide and the daughter cells without flagella remain enclosed by a common mass of mucilage. Such a colony is known as **palmella stage** of *Chlamydomonas* (Fig. 3.1 C). This is only a temporary stage and on flooding with water individual cells develop flagella and escape swimming away from the colony. Thus the beginning of the colony construction found in *Volvox* can be seen in *Chlamydomonas*.

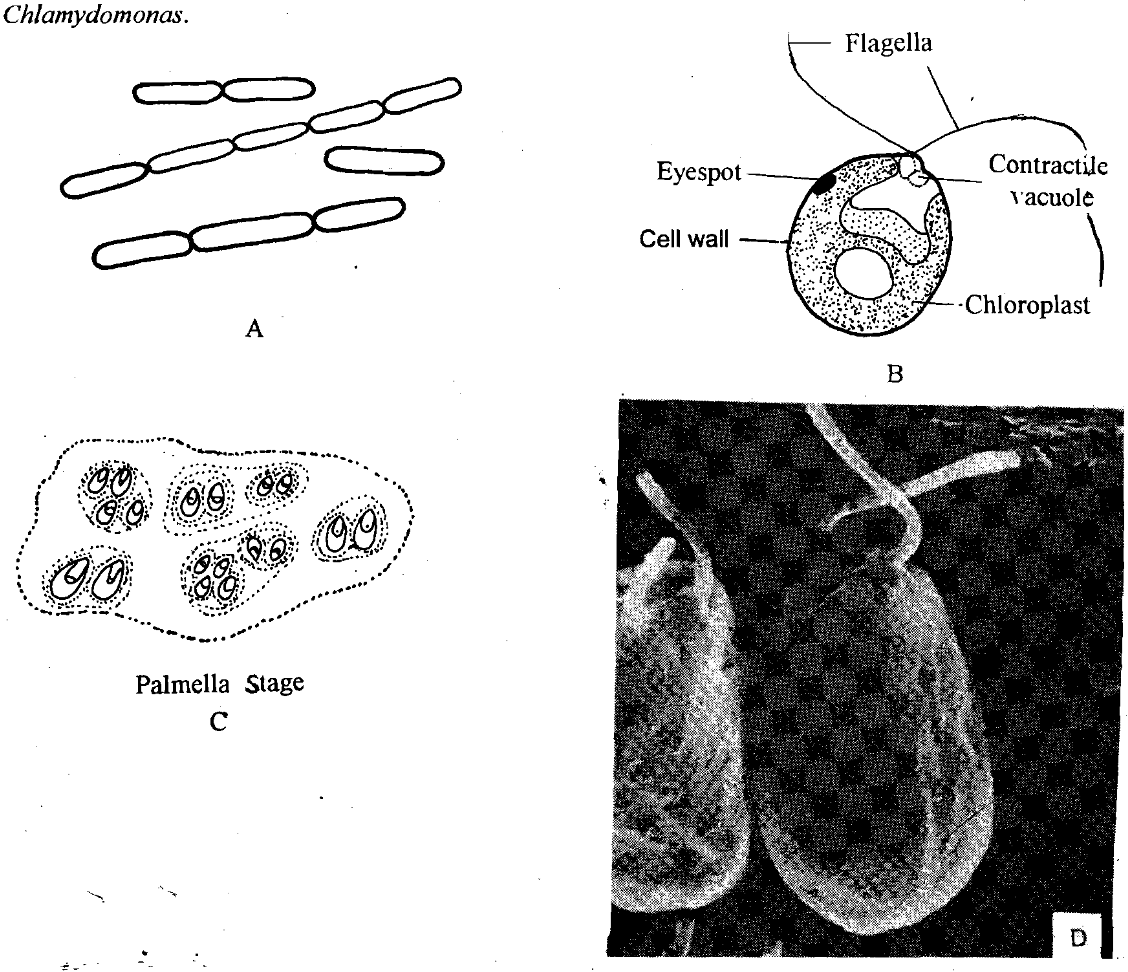

Fig. 3.1 : Unicellular algae; A) *Anacystis nidulans*, B) *Chlamydomonas*, C) palmella stage of *Chlamydomonas*, D) Scanning electron micrograph of *Chlamydomonas reinhardii* growing on a solid culture medium (Courtesy of P. Dayanandan).

3.2.2 Colonial Algae

When a cell divides and the daughter cells formed remain together within a common mucilage mass, it is known as a colony. A colony may contain large number of cells. Sometimes it may be so big that one can see it with unaided eyes.

Microcystis

This is a colonial alga, most common in polluted ponds and lakes in India (Fig. 3.2 A). Sometimes the colonies are big and can be seen by unaided eyes. They accumulate on the surface of water forming quite a thick layer in some seasons (water blooms).

Single cells are spherical and colony is formed because of loose aggregates of several thousand cells held by mucilage (Fig. 3.2 B). The colonies float on the surface of water because of the presence of elongated cylindrical gas vesicles inside the individual cells. Reproduction is by division of cells called binary fission.

Volvox

The colonies of *Volvox* are spherical, ball-like and big enough to be seen with unaided eye (Fig. 3.2 C). Each colony contains 1000-5000 cells arranged on the outside of a mucilagenous ball called **coenobium**. Two types of cells can be seen generally, vegetative or **somatic** and **gonidia**. In younger colonies cytoplasmic connections - plasmodesmata between individual cells can be seen under the microscope.

Coenobium - it is a colony in which the number of cells is fixed at the time of formation. No further addition of cells occurs. Generally the cells are also in a special arrangement.

Vegetative cells are more or less like *Chlamydomonas* with two flagella, cell wall, single cup-shaped chloroplast, eyespot, pyrenoid, contractile vacuole and a nucleus (Fig. 3.2 D). The cells on the posterior side of the colony may be larger than in the front.

Gonidia-cells meant for sexual reproduction are on the posterior side and they lose their flagella early. They divide and give rise to daughter colonies. After the rupture of the parent colony the daughter colonies are liberated into the water.

The daughter colonies produced from gonidia may later develop into male colonies that produce spermatozoa or female colonies that produce eggs. *Volvox* colonies are generally unisexual but some species are bisexual.

It is to be noted that *Volvox* colony is much more advanced than a *Microcystis* colony. The individual cells in *Microcystis* after division remain suspended in a common mass of mucilage without any contact between them. Each cell may go on dividing continuously forever as long as conditions are suitable.

In *Volvox* all the cells of a colony are derived from a single parental cell. They are arranged on the surface of mucilaginous ball, connected with other cells by cytoplasmic connections. Some cells behave as sex cells meant for reproduction whereas others remain vegetative and ultimately grow old and die. This differentiation into vegetative and reproductive cells is a very important feature in the development of multicellular organisms.

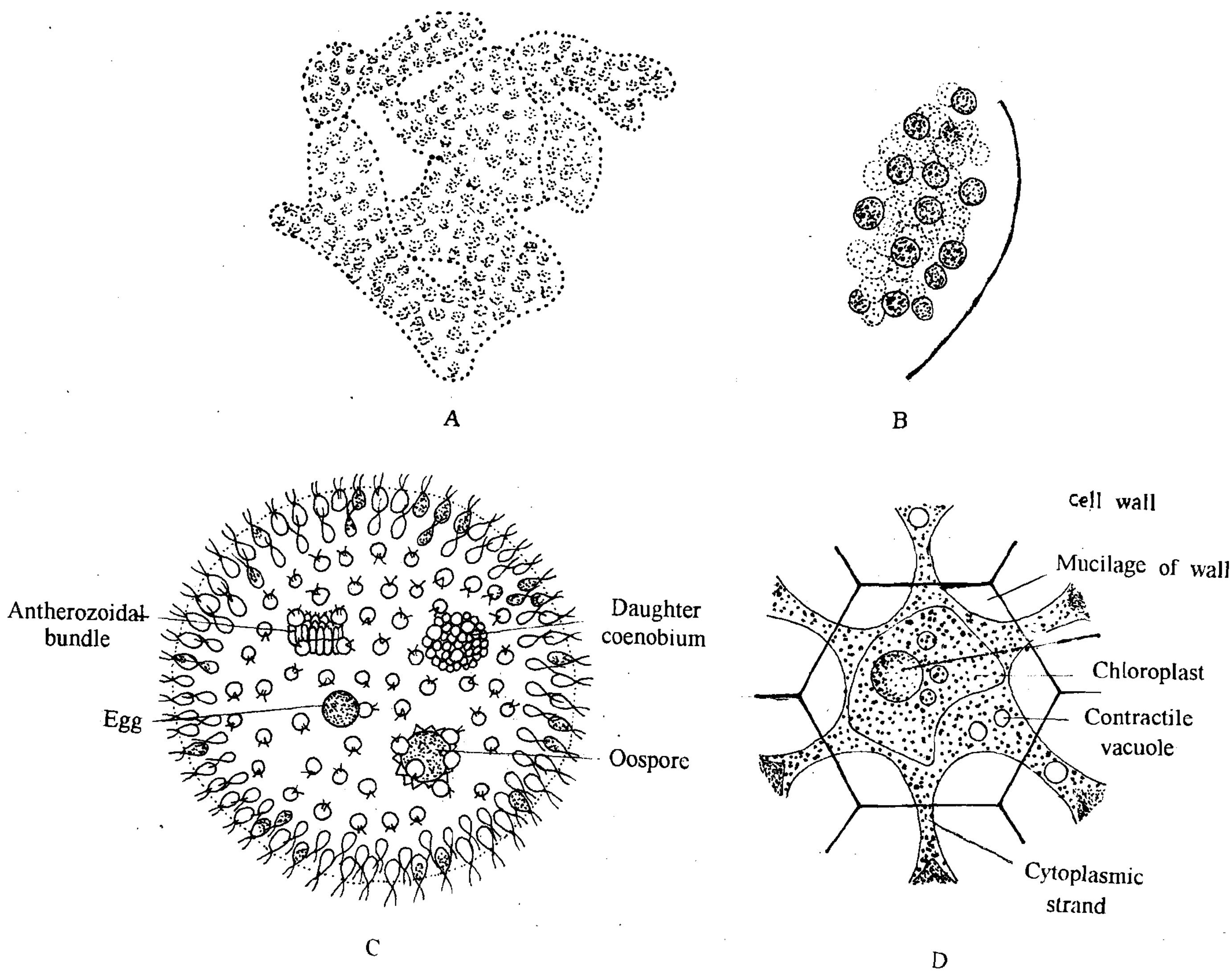

Fig. 3.2 : Colonial algae; A) *Microcystis aeruginosa*, B) portion of A magnified, C) *Volvox aureus*, D) cells of C in the interior polar view.

3.2.3 Filamentous Forms

When a cell divides always cross-wise and the daughter cells do not separate from each other, it results in a linear row of cells as in *Nostoc, Ulothrix* and *Oedogonium*. However, the three algae show different levels of differentiation.

Nostoc

This is a simple filamentous form, a single row of cells, uniseriate (Fig. 3.3 A). Several filaments of *Nostoc* are generally enclosed within a common mucilage envelop to form a colony (Fig. 3.3 B). Some cells in between the vegetative cells are modified into **heterocysts.** All the vegetative cells are capable of developing into spores called **akinetes.**

Heterocyst – a highly differentiated cell in some filamentous blue-green algae that is a site of nitrogen fixation.

Ulothrix

This is also a filamentous alga but differentiated into narrow basal holdfast by which it is attached to the rock in water (Fig. 3.3 C). Fig. 3.3 D shows the structure of cells of *Ulothrix* with girdle shaped chloroplasts. The cells at the apical end are relatively broad. These undergo division and produce within, a large number of motile cells meant for reproduction.

Akinete – a thick-walled, nonmotile reproductive cell found in algae.

Uniseriate – Single row of cells in the form of filament.

Oedogonium

The filaments of *Oedogonium* are unbranched, usually differentiated at one end into a holdfast (Fig. 3.3 E). The cylindrical cells are short or longer than broad. The growth of the filaments is due to the division of specific cells called **cap cells** which show caps (or ring like scars) on their walls (Fig. 3.3 F). Such cells may divide many times and the number of caps present on a cell indicates the number of divisions it has undergone.

SAQ 3.1

a) Indicate which of the following statements are true or false. Write T for true and F for false in the given boxes.

i) Cap cells of *Oedogonium* serve as holdfast. ☐

ii) Holdfast is found in *Nostoc*. ☐

iii) *Chlamydomonas* floats because of the presence of gas vesicles. ☐

iv) Plasmodesmata are not found in *Microcystis*. ☐

b) Choose the correct answer in the following.

i) Which of the following alga is colonial in form?
1) *Microcystis*
2) *Anacystis*
3) *Chlorella*
4) *Chlamydomonas*

ii) Heterocysts are present in
1) *Microcystis*
2) *Nostoc*
3) *Volvox*
4) *Ulothrix*

c) In the following statements fill in the blank spaces with appropriate words

i) .... is a unicellular alga.
ii) In younger colonies of *Volvox*, the cells of the colony are connected with ....
iii) The colony of .... floats on the surface of water because the individual cells have gas vesicles.
iv) Under partially .... conditions, the cells of *Chlamydomonas* divide and get enclosed in a mucilagenous mass.

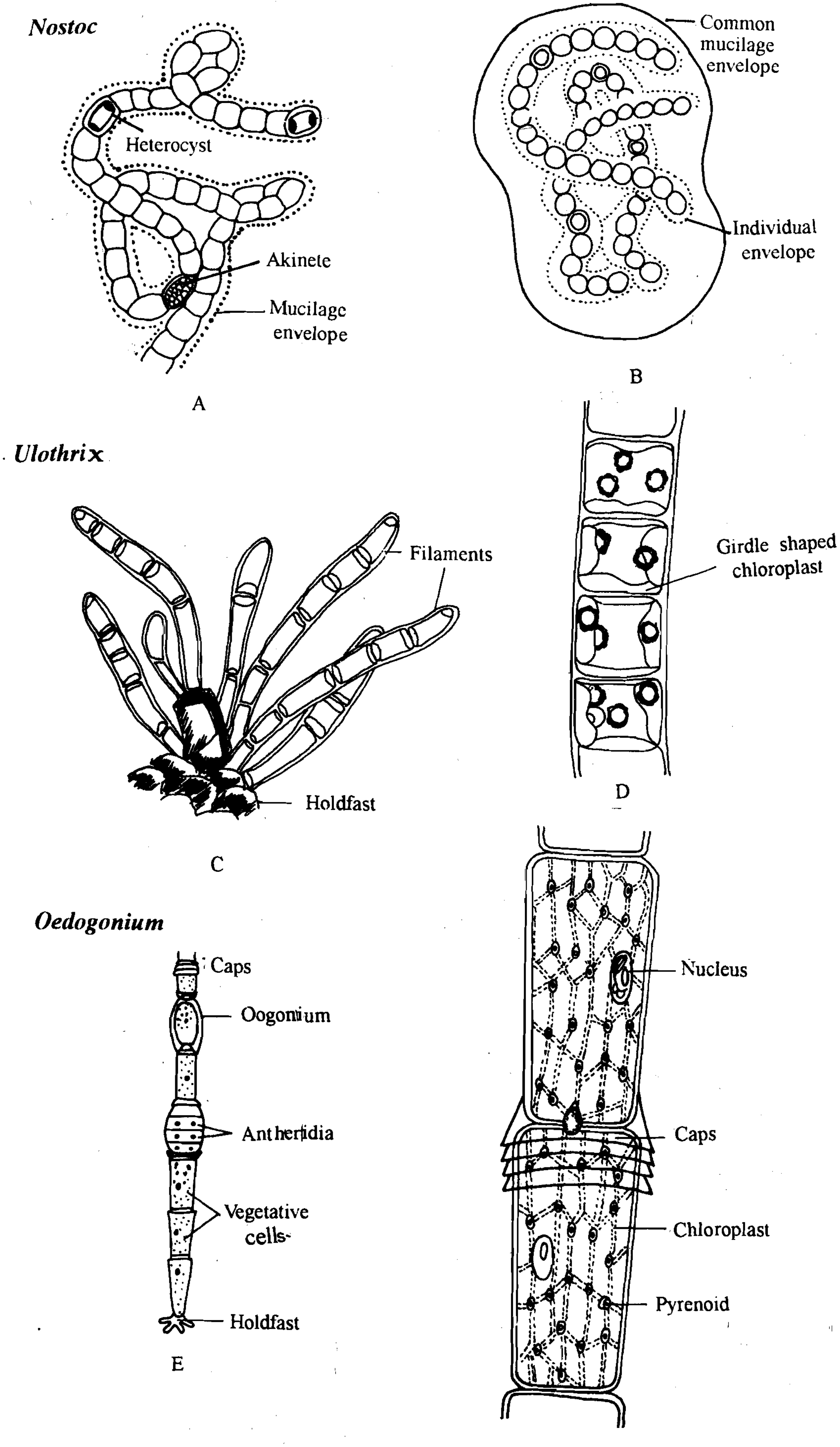

Fig. 3.3 : Filamentous algae ; A) filaments of *Nostoc* showing akinetes and heterocysts, B) an aggregate of *Nostoc* filaments forming a ball, C) germlings of *Ulothrix*, D) cell structure of *Ulothrix* showing gridle shaped chloroplasts, E) filament of *Oedogonium* showing vegetative and reproductive cells. F) part of filament of *Oedogonium* showing cell structure and cap cell with four caps.

3.2.4 Heterotrichous Forms

When some cells of a filament divide vertically it results in a branch. Many filamentous forms show extensive branching of the main filament giving it a bushy appearance.

In some algae the branches at the base remain horizontal, attached to the substratum known as prostrate system from which erect system of vertical branched filaments arise. This type of body is known as heterotrichous habit. Heterotrichous habit is the most highly developed filamentous construction in algae.

Draparnaldiopsis

It is a heterotrichous alga which shows greater differentiation in plant body. The prostrate system is very much reduced. The main axis contains long internodal cells alternating with short nodal cells (Fig. 3.4). The short nodal cells bear a bunch of short branches. Some of the side branches may develop into long colourless hairs or setae. The main axis produces at the base long multicellular colourless rhizoids in large number to form a kind of cortex. Their main function is to attach the alga to the substratum.

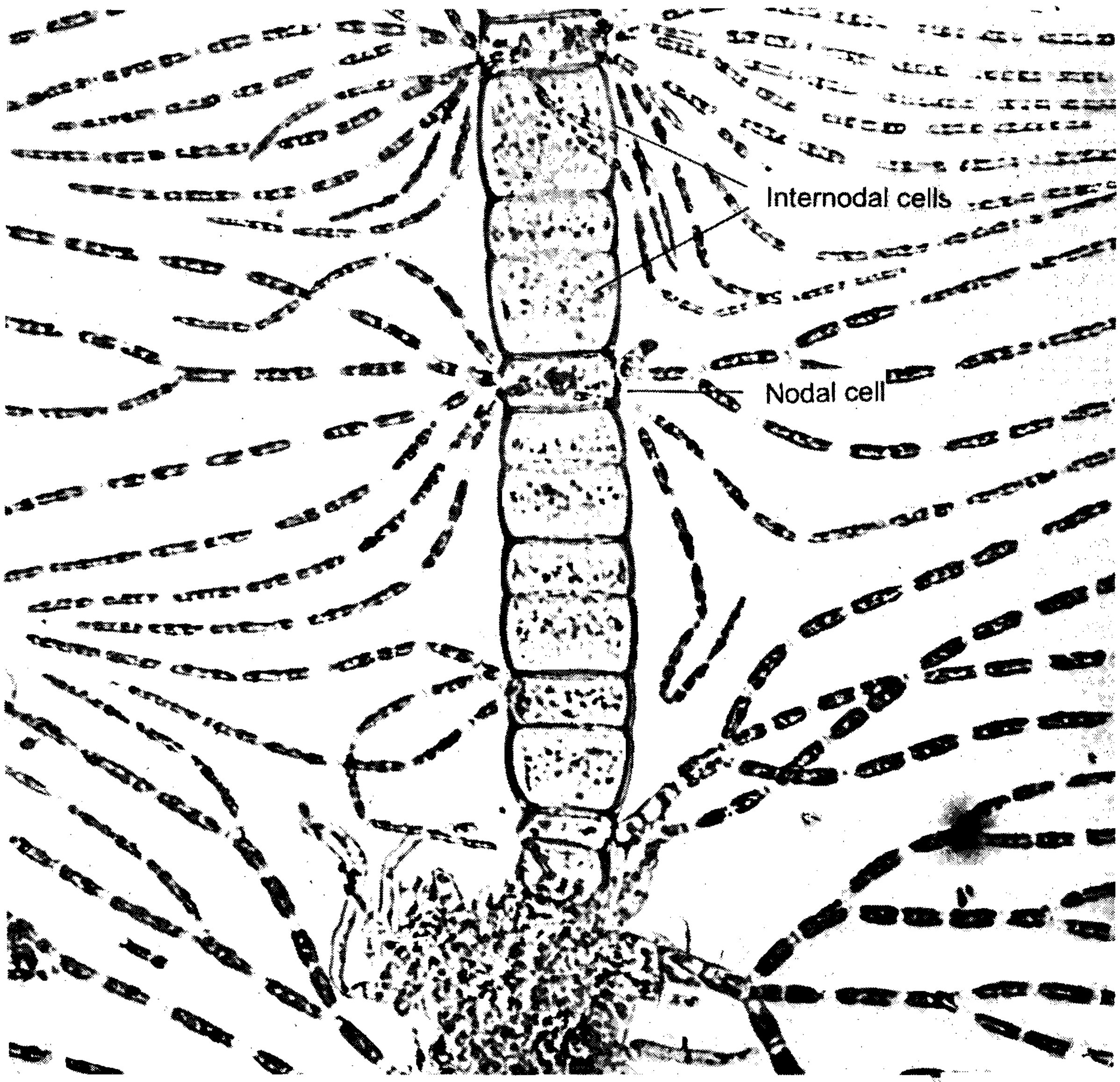

Fig. 3.4 : *Draparnaldiopsis indica* (photograph by late Prof. Y.B.K. Chowdary).

Coleochaete

Coleochaete is an aquatic alga growing on the surface of water plants (Fig. 3.5 A). *C.pulvinata* is heterotrichous. The erect system is in the form of branched filaments. In *C.scutata* the erect system is absent and the prostrate system is made of short repeatedly branched filaments that form a compact disc (Fig. 3.5 B). In both the forms some cells produce hair like bristles, known as setae from their upper surface.

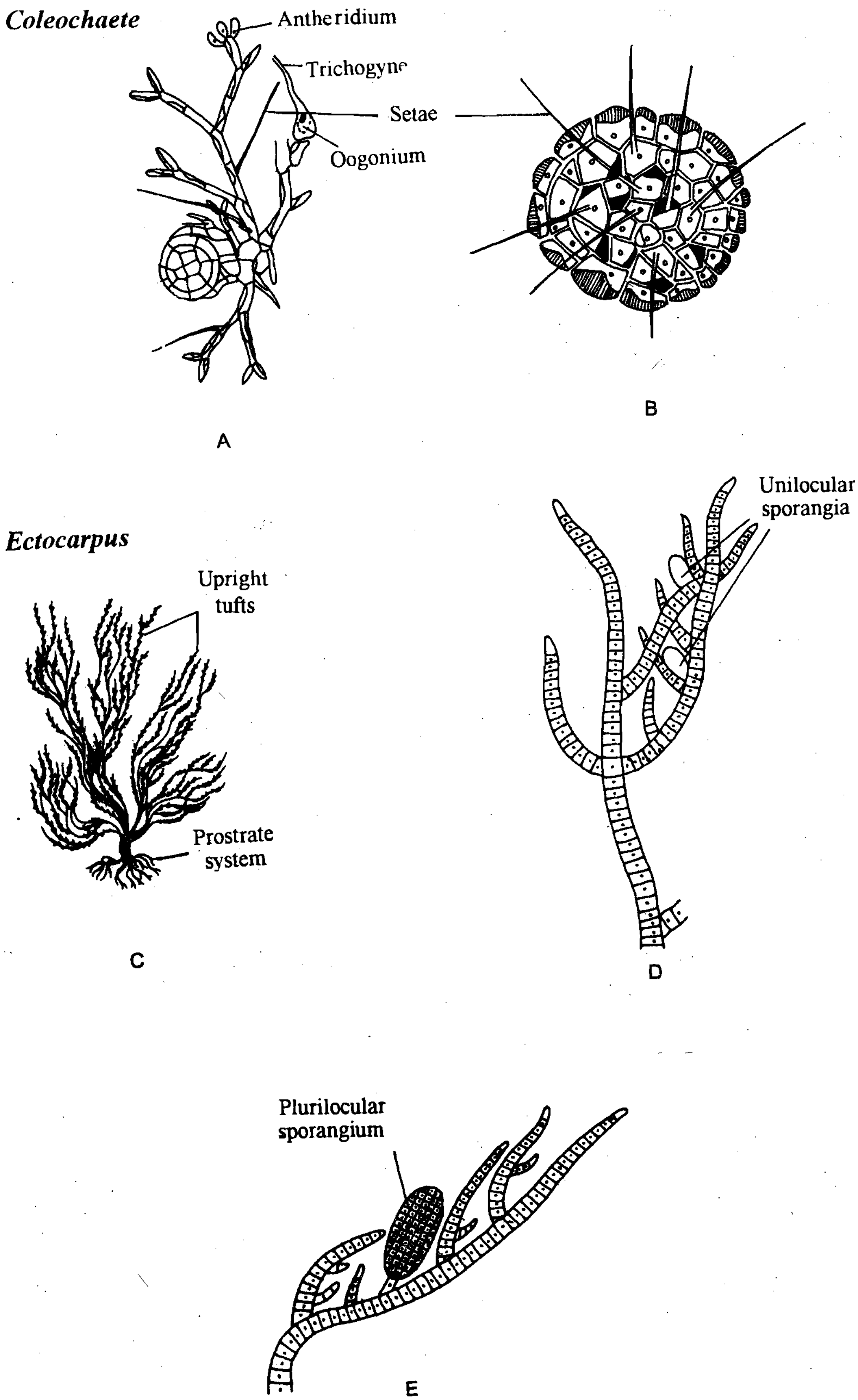

Fig. 3.5: Heterotrichous algae; A and B) *Coleochaete*, C) *Ectocarpus* showing habit, D and E) thalli with unilocular and plurilocular sporangia or gametangia.

Ectocarpus

It is another heterotrichous alga (Fig. 3.5 C).The prostrate system which attaches the alga to the substratum is made of branched filaments. The erect system is in the form of uniseriate (single row of cells) branched filaments forming loose tufts of 1 mm to 10 mm or more.The asexual thallus may be with unilocular or plurilocular sporangia (Fig. 3.5 D and E).

The branches arise just below the cross walls of the cells of the main filament. Most of these branches terminate in elongated hairs.

3.2.5 Thalloid Forms

When the cells of a filament divide in more than one plane, that is not only cross-wise but also lengthwise it results in a sheet of cells. The thallus may be one cell or many cells in thickness.

Ulva

Ulva is a very common alga found on rocky coasts of sea (Fig. 3.6 A). The thallus is attached to the substrate such as rocks by rhizoids at the base. When a sheet of the thallus is cut, one can observe two layers of cells, pressed to each other. Together they form a single sheet (Fig. 3.6 B).

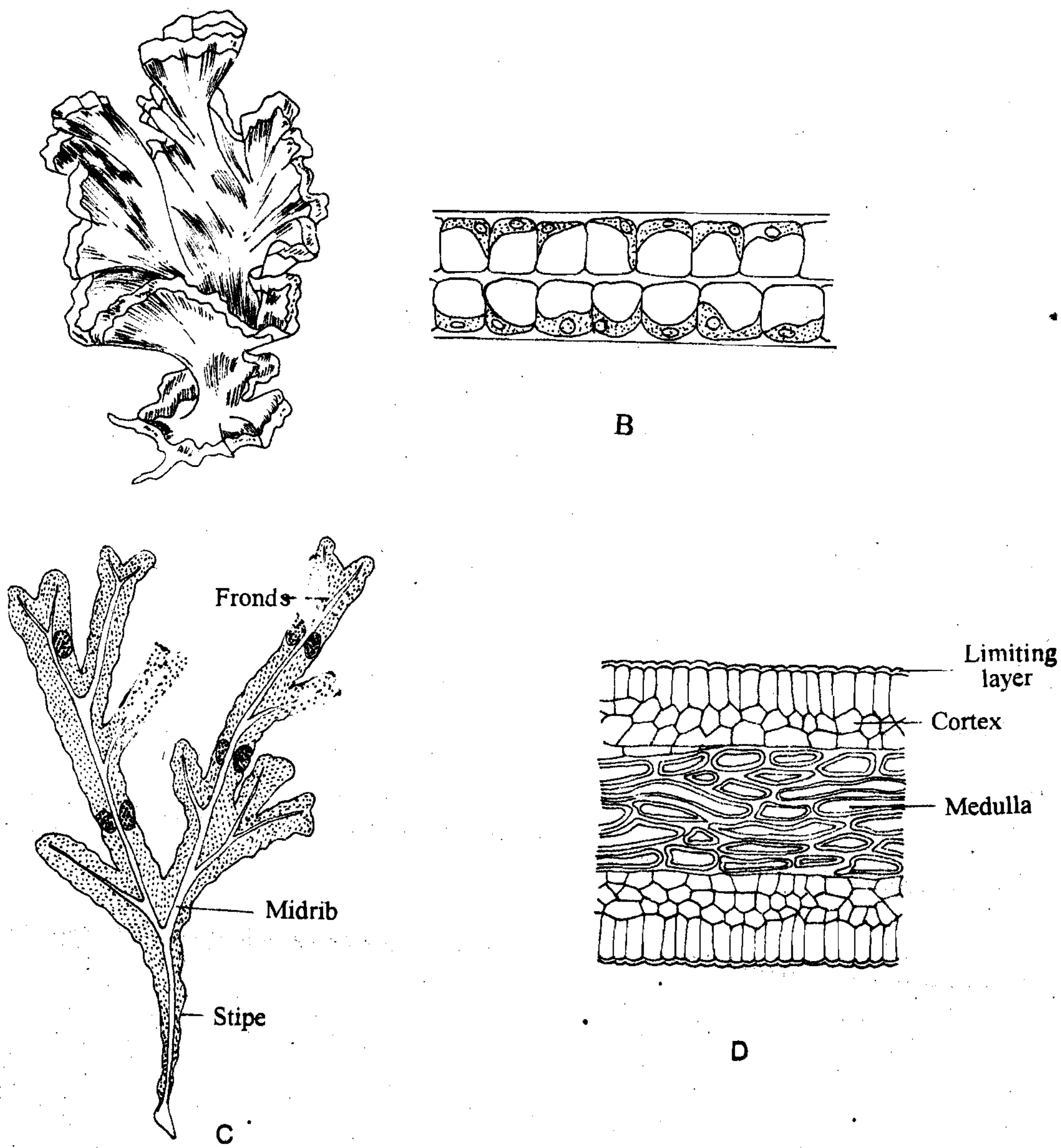

Fig. 3.6: ***Ulva lactuca*; A) habit of growth, B) transection, C) *Fucus vesiculosus* - morphology of the thallus, D) transection through a portion of thallus.**

Frond - the term generally is used for large well divided leaf of fern. The large blade-like thallus of algae is also called frond.

Chromatophore - are plastid containing Chl *a* and other pigments but lack Chl *b*. Plastids containing both Chl *a* and Chl *b* are called chloroplasts.

Dichotomous branching- branching pattern in which the two arms of the branch are more or less equal in length.

Fucus

Fucus is a brown algal seaweed common on the rocky coasts of sea in temperate countries (Fig. 3.6 C). The body of *Fucus* is large about half a metre or so in length. It has a basal discoid holdfast, a short stipe and long flat and dichotomously branched fronds or blades. At the tip of the blade are found air bladders which make the plant float in water.

Fucus is multicellular and has a complex internal structure showing three regions (Fig. 3.6 D). The outer layer is epidermis, the central cortex and the inner medulla. The growth of the thallus is due to the division of apical cell situated in a hollow depression at the tip of a branch. The epidermis and the other layers of cortex contain **chromatophores** which take part in photosynthesis. Cortical region stores food materials and the medullary cells take part in the transport of food to different regions of the fronds.

3.2.6 Polysiphonoid Forms

This form of algae has more complex than the earlier described forms. It is found in the red alga *Polysiphonia* (Fig. 3.7) which is marine in habitat.

Polysiphonia

The algae shows in general heterotrichous habit. The prostrate system is in the form of an elongated rhizoid which attaches the algae to the substratum. The erect system is highly branched. The branches are of two kinds, some are long and some short and hair-like. The main filament grows by the division of a single apical cell. The mature plant body is made up of central row of cells - central siphon, surrounded by vertical rows of cells, 4 to 24 - pericentral siphons.

All the pericentral cells are connected with the cells of central siphon and are also connected with each other.

When the cytoplasm of one cell is connected to the cytoplasm of the neighbouring cell through a pit in their wall, it is known as **pit connection**. In *Polysiphonia* although all the cells are separate, their cytoplasm is connected by means of pit connections.

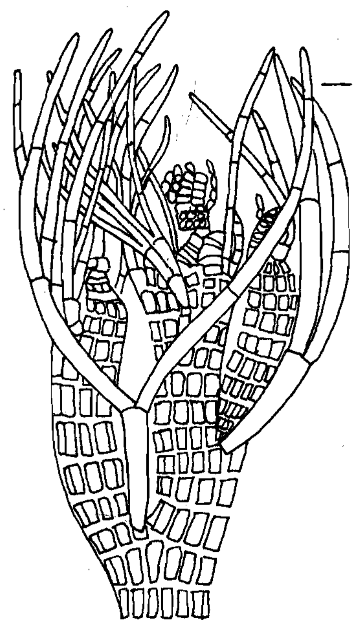

Fig. 3.7: ***Polysiphonia*** **; habit showing multicellular construction of several interconnected rows of siphons of cells.**

New branches may develop from the cells of central siphon or from the pericentral cells. The **trichoblasts** which are simple or branched hair-like lateral branches arise from the pericentral cells.

SAQ 3.2

a) In the following statements fill in the blank spaces with appropriate words.

i) In heterotrichous habit the erect filaments of alga arise from the ....
....

ii) The three layers of *Fucus* thallus are outer epidermis central ....
and inner ....

iii) When algal cells divide vertically as well as .... , a sheet of cells is formed.

iv) In the thallus of .... two layers of cells are pressed to each other forming a single sheet.

v) The fronds of *Fucus* can float because .... are present in their tips.

b) Which of the following characteristics features are special to *Draparnaldiopsis*?

i) Presence of nodal and internodal cells
ii) Reduced prostrate system
iii) Absence of erect system
iv) Sheet like thallus
v) Multicellular colourless rhizoids

c) Which of the following alga is thalloid in morphology?

i) *Fucus*
ii) *Ectocarpus*
iii) *Coleochaete*
iv) *Oedogonium*

d) Indicate whether the following statements are true or false. Write **T** for true and **F** for false in the given boxes.

i) In *Polysiphonia* all the peripheral cells are connected with central siphon. ☐

ii) In *Fucus* the food material is stored in inner cells of the medulla. ☐

iii) Uniseriate filaments are characteristics of *Ectocarpus*. ☐

iv) *Coleochaete* is a terrestrial algae. ☐

3.3 STRUCTURE OF ALGAL CELL

In Unit 1 and 2 you have learnt the general features of algae and their position among various other groups of organisms. Alage show two distinct basic types of cell structure, hence they can be divided into two groups - Prokaryotes and Eukaryotes. Prokaryotes include the so called blue-green algae classed earlier as *Cyanophyceae* or *Myxophyceae*, but now designated as Cyanobacteria because their cells are prokaryote type. Eukaryotic algae are quite diverse in cell structure and morphology, which is taken into account for classification. In recent years, use of electron microscopy has brought much new information regarding the ultrastructure of cellular components of algae. The chemical composition and functions are determind by breaking the cell and isolating each of its organelles separately. Such studies reveal that eukaryotic algae show many features that are similar to higher plant groups.

In the following account you will study the basic features of cell of both prokaryotic and eukaryotic algae and various cellular organelles present in them.

3.3.1 Prokaryotic Algal Cell

You have learnt that cyanobacteria closely resemble bacteria in their ultrastructure (see Unit 1, Section 1.5, Page 10). However, you must note that cyanobacteria are not flagellated. The specific features of their cellular components shown in Fig. 3.8 A are describes below.

Cell Wall and Cell Sheath

The cells of cyanobacteria are enveloped by a gelatinous sheath and also have a distinct cell wall outside the plasma membrane. This can be removed by digesting it with enzyme–lysozyme. Its chemical analysis shows that it is made of mucopolysaccharide (peptidoglycan) like that of bacterial cell wall. It has a complex structure, made of a polymer of N- acetylmuramic acid and N-acetylglucosamine, that are cross linked by peptides and other compounds. The wall in fact, shows at least four layers and the outermost may contain lipo-polysaccharides and proteins.

Plankton – free-floating or motile, mostly microscopic, aquatic organisms. Photosynthetic plankton are called as phytoplanktons. A large number of unicellular algae float in open sea, ocean and lakes. They dominate open sea or lakes and provide food as primary producers to aquatic organisms and thus sustain life in water. It is estimated that 1/3 of oxygen of atmosphere is released by these organisms.

In many cyanobacteria the cell wall is enveloped by gelatinous mucilage. It may be thin and colourless as in planktonic forms. In subaerial forms the sheath is thick, firm and coloured yellow or orange brown and is multilayered. Some aquatic forms like *Scytonema, Petalonema* may also have multilayered and coloured sheath.

Photosynthetic Lamellae

Cyanobacteria have no chloroplasts but only pigmented membranes which occupy the peripheral region of the cells called **chromatoplasm**. In this area photosynthetic lamellae or thylakoids are present. The lamellae are folded double membranes in which the photosynthetic pigments–chlorophyll *a*, and several types of carotenoid are embedded. On the surface of the thylakoids are found rows of granules called **phycobilisomes**, that contain phycocyanin, allophycocyanin and sometimes also phycoerythrin, characteristic of cyanobacteria. It has been found that the thylakoids also contain enzymes required for respiration.

Phycobilisomes – a protein and phycobilin pigment complex located on the thylakoid membrane in blue-green and red algae.

In *Gloeobacter* thylakoids are absent. The photosynthetic pigments are associated with its cell membrane.

Granular Inclusions of Cytoplasm

The ultrastructure of cyanobacterial cytoplasm shows several types of granules. Between the thylakoids glycogen is found in the form of granules of different sizes. Protein granules called cyanophycin granules made up of polymer of two aminoacids aspartic acid and arginine are for storage of nitrogen. Another type of granule common in algae growing in waters rich in phosphate, is polyphosphate, a storage form of phosphate. Some algae also contain granules of polybetahydroxybutyrate as big crystals.

Another unique granules found in cyanobacteria are polyhedral crystalline bodies known as **carboxysomes**. They are made up of ribulose-biphosphate carboxylase (Rubisco) enzyme which as you know is required in the photosynthetic fixation of carbon dioxide.

Like all bacterial cells cyanobacteria also contain ribosomes needed for protein synthesis. They are dispersed in the cytoplasm. All prokaryotic ribosomes are of 70s type unlike the 80s type found in eukaryotes.

Gas Vesicles

Recently introns have been identified in the chromosomes of cyanobacteria.

Many planktonic cyanobacteria like *Microcystis* contain in their cells elongated, cylindrical vesicles singly or in bundles known as gas vesicles. They make the cells float on the surface of water. When, the gas escapes they collapse, become flat, and the cells sink to the bottom. The wall of the vesicle is made of single layer of protein molecules and is permeable to gases but not to water.

Nucleoplasm

The central portion of the cell usually referred as nucleoplasm contains the genetic material, DNA, equivalent to the nucleus of eukaryotes. It appears as a net work of fibrils, and like that of bacteria it is a long thread in the shape of a ring, generally referred to as circular chromosome. There may be multiple copies of it in a cell. The histone proteins found in eukaryotic cells are not associated with the DNA of cyanobacteria.

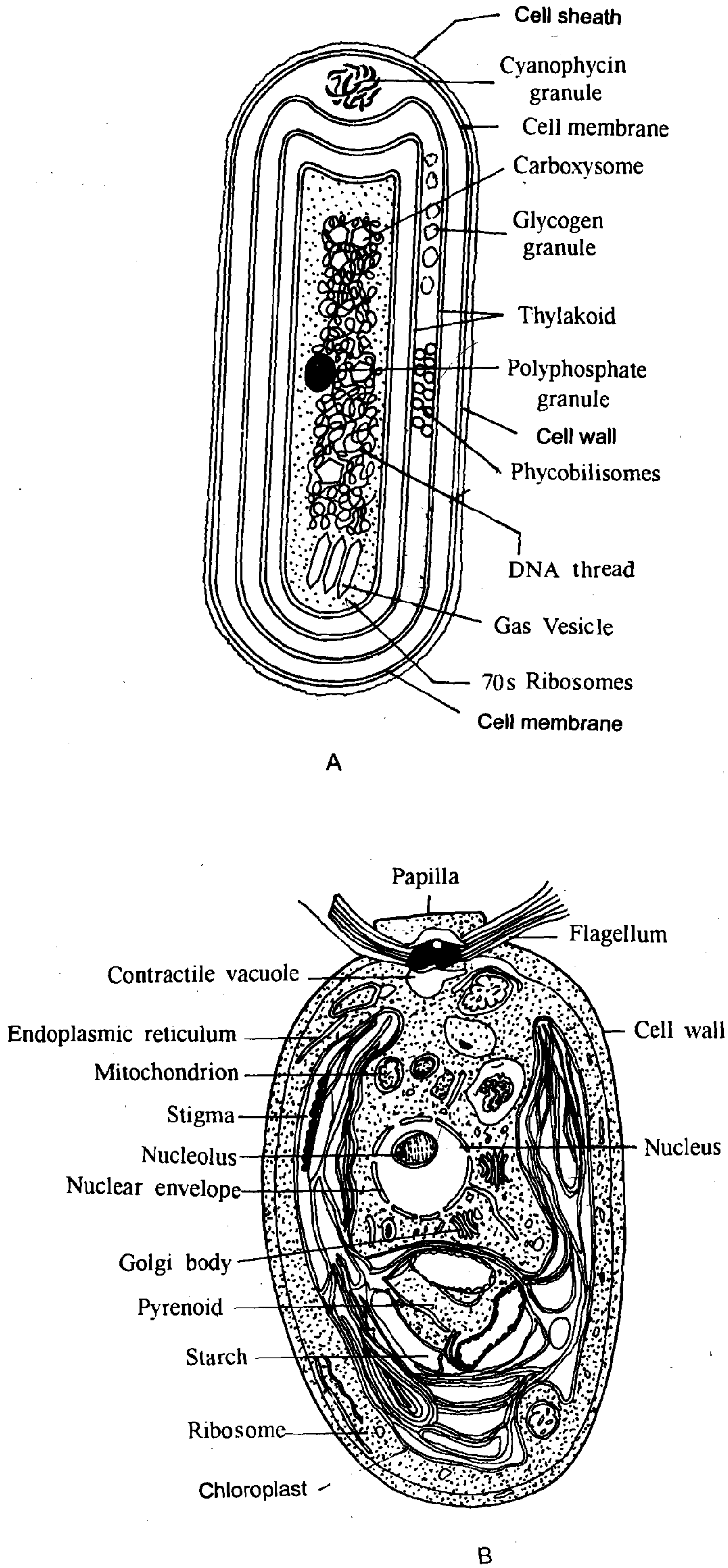

Fig. 3.8: Line drawing of the ultrastructure of A) a prokaryotic and B) eukaryotic cell.

Plasmids

Like in bacteria, DNA is also found in the cells of cyanobacteria as a small covalently linked circular molecule known as plasmid which has genes that make the organism resistant to antibiotics. Plasmids are not a permanent feature of cells, they may be lost and regained further, they can also multiply inside the host cells.

Specialised Cells of Cyanobacteria

As you have learnt that besides the common vegetative cells, filamentous cyanobacteria show two other types of structures, heterocysts and akinetes. These are breifly described below.

Heterocysts

These are thick walled cells found in filamentous cyanobacteria either in between the vegetative cells (intercalary) or at the ends (terminal) of a filament (Fig. 3.3). Most important function of heterocysts is fixation of atmospheric nitrogen as they contain the necessary enzyme system, nitrogenase.

Formation of Heterocyst

Vegetative cells differentiate into heterocysts when dissolved mitrogen compounds are low in surroundings.

Heterocystous cyanobacteria
Anabaena
Nostoc
Calothrix
Gloeotrichia
Scytonema
Tolypothrix
Stigonema

Structure of Heterocyst

Look at the structure of heterocyst given in figure 3.9. Unlike a vegetative cell, heterocyst has a thick wall with three layers which are structurally different. The inner most layer contains certain glycolipids which make the heterocyst impermeable to oxygen, otherwise O_2 inhibits the action of nitrogenase and prevents nitrogen fixation.

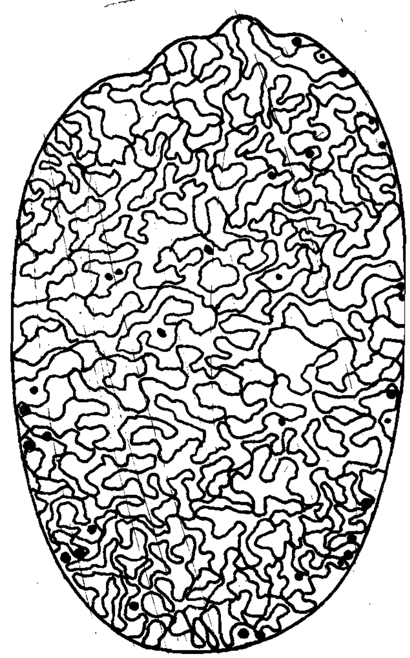

Fig. 3.9 : Heterocyst of *Anabaena* (line drawing of electronmicrograph, adapted from G.B. Chapman).

The heterocysts are connected with the adjacent cells through fine protoplasmic strands, plasmodesmata at the poles and also with large shiny granules - polar granules made up of cyanophycin.

The heterocysts also contain many photosynthetic lamellae, but these are less dense than in the vegetative cells. The lamellae contain chlorophyll *a* and carotenoids. However, phycocyanin is lost when a vegetative cell changes into a heterocyst. Therefore, mature heterocysts cannot fix carbon dioxide, so O_2 is not liberated in light. Polyphosphate and glycogen granules, carboxysomes and gas vesicles are entirely absent in the cytoplasm of the heterocyst.

Akinetes

These are thick walled cells also known as spores, meant for perennation. All the vegetative cells of a filament or only a few cells like those adjacent to a heterocyst may develop into spores.

Akinetes have thick walls and they are generally light brown, deep brown or black in colour. The contents of the cell are highly granular with glycogen but polyphosphate is lacking.

Akinetes can withstand prolonged desiccation and under suitable conditions germinate giving rise to new filaments.

SAQ 3.3

a) List the types of inclusions present in the cytoplasm of cyanobacteria and describe them briefly.

....

....

....

....

....

b) In the following statements choose the alternative correct word given in parentheses.

i) The heterocysts of cyanobacteria fix (CO_2/N_2).

ii) Cyanobacteria contain (circular DNA/DNA filaments) in the nucleoplasm.

iii) A gelatinous sheath outside the cell wall is (present/absent) in cyanobacteria.

iv) The ribosomes in blue-green algae are (70s/80s) type.

c) In the following statements fill in the blank spaces with appropriate words.

i) The cell wall of cyanobacteria is made up of .... like that of bacteria.

ii) The pigments containing granules present on the surface of photosynthetic lamellae are called ....

iii) The innermost layer of heterocyst is impermeable to oxygen as it contains certain ....

iv) In cyanobacteria the region of cytoplasm where pigmented photosynthetic lamellae are present is called ....

3.3.2 Eukaryotic Algal Cell

Eukaryotic algae comprise several divisions each having its own cell structure and other specific characters. However, the basic features as shown in Fig. 3.8 common to all groups are - presence of membrane bound nucleus, chromosomes, plastids, mitochondria, golgi bodies, and 80s type of ribosomes. Besides cell division by mitosis, many groups show sexual method of reproduction involving fusion of gametes and meiosis (reduction division). The following account gives important features of algal cells of various groups.

Coccolithophorides - Those organisms that possess coccoliths. Coccoliths are calcified scales covering the cells of unicellular, primarily marine organisms closely related to golden-brown algae.

Cell Wall

Algal cell wall is mainly made up of cellulose. Other additional compounds may be added to it during development. In brown algae hemicelluloses, alginic acid, fucin, fucoidin are also present. In diatoms the wall material is mainly silica.

The cells of Division Chrysophyta have no proper cell wall. They are covered by scales of silica (e.g. *Mallomonas*), **In coccolithophorides** elaborate scales contain calcium carbonate (calcite). The cell wall of red algae contains polysulphate esters of carbohydrates in addition to cellulose and pectin.

Calcium carbonate deposits are found over the surface of algae belonging to different groups of many marine seaweed, known as **calcarious algae**, for example, *Neomeris, Udotia* (green algae). *Corallina* (red alga), *Padina* (brown alga) and fresh water alga *Chara.*

Coralline algae are a group of red algae that secrete calcium carbonate around their cells and form stiff thalli. Coralline algae are important builders of coral reefs in tropical water, contrary to the believe that coral animals alone make up coral reefs.

Plastids

All photosynthetic algae show plastids - chloroplasts whose basic structure is similar to the chloroplasts of higher plants. The shape and location of chloroplasts in algae varies from species to species. When located at the centre of a cell, they are called axile, and when located near the periphery they are called parietal. Their number also varies from one to many, but fixed for a species. Under the microscope, the following shapes of chloroplasts can be easily recognised: cup like (*Chlamydomonas*), girdle like (*Ulothrix*), spiral band (*Spirogyra*) and stellate (star-shaped-*Zygnema*) These are shown in the Fig.3.10 given below.

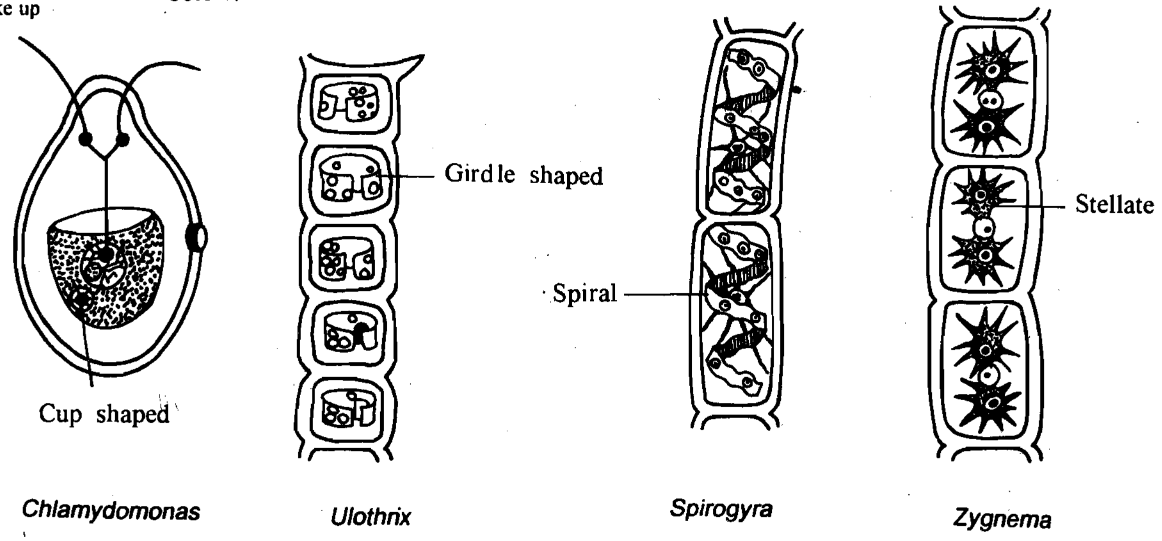

Fig. 3.10 : Various shapes of chloroplasts of algae.

Ultrastructure

The ultrastructure of algal chloroplast is similar to that of higher plants. It is enveloped by a double membrane. A number of thylakoid lamellae are spread into the matrix - the stroma. The lamellae are made of lipoprotein complexes interspersed with molecules of chlorophylls and carotenoids. When phycobilins are present as in the case of red algae, they are present in the form of granules known as phycobilisomes, attached to the membrane surface in linear rows (Fig. 3.11). The stroma of chloroplast contains several enzymes connected with photosynthetic carbon fixation.

The arrangement of thylakoids in chloroplasts varies in different algae. They may be very closely stacked to form grana (sing. granum), as in green, brown algae and euglenophytes. In red algae they are widely separated from each other (see Fig. 2.6, Unit 2).

One important feature of chloroplast is the presence of circular or ring like DNA. Plastids of *Euglena, Acetabularia, Chlamydomonas*, diatoms,. members of Chrysophyceae, Xanthophyceae, Phaeophyceae all have been shown to contain circular DNA. Chloroplasts give rise to new plastids by simple division.

Chloroplasts contain ribosomes of 70s type not 80s type which are present in the cytoplasm. They also contain the complete machinery for protein synthesis. Ribosomes of 70s type are characteristic of prokaryotes like cyanobacteria. Because of this fact it is believed that chloroplasts of eukaryotes were indeed cyanobacteria which became endosymbiontic during the course of evolution.

Pyrenoids

Plastids of many green algae have prominent proteinaceous granules called pyrenoids around which starch is deposited. In many cases one can see photosynthetic thylakoids traversing the matrix of the pyrenoid or at least closely associated with it. When the chloroplasts divide, pyrenoids also divide to give rise to new pyrenoids.

Fig. 3.11 : Chloroplast of red alga *Porphyridium*.

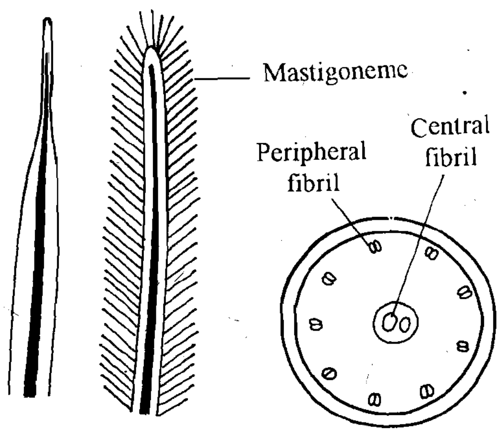

Fig. 3.12 : Pyrenoid of *Chlamydomonas* (line drawing of electron micrograph)

Nucleus

Many algae contain only one nucleus per cell. However, green algae like *Cladophora, Caulerpa* and *Vaucheria* (Xanthophyceae) contain more than one nucleus (multinucleate).

Like the eukaryotic plant and animal nuclei, algal nucleus is enveloped by a distinct double membrane punctured by pores. During the interphase (not dividing, resting nucleus) uncoiled, fine chromatin threads are visible in the nucleus. As you know chromatin is complex of DNA, histone and non-histone proteins. During the cell division, it condenses to form the chromosomes.

Many algal nuclei contain globular **nucleoli**, one or more in number, sometimes attached to the specific region of a chromosome nucleolus organiser. Nucleolus may degenerate and disappear during the cell division but reappear during the interphase. It is now known that the nucleolus is involved in the synthesis of cytoplasmic ribosomes.

The structure of nucleus in the algal groups Euglenophyta and Dinophyta is quite unique and is different from all other eukaryotes. During the interphase, the nucleus inside its membrane shows not uncoiled chromatin fibres but highly condensed chromosomes. Further, unlike in other organisms, they do not contain histone proteins.

The number of chromosomes present in each genus or species of an alga has no relation with its systematic position. The smallest number recorded is n=2 and the highest may be 600 or more. The size of individual chromosomes is also variable. Large chromosomes are found in *Oedogonium, Cladophora* and *Chara.*

Other Organelles of the Eukaryotic cells

Mitochondria

The number of mitochondria in algal cells varies from one as in some flagellates to many in other algae. Their size and shape also varies widely. The ultrastructure shows a double membrane, the inner one folded inwardly forming cristae protruding into the lumen. New mitochondria arise by the division of the mitochondria present in the parent cell, much like plastids. It is believed that mitochondria originated from endosymbiotic bacteria adapted to intracellular existence inside the ancestral host eukaryotic cells. Like the chloroplasts, they also contain circular DNA, RNA, 70s ribosomes and machinery for protein synthesis.

Golgi bodies

These are also known as dictyosomes and are widely found in algal cells. They are made up of 2-20 lamellae or membranes arranged in stacks. They play an important role in the formation of cell wall material as in the case of red algae. In many algae they are connected with secretory function.

Flagella

Flagella are means of locomotion for the motile cells of algae, found in all divisions except Rhodophyta. The alga may itself be motile (as in unicellular and colonial algae) or at some stage in its life cycle produce reproductive motile cells - zoospores and gametes.

The flagella of algae differ in their number, length, appendages and place of insertion on the cell. The surface of the flagellum may be smooth (**acronematic**) may have one or more lateral hairs (**pleuronematic**). When two flagella are found they may be equal in length (**isokonton**) or one flagellum shorter than the other (**heterokonton**).

Ultrastructure of a flagellum shows that it is made up of microtubules, two at the centre surrounded by nine pairs or doublets in a ring, 9+2, all enclosed by a membrane.

Flagellar surface is generally smooth or covered with prominent hairs, **mastigonemes**. Some green algae and the members of Phaeophyta, Chrysophyta, Dinophyta show two flagella, one with smooth surface and the other with fine hairs.

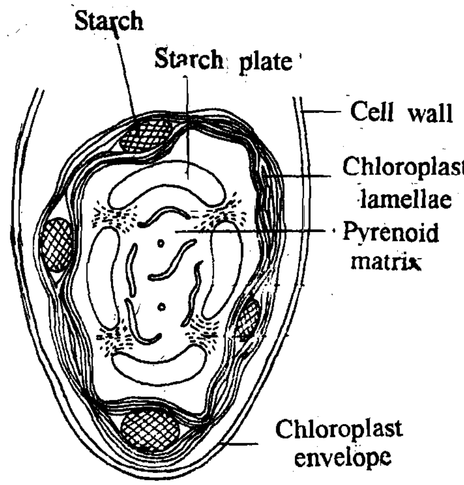

Fig. 3.13 : Fine structure of algal flagella.

Eyespots

Motile cells of algae belonging to Chlorophyta, Phaeophyta, Euglenophyta, Chrysophyta contain orange - red coloured eyespots. In some algae eyespot may form a part of the chloroplast and it is located at the base of the flagellum, but in *Euglena* it is quite distinct and away from the chloroplasts.

The common type of eyespot as found in green algae e.g. *Chlamydomonas* appears to have a row of orange coloured lipid granules as a part of thylakoids at the anterior portion of the chloroplast. The granules are found to contain carotenoids, β-carotene being most prominent.

SAQ 3.4

a) Match the algae given in column 1 with the shapes of chloroplast given in column 2.

	Column 1		Column 2
a)	*Chlamydomonas*	i)	Stellate
b)	*Ulothrix*	ii)	Spiral band
c)	*Zygnema*	iii)	Cup shaped
d)	*Spirogyra*	iv)	Girdle shaped

b) Indicate whether the following statements are true or false. Write T for true and F for false in the given boxes.

i) The thylakoids in red algae are closely stacked together to form grana. ☐

ii) Unlike higher plants the chloroplast and mitochondria of algae lack circular DNA and ribosomes of 70s type. ☐

iii) Pyrenoids are present in the chloroplasts of green algae. ☐

iv) All algal cells are uninucleate.

v) 70s ribosomes are present in golgi bodies. ☐

vi) Flagella are present in all divisions of algae except Rhodophyta. ☐

3.4 SUMMARY

In this unit you have learnt that:

- Algae are diverse group of organisms ranging from microscopic unicellular to giant thalloid forms anchored to the rocks in the sea. Morphologically they can be distinguished as unicellular, colonial, filamentous, heterotrichous, thalloid and polysiphonoid forms.

- The unicellular algae are simplest in morphology. Some advancement is observed in colonial forms. The cells of a colony may communicate through plasmodesmata. There is division of labour between cells, some remain vegetative while others take part in reproduction.

- Filamentous forms have evolved as a result of repeated divisions of a single cell in the same plane. Some cells of a filament may show differentiation into specialised cells like holdfast, cap cells, hairs, hetrocysts etc.

- Some algae have a prostrate system attached to the substratum and an erect system of vertical branches This is called heterotrichous habit.

- Thalloid forms are sheet like with one or two cells in thickness. Polysiphonoid forms are more complex. They possess rhizoids and branched erect system. Mature thallus consists of central row of cells-central siphon surrounded by pericentral siphon. Complex multicellular thallus with external and internal differentiation represents most advanced state of thallus development in algae.

- The cells of cyanobacteria are prokaryotic type. Like bacteria, their cell wall is made up of mucopolysaccharides. They lack membrane bound nucleus, chloroplasts and mitochondria. Like bacteria, they contain only naked circular DNA, and 70s type of ribosomes. Their thylakoid membranes contain photosynthetic pigments and are the site of photosynthesis. The cells show several types of granules.

- The eukaryotic algal cells show a distinct cell wall, a well organised nucleus with nuclear membrane and chromosomes. Their chloroplasts are distinct organelles that contain stacked thylakoids with photosynthetic pigments. and are sites of photosynthesis. Mitochondria which are also made of membranes are the site of respiration. Both the chloroplasts and mitochondria have their own circular DNA, RNA and ribosomes of 70s type unlike the cytoplasmic ribosomes which are 80s type. The algal cells show various organelles like pyrenoids, golgi bodies, vacuoles and eyespots. Motile cells of algae have flagella made up of microtubules. The cell wall is made of cellulose and some marine algae may contain complex polysaccharides, silica or calcium carbonate.

3.5 TERMINAL QUESTIONS

1. Illustrate with an example the most highly developed filamentous construction in algae.

....

....

....

....

....

2. Draw and label the morphological structure of various types of algae you have studies in this unit.

3. Match the algae given in column 1 with the morphological forms given in column 2.

Column 1	Column 2
a) *Ulva*	i) Heterotrichous
b) *Ulothrix*	ii) Colonial
c) *Microcystis*	iii) Thalloid
d) *Ectocarpus*	iv) Filamentous

4. Choose the correct answer in the following:

a) Thallus is filamentous and highly branched in
   i) *Ulva*
   ii) *Fucus*
   iii) *Draparnaldiopsis*
   iv) *Anacystis*

b) Multicellular thallus with most advanced plant body is found in
   i) *Nostoc*
   ii) *Ectocarpus*
   iii) *Fucus*
   iv) *Ulothrix*

5. Indicate which of the following statements are true or false. Write **T** for true and **F** for false in the given boxes.

i) A branched filament results when its cells divide vertically. ☐

ii) Setae or colourless hairs are found in *Ulothrix*. ☐

iii) Heterotrichous algae are attached to the substratum by holdfast. ☐

iv) Palmella stage is found in *Volvox*. ☐

v) Filaments of *Oedogonium* are attached to substratum by holdfast. ☐

vi) Algal cells do not form complex organs or tissues. ☐

vii)The cells of algal thallus are more or less independent of each other. ☐

3.6 ANSWERS

Self-assessment Questions

3.1 a) i) F, ii) F, iii) F, iv) T
b) i) 1 ii) 2
c) i) *Chlamydomonas*, ii) plasmodesmata, iii) *Microcystis*, iv) unfavourable

3.2 a) i) prostrate system, ii) cortex, medulla, iii) horizontally, iv) *Ulva*, v) air bladders
b) i), ii) and v)
c) i)
d) i) T, ii) F, iii) T, iv) F

3.3 a) Elaborate the following and draw a diagram to show their location in the cell.
i) Glycogen granules of different sizes
ii) Cyanophycin
iii) Polyphosphate granules
iv) Carboxysomes.
b) i) N_2, ii) circular DNA, iii) present, iv) 70s
c) i) mucopolysaccharides, ii) phycobilisomes, iii) glycolipids , iv) chromatoplasm

3.4 a) a) iii, b) iv, c) i, d) ii
b) i) F, ii) F, iii) T, iv) F, v) F, vi) T

Terminal Questions

1. Ref. to section 3.3.6.
2. See the figures given in the text.
3. a) iii, b) iv, c) ii, d) i.
4. a) iii, b) iii.
5. i) T, ii) F, iii) F, iv) F, v) T, vi) T, vii) T.