Lectures in

Botany 4

(Phycology and Plant Ecology)

For the 2nd year students

Biology and geology students

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PHYCOLOGY

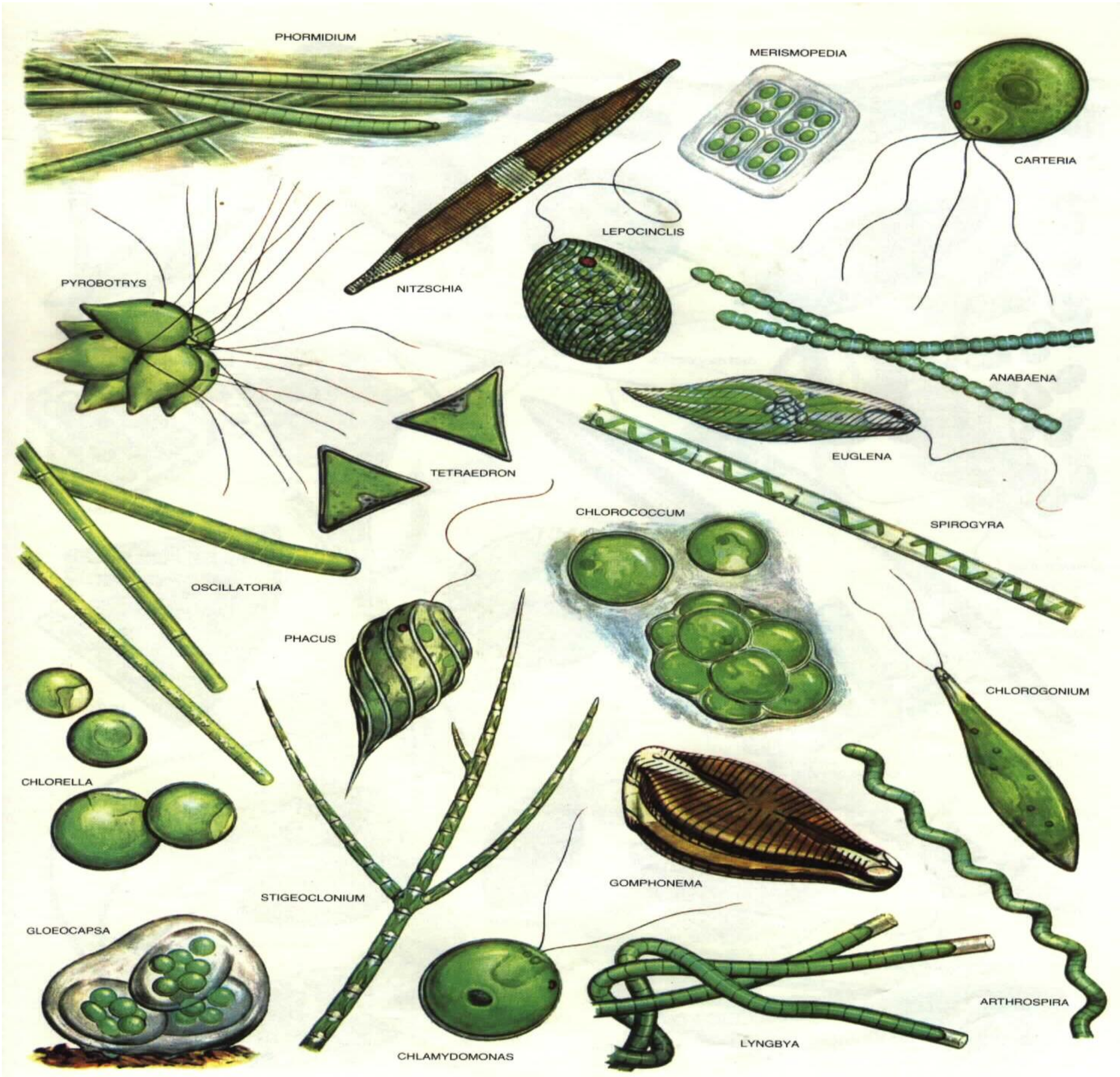

Plate 39. Polluted-water algae.

FOR 2ND YEAR BIOLOGY &GOLOGY

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. Aerophytes 4. Cryophytes
5. Thermophytes 6. 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- 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.

4. 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*.

5. 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.

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

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

b) 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.

c) *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.

d) Endophytic algae. found inside the aquatic plants

e) *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.

f) *Endozoic algae.* Contrary to epizoic algal forms endozoic algae are found inside the aquatic animals *e.g., Zoochlorella* is found insi

inside *Hydra viridis* while *Zooxanthe* known to occur inside the fresh water sponges.

g) *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.*

h) *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 *Azotobacter 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.

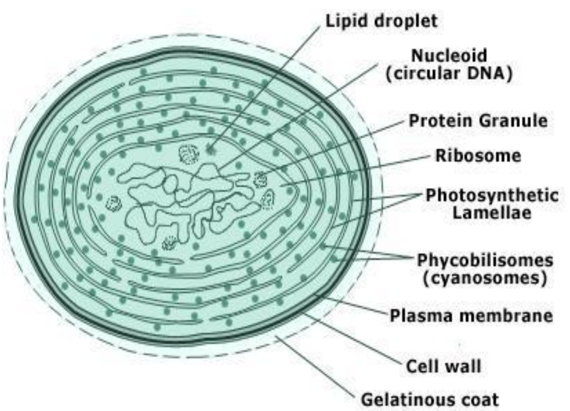


Fig.2. Cell Structure of Cyanophyta

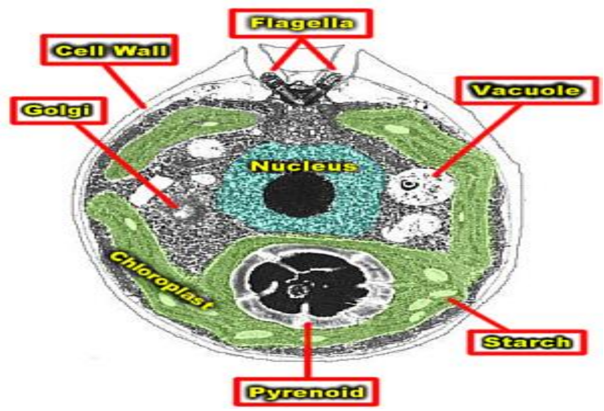


Fig.3. Cell structure of green algae

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.

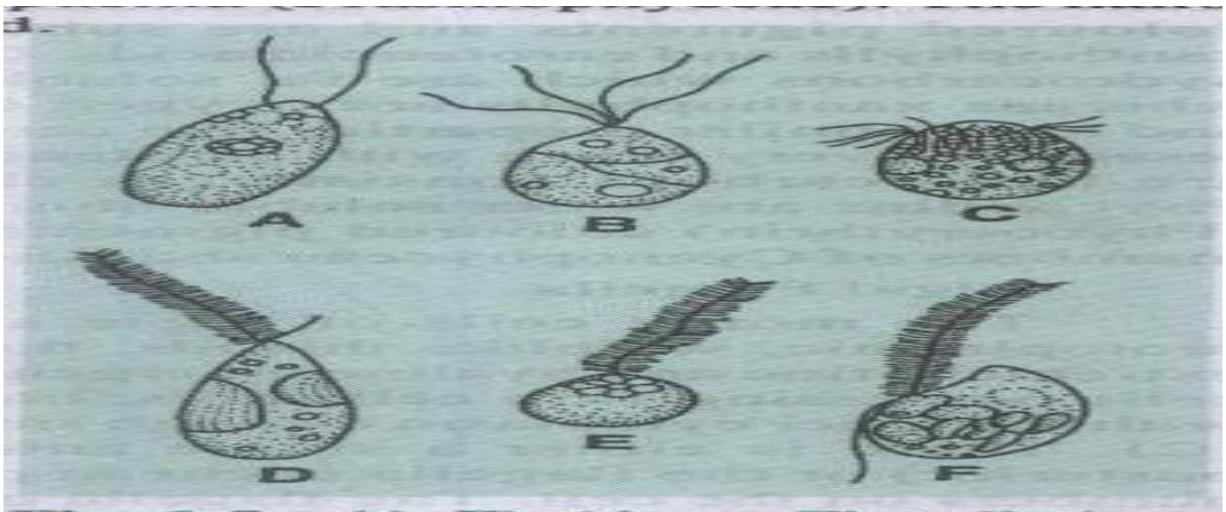


Fig. 1.5. (A-F) *Algae*. Flagellation., Chlorophyceae (A-C); Xanthophyceae (D); Bacillariophyceae (E) and Phaeophyceae (F).

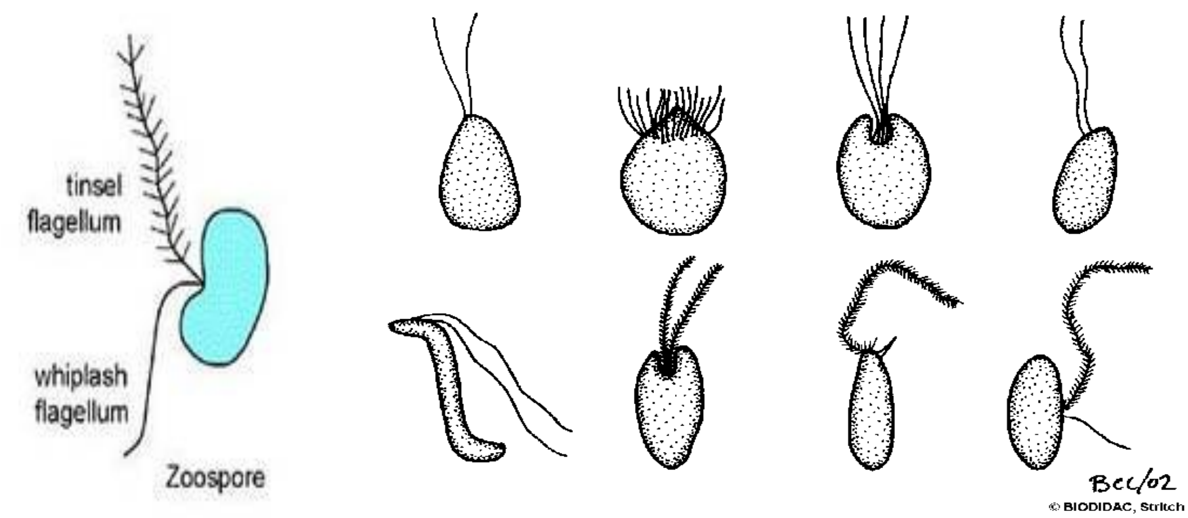


Fig 4. Types of Algal flagella

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*.

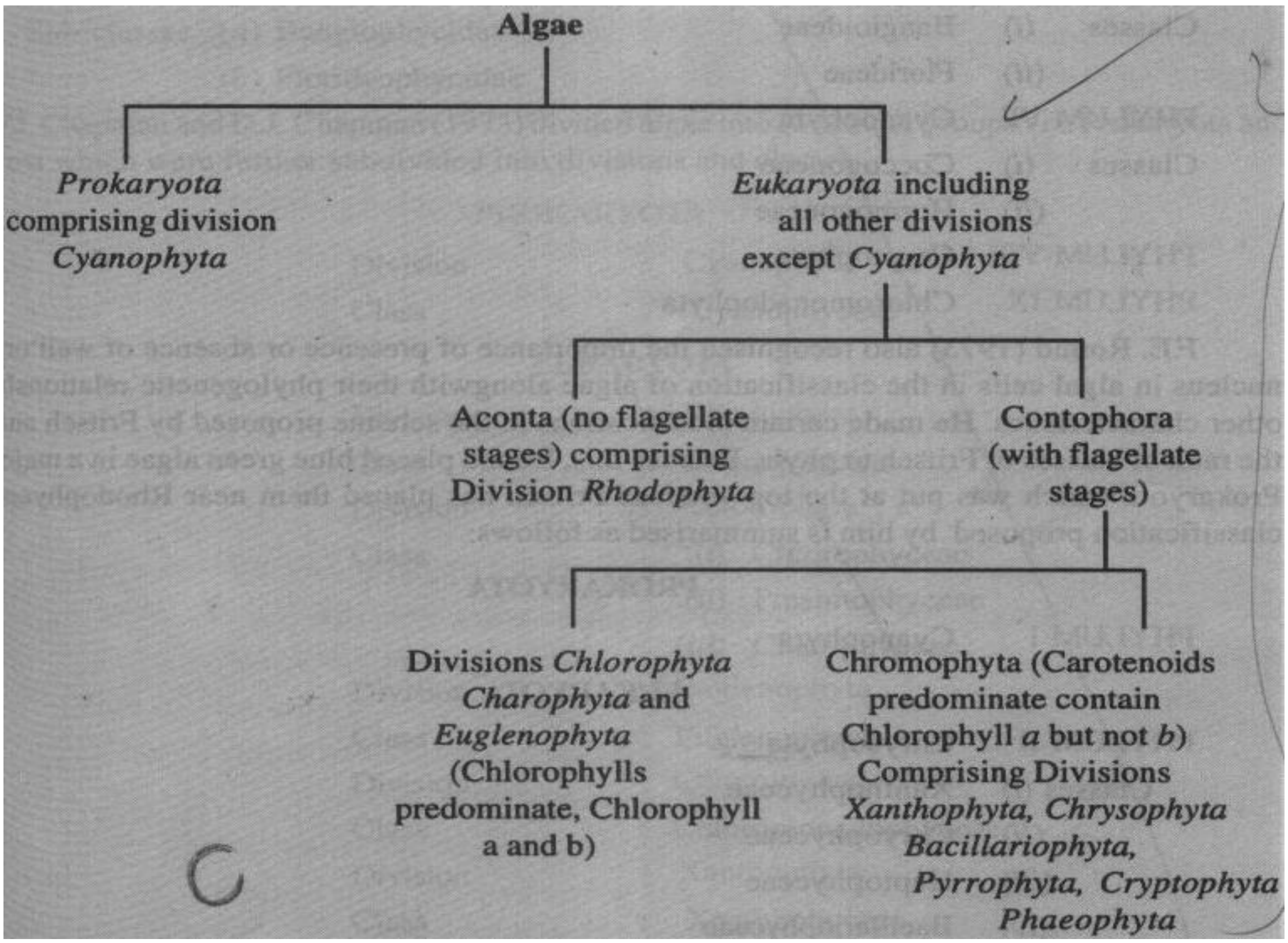
Division 4 : *Pyrrophyta* include 1000 species mainly unicellular rarely colonial. Pigments are chlorophyll a & c, carotene and xanthophyll. Reserve foods is starch/oil. Divided into two classes: (1) *Desmophyceae* (dinophysids) e.g., *Desmarestia',* (2) *Dinophyceae* (Dinoflagelloids) e.g., *Dinophysis*

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.

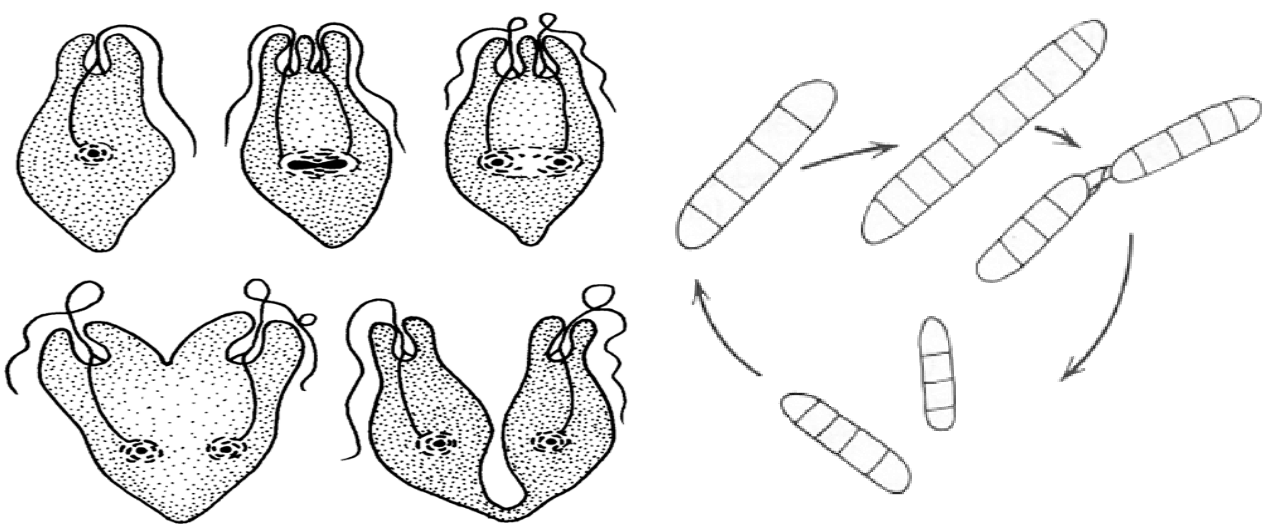


Fig.5: Vegetative reproduction: simple cell division and fragmentation

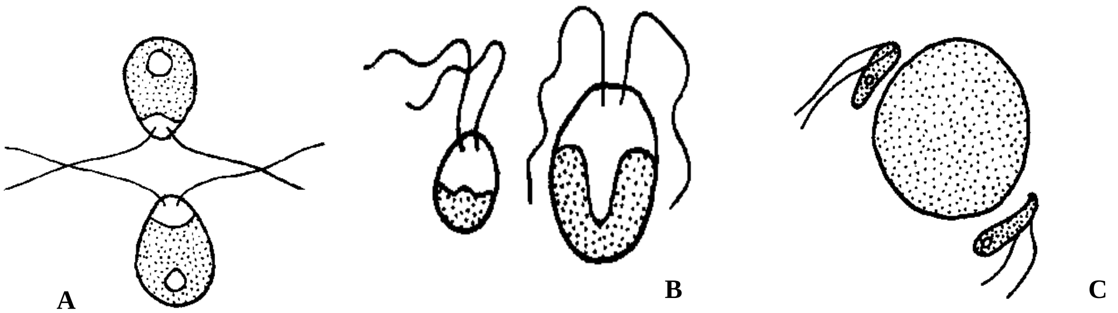


Fig. 6: Types of sexual reproduction in algae; **A- Isogamy**, **B- Anisogamy** and **C- Oogamy respectively.**

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*.

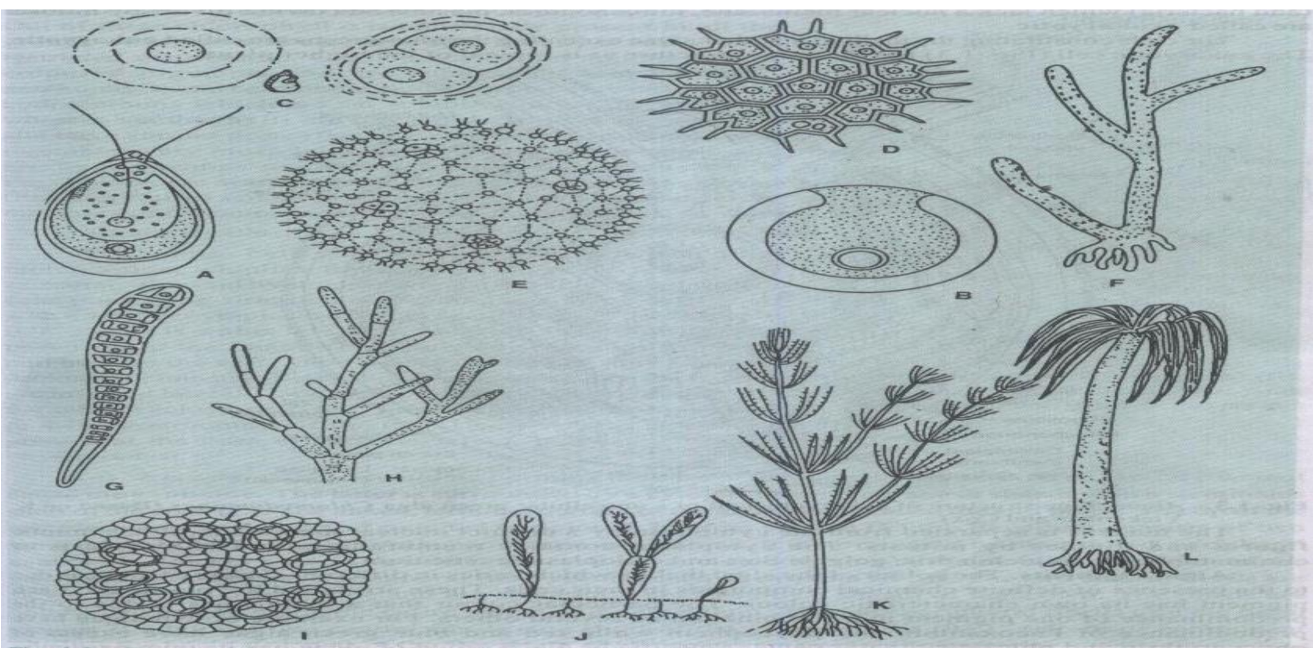


Fig. 1.2. Range of thallus organisation in Algae. (A). *Chlamydomonas*, (B). *Chlorella*, (C). *Gloeocapsa*, (D). *Pediastrum* (E). *Volvox* (F). *Vaucheria* (G). *Ulothrix* (H). *Cladophora*, (I). *Coleochaete* (J). *Caulerpa* (K). *Chara* (L). *Postelsia*

