PHYCOLOGY

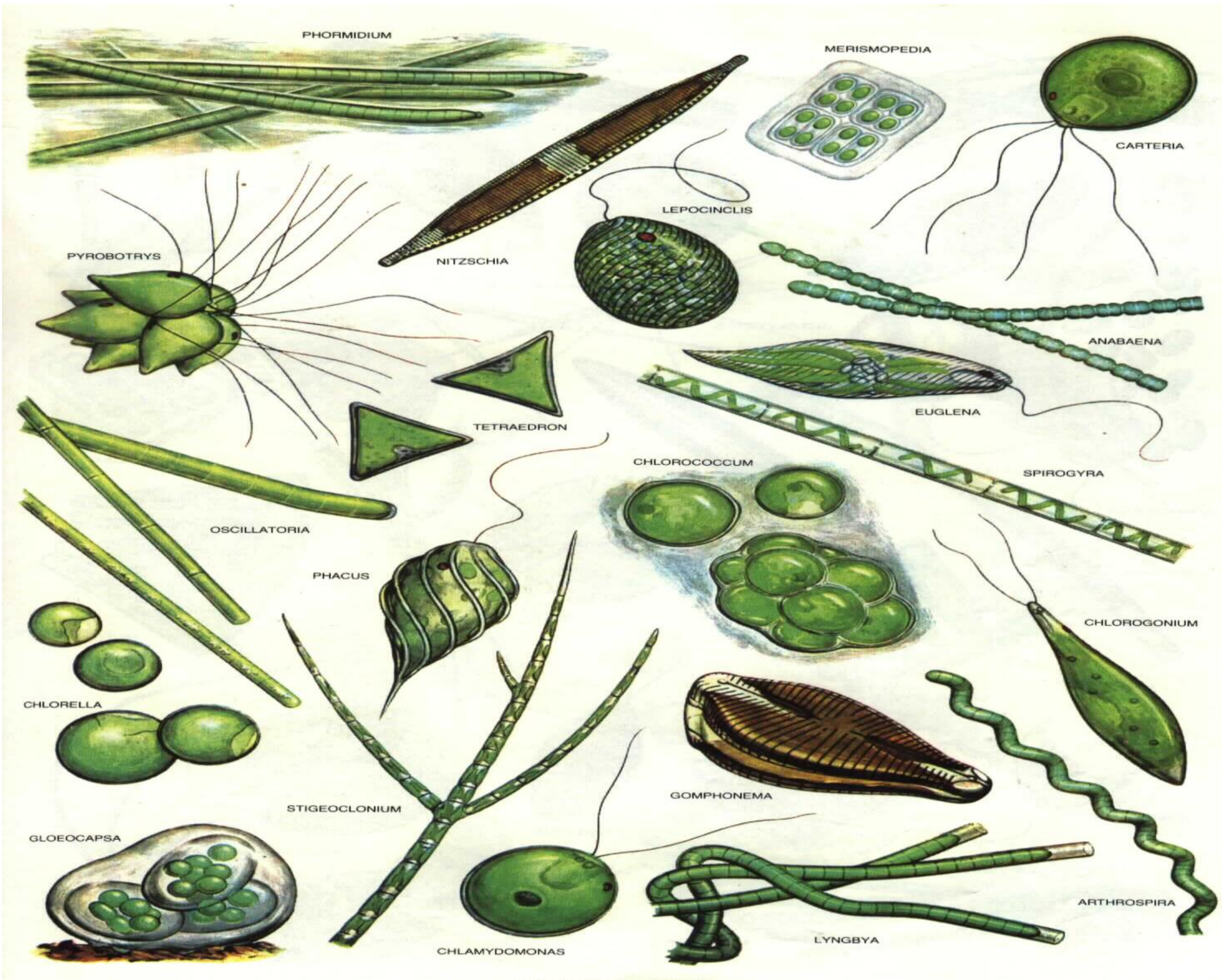

Plate 39. Polluted-water algae.

FOR 2ND Year Microbiology & Chemistry

BY

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INTRODUCTION

Definition of Algae

Algae are a diverse group of simple, plant-like organisms. Like plants, most algae use the energy of sunlight to make their own food, a process called photosynthesis. However, algae lack the roots, leaves, and other structures typical of true plants. Algae are the most important photosynthesizing organisms on earth. They capture more of the sun's energy and produce more oxygen (a byproduct of photosynthesis) than all plants combined. Algae form the foundation of most aquatic food webs, which support an abundance of animals. Algae vary greatly in size and grow in many diverse habitats. Microscopic algae, called phytoplankton, float or swim in lakes and oceans. Phytoplanktons are so small that 1000 individuals could fit on the head of a pin. The largest forms of algae are seaweeds that stretch 100 m (300 ft) from the ocean bottom to the water's surface. Although most algae grow in fresh water or seawater, they also grow on soil, trees, and animals, and even under or inside porous rocks, such as sandstone and limestone. Algae tolerate a wide range of temperatures and can be found growing in hot springs, on snow banks, or deep within polar ice.

The Study of Algae is called ***Phycology*** *(Phycos* = Algae, *logos =* Study of/Discourse of) and its history is quite old. *Phycos* is a Greek word which means seaweed and the references to algae are available in the early Chinese, Roman and Greek literatures. Roman named it *Fucus,* whereas Chinese called it *Tsao.* The ancient *Hawanians* used algae as food and called them *Limu.* The algae were used as manure on the north coast of France as early as the 12th century.

General characteristics of algae

1. The algae are chlorophyll bearing organisms with a thallus-like plant body.
2. The thallus shows little differentiation of true tissues.
3. Even the complex thalli lack vascular tissue and epidermis with stomata.
4. The sex organs are one-celled, when multicellular, each cell is fertile and there is no jacket

of sterile cells.

5. There is no embryo formation after gametic union.

6. Both the generations when represented in the life cycle are independent. There are no algae with a sporophyte parasitic on the gametophyte plant.

7. Excepting a few all the algae are aquatic.

8. Under favourbale conditions the gametophyte multiplies repeatedly by means of asexual spores called the mitospores.

Occurrence of algae

According to the habitat, the algae may be classified as follows :

1. Aquatic algae 2. Terrestrial algae 3. Algae of unusual habitats.

1. Aquatic algae: Majority of the algal genera are aquatic and found either completely submerged or free floating on the surface of water. Aquatic algae usually occur in ponds, pools, tanks, ditches, streams or in slow running rivers and are called fresh water forms. Marine algae are found in sea and macroscopic large thalli of brown algae are commonly known as "sea weeds". Fresh water algal forms like *Chlamydomonas, Volvox, Hydrodictyon* are found in stagnant waters, whereas *Cladophora, Oedogonium, Ulothrix* and few species of *Vaucheria* occur in slow running water bodies. Most of the members of Phaeophyceae and Rhodophyceae are found in sea either floating on the surface of sea water or attached with rocks or any other substratum. The free floating and free swimming microscopic algal forms together with other similar organisms constitute the *Planktons* of water bodies. Plankton forming algae may either be free floating from very beginning and are never attached (Euplanktons) *e.g., Microsystis, Chlamydomonas, Scenedesmus* and*, Cosmarium* or in the beginning may be attached but later on they get detached and become free floating (Tychoplanktons) *e.g., Zygnema, Oedogonium, Cladophora, Cylindrospermum, Rivularia* etc.

2. Soil algae: Many algal genera are found on or beneath the moist soil surface are called terrestrial algae. The algal forms occurring on the surface of soil *e.g.* few species of *Vaucheria, Botrydium, Fritschiella* and *Oedocladium* are called *Sapophytes* while algal genera having subterranean habit *e.g.,* few species of *Nostoc, Anabaena* and *Euglena* are known as *Cryptophytes.*

3. Algae of unusual habitats: Many algae are found at various interesting places and according to their habitats may be of following types:

1) Halophytic algae. These algae are found in saline water containing high percentage of salts e.g., *Dunaliella,* and *Chlamydomonas chrenbergii*.

2) Lithophytic algae. Usually the members of Cyanophyceae grow on moist rocks, wet and other rocky surfaces. Blue green algae *Rivularia* and *Gloreocapsa* occur on exposed rocks, whereas *Nostoc* is found growing in damp shady habitats. Several marine belonging to Rhodophyceae and Phaeophyceae are lithophytic in habit and grow o submerged rocks or rocky surface *e.g., Ectocarpus, Polysiphonia* etc.

3) *Epiphytic algae.* Such algal forms which grow on the other aquatic plants are called *Epiphytic algae.* Green algae *Chaetonema* has been found growing on *Tetraspora* and *Batrachospermum. Rivularia* are observed to grow on Angiospermic plant.

4) Endophytic algae. Found inside the aquatic plants

- *Anabaena azollae* – **leaf tissue** of aquatic fern **Azolla** [Gymnosperm]
- ***A. cycade*** – **corrolloid roots of Cycas** [Gymnosperm]
- *Nostoc* – **cavities** in the thallus of **anthoceros** [Bryophytes]
- *Chlorochytrium* – **inside** Lemna [Angiosperm]

5) *Epizoic algae.* Many algae grow on the shells of molluscs, turtles and fins of fishe are known was *epizoic algae. Cladophora* is found on snails and shells of bivalves.

6) *Endozoic algae.* Contrary to epizoic algal forms endozoic algae are found inside the aquatic animals *e.g., Zoochlorella* is found insiinside *Hydra viridis* while *Zooxanthe* known to occur inside the fresh water sponges.

7) Aerophytes: Such algal forms as are adapted for aerial mode of life and occur on the trunks, moist walls, flower pots, rocks, and get their water and carbon dioxid requirements completed directly from atmosphere are called Aerophytes. *Trentepohlia* is found the bark of trees in moist and humid climatic conditions while *Phermidium, Scytonema* & *Hapalosiphon* have been observed to grow on bark of trees alongwith Bryophytes.

8) Cryophytes: These algae are found on the mountain peaks covered with snow and impart attractive colours to the mountains. *Haematococcus nivalis* gives red colour to Arctic and Alp

regions while *Chlamyodomonas yellowstonensis* alongwith some species of *Ankistrodesmus* is responsible for the green colour of the snow of the mountain of European countries particularly in Arctic region.

a) Those algae which are found on snow and not on ice *e.g.,* some species of *Raphidone* and *Chlamydomonas.*

b) Those algae which can grow only on ice and result in "ice bloom" *e.g., Ancyclone, Mesotaenium.*

c) Those algae which can grow on snow and ice both *e.g.,* and *Cylmdrocys*

d) Those algae which are not true cryophytes and have their temporary growth on ice snow e.g., *Phormidium* and *Gloeocapsa*.

9) Thermophytes: The algal genera occurring in hot springs at quite high temperature are called thermophytes. There are certain algae which are known to tolerate the temperature up to 85 ^{0}C e.g. few genera belonging to family Chroococcaceae and Oscillatoriaceae. *Oscillatoria brevis, Synechococcus elongatus* and *Haplosiphon lignosum* are some common examples of thermophytes which can survive up to a temperature of 70°C at which generally plant life is not possible.

10) *Parasitic algae. Cephaleuros virescens* which causes 'red rust of tea' is a striking example of parasitic algae and causes heavy damage to tea foliage. *Chlorochytrium* and *Phyllosiphon* are other examples of parasitic algae. *Polysiphonia festigata* a member of Rhodophyceae is reported as semiparasite on *Ascophyllum nodosum.*

11) *Symbiotic algae.* Several members of Cyanophyceae grow in association with other plant and lichens exhibit good example of it. Almost all the plant groups are known to have symbiotic association with blue green algae *e.g., Nostoc* is found within the thalli of *Anthoceros* and *Notothylas, Anabaena cycadeae* is reported in the coralloid roots of Cycas, *Anabaena azollae* occurs in *Azolla* etc. The association of *Chlorella* with nitrogen fixing bacterium *Azotobactor chrooccocum,* and with that of certain species of *Ceratophyllum* and mosses are other examples of symbiotic algae.

Structure of algal cell

The cells constituting the algal thalli are basically of two kinds, prokaryotic and eukaryotic. The prokaryotic cells (Fig.2) which constitute thalli of cyanophyta (blue-green algae) have a cell wall which contains a specific strengthening component not found in the cell walls of other algae. The central nucleoid has many irregularly arranged fine strands of DNA. The chlorophyll-pigment is bound to photosynthetic lamellae or thylakoids which may be arranged in parallel layers in the periphery of the cytoplasm or form a network extending throughout the cell cytoplasm. They are not organised into grana. The chloroplasts are thus absent and so are the mitochondria, golgi body and endoplasmic reticulum. The ribosomes are, however, present. The nuclear division does not take place by mitosis and no cell plate is formed. Such simple cells of blue-green algae (and bacteria) which lack a nuclear membrane, mitochondria, and plastids and do not divide by mitosis are called prokaryotic. The cells constituting the thalli of all other algae excepting the blue-greens are called eukaryotic. The eukaryotic cell (Fig.3) has the same structure as is typical of the higher plants. The nucleus is separated from the cytoplasm by a distinct nuclear membrane. It has mitotic figures and divides by mitosis. The cytoplasm contains membrane bound chloroplasts or chromatophores, mitochondria, golgi bodies and endoplasmic reticulum.

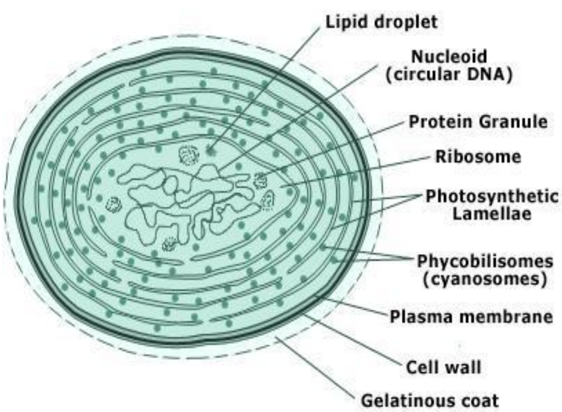


Fig.2. Cell Structure of Cyanophyta

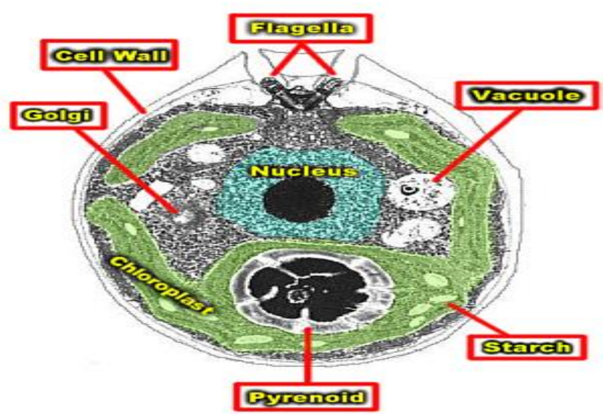


Fig.3. Cell structure of green algae

Algal pigments

The colour of the algal thallus which varies in different classes of algae is due to the presence of definite chemical compounds in their cells. These are called the pigments; each pigment has its own characteristic colour. The particular colour that a thallus has is due to the predominance of one pigment in a combination of several others. For example brown algae have predominance of Fucoxanthin and phycophein while red and blue green algae have excess of phycoerythrin and phycocyanin pigments respectively. Each group of algae has its own particular combination of pigments and a characteristic colour which is not found in the other algal groups. The photosynthetic pigments in algae are of three kinds, namely, **chlorophylls, carotenoids** and **phycobilins** or **biliproteins**. The algal chlorophylls are characterized by green colour and in solution they show the phenomenon of fluorescence and emit red light.

Chlorophyll pigments are fat soluble compounds and are of five different types. chlorophyll a, b, c, d, and e. Out of these chlorophyll a is universally present in all the groups of algae whereas chlorophyll b, c, d and e have restricted distribution.

Chlorophyll a - present in all higher plants and algae.

Chlorophyll b - present in all higher plants and green algae. Chlorophyll c - present in diatoms and brown algae and Chlorophyll d - present in red algae.

(Chlorophyll a is present in all photosynthetic organisms that evolve O_2.)

2. Carotenoids are fat soluble yellow coloured pigments and are subdivided into carotene, xanthophylls and carotenoid acids.

3. Phycobilins are water soluble blue (phycocyanin) and red (Phycoerythrin) coloured pigments and are present in the members of Cyanophyceae and Rhodophyceae.

Taxonomic Group	Photosynthetic Pigments
Cyanobacteria	chlorophyll *a*, chlorophyll *c*, phycocyanin, phycoerythrin
Green Algae (Chlorophyta)	chlorophyll *a*, chlorophyll *b*, carotenoids
Red Algae (Rhodophyta)	chlorophyll *a*, phycocyanin, phycoerythrin, (phycobilins)
Brown Algae (Phaeophyta)	chlorophyll *a*, chlorophyll c, fucoxanthin and other carotenoids
Golden-brown Algae (Chrysophyta)	chlorophyll *a*, chlorophyll c, fucoxanthin and other carotenoids
Dinoflagellates (Pyrrhophyta)	chlorophyll *a*, chlorophyll *c*, peridinin and other carotenoids

Algal flagella

They are of two main types, whiplash (A) and tinsel (B). The whiplash flagellum has a smooth surface. The tinsel flagellum bears longitudinal rows of fine, minute flimmer hairs arranged along the axis almost to the tip of the flagellum. There may be a single row of hairs as in the Euglenophyta and Pyrrophyta or two as in Chrysophyceae and Phaeophyceae. The hairs arise from the margins of the peripheral fibrils. The whiplash or smooth flagella are also known by other names such as acronematic or peitchgeisel. The other names for the tinsel flagella are pantonematic**,** flimmer or flimmergeisel.

The use of electron microscope has revealed a third kind of flagellum in which the surface of the flagellum is covered by scales (*Chara*) and minute, short, stiff hairs. The hairs differ from those on the tinsel type. They can be easily detached.

Flagellation

The position, number and kinds of flagella on the motile cells are strikingly constant in each division of algae but differ from division to division. Thus it forms an important taxonomic feature for primary classification of algae. The blue –green and red algae lack flagella. The motile cells in green algae and stoneworts usually have two, rarely four equal flagella of whiplash type inserted at the anterior end (A and B) the only exception is the Oedogoniales in which the motile cells have a crown of flagella (C) . The yellow green algae (Xanthophyceae) have two unequal anterior flagella. One of these is of whiplash type and the other tinsel (D). The diatoms (Bacillariophyceae) are characterized by a single tinsel flagellum on the male cell at the anterior end (E). In brown algae only the reproductive cells are motile. They are furnished with two unequal flagella. One of these is of tinsel type and other whiplash (F).

Food reserves

The food materials which accumulate as food reserves in the form of polysaccharides, however, vary from group to group and thus provide useful data for preliminary classification of algae. True starch is typical of only two algal divisions namely, Chlorophyta and Charophyta. The two other kinds of characteristic starches are the cyanophycean starch (Cyanophyta) and floridean starch (Rhodophyta). The three other important polysaccharides which accumulate as reserve food are laminarin found in the brown algae, paramylon characteristic of Euglenoids and leucosin peculiar to the Xanthophyta, Bacillariophyta and Chrysophyta. Besides, a proteinaceous compound cyanophycin is found only in the cells of blue-green algae. Mannitol which was formerly considered to be unique to the brown algae has recently been reported to occur in a few red algae. Fats occur as reserve food in the cells of Xanthophyta, Bacillariophyta and Chrysophyta.

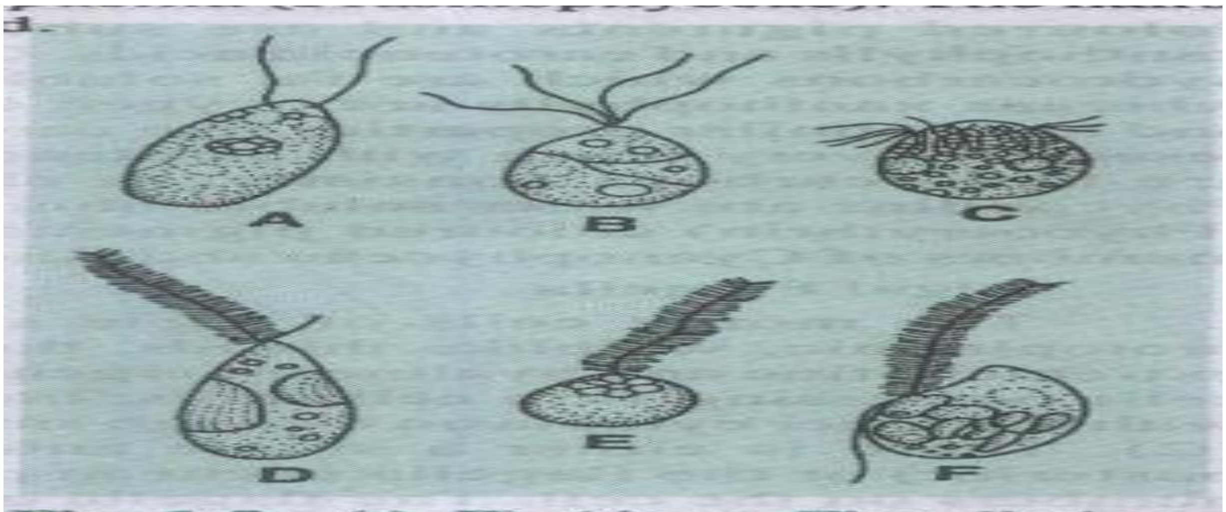


Fig. 1.5. (A-F) *Algae*. Flagellation., Chlorophyceae (A-C); Xanthophyceae (D); Bacillariophyceae (E) and Phaeophyceae (F).

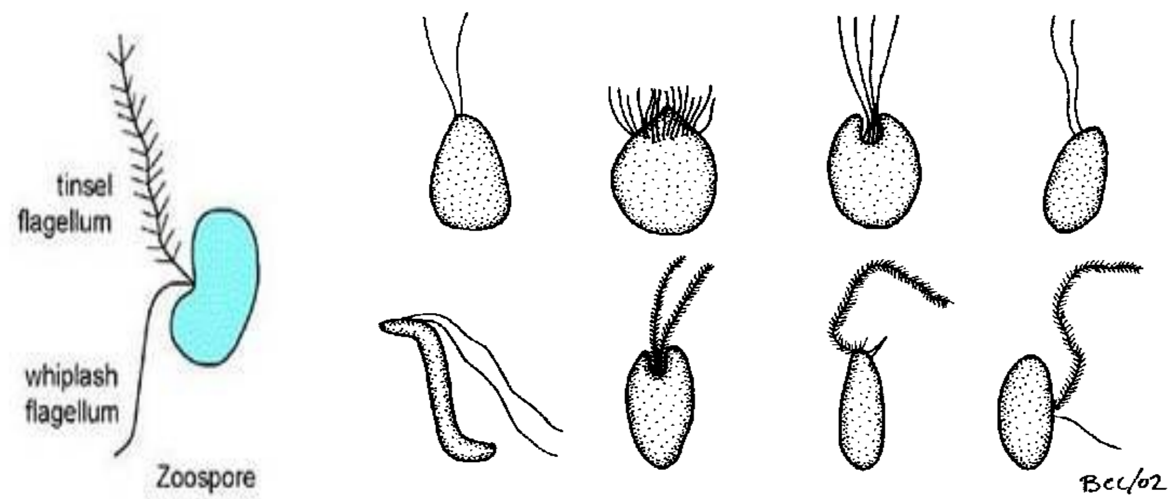


Fig 4. Types of Algal flagella

Factors affecting algal growth

1. Light

The light of the important factors affecting the growth of algae in the waters of rivers and lakes and in rivers, but the light may be less often because of turbidity, which accompany the rivers, which lead to block the light from the sun except a thin layer of surface water.

2. Macronutrient

Nutrients, major inorganic Macronutrient such as:

a-phosphate. b-Nitrate.

Are the major nutrients of the key factors that determine the number and types of algae, especially nitrates and phosphates and the element is added to the silica for the diatoms.

3. Temperature

Various factions of algae for micro-, super- and optimal temperature in which to grow, for example, the optimum temperature for the growth of Diatoms ranging from 18-30 °C, while green algae thrive at temperatures ranging from 30-35 °C, and blue-green algae thrive at temperatures ranging between 35 -40°C.

4. Micronutrient

Most algae grow best when the concentration of iron in the water ranges between 0.2 to 2 mg/l, while the observed toxicity of iron when the increased focus on the 5 mg/l.

5. Biological Factors: Biological Factors such as**:**

a) Competition between aquatic organisms on nutrients.

b) The rate of other organisms feeding on algae.

Classification of algae

The committee on the International Code of Botanical Nomenclature has recommended certain suffixes for use in the classification of Algae. These are phyta for division, phyceae for class, phycideae for subclass, ales for order, inales for sub-order, aceae for family, oideae for sub-family, Greek name for genus and Latin name for a species. Algal characteristics basic to primary classification.

The primary classification of algae is based on certain morphological and physiological features. The chief among these are: (a) pigment constitution of the cell, (b) chemical nature of stored food materials, (c) kind, number, point of insertion and relative length of the flagella on the motile cell, (d) chemical composition of cell wall and (e) presence or absence of a definitely organised nucleus in the cell or any other significant detail of cell structure. The details of vegetative structure and reproduction are useful for algal classification only at the level of families, genera and species.

G.M. Smith (1955) divided algae into seven divisions, which were further subdivided into classes. The names of Divisions and classes are given below:

Division 1: *Cyanophyta/Myxophyta* (Blue green algae-Prokaryotic algae). Represented by 1500 mostly fresh water species. Pigments are chlorophyll a ,C-phycocyanin and C-phycoerythrin and the reserve food is cyanophycean starch. Motile cells absent. Divided into a single class *Myxophyceae* e.g., *Nostoc, Anabaena*.

Division 2: *Chlorophyta* includes about 5700 forms out of which 90% are fresh water and the remaining 10% are marine. Dominant pigments are Chlorophyll a and b, the reserve food starch. Divided into two classes: (l) *Chlorophyceae* (green algae) e.g., *Volvox, Ulothrix;* (2) *Charophyceae* (stoneworts) e.g., *Chara*.

Division3: *Euglenophyta* includes 450 fresh water or terrestrial forms. Dominant pigments are chlorophyll and (3 carotene and reserve foods are paramylum and fats. Has been divided into a single class *Euglenophyceae* (the euglenoids) e.g., *Euglena*.

Division 4 : *Pyrrophyta* include 1000 species mainly unicellular rarely colonial. Pigments are chlorophyll a & c, carotene and xanthophyll. Reserve foods is starch/oil. Divided into two classes: (1) *Desmophyceae* (dinophysids) e.g., *Desmarestia',* (2) *Dinophyceae* (Dinoflagelloids) e.g., *Dinophysis*

Division 5: *Chrysophyta* represented by 6000 species of which 75% are freshwater and the remaining 25% marine. Dominant pigments are carotene and xanthophyll and reserve food is leucosin and oil. Divided into three classes: (1) *Chrysophyceae* (golden brown algae) *e.g., Chromulina* (2) *Xanthophyceae* (Yellow green algae) *e.g., Botrydium* (3) *Bacillariophyceae* (diatoms) *e.g., Pinnularia*

Division6: *Phaeophyceae* (Brown algae) represented by 1000 mostly marine forms, dominant pigments are phycophyein and fucoxanthin and reserve foods are *laminarin* and *mannitol.*

Divided into three classes: (1) *Isogeneratae e.g.Ectocarpus* (2) *Hetero generatae e.g., Myrionema* and (3) *Cyclosporae* e.g., *Sargassum*

Division 7: *Rhodophyta* (Red Algae) Includes 2500 species mostly marine. Predominant pigments are *r-phycoerythrin.* Reserve food is floridean starch*.* Division contains only one class *Rhodophyceae e.g., Polysiphonia, Gracilaria, Batrachospermum* (fresh water).

Christensen (1964) proposed a new scheme of primary classification of algae into Procaryota and Eucaryota on the basis of difference between the Procaryotic and Eucaryotic cells. It is briefly given below:

Reproduction

In their methods of reproduction, the algae are as diverse as they are in the nature of the thallus. The primitive algae reproduce only by vegetative methods but in the higher forms both asexual and sexual reproduction are of common occurrence. The common methods of vegetative reproduction are by simple **cell division**, **fragmentation** and **Hormogone formation**. Asexual reproduction in algae takes place by different types of spores formed in favourable and unfavourable conditions by division of the protoplast. Zoospores are usually produced in favourable conditions whereas thick walled hypnospores are formed during adverse conditions. Other asexual spores which are formed in different groups of algae are aplanospores, autospores and endospores. Higher forms reproduce sexually which is an advanced method of reproduction in which fusion of two specialized cells known as sex-cells or gametes takes place.

Sexual reproduction may be **isogamous** in which two identical gametes fuse to form zygote or **heterogamous** in which the gametic union takes place between two dissimilar gametes having different size and behavior. Heterogamy is further divided in Anisogamy and oogamy.

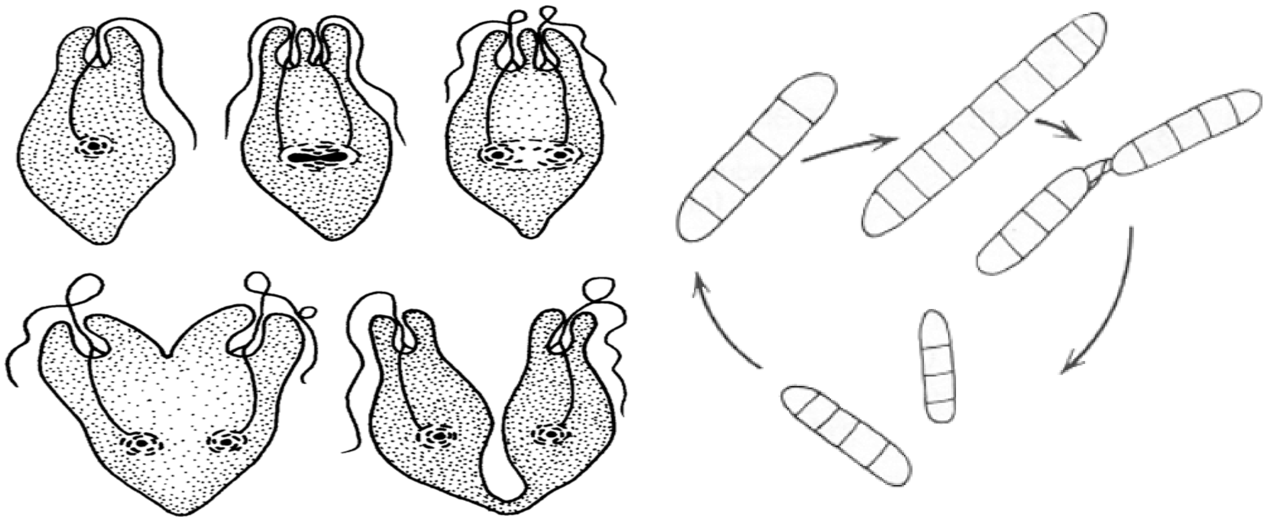


Fig.5: Vegetative reproduction: simple cell division and fragmentation

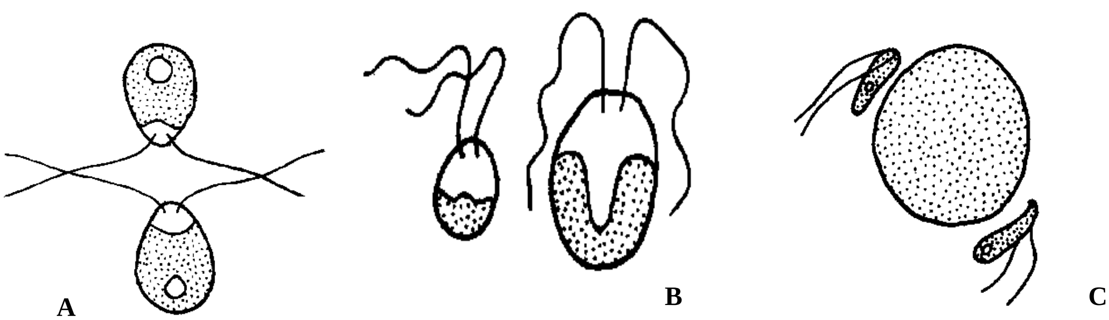


Fig. 6: Types of sexual reproduction in algae; **A- Isogamy**, **B- Anisogamy** and **C- Oogamy respectively.**

Organisation of the thallus

The algae exhibit a great diversity in the organisation of the plant body. The simplest forms are motile or non-motile unicells (*Chlamydomonas* and *Chlorella*). In many species, the cells are grouped into aggregations called colonies *e.g., Volvox* and *Pediastrun.* These assume various forms and may be a hollow sphere, a flat plate or a filament. The filamentous types are usually multicellular and the filament may be simple *e.g., Ulothrix, Zygnema* or branched or an aggregation of filaments or a, highly organized thallus of a large size. In some multicellular forms the cells may perform both functions, vegetative and reproductive as in *Oedogonium,* while in others special reproductive cells or organs may be developed, e.g., *Chara*.

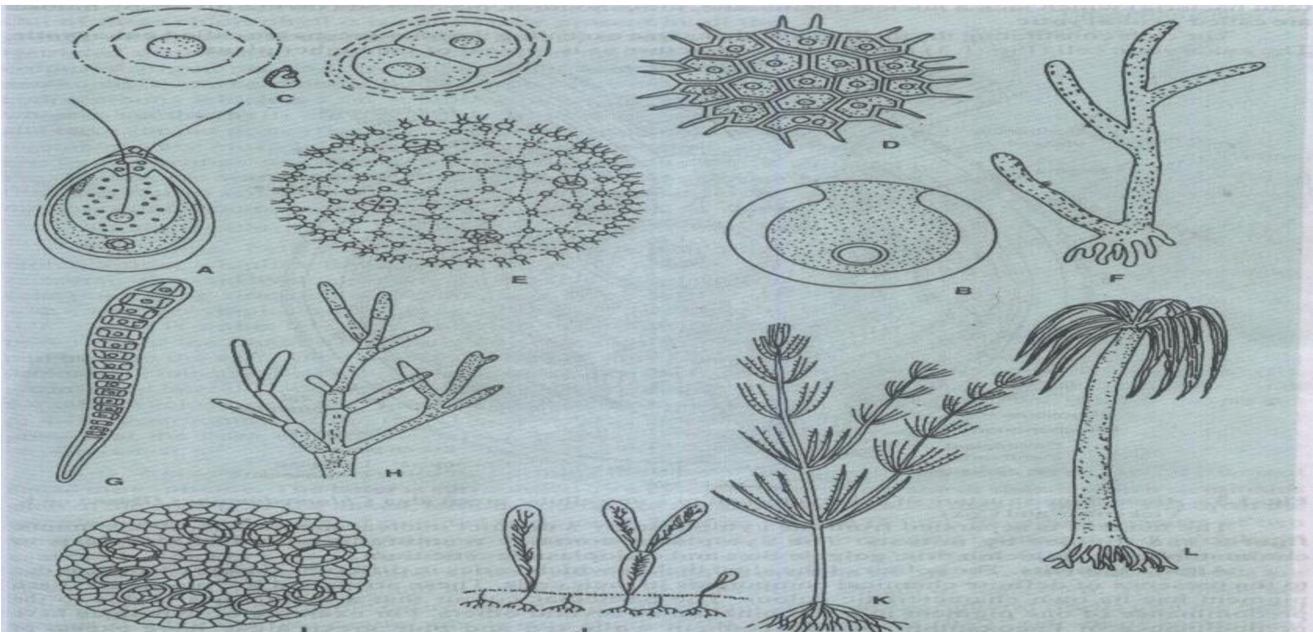


Fig. 1.2. Range of thallus organisation in Algae. (A). *Chlamydomonas,* (B). *Chlorella,* (C). *Gloeocapsa,* (D). *Pediastrum* (E). *Volvox* (F). *Vaucheria* (G). *Ulothrix* (H). *Cladophora,* (I). *Coleochaete* (J). *Caulerpa* (K). *Chara* (L). *Postelsia*

Economic important of algae

Beneficial role of algae

1. Algae as human food: From ancient times large numbers of algae have been used as human food. They are often mixed with rice and fish and consumed as salad, soups etc. *Spirulina* is a blue-green microalga with a long history as a food source in East Africa. As it is high in protein and other nutrients it is currently used as a food supplement and as a treatment for malnutrition. *Chlorella elliposidea* is used successfully with tea in Japan.

2. Algae as fodder: Seaweeds are classified as Rhodophyta (red algae), Phaeophyta (brown algae) or Chlorophyta (green algae) depending on their nutrition and chemical composition.The Chlorophyta (green algae) is an important group of marine algae, which is important both ecologically and scientifically. Seaweeds mainly the members of brown algae are used as feed for domestic animals in different parts of the world. *Sargassum, fucus* and *Laminaria* are consumed by cattles in Scotland. The use of dried seaweeds as cattle food has enhanced ten percent milk yield. The milk dose not any taste of algae after the Seaweed diet. *Rodymenia* is a common cattle-feed in France. Macrocystis is used for cattle-feed because it is rich in vitamins A and E. in Japan *pelvetia* is used as a cow- feed. Hens which feed on *Ascophyllum* –meal and *Fucus*-meal produce eggs with increased iodine content.

3. Algal role in fisheries: Various algae have utilized in fish culture. The members of planktonic and periphytic algae serve as primary food for fishes and other aquatic animals. Species of *oedogonium, Microspora, Ulothrix, Spirogyra, Cladophora,* diatoms, etc. sever as fish food in freshwater systems. It has been estimated that about a hundred Kg of algae produce approximately one Kg of fish. As oxygen is vital for the fish life and the higher concentration of Carbone dioxide is lethal, the role of photosynthetic algae is very important in aquaculture, the removal of carbon dioxide and the release of oxygen during photosynthetic process. A fish named *Tilapia* uses only the members of Cyanophycea and Chlorophyceae as its food. Many fishes depend on their food only on diatoms.

4. Algae as nitrogen fixation: conversion of atmospheric nitrogen into nitrogenous compound i.e., nitrogen fixation is one important attribute of blue-green algae. A large number of members belonging to order Chroococcales and Nostocales have been found to perform this function.

5. Algae in soil fertility and land reclamation: The species of *Nostoc*, *Scytonema*, *Lyngbya, Anabaena,* and *cylindrospermum* grow extensively on moist soil surfaces. Many of these are fix atmospheric nitrogen and increase the soil fertility due to their mucilaginous sheath they are able to prevent soil erosion by binding the soil particles firmly. They also reduce the evaporation of water because of thick covering on the soil. Due to the presence of these algae, water holding capacity is increased by 40 % and pH is reduced from 9.7 to 7.6.

6. Algae as fertilizer: These algae increase the water holding capacity besides the addition of their chemical constituent in the soil. Seaweeds, particularly brown algae improve the fertility of soil in cultured fields as their algin content helps in conditioning the soil, facilitating aeration, moisture retention and adsorption of nutrient elements. Seaweed liquid fertilizers will be useful for achieving higher agricultural production, because the extract contains growth promoting hormones (IAA and IBA), gibberellins, cytokinins, trace elements and vitamins and increased resistance to diseases upon treatment in various crops have been reported, among them, Fucus spp., Padina spp., Laminaria spp., Sargassum spp., and Turbinaria spp. are used as biofertilizers in agriculture**..** They are either mixed with some other organic materials or are allowed to rot in the field as such.

Fucus is used as common manure by Irish people. Genera like *Lithophyllum*, *Lithothamnion* and *Chara* are used in the deficiency of calcium in the field.

A 30% increase in the total production of rice grains was reported by algologists at Central Rice Research Institute, Cuttack, when the rice fields were inoculated by some nitrogen –fixing blue- green algae.

7. Algae as oxygen donors and link of food Chain: Algae oxygenate the environment by photosynthesis. They are primary link of many diverse food chains. Aquatic animals depend ultimately for food on algae.

8. Algae in sewage treatment: In sewage oxidation tanks, presences of algae oxygenate the sewage to a great extent. The released oxygen is utilized by bacteria in rapid decomposition of the sewage. Algae used in sewage ponds mainly belong to Chlorococcales, Volvocales (Chlorophyceae) and Euglenophyceae. The common members are *Chlorella, Scenedesmus, Pediastrum, Euglena; Phacus* etc. algae of sewage disposal ponds utilize nutrients to breakdown sewage.

9. Algae as research material: *Chlorella* culturing tanks are used in space vehicles because the alga restores the oxygen by it photosynthesis. Algae like *Chlamydomonas, Chlorella* etc. are very much useful in physiological, cytological and genetical studies. Species of *Nitella* are used in the studies of cytoplasmic movement, ion accumulation etc. *Valonia* and *Halicystis* help in understanding the phenomenon of permeability.

10. Algae and medicinal use: Brown algae are used in various goiter medicines due to their high iodine content. *Sargassum* which is used against goiter and other glandular troubles. Insect diseases to humans are treated with extract from *Corallina, Digenia, Codium, Alsidium* and *Durvillea*. Fucoidin and compounds of laminarin are used as anticoagulant while carrageenin acts as blood coagulant. Algae are used in the treatment of kidney, bladder and lung disease in China and Japana. *Gelidium* is used in stomach disorders and in heat induced illness.

Antibiotic chlorellin is extracted from *Chlorella vulgaris* which inhibits the growth of certain bacteria and a few algae. The growth of Escherichia coli (E. coli) is found to be reduced by *Nitzschia palea* (diatom). Microcystis reveals inhibitory action to *Staphylococcus, Closteridium* and zooplanktons like *Cyclops* and *Daphnia*.

11. Algae as source of growth promoting substances: Algae have been to increase the yield even when the soils are well manured. Seed treatments with *Phormidium* results in profuse tillering, increased height and multiple rice yields. There is also an increase in protein contents of grains of treated plants. *Phormidium* is not a nitrogen-fixing alga.

12. Algae in uptake of heavy metals and radioactive wastes: There are important role of algae in absorbing radioactive wastes and heavy metals. Species of *Chlorella, Euglena, Spirogyra, Cladophora, Scenedesmus* and *porphyra* have been found to absorb the radioactive elements and heavy metals.

13. Lens paper: For cleaning optical articles, lens paper is produced from *Spirogyra*.

14. Algae in the origin of petroleum and gas: The plankton of the seas is probably of great importance as a source of organic matter. Organic compounds produced from photosynthesis get accumulated in bottom deposits and in an oxygen-free environment gradually converted into oil and gas. Natural gas (largely methane) can be produced by certain kinds of anaerobic bacteria and oil formation is also associated with this.

15. Algae and limestone formation: Some members of green algae, blue green, red algae and flagellates deposit calcium carbonate on their cell wall or gelatinous sheath both in fresh and salt water. Algae also play an important role in formation of beds of limestone rocks.

16. Algae as indicator to the source of water : Can identify the source of the water potential of a sample of surface water, by selecting the numbers and types of algae and associated in this sample, this is possible because the numbers and types of micro-organisms that may be established linked to the quality of water sources where they live. For example, green algae are more prevalent in the open lakes of fresh water while hosting the blue-green algae in lakes closed.

17. The role of Algae in industries: Many commercial products are extracted from algae and their cell walls. Here only brief accounts of these are given.

a) Alginates (Alginic acid): derived from cellulose free middle lamella and primary wall of the members of phaeophyceae like *Macrocystic, Laminaria, Ascophyllum* ,*Lessonia* etc. Alginic acid content varies with the location, seasones, temperature and parts of the plants. Its content approximately 30-40% in brown algae on dry weight. It is similar to cellulose and pectic acids in composition consisting of a long unbranched chain of β-d-mannuronic acid joined by 1:4 glycosidic linkages. The soluble calcium salt of alganic acid is algin. As algin has remarkable water absorbing capacity it is used in many industries where there is the requirement of thickening, suspending, emulsifying, gel-forming, and stabilizing. Sodium salt of algainic acid is used in textile industry as they form excellent polishing and dressing material. Alginates are used also in food industry for filing creams, thickening soup, sauces, in cosmetics industry as dispensing agents in ointments, creams tooth pastes, shampoos, in paint industry for suspension of pigments, stabilization of emulsion; in pharmaceutical industry as emulsifyers and as filters in the manufacture of tablets, pills. Aginats are also used as gel in the freezing of fish, antibiotics and in the treatment of shocks.

b) Agar (Agar-agar): This is dried gel-like non-nitrogenous, gelatinous extract obtained from many red algae. This is one the best known algal products and used as a solidifying agent in the preparation of microbiological culture media. Dried agar is insoluble in cold water but soluble in hot water. The important algae used for the extraction of agar are *Gelidium, Gracilaria, Pterocladia, Gigartina, Chondrus*. Gelling property varies with the species but it will set at from 35to 52 ^{0}c. The major component of agar is agarose. Uroinc acid, pyruvic acid, polysaccharides like agarose and agaropectin are also present in agar-agar. Besides most important use of agar in the preparation of culture media. It has also been used in food industry, cosmetics, leather, textile industry, pharmaceuticals, dental impression mold and meat packing, for clotting of blood and as emulsifyers, laxatives.

c) Carrageenan (Carrageenin): it is carbohydrate mucilage named after Irish village Carrageenin which is extracted from red alga *Chondrus crispus* and to a lesser extent from *Gigartina*. The compound is a cell wall polysaccharide complex of D-galactose-3, 6-anhydro-D-galactoseand monoesterified sulphuric acid. These compounds are used like alginates in food, textile, leather, and industry, pharmaceutical and brewing industries. This gelatinous carbohydrate is variously used with pudding, consumed with milk, fruit and ice-cream. It is used as clearing agent in beer preparation.

d) Iodine and other compounds: Members of brown algae such as *Laminaria digitata* and *Fucus* spp. are known for the extraction of iodine. The maximum percentage of iodine (1.23%) has been obtained in Laminarias of Britsh Coasts*.* Seaweed are also known for the presence of macronutrients useful for human consumption like iron, manganese, zinc, copper etc. bromine , formic acid , acetone, acetic acid are also extracted from seaweeds. Seaweed ash is also used as source of salt and soda.

Harmful roles of algae

Besides many uses, algae are also known to create problems for human beings.

1. Death of aquatic animals and fishes: Many of blue green algae produce toxins which cause death to domestic animals and fishes. Important among these algae are *Microcystis, Anabeana* and *Aphanizomenon*. Besides death many harmful effects like loss of weight, weakness, abortion etc. have been reported in cattles. Phycocyanin pigment found in blue-greens is sensitive to light and when they enter in the blood capillaries of cattle cause an internal and peeling of the skin.

2. Disease and death to human beings: The direct consumption of dinoflagellates through fishes has resulted in human death. Dinoflagellates like *Gonyaulax*, when consumed with shell fish, produce several diseases. Reports about the occurrence of paralysis, respiratory failure and death within 2 to 12 hours after consumption of dinoflagellates are available.

3. Algae and water supply: algae interfere and create problems in water supply and storage reservoirs in many ways like in a) profuse growth and interference with filtration process, b) production of bad odour by their decomposition, c) imparting objectionable tastes, d) formation of slimes in water, colouration to the water, f) corrosion of pipes, g) interference in disinfection process by imparting turbidity, h) formation of sediments in service reservoirs.

The increase in the rate of excessive growth of algae to changes in physical properties, chemical and biological agents in water bodies. Where that rise to the phenomenon of the eutrophication is characterized by a high concentration of phosphates and nitrates, which lead to a significant increase in the rate of growth of some species of algae over some of the other races and species usually prevail in the unwanted presence of water bodies because of their detrimental effect on the rest of the organisms that coexist with them and the quality of the water.

The water quality is divided into a water body according to the abundance of nutrients, depending on the rate of growth of algae as follows:

a) Oligotrophic Water

It is characterized by the water that the concentration of major nutrients is rare, so do not lead to an increase in the numbers and types of algae. Featuring the region that the water is pure and transparent and the bottom of the river is relatively free from sediment, and inorganic materials such as calcium, magnesium, iron, sulfur, and dissolved half carbonate are found in small quantities.

b) Mesotrophic Water

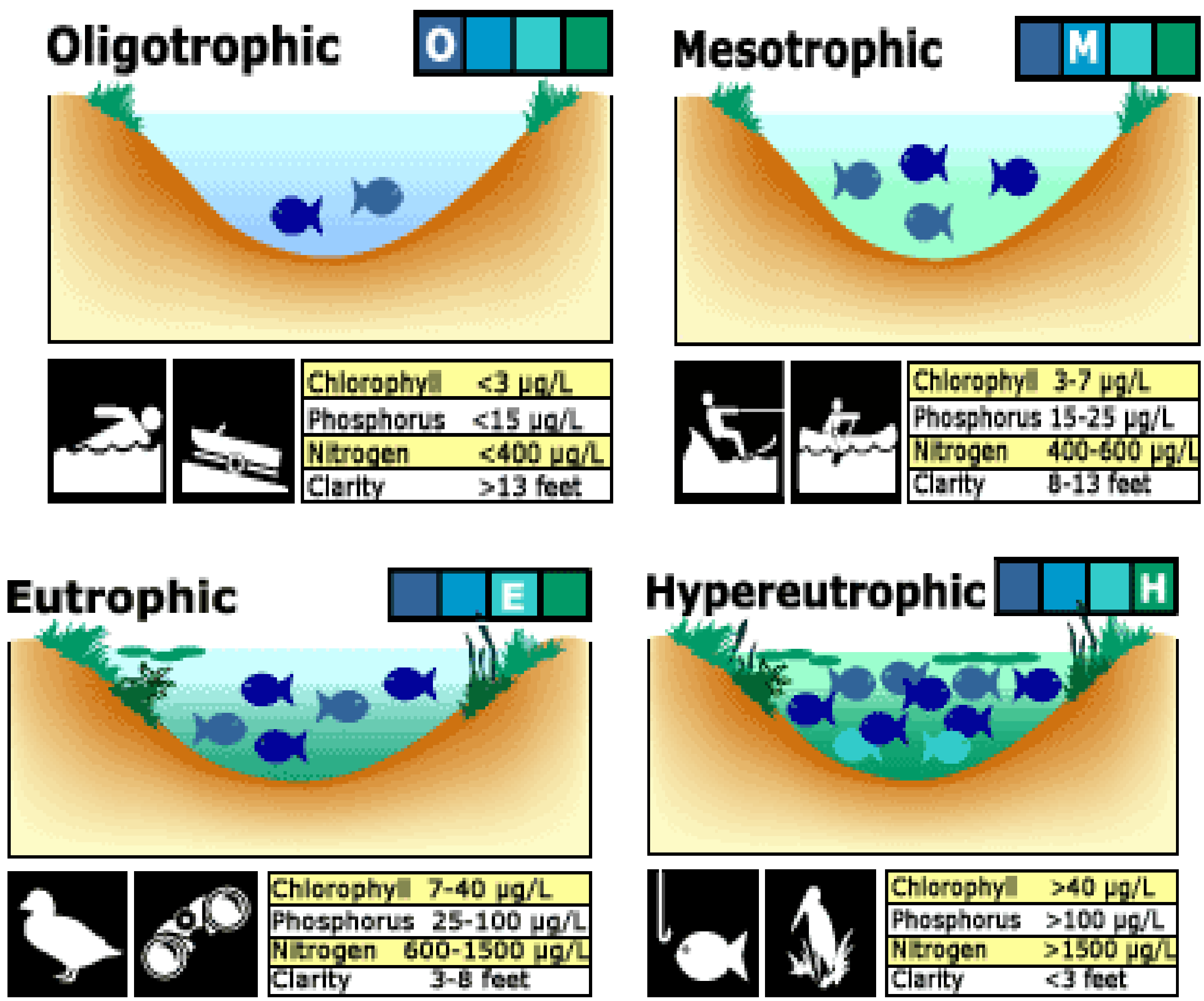
Water containing medium concentrations of major nutrient which allows an increase of algae growth rate slightly

c) Eutrophic Water

A water with a high concentration of major nutrients leading to increased algae growth rate substantially, which in turn leads to a phenomenon of the Euotrophication, which is usually accompanied by a phenomenon of algal bloom and which is characterized by a predominance of certain species of harmful algae, especially those excreted phycotoxins or algal toxins that produce certain chemicals that occur a change in the taste and smell of water.

d) Hypereutrophic Water

It is water that is characterized by high abundance of nutrients in the major, which in turn leads to a dramatic growth and the significant increase in the numbers and types of algae Algae causing these problems belong to cyanophyceae (*Oscillatoria, Microcystis, Scytonema, Cylindrospermum, Chroococcus* and *Anabaena*), Chlorophyceae (*Ankistrodesmus, Chlorella, Pediastrum*), Euglenophyceae (*Euglena and Phacus*).



4. Damage to building: During rainy season, on moist wall surface many blue- green algae grow. Gradually these spoil the walls of the buildings. *Scytonema, Tolypothrix* and *Chlorococcum* are some common algae causing such damage in tropical countries.

5. Accidents due to blue-green algae: Due to intensive growth of blue-greens, ground surface becomes slippery by which cattles and human beings get slipped.

6. Parasitic algae: Many algal forms are true parasites which cause severe damage to economically important parts of the plants.

Algal bloom

An algal bloom (water bloom) occurs when the numbers of algal cells increase rapidly to reach concentrations usually high enough to be visible to the naked eye. Algal bloom concentrations may reach millions of cells per milliliter. Many types of algae form blooms. Algal blooms are often green, but they can also be yellow-brown or red, depending on the species of algae. Not all algal blooms are toxic. Some, such as the blooms of diatoms in the early spring, are very important to the health of the ecosystem.

Bright green blooms are a result of blue-green algae, which are actually bacteria (cyanobacteria). Blooms may also consist of macroalgal, not phytoplankton, species. These blooms are recognizable by large blades of algae that may wash up onto the shoreline. "Black water" is a dark discoloration of sea water, first described in the Florida Bay in January 2002.

Algae causing water blooms: *Microcystis aeruginosa, M.viridis, M.flos-aquae, Anabaena circinalis, A.microspora, A.spiroides, Lyngbya limnetica, Oscillatoria planktonica, Spirulina gomontiana, Nostoc linckia, Noduaria spumigena (*cyanophyta*), Chlamydomonas, Pandorina, Volvox, Scenedesmus, Botryococcus, Cosmarium, Zygnema, Mougeotia, Odogonium (*Chlorophyta*) and Tabellaria* are the common bloom-forming algae.

Factors of bloom formation: There is no single factor which causes an algal bloom. A large number of factors have been found to be associated with the formation of water blooms such as water temperature, water movements, light and inorganic nutrients (mainly phosphorus and nitrogen). When phosphates are introduced into water systems, higher concentrations cause increased growth of algae and plants. Algae tend to grow very quickly under high nutrient availability, but each alga is short-lived, and the result is a high concentration of dead organic matter which starts to decay. The decay process consumes dissolved oxygen in the water, resulting in hypoxic conditions. Without sufficient dissolved oxygen in the water, animals and plants may die off in large numbers. Excess carbon and nitrogen have also been suspected as causes, although a study suggested that this is not the case. Major elements and heavy metals like zinc play an important role in the bloom formation. Blooms of dinoflagellates are related to cobalamino begine washed out in the sea from the soils which posses sufficient amount of this vitamin. As the planktonic blue-green algae have floating devic (gas vacuoles), blooms of the members of this class are mostly of permanent nature. Within a few days, a bloom can cause clear water to become cloudy. The blooms usually float to the surface and can be many inches thick, especially near the shoreline. Cyanobacterial blooms can form in warm, slow-moving waters that are rich in nutrients such as fertilizer runoff or septic tank overflows. Blooms can occur at any time, but most often occur in late summer. They can occur in marine and fresh waters, but the blooms of greatest concern are the ones that occur in fresh water, such as drinking water reservoirs or recreational waters.

Measurement: Algal blooms are monitored using biomass measurements coupled with the examination of species present. A widely-used measure of algal and cyanobacterial biomass is the chlorophyll concentration. Peak values of chlorophyll a for an oligotrophic lake are about 1-10 µg/l, while in a eutrophic lake they can reach 300 µg/l. In cases of hypereutrophy, such as Hartbeespoort Dam in South Africa, maxima of chlorophyll a can be as high as 3,000 µg/l.

Harmful effects: HAB stands for harmful algal bloom. There are many species of single-celled organisms living in the oceans, including algae and dinoflagellates. When certain conditions are present, such as high nutrient or light levels, these organisms can reproduce rapidly. This dense population of algae is called a bloom. Some of these blooms are harmless, but when the blooming organisms contain toxins, other noxious chemicals, or pathogens it is known as a harmful algal bloom (HAB). Of particular note are harmful algal blooms (HABs), which are marine algal bloom events involving toxic phytoplankton such as dinoflagellates of genus Alexandrium and Karenia. Such blooms often take on a red or brown hue and are known colloquially as red tides.

Examples of common harmful effects of HABs include:

1. The production of neurotoxins which cause mass mortalities in fish, seabirds and marine mammals.
2. Human illness or death via consumption of seafood contaminated by toxic algae.
3. Mechanical damage to other organisms, such as disruption of epithelial gill tissues in fish, resulting in asphyxiation.
4. Oxygen depletion of the water column (hypoxia or anoxia) from cellular respiration and bacterial degradation.

Red tides

"Red tide" is a term often used to describe HABs in marine coastal areas, as the dinoflagellate species involved in HABs are often red or brown, and tint the sea water to a reddish colour. The more correct and preferred term in use is harmful algal bloom, because:

1. These blooms are not associated with tides
2. NOT all algal blooms cause reddish discoloration of water
3. Not all algal blooms are harmful, even those involving red discoloration

Control of blooms

1. The chemical method: the application of copper sulphate or chlorine (as bleaching powder or calcium hypochlorite) is the easy and most common method. As the higher concentration of chemicals (algicides) may be lethal to fish and cattles, it is applied in low concentration.

2. Mechanical methods: by covering the water with floating plants or with parts of plants like banana leaves.

3. Biological methods: by used Cyanophages (virus infecting the members of Cyanophyceae), bacterial species and the members of fungi known to infect algae are used for controlling the blooms. The pathogenic fungi (Phycomycetes) and a number of gram negative bacteria have been reported which cause lysis of blue-green algae. The algal blooms of *Microcystis* can be destroyed by using a specific bacterium (CP-1). The biological control of algal blooms is much more economical, easier and advisable than the chemical control.

Water treatment: Algal blooms sometimes occur in drinking water supplies. In such cases, toxins from the bloom can survive standard water purifying treatments. Researchers at Florida International University in Miami are experimenting with using 640-kilohertz ultrasound waves that create micropressure zones as hot as 3,700 °C. This breaks some water molecules into reactive fragments that can kill algae.

Classification of algae

Division1 : Cyanophyta *(*Cyanophycophyta*)*

Class *:* Cyanophyceae

General characteristics

This division includes the blue-green algae which are the only known oxygen producing prokaryotes. It is a small primitive group comprising of about 2,500 species placed under 150 genera. All of them are included in a single class Cyanophyceae or Myxophyceae. The diagnostic features of the division and the class are:

1. The cells constituting the thallus are prokaryotic.

2. The flagella are entirely lacking (even the reproductive cells are non- flagellated);

3. The phycobilin pigments unique to this class are blue *C*-phycocyanin and *C*-phycoerythrin in addition to chlorophyll*-a, B-carotene* and unique,xanthophylls, namely, myxoxanthin and mycoxanthophyll*;*

4. The unique food-storage compounds are the myxophycean starch / cyanophycin.

5. Sexual reproduction is completely absent.

Some blue-green algae which occur in soil up to a depth of several feet and in semi-aquatic environments (paddy fields) fix atmospheric nitrogen. The factors which contribute to their wide distribution are:

1. Ability to withstand prolonged drying and extremes of temperature,
2. Capacity of some to assimilate atmospheric nitrogen,
3. Labile metabolism,
4. Ability of many of them to enter into symbiotic relationship with other plants, and
5. Their constancy of form along with their modes of reproduction.

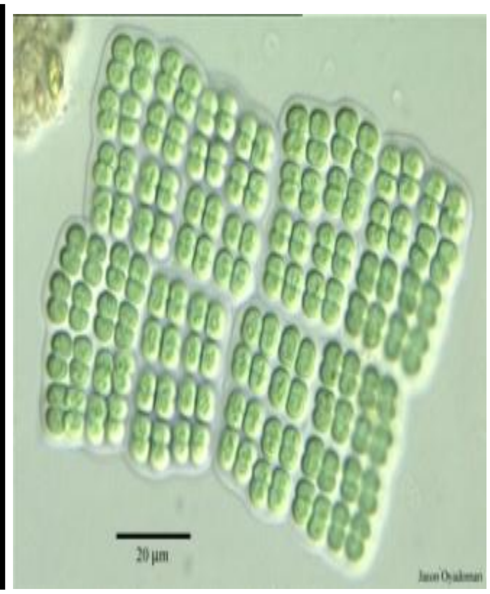
Gliding movement

When viewed under the light microscope, blue-greens show a variety of movements, such as gliding, rotation, oscillation, jerking and flicking.

Organisation of the thallus

The blue green algae amongst the simplest photosynthetic plants living today. Just as do they vary in the choice of their habitats, so do they in the range of vegetative structure. The thallus may be a solitary cell or a colony.

1. **Unicellular Forms**. The thallus, in some species, is a unicellular which is usually spherical or oval (*Chroococcus* and *Gloeocapsa*). There is immediate separation of the daughter cells from each other after cell division. Actual unicellular forms, however, are not many because the copious secretion of mucilage by the daughter cells results in the daughter cells remaining together after division.



Chroococcus ***Microcystis*** ***Merismopedia***

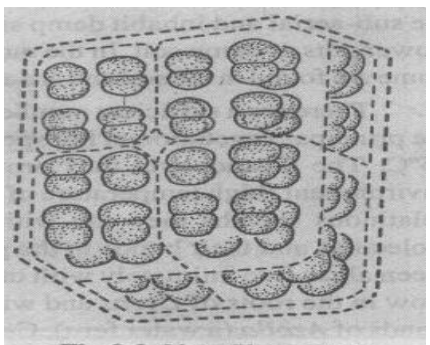
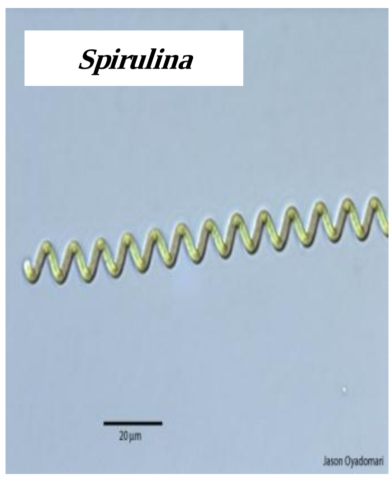
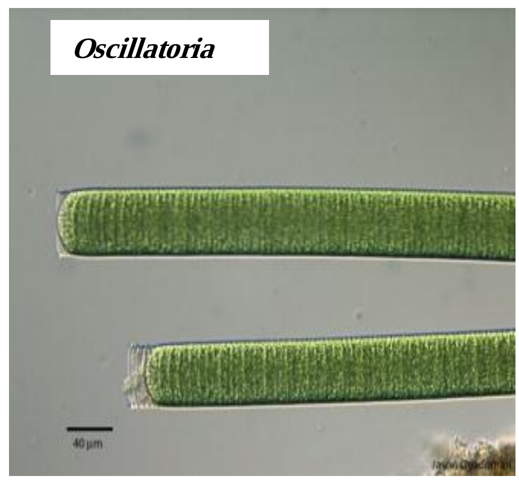


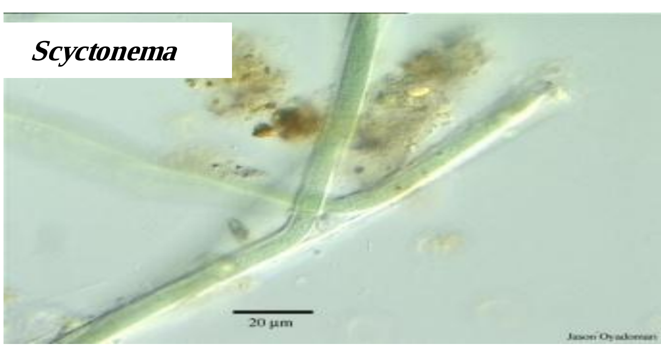
Fig.2.2. Non-filamentous Cyanophyceae. *Eucapsis alpina* (After Clemants and Shantz).



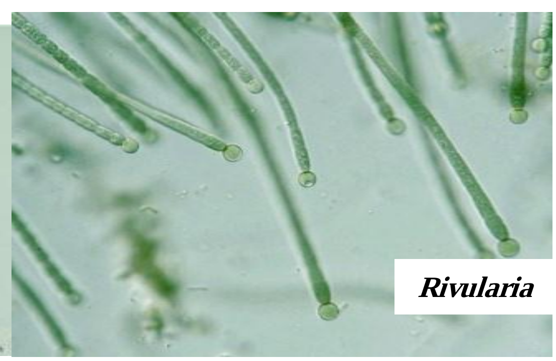
Spirulina



Oscillatoria



Scyctonema



Rivularia

2. **Colonial Forms**. In most blue-greens, the cells after division remain attached by their walls or are held in a common gelatinous matrix to form a loose organization of cells which is termed a

colony. Of crse the cells in the colonies are often aggregated into irregular, palmelloid forms of great variability. *Gloeothece* is an example of an aggregation of a few cells. *Aphanocapsa* and *Aphanothece* are examples of aggregations of numerous cells.

The colonies may either be filamentous or non–filamentous. Each colony is generally enclosed in a gelatinous sheath.

a) Non-filamentous colonies. The non-filamentous colonies are of various forms. They may be cubical, spherical, square or irregular depending on the planes and direction in which the cells divide.

b) Filamentous colonies. The Filamentous colony is the result of repeated cell divisions in a single plane and direction forming a chain or a thread. It is known as the trichome. The cells in the trichome may be held together either by separation walls or a common gelatinous sheath around it. The trichome is usually straight but in *Spirulina* it is more or less permanently spirally coild. In *Rivularia* it is ship-like with the upper end drawn out into a colourless, multicellular hair. the trichome of *Aphanizomenon* tapers towerds both ends. the trichome with its enclosing sheath is called a filament.

Branching

The trichomes may be branched (*Scytonema* and *Stigonema*) or unbranched (Oscillatoria and Lyngbya).

Types of branching:

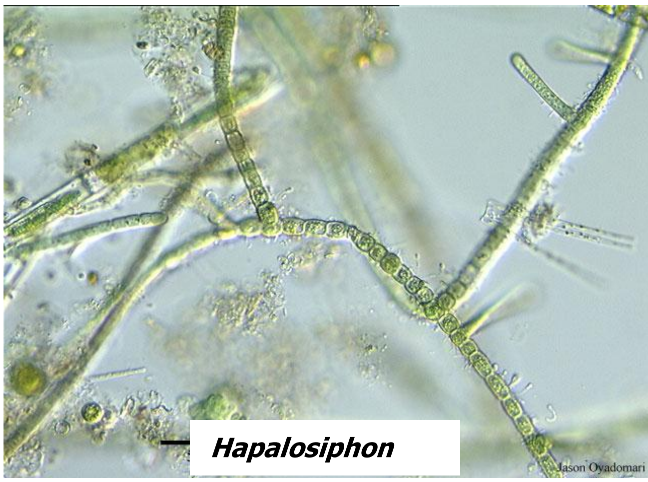
The chains of cells (called **trichomes**) are held together by a shared **sheath** to form the **filament**. A break in the chain of cells in the trichome results in a branch.

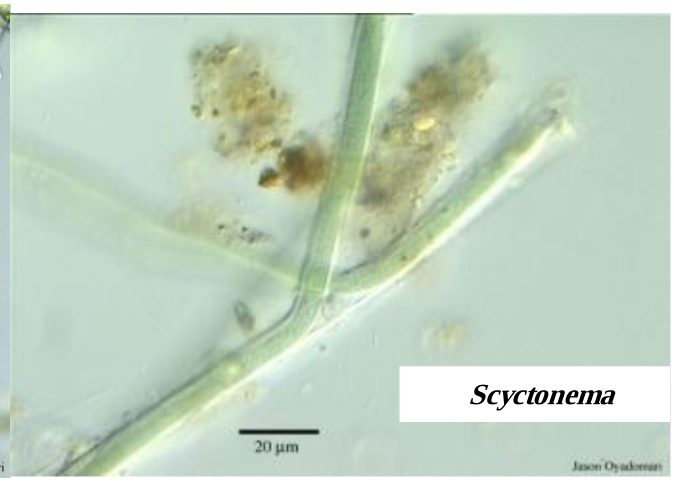
a) False branching (*Tolypothrix- Scytonema*)

b) The chains of cells (called **trichomes**) are held together by a shared **sheath** to form the **filament**. A break in the chain of cells in the trichome results in a branch. The broken trichome grows out at some angle inside a branch of sheathing material. The break makes this a false branch as it is attached only by means of the containing sheath.

In false branching, there is an appearance of a branch, but the cells in one branch are not actually continuous with those of the other. This occurs in two main ways: double false branching (as in Scytonema) and single false branching (as in Tolypothrix, upper); this kind of false branching often begins at a heterocyte. Both of these types of false branching can be readily distinguished from true branching, as show by Stigonema (lower right).

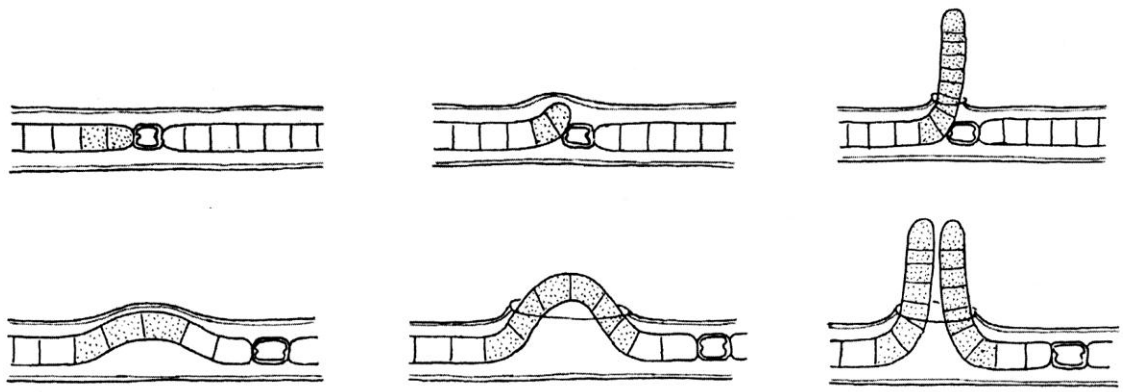
c) True branching (*Stigonema-Hapalosiphon*): In the Stigonematales, true branching occurs. Here a single cell divides in two directions forming a connected branch.



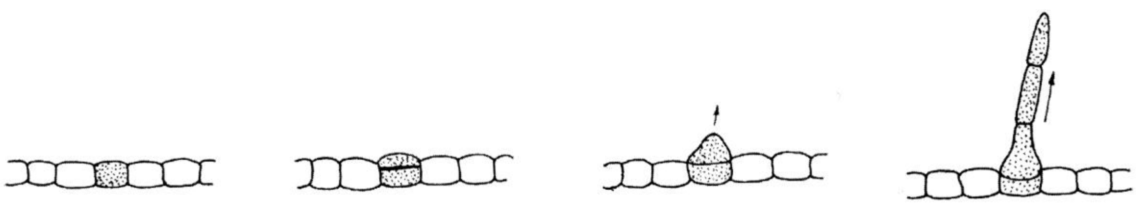


Cell Structure. The blue-green algal cell is an example of a typical prokaryotic cell. It lacks all the membrane bound cell organelles characteristic of a eukaryotic cell. Thus it has no discrete or well-defined nucleus, Chromatophores, mitochondria, endoplasmic reticulum and dictyosomes. Nucleoli, pyrenoids and true vacuoles are also absent. It rarely exceeds 10 µ in dia. Most often it is surrounded by a thin or thick mucilagenous sheath. The inner layer of cell wall has a chemical composition similar to bacterial cell, made up of peptidoglycans. The cell wall is followed by a cell membrane composed of lipids and proteins. The inner contents of the cell can be distinguished into an outer pigmented region called **chromoplasm** and a central clear, hyaline region called **centroplasm**. The centroplasm contains photosynthetic pigments chlorophyll - a, carotene and others located in broad sheet-like, structures called **thylakoids**. The central nucleoid has many irregularly arranged fine strands of DNA. The planktonic forms contain gas vacuoles in their cells to help in floating. Some cyanophycean members possess special types of cells called heterocysts, as in *Anabena* and *Nostoc*. They are large, thick walled, round cells without a nucleoid. These cells represent the sites of protein synthesis.

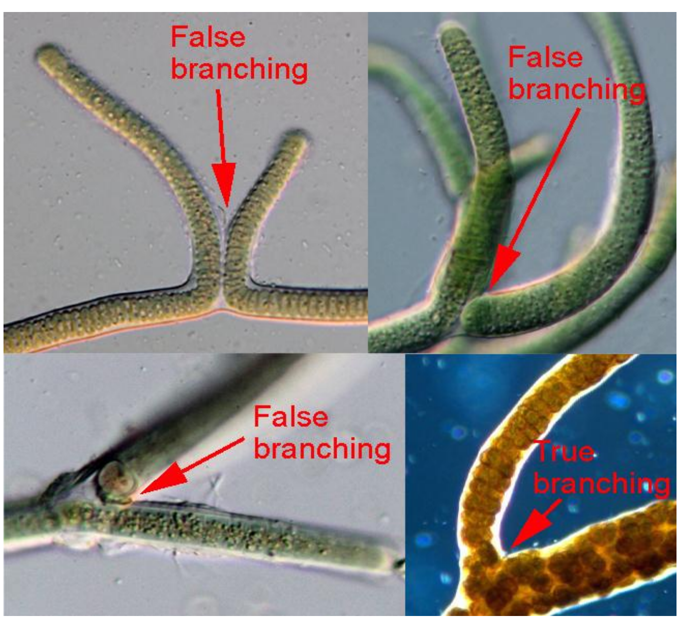
They also represent regions where filaments can break into fragments.



False branching



True branching



Types of branching

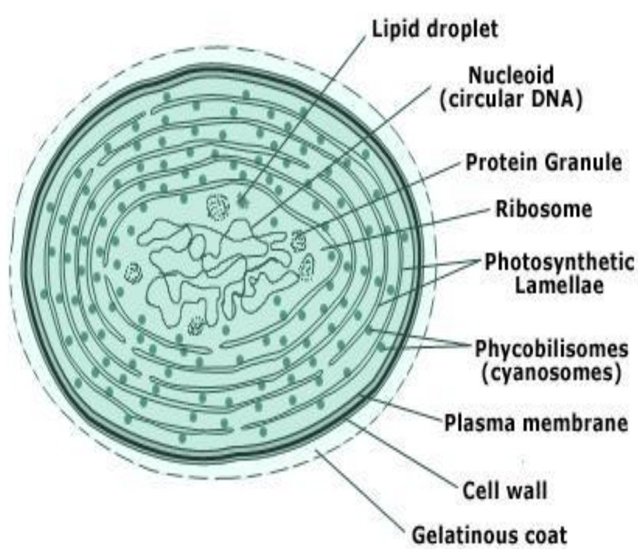


Fig. Cell Structure of Cyanophyta

Heterocysts

The heterocysts differ from the vegetative cells and occur between them along the length of the trichome at some regular intervals. These are large, empty looking specialized cells found in the trichomes of certain filamentous blue-green algae.

The heterocysts can easily be distinguished from the vegetative cells of the trichome by their i) large size, ii) thicker walls, iii) homogenous transparent, pale yellowish contents and iv) a distinct pore either at both ends.

Position of heterocysts in the trichomes.

The heterocysts usually occur singly. In some genera they occur in pairs (*Anbaenopsis*, and rarely in chain. When they singly are either terminal (*Gloeotrichia*) or intercalary in position (*Nostoc*,). Lateral heterocysts are found in *Nostochopsis*. In shape they are identical to the vegetative cells. They are almost round in *Nostoc*, *Anabaena*, *Rivularia* and *Gloeotrichia* but somewhat rectangular in *Hapalosiphon* and *Scytonema*.

Factors controlling heterocyst formation.

i) The reproduction of heterocysts increases under conditions of low light intensity and increase in the amount of phosphate in the medium.

ii) Heterocyst formation depends on the availability of carbon intermediaries and ATP. The former are supplied by photosynthesis and the latter by oxidative metabolism. The different wavelengths of the visible spectrum, the red light (630-680nm) was most effective in maximum heterocyst production in *Anabeana dolioum*. Absence of carbon dioxide inhibited heterocyst formation. Possibly heterocyst formation depends firstly on photosynthesis for the synthesis of some enzymes.

iii) The concentration of nitrogen in the medium above a certain level results in complete inhibition of heterocyst production. Grow in high concentration of nitrogen in the medium the heterocysts were absent in *Tolypothrix arenophila*, *Scytonema praegnans*, *Anabaena naviculoides*, and many others.

Function of Heterocysts.

The subject is till controversial. Various suggestions put forth from time to time have been discussed beautifully by Tyagi (1973). These are:-

1. Storehouses of reserve food material or enzymatic substances. Both suggestions did not receive much attention because for want of experimental evidence.

2. Heterocysts produce substances which stimulate growth and cell division in adjacent vegetative cells. Heterocysts produce and secrete certain vital substances needed to keep the adjacent cells in active physiological state.

3. Play role in sporulation. The akinetes, the so called spores of heterocystous blue-green algae, are formed only adjacent to the heterocysts.

4. Sites of nitrogen fixation. About 50 species of the blue–greens are now known to be active nitrogen fixers. A direct relationship between heterocyst and ability to fix nitrogen has been provided by the fact all the heterocystous species fix nitrogen. Inhibition of heterocyst formation by combined nitrogen in the medium lends further support to the hypothesis that heterocysts are the sites of nitrogen fixation. Because of their role nitrogen fixation, the hterocysts are considered ecologically and agriculturally important in tropical rice field.

5. The relation between the position of heterocyst and the point of origin of a true of false branch.

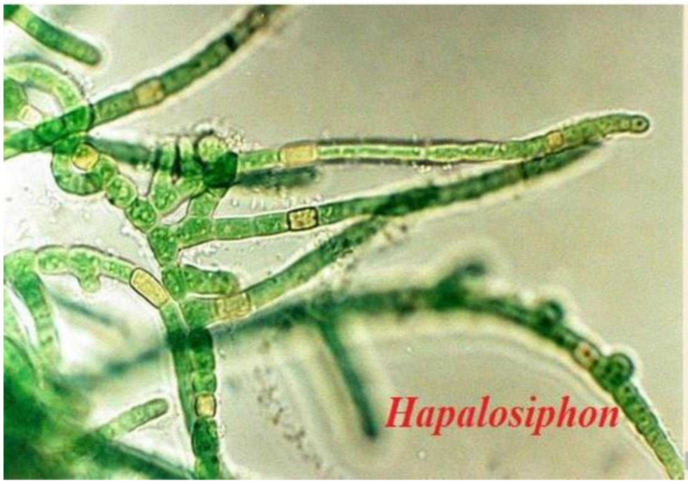
6. Locus for filament breakage. Heterocyst serves as the weakest link in the trichome and thus serves as a locus for breakage. Some workers, therefore, maintain that intercalary heterocysts serve to break the trichome into small sections of living cells called hormogonia.

Shape of Heterocysts

1- They are identical to the vegetative cells.

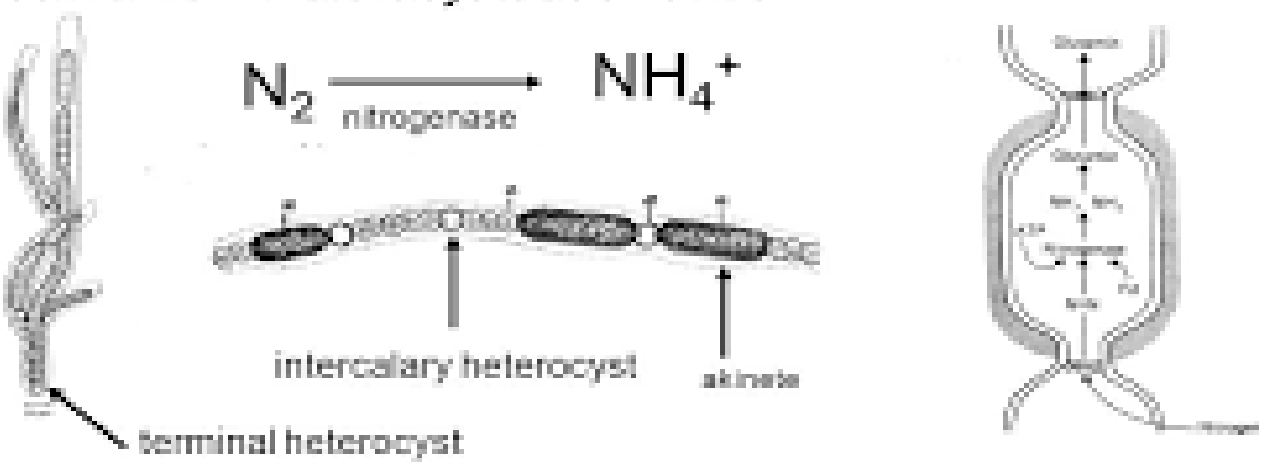
2- They are also round *Nostoc, anabena , Rivularia*

3- Some time rectangular in *Hapalosiphon, Aulosira, Scytonema*.



Cyanobacteria: systematic characters

Heterocytes (heterocysts) are cells with nitrogen fixation as a special function.Heterocytes only present in some filamentous forms (Nostocales, Stigonematales), though N-fixation may occur also in some non- heterocysteous forms



Similarities between Bacteria and Cyanobacteria

The taxonomic position of blue green algae (Cyanobacteria /Cyanophyceae) is a thing of controversy. They show resemblance to bacteria. Their structure is very simple. Both bacteria and blue green algae are prokaryotic. Like bacteria several blue green algae are colourless. There is no sexual reproduction in both and they reproduce by asexual methods. Recently many phycologists have found out a number of similarities between cyanophyceae and bacteria. Some of them are the following:

1. Both bacteria and blue green algae are simple and their DNA is devoid of histone proteins and hence true chromosomes are not organised.

2. Both posses saprophytic mode of life.

3. In both groups the cells are covered by mucilage sheath.

4. True cell organelles like plastids, golgi bodies, mitochondria etc are absent.

5. Bacteria are unicellular forms and some of the cyanophycean are also unicellular in nature.

6. In both bacteria and blue green algae, the cell wall composed of mucopeptide (murein).

7. Both possess the ability to fix nitrogen from the atmosphere.

8. Formation of resting spores is characteristic in both.

9. Motile spores are not seen in both groups.

10. Absence of sexual reproduction.

11. Both organisms are capable of withstanding high rate of desiccation and high temperature.

Differences between Bacteria and Cyanobacteria

Cyanobacteria is also known as blue-green algae.

They differ from other bacteria in that cyanobacteria possess chlorophyll-a, while most bacteria do not contain chlorophyll.

Chlorophyll-a gives them their characteristic blue-green color.

Reproduction

Reproduction in Cyanobacteria reproduces by simple and primitive methods of reproduction, which are vegetative and asexual. The sexual reproduction is totally absent.

1. **Vegetative Reproduction:** It occurs by following methods:

(i) **Fission:** Unicellular cyanobacterial cells divide and reproduce by fission.

(ii) **Fragmentation:** in this method, filaments break down into small pieces and each piece develops into a new colony.

(iii) **Hormogonia:** in this method, filaments break into pieces or trichomes, which are called hormogonia and develop into new filaments.

2. **A sexual Reproduction:** Many non-motile Cyanobacteria reproduce by spores, which are of the following types:

(i) **By Endospore:** In this condition one or more cells increase in size and their protoplasm divides into many parts to form endospores, e.g., ***Dermocarpa***.

(ii) **By Exospore:** These structures are formed in the distal part of the protoplasm, e.g., ***Chaemosiphon***.

(iii) **By Akinetes:** Thick walled resting spores. These are formed close to the heterocysts. In this case, cells increase in size and a thick layer is formed around it. Appear as larger cells in the chain and different than heterocyst. Akinete resistant to unfavourable environmental conditions. Under favourable conditions, they give rise to new filaments, e.g., *Anabaena*.

(iv) **By Nannocytes:** In some of the filamentous Cyanobacteria, cells may divide into many parts without any change in shape. In this way so many bodies are formed which are known as nanocysts, e.g., ***Microcystis***.

Economic Importance

Beneficial Activities

1. Nostoc commune is boiled and used as soup in China.

2. The blue-green algae furnish food for fish and other aquatic animals. *Oscillatoria* is the most favoured blue-green alga consumed by 56 species of fishes.

3. The blue-greens add organic matter to the soil and increase fertility. Barren alkaline soils in India have been reclaimed and brought to a productive state by inducing a proper growth of certain Cyanophyceae. Decomposition of successive crops of these neutralizes the alkalinity of the soil.

4. Recent investigations have definitely proved that some of the blue-green algae increase the fertility of the soil by fixing atmospheric nitrogen. The important nitrogen-fixing blue-green algae are *Oscillatoria princeps, O. formosa* and some species of *Anabaena, Spirulina, Nostoc,* and *Cylindrospermum and* some species of *Scytonema*. The blue-greens form an important group of soil organisms which are of great agricultural importance because of the ability of

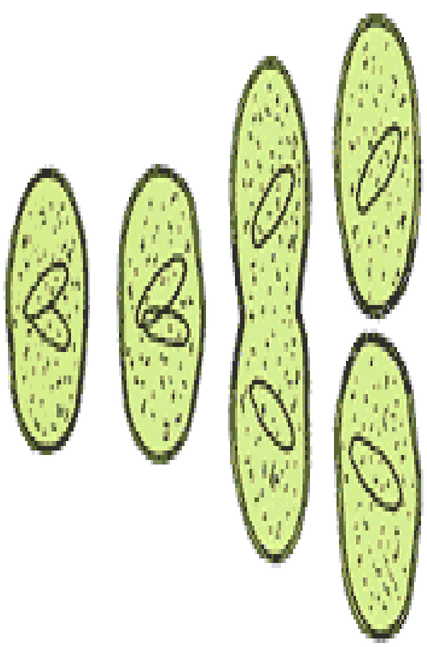
some of them to synthesize organic substance as well as to fix atmospheric nitrogen. They thus serve as an excellent source of nitrogen and organic matter. The practical application of these algae is the seeding of rice fields with the nitrogen-fixing species. This results in appreciable increase in yields of rice.

Harmful Activities

1. Some members of Cyanophyceae cause damage of building plasters, stones etc. It can be avoided by spraying $CuSO_4$ and sodium arcenate.

2. Some members like Microcystis, Anabaena, form water blooms and can grow well in O_2 deficient water. Continuous respiration by submerged plants and animals during night time (when photosynthesis does not take place) causes the depletion of O_2 to almost zero level. At that condition mortality of both animals and other submerged plants takes place due to suffocation.

3. Blue green algae contaminate the water of reservoirs. They develop a foul odour in water and make it unhygienic for human being and cause several diseases. Different diseases like gastric troubles may appear by drinking the water contaminated with *Microcystis* and *Anabaena*.



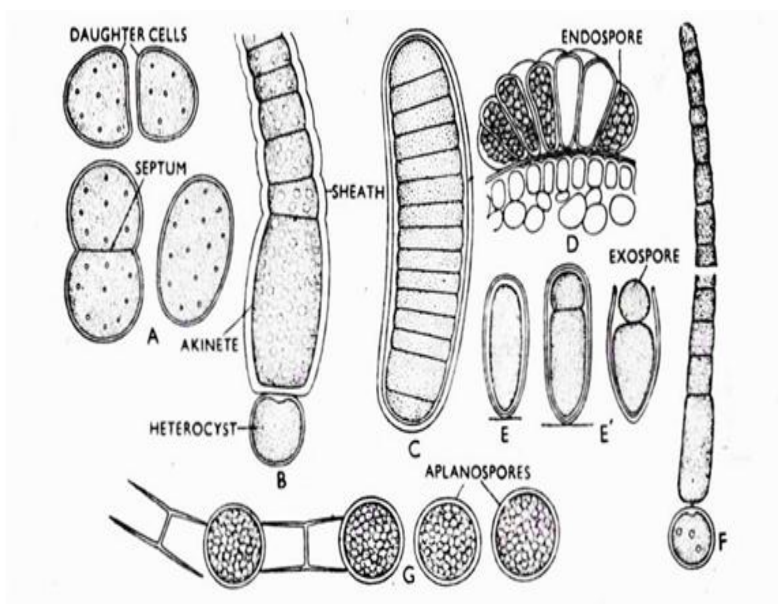
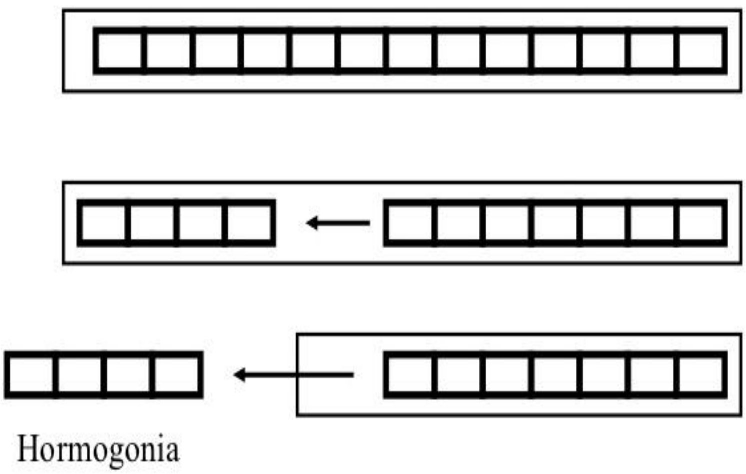


Fig. 10. Spore forms and vegetative reproduction in Algae. A. Simple cell division in unicellular alga *Synechococcus* sp. B. Filament of *Gloeotrichia natans* with akinete and heterocyst. C. Hormospore of *Westiella* sp. D. Group of individuals with endospores of *Dermocarpa prasina*. E–E′. *Chamaesiphon incrustans* showing exospore formation. F. Fragmentation of filament of *Cylindrospermum muscicola*. G. Aplanospores of *Microspora willeana*.

Hormogonia – short piece of trichome found in filaments. It detaches from parent filament and glides away

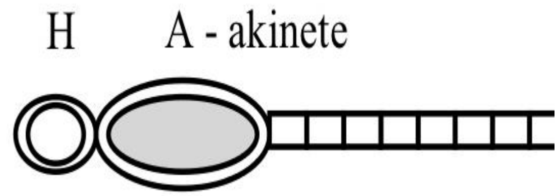


Asexual Reproduction

Akinete – thick walled resting spore

Function – resistant to unfavorable environmental conditions.

Appear as larger cells in the chain and different than heterocyst. Generally lose buoyancy



Chroococcus

Reproduction. Multiplication takes place by two methods, cell division and colony fragmentation.

(i) Cell division or fission: Single cell may be released from the colony by the disorganisation of the parent sheath. Each released cell grows into a new colony by cell division. The mother cell divides into two. The process may be repeated. All the daughter cells are held together within the original sheath of the mother cell to form the colony.

(ii) Colony Fragmentation.

Reaching a certain size the colony may break into fragments. Each fragment by cell division forms a new colony.

Taxonomic Position
Division : Cyanophyta (Cyanophycophyta)
Class : Cyanophyceae
Tribe : Coccogoneae
Order : Chroococcales
Family : Chroococcaceae
Genus : Chroococcus
Species : turgidus (Kutz)

TRIBE : HORMOGONEAE : ORDER : Oscillatoriales

The trichomes consist of undifferentiated cells and are unbranched and usually straight or trichome of more than one. The order includes a single family Oscillatoriaceae.

Family Oscillatoriaceae: The trichomes consist of a single row of cells. The heterocysts and spores are absent. Hormogones develop along the longitudinal axis. The family includes several genera such as *Oscillatoria*, *Lyngbya*, *Spirulina*, *Arthrospira*, *Phormidium*, *Microcoleus*, *Trichodesmium* and others. Oscillatoria is taken here as an example.

Oscillatoria (voucher, 1803)

Occurrence. It is an exceedingly common, fresh water, filamentous, dark, blue-green alga. It occurs in a wide variety of habitats. Usually it is found on damp soil, in temporary rain water pools and roadside ditches. A few species are marine.

Movement: Under the microscope the movements are seen to be of the following types:

1. *Gliding or creeping movements.* Defined gliding as, "the active movement of an organism in contact with a solid substratum where there is neither a visible organ responsible for the movement, nor a distinct change in the shape of the organism". The trichome glides forwards and backwards. It moves back and forth (backwards and forwards) in water accompanied in some species, by clockwise or anticlockwise rotation of the forward end of the trichome.

2. *Oscillatory movements. Oscillatoria* also exhibits slow waving movements. Oscillations of the front end, hence the generic name *(oscillare* to swing). Oscillations generally occur when

there is no forward progression.

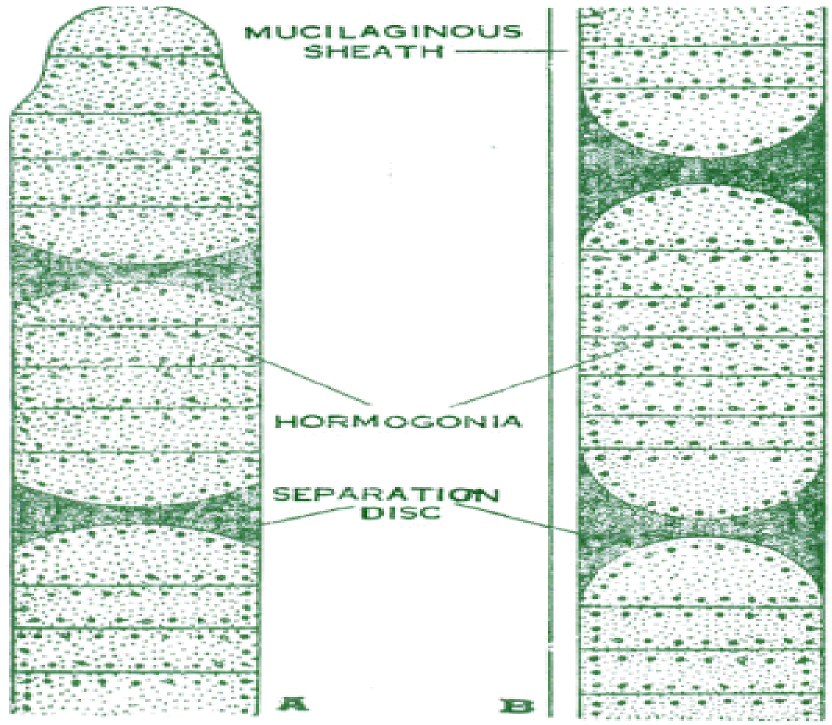
Reproduction: *Oscillatoria* reproduces vegetatively. The only known method is by the formation of hormogones. The hormogones are short sections or lengths or living cells separated from the trichomes. The break takes place where a dead cell (necridium) is situated. During the growing season a cell here and there in the trichome will collapses (dies). The protoplast of such cells changes into a transparent, viscous substance called the mucilage. The mucilage filled dead cells are called necridia. The dead cell loses its turgidity. The mutual pressure on the walls of the adjacent cells is released. The mucilage swells and necridia break down releasing the hormogones. Each hormogone may consiste a few to several living cells. Sometimes hormogone break off from the extremity of the trichome. The hormogones exhibit a greater capacity for a slow forward motion than the vegetative trichome. They move away from the latter. By repeated cell division (fission) in all the cells hormogone grows into a full-length, typical trichome.

Occasionally propagation by fragmentation also takes place. It may result from the bites of the animals feeding on the trichomes. Formation of spores, heterocysts and akinetes has not been observed in *Oscillatoria.*

TRIBE: HORMOGONEAE: ORDER 2 : Nostocales

Family Nostocaceae. The trichomes are composed of a row or similar cells and are either free or embedded in a common matrix of mucilage. Certain cells in the trichome form heterocysts and some akinetes. The former are intercalary, rarely terminal in position and occur either singly or more than one together. Reproduction is by hormogonia and in some by spores in addition. The important genera included in the family are *Nostoc, Aulosira, Nodularia, Anabaena* and *Aphanizomenon.* Here *Nostoc* is taken as a type.

Taxonomic Position:
Division: Cyanophyta
Class : Cyanophyceae
Tribe : Hormogoneae
Order : Oscillatoriales
Family : Oscillatoriaceae
Genus : *Oscillatoria*



NOSTOC (Vaucher, 1803)

Occurrence. It is filamentous form of both terrestrial and aquatic habitats. It does not occur in single filaments but grows in large colonies of closely packed trichomes embedded in a firm matrix of gelatinous material. Nostoc colony thus forms a mucilaginous lump or thallus which occurs floating or attached. The thalli are of various sizes and shapes and may be solid or hollow. They may be balls of a jelley-like substance (Fig. 2.22A) or may be irregularly shaped. In size they may be microscopic, pea-size, walnut size or as large as a plum. Sometimes they may reach a diameter of eight centimetres. *Nostoc* also occurs in symbiotic association with fungi to form lichens. Some species of *Nostoc* have been reported to fix atomspheric nitrogen and tend to maintain fertility of paddy fields in which these forms regularly occur. Large colonies of terrestria species are eaten in the orient.

Reproduction. *Nostoc* reproduces entirely vegetatively by the following methods:-

1. Colony Fragmentation. The *Nostoc* colony as it gets larger frequently breaks up into flat expanses as a result of storms and other disturbances. Each of these grows up to the size of the parent'colony.

2. Hormogonia (Fig. 2.12 C). Hormogone formation is very common in *Nostoc.* The trichome ruptures at places where a heterocyst and the vegetative cell adjoin. This junction is the weakest link in the chain. In fact some algologists believe that heterocysts represent a mechanism for the fragmentation of the trichome. In this way short segments of living cells called the hormogonia became isolated.

3. **Resting spores or akinetes** (Fig. 2.23). Under certain conditions any cell or some of the vegetative cells of the trichome become enlarged and each secretes a thick, highly resistant wall around it. They get gorged with reserve food materials. These are well adapted to survive unfavourable conditions such as water shortage and unsuitable temperature. It is not unusual to find all the cells between two heterocysts and occasionally the entire trichome converted into akinetes. With the return of favourable season each akinete germinates to form a new filament of *Nostoc.*

Taxonomic Position:

Division**:** Cyanophyta
Class : Cyanophyceae
Tribe : Hormogoneae
Order : Nostocacales
Family : Nostocaceae
Genus : *Nostoc*
Species : *muscorum*

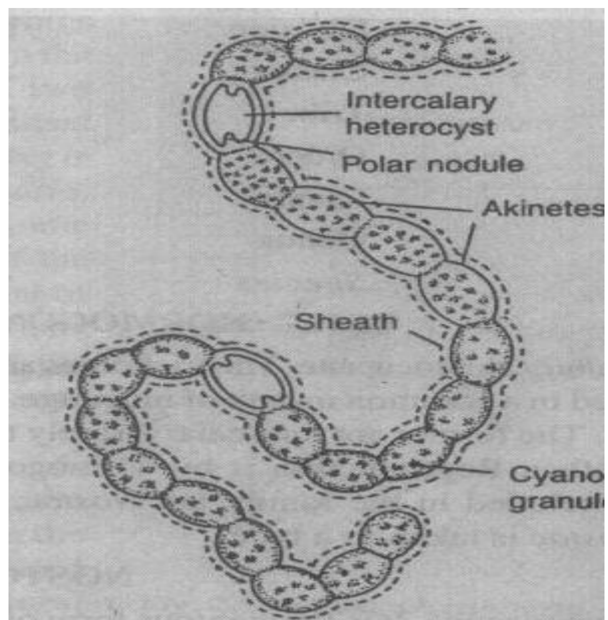
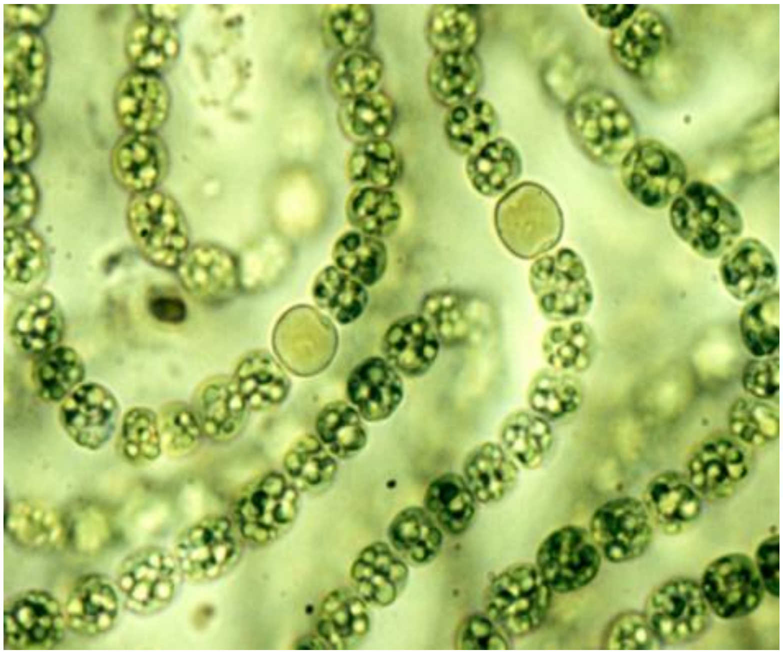
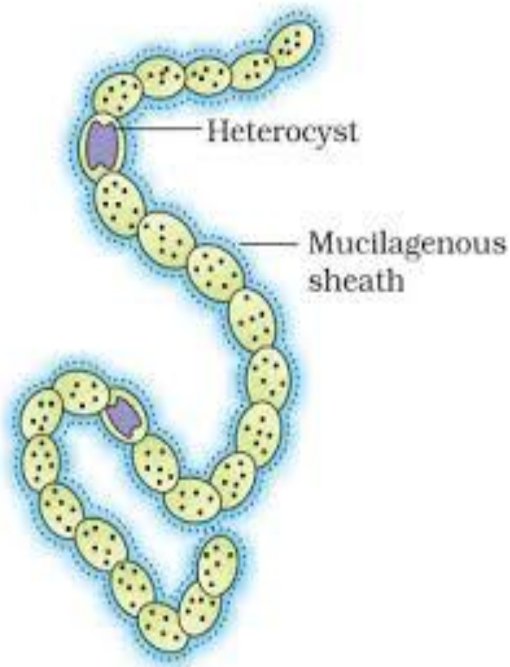
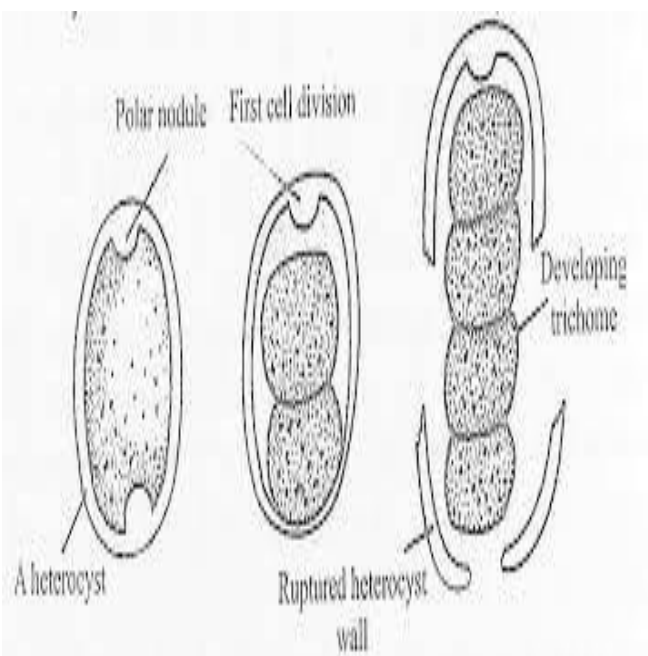


Fig. 2.23. *Nostoc* sp. A filament with trichome.







Heterocyst germination of Nostoc

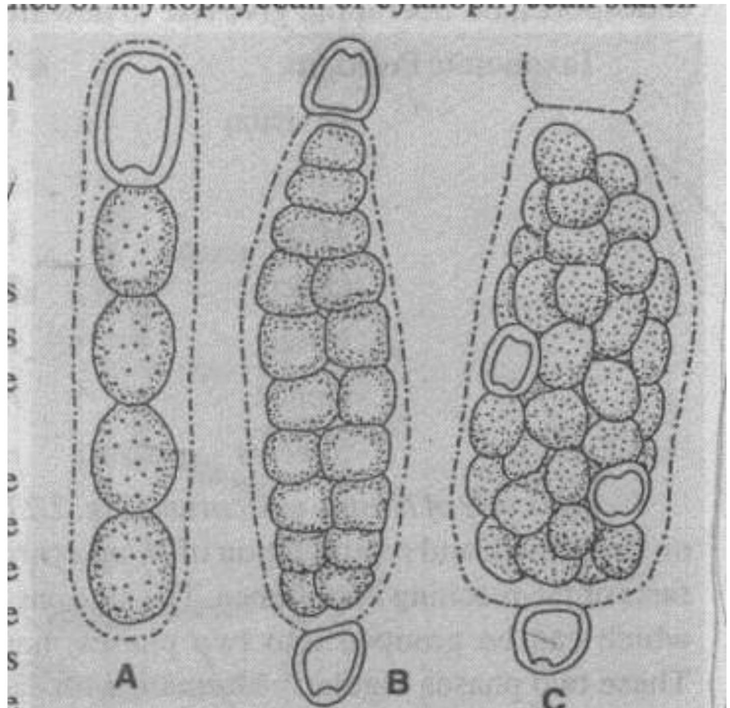


Fig. 2.25 (A-C). *Nostoc*, Stages in germination of a hormogone to form a new colony (C).

Rivularia

Vegetative Body of Rivularia

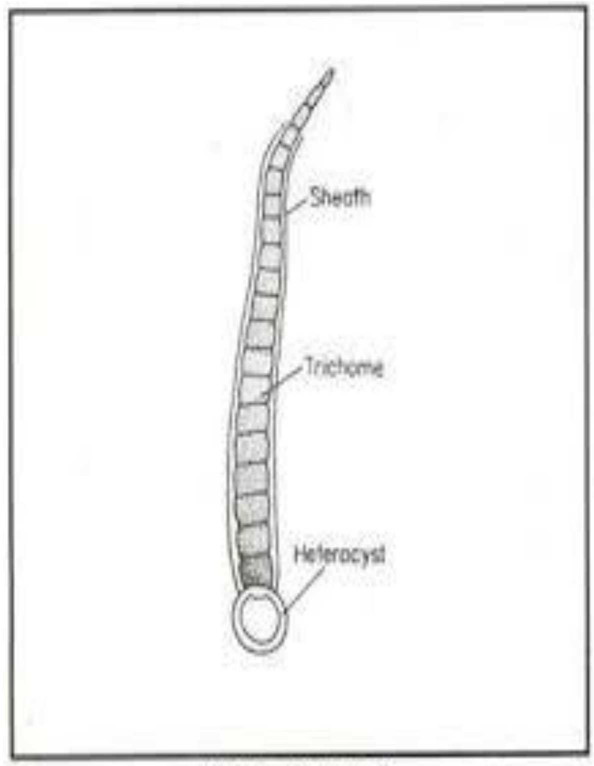


Fig 2.9. Rivularia Sp.

Each filament is whip-like and consists of a single trichome, which is gradually attenuated from the base to the apex and surrounded by a distinct sheath. There is always a heterocyst at the base of each trichome. The sheath, either homogeneous or stratified, is usually distinct towards the lower portion of the trichome. The sheaths of several such filaments become partially or wholly fused forming hemispherical, globose or expanded masses of macroscopic size. Within such a mass, the filaments are somewhat radiately arranged, and this is due to repeated false branching towards the basal portion of the thallus. But these branches are so much displaced that it becomes difficult for observation in a mature thallus.

Reproduction in Rivularia:

Reproduction takes place by the formation of hormogones, which are normally developed towards the distal end of each filament. Akinetes are not found in this alga.

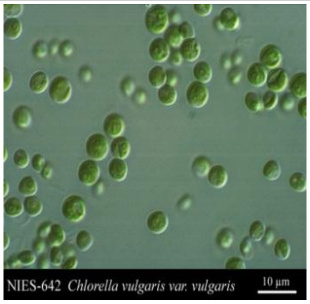
Division : Chlorophyta (Chlorophycophyta)

Class$_1$: Chlorophyceae

The division Chlorophyta more appropriately called Chlorophycophyta includes a large number of species. Prescott makes as many as 20,000 species. These are included in a single class Chlorophyceae. The Chlorophyta and the Chlorophyceae have the same features. The cells constituting the thallus are eukaryotic and thus contain all the membrane bound cell organelles such as the definitely organised nucleus, plastids, mitochondria, dictyosomes, endoplasmic reticulum, and true vesicles.

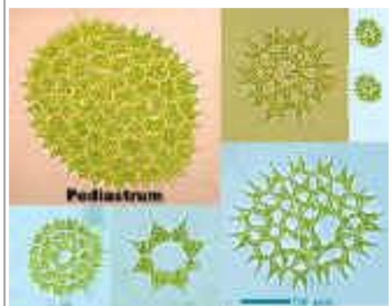
The thallus is typically green in colour due to the presence of a green pigment, the chlorophyll. It is contained in plastids called the chloroplasts. Embedded in the chloroplasts are rounded, proteinaceous bodies one or more in number, the pyrenoids. The pyrenoids are intimately associated with the elaboration of starch, which is the principal storage product. The cytoplasm contains vacuoles. Some of these may be contractile. The motile cell of the primitive forms contains an eyespot or stigma. The presence of membrane bound chloroplasts; a sap cavity and a definite nucleus in the cell are the chief characteristics besides others which distinguish the Chlorophyta from the Cyanophyta. The reserve carbohydrates are usually stored in the form of starch. The cell wall invariably contains cellulose. Unlike the blue-greens most of the green algae produce motile reproductive bodies generally furnished with two to four flagella. The flagella are of equal length and of whiplash type. They are inserted at the anterior end. Occurrence of sexual reproduction is another feature which distinguishes the Chlorophyceae from the Cyanophyceae.

Organisation of thallus



Chlorella (non-motile unicell)

Chlamydomonas (motile unicell)



Pediastrum (non-motile colony)

Volvox (motile colony)

Pandoria (motile colony)

Gonium (motile colony)

The Chlorophyceae are a heterogeneous group of plants exhibiting a wide range of the body plan (architecture). The plant body may be single-celled or many-celled. In size it varies from minute unicells no more than a micron or two in diameter to a few feet long, strand like structure. Morphologically it may consist of motile or non motile unicells, motile and non-motile colonies, simple and branched filaments, siphonaceous and coenocytic filaments, foliaceous thalli, cushion-like thalli and highly evolved heterotrichous filament. However it is always of a simple construction. It shows no differentiation into true root, stem and leaves. For this reason the plant body of the algae is called a thallus.

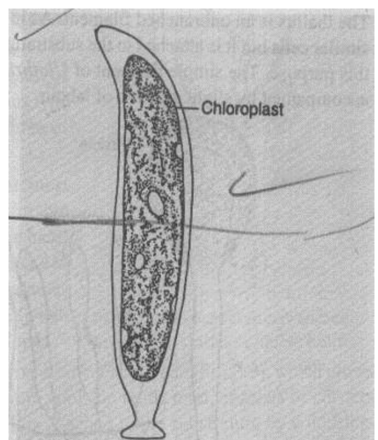
1. **Unicellular thallus**. In the simplest forms the hallus is a unicell. It is motile in some and non-motile or amoeboid in others.

a) Motile Unicellular Thallus. *Chlamydomonas* is an example. The cell may be spherical, oval or pear-shaped. It is furnished with two flagella at its anterior end and has a single cup-shaped chloroplast situated in its posterior part. The single nucleus lies in the cavity of the cup surrounded by cytoplasm. There are two pulsating contractile vacuoles at its anterior end and a single red eye spot. *Chlamydomonas* has animal-like locomotion but is autophytic in its nutrition.

b) Non-motile Unicellular Thallus. *Chlorella* and *Chlorococcum* represent such a type of thallus. The plant body is a small spherical cell. It is non-motile and lacks flagella, eyespot and contractile vacuoles. It has a parietal chloroplast and a centrally located nucleus. Such non-motile unicellular forms are called coccoid Chlorophyta.

2. Colonial thallus. Many of the green algae have a thallus consisting of a loose assemblage of cells mechanically held together generally in a gelatinous envelope. It is known as a colony. The cells in the colony have little or no dependence upon one another. The colonial thalli are of diverse forms. They may be plate like or hollow spheres, motile or non-motile.

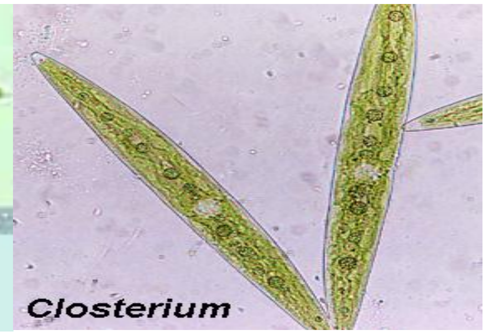
a) Motile colonial thallus. It consists of a definite number of motile, unicellular *Chlamydomonas* or Sphaerella type cells held together in a common mucilaginous sheath. The individual cells are complete in themselves and independent of each other.



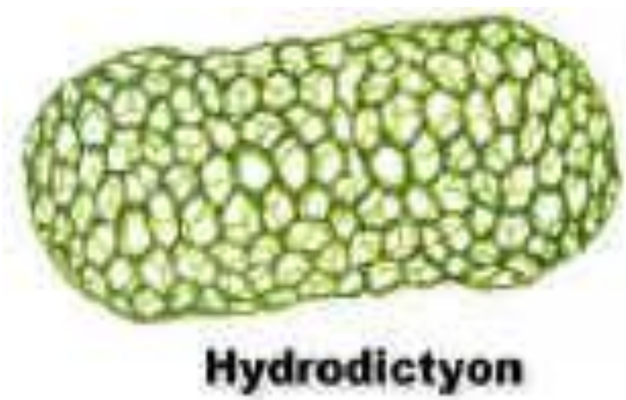
Fig, 3.3(A). *Chlorophyceae*. Tubular uni-nucleate thallus of *Characium*

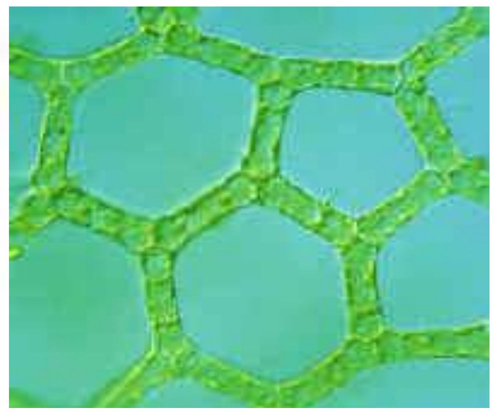
They act together and bring about the movement of the entire colony. Examples are *Gonium*, *Pandorina* and *Eudorina*. Hollow spherical colony of *Volvox* represents the most highly developed motile colonial thallus. It is made up of thousands of cells, which in some species are connected with one another by cytoplasmic strands.

a) Non-motile colonial thallus. In certain members of the order Chlorococcales the small, non-motile cells are held together to form non-motile colonies with either a definite or an indefinite number of cells. They are free floating colonies. *Pediastrum* and *Hydrodictyon* are the important examples. *Hydrodictyon* represents the highest state of organisation of this type.



Scenedesmus

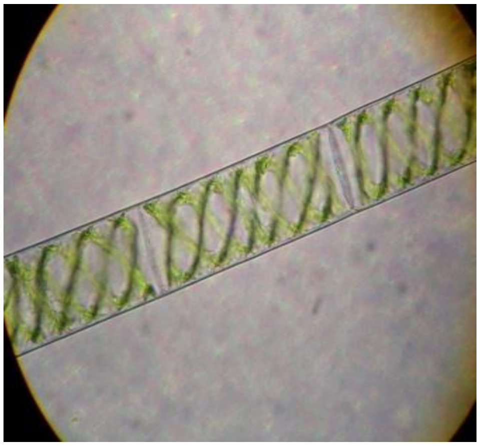
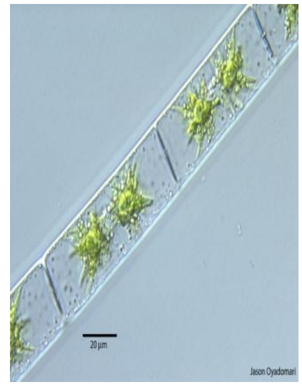
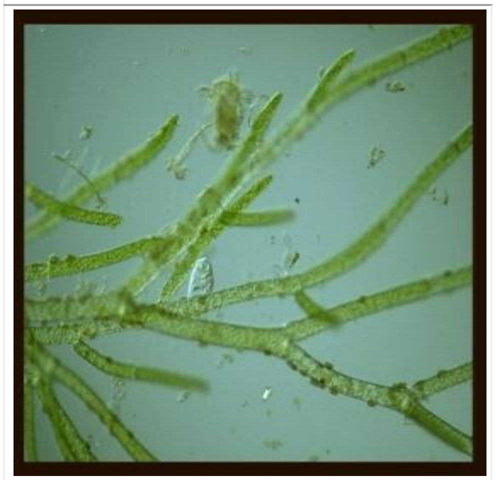
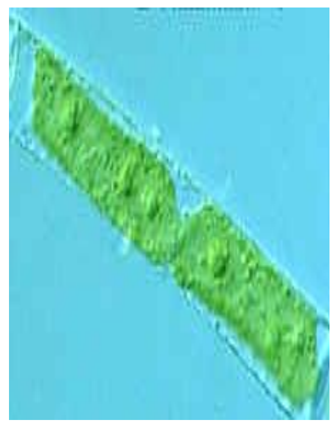




3. Siphonaceous or Coenocytic thallus.

In this case the unicellular thallus is enlarged to form a non septate multinucleate sac-like or tubular structure which is not divided into cells in the somatic phase. *Protosiphon* has an unseptate, unbranched, tubular thallus containing numerous nuclei.

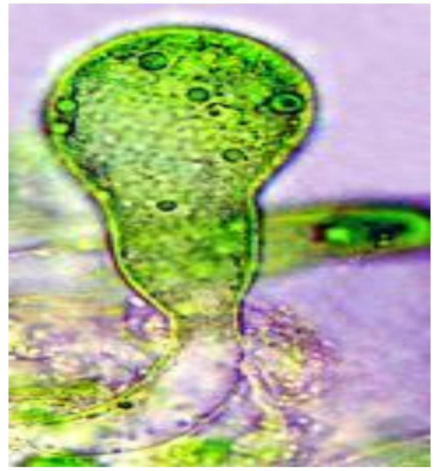
4. Multicellular filamentous thallus. In this species of green algae, the cells are arranged in linear rows called the threads or filaments. The filament is the result of repeated cell division of a non-motile cell in a single plane. The divisions are all in parallel planes resulting in the formation of a chain of cells. The daughter cells in the chain remain united and further keep on divided in the same plane forming a simple filament. The filamentous thallus is well adapted for a great variety of fresh water and marine habitats.

 *Spirogyra* has spiral Chloroplasts	 *Ulothrix* has band-shaped Chloroplasts	 *Zygnema* has Star-shaped Chloroplasts
 *Cladophora*	 *Cladophora* has many small oval Chloroplasts	 *Mougeotia* has a flat Chloroplast. The disk-like areas are Pyrenoids.

a) Simple filament. The simple multicellular forms such as *Spirogyra* have a plant body in which the cells are arranged from end to end in a single file and are held together firmly (filament). As in *Spirogyra* the simple filament of *Ulotherix* consistes of similar cells but it is attached to the substratum at one end by a rhizoidal cell specially modified for this purops.

b) Branched filament. In more advanced multicellular green algae such as *Cladophora*. The thallus is a branched filament. It is formed when an occasional cell in the filament divides in a second plane.

5. Foliaceous thallus. When cell divisions occur in two planes (transverse and longitudinal) in the cells of a simple filament, the result is a thin, flat, plate-like thallus resembling papery expansion (large-green sheets of paper).



Ulva *Protosiphon*

Ulva is an example possessing a foliaceous type of thallus which is a modification of a filamentous habit.

Reproduction: In green algae it takes place by all the three methods, namely, vegetative, asexual and sexual.

1. Vegetative reproduction.

Propagation of the species by any method which uses only vegetative cells is known as vegetative reproduction**.** In this method the parent cell wall is retained**.** It may take place by cell division, fragmentation or akinete formation.

a) Cell division. The unicellular forms commonly. Reproduce by a simple process involving cell division. It is called fission. The division of the cell is preceded by the division of the nucleus which is mitotic. The nuclear division is followed by cleavage of the cytoplasm which begins by a median**.**

b) Fragmentation. It involves the breaking up of the multicellular filamentous thallus (*Spirogyra*) into one or many-celled segments of living cells. These are called the fragments. The fragmentation of the filament may be result of external forces or formation of mitospores (zoospores and aplanospores) or gamates in certain parts of the filament followed by the breaking up of empty cells**.** Each fragment function as a reproductive unit. The fragment by repeated cell division and subsequent growth of the component cells grows into a new filament. Fragmentation thus serves to increase the number of filaments in a mass. Cell division and fragmentation both constitute vegetative methods of reproduction which takes place under exceptionally favourably conditions.

c) Akinetes. These one –celled specially modified resting vegetative structures. Some scientists consider them to be modified one- celled fragments. Under certain conditions cells here and there in the filament (*Pithophora*) lose water and contract to become rounded or ovalin form. They become gorged with reserve food materials. The parent cell wall becomes thickened and highly resistant. They occur either singly or in chains in the vegetative filament and enable the plant to tide over unfavourable conditions. Each akinete may germinate directly to form a new individual or its protoplast divides to form asexual spores which on liberation germinate to form a new plant.

2. Asexual reproduction.

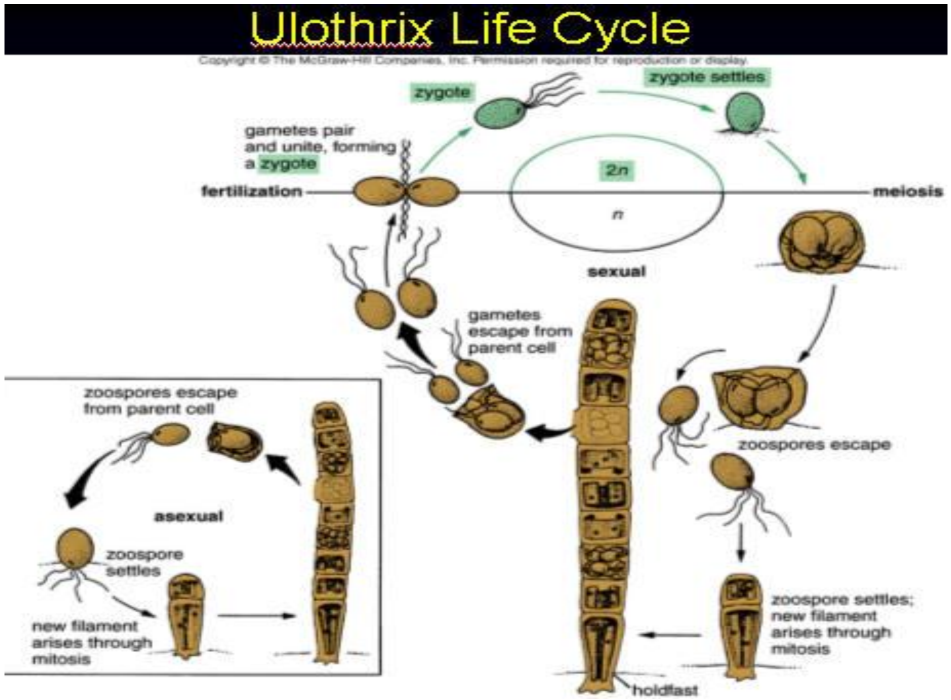
It involves the multiplication of the species by the formation of highly specialized reproductive cells called the asexual spores. Reproduction by asexual spores is a very common method of propagation under normal conditions of life and is called sporulation. Each asexual spore, on germination, is alone capable of directly giving rise to a new individual without uniting with any other cells. In green algae the asexual spores are usually produced by the haploid plants and thus are genetically haploid. They are usually produced endogenously in more or less specialized cells called the sporangia and are differentiated by mitosis from the protoplast of the sporangium. The mitospores are asexual spores. They may be motile (zoospores) or non-motile (aplanospores).

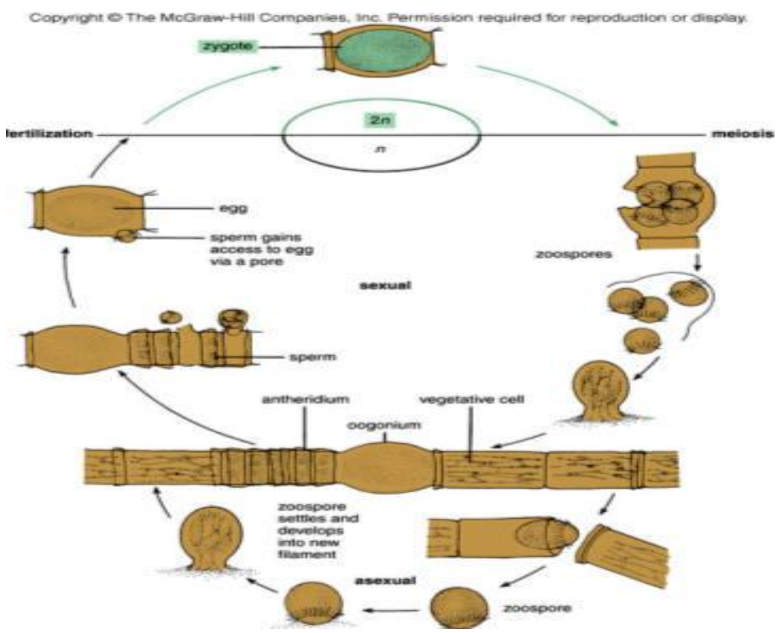
a) Zoospore formation. The common and characteristic method by which asexual reproduction operates in the green algae is by the formation of motile, naked asexual spores called the zoospores. They may be bi-or quadric-flagellate (*Ulothrix*), with a ring of flagella and thus multiflagellate (*Oedogonim*). They are usually formed during night and develop either in any of the vegetative cells or in specialized cells called the zoosporangia. The protoplast of the cell may develop into a single zoospore (*Oedogonim*) or it may divisions resulting in the formation of several zoospores (*Ulothrix*). They escape in the morning from the parent cell through a pore in the surrounding cell wall or by rupturing of the cell wall. The liberated zoospore is tiny, naked mass of protoplast containing a single nucleus, an eye-spot and one or more chloroplast. The flagella are of equal lengths (isokont). Each zoospore under favorable conditions develops into a new plant resembling the parent.

b) Aplanospore formation. The non-motile asexual spores called aplanospores are formed in the algae subaerial habitats. In the aquatic forms they are produced under unsuitable conditions. The protoplast of the cell may form a single aplanospore (*Microspora*) or more than one. Each aplanospore secretes a wall around itself before liberation from the parent cell. It lacks flagella and thus is non-motile. It has no eye spot and is enclosed by a cell wall. The Aplanospore germinates directly to give rise to a new individual resembling the parent. when the non-motile spores produced appear identical to the parent cell, they are autospores (*Chlorella*). Under certain circumstances the aplanospore secrete thick walls around them and store food reserves are called hypnospores.

3- Sexual reproduction

Sexual reproduction is very common and may be isogamous (gametes both motile and same size); **anisogamous** (both motile and different sizes - female bigger) or **oogamous** (female non-motile and egg-like; male motile). Many green algae have an alternation of haploid and diploid phases. The haploid phases form gametangia (sexual reproductive organs) and the diploid phases form zoospores by reduction division (meiosis). Some do not have an alternation of generations, meiosis occurring in the zygote. When two gametes meet, fertilization takes place and a diploid zygote is formed. The zygote then germinates, undergoes meiosis and forms haploid spores. The diploid phase of the life cycle is brief and unicellular. There are a few exceptions this general life cycle, such as the *Ulva* (sea lettuce), which has a multicellular diploid phase similar to that found in brown algae.





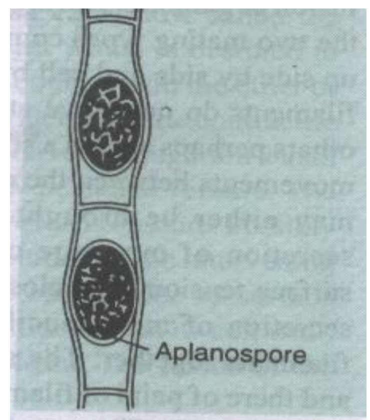
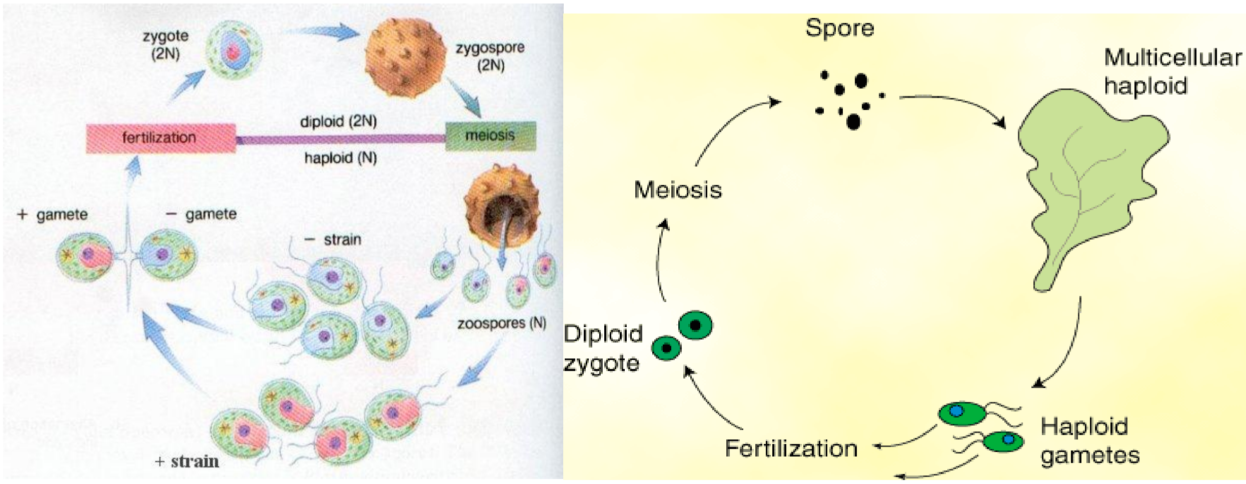
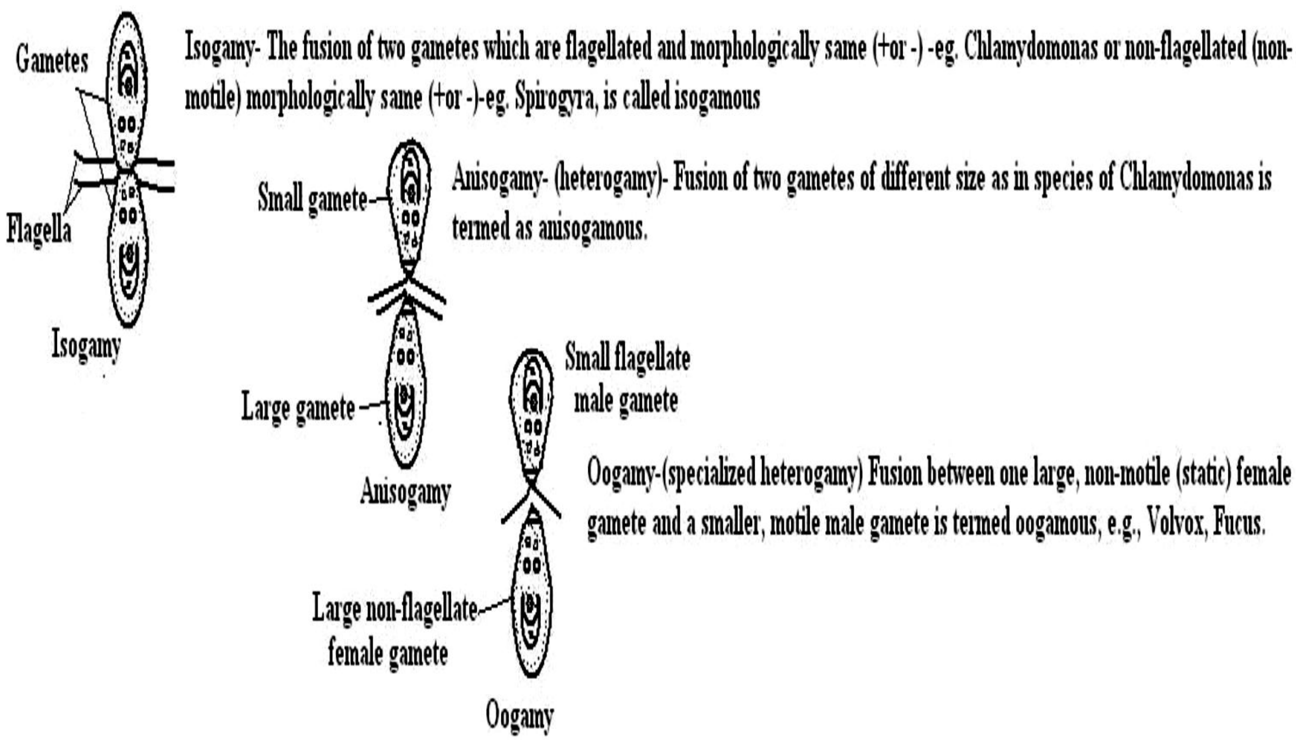


Fig. 11.19. *Spirogyra karnalae*. Aplanospore formation (After Randhawa).

Odogonium **life cycle**



Life cycle of the green algae



Salient Features of Green Algae:

The **Chlorophyta** are characterised by the following :

1. They are grass green in colour owing to the preponderance of chlorophyll *a* and *b* over carotene and xanthophyll.

2. The pigments are localised in the green plastids known as chloroplasts.

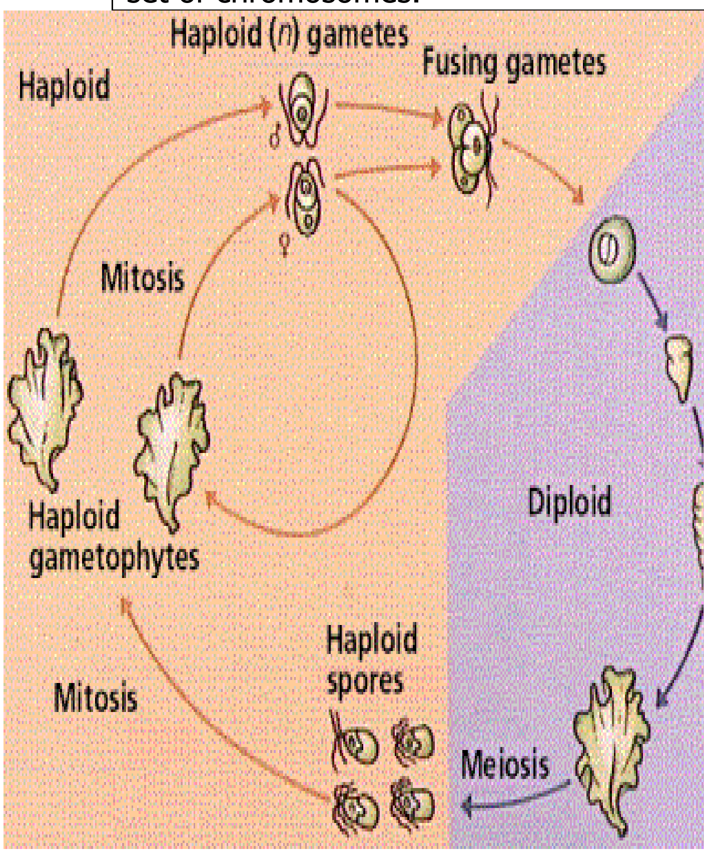
3. The reserve carbohydrate food is stored as starch.
4. The chloroplasts normally contain the pyrenoids.
5. The cell has a well defined nucleus and in the higher forms a central sap cavity in addition.
6. The cell wall is stable and invariably contains cellulose.
7. The majority produce motile reproductive cells which may be bi-or quadriflagellate rarely with a ring of flagella as in oedogoniales. The flagella are of equal length and of whiplash type inserted at the anterior end.
8. Sexual reproduction ranges from isogamy to oogamy. The zygote nearly always enters upon the resting period.
9. The sex organs are always unicellular.
10. Zygote generally is the only diploid structure in the life cycle.

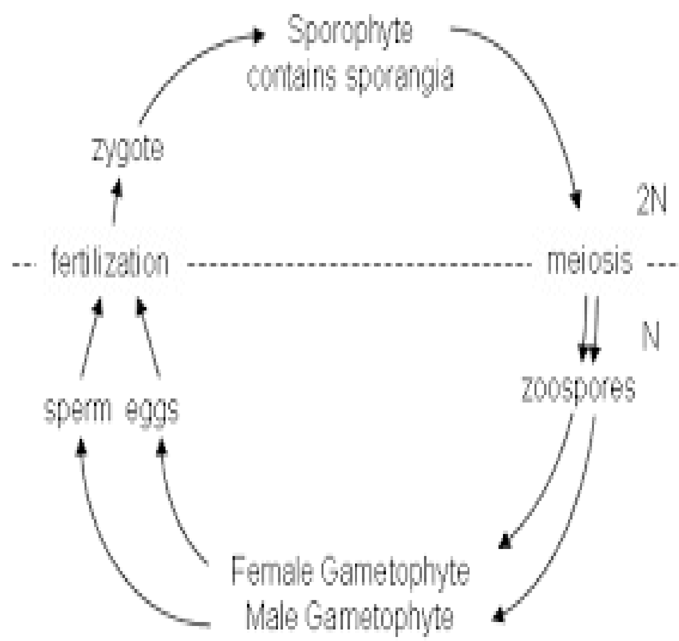
Alternation of Generation in green algae

Alternation of generations is a term used to describe the type of life cycle that occurs in those plants and algae. The alternation of generations allows algae to reproduce both sexually and asexually. In the single life cycle of the certain sexually reproduction plants there occur two individuals. One of these is the **sporophyte**. It is characterized by the diploid number of chromosomes in the nuclei of its cells. The diploid sporophyte is concerned with the production of haploid spores called the meiospores. They are differentiated by meiosis. The other individual is the **gametophyte**. It is charaterised by the haploid number of chromosomes in the nuclei of its cells.it is responsible for sexual reproduction. It bears the haploid gametes. These two individuals normal follow each other. In algae, the dominant phase is gametophyte (1n). Sporophytic and gametophytic stages are independent.

The difference between sporophyte and gametophyte

Gametophyte	Sporophyte
It is the haploid (n) phase in the life cycle	It is the diploid (2n) phase in the life cycle.
It forms gametes.	It forms spores.
The gametes are formed either directly or through mitosis.	The spores are formed after meiosis.
Gametes take part in fertilization or fusion forming diploid (2n) zygote.	The diploid spore mother cell undergo meiosis to form haploid (n) Meiospores.
Growth of zygote produces the sporophyte.	Growth of meiospore produces the gametophyte.
The cells possess a single genome or one set of chromosomes.	The cells possess two genomes or two sets of chromosomes.





CLASS1 : Chlorophyceae

Order 1 : Volvocales

The Volvocales include chiefly the microscopic genera of the green algae in which the thallus ' is one-celled and generally motile throughout life. The unicell is furnished with 2 rarely 4 whiplash type flagella of equal length. This is the only order of the green algae in which the vegetative cell is actively motile. In some genera the motile cells are joined into groups to form an organisation called a colony, A colony is an aggregation of individuals mechanically held together generally in a gelatinous sheath. The individuals in the colony have little or no dependence upon others. The colonies included in this order have a definite number of cells arranged in a specific manner. This type of colony is called cocnobium. The coenobia are motile. The order Volvocales, therefore, includes both **unicellular** and **colonial** forms which occur widely in fresh water plankton. They are absent from the sea. Almost all the representatives are fresh water. Many of them prefer water rich in nitrogen and organic substances and thus occur in quiet pools. The order comprises at least six families (Chlamydomonadaceae, Volvocaceae Polyblepharidaceae, Chlorodendraceae, Phacotaceae and Sphaerellaceae) with about 60 genera and about 500 species. Of these Chlamydomondaceae is described here .

Family 1. Chlamydomonadaceae

The family includes unicellular motile forms with a distinct cell wall. It comprises about 20 genera. The cell is bi-or quadriflagellate *(Carteria),* The flagella are of equal length (isokont). Asexual reproduction takes place by zoospores. Sexual reproduction ranges from isogamy to oogamy through anisogamy. The zygote undergoes the resting period. The division of the zygote nucleus is meiotic. The important genera included in this family are *Chlamydomonas, Hqematococcus (Sphaerella), Carteria, Chloromonas, Polytoma, Polytomella* and *Hyaliella.* Of these *Chlamydomonas* is usually taken as a type.

Chlamydomonas

Structure of Thallus. (Fig. 4.1 A).

The plant body is a thallus which consists of a single biflagellate cell (A). In some species the unicell is about 20 microns in length. It rarely exceeds 30 M in major diameter. The unicellular thallus is biflagellate and usually oval (egg-shaped) or rather oblong in form. Other forms such as cylindric, pear-shaped and spherical are by no means rare. The motile forms like *Chlamydomonas* have an advantage over the non-motile blue green algae in that they swim toward better conditions of light and also move away from shallow water which becomes unbearably hot in summer months.

Nutrition :*Chlamydomonas* is an autotroph. The mode of nutrition like other green plants is holophytic. By virtue of its chlorophyll *Chlamydomonas* cell manufactures sugar in the presence of sunlight from water and carbon dioxide. The raw materials for the photosynthetic process are absorbed over its surface from the surrounding water. The sugar formed is used up as a source of food. The excess of sugar synthesised during photosynthesis is converted to starch which accumulates in the form of little grains or plates around the pyrenoids. All the species of *Chlamydomonas* thus are obligate phototrophs. The only exception if C. *dysosmos* which is a facultative heterotroph.

Respiration : Oxygen is absorbed from the surrounding water over the entire surface of the cell. It combines with the sugar and sets free the potential energy (absorbed from the sun during photosynthesis) in the form of kinetic energy which keeps the vital processes of the cell going.

Excretion: The two contractile vacuoles function as reservoirs for the accumulation of waste materials. They pulsate rhythmically in alternation by the contraction of the surrounding cytoplasm. As a result the waste materials are forced out through the cell wall.

Growth: It consists entirely of cell enlargement.

Reproduction: *Chlamydomonas* reproduces both by asexual and sexual methods.

I. **Asexual Reproduction**: It takes place by the following methods:

(a) *Zoospore Formation* (Fig. 4.4). *Chlamydomonas* multiplies asexually by Zoospore in the growing season. The parent cell comes to rest. The flagella are resorbed, contractile vacuoles disappear and the protoplast withdraws from the cell wall (A). In this quiescent state the cytoplasm, chloroplast and the nucleus divide along a longitudinal plane into two daughter protoplasts (B). The nuclear division is mitotic. A few species, however, remain motile during division. The division of the parent protoplast into two daughter protoplasts is brought about by a constriction which appears at the back and front ends and gradually deepens. In some species the protoplast during or after division rotates through a right angle (C and D). Consequently the division comes to be transverse with respect to the cell as a whole (D). It lies across the short diameter of the parent cell. However it is still longitudinal with respect to the protoplast. No rotation of the protoplast during division takes place in other species. The second division is at right angles to the first. It is again longitudinal to the axis of the protoplast. In this way usually four daughter protoplasts may be formed (E). The chloroplast is halved along with the pyrenoid at each successive division. One daughter cell receives the eye spot of the parent, the other forms it a fresh. The a flagellate daughter protoplasts remain bound within the parent cell wall (F).

(c) Palmella stage (Fig. 4.5). Under certain unsuitable conditions the motile cells come to rest and lose flagella. The protoplast of each divides repeatedly by the method of successive bipartition into two (A and B), four or eight daughter cells. The resultant daughter protoplasts fail to develop flagella (particularly in species growing on moist soil) and thus do not escape. They remain clustered together in the parent cell wall which subsequently becomes mucilaginous and swells up considerably. Numerous aflagellate daughter protoplasts thus become embedded within a common mucilaginous matrix formed by the gelatinisation of the parent cell walls (C). Each such daughter cell may in turn divide and the process of division may continue indefinitely. Repeated divisions of these daughter cells are accompanied by progressive gelatinization of the walls of the successive generations.

Palmella stage: Under the unfavorable condition the cell becomes non motile by withdrawing its flagella then protoplasmic content divide into 2, 4 0r 8 daughter protoplast. But the daughter protoplast fails to develop their flagella. So they cannot escape out. Instead of releasing out, the protoplast divides into small daughter protoplast. As number of cells is increased the parent cell gelatinized and increases its circumference. As a result, certain no. of cells is embedded within parent cell wall and is called palmella stage. When the condition becomes favorable, each daughter protoplast is converted into zoospores and after releasing out it forms new individual.

Finally a colony of considerable size containing numerous cells embedded in a common mucilaginous mass is formed. This assemblage of the cells is known as the Palmella stage (C) because the older phycologists mistook them to be species of another alga of that name (Palmella). This stage is usually of brief duration. The individual cells, after some time when conditions for growth become favourable, become motile and escape from the mucilage envelope to produce the motile stage again. Palmella stage is an immobile reproductive phase. It helps *Chlamydomonas* to survive periods of partial desiccation or tide over spells of adversity when the ionic balance of the medium becomes unfavourable.

2. Sexual Reproduction

Sexuality is controlled by certain environmental factors. The chief among these which favour sexual reproduction are (i) low supply of nitrogen, (ii) deficiency of nutritive materials, (iii) temperature and ion concentration, and (iv) bright sunlight and high CO_2 concentration. The presence of calcium, essential for mating. Ammonium nitrogen inhibits sexuality. Sexual reproduction in *Chlamydomonas* varies through a wide range. It ranges from isogamy to anisogamy. The gametes are biflagellate and may be naked or covered with a cell wall. The former are called gymnogametes and the latter lyptogametes.

(a) Isogamy. The fusing gametes are similar in size, form and structure and thus are called the isogametes.

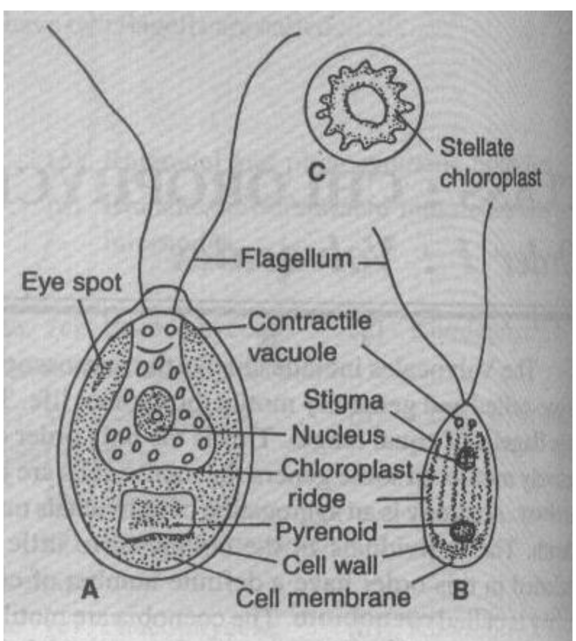


Fig. 4.1 (A-C). *Volvocales* (A) *Chlamydomonas angulosa*; (B) *C. steinu steinii*; (C) Optical T.S. of B (After Dill).

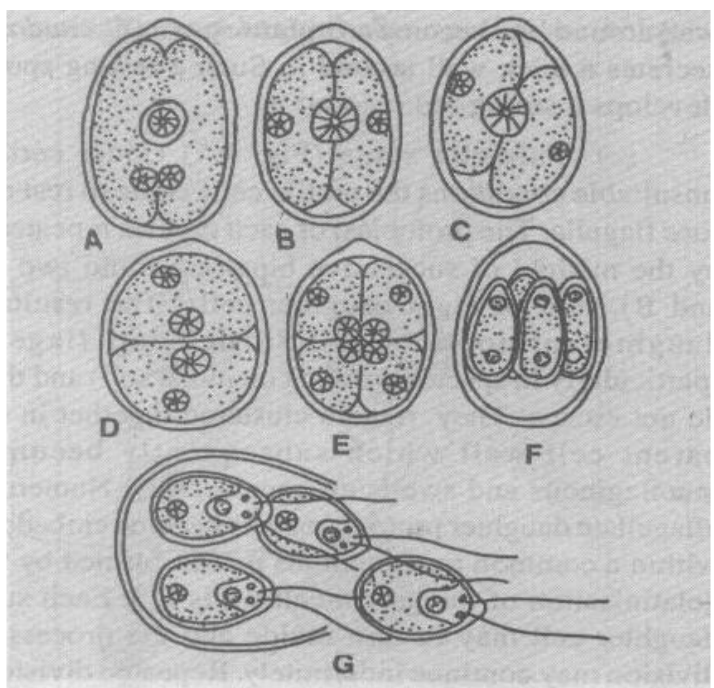


Fig. 4.4 (A-G) *Chlamydomonas sp.* Successive stages in zoospore formation.

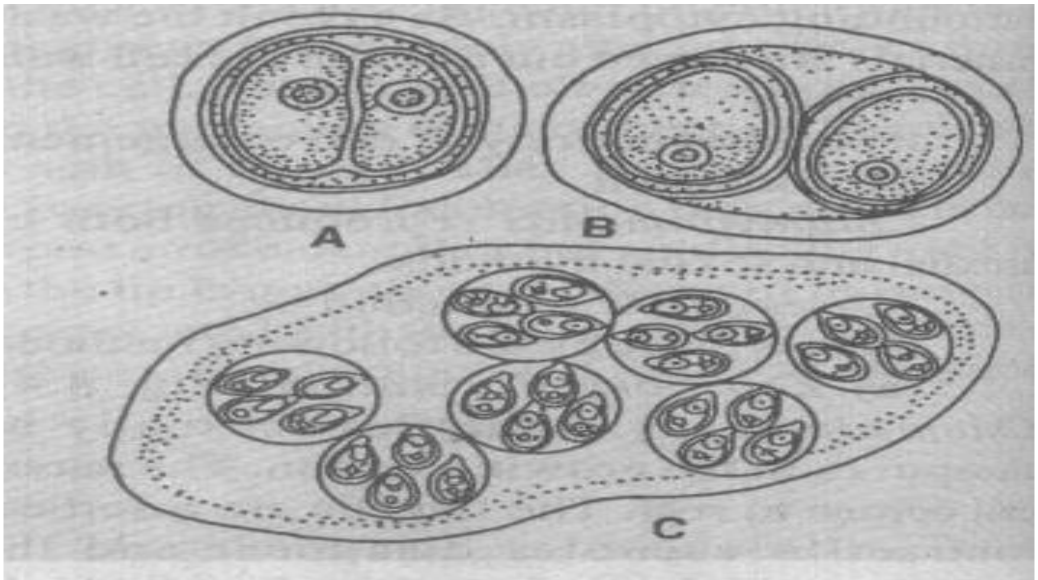
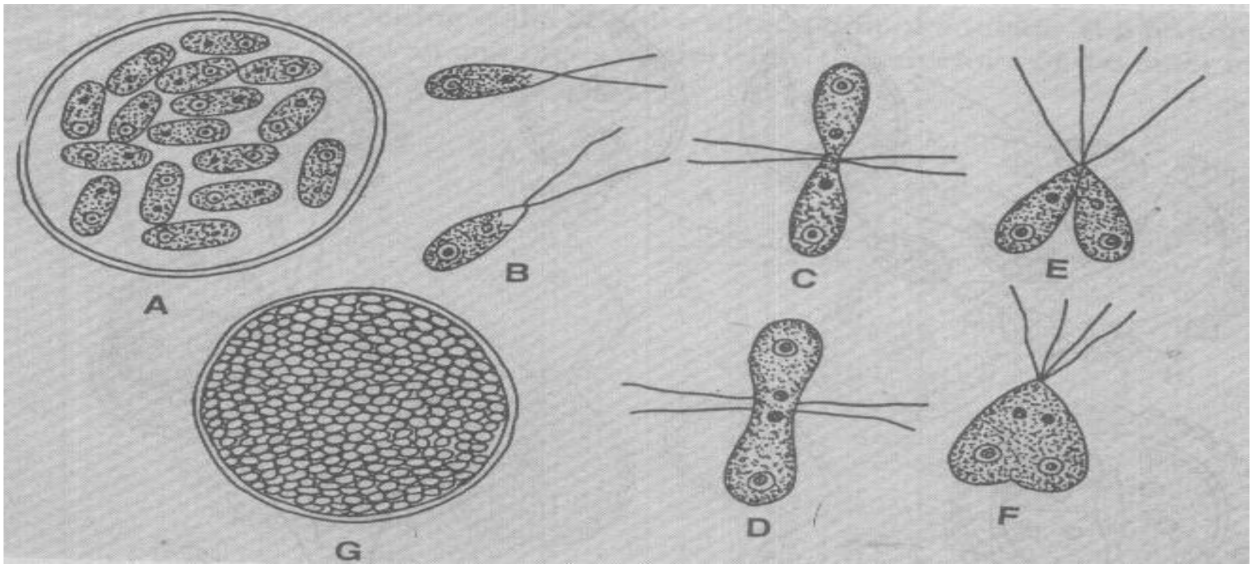


Fig. 4.5 (A-C) *Chlamydomonas sp*. Successive stages in the formation of palmella stage (After Goroschanken).

Life Cycle of *Chlamydomonas* sp.

The sexual life cycle of *Chlamydomonas* consists of two phases, the haploid and the diploid. The haploid-phase is represented by the motile *Chlamydomonas* cell and the gametes which it produces. Both have a haploid number of chromosomes which in C. reinhardii is sixteen. The zygospore is the only diploid structure which represents the liplophase. The haploid *Chlamydomonas* normally multiplies repeatedly by zoospores. There is thus a succession of haploid phases. Towards the close of the growing season *Chlamydomonas* resorts to sexual reproduction. It takes place only once in the growing season. During sexual reproduction there is fusion between the two motile or one motile and the other non-motile gametes. With the fusion of the gametes or fertilisation the haplophase ends. The resultant fusion cell is diploid and is called the zygote.



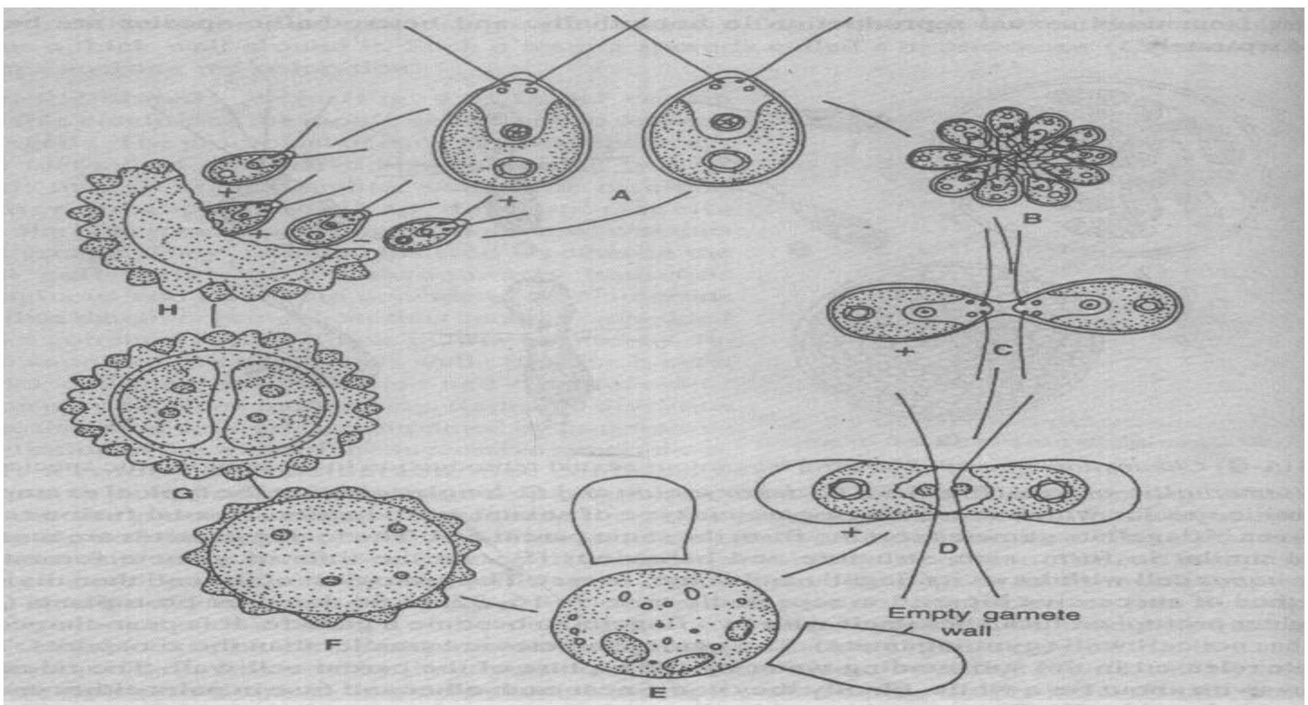


Fig. 4.7 *Chlamydomonas sp.* Showing isogamous sexual reproduction in the heterothallic spe

Sexual Reproduction of *Chlamydomonas* sp

Systematic Position:

Division : Chlorophyta
Class : Chlorophyceae
Order : Volvocales
Family : Chlamydomonadaceae
Genus : Chlamydomonas
Species : eugametos
CLASS1 : Chlorophyceae

Order 2 : Chlorococcales

General characteristics

The order includes unicellular, coenocytic and colonial, non-motile green algae. The colonial forms consist of a definite number of non-motile cells arranged in a specific manner. Such colonial forms are called coenobia. This coenobia included in this order are non-motile. Motility is confined to the gametes and zoospores only. The thallus in non-motile. Vegetative division of the cell is absent. Division takes place only at the time of reproduction. Unlike the Volvocales, the nuclear division in the reproductive cells is not immediately followed by cleavage of cytoplasm. There is thus a tendency for the cells in the Chlorococcales to become multinucleate for a short while. Even the unicellular forms do not multiply by binary fission. The vegetative cell in most species resembles *Chlamydomonas* in having a well-defined cell wall, a single nucleus and a single, massive parietal chloroplast with a single pyrenoid but differs in the absence of flagella, eyespot and contractile vacuoles. Some species reproduce by the formation of biflagellate zoospores but some are azoosporic and reproduce by aplanospores. The order comprises about 173 genera and 1,079 species. *Chlorococcum, Chlorella, Scenedesmus, Pediastrum, Hydrodictyon, Characium* and *Protosiphon* are the most important genera. Most of the members occur as fresh water plankton. Only a few species of *Chlorella, Characium* and *Oocystis* are marine. Some live in the moist soil, on walls and bark of trees. Some live in symbiotic relationship with fungi to form lichens and some in the lower animals. The order is divided into eight families by Fritsch (1935) and Smith (1955). The chief among these are Chlorellaceae, Selenestraceae, Dictyosphaeriaceae, Hydrodictyaceae, Coelastraceae, Protosiphonaceae.

Familyl : Chlorellaceae

The family Chlorellaceae includes forms which are usually solitary, free living or symbiotic and a few colonial members *(Radiococcus).* The cells are usually spherical or ellipsoid. Reproduction is by autospores. The autospores are non-motile spores resembling the parent in form and structure. The important unicellular member of this family is *Chlorella.* We study it in detail.

Chlorella

Occurrence

The genus comprises a number of species. These are *C. vulgaris, C. gonglomerata,* C. *conducterix* and *C. parasitica.* All are small, spherical, green unicells. They are generally found in fresh water of ponds and ditches, in moist soil or other damp situations such as the surface of tree trunks, water pots and damp walls. The common examples of the free living species are *Chlorella vulgaris* and *C. variegata.* The former is the commonest of the free living species. Some form symbiotic association in lichens and in certain invertebrates such as *Hydra, Paramecium* and *Sponges.* The species living as symbionts in these animals are called *C. zoochlorella.* A few species are reported to occur as parasites *(C. parasiticd).*

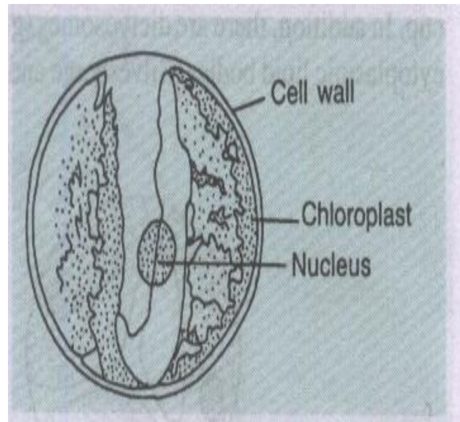


Fig. 5.1. *Chlorella.* A cell under light microscope.

Structure

Chlorella (Fig. 5.1) is known for its extreme simplicity. The plant is a unicell which at the most may grow to 10 M- in diameter but usually it is much smaller. Most of the cells of *C. variegata* are approximately 7 to 7.5JJ- in diameter. The small cells are non-motile, round or oval, usually found solitary, some times in groups. The **cell protoplast** is enclosed in a **membrane** which is selective in what it will allow to enter the cell. External to the cell membrane is the thick ceil wail. There is a single thin, usually cup-shaped or bell-shaped **chloroplast** which is parietal in position. Sometimes the chloroplast is a curved band or of irregular shape usually flattened against the cell wall. In the cavity of the chloroplast is the colourless cytoplasm in which lies the single central **nucleus.** The pyrenoids are usually absent. The stigma and contractile vacuoles are lacking.

Reproduction (Fig. 5.3, A-D)

The sole method of reproduction is asexual. The contents of the cell divide into 2,4 (B), 8(C) sometimes 16 daughter protoplasts. Each daughter protoplast rounds off to form a non-motile spore. These autospores (spores having the same distinctive shape as the parent cell) are liberated by the rupture of the parent cell wall (D). On release each autospore grows to become a new individual. The presence of sulphur in the culture medium is considered essential for cell division. It takes place even in the dark with sulphur alone as the source material but under light conditions nitrogen is also required in addition.

Asexual reproduction in *Chlorella ellipsoidea* has been studied in detail and the following four phases have been observed during the asexual reproduction.

a) Growth phase. During this phase the cells grow in size by utilising the photosynthetic products.

b) Ripening phase. In this phase the cell mature and prepare themselves for division.

c) Post ripening phase. During this phase, each mature cell divides twice either in dark or in light. The cells formed in dark are known as dark nascent cells which in turn give rise to photosynthetically active cells. During transition from dark to light, cells again grow in size.

d) Division phase. During this the parent cell wall ruptures and unicells are released.

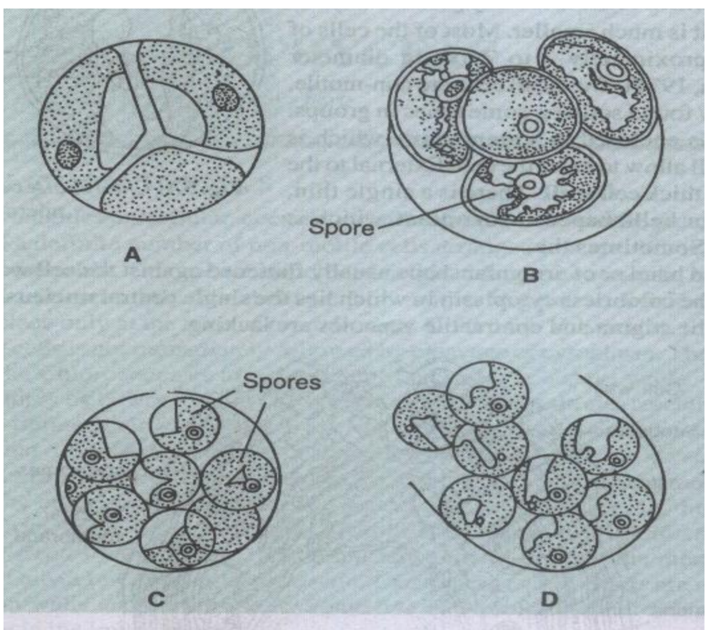
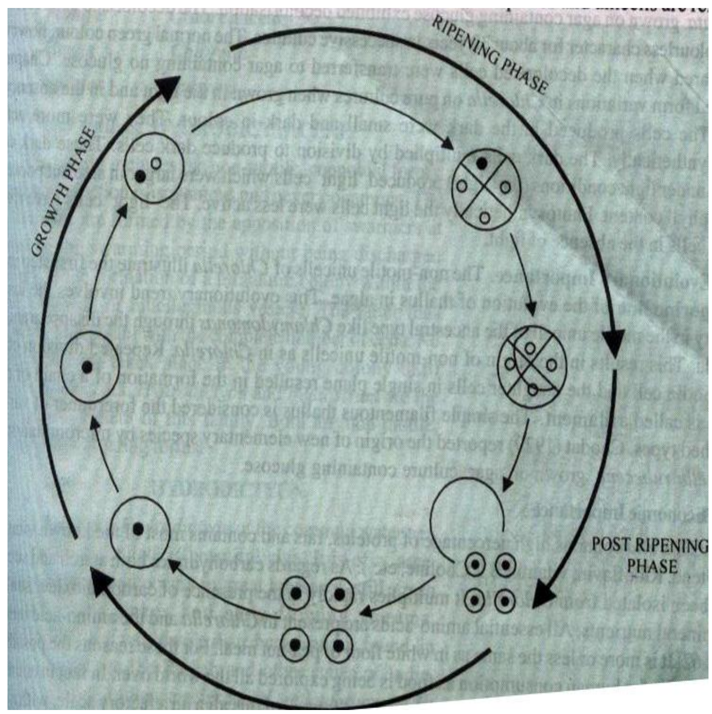
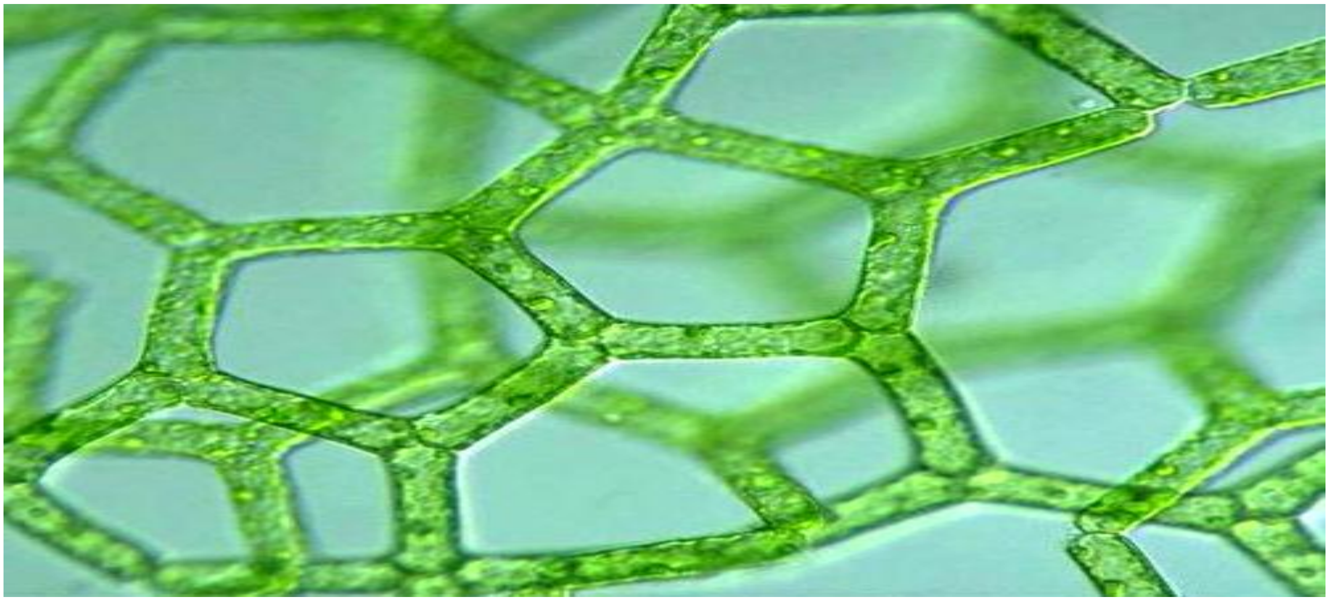


Fig. 5.3 (A-D). *Chlorella*. Asexual reproduction.



Division phase: Four phases in the life cycle of *C. ellipsoidea*.

Hydrodictyon



Systematic Position of Hydrodictyon:

HYDRODICTYON

Class	:	Chlorophyceae
Order	:	Chlorococcales
Family	:	Hydrodictyaceae
Genus	:	*Hydrodictyon*

Occurrence of Hydrodictyon:

Hydroclictyon, a non motile coenobium is macroscopic and beautiful alga. Due to its net like plant body, it is commonly known as **'water net'**. It is represented by 5 species. Only two species of Hydrodictyon i.e., H. reticulatum and H. indicum are reported from India. H. reticulatum is cosmopolitan in distribution. The species are commonly found between spring and rainy season in slow running water or still water of ponds, pools and lakes. It generally floats on the surface of the water but may also lie on the bottom. Very often due to profuse growth, the nets assume big size and cover the entire pond.

Thallus Structure of Hydrodictyon:

A mature coenobium consists of a hollow cylindrical network which is closed at both the ends (Fig. 1). It is flat and saucer shaped and its maximum size is generally 20-30 cm. Rarely it may reach up to a length of 60 cm. The mature net of coenobium is made up of a few hundred to several thousand cells.

These cells are joined at the end and form pentagonal or hexagonal structures. These structures are called meshes. Bach mesh interspace is generally bounded by 5-6 or rarely three cells. At each angle of the net or mesh meet three cells (Fig. 2 A, B).

Cell Structure of Hydrodictyon:

Each cell is long, cylindrical or ovoid in shape. Its internal structure can be differentiated into two parts: cell wall and protoplasm. Cell wall is two layered and is made up of cellulose. It encloses protoplasm. When young, the cells are uninucleate, but at maturity they become multinucleate (coenocytic).

Cells contain reticulate chloroplast with many pyrenoids (Fig. 2C). All the typical structures of green algae like ribosomes, mitochondria, dictyosomes are also present. As the cell matures, a central vacuole appears and the protoplasm becomes peripheral.

Reproduction in Hydrodictyon:

It is of three types: Vegetative, asexual and sexual.

Vegetative Reproduction:

It takes place by fragmentation. Coenobium breaks up into small pieces called fragments. Which have capability to grow into new colonies. It may be due to water currents and movement of aquatic animals.

Asexual Reproduction:

It takes place by the formation of auto colonies or daughter colonies (Fig. 3 A-G). These colonies are formed by the biflagellate, uninucleate zoospores. Under favourable conditions each coenocytic cell behaves as zoosporangium. Its nuclei undergo mitotic divisions to form a large number of nuclei (7000-20000).

Protoplasm gets segmented into as many segments as there are nuclei. Each segment gets surrounded by small amount of cytoplasm, a limiting membrane and develops two whiplash type equal flagella and represents biflagellate zoospore (Fig. 3 A-C). In Hydrodictyon a peculiar phenomenon is observed. The zoospores thus formed are never liberated outside the parent cell.

They remain motile within the restricted region i.e., within the cell. After swimming inside the cell, they ultimately withdraw their flagella and get themselves arranged into characteristic hexagonal or pentagonal fashion to form a new net (Fig. 3 D, E). This new net is called auto colony or daughter colony (Fig. 3 F, G).

The auto colonies are liberated by disintegration of the parent cell wall. The number of the cells in the daughter colony is fixed. Further growth of the coenobium is entirely due to increase in the cell size and not the number of the cells.

They withdraw their flagella and arrange themselves in the form of a net of Hydrodictyon. It is a daughter or juvenile colony. It is released in water by the dissolution of the vesicle. Its cells grow in size and produce new coenobium where the cell number typical of the species is stored.

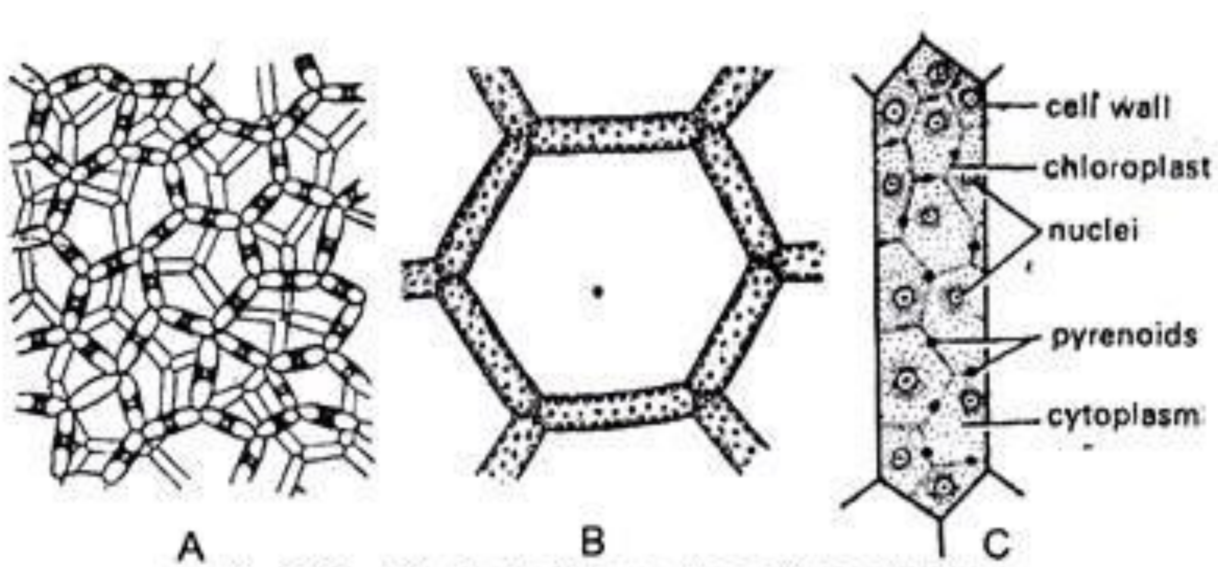


Fig. 2 (A—C). *Hydrodictyon*. Vegetative structure.
A. A part of the net; B. Hexagonal mesh; C. A cell.

Sexual Reproduction:

It is isogamous. Any vegetative cell of the coenobium can function as gametangium. The biflagellate gametes are produced by the cleavage of the protoplasm of the gametangia like that of zoospores (Fig. 4A, B). They are produced in large number and are smaller in size than the zoospores. They are liberated individually through a hole in the parent cell wall and swim freely in water.

The gametes are uninucleate and biflagellate. Hydrodictyon is monoecious. The gametes from the same or different coenobia after liberation fuse to form quadriflagellate zygotes (Fig. 4C). Soon they lose their flagella and settle down. The immobilised zygote enlarges in size, becomes spherical and develops thick wall to form zygospore. First it is green but it becomes red because of the development of a red pigment haematochrome.

Germination of zygospore:

Zygospore is capable to tide over the low winter temperature. At the onset of the spring season, its diploid nucleus undergoes zygotic meiosis to form four, haploid uninucleate, biflagellate gonozoospores meiospores (Fig. 4 D-F). The zygospore wall bursts and the meiospores are liberated in the surrounding water. After swimming for some time these meiospores come to rest.

They retract their flagella, enlarge and form the thick walled angular cells called polyhedrons or polyeders (Fig. 4 G, H). This stage is known as polyhedron stage. The single nucleus of the polyhedron divides and re-divides several times and ultimately forms the second generation of zoospores (Fig. 41). These zoospores are also uninucleate and are anteriorly biflagellate.

The wall of the polyhedron cracks down and the zoospores emerge into a thin vesicle (Fig. 5J). These zoospores do not escape outside in the water but actively swim within the vesicle for some time.

Fig. 3 (A—G). *Hydrodictyon*. Asexual reproduction. (A, B). Zoospores formation. C. A zoospore; (D, E). Arrangement of biflagellated zoospores into a net; F. Formation of new net (autocolony) within parent cell. G. A autocolony in the parent cell.

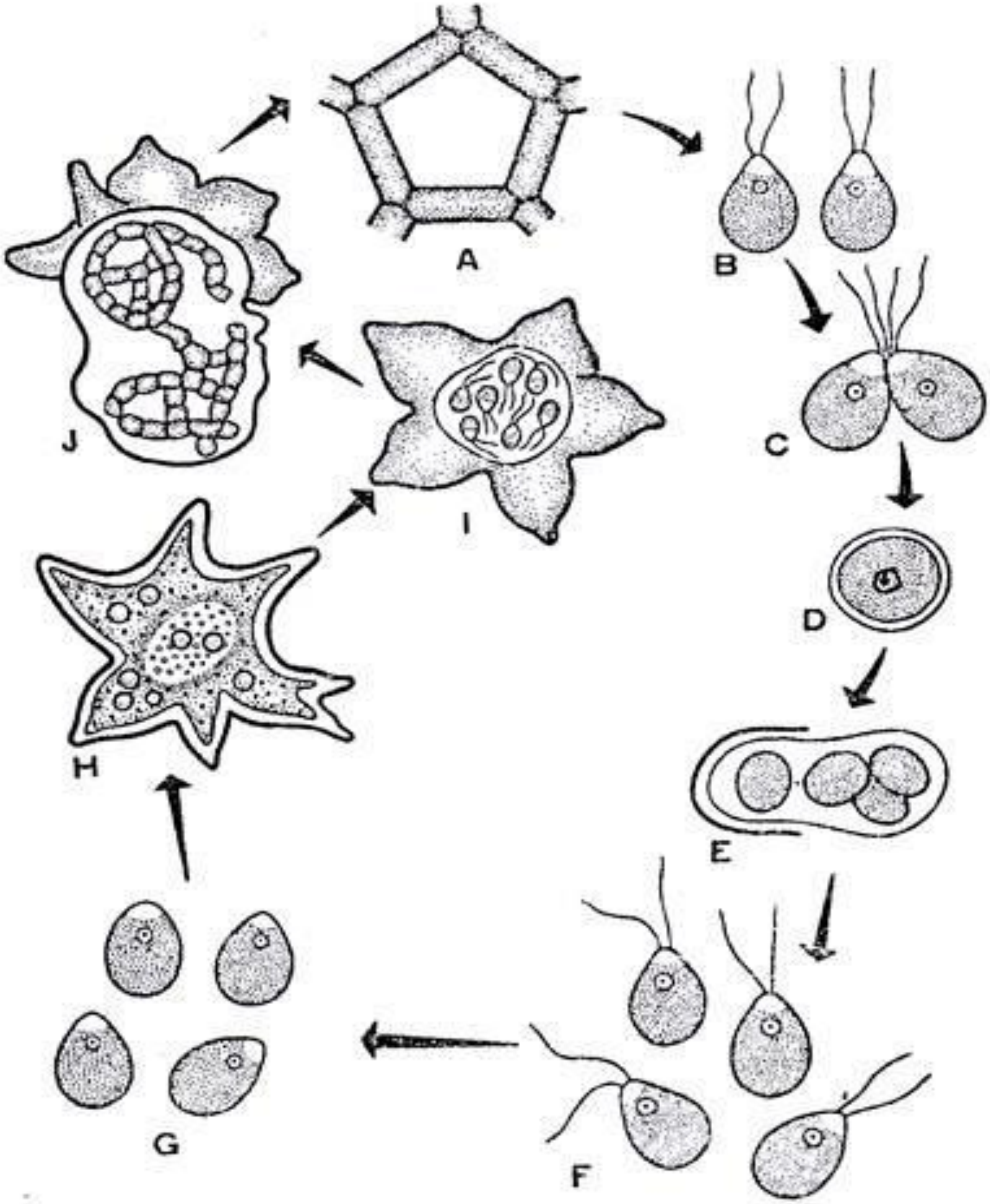


Fig. 4 (A—J). *Hydrodictyon*. Sexual reproduction.

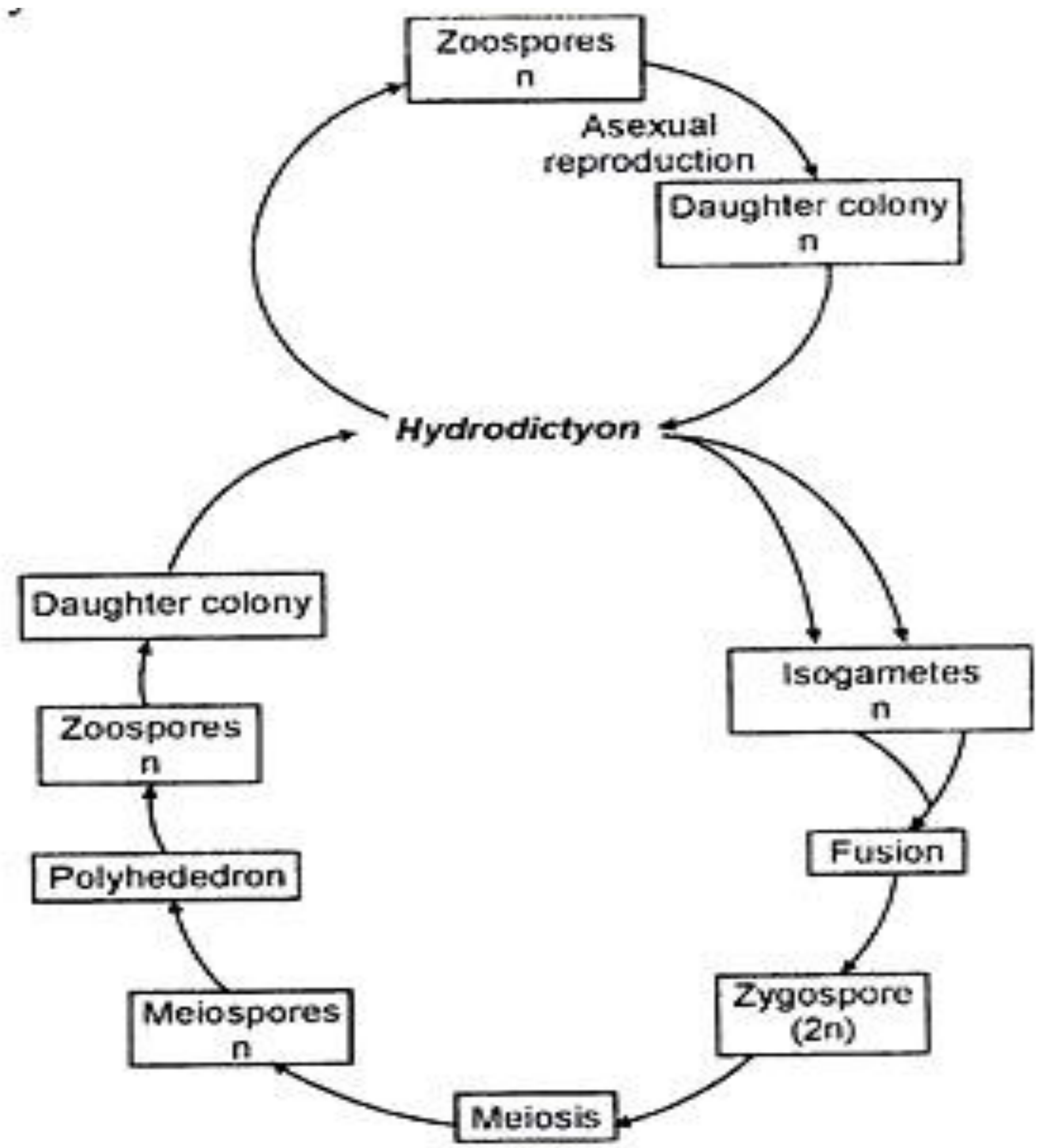
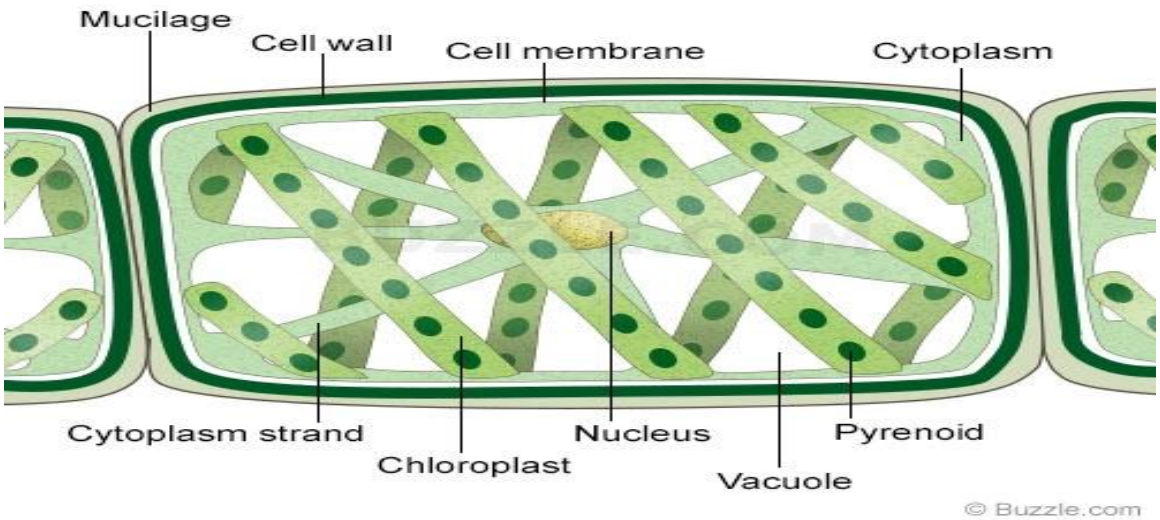


Fig. 5. *Hydrodictyon*. Graphic life cycle.

Spirogyra



Spirogyra is a freshwater alga found freely floating on the surface of the stagnant pools, ponds and ditches, etc. It is commonly known as **water silk or pond silk.**

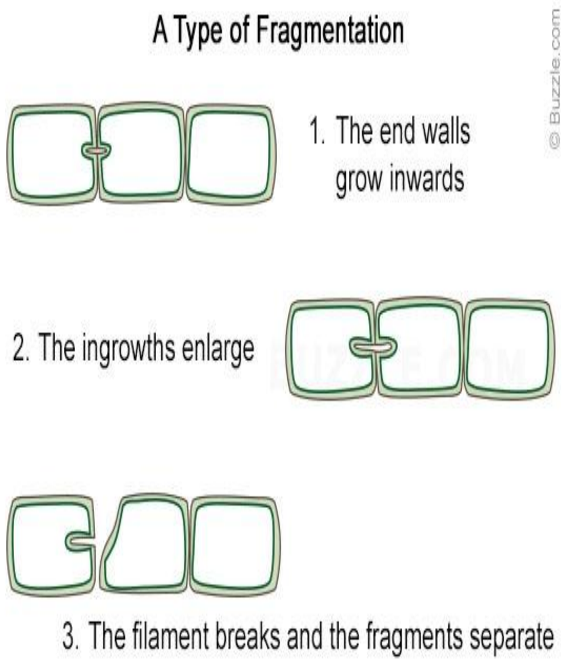
Spirogyra is a genus of green algae that belong to the order Zygnematales.

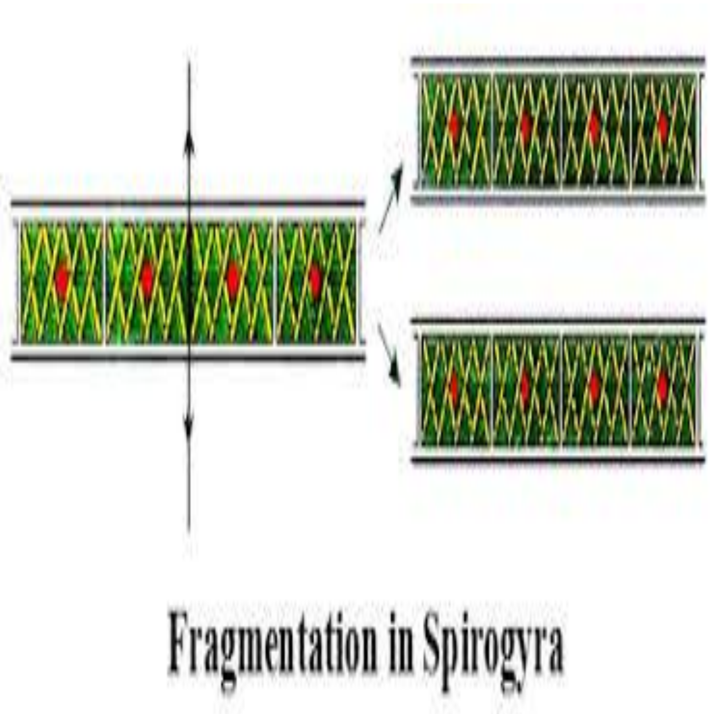
The growth of filament can take place by cell division of any cell of the filament except the holdfast.

Reproduction

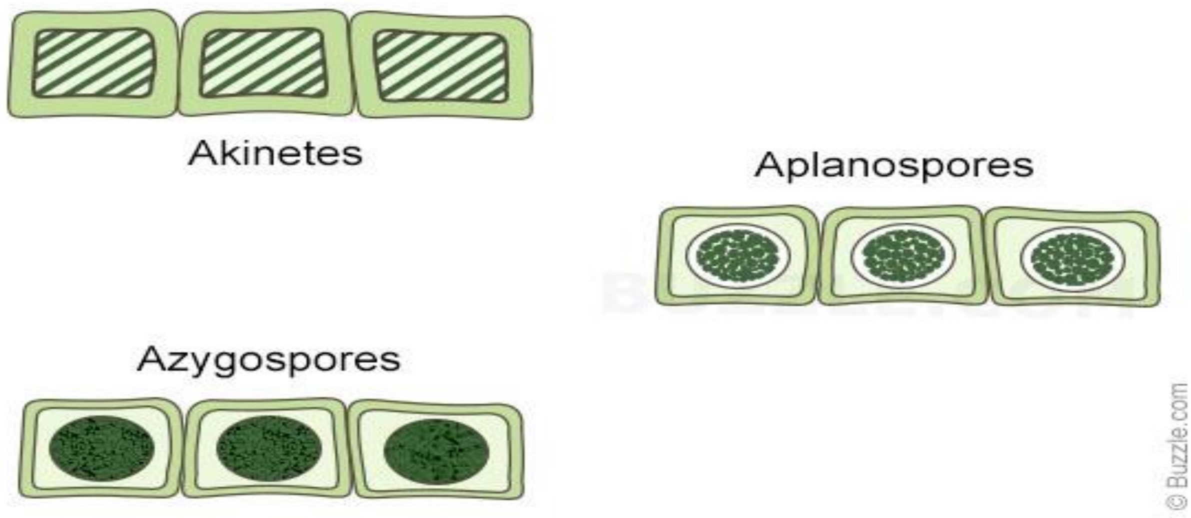
The reproduction in *Spirogyra* is vegetative and sexual mostly. However, some species exhibit asexual reproduction.

Vegetative reproduction happens through fragmentation of the filaments. Fragmentation happens in different ways. In case of mechanical injuries, the spirogyra filament breaks into fragments, and each fragment develops into a new filament. In some cases, the middle lamellae of the end walls of the cells dissolve, thereby causing breakage of the filament. This happens when the temperature and the pH of the water changes. It has also been observed that the lamellae of the end walls protrude inwards into the adjacent cells, thereby breaking the filament. The illustration given below shows fragmentation of a spirogyra filament as the end walls grow inwards, thereby causing fragmentation.





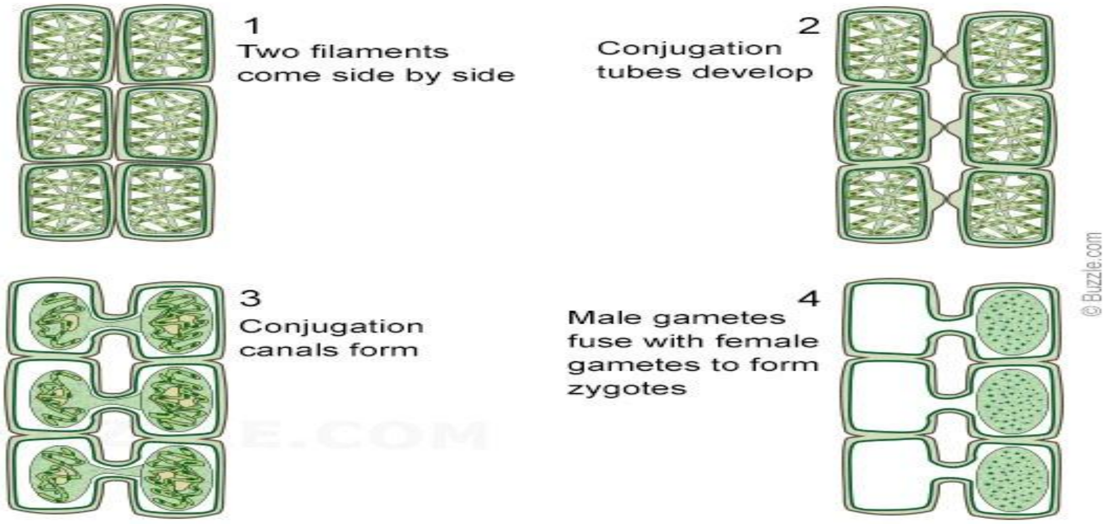
Asexual reproduction in spirogyra involves formation of akinetes, aplanospores, or azygospores. During unfavorable conditions, some types of spirogyra form thick-walled resting spores called akinetes. For this purpose, some cells of the filament contract lose water, and form thick walls of cellulose and pectin. These spores are called akinetes that can form new filaments during favorable conditions. The process of formation of aplanospores is similar to that of akinetes, but the former have thinner walls. These non-motile spores develop new filaments when the parent filament decays. Azygospores or parthenospores are those gametes that fail to fuse during sexual reproduction. The protoplast of the cells form gametes that fuse with the gametes of other cells. If such fusion does not happen, the gametes reproduce asexually, and they are called azygospores.



Sexual reproduction in spirogyra can be of two types: scalariform conjugation and lateral conjugation.

In scalariform conjugation, two filaments come together and lie side by side. The mucilage of the cell walls holds them together. The cells of each filament develop small tube-like structures that fuse together to form conjugation canals. The male gametes of one filament travel through these canals and fuse with the female gametes in the other filament, to form zygotes, which are oval or circular. After conjugation, one filament becomes empty, and the other has zygotes. Once the zygotes are released, the parent filaments die. The zygotes wait for favorable conditions to germinate.

In **lateral conjugation**, the contents of adjacent cells act like male and female gametes. So the adjacent cells of the same filament develop conjugation tubes. There are two types of lateral conjugation - direct and indirect. The style of conjugation canal formation differs in these two methods. In direct lateral conjugation, conjugation canals develop when the end walls of the adjacent cells lose contact with their middle lamella. In other words, the adjacent cells fuse through the middle lamella. In case of indirect lateral conjugation, the cells that act like male gametes form separate conjugation canals that connect with their adjacent cells, which act like female gametes. In both cases, the male gametes enter their adjacent cells and fuse with the female gametes. After conjugation, alternate cells of the same filament have zygotes and others will be empty.



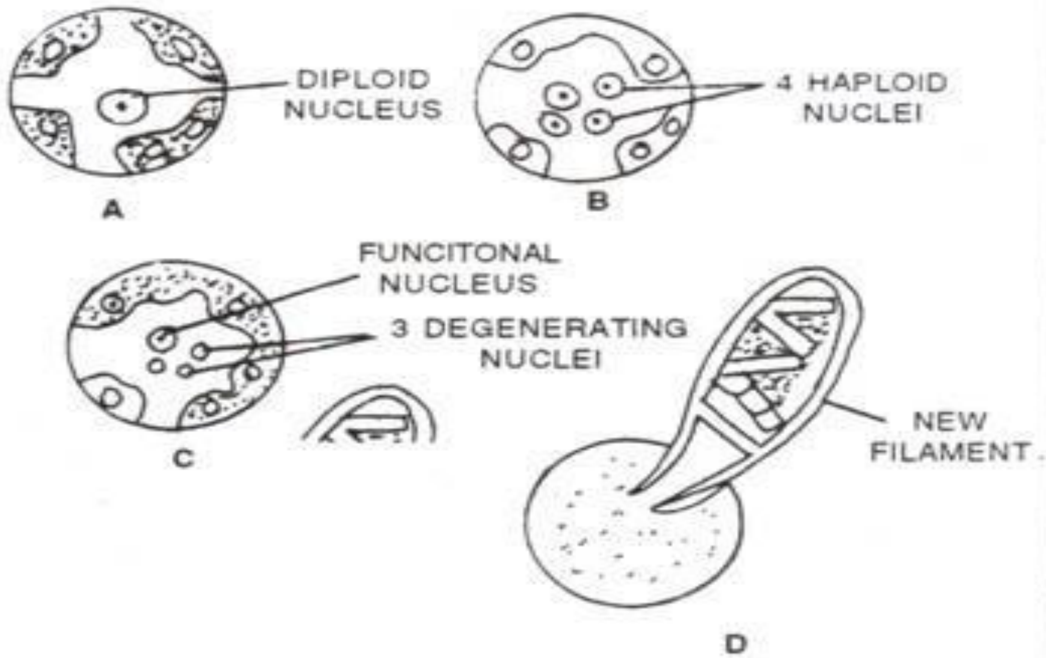
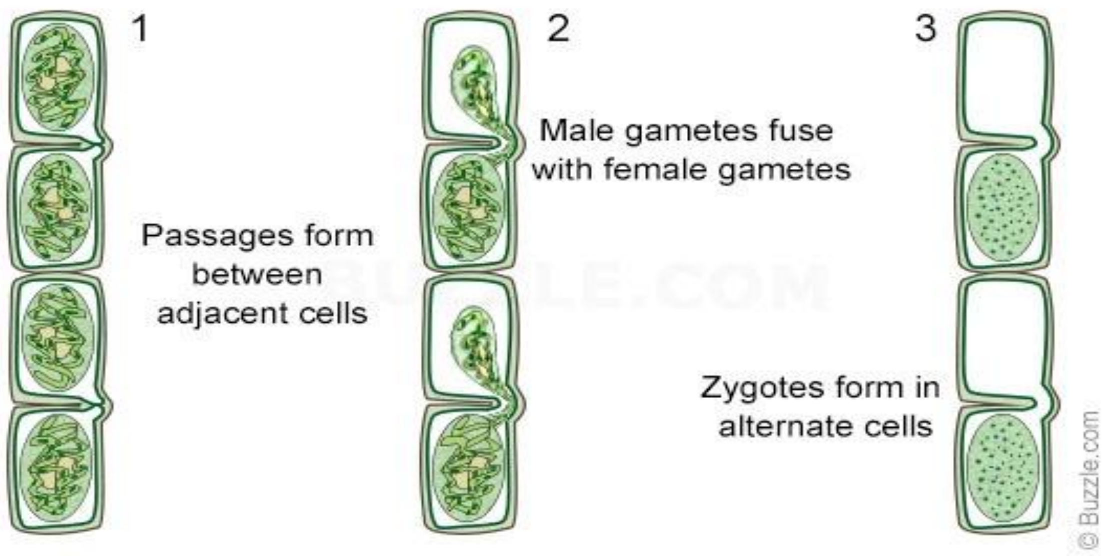
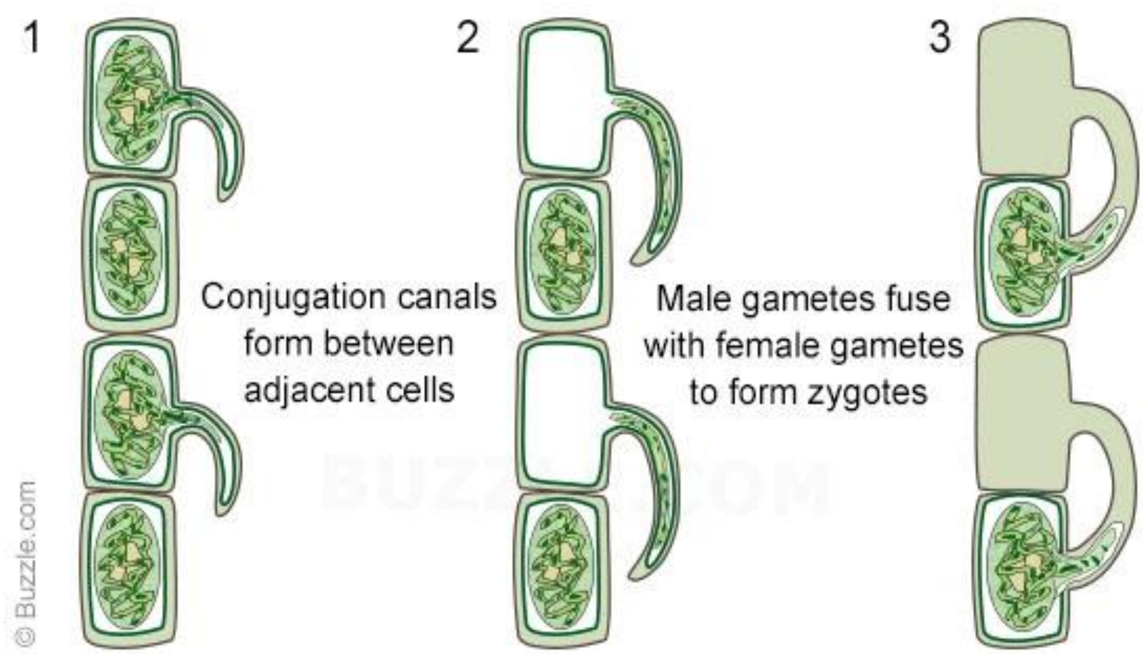


Figure 5.9 *Spirogyra*. Stages in germination of zygospore



Direct Lateral Conjugation



Indirect Lateral Conjugation

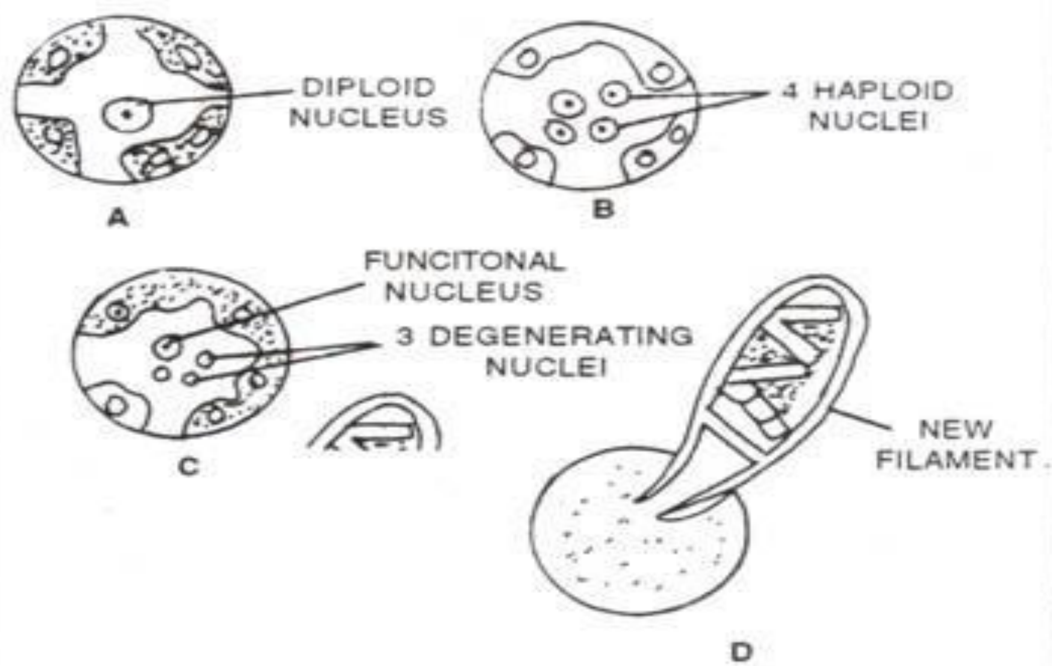
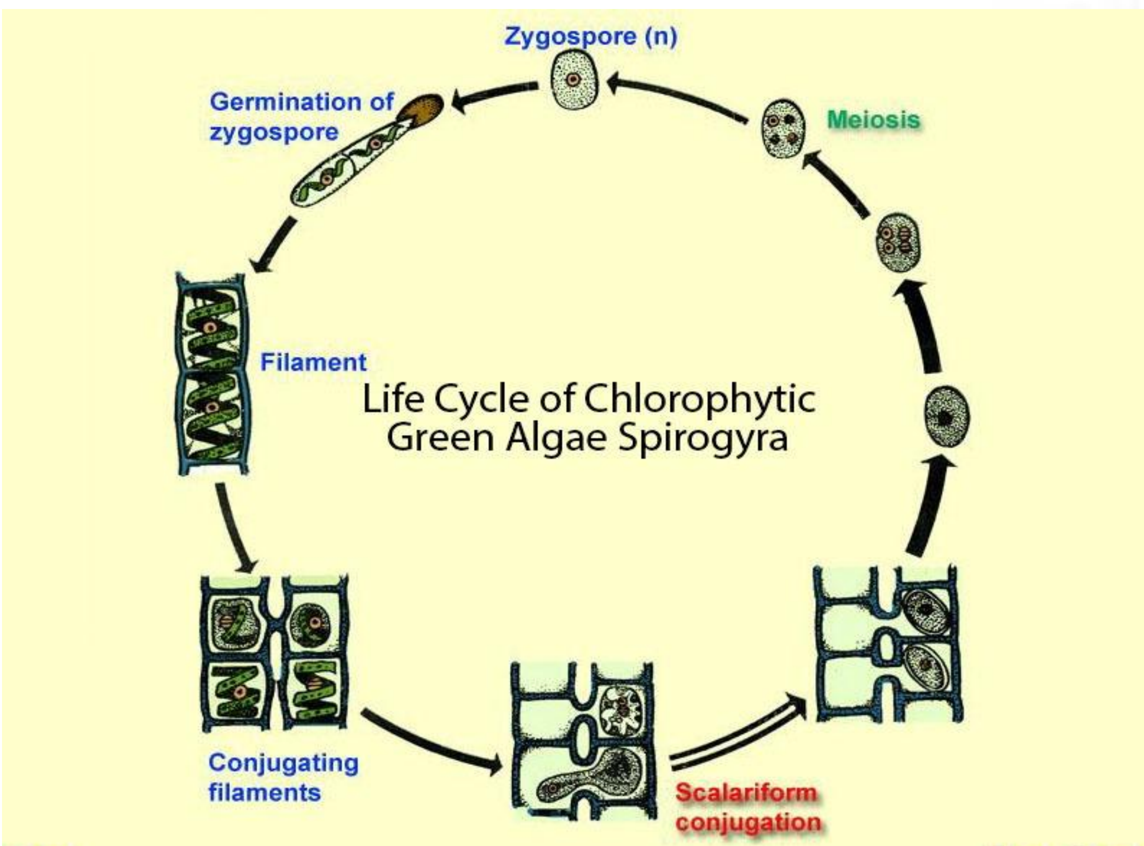


Figure 5.9 *Spirogyra*. Stages in germination of zygospore



Ulothrix

Body of ulothrix has un-branched filaments. Filaments contain short cylindrical cells joined end to end. Cells are as broad as long. The filament remains attached to substratum by modified based cell called hold fast. Upper cell or tip cell is sub spherical in outline. Each cell except hold fast cell has got an outer wall composed of cellulose plus pectic substances.

Within the cell wall is cytoplasmic layer in which nucleus is embedded. Chloroplast has two more pyrenoids. Filament is autotrophic in nutrition and grows in length.

Reproduction: It takes place by vegetation, Asexual and Sexual method.

(1) **Vegetative Reproduction**: It takes place by chance but not by regular method of multiplication. In this case the filament breaks up into two or more parts and each part is capable of converting itself into a new filament.

(2) Asexual Reproduction:

(A) By zoospore formation: The cell of filament under favourable conditions produces the zoospores. The zoospores are produced by ordinary cells of the filament whose contents divide into 2, 4, 8 and 16 parts. Zoospores are (i) Macro zoospores which are slightly flattened and have four flagella and (ii) Micro zoospores which are ovoid and have four or two flagella. Each zoospore is uni nucleate and has a chloroplast in broader part of spore and the apical part consists protoplasm and flagella. After liberation the spores swim for some time and come to rest, attach themselves and grow out directly into new filament.

(B) By Aplanospores: Occasionally the development zoospores stop just before development of cilia. In such cases non motile thin walled aplanospores are produced instead of motile zoospores. These aplanospores may germinate inside the parent cell or may be liberated outside. They then develop into new filament.

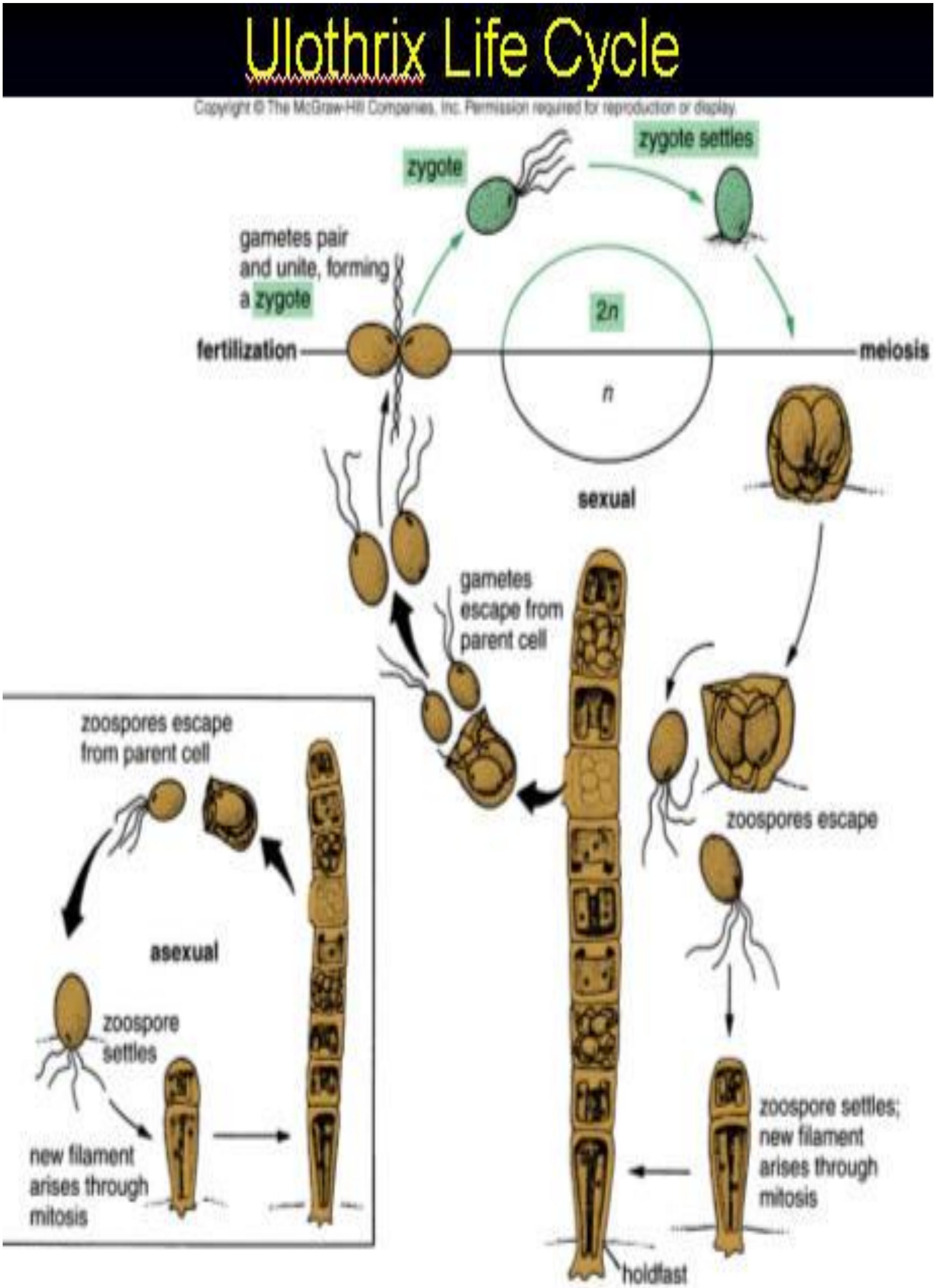
(C) By Akinetes: Sometimes in unfavourable conditions cell of the filament forms a single rounded thick walled structure called akinete. Akinetes are double walled with exospore and endospore. On return of favourable conditions the exospore ruptures and it develops into new filament.

(D) Palmella stage: Sometimes the contents of cell divide and their walls become mucilaginous. These cells either directly form new filaments or they give rise to zoospores which form new filaments.

(3) Sexual Reproduction: It is isogamous.

Sexual reproduction consists simply fusion of similar two gametes. In unfavourable conditions each cell of filament produces 16, 32 or 64 gametes by divisions on the same manner as zoospores are produced. Isogametes are avoid and biflagellate. Each has chloroplast and a single pyrenoid. Isogametes come out of parent cell in membranous vesicle. Very soon the vesicle disappears and gametes move freely in the water.

Gametes fuse in pairs interiorly and quadric-flagellate zygospores or zygotes are developed. The cilia of zygotes are withdrawn, it becomes round and thick wall is secreted around it. Zygote after a definite resting period increases in size and its nucleus divides by reduction division. Protoplast of zygote divides and re-divides and 4 to 16 aplonospores or zoospores formation takes place. Each one of them develops into new filament of ulothrix.


Ulothrix Life Cycle
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zygote
zygote settles
gametes pair
and unite, forming
a zygote
2n
fertilization
meiosis
n
sexual
gametes
escape from
parent cell
zoospores escape
zoospores escape
from parent cell
asexual
zoospore
settles
new filament
arises through
mitosis
zoospore settles;
new filament
arises through
mitosis
holdfast

Oedogonium sp.

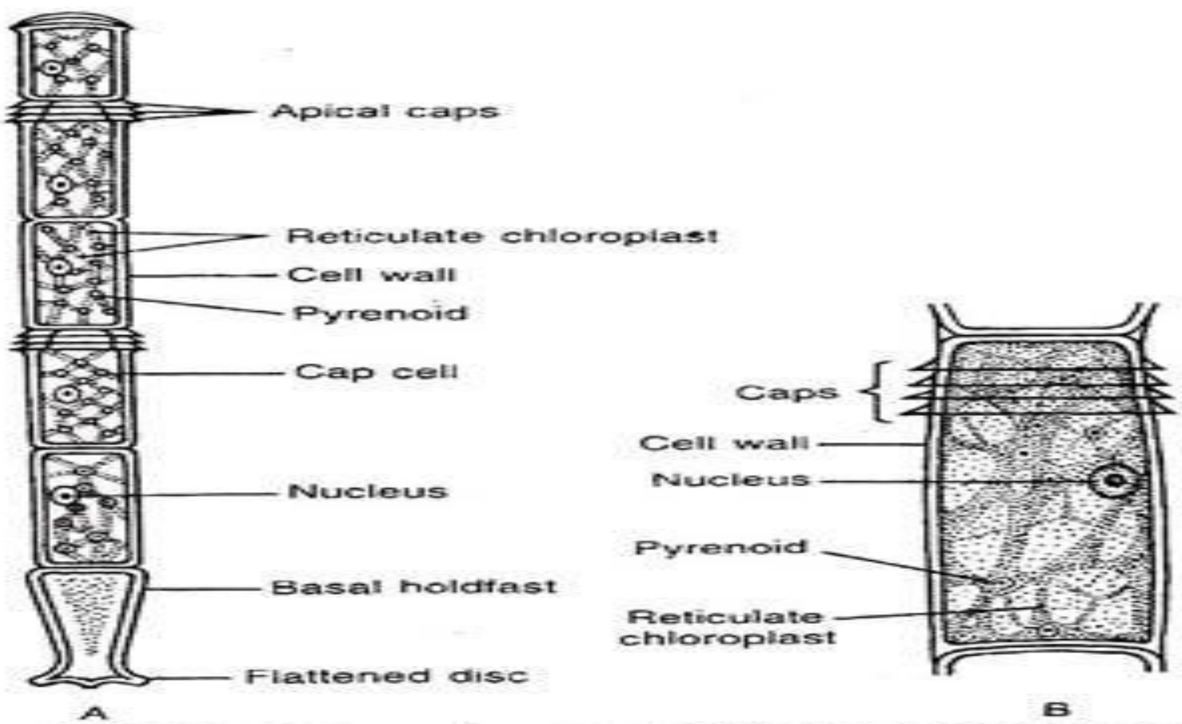


Fig. 3.72 : *Oedogonium* sp. : A. Single vegetative filament with holdfast and apical cell, B. Single vegetative cell

Reproduction in Oedogonium:

Oedogonium reproduces by all the three means: vegetative, asexual and sexual.

Vegetative Reproduction:

It takes place by fragmentation and akinete formation:

1. Fragmentation:

It takes place by accidental breakage of the filament, dying off of intercalary cells or by the formation of intercalary sporangia. The fragments are capable of developing into new filaments.

2. Akinete: During unfavourable condition the entire protoplast of a cell becomes a thick-walled, reddish-brown, round or oval structure, the akinete. The akinete germinates during favourable condition and develops a new filament. They generally form in chain.

Asexual Reproduction:

Asexual reproduction takes place by means of zoospores (Fig. 3.74A-C). Zoospores are formed singly within a cell. Comparatively younger cell i.e., the cell with cap behaves as sporangium mother cell.

The zoospores are multiflagellate and ovoid, pyriform or spherical in shape. They are uni-nucleate with single chloroplast and occasionally with an eye-spot.

During favourable condition, the zoospore formation begins in a cap cell of the filament. The entire protoplast of zoosporangium contracts from the wall and behave as a unit. The proto-plast becomes round or oval in shape and its nucleus moves at one end.

Near the nucleus a semicircular hyaline area develops. Just below the hyaline area a ring of blepharoplast granules develops, connected with each other by fibrous strands (Ringo, 1967). Later on, from each blepharoplast granule, single flagellum develops. Thus a crown of flagella is present around the colourless semicircular area.

The fully developed zoospores are liberated by breaking the zoosporangium wall. The wall of the zoosporangium breaks near the cap region and the neighbouring cell bend on one side to make way for the liberation of zoospore. During liberation, the zoospore remains as a delicate mucilaginous vesicle for 3-10 minutes. After dissolution of vesicle the zoospore gets free and starts swimming in the surrounding water.

Germination:

The zoospore can swim for about one hour or more. Coming in contact with substratum by the anterior end, it loses flagella and starts to elongate. The lower hyaline part becomes separated by cell wall, which forms the hold fast. Through the subsequent division and re-division in a single plane, new filament is formed.

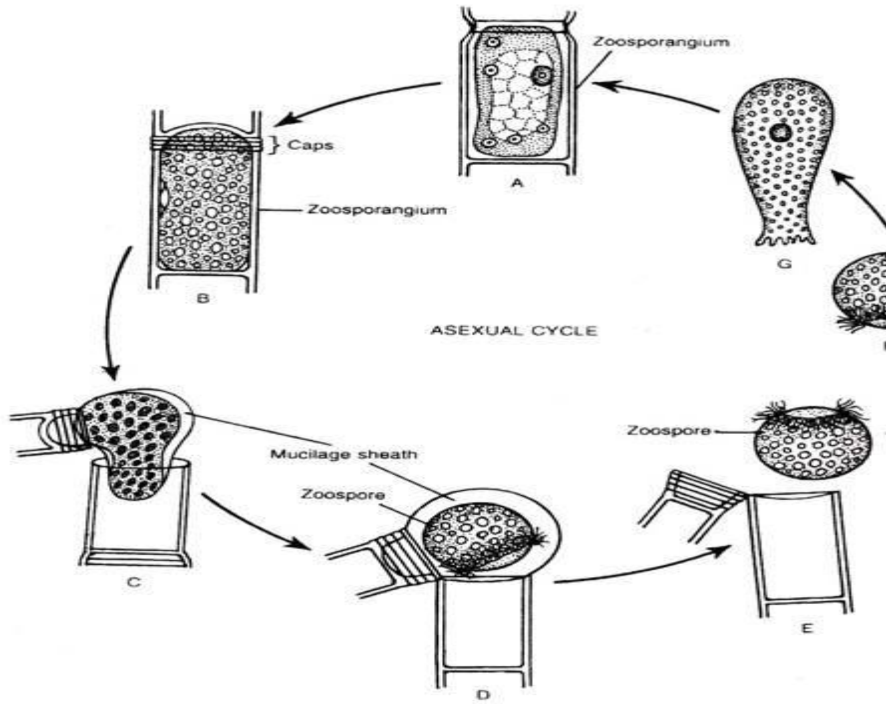


Fig. 3.74 : *Oedogonium* sp. Asexual reproduction : A-E. Successive stages of zoospore formation, F. Single zoospore, and G. Germination of Zoospore

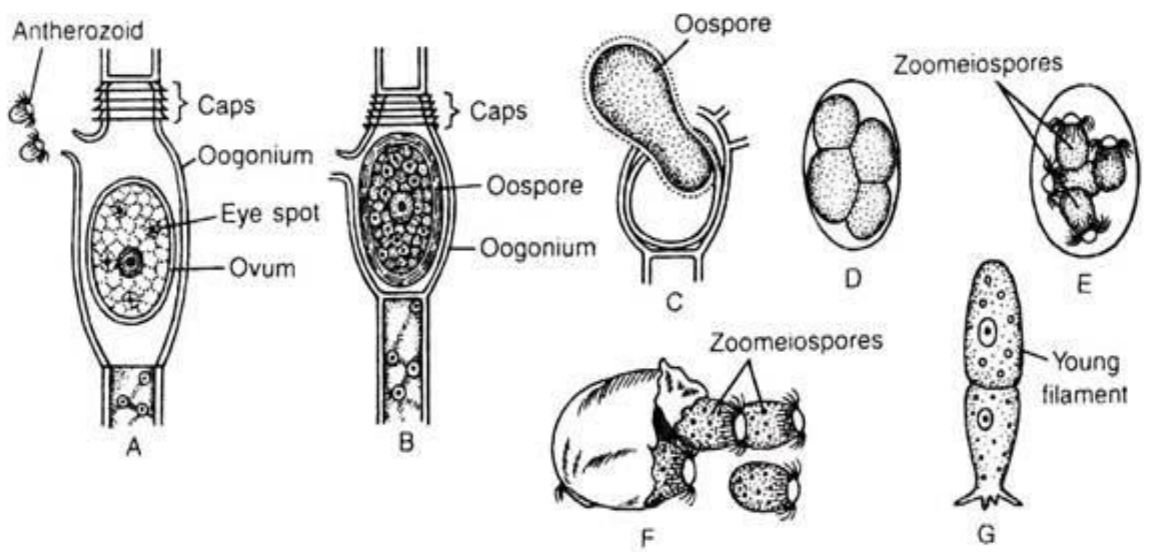
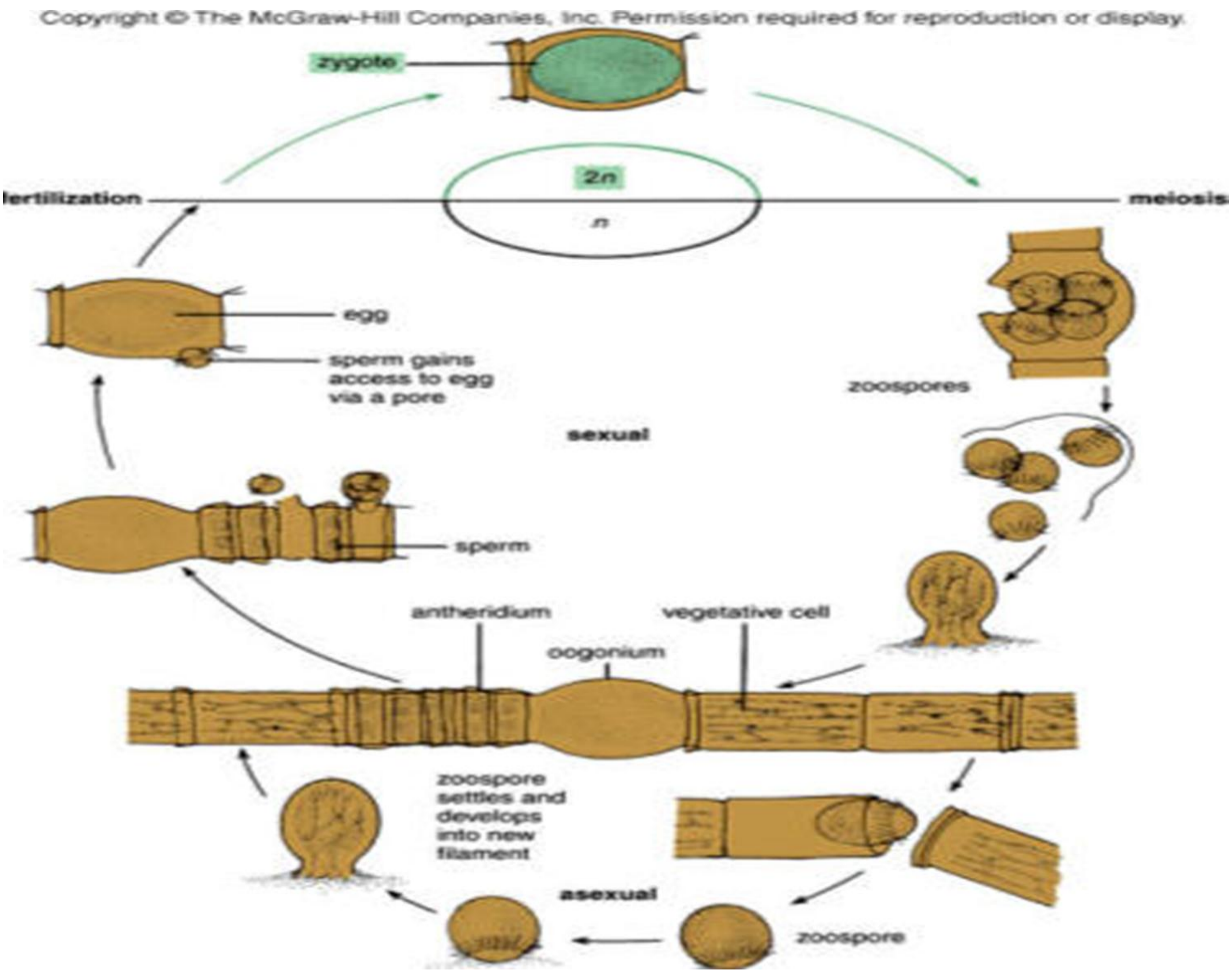


Fig. 3.78 : *Oedogonium* sp. : A. A stage before fertilization, B. Oospore in oogonium, C. Liberation of oospore from oogonium, D-E. Stages of zoospore formation, F. Liberation of zoospore, and G. Young filament develops after germination of zoomeiospore.

Sexual Reproduction:

The sexual reproduction in Oedogonium is an advanced oogamous type. The male gametes or antherozoides are produced in antheridium (Fig. 3.75) and the female gamete or egg is produced in oogonium (Fig. 3.76). Male and female gametes differ both morphologically and physiologically. Only one egg is produced in each oogonium and two antherozoides in each antheridium. Another motile structure, the androspore, is produced singly in each androsporangium. Deficiency of nitrogen and alkaline pH are the important factors for promoting sexual reproduction.



Family Cladophoraceae:

This family contains many fresh-water forms. Some of the large genera, such as Cladophora, have both fresh-water and marine representatives, but there are several strictly marine genera. The plants are composed of multinucleate cells arranged in uniseriate fashion in branched filaments.

The chloroplast is parietal and reticulate. The filaments are usually attached by rhizoids. Generic separations have traditionally been made on vegetative characters such as the presence or absence of branches, the kind of branches, and the form of the basal cell and its attachment rhizoids.

The reproduction in *Cladophora* may be (a) vegetative (b) asexual (c) sexual
Vegetative reproduction: The vegetative production takes place by (1) fragmentation (2) tubers and (4) akinetes
Fragmentation : The filaments break in small filaments, each fragment may give rise to a new plant.
Akinetes : The akinetes are vegetative bodies. The protoplast of the cell becomes round and thick-walled and known as akinete. Such structures are filled up with food reserves and germinate in favourable conditions.

Asexual: The asexual reproduction takes place by means of zoospores. The zoospores are produced inside the cells, called zoosporangia. At the times of zoospore formation the protoplast divides into several bits. Simultaneously the nuclei also divide. Each protoplasmic bit having a nucleus in it metamorphoses into a biflagellate or quadriflagellate zoospore. The zoospores usually develop in the terminal cells of the finer branches. The zoospores formation takes place in basipetal succession. In most of the cases the zoospores are pear shaped and quadriflagellate. The zoospores liberate from the cell through a small lens shaped are at just below the apical end of the cell. The zoospores move here and there in the water after liberation. The cilia are retracted. The one-celled structure secretes a wall around it. This structure soon becomes elongated and coenocytic simultaneously a cross wall develops. He upper cell develops into filamentous plant body and the lower cell in rhizoidal system.

Sexual reproduction: In *cladophora* the sexual reproduction is isogamous. Almost all the species are heterothallic. The isogametes are formed in the same way as the zoospores are formed. Here the parent cells may be called gametangia instead of zoosporangia. After their liberation from different parents they unite in pairs and the zygote is formed. Soon the flagella are retracted and a wall is secretes around the zygote. This zygote germinates immediately and has no resting period.

The protoplast of the zygote divides meiotically producing 4 quadriflagellate zoospores. Thus four quadriflagellate zoospores are produced which escape through an apical pore. The zoospores swims for some time and the flagella are withdrawn. The structure becomes elongated and a wall is secreted around it. It becomes multinucleate and a cross wall develops in it. The lower cell of the germling acts as rhizoidal cell and the upper develops in a new plant.

Alternation of generation: A definite alternation of generation occurs in *cladophora*. This means that the plants with 2x number of chromosomes alternate with plants having an x number of chromosomes. The meiosis occurs in the 2 x plant, producing meiospores and that the x plant produce gametes. It is thus seen that alternation of generation means that the spores producing generation alternate with the gametes producing generation. The 2x plant is known as the diploid plant or the diploid generation or diploid phase. The x plant as the haploid plant or generation or phase. In *Cladophora* x and 2x plants are morphologically identical. Both contains similar type of chloroplast and dense cytoplasm. Zoospores are produced in vigorously growing cells near the tips of branches of the diploid plant. Meiosis occurs prior to their formation. The zoospores contain half as many chromosomes in each nucleus as did the cells of the filament which bore them. Here the original filament is diploid while the zoospores are haploid. The zoospores on germination give rise to filaments similar in appearance to the diploid filaments except that the nuclei within their cells contain the haploid number of chromosomes. The haploid filament produce isogametes. The haploid isogametes unite to form a zygote. A new diploid filament develops from the zygote.

Class2 : Charophyceae

General Features: The green algae included in this division are best known as the Characean algae. Commonly they are called the stoneworts. The stoneworts have a worldwide distribution. They occur more or less in still, clean waters, fresh-water or brackish. A few species are found in both the habitats. Typically they form subaquatic meadows in shallow waters growing in soft mud. Light favours growth of the Charophytes which flourish from the months of August to March disappearing in the hot summer months. They are abundant during the cold season in northern India. Drying up conditions hasten the formation of sex organs. This division includes both living as well as fossil forms. So far about 294 living species have been recorded. They have been placed under 7 genera. About 69 species have been recorded in India, Burma, Ceylon and Pakistan. They belong to five genera. These are Chara (27 species), Tolypella (3 species), Nitella (37 species), Nitellopsis (1 species) and Lychnothamnus (1 species).

The plant body presents a great elaboration of vegetative structures. It is practically always erect and consists of a long, slender, jointed, green or grey main axis with a regular succession of nodes and internodes. The central axis is branched. At each node arises a whorl of lateral branchlets. Sexual reproduction is oogamous and very complex. Antheridia and oogonia differ considerably from the corresponding organs in the other green algae in structural complexities and elaboration. They are large and can be seen even with the naked eye. There is no asexual reproduction by the formation of asexual spores. The zygote, on germination, forms a protonema from which a Chara plant is developed.

Classification

The division includes a single class, Charophyceae. The Charophyceae comprises a single order, the Charales. The order Charales comprises four families. All the 7 living genera are included in a single family, the Characeae. The other three families include only fossil forms.

CHARA

Occurrence. It is a submerged aquatic alga which grow attached to the soft mud at the bottom, along the margins of fresh water pools, lakes and slow-flowing streams forming thick masses.

Organisation of the Thallus (Fig. 5.1). The plant body is a thallus attached in the mud by multicellular rhizoic The individual plants generally attain a length of 20 to 30 cms The maximum height achieved however, is 90 cm. The thallus has a long, slender, flexuous upright branched main axis which is differentiated into a well-marked series of alternating short nodes and long internodes. The internode consists of a sing elongated, multinucleate and cylindrical cell, several times longer than broad. The internodal cell is in some species, surrounded by a jacket of narrow, elongated cells constituting the cortex. Half of the cortical cells investing the internode are derived from the node below. They grow in opposite directions to form an investment around the internodal cell. The node remains short and is made up of a cluster of several, small isodiametric cells. There are two central cells surrounded by 6-20 peripheral cells in the cluster. From each node arise the following four types of appendages :

Branchlets (Fig. 13.2). 1-The short branches of branchlets consist of a limited number of nodes and internodes characteristic of a particular species. Usually the number varies from 5 to 15. The primary laterals in turn often develop much shorter, one called, spine-like branches called secondary laterals at their nodes.

2. Long branches. In addition, the stem node may bear one or more branches of unlimited growth. They arise usually singly at some of the older nodes of the main axis on the inner side of the oldest primary lateral in the whorl.

Sexual Reproduction (Fig. 13.11). It is oogamous. The sex organs display a high degree of specialisation and are far more complicated than among any other thallophytes. In fact they bear a superficial resemblance to the multicellular sex organs of Archegoniates. They are visible to the naked eye when mature.

The male sex organ is a large, round, bright yellow or red structure. It is commonly called the **antheridium**. The female sex organ or the **oogonium** is a large, oval body covered with amulticellular envelope. Most of the species are monoecious or homothallic but a few are dioecious or heterothallic (C. wallichii). In the homothallic species both the sex organs develop in pairs at the nodes of the primary laterals amidst the secondary laterals (Fig. 13.9). The oogonium always lies above the antheridium at the same node. The antheridium has a wall composed of eight closely fitting large, hollow, curved plate-like cells, the shield cells which are filled with red or yellow pigment giving characteristic colour to the antheridium (A).

Fertilization: Many antherozoids enter oogonium but one of those fertilizes the egg to make a diploid zygote. The zygote secretes a thick wall around itself to make oospore.

The oospore inside contains a diploid nucleus and many oil globules in cytoplasm. On maturity of the inner walls of tube cells get thickened, suberised and silicified. The oogonial as well as oospore walls become thick. The oospore nucleus moves towards the apical region. In advanced stage the outer walls of the envelope or sheath cells fall off and the inner parts remain attached to mature oospore in form of ridges. The oospore germinates when favourable conditions appear. The diploid nucleus present in apical colourless region divides by meiosis forming four haploid daughter nuclei. At this stage a septum divides oospore into two unequal cells. The upper smaller apical cell contains a single nucleus and the large basal cell contains three nuclei.

The three nuclei of basal cell degenerate gradually. The oospore apical cell divides by longitudinal division to make a rhizoidal initial and protonemal initial. The rhizoidal initial shows positive geotropism and forms primary rhizoid. The protonemal initial shows negative geotropism and forms primary protonema. The primary protonema differentiates into nodes and internodes. The peripheral cells of the basal node give rise to rhizoids and secondary protonema. The peripheral cells of the upper nodes give rise to lateral branches.

Salient features of Chara

1. The thallus shows an elaborate organisation and may attain a height of 20 to 30 cms. It has the appearance of miniature horse-tails (Equisetwri).
2. The main axis consists of a series of alternating nodes and internodes.
3. The internode consists of a single, undivided, elongated, cylindrical cell.

4. The node is made up of a transverse layer of short cells.

5. From the axil of the primary laterals arise one or two long branches which continue the

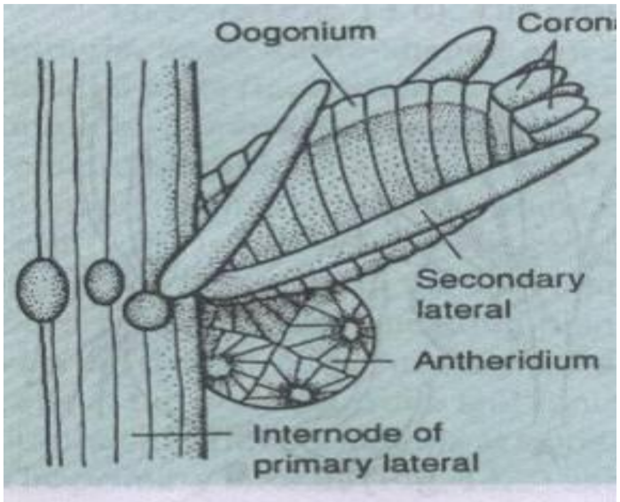


Fig. 13.11 (A-F). *Chara.* A node of fertile primary lateral showing sex organs.

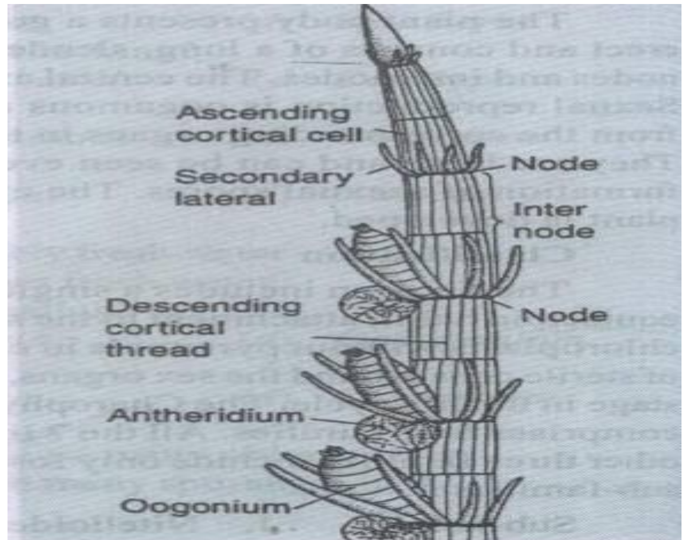


Fig. 13.2. *Chara.* A fertile primary lateral.

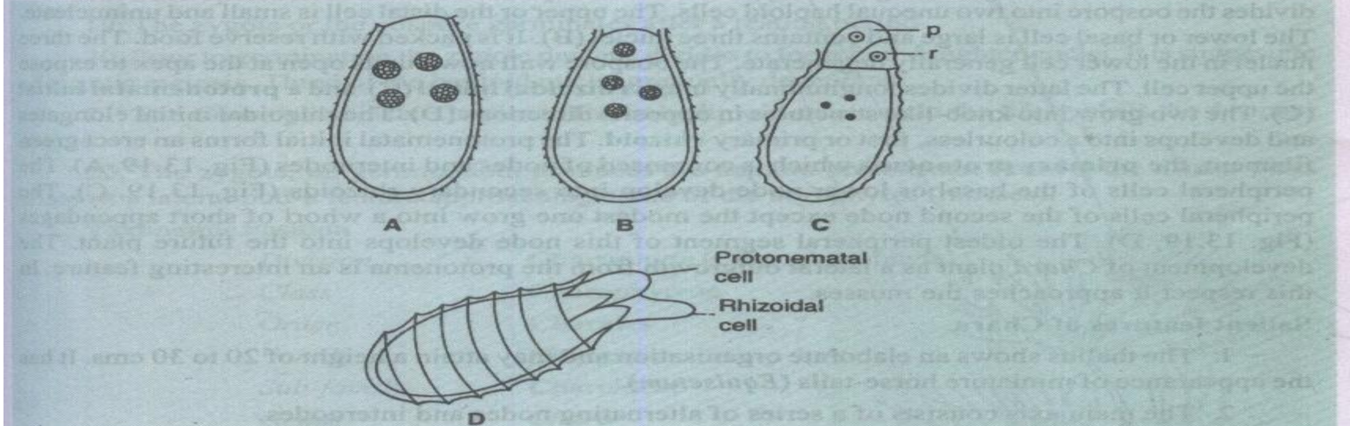


Fig. 13.18 (A-D). *Chara.* Germination of oospore. (A), Zygote at 4-nucleate stage; (B), Zygote with uninucleate upper cell and 3-nucleate basal cell; (C), Formation of protonematal cell (p) and rhizoidal cell (r); (D), Enlargement of protonematal and rhizoidal cells.

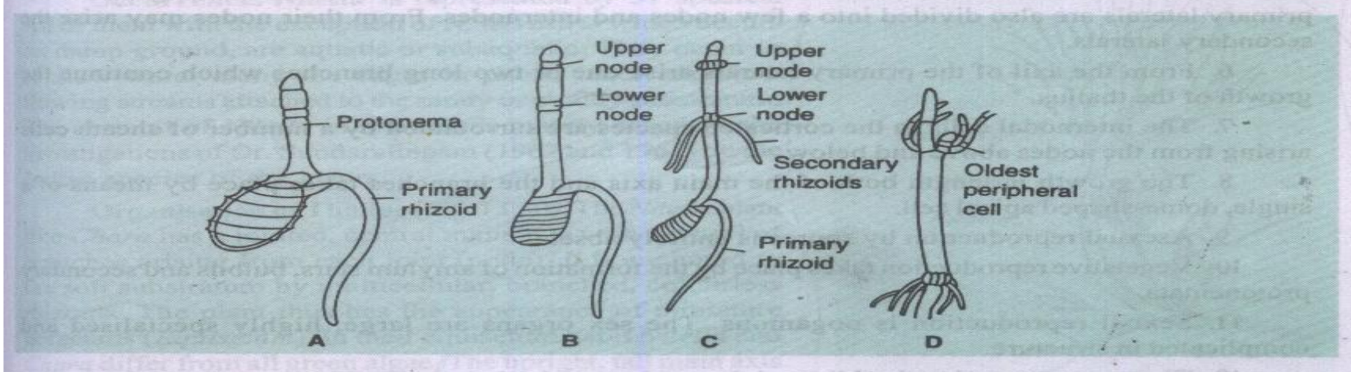


Fig. 13.19 (A-D). *Chara.* Later stages in the germination of oospore.

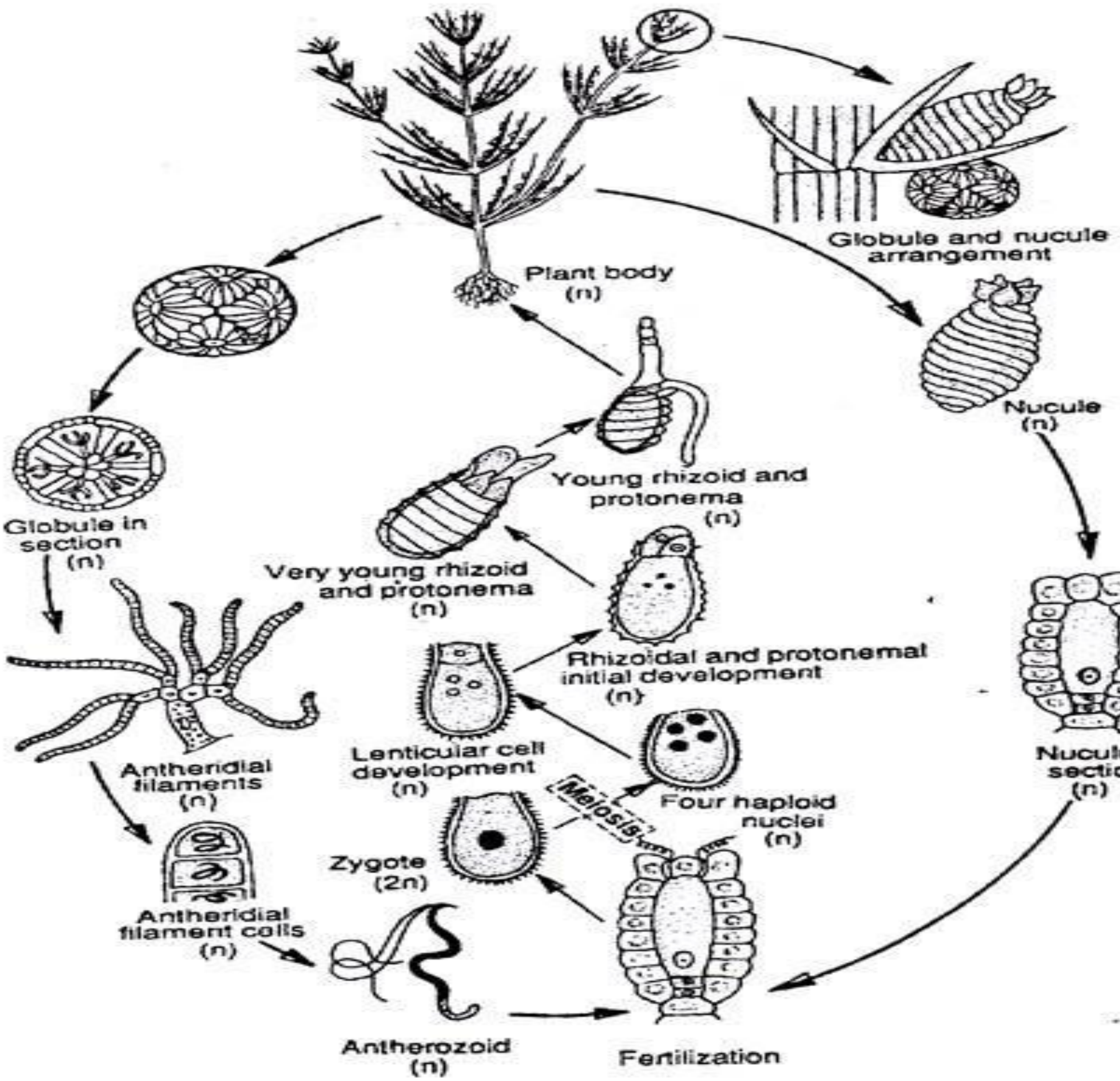


Fig. 12. *Chara*. Diagrammatic life Cycle

Taxonomic Position

Division : Chlorophyta
Class : Charophyceae
Order : Charales
Family : Characeae
Sub-family : Charoideae
Genus : Chara

Division: Chrysophyta

General features of Chrysophyta

Golden brown chromatophores present, assimilation product fatty oil, flagella present.

A-Planktonic species are mostly motile (flagella), require Si (but less than diatoms), and are often mixotrophic (bacterivores)

B-Chrysophyta are slower-growing than diatoms but need less Si, suffer less sedimentation (almost none), and some can supplement their nutrition by mixotrophy.

C-Early stages of fall mixing can stimulate a fall bloom, smaller in magnitude than spring bloom, as failing supply of sunlight and deepening of mixed depth curtail growth

D-Intolerant of eutrophic conditions.

E-Structure: Unicellular motile to branched filamentous.

F- Flagella: Present, Two in number, equal or may be unequal, inserted anteriorly.

G- Reproduction: Vegetative and Sexual (normally absent, but if present isogamous)

Xanthophyceae: General feautres

1- Occurrence: Mostly freshwater and a few marine representative

2- Pigments: Chlorophyll a, e, β carotene and xanthophylls

3- Pyrenoids: Usually absent

4- Reserve food material: Chrysolaminaran, Oil and fat

5-Cell wall: Rich in pectic compounds and composed of two equal pieces overlapping at the edges.

6-Structure: Eukaryotic unicellular motile to simple filamentous,

7- Flagella: Present, two unequal, situated anteriorly. Longer one tinsel and shorter one whiplash

8-**Reproduction**: Vegetative, Asexual and Sexual (Mainly Isogamous, Anisogamy is rare, Oogamous in Vaucheria) Yellow-green algae or xanthophytes are an important group of heterokont algae. Most live in freshwater, but some are found in marine and soil habitats. They vary from single-celled flagellates to simple colonial and filamentous forms. Xanthophyte chloroplasts contain the photosynthetic pigments Chlorophyll a, Chlorophyll c, β-Carotene, and the carotenoid diadinoxanthin. Unlike other heterokonts, their chloroplasts do not contain fucoxanthin, which accounts for their lighter colour. Its storage polysaccharide is chrysolaminarin. Xanthophyte cell walls are produced of cellulose and hemicellulose. They appear to be the closest relatives of the brown algae.

Vaucheria sp.

Vaucheria is a genus of Xanthophyceae or yellow-green algae. It is one of only two genera in the family Vaucheriaceae. The type species of the genus is Vaucheria disperma. *Vaucheria* exhibits apical growth from the tip of filaments forming mats in either terrestrial or freshwater environments. Its filaments form coenocytes with a large central vacuole pushing against the surrounding cytoplasm; the vacuole extends along the entire filament except for the growing tip. The chloroplasts are located on the periphery of the cytoplasm with the nuclei aggregating toward the center near the vacuole.

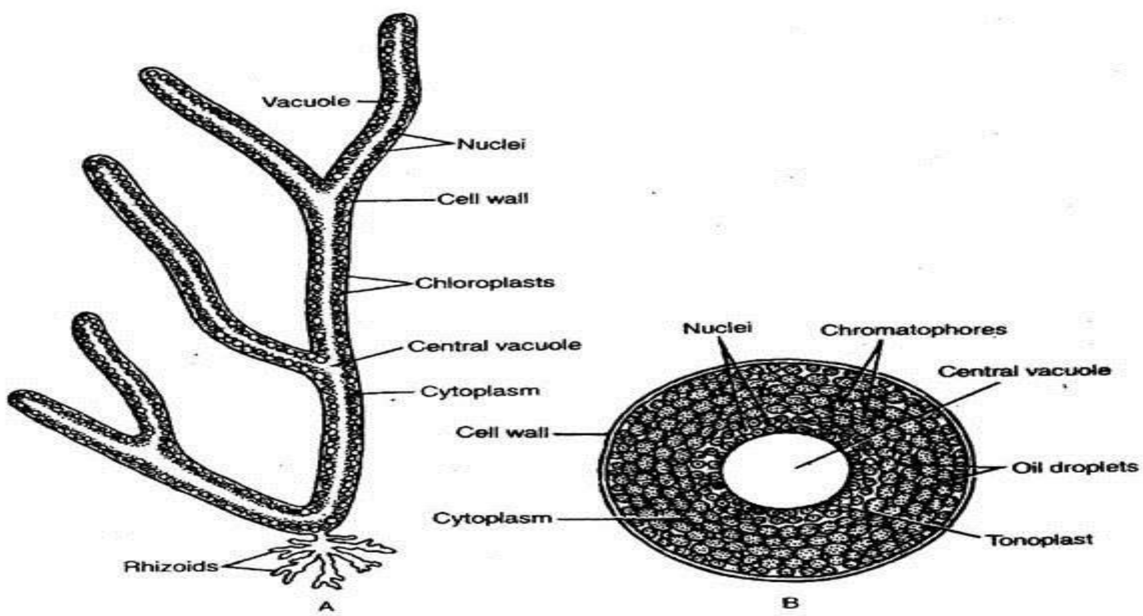


Fig. 3.83 : *Vaucheria* sp. : A. Single vegetative filament with rhizoid, B. T.S. through vegetative filament

Reproduction in Vaucheria:

Reproduction in *Vaucheria* takes place by vegetative, asexual and sexual methods.

(i) Vegetative Reproduction in *Vaucheria:*

The vegetative reproduction takes place by fragmentation. The thallus can break into small fragments due to mechanical injury or insect bites etc. A septum develops at the place of breaking to seal the injury. The broken fragment develops thick wall and later on develops into *Vaucheria* thallus.

(ii) Asexual reproduction in *Vaucheria*:

The asexual reproduction takes place by formation of zoospores, aplanospores and akinetes.

By Zoospores:

The zoospores formation is the most common method of reproduction in aquatic species. In terrestrial species it takes place when the plants are flooded. Zoospore formation takes place in favourable seasons or can be induced if aquatic species are transferred from light to darkness or from running water to still water.

Zoospores are formed singly within elongated club shaped zoosporangium .The development of zoosporangium begins with a club shaped swelling at the tip of a side branch. A large number of nuclei and chloroplasts along with the cytoplasm move into it. A colourless protoplasmic region becomes visible at the base of cytoplasm and it is separated from rest of the cytoplasm of thallus.

Each separated protoplast secretes thin membrane and zoosporangium gets separated by a cross wall. Inside zoosporangium the vacuole decreases, the contents of sporangium become very dense and round off. The change takes place in relative position of chloroplasts and nuclei, the nuclei become peripheral and chloroplasts enter in inner layer of cytoplasm. the entire protoplasm of the zoosporangium contracts to form oval zoospore. Opposite to each nucleus two flagella are produced making zoospore a multi-flagellate structure. A terminal aperture develops in zoosporangium by gelatinization of wall. The zoospore is liberated through aperture in morning hours (Fig. 2 C, D).

Each zoospore is large yellow green, oval structure. It has a central vacuole which has cell sap and may be traversed by cytoplasmic strands. The protoplasm outer to vacuole has many nuclei towards the walls and chromatophores towards vacuoles. Two flagella arise opposite to each nucleus. This part of cytoplasm can be regarded equivalent to one zoospore.

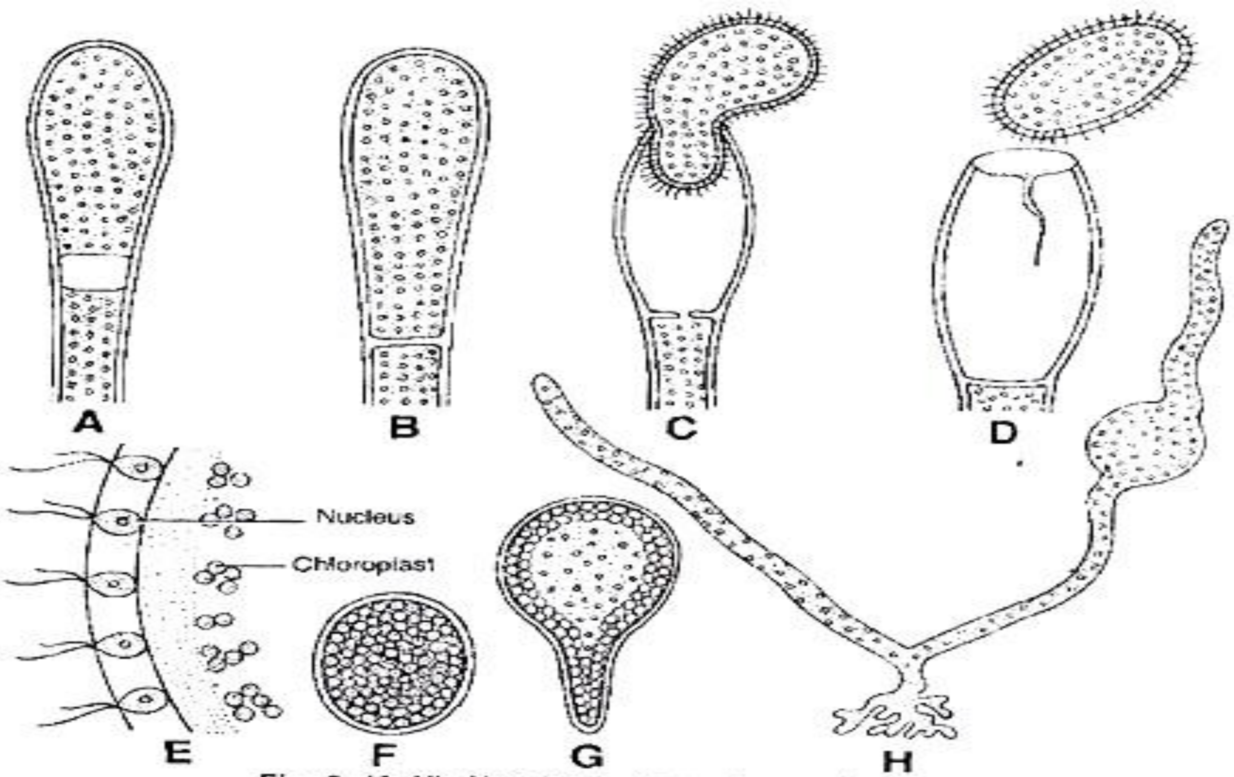


Fig. 2. (A–H). *Vaucheria*. Asexual reproduction.

(iii) Sexual reproduction in *Vaucheria*:

In *Vaucheria* sexual reproduction is of advanced oogamous type. The male and female sex organs are antheridia and oogonia, respectively. Majority of the freshwater species are monoecious or homothallic while some species like *V dichotoma*, *V. litorea* and V. *mayyanadensis* are dioecious or heterothallic. There are different types of arrangement of antheridia and oogonia in homothallic species. The position, structure and shape of antheridia are of taxonomic importance in *Vaucheria*.

Fertilization:

The oogonium secretes a gelatinous drop through a pore near the beak. A large number of liberated antherozoids stick to the drop. Many antherozoids push into the oogonium. The antherozoids strike violently, fall back and push forward again and fall back. Only one antherozoid enters into the oogonium.

After its entry the membrane develops at the pore to stop the further entry of antherozoids. The male nucleus increases in size and fuses with the egg nucleus to make diploid zygote. The zygote secretes a thick 3-7 layered wall and is now called as oospore (Fig. 6 G-I). The chromatophores degenerate and lie in the centre of the cell.

Germination of oospore:

The oospore undergoes a period of rest before germination. During favourable season the oogonial wall disintegrates and the oospore is liberated. The oospore germinates directly into new filaments.

Although the exact stage at which the reduction division takes place in *Vaucheria* is not clear, it is believed that reduction division occurs in first nuclear division in the germinating oospore (Fig. 7 A-D). The oospore germinates to make haploid thallus of *Vaucheria*.

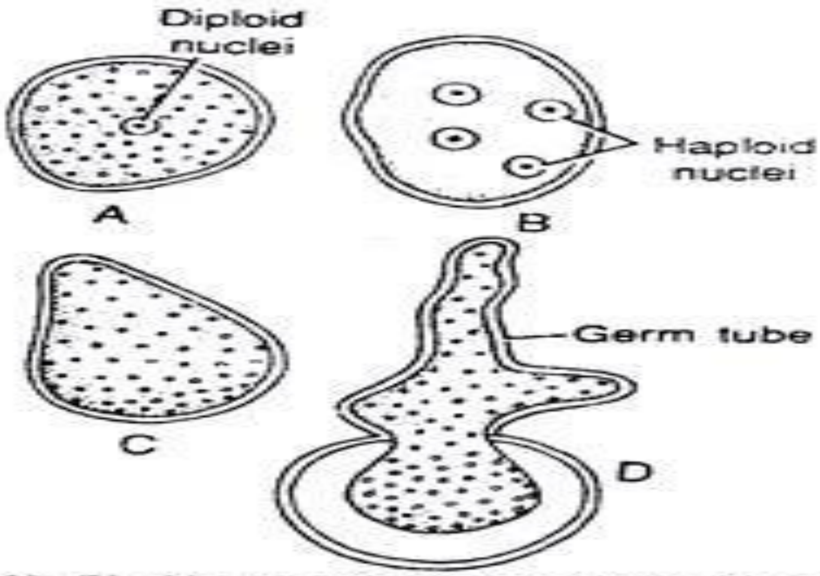


Fig. 7. (A–D). *Vaucheria*. Germination of oospore.

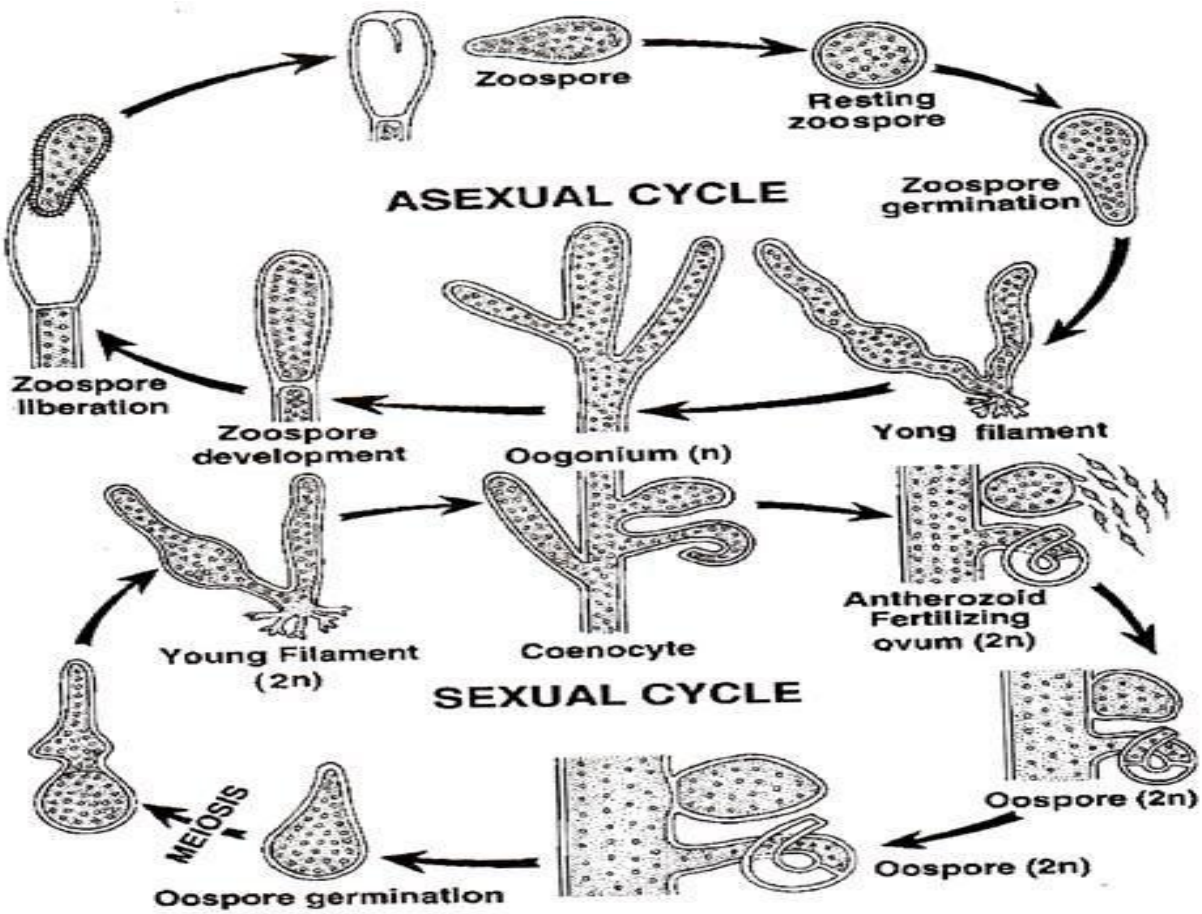


Fig. 8. *Vaucheria*. Diagrammatic life cycle.

Division: Phaeophyta (Brown Algae)

The Phaeophyta or brown algae are mostly marine algae. Phaeophyta are characterized by the pigment fucoxanthin that gives them the brown colour. The cell wall in Phaeophyta is two layered; inner layer consists of cellulose and outer layer mainly of algin and fucoidan. The brown seaweeds serve as important source of the industrial hydrocolloid alginate as well as food in countries like Japan, Korea and China.

General characteristics

(a) Occurrence: Mostly marine.

(b) Pigments: Fucoxanthin is dominant, Chlorophyll a, c and carotene.

(c) Pyrenoids: Stalked pyrenoids present outside the chloroplast envelope..

(d) Reserve food material: Laminarin, mannitol and fats.

(e) Cell wall: Cellulose, alginic acid and fucinic acid.

(f) Structure: Microscopic to branched, filamentous macroscopic Parenchymatous plants.

(g) Flagella: Zoospores flagellated, flagella unequal, one is tinsel type.

(h) Reproduction: Sexual reproduction (isogamous, anisogamous and oogamous).

Division: Rhodophyta

The scientific name of Red Algae is Rhodophyta and they belong to Class Rhodophyceae. There are two classes of red algal namely the **Florideophyceae** and **Bangiophyceae**. Both Florideophyceae and Bangiophyceae comprise 99% of red algal diversity in marine and freshwater habitats.

Red algae or Rhodophyta. It is a distinctive type of species that are mostly found in the freshwater lakes and are the oldest type of eukaryotic algae. They are red in colour due to the presence of a pigment called chlorophyll A, phycocyanin, and phycoerythrin.

General characteristics of Red Algae

Red algae are different from other groups except for diatoms. Listed below are general characteristics of Red Algae.

- Lack of flagella and centrioles
- Have chlorophyll a and d, phycobiliproteins,,
- Floridean starch granules are the storage product (outside chloroplast).
- • No chloroplast ER.
- The majority of seaweeds are red algae (~400 species which is more than all other seaweeds groups).
- • They live at depth as great as 200 m.
- • About 200 sp. Are found in freshwater with smaller size than seaweeds.
- Found both in marine and freshwater
- They show biphasic or triphasic life cycle patterns.
- They are a multicellular, filament, blade structure.
- A pit connection (hole in the septum) is formed between two algal cells.
- Have a diffuse growth pattern- Apical growth, Complex oogamy(triphasic)
- These group of red algae is generally found in tropical marine locations
- The mode of nutrition may either be saprophytic, parasitic or also epiphytic.
- Their cell walls consist of cellulose and many different types of carbohydrates.
- Grow on solid surfaces independently or sometimes found attached to other algae.
- Presence of pit in the cell walls, through which cytoplasmic connections are maintained.
- The male sex organs are known as spermatangium and the female sex organs are called carpogonia or procarp.
- Mode of Reproduction: It takes place by all the three means: vegetative, asexual and sexual. Asexual mode of reproduction is by monospores and during the sexual mode of reproduction, they undergo alternation of generations.

Uses of Red Algae

Red Algae has great ecological importance. They form a vital part of the food chain and are also involved in producing about 40 to 60 per cent of the total global oxygen for both terrestrial habitat and other aquatic habitats. Listed below are a few ecological and commercial importance of red algae.

- Algae provide natural food for fish and other aquatic animals.
- Red alga is the most important commercial food in Japan and in the region of North Atlantic.
- Agar or agar-agar, a jelly-like substance which is used in puddings, dairy toppings and other instant food products is extracted from Red algae.
- Red algae are used as the source of food for thousands of years as they are high in vitamins, minerals, a rich source of calcium, magnesium, and antioxidants.
- They are sources of dietary fibre as they have the ability to promote healthy circulation, lower bad cholesterol and regulate blood sugar levels.
- They are also involved in nourishes your skin, boosting the immune system and contributing to bone health.

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Phycology (Practical part)

Phycology (Practical part)

Division1 : Cyanophyta (Cyanophycophyta)

Kingdom: Monera

Division: Cyanophyta

Class: Cyanophyceae

Prokaryotic that contains chlorophyll a, phycobiliproteins, glycogen as storage product and cell walls consisting of amino acids and amino sugars.

It is a small primitive group comprising of about 2,500 species placed under 150 genera. All of them are included in a single class Cyanophyceae or Myxophyceae.

Morphology

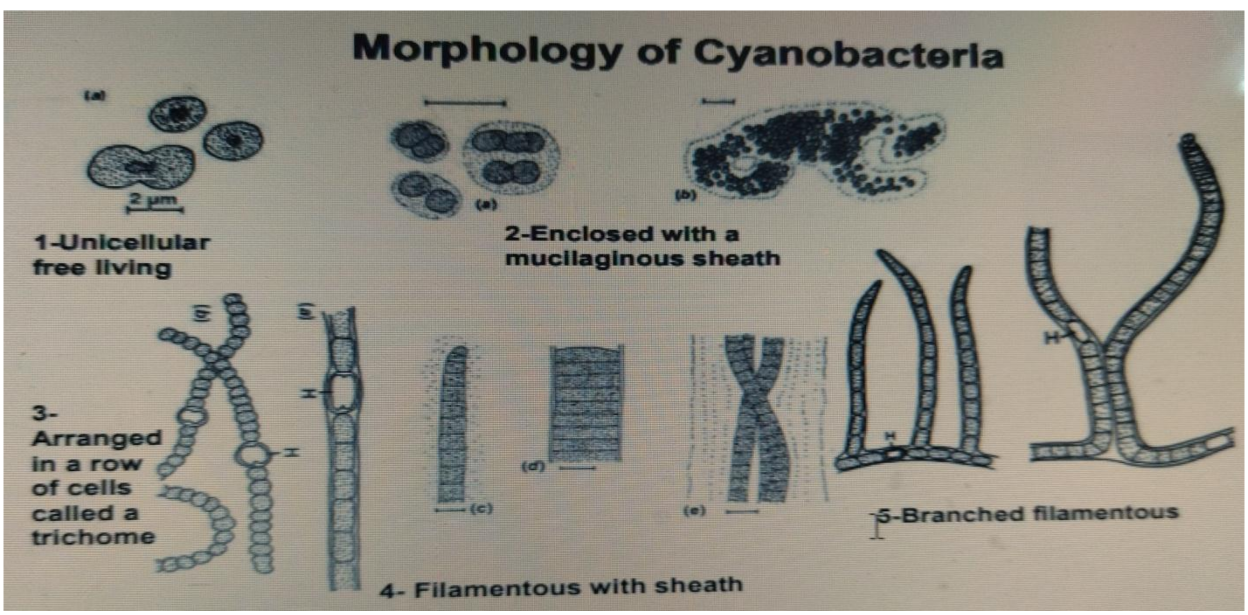
1- unicellular free living

2-Enclosed with a mucilaginous envelope

3-Arranged in a row of cells called a trichome

4- Filamentous: the trichome (one or more) is surrounded by a sheath.

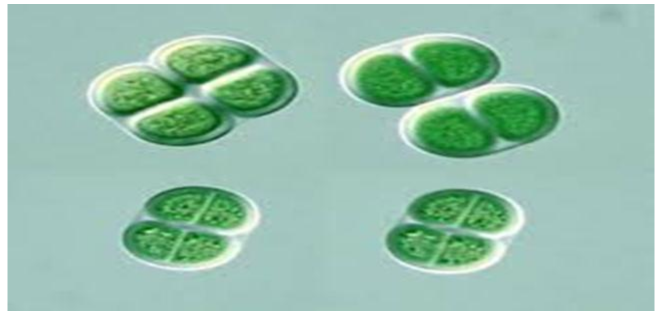
5-Branched filamentous which could be uniseriate (one row of cells) or multiseriate (more than one row).

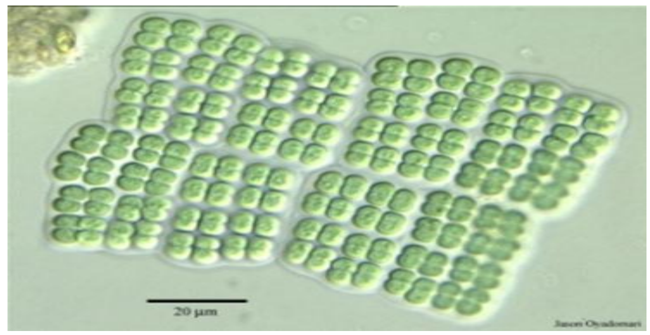


Taxonomic Position

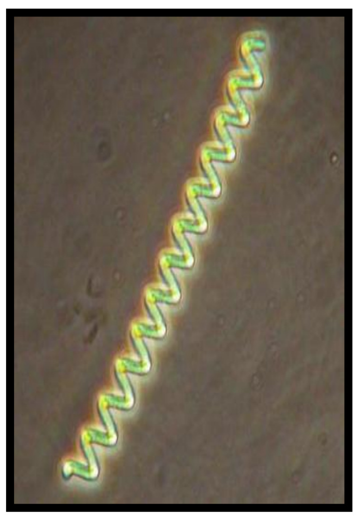
Genus

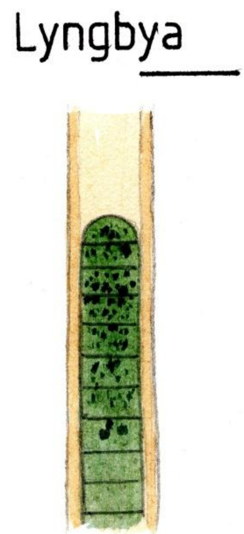
Division : Cyanophyta
Class : Cyanophyceae
Tribe : Coccogoneae
Order : Chroococcales
Family : Chroococcaceae
Genus : *Chroococcus sp*
Mrismopedia sp





Order : Oscillatoriales
Family : Oscillatoriaceae
Genus : *Oscillatoria sp*
Spirulina sp
Lyngbya sp





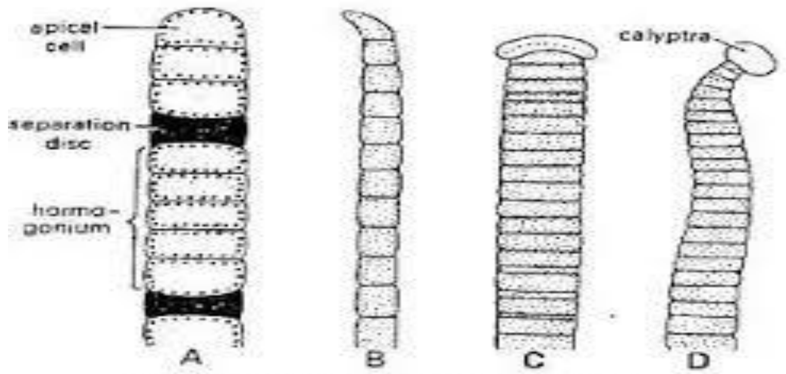
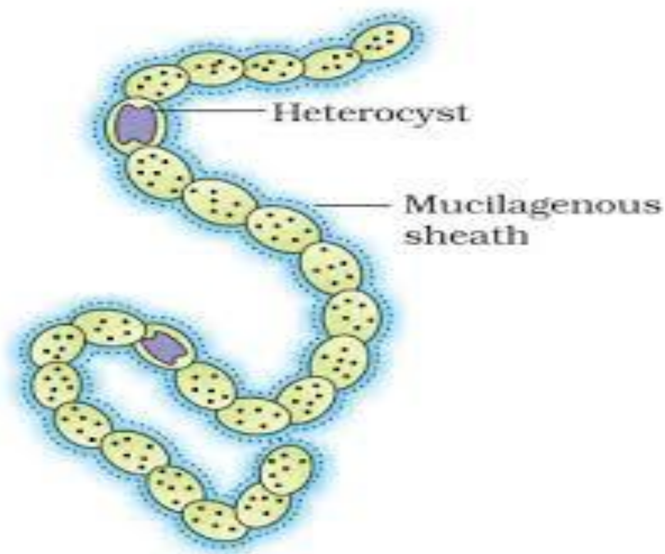
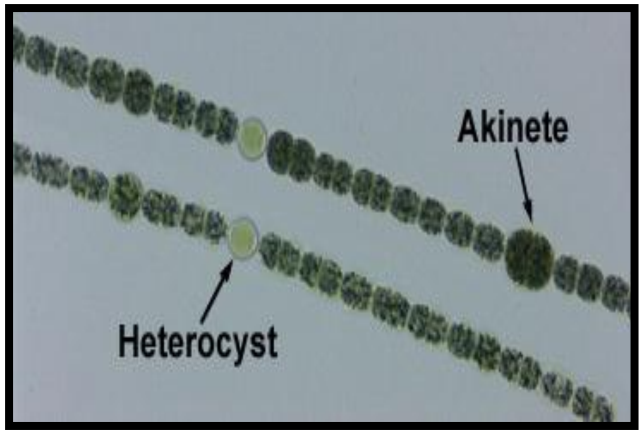


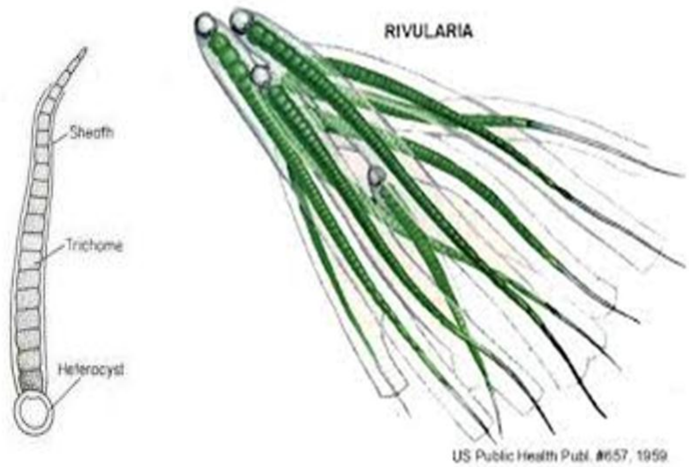
Fig. 1 (A–D) : *Oscillatoria* : Trichomes.

Order : Nostocacales
Family1 : Nostocaceae
Genus : Nostoc
Anabaena





Order : Nostocacales
Family: Rivulariaceae
Genus : Rivularia



Kingdom Protista (Eukaryotes)

Algae

Division1: Chlorophyta

have chlorophylls a and b.

• form starch with the chloroplast, usually in association with a pyrenoid. The Chlorophyta thus differ from the rest of the eukaryotic algae in forming the storage product in the chloroplast instead of in the cytoplasm.

• No chloroplast endoplasmic reticulum occurs around the chloroplasts.

• The Chlorophyta are primarily freshwater; only about 10% of the algae are marine, whereas 90% are freshwater.

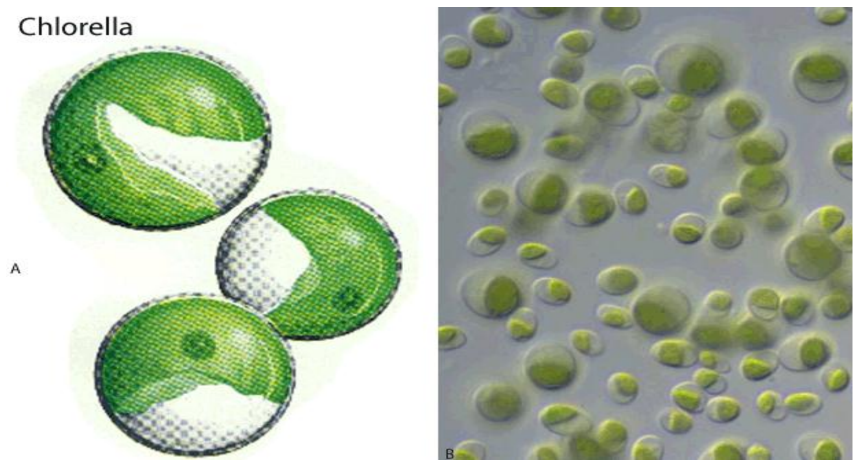
• Some orders are predominantly marine, whereas others are predominantly freshwater or exclusively freshwater. The freshwater species have a cosmopolitan distribution, with few species endemic in a certain area.

• In the marine environment, the green algae in the warmer tropical and semitropical waters tend to be similar everywhere in the world. This is not true of the Chlorophyta in the colder marine waters; the waters of the Northern and Southern hemispheres have markedly different species.

Taxonomic Position **Genus**

Division : Chlorophyta
Class1 : Chlorophyceae
Order : Chlorococcales
Family : Chlorococcaceae
Ex : *Chlorococcum* sp.

Family : Oocystaceae
Ex : *Chlorella* sp.
: *Ankistrodesmus* sp.



Family : Hydrodictaceae
Ex : *Hydrodictyon* sp.
: *Pediastrum* sp.

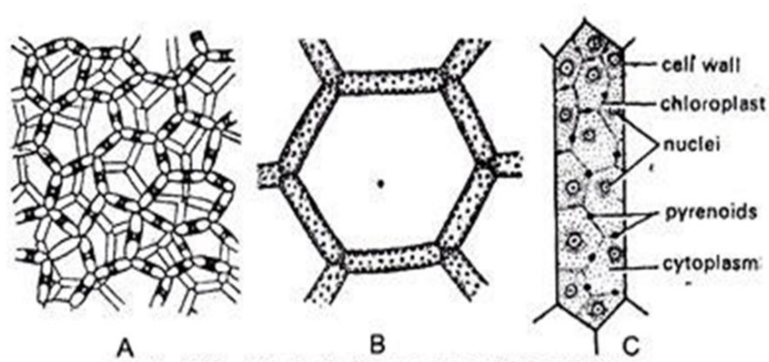
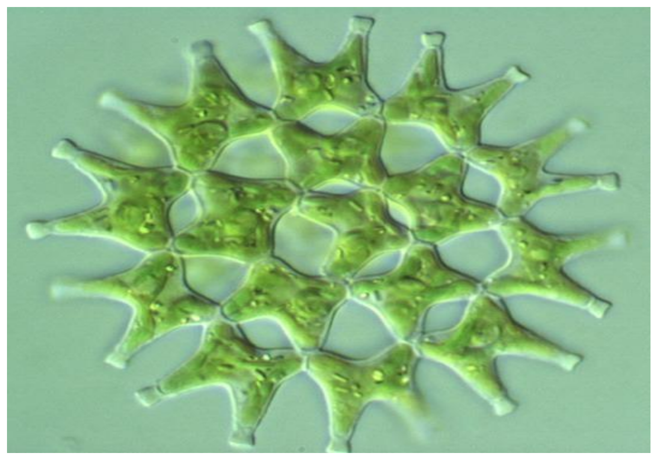
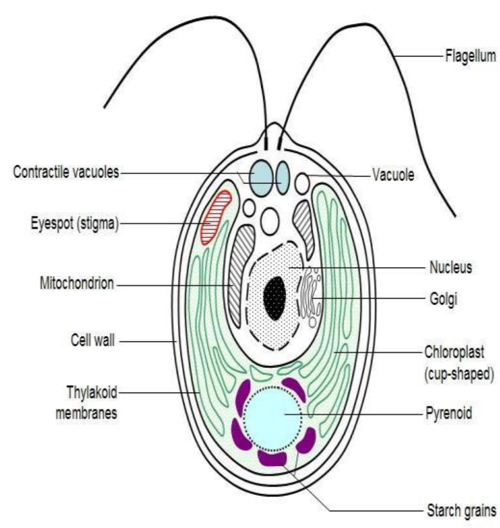


Fig. 2 (A—C). *Hydrodictyon*. Vegetative structure.
A. A part of the net; B. Hexagonal mesh; C. A cell.

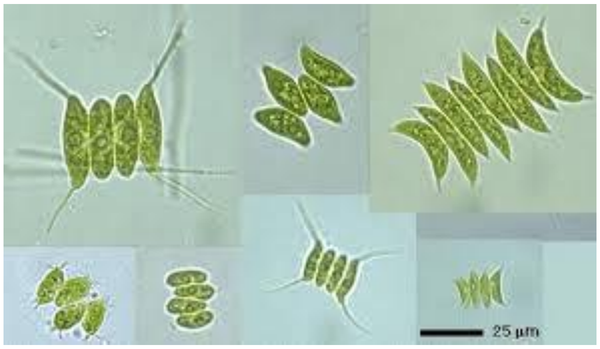


Order : volvocales
Family : Chlamydomonaceae
Ex : <u>*Chlamydomonas*</u> <u>*sp.*</u>

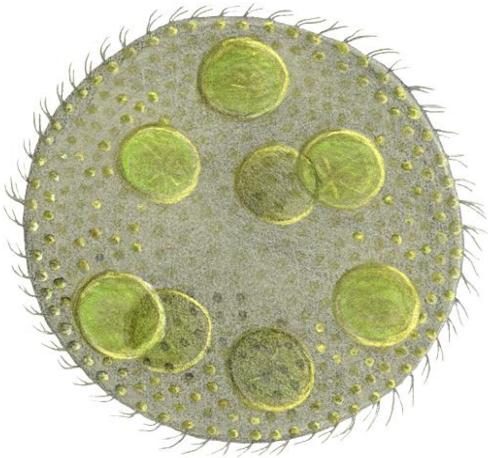
<u>*Chlamydomonas*</u>



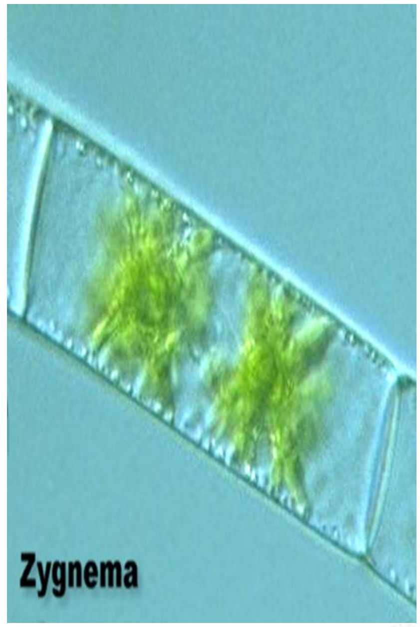
Family : Scenedesmaceae
Ex : *Scenedesmus* sp

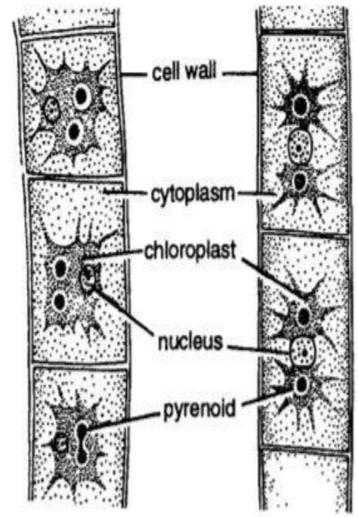


Order : Volvocales
Family : Volvocaceae
Ex. : *Volvox sp.*
: *Gonium sp.*
: *Pandorina sp.*
: *Eudorina* sp.

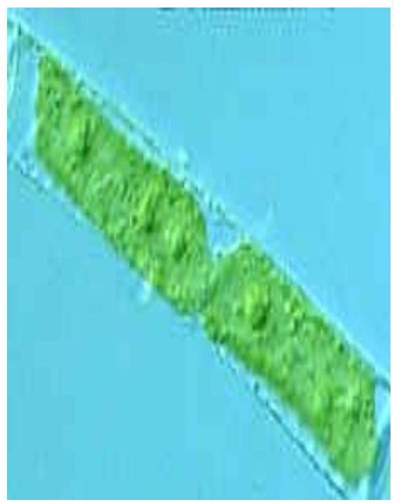


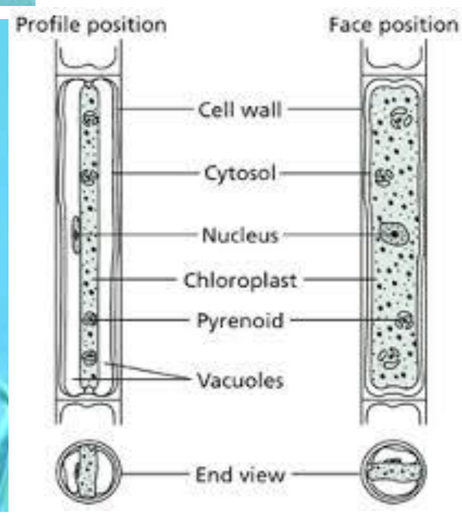
Order : Zygnemales (Zygnematales
Family1 :Zygnemaceae (Zygnemataceae)
Ex :*Zygnema* sp.
:*Spirogyra* sp.
:*Mougeotia*_ sp.

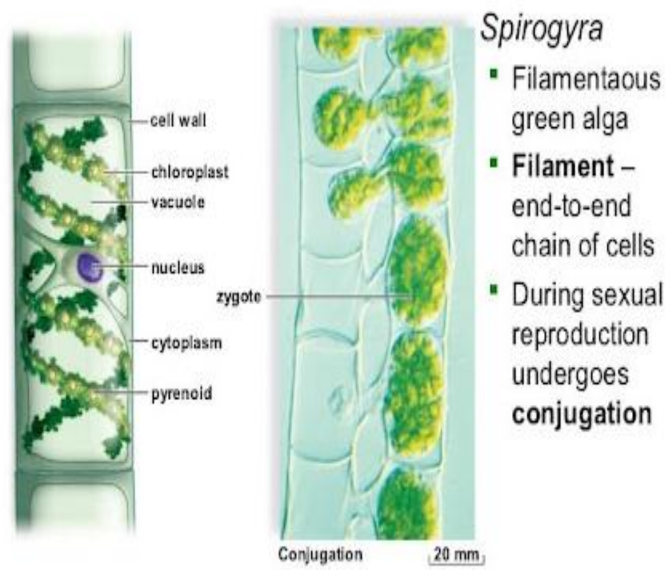




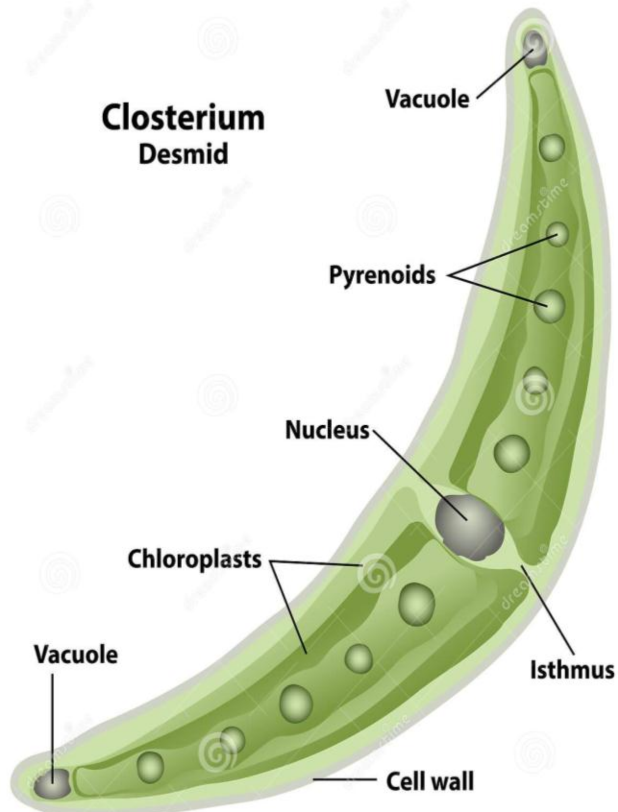
Zygnema. Filaments showing internal structure of the cell.





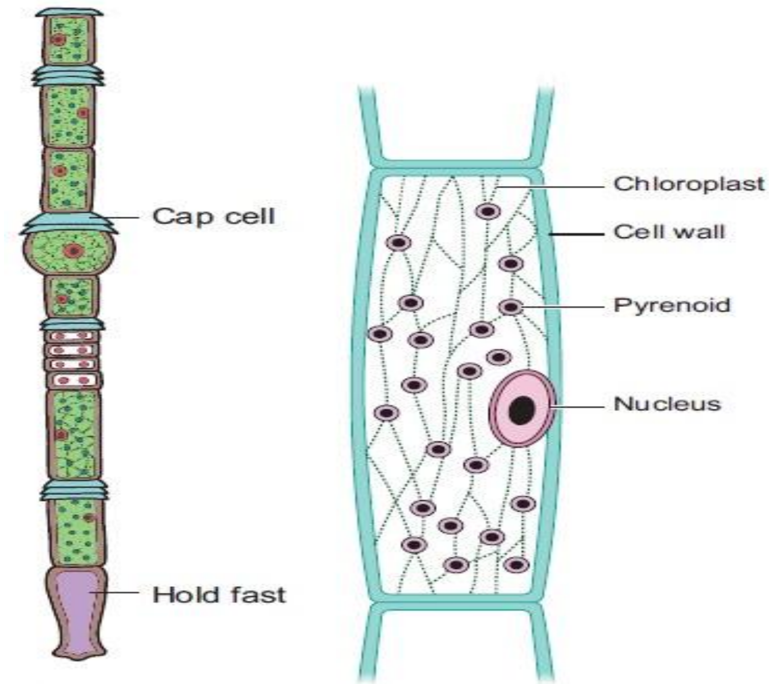


Family 2 :Desmidiaceae
Ex :Cosmarium sp.
: Closterium sp.



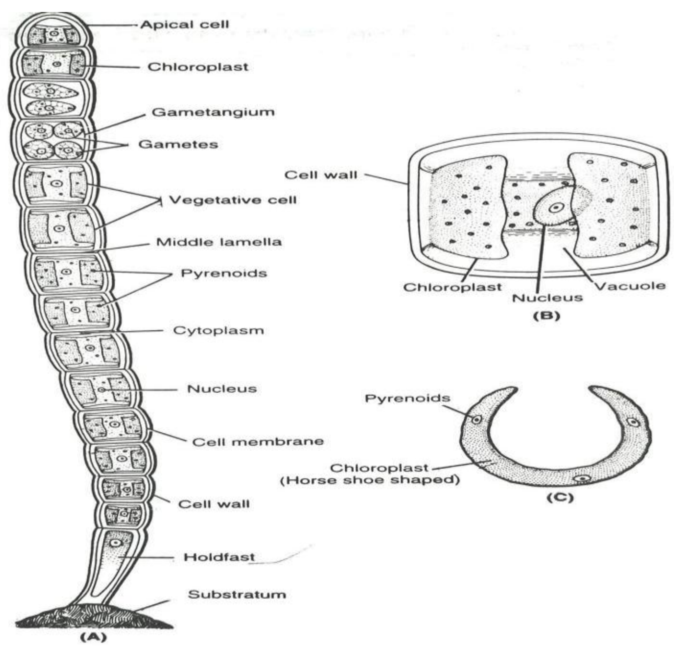
Order :Cladophorales
Family :Cladophoraceae
Ex :*Cladophora* sp.

Order :Oedogoniales
Family :Oedogoniaceae
Ex :*Oedogonium* sp.

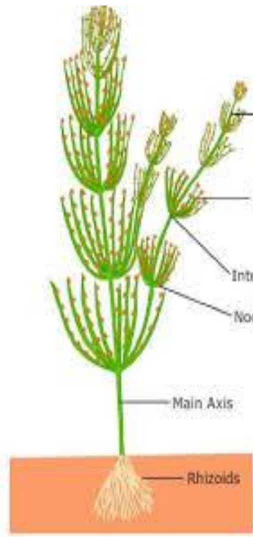


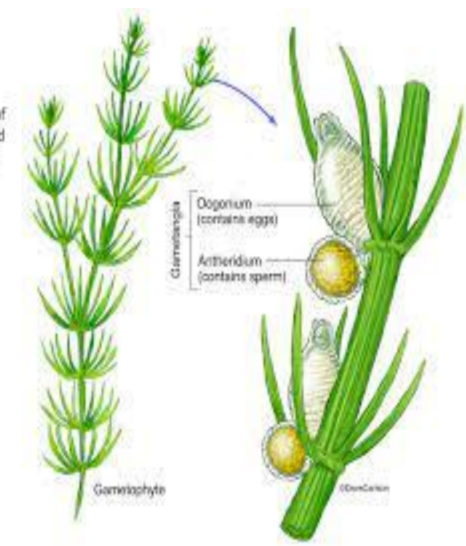
a) A single filament b) A cell enlarged

Order :Ulotrichales
Family :Ulotrichaceae
Ex :*Ulothrix* sp.



Class2 : Charophyceae
Order :Charales
Family :Characeae
Ex. :*Chara* sp.





Class :Xanthophyceae
Order :Heterosiphonales
Family :Vaucheriaceae
Ex. :*Vaucheria* sp.

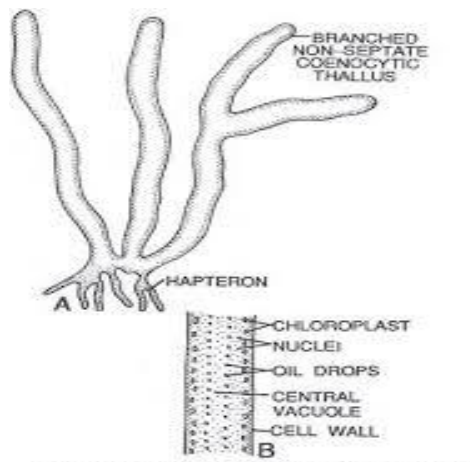
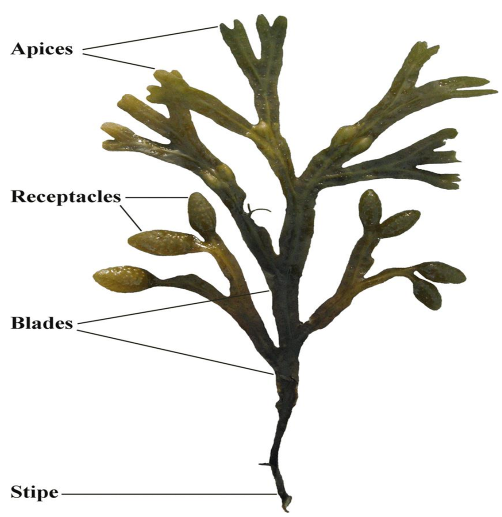


Fig 5.1. *Vaucheria* sp. Vegetative structure; A, a complete thallus; B, a part of thallus (enlarged).

Division : Phaeophyta
Class :Phaeophyceae
Order :Fucales
Family :Fucaceae
Ex. :*Fucus* sp.



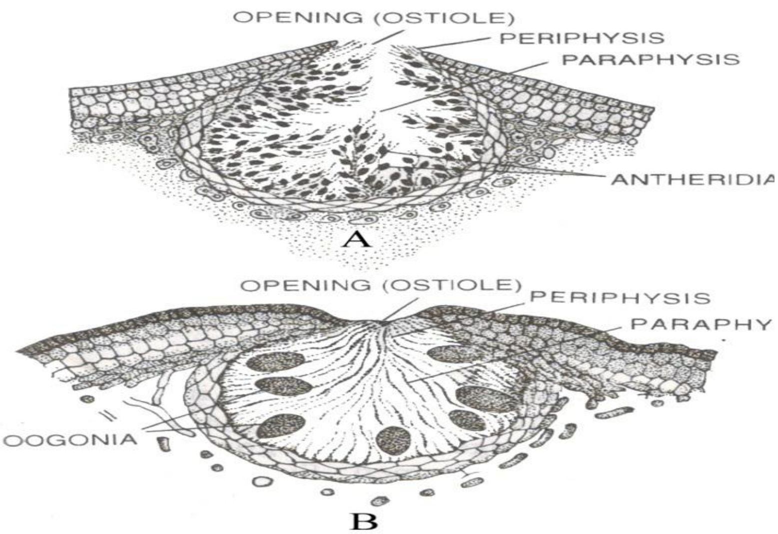


Fig : Male Conceptacle bearing Antheridia
Fig : Female Conceptacle bearing Antherid

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