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

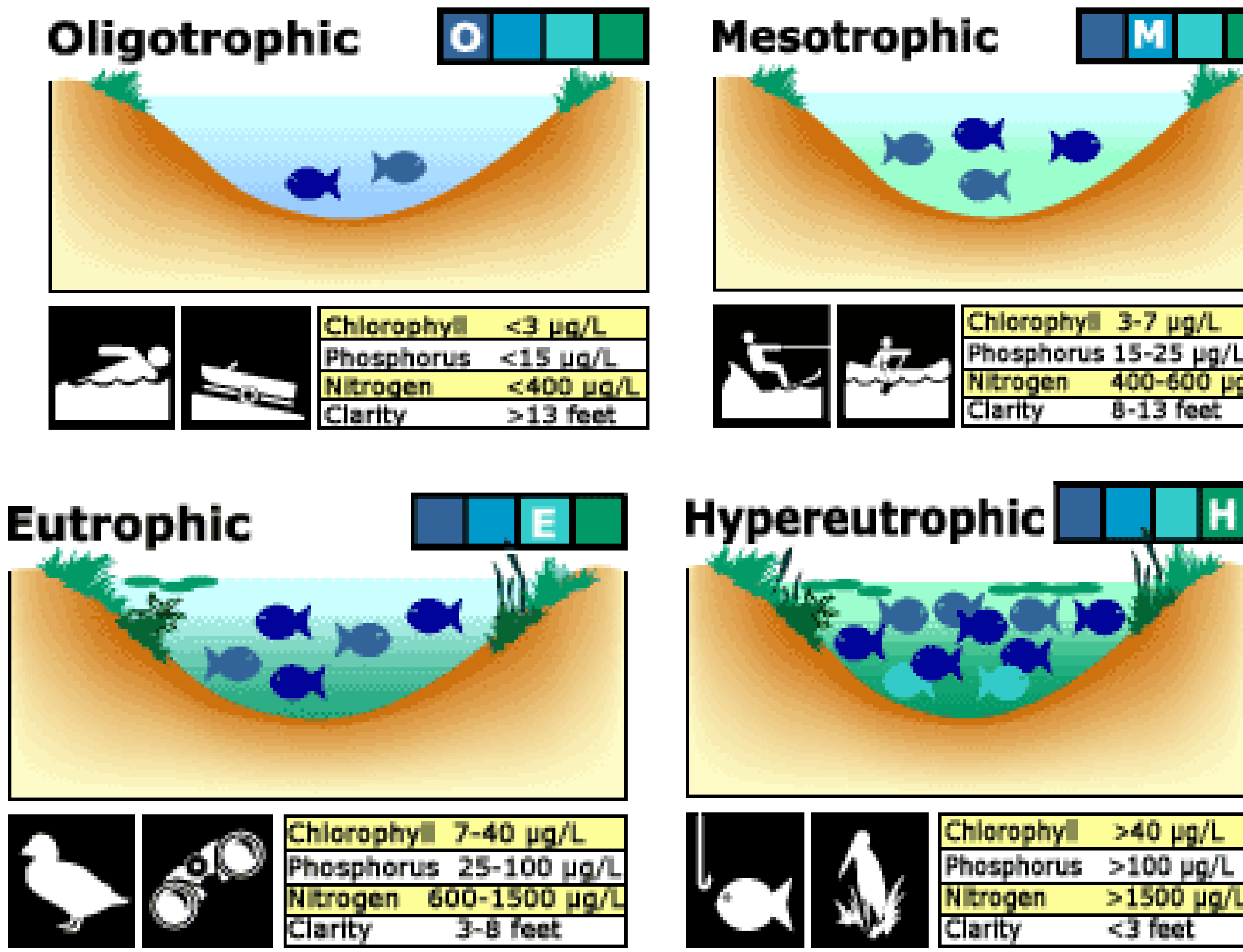
c) Eutrophic Water

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.

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.

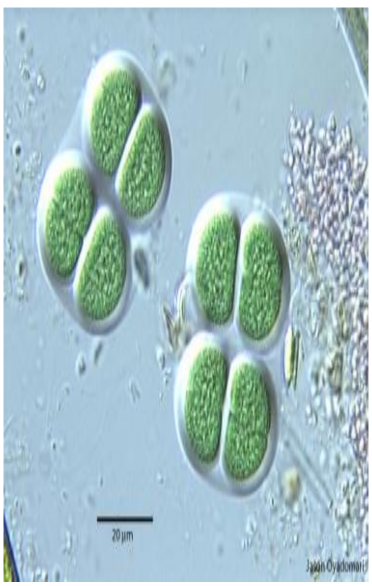
Gliding movement

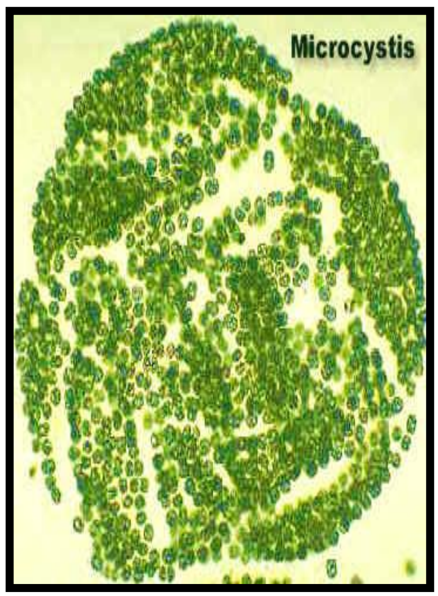
When viewed under the light microscope, blue-greens show a variety of movements, such as gliding, rotation, oscillation, jerking and flicking.

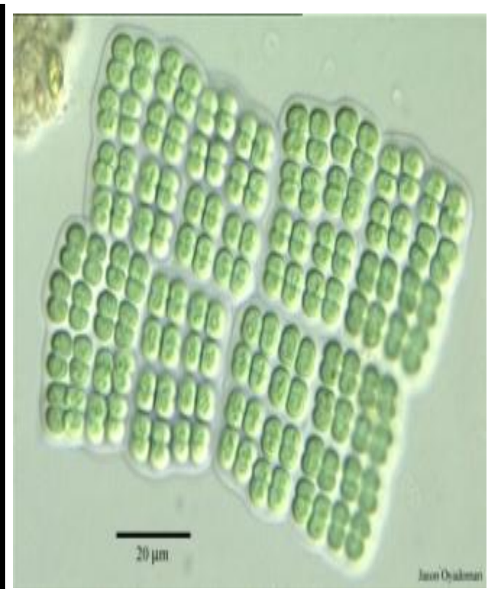
Organisation of the thallus

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***

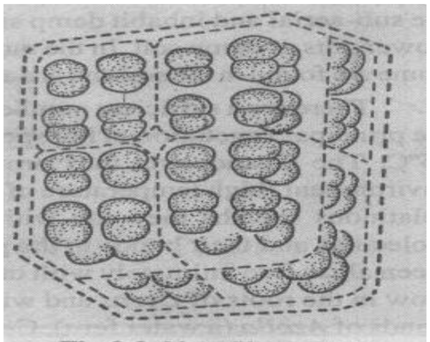
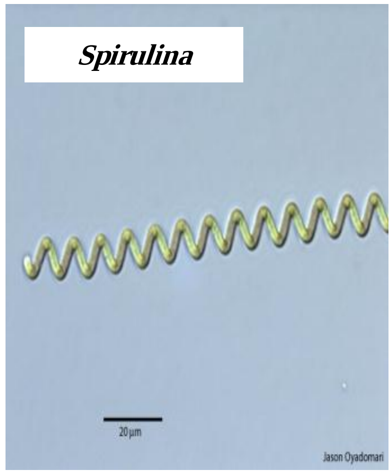
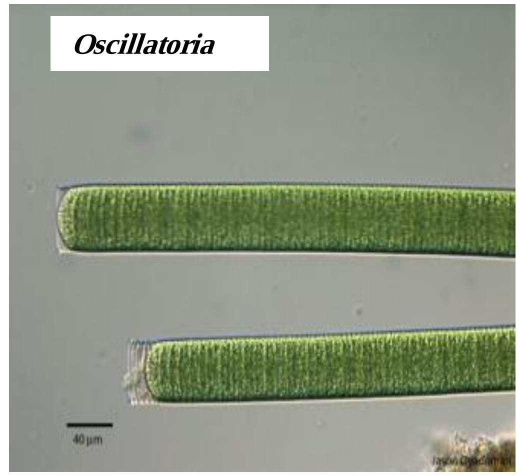
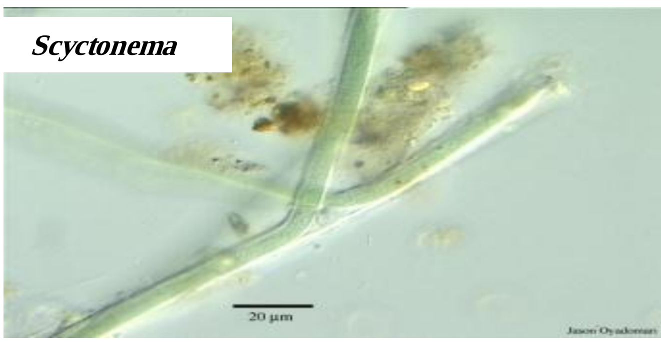
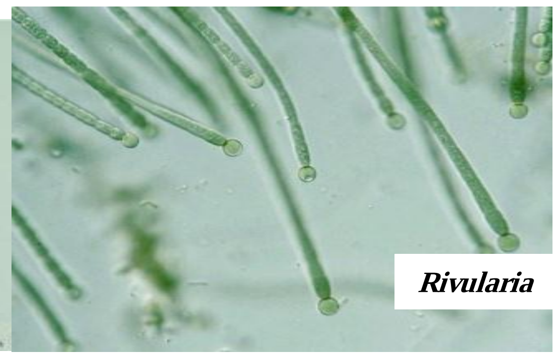


Fig.2.2. Non-filamentous Cyanophyceae. *Eucapsis alpina* (After Clemants and Shantz).









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:

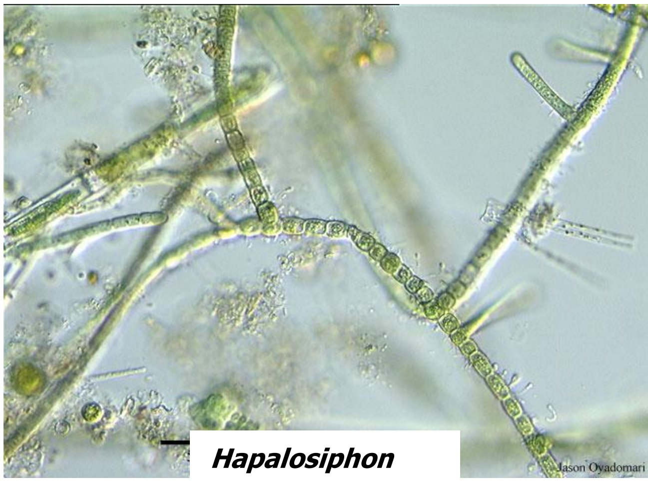
The chains of cells (called **trichomes**) are held together by a shared **sheath** to form the **filament**. A break in the chain of cells in the trichome results in a branch.

a) False branching (*Tolypothrix- Scytonema*)

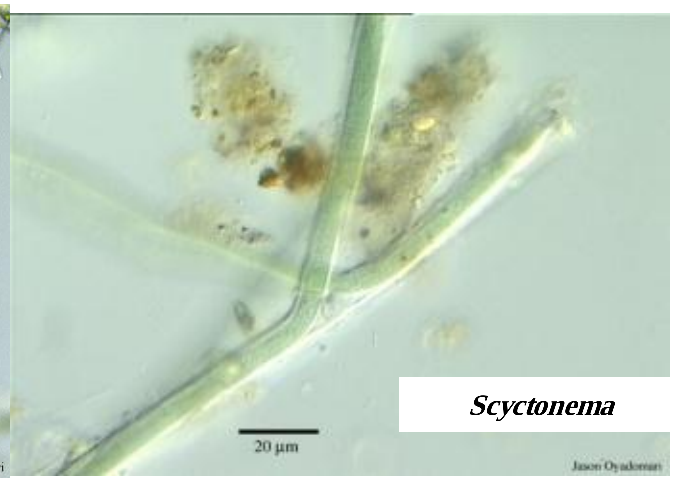
b) The chains of cells (called **trichomes**) are held together by a shared **sheath** to form the **filament**. A break in the chain of cells in the trichome results in a branch. The broken trichome grows out at some angle inside a branch of sheathing material. The break makes this a false branch as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



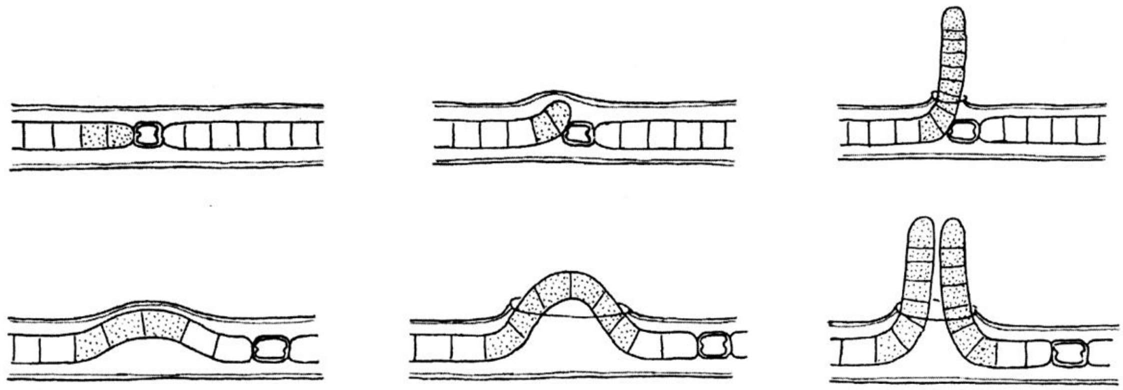
Hapalosiphon



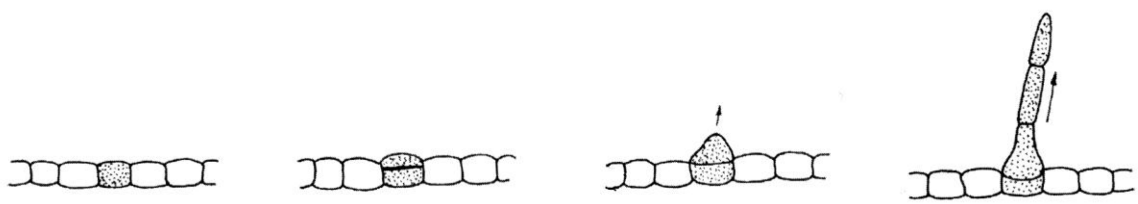
Scyctonema

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.

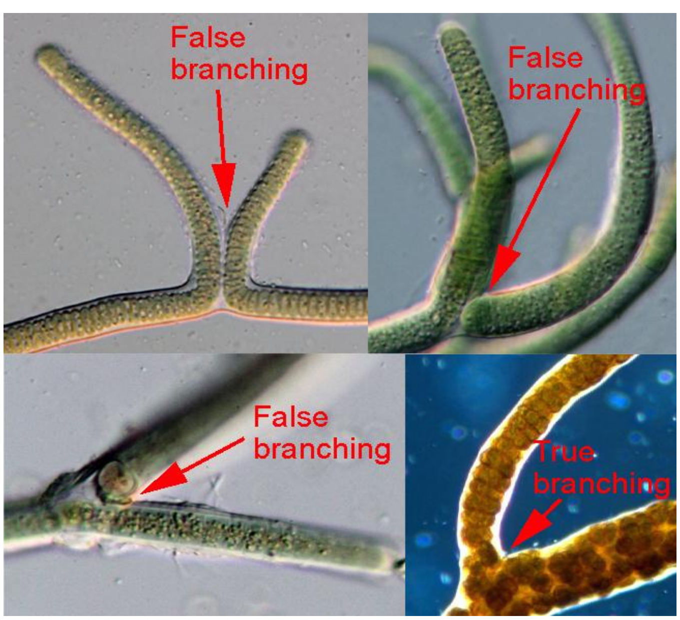
They also represent regions where filaments can break into fragments.



False branching



True branching



Types of branching

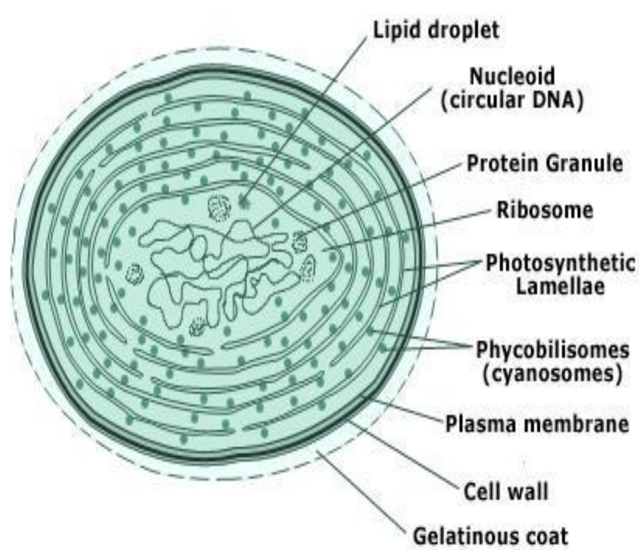


Fig. Cell Structure of Cyanophyta

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.

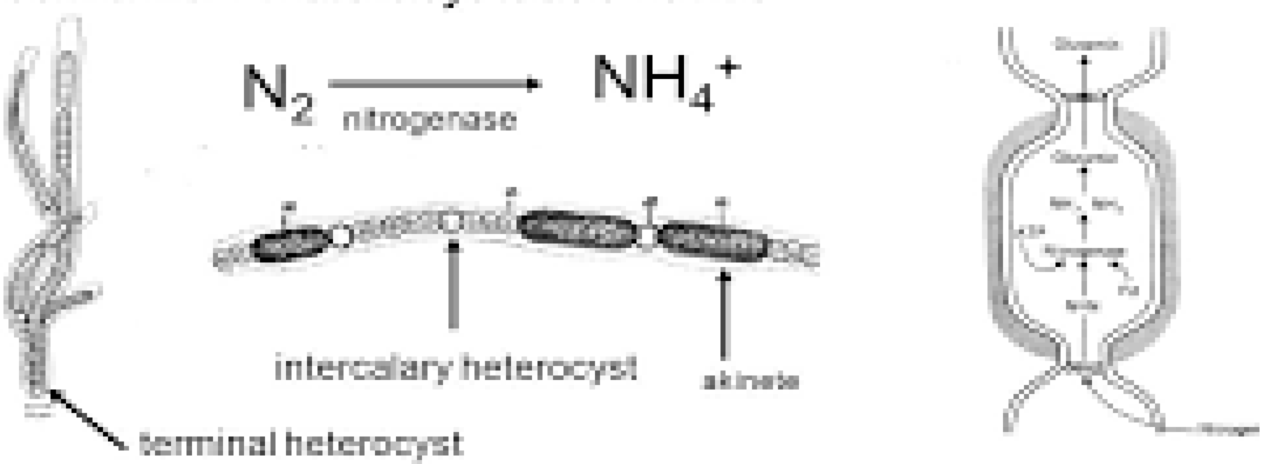
6. Locus for filament breakage. Heterocyst serves as the weakest link in the trichome and thus serves as a locus for breakage. Some workers, therefore, maintain that intercalary heterocysts serve to break the trichome into small sections of living cells called hormogonia.

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 Cyanobacteria and Bacteria

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

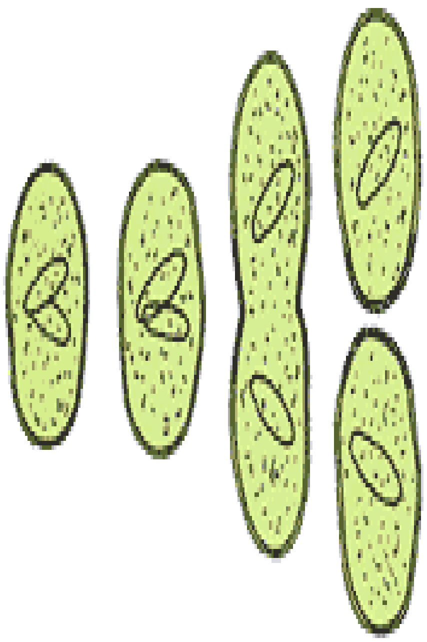
some of them to synthesize organic substance as well as to fix atmospheric nitrogen. They thus serve as an excellent source of nitrogen and organic matter. The practical application of these algae is the seeding of rice fields with the nitrogen-fixing species. This results in appreciable increase in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



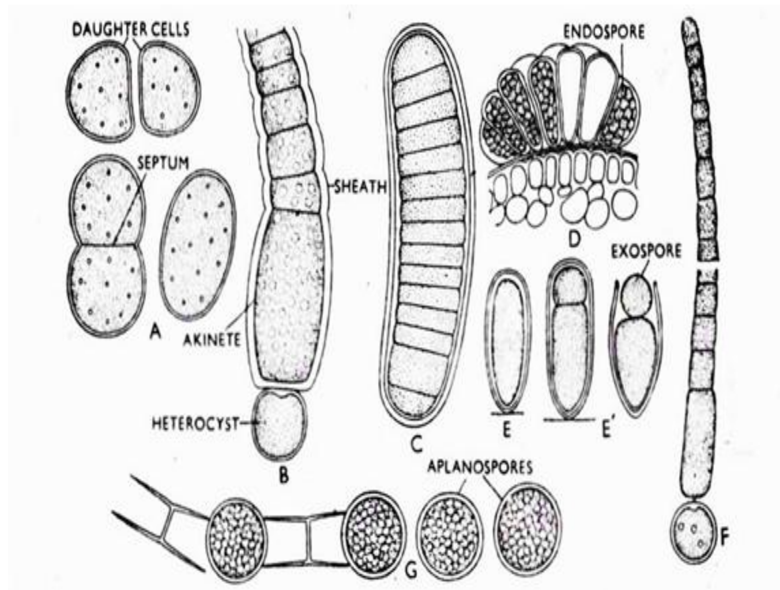
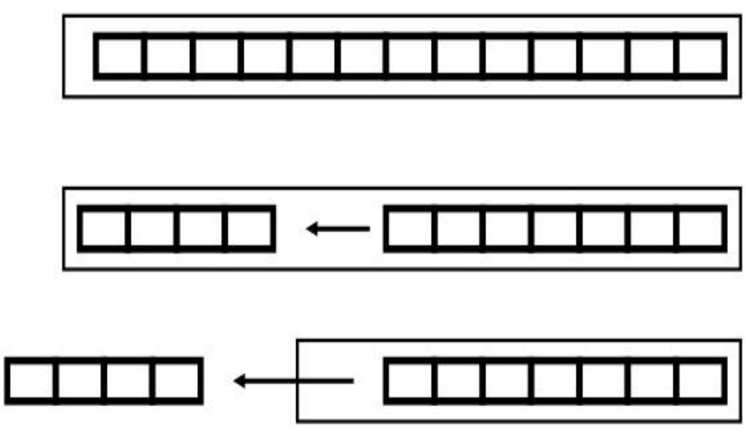


Fig. 10. Spore forms and vegetative reproduction in Algae. A. Simple cell division in unicellular alga *Synechococcus* sp. B. Filament of *Gloeotrichia natans* with akinete and heterocyst. C. Hormospore of *Westiella* sp. D. Group of individuals with endospores of *Dermocarpa prasina*. E–E'. *Chamaesiphon 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

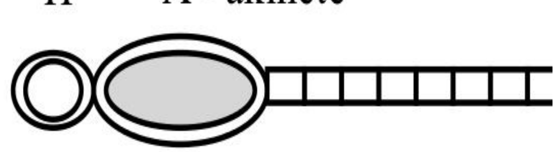


Asexual Reproduction

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.

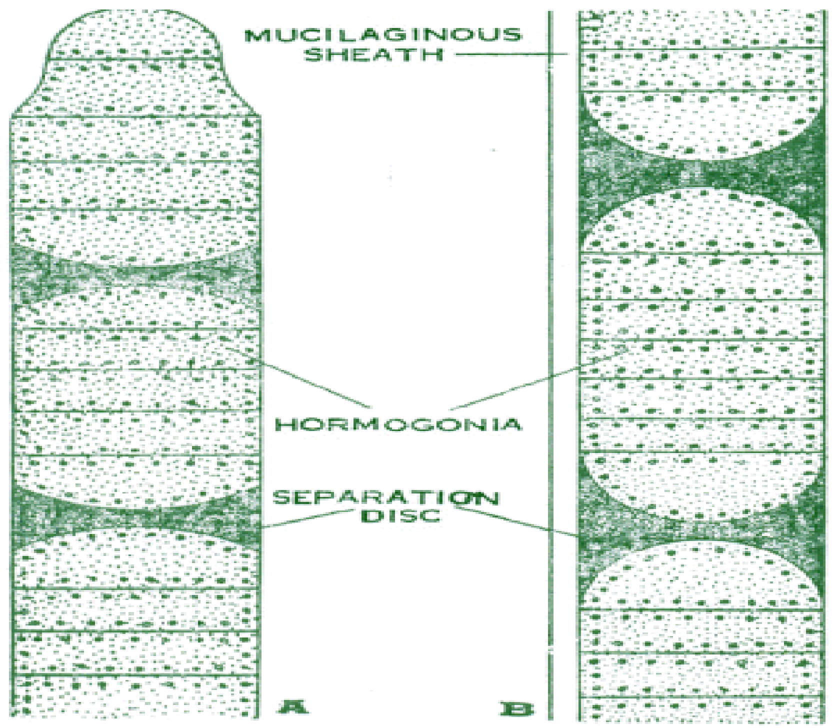
Reproduction: *Oscillatoria* reproduces vegetatively. The only known method is by the formation of hormogones. The hormogones are short sections or lengths or living cells separated from the trichomes. The break takes place where a dead cell (necridium) is situated. During the growing season a cell here 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*

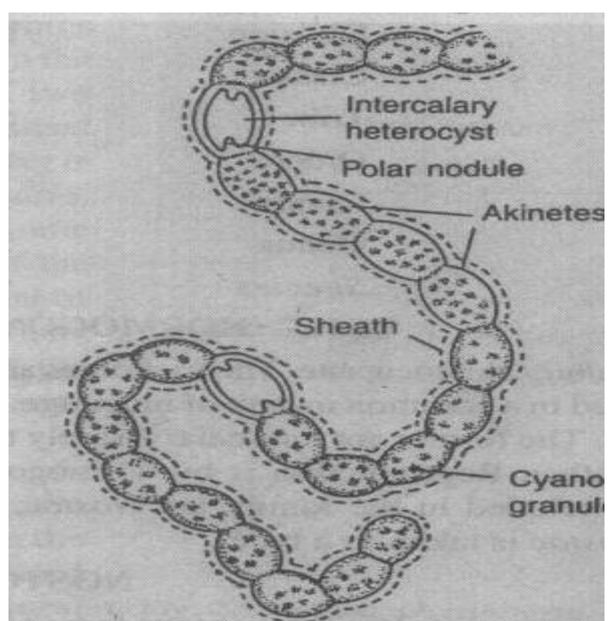
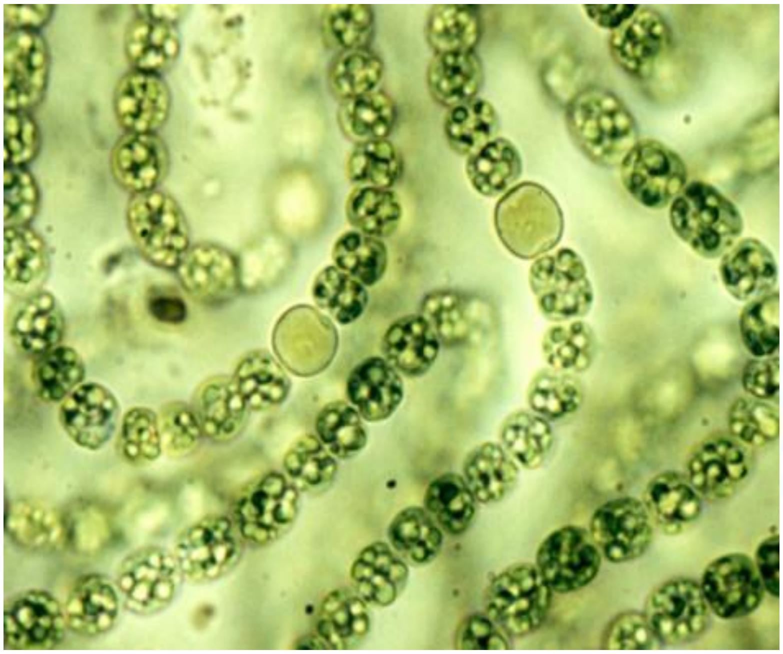
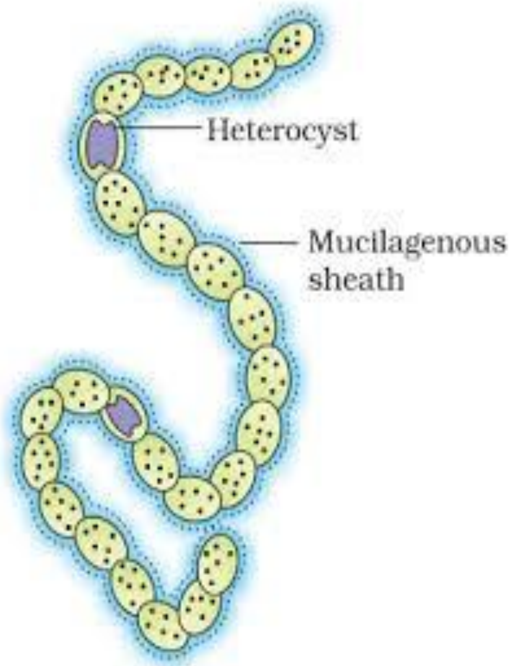
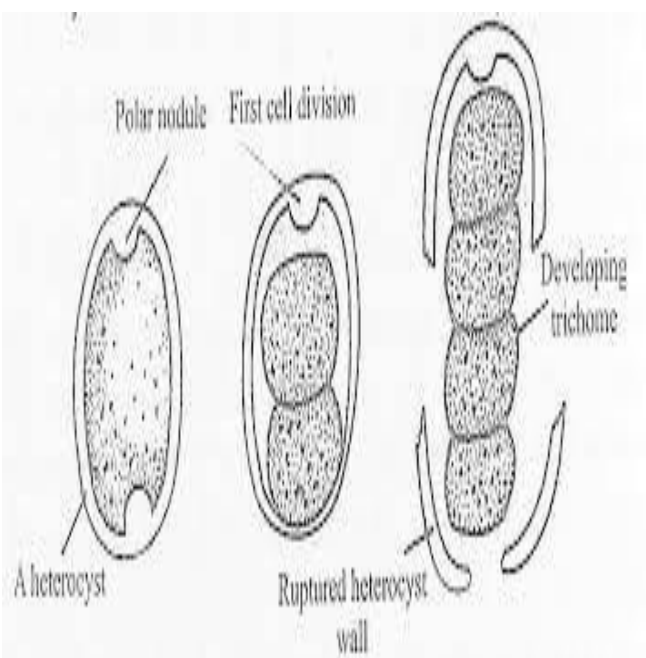


Fig. 2.23. *Nostoc* sp. A filament with trichome.







Heterocyst germination of Nostoc

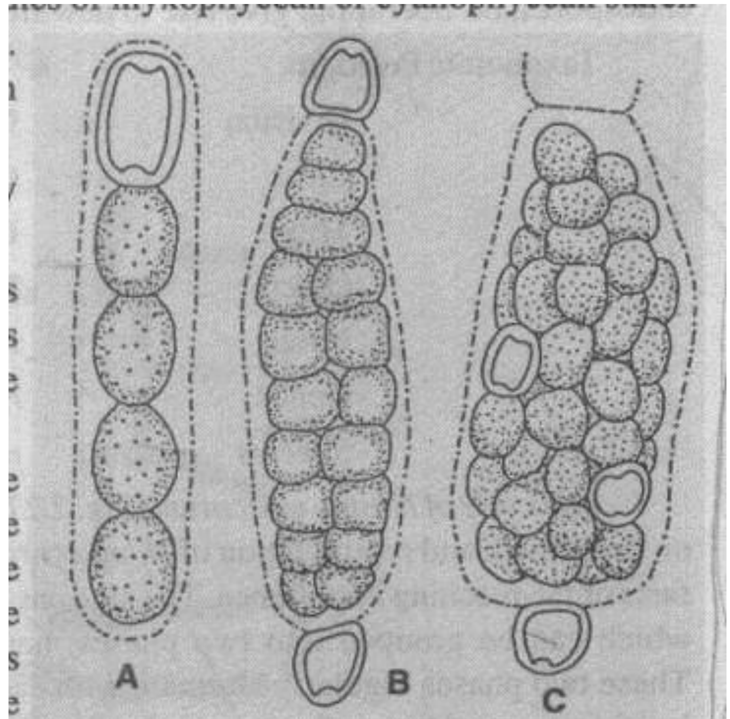


Fig. 2.25 (A-C). *Nostoc*, Stages in germination of a hormogone to form a new colony (C).

Rivularia

Vegetative Body of Rivularia

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.

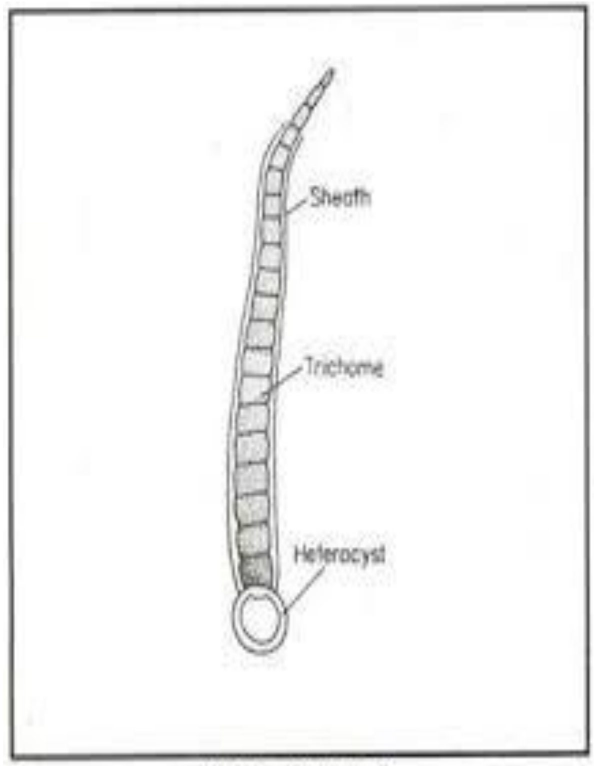


Fig 2.9. Rivularia Sp.

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.

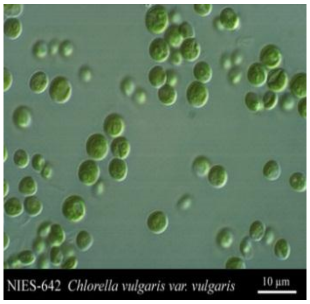
Division : Chlorophyta (Chlorophycophyta)

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.

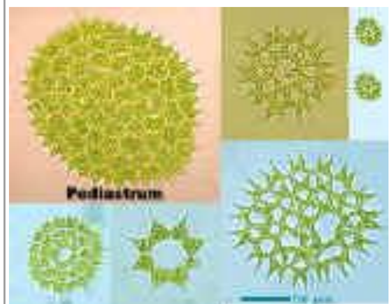
The thallus is typically green in colour due to the presence of a green pigment, the chlorophyll. It is contained in plastids called the chloroplasts. Embedded in the chloroplasts are rounded, proteinaceous bodies one or more in number, the pyrenoids. The pyrenoids are intimately associated with the 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)

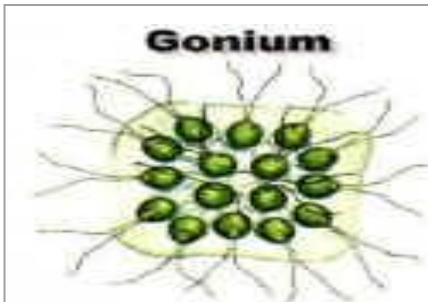
Chlamydomonas (motile unicell)



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.

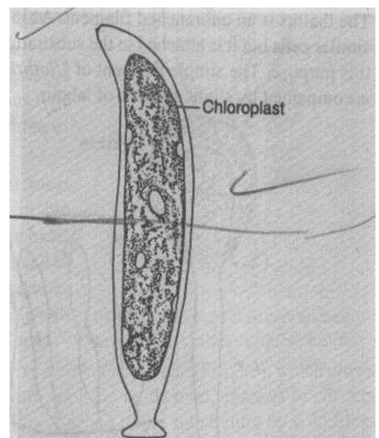
1. Unicellular thallus. In the simplest forms the hallus is a unicell. It is motile in some and non-motile or amoeboid in others.

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.

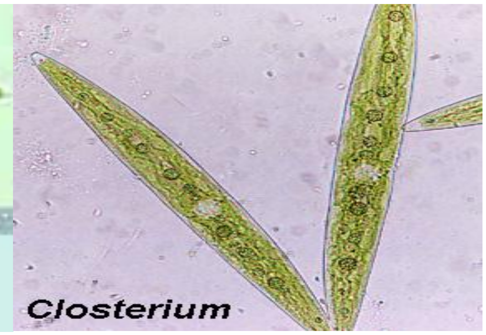
a) Motile colonial thallus. It consists of a definite number of motile, unicellular *Chlamydomonas* or Sphaerella type cells held together in a common mucilaginous sheath. The individual cells are complete in themselves and independent of each other.



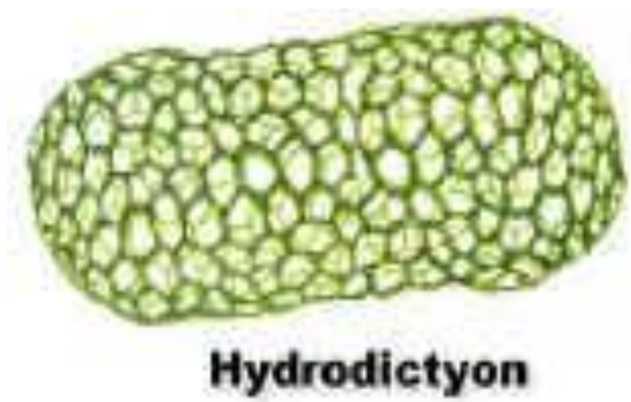
Fig, 3.3(A). *Chlorophyceae*. Tubular uni-nucleate thallus of *Characium*

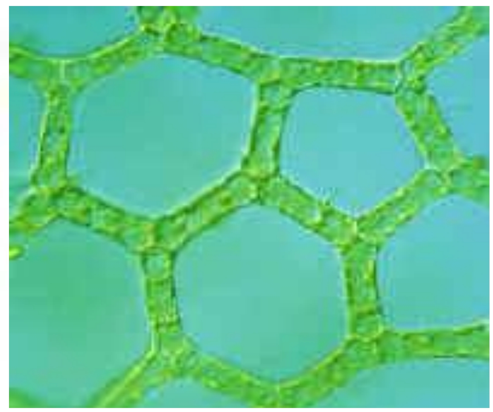
They act together and bring about the movement of the entire colony. Examples are *Gonium*, *Pandorina* and *Eudorina*. Hollow spherical colony of *Volvox* represents the most highly developed motile colonial thallus. It is made up of thousands of cells, which in some species are connected with one another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

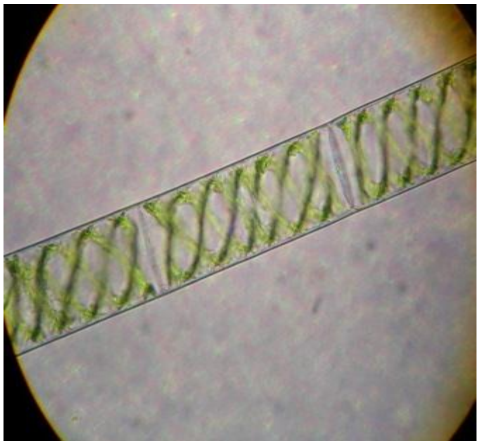
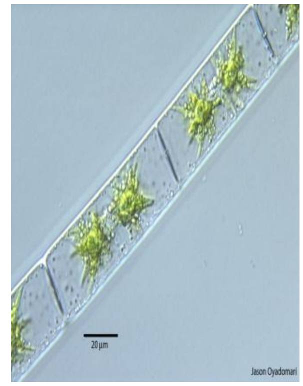
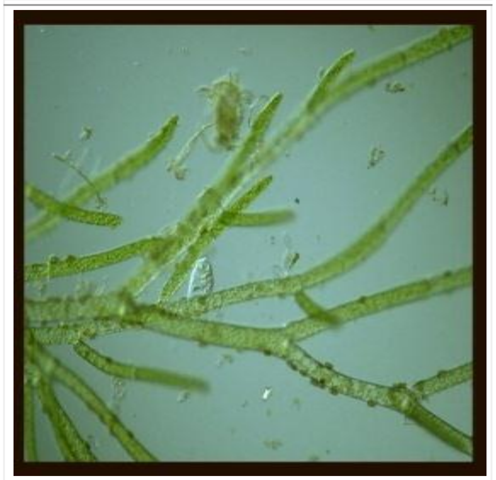
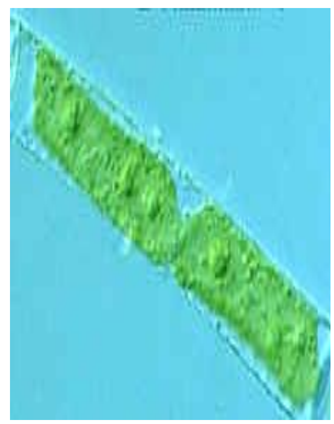




3. Siphonaceous or Coenocytic thallus.

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.

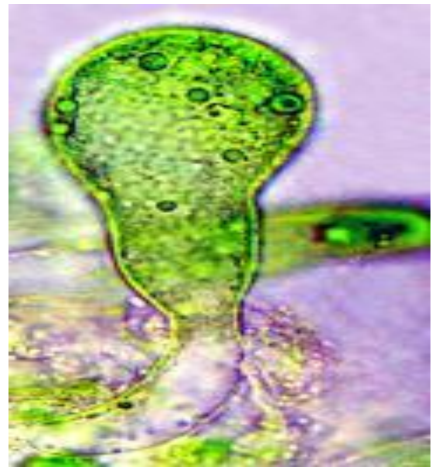
 *Spirogyra* has spiral Chloroplasts	 *Ulothrix* has band-shaped Chloroplasts	 *Zygnema* has Star-shaped Chloroplasts
 *Cladophora*	 *Cladophora* has many small oval Chloroplasts	 *Mougeotia* has a flat Chloroplast. The disk-like areas are Pyrenoids.

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.

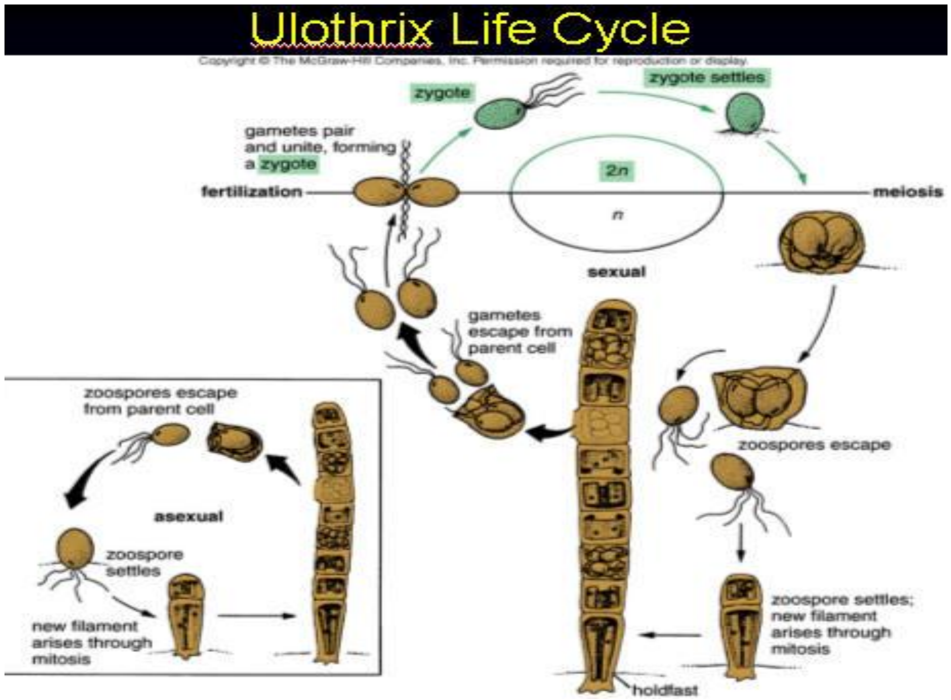
It involves the multiplication of the species by the formation of highly specialized reproductive cells called the asexual spores. Reproduction by asexual spores is a very common method of propagation under normal conditions of life and is called sporulation. Each asexual spore, on germination, is alone 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).

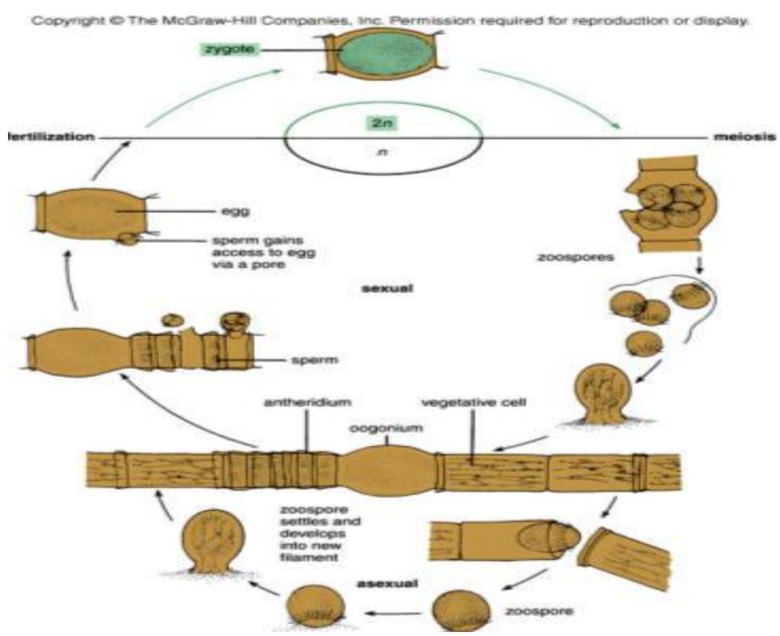
a) Zoospore formation. The common and characteristic method by which asexual reproduction operates in the green algae is by the formation of motile, naked asexual spores called the zoospores. They may be bi-or quadric-flagellate (*Ulothrix*), with a ring of flagella and thus multiflagellate (*Oedogonim*). 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.





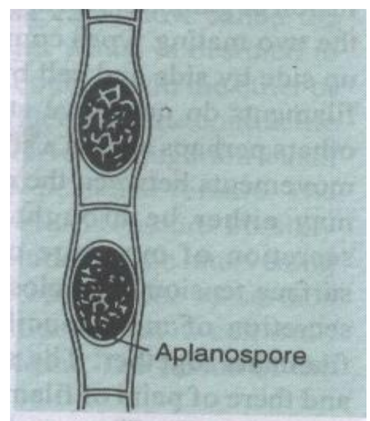
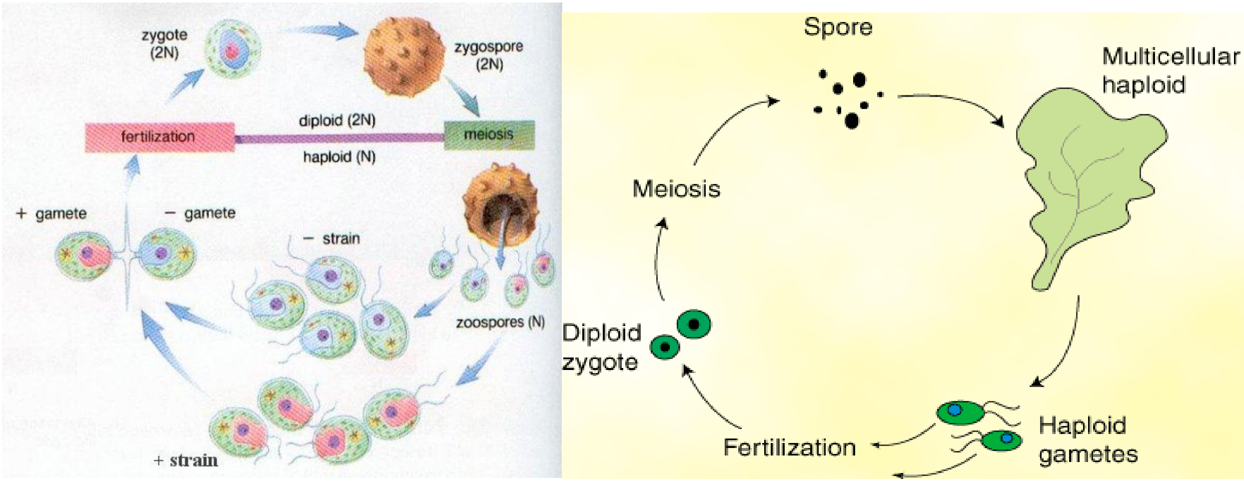
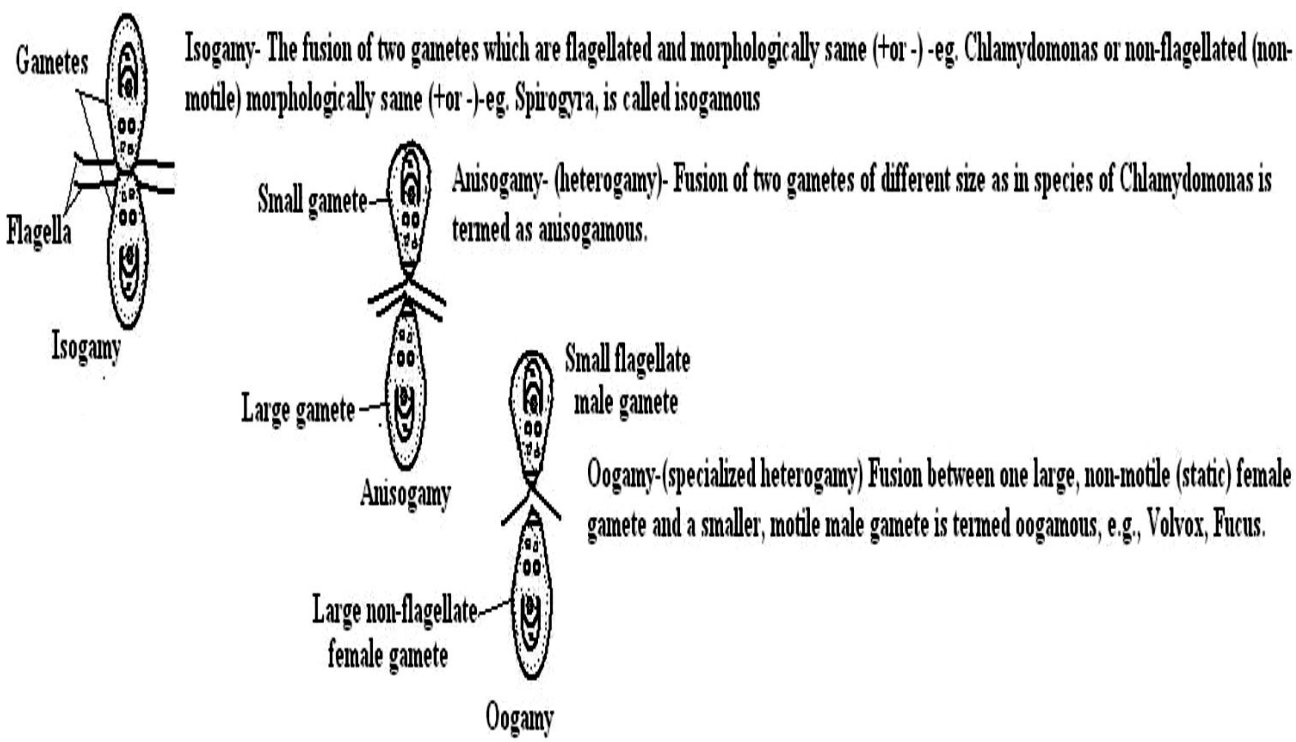


Fig. 11.19. *Spirogyra karnalae*. Aplanospore formation (After Randhawa).

***Odogonium* life cycle**



Life cycle of the green algae



Isogamy- The fusion of two gametes which are flagellated and morphologically same (+or -) -eg. Chlamydomonas or non-flagellated (non-motile) morphologically same (+or -)-eg. Spirogyra, is called isogamous

Anisogamy- (heterogamy)- Fusion of two gametes of different size as in species of Chlamydomonas is termed as anisogamous.

Oogamy-(specialized heterogamy) Fusion between one large, non-motile (static) female gamete and a smaller, motile male gamete is termed oogamous, e.g., Volvox, Fucus.

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.

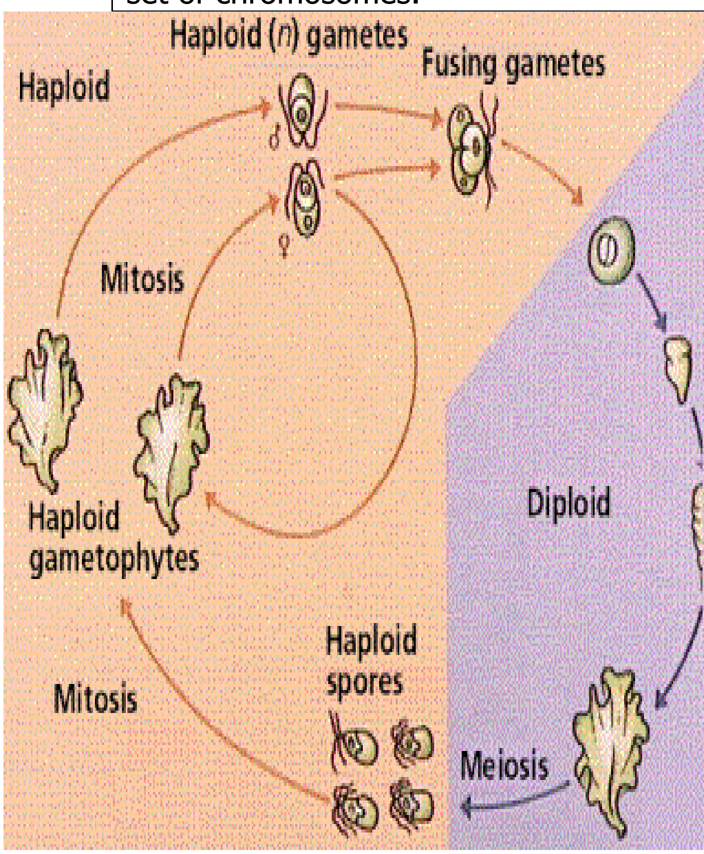
3. The reserve carbohydrate food is stored as starch.
4. The chloroplasts normally contain the pyrenoids.
5. The cell has a well defined nucleus and in the higher forms a central sap cavity in addition.
6. The cell wall is stable and invariably contains cellulose.
7. The majority produce motile reproductive 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.

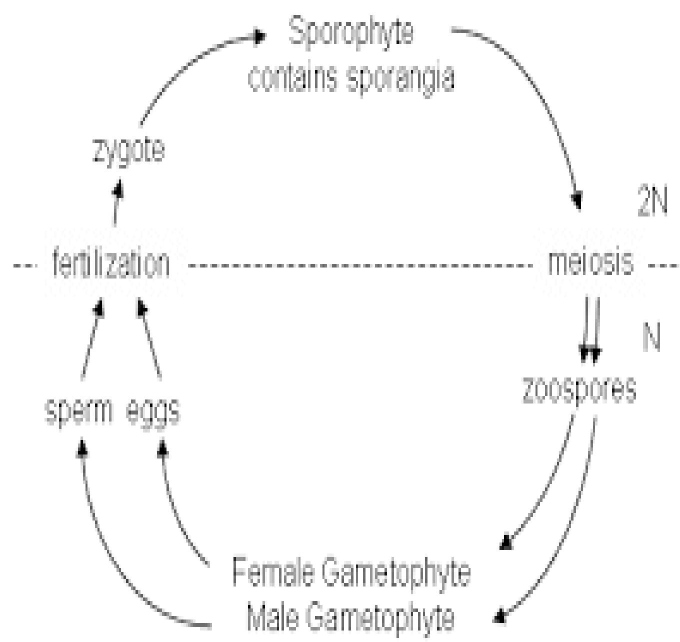
Alternation of Generation in green algae

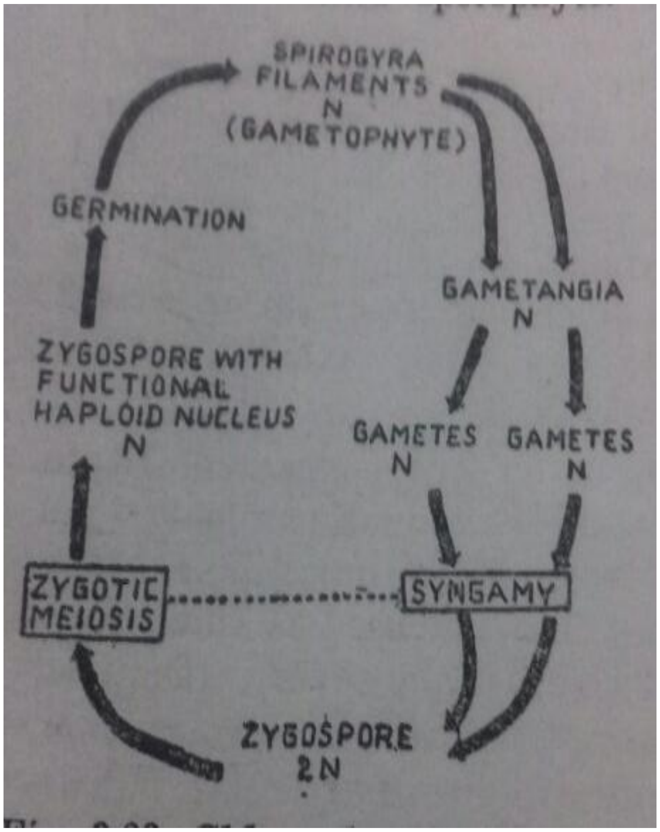
Alternation of generations is a term used to describe the type of life cycle that occurs in those plants and algae. The alternation of generations allows algae to reproduce both sexually and asexually. In the single life cycle of the certain sexually reproduction plants there occur two individuals. One 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.







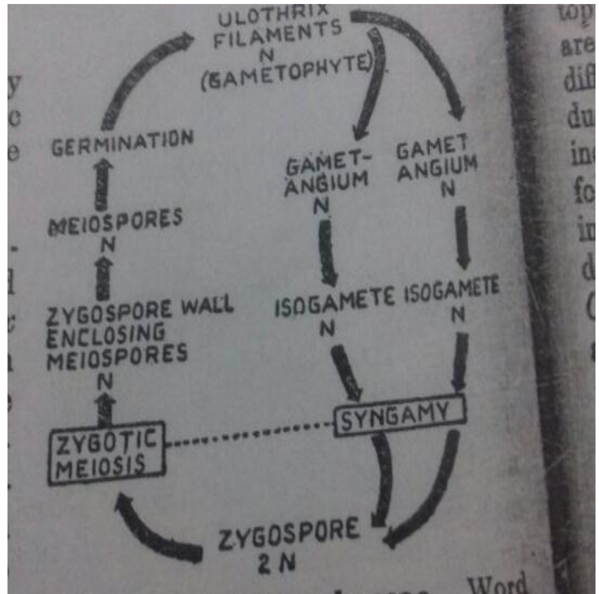
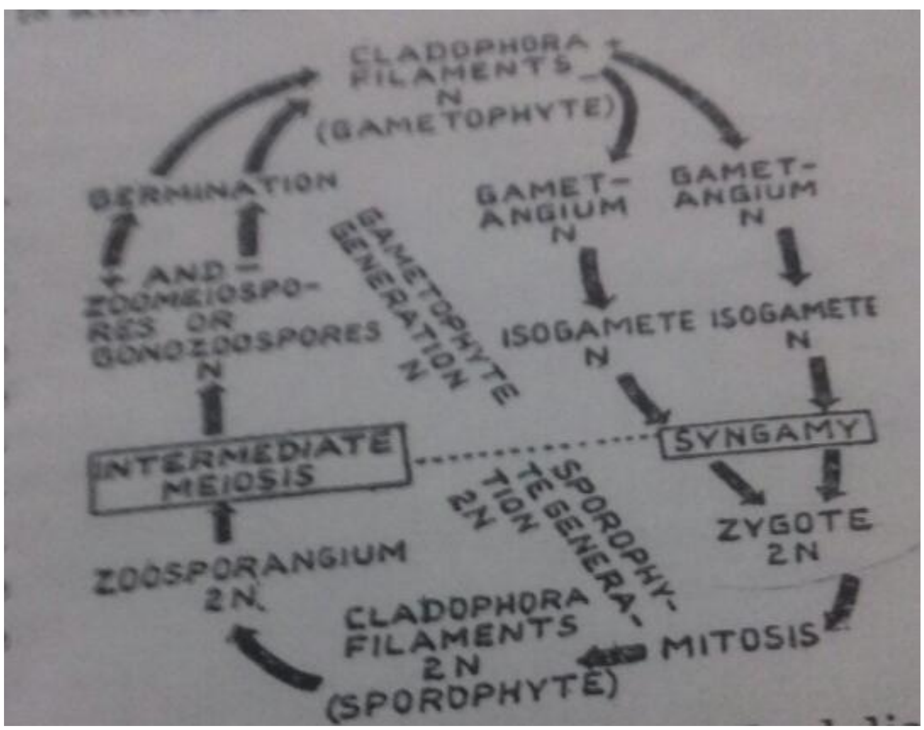


Fig. 3·24. **Chlorophyceae.** Word diagram of the **haplontic** life cycle of *Ulothrix*.



Types of alternation of generation in green algae

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.

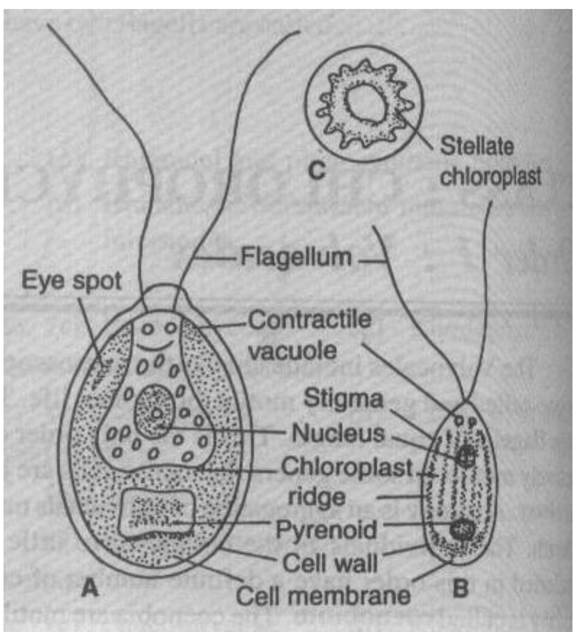


Fig. 4.1 (A-C). *Volvocales* (A) *Chlamydomonas angulosa*; (B) *C. steinu steinii*; (C) Optical T.S of B (After Dill).

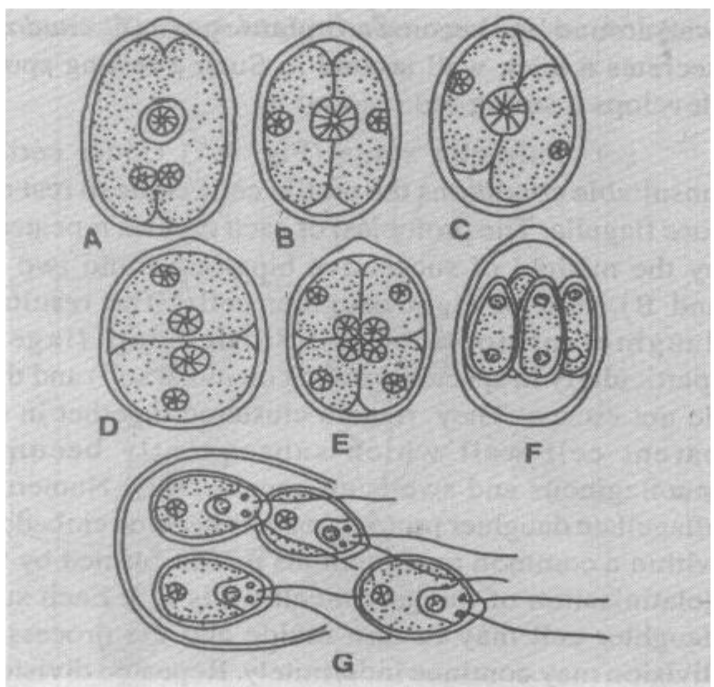


Fig. 4.4 (A-G) *Chlamydomonas sp.* Successive stages in zoospore formation.

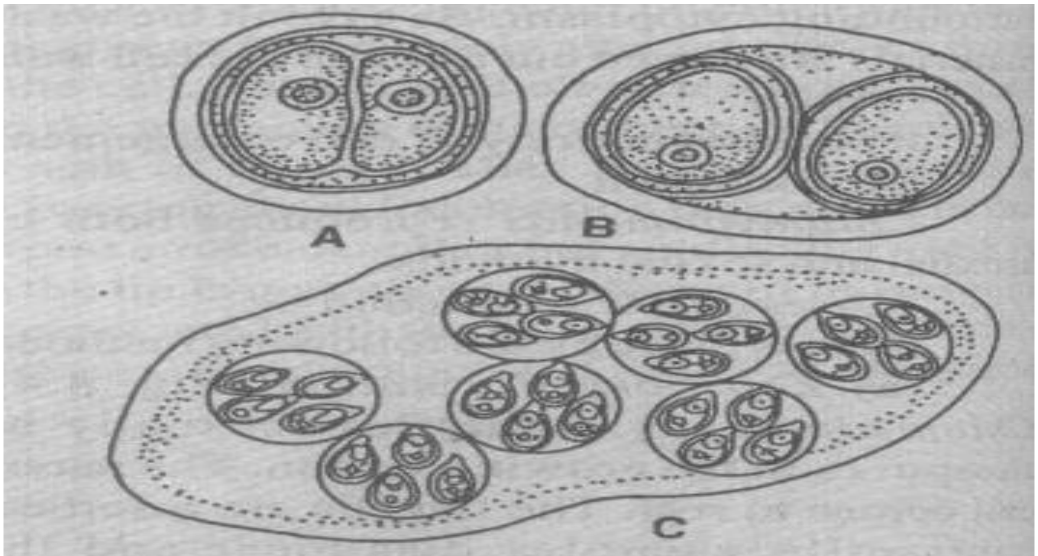
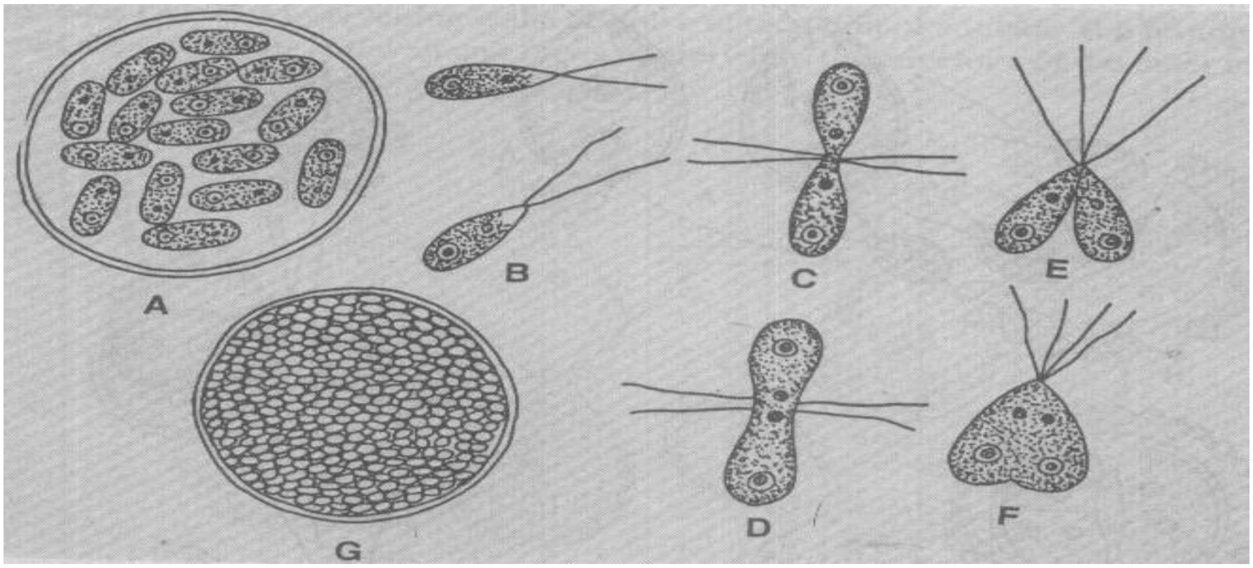


Fig. 4.5 (A-C) *Chlamydomonas sp*. Successive stages in the formation of palmella stage (After Goroschanken).

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.



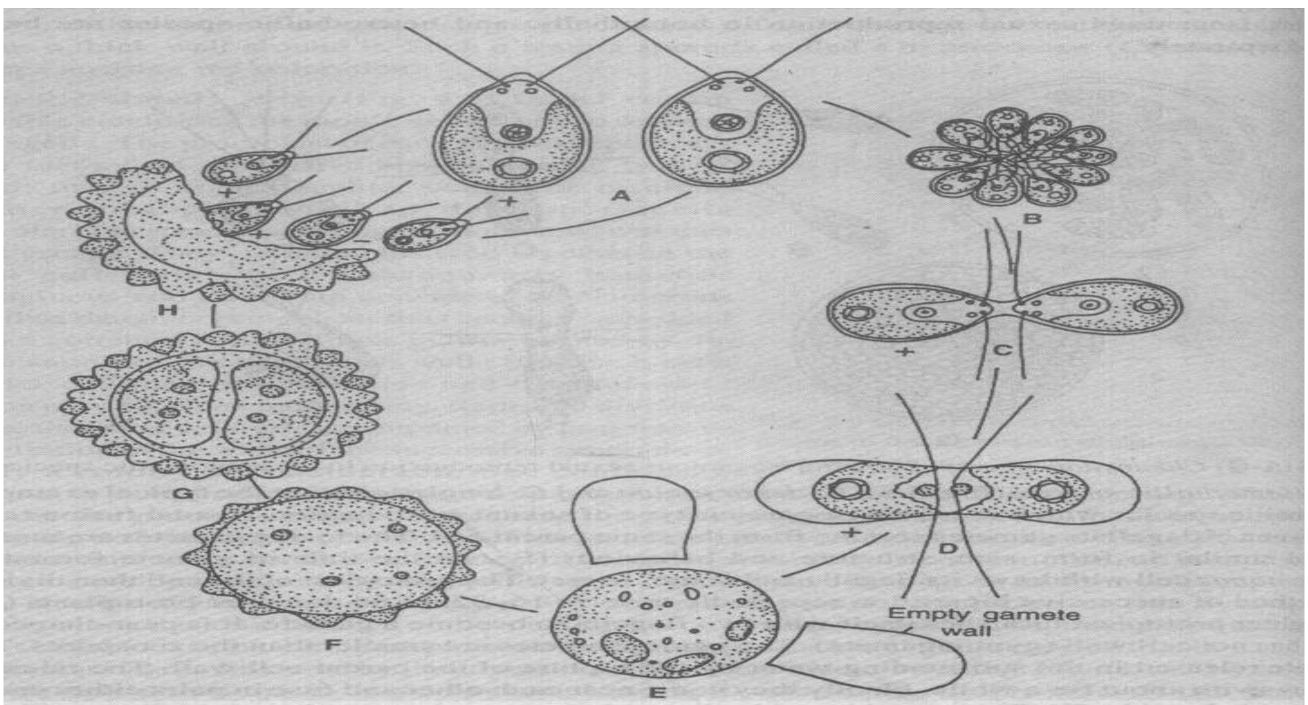


Fig. 4.7 *Chlamydomonas sp.* Showing isogamous sexual reproduction in the heterothallic spe

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).*

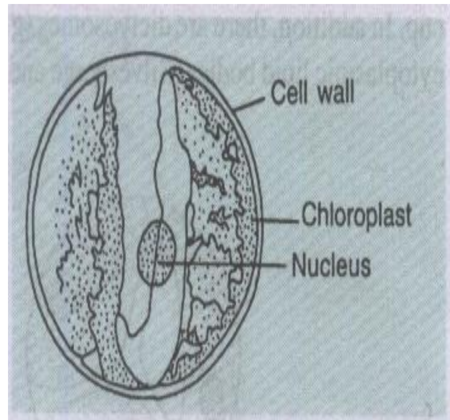


Fig. 5.1. *Chlorella.* A cell under light microscope.

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.

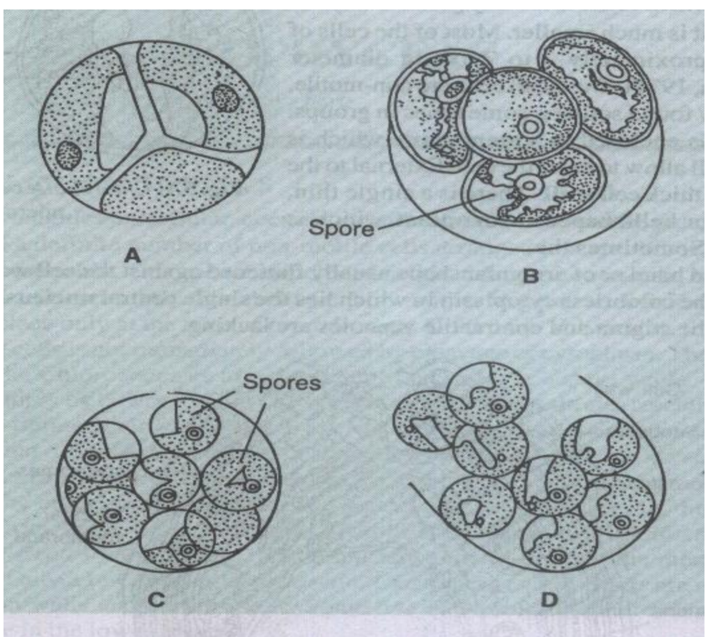
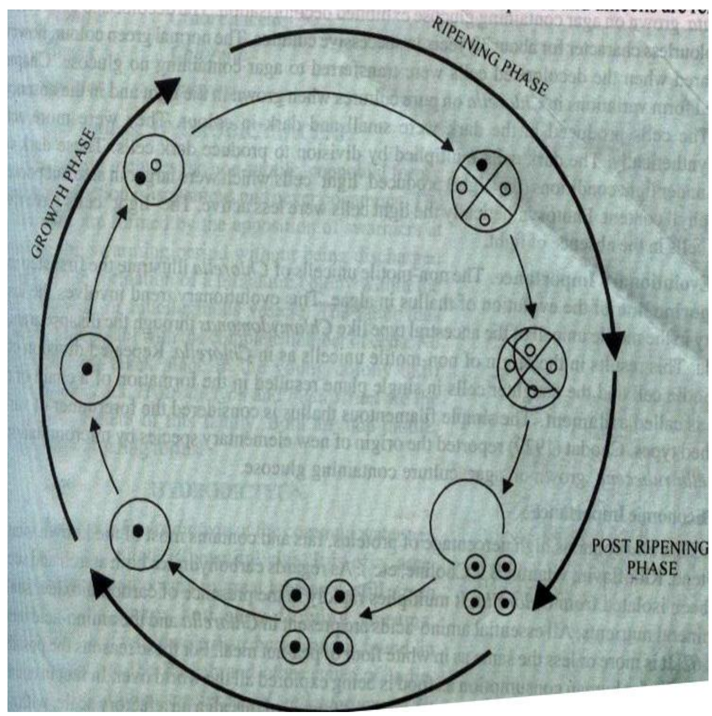
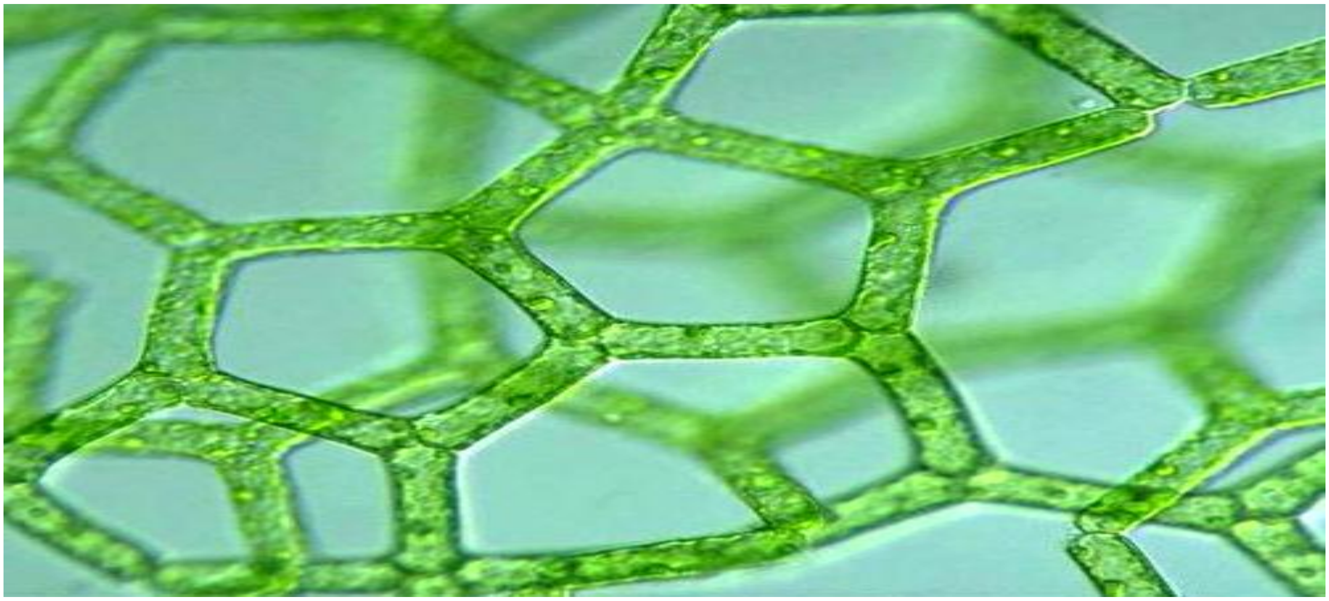


Fig. 5.3 (A-D). *Chlorella*. Asexual reproduction.



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.

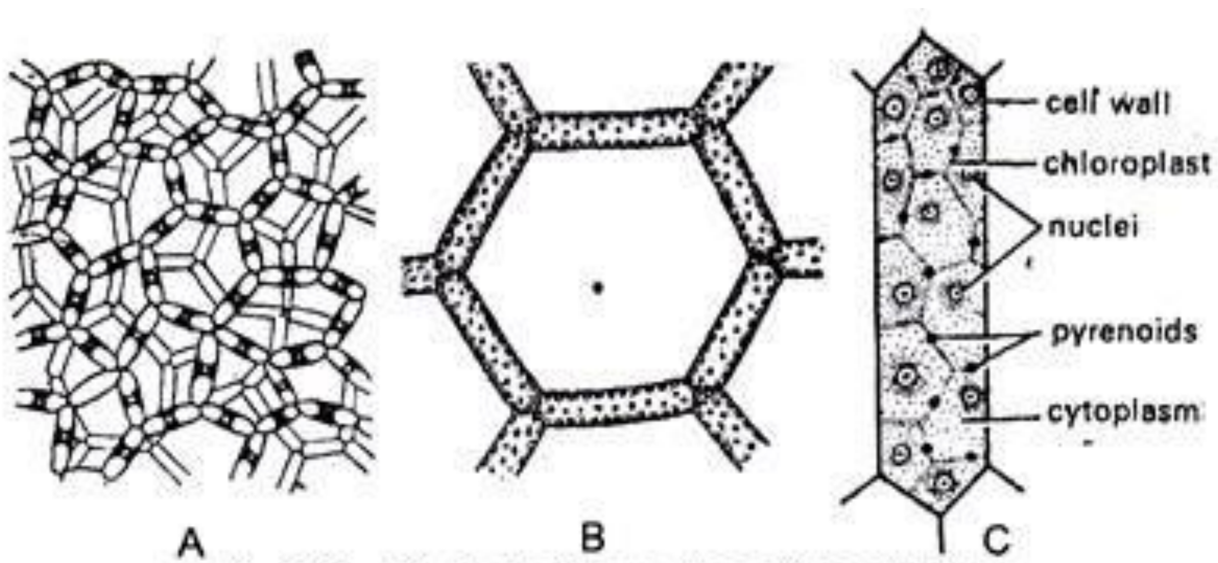


Fig. 2 (A—C). *Hydrodictyon*. Vegetative structure.
A. A part of the net; B. Hexagonal mesh; C. A cell.

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.

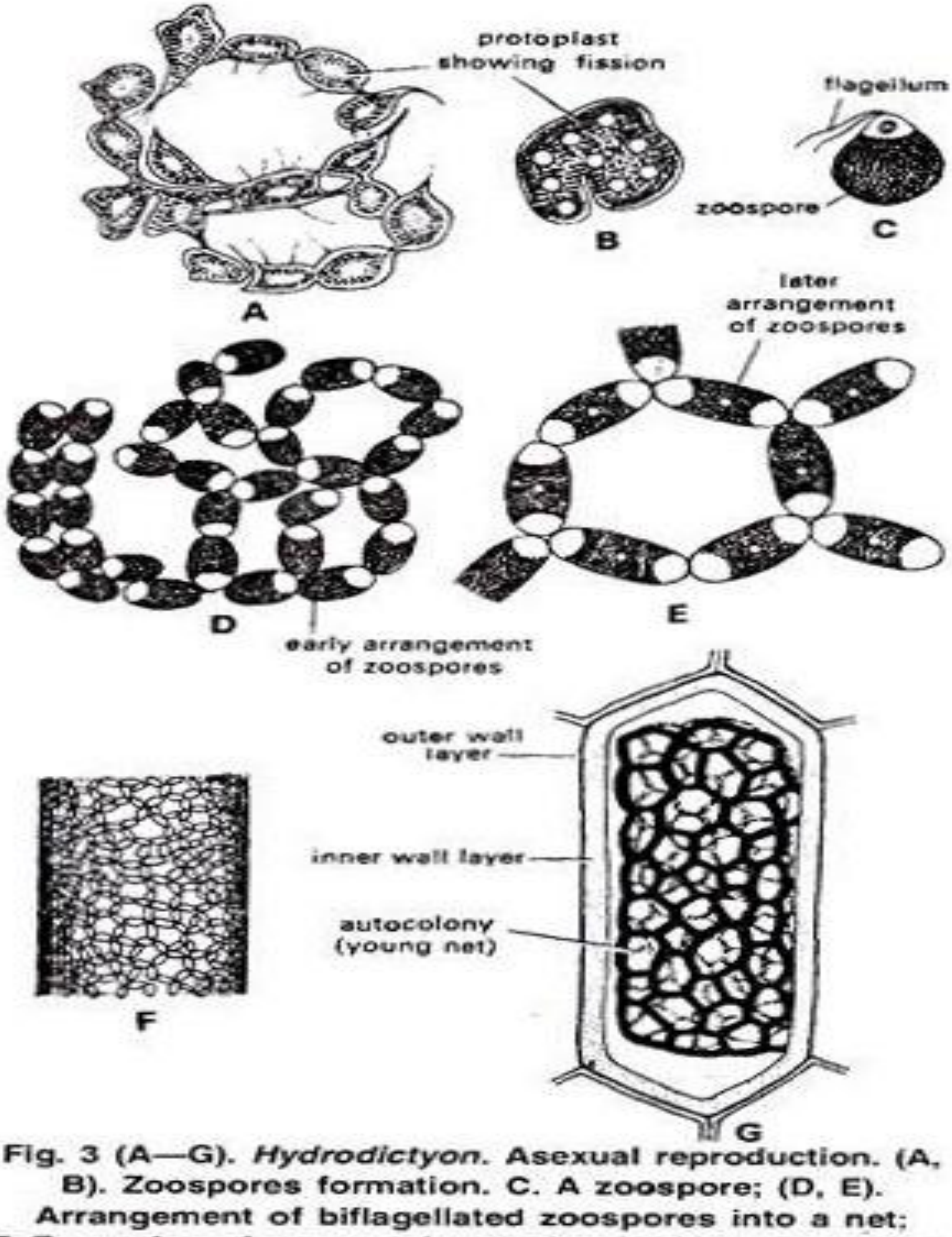


Fig. 3 (A—G). *Hydrodictyon*. Asexual reproduction. (A, B). Zoospores formation. C. A zoospore; (D, E). Arrangement of biflagellated zoospores into a net; F. Formation of new net (autocolony) within parent cell. G. A autocolony in the parent cell.

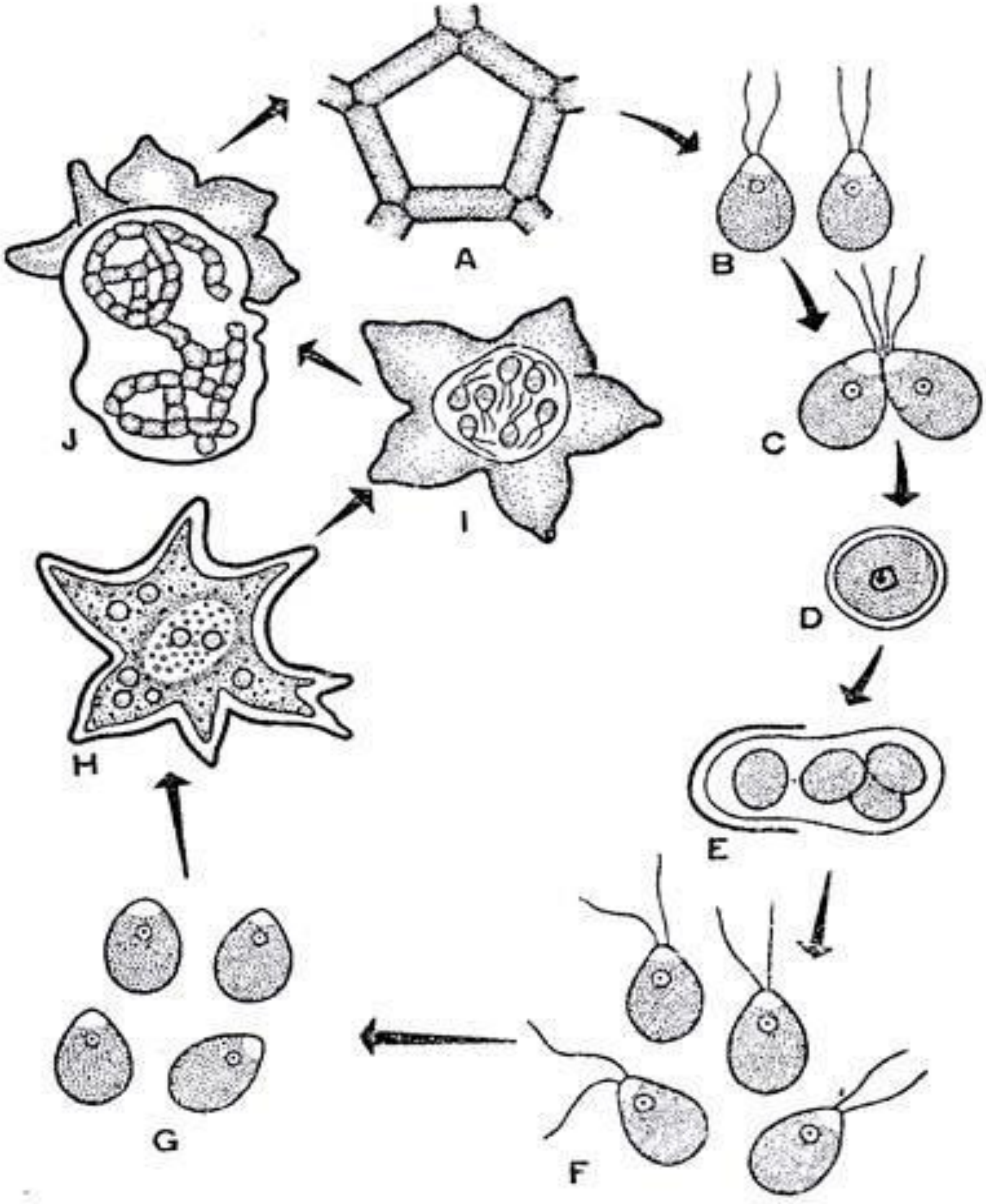


Fig. 4 (A—J). *Hydrodictyon*. Sexual reproduction.

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.

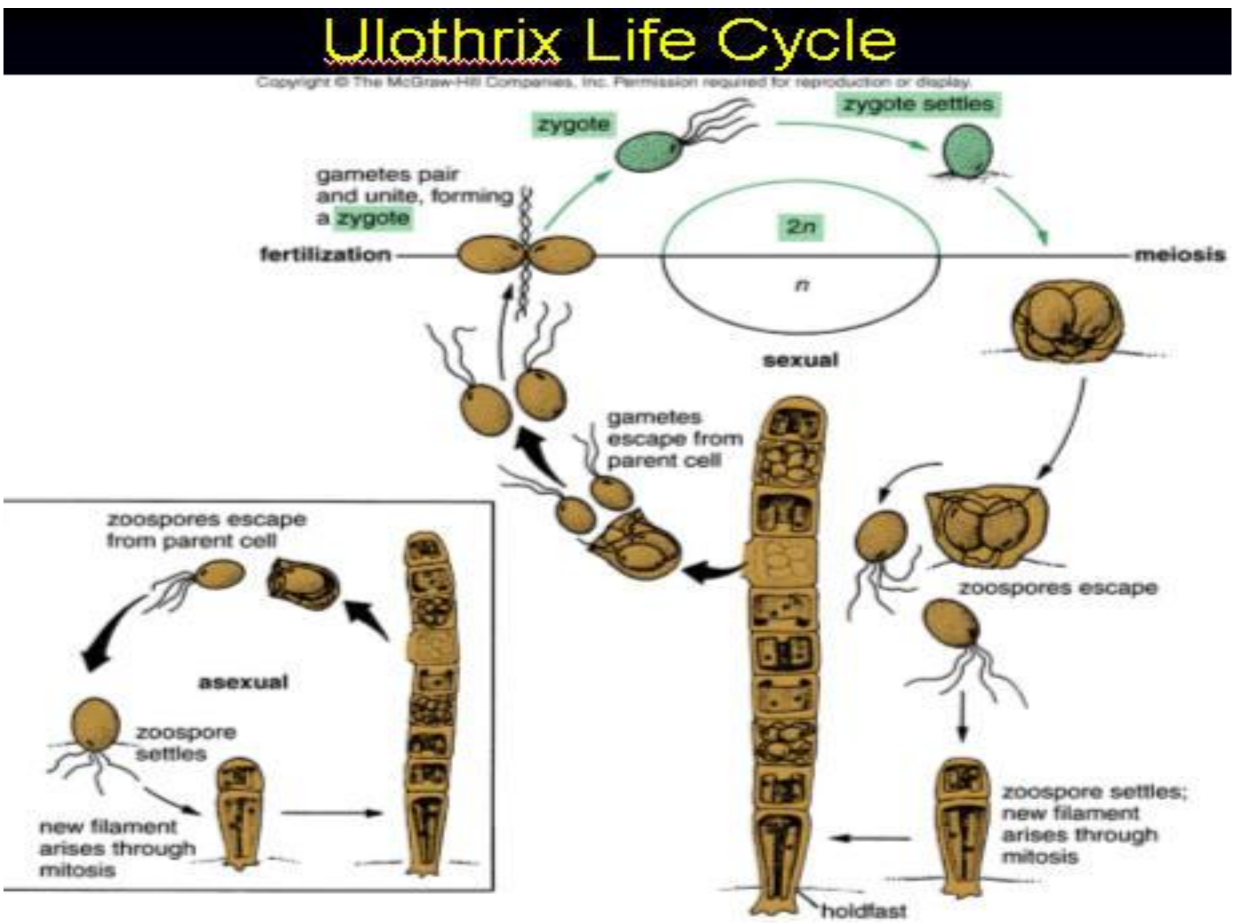
(C) By Akinetes: Sometimes in unfavourable conditions cell of the filament forms a single rounded thick walled structure called akinete. Akinetes are double walled with exospore and endospore. On return of favourable conditions the exospore ruptures and it develops into new filament.

(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.



Oedogonium sp.

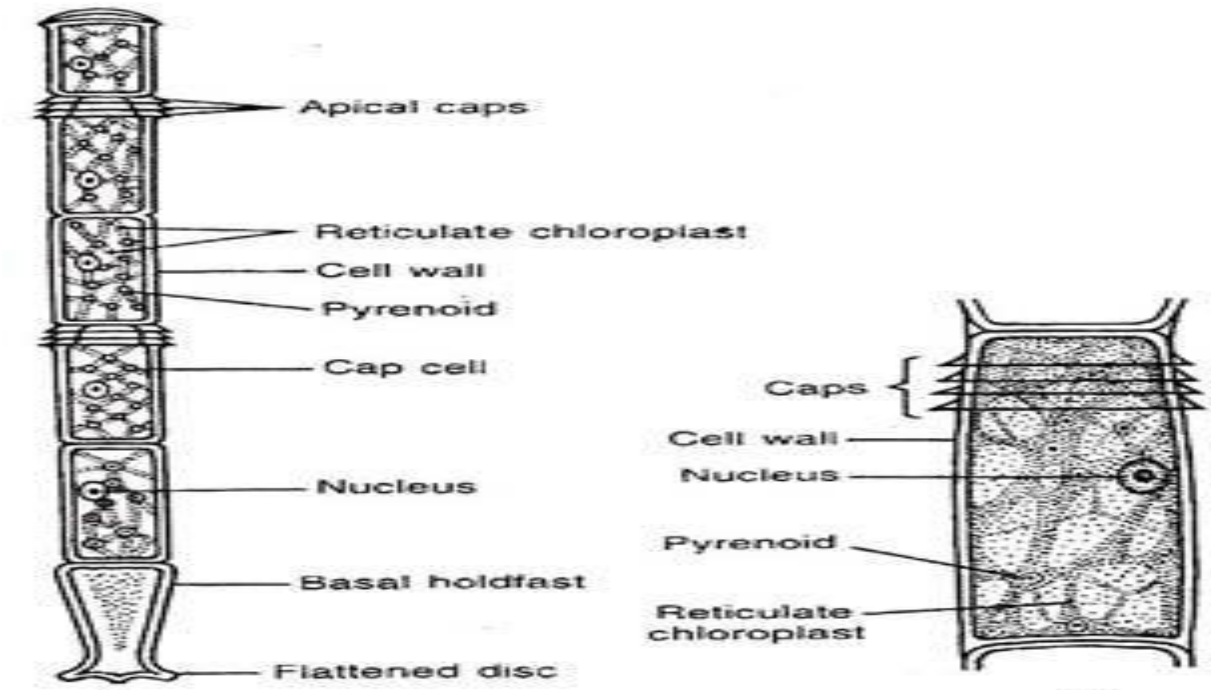


Fig. 3.72 : *Oedogonium* sp. : A. Single vegetative filament with holdfast and apical cell, B. Single vegetative cell

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.

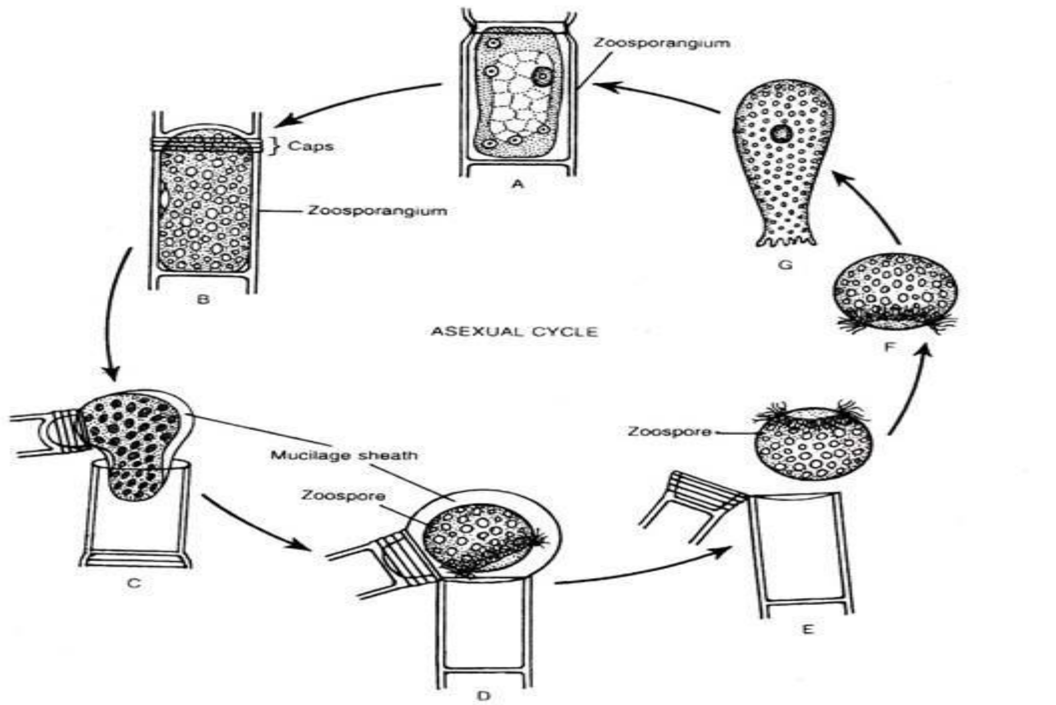


Fig. 3.74 : *Oedogonium* sp. Asexual reproduction : A-E. Successive stages of zoospore formation, F. Single zoospore, and G. Germination of Zoospore

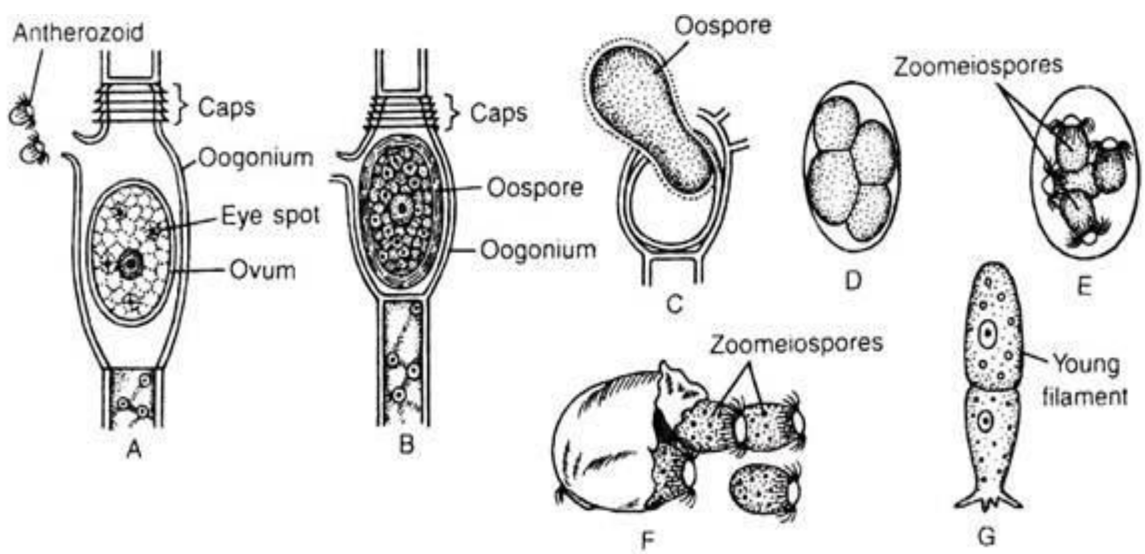
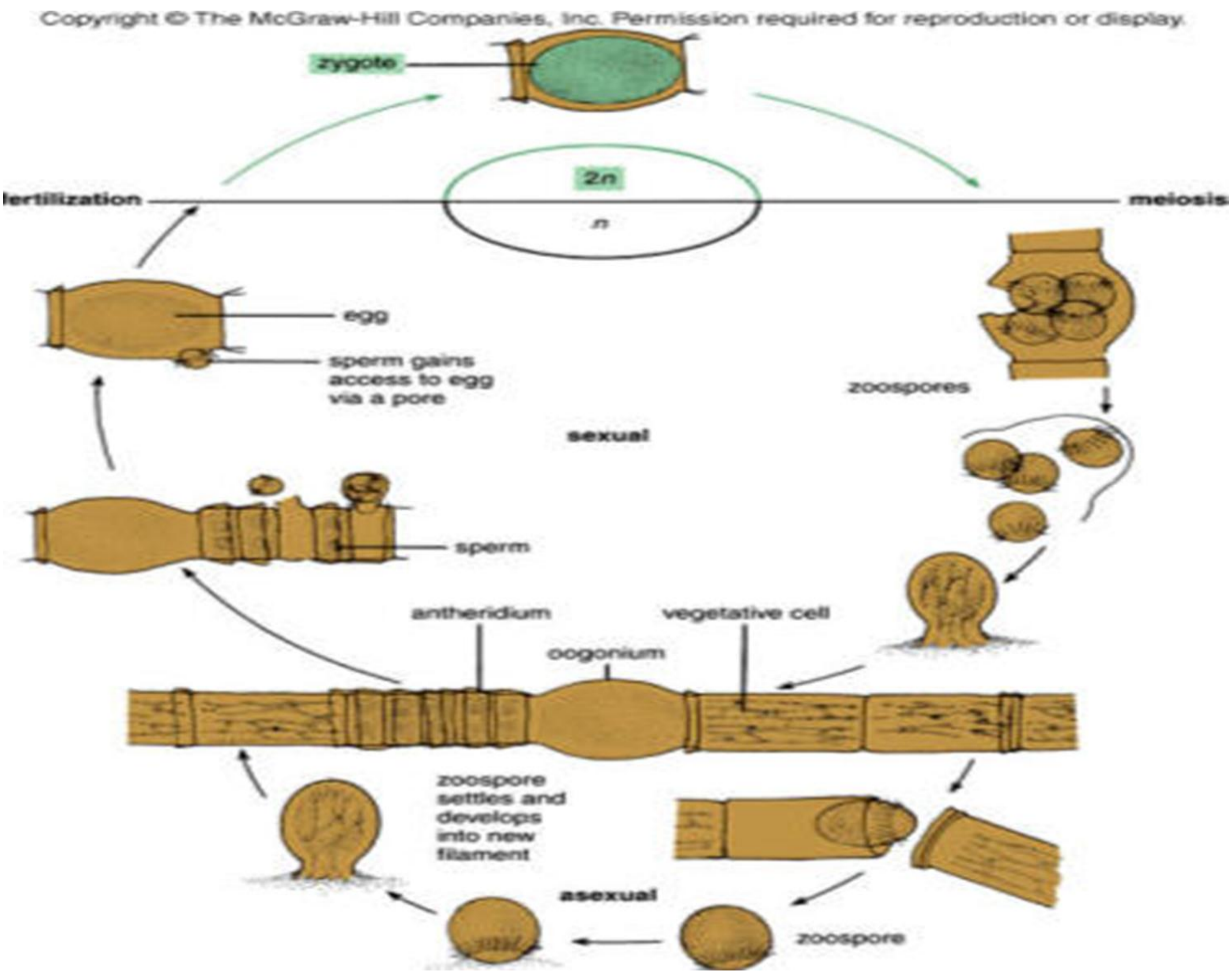


Fig. 3.78 : *Oedogonium* sp. : A. A stage before fertilization, B. Oospore in oogonium, C. Liberation of oospore from oogonium, D-E. Stages of zoospore formation, F. Liberation of zoospore, and G. Young filament develops after germination of zoomeiospore.

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.

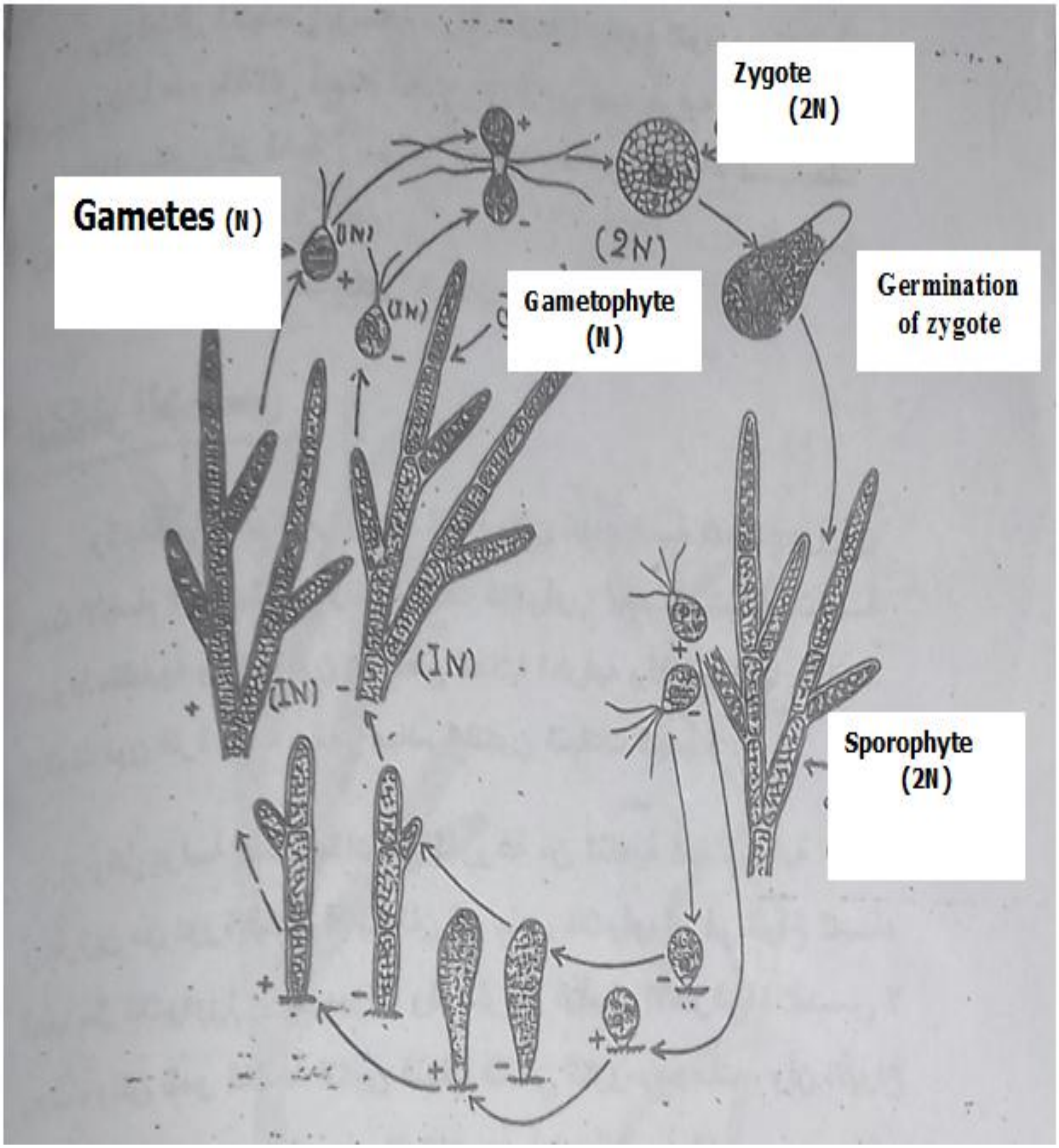
Asexual: The asexual reproduction takes place by means of zoospores. The zoospores are produced inside the cells, called zoosporangia. At the times of zoospore formation the protoplast divides into several bits. Simultaneously the nuclei also divide. Each protoplasmic bit having a nucleus in it metamorphoses 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* 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.



Life cycle of *Cladophora* sp.

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 isoogamous. 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

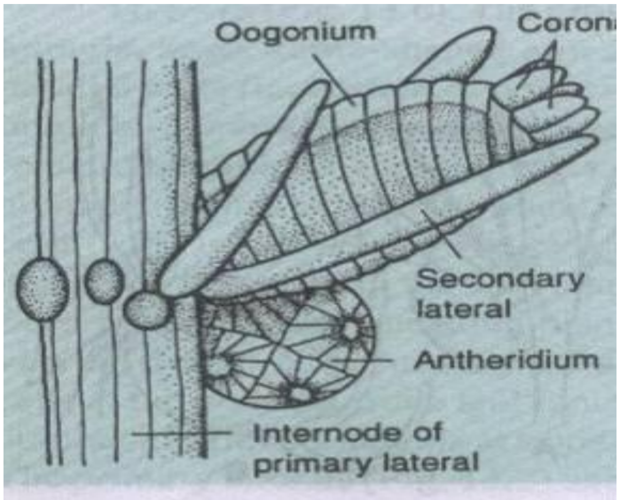


Fig. 13.11 (A-F). *Chara.* **A node of fertile primary lateral showing sex organs.**

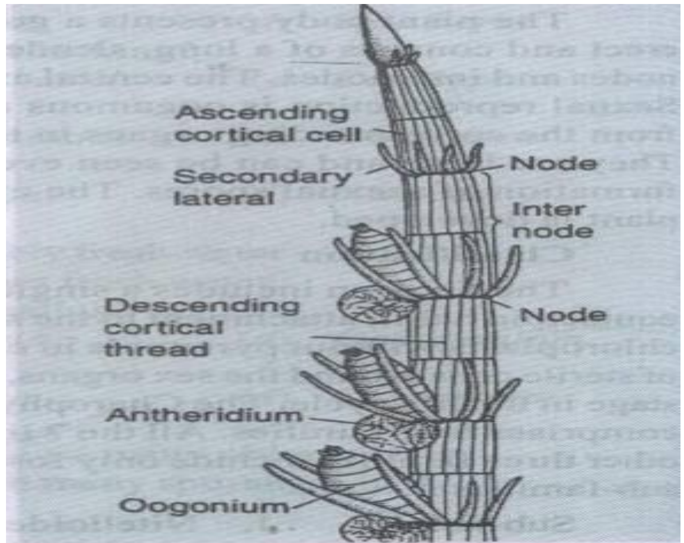


Fig. 13.2. *Chara.* **A fertile primary lateral.**

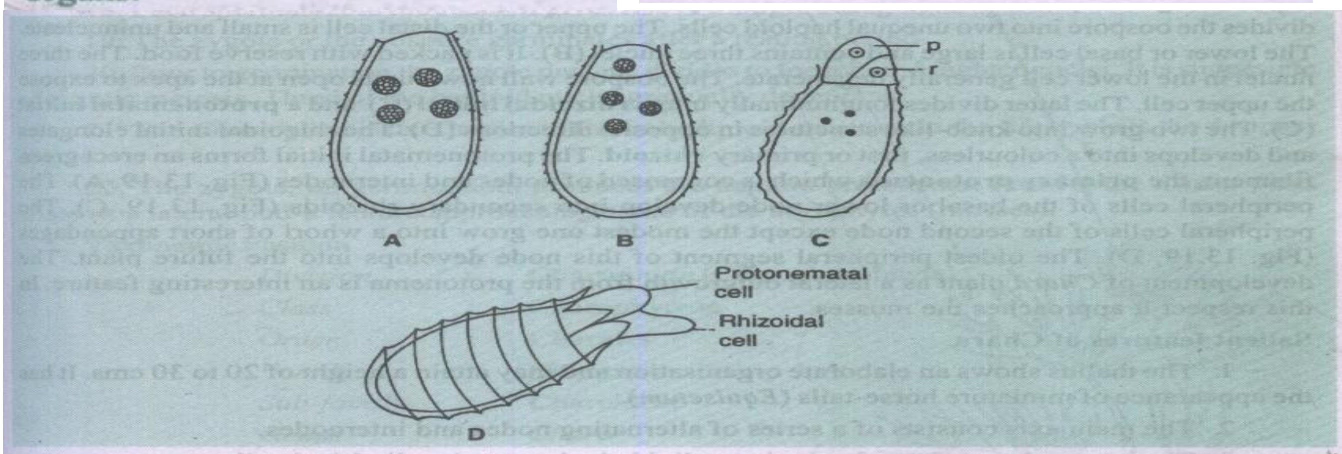


Fig. 13.18 (A-D). *Chara.* **Germination of oospore. (A), Zygote at 4-nucleate stage; (B), Zygote with uninucleate upper cell and 3-nucleate basal cell; (C), Formation of protonematal cell (p) and rhizoidal cell (r); (D), Enlargement of protonematal and rhizoidal cells.**

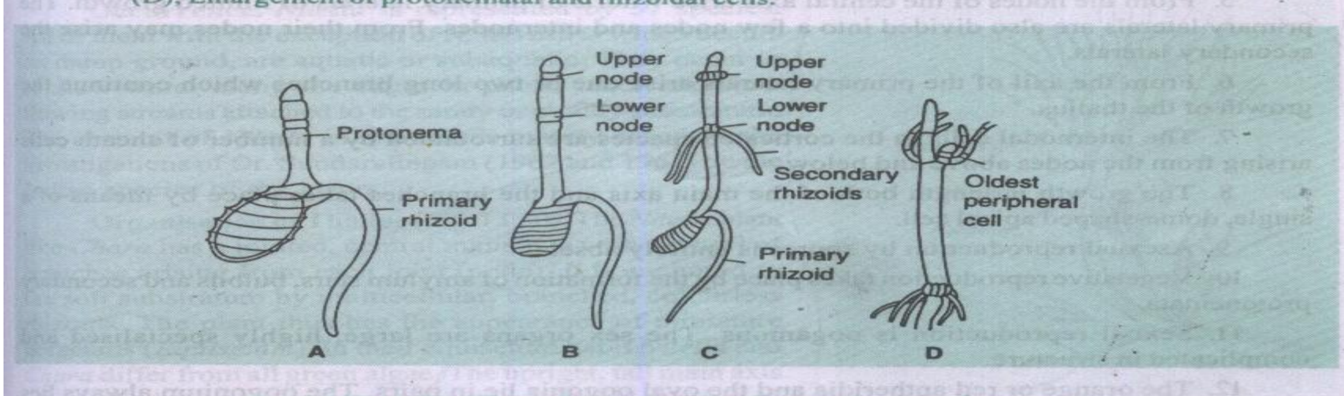


Fig. 13.19 (A-D). *Chara.* **Later stages in the germination of oospore.**

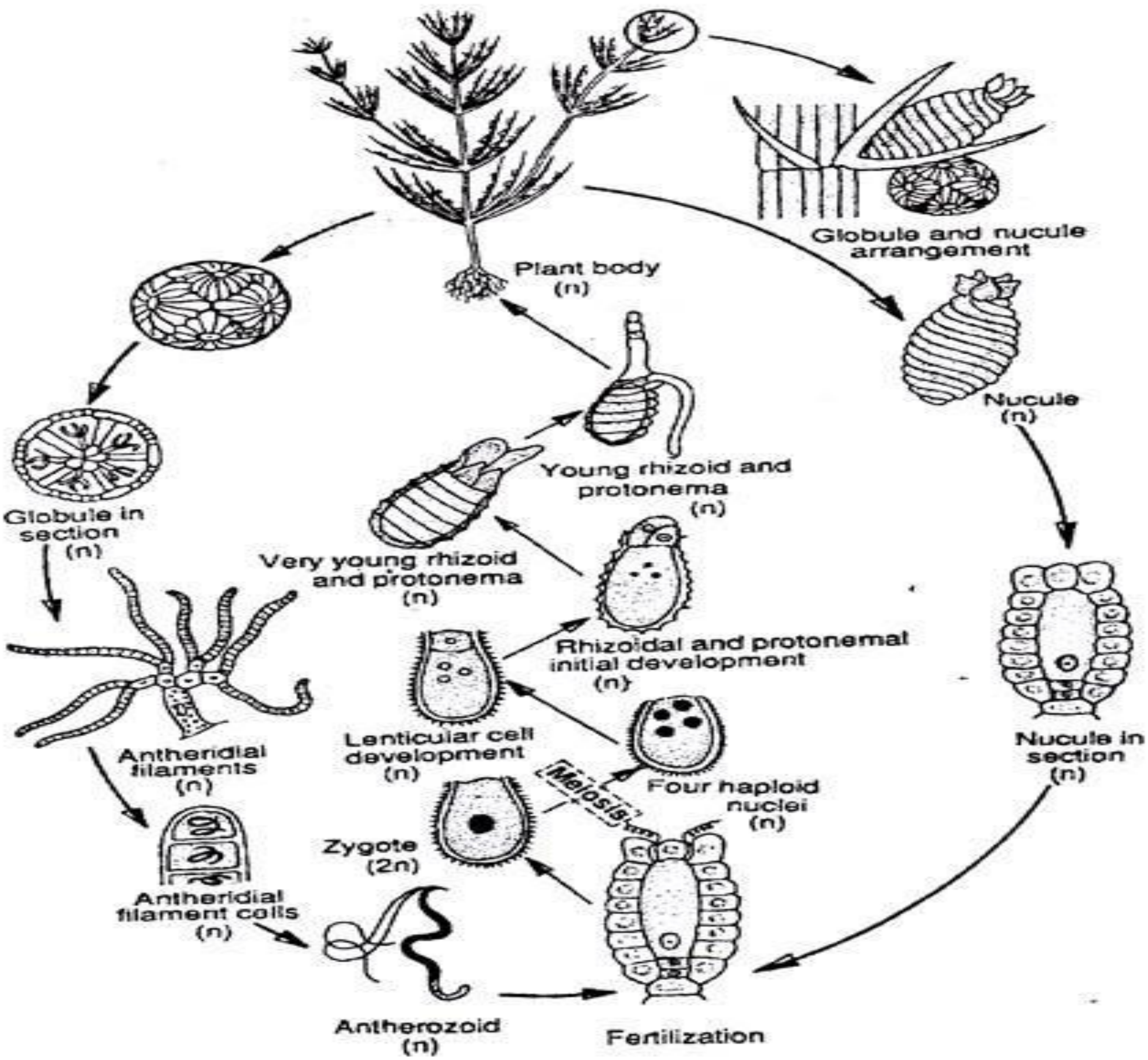


Fig. 12. *Chara*. Diagrammatic life Cycle

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.

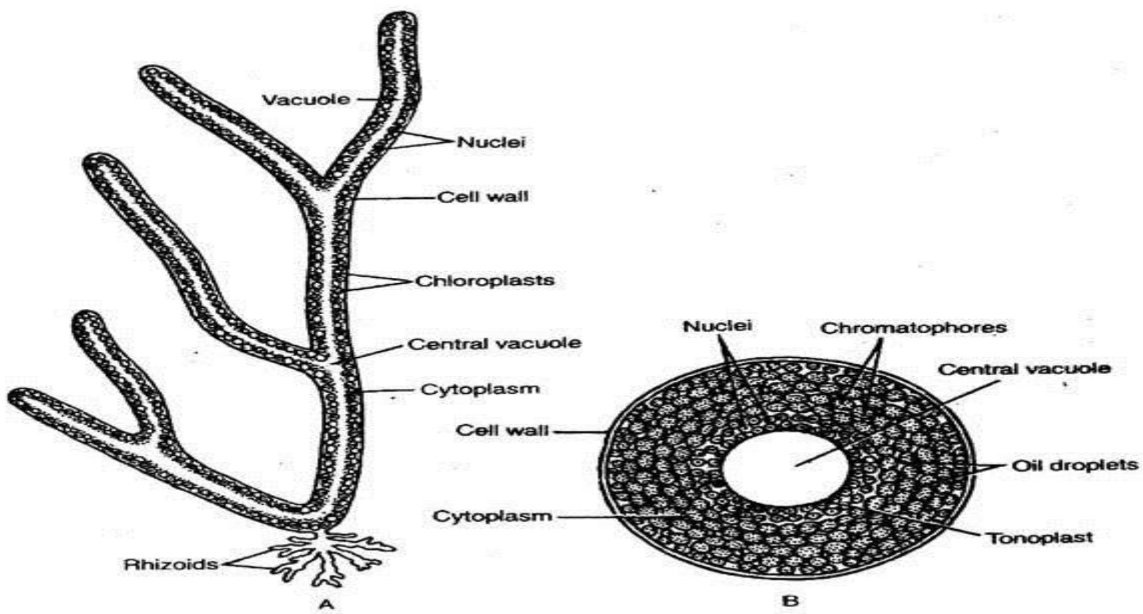


Fig. 3.83 : *Vaucheria* sp. : A. Single vegetative filament with rhizoid, B. T.S. through vegetative filament

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.

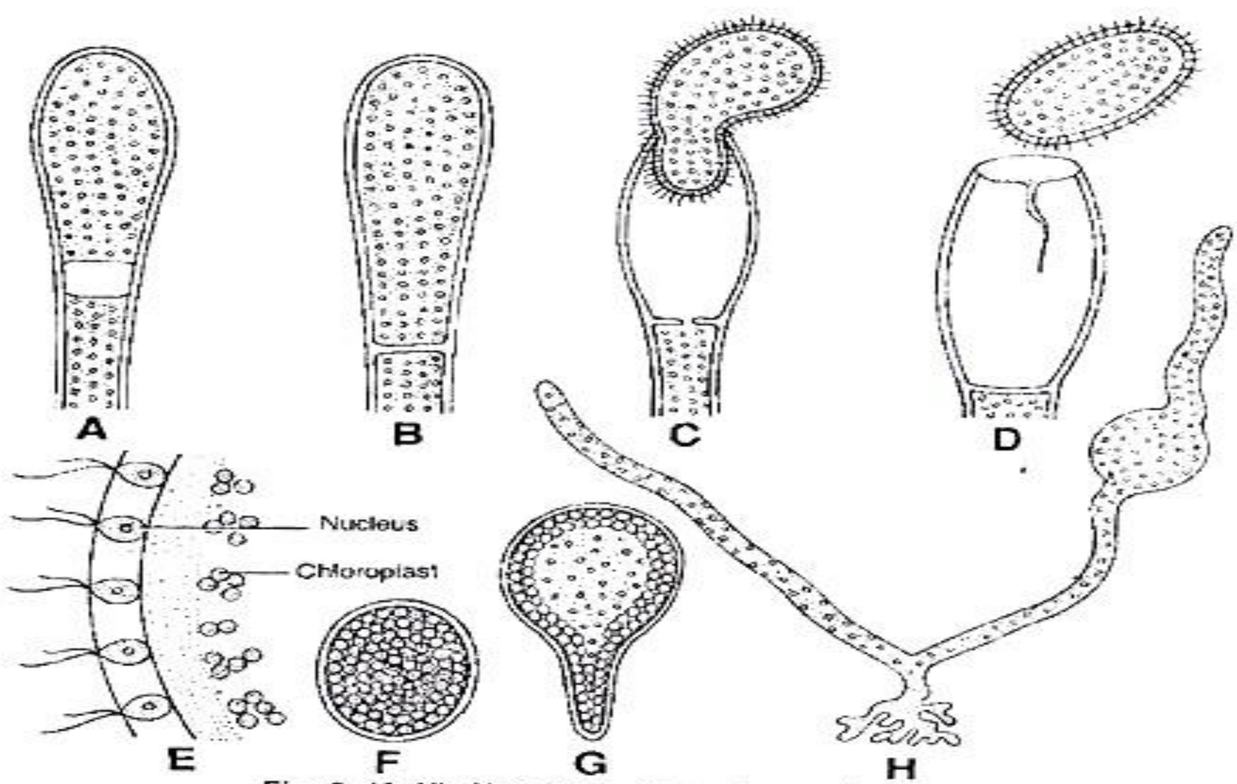


Fig. 2. (A–H). *Vaucheria*. Asexual reproduction.

(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*.

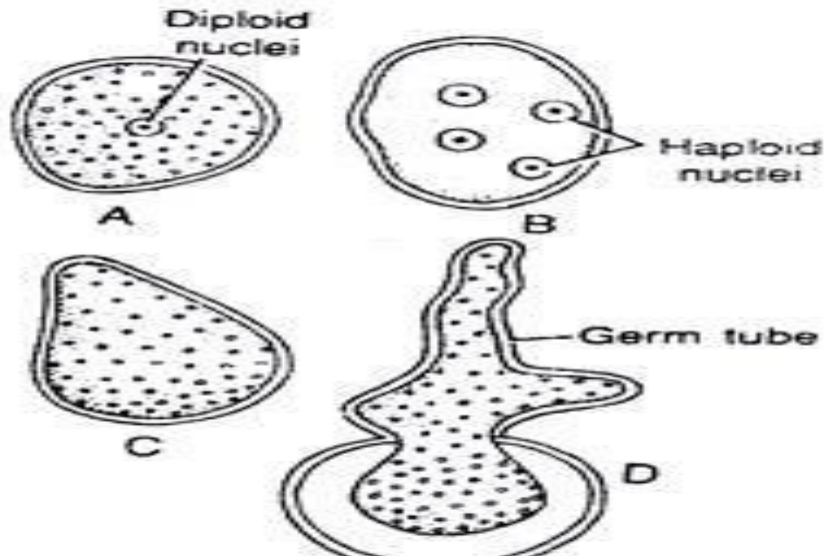


Fig. 7. (A–D). *Vaucheria*. Germination of oospore.

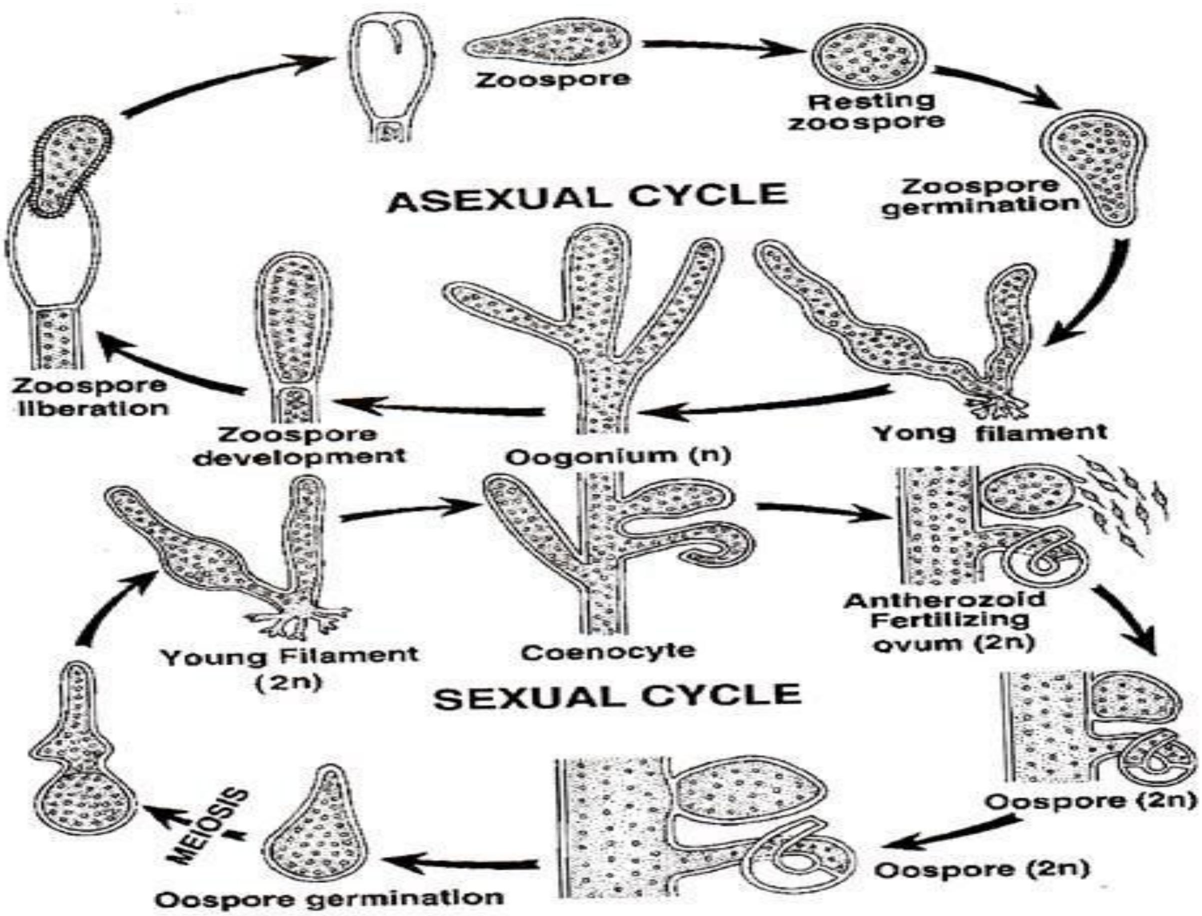


Fig. 8. *Vaucheria*. Diagrammatic life cycle.

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

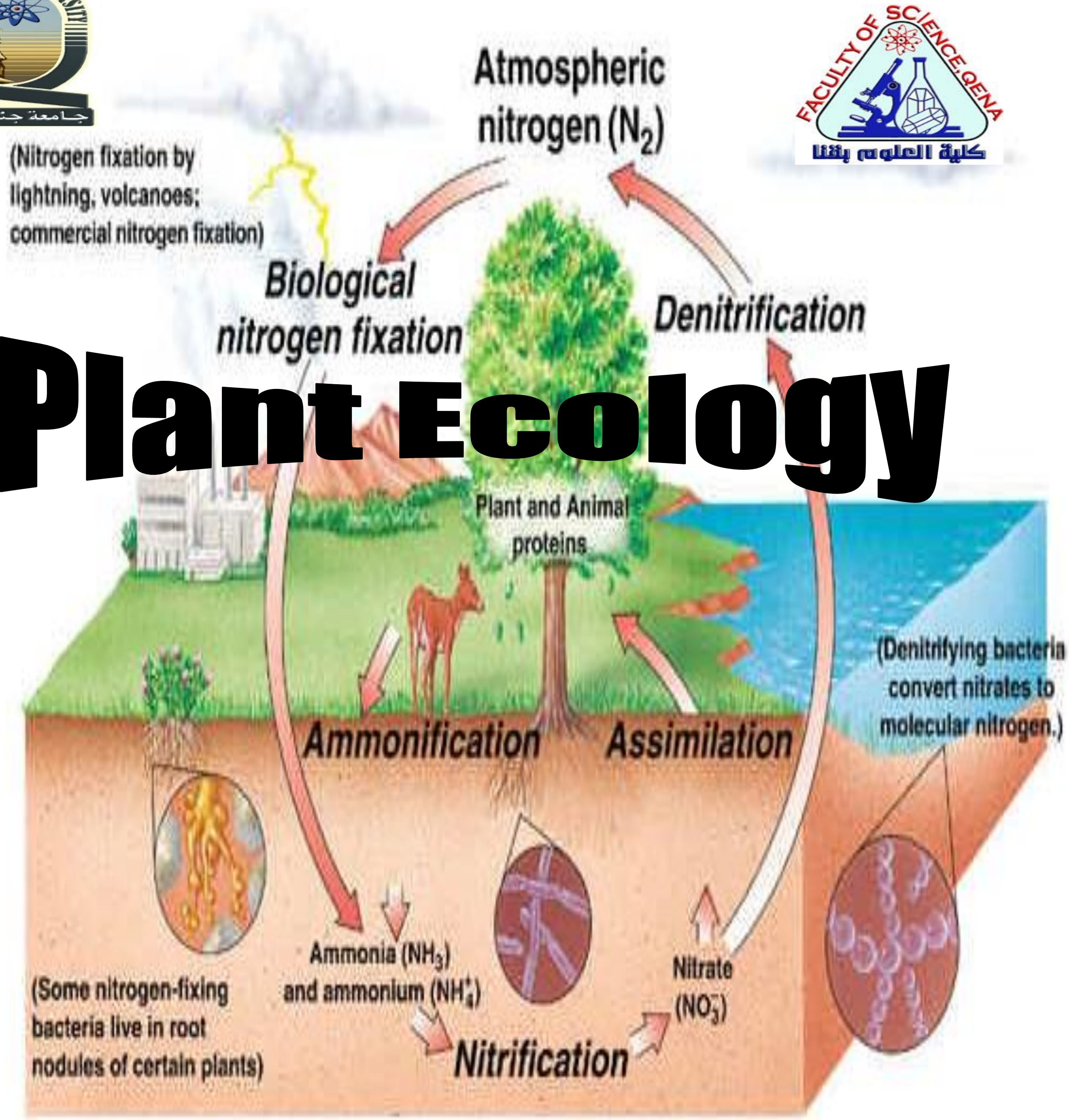
Red Algae has great ecological importance. They form a vital part of the food chain and are also involved in producing about 40 to 60 per cent of the total global oxygen for both terrestrial habitat and other aquatic habitats. Listed below are a few ecological and commercial importance of red algae.

- 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.

WITH MY BEST WISHES

DR. ABLA AM FARGHL

Plant Ecology



Preparation by

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Professor in plant ecology

PLANT ECO LOGY

- The term ecology is derived from the Greek words **Oikos** meaning home and logia which means the study of it.
- Ecology is: "the study of organisms in relation to their environment”.

The Organisms:

- It refers to all plants and all animals, including man. This means not only the larger organisms such as trees, grasses, deer, cows etc., but also any of the other lesser species in such environments. Some of these may be dependent on the larger organisms, some may be parasites, but all have relationships to each other and are using the resources available in their environments.
- The least of these such as bacteria and protozoa, contribute to the breakdown of dead organic matter and the release of its components to be used again, fix nitrogen or they may cause diseases.
- All the organisms in an environment are subjects for ecological consideration, all affect each other in some way and all have relationships to the environment.

The environment:

- The term "environment" includes everything that may affect an organism in any

1- Substances, such as soil and water
2- Forces, such as wind and gravity
3- Condition. such as light and temperature or
4- Other organisms.

- These factors may be studied or measured individually, but they must always be considered in terms of their interacting effects upon organisms and upon each other.
- The environment may be analyzed into a number of factors which may be grouped into three major categories:

1- Climatic (aerial), such as rainfall, and air temperature.
2- Edaphic (related to soil), such as soil moisture and soil temperature.
3- Biotic (related to other organisms) such as parasitism, herbivore and symbiosis.

- A fourth factor, which is not commonly recognized as being of universal occurrence, is the "pyric" factor which refers to the effect of fires caused by natural forces (such as , thunder storms) in forest and grass areas or by accidentally man-made fires.

The Habitat:

- It is the place where an organism or a community of organisms lives. A habitat has a particular set of environmental conditions such as a sand-dune habitat, salt-marsh habitat etc.

The subdivisions of ecology:

- Ecology is commonly divided into two types of studies:

l- **Autocology**: This branch deals with the study of individual organism or an individual species. The life history of the species as a means of adaptation to the environment is usually emphasized.

2- **Synecology**: Deals with the study of groups of organisms which are associated together as a unit. In other words synecology is concerned with populations and communities rather than with individuals. Useful subdivisions may be also based on the kind of environment or habitat such as:

1- Marine ecology: concerned with the organisms living in the seas and oceans.

2- Fresh water ecology: deals with organisms having rivers, and fresh water courses as their habitats.

3- Terrestrial ecology: which is the study of land plants in their relatively dry habitats. Ecology may also subdivide according to taxonomic groups such as: Animal ecology plant ecology, insect ecology etc.

THE ECOSYSTEM

- The whole complex of the plant and animals forming a community, together with all the interacting physical factors of the environment really form a single unit, which has been called the **ECOSYSTEM**.
- This takes into account all the living creatures in the community, from the fungi, bacteria and worms living in the soil to the mosses, caterpillars and birds up in the tree and all the factors of the environment, from the composition of the soil atmosphere and soil solution to wind, length of day, relative humidity and atmospheric pollution. etc.
- The ecosystem differs everywhere in the world e.g the ecosystem in tropical region differs than in alpine region but both have the same components. Any ecosystem consists of:

A Physical components, which are:

1- Climatic factors. 2- Edaphic factors.

B- Biotic components which are:

1- Plants 2- Animals. 3- Microorganisms. 4- Man.

All these components are in balance with each other every factor affect and effect in each other, the reactions between them are reversible and finally they are in balance state. Man represents the top on all the components of the ecosystem because he can affect and change them.

Biotic (living components). In most ecosystems the Kinds of organisms are numerous, and diverse and include producers, consumers, and decomposers.

A- Autotrophs or producers (plants).
B- Heterotrophs or consumers (animals).
1- First order: Consumers - herbivores.
2- Second order: Consumers - Carnivores, animals which eat the flesh of other animals.
3- Third order: Top Consumers (Carnivorous eat other carnivores)
C- Decomposers,(decompose dead organic substances) like fungi, bacteria and protozoa.

Characteristics of the ecosystems
l- The ecosystem consists of living (biotic) and non living (A biotic Factors or physical) components.
2- The relationships between the components of the ecosystem are always in balance (in two direction).Each factor affect and effect in each other, the reactions between them are reversible; finally they are in balance state.
3- The relationships between the components of the ecosystem are energetic i,e. The energy is not stable in the ecosystem.
4- The energy transfers between the components of the ecosystem in two ways:
a- between the living components through nutritional relations.
b- from living to non-living components through decaying (by microorganisms).
5- Energy transfers between the living components called the food chain. Energy transfers from living to non-living components called the mineralization chain.
6- The energy in the ecosystem transfers either in food chains or in mineralization chains through definite levels called energy levels.

RADIANT ENERGY

- The sun's radiant energy (often called insulation) comes to the earth’s surface as "electromagnetic waves", the lengths of which are measured in microns (1\1000 mm) or mill microns, ($1/10^6$ mm). This energy (called the electromagnetic spectrum) includes those wavelengths of the "visible spectrum" that we called light and those that lie just beyond the visible spectrum, which we call "heat" or infrared radiation if slightly longer or "ultraviolet" if slightly shorter.

The ultraviolet (UV) light includes all wavelengths below 400 nm.
visible light (v.) includes wavelengths between 400-720 nm.
Infra-red (I.R.) includes wavelengths above 720 nm.

- The amount of solar radiation that falls on earth, at sea level, is much less than that received outside the earth's atmosphere, because of the absorbing effect of the different gases contained in the atmosphere around the earth.
- The amount of radiation reaching' the earth is always reduced because of absorption by the atmosphere (6 - 8 %) and sometimes as much as 40% may be reflected by clouds.

- The remainder reaching soil or water on the earth may be further varied by such factors as distance from the sun at different seasons, duration of radiation, and the angle of the rays with the earth's surface.
- The last determines the amount of air through which the rays pass, modifies the amount of reflection and absorption, and likewise controls the amount of energy falling on a unit area simply by spreading or concentrating a given amount of energy over more or less space.
- The reduction in radiant energy, **caused by the earth's atmosphere is** as follows: Percent of radiant energy portion of electromagnetic

Percent of radiant energy		Portion of electromagnetic spectrum	
At ground Surface	Outside atm.		
1%	9 %	U.V.	Ultra Violet
39 %	41 %	V.	Visible
60 %	50 %	I.R.	Infra-red

- For these reasons, ultra-violet and infra-red radiation is reduced much more on a cloudy day than on a clear sunny day. This is also the case for high mountains where ultraviolet radiation is much more abundant than at lower levels in the same place.
  - In its passage down through the atmosphere, **the depletion of solar energy results chiefly from selective absorption by the constituent gases and water vapour, from the scattering by molecules of air and small solid and liquid particles, and from reflection outward to space by larger particles and cloud surfaces.** واستنزاف نتائج الطاقة الشمسية أساسا من الامتصاص الانتقائي من الغازات المكونة وبخار الماء، من تشتت جزيئات الهواء والجسيمات الصلبة والسائلة الصغيرة، ومن انعكاس إلى الخارج إلى الفضاء من قبل الجسيمات الكبيرة و اسطح الغيوم. The constituents of the atmosphere that take a significant part in the absorption of solar radiation are the following:

Absorption wavelength	Component
120 - 180 n.m. U.V.	1- Oxygen atoms in upper air
200 - 330 n.m. U.V.	2- Ozone
750 - 1470 n.m. I.R.	3- Water vapour
2700 n.m. I.R.	4- CO_2

For these reasons, ultra-violet and infra -red radiation is reduced much more on a cloudy day than on a clear sunny day.

The effect of the various bands of the solar spectrum on plants is as follows:

Band W.L. in n.m.		Effect on plants
1000 - 3000 n.m.	I.R.	No specific effect on plants, when absorbed by the plant, it is transformed into heat without affecting the biochemical processes.
720 - 1000 n.m.	far-red	Have specific elongation effect upon plants. Also affects photo-periodism, seed germination, control of flowering and coloration of fruits.
610 - 720 n.m.	red	Strongly absorbed by chlo-rophyll,therefore generates strong photosYnthetic activity.
510 - 610 n.m.	green	Have little or no effect on photosynthetic,activity.
400 - 510 n.m.	Blue violet	The region of strongest and yellow pigment absorption, strong photosynthesis.
315 - 400 n.m.	U.V.	Plants become shorter and leaves thicker (affect the form of plant).
280- 315 n.m.	U.V.	Detrimental to most plants Rapidly
Less than 280 nm.	U.V.	kills the plant.

CLIMATIC FACTORS
I. TEMPERATURE

- As a result of the absorption, of shorter wave lengths from the sun's radiation by the earth's atmosphere, most of the radiation falling on earth has a heating effect' This radiation, when hitting the surface of solids (like the soil) or liquids (like the seas & oceans) their particles are set in rapid vibration, resulting in a heated condition' The earth's surface quickly reradiates much of the heat it receives from the sun resulting in a heating effect upon the atmosphere.

- The heating effect of the air layer just at the soil surface is the result of the process of "conduction". The heated air layer decreases in density and starts to move upward and also horizontally to cooler areas of the air mass above and around. This process of transfer is called “convection".
- The heated condition of a solid or liquid body, and of the air, is expressed by either one of two terms:

1- Heat which is a quantitative term used to refer to the quantity of energy received by or contained in this body' The unit of measurement of heat energy is the "gram calorie" which is defined as the quantity of energy that can raise the temperature of one gram of water from 15 to 16°C Radiation may therefore be expressed as gram calories per square centimeter per hour.

2- Temperature, which is a term used to refer to a particular level or degree of molecular activity (energy). This is a qualitative term as it expresses a condition rather than a quantity because a fewer gram calories are required to raise the temperature of a small body of water through the same number of degrees (that is to the same temperature level) as would be required for a large body

Temporal variations in temperature:

- The amount of heat received from the sun fluctuates owing to the momentary passing of clouds, the daily and seasonal phenomena. As the sun rises in the morning, the earth’s surface begins to gain more heat than it loses by re-radiation so that its temperature rises progressively and rapidly.
- After several hours a relatively high surface temperature is attained and radiation gains are approximately equaled by losses due to re-radiation and conduction. This equilibrium is maintained until radiation begins to weaken during the afternoon.
- After the sun sets, the earth's warmed surface continues to give up its accumulation of heat to the atmosphere by radiation, and since it receives no more of this energy from sun, its temperature declines steadily during the night.
- This nocturnal loss of heat is accelerated by the cooling effect of evaporation from the soil, so that the soil temperatures characteristically drop below air temperatures, with the minimal surface temperature occurring just before sunrise. Because the daily maxima are higher and the nightly minima are lower, the surface temperature of exposed soil fluctuates more widely each 24-hour period than doe's air temperature.

Importance of temperatures to plants:

- Temperature is like water in its action upon plants. It has more or less to do with nearly every function, but as a working condition, not as a material. All the chemical processes of metabolism and also many physical processes such as diffusion, precipitation, coagulation of cell proteins etc. are dependant upon temperature and accelerated by its increase up to an optimum. with a decrease in temperature to a certain minimum, growth is retarded; at lower temperatures, cell division and photosynthesis are also decreased and, at a still lower minimum respiration stops and death of the plant takes place. Therefore, temperature is not only necessary for life processes but also furnishes the energy for some of them. Radiant energy' for example, is absorbed in photosynthesis and set free in respiration.

- The habitat plays an important part in determining the influence of temperature upon each species. A particular species has been accustomed for countless generations to certain extremes of heat and cold as well as to certain seasonal temperatures. The temperatures beyond these extremes decrease the plants activity.
- Temperatures favorable and unfavorable to plants: (cardinal temperatures) plants are adapted to a wide range of temperature. Some species are able to grow in extremely low or extremely high temperatures. In fact, some of the lower forms of plant life such as algae may grow and fruit in arctic waters at temperatures below zero.
- Conversely, numerous algae and bacteria thrive in hot springs at temperatures as high as 77^{o}C and a few fungi can endure temperatures of 89^{o}C plants are subjected to a considerable range of temperature during their period of growth. They grow only when the temperature remains within certain limits, and mature and die became dormant when it falls to low or too high levels. There are three critical temperatures in the life of the plant which affect its state of functioning. These are the optimum, the minimum and, maximum temperatures. These temperatures are known as "cardinal temperatures”.

1- The Optimum temperature:

- The temperature at which a plant functions best is called the optimum. optimum temperatures for the various physiological processes, e.g photosynthesis, respiration, and reproduction do not coincide, that for respiration, for example, being much higher than the optimum for food manufacture. Therefore, it seems clear that the ecological optimum or temperature at which the plant as a whole develops best is never a mere point but a range of several degrees at least. As the chemical and physical processes within the plant are quickened by a favorable temperature, demands for water and nutrients are also increased.

2- Maximum temperatures:

- The maximum temperature that can be tolerated without injurious effects in the plant, often resulting in death, varies greatly with the species. It seems to be an inherent quality of the protoplasm gained through the evolutionary adaptation of every plant At high temperatures, the growth rate of plants rapidly falls and soon a point is reached beyond which the plant dies. At about 40oc, changes begin to occur in the protoplasm that are inimical to the life of the plant, and most plants fail at temperatures between 45 and 55^{o}C.

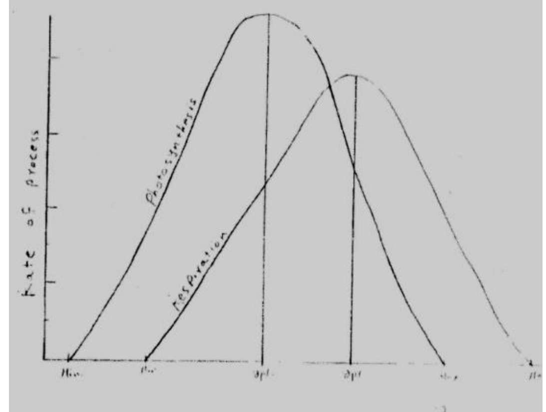
- Like minimum temperatures, maximum ones vary widely with different species. Some tropical plants carry on their life processes at temperatures so high that most plants if subjected to them would die in a very short time. Furthermore' a plant withstands extremes of heat and cold much better in some stages than in others.
- It is least resistant in the active condition when the tissues are filled with water and most resistant in the resting states typical of spores, seeds, corm etc. when dry, seeds can endure, temperatures above 100^{o}C although they are readily killed at 70oc if water soaked. Certain species of yeast have been shown to be capable of enduring a temperature of ll4^{o}C when dormant, and bacteria in the spore condition are able to withstand temperatures of 120 to l30^{o}C.

3- Minimum temperatures and freezing:

- The minimum temperature at which any plant can continue activity is approximately the freezing point of water. Some arctic and alpine plants may produce their flowers after coming up through banks of conifer and may continue to flourish, although the temperature falls freezing every night. The activities of marine algae at temperatures below zero have been observed.
- On the other hand, many tropical plants are retarded in growth at 20^{o}c and some are frequently killed at 20^{o}C. The minimum temperature, moreover, varies greatly at different times of the year and with different conditions of the plant as well as its previous experience with low temperatures. The chief difference lies in the amount of water the plant contains. The watery leaves and herbaceous stems of plants of temperate climates, for example, are usually killed by an exposure to l00^{o}c and frequently at temperatures 2 to 4^{o}C above freezing,
- The drier seeds and inactive ground parts resist the long continued effect of temperatures of -30 to -40oc; dry seeds being uninjured by -193 to -250^{o}c. Death by winter killing or cold at any time is usually a matter of desiccation and its attendant results brought on by low temperatures.
- Since the cell sap always contains solutes that depress its freezing point, only temperatures lower than 0^{o}c cause the water to freeze. Plant tissues can be under cooled several degrees below the freezing point and warmed up again without injury provided no ice formation occurs. A plant or its growing parts (buds, cambium etc') are not necessarily killed, even though they are solidly frozen.
- On the arctic coast of Siberia, some plants are struck by winter climate and are exposed to extremely low temperatures (-46^{o}C) while still in the flowering stage. In spite of this, they began again to blossom quite unharmed upon the recurrence of warm weather'

Cardinal Temperatures for Physiologic Processes:

- Cardinal temperatures differ for the same function in different plants. For example, the minimal temperature for growth in melons, sorghums, and the



date palm lie between 15 and 18°C, and the corresponding value for peas, rye, and wheat lie between -2 and 5°C.

- The maximal temperature for growth in boreal shade plants is not many degrees above freezing, but a species of ***Opuntia*** was observed to make growth when its tissue temperature was 56.5°C and the air temperature was 58°C.
- Certain arctic marine algae and the snow algae complete their life cycles in habitats where the temperature never rises significantly above 0°C, whereas hot-spring algae may live in water uniformly as hot as 77°C. Because of evolutionary adaptation it is generally true that the warmer the native habitat of a species the higher up the temperature scale its cardinal temperatures lie.

- Different functions of the same plant may have different cardinal temperatures. In many, if not most plants, the optimal temperature for photosynthesis is distinctly lower than the optimum for respiration. In the white potato the rate of photosynthesis rises to a sharp maximum at about 20°C, but respiration at this temperature is only 12% of its maximum rate. With an increase to approximately 48oc respiration reaches its optimum, but the photosynthetic rate has declined to zero by this time. Because both growth and reproduction depend upon a more rapid rate of accumulation than of oxidation of organic compounds, plants are at a disadvantage whenever the temperature rises above the optimum for photosynthesis.
- This is believed to be the explanation for the facts that peaches, apples, white potatoes, etc., do not accumulate normal food reserves when planted below certain altitudinal or latitudinal limits, and those anthocyanins, which are usually associated with abundant sugars, fail to develop at high temperatures. This photosynthesis-respiration relationship may prove to be of considerable importance in setting the lower altitudinal and latitudinal limits of many plants. Quite possibly the more rapid rate of carbohydrate accumulation observed in certain crop plants as temperatures decline at the end of summer is in part at least a result of temperature control of the photosynthesis-respiration relationship.
- Various organs of the same plant may have different cardinal temperatures for the same function. Roots, the temperature of which follows that of the soil' appear to have lower (i.e. threshold minimal) temperatures for growth than do shoots. In many plants of temperate regions the roots continue growing as long as the soil is not frozen, although in general the roots of most plants in temperate climates become relatively inactive for at least a part of the winter. Because of definite and often different temperature requirements of roots and shoots, the relations between soil and air temperatures have a pronounced effect upon the welfare of certain species.
- Cardinal temperatures vary also with the age of the plant, with its physiologic condition, with the duration of particular temperature levels, and with variations in

other environmental factors. Strictly speaking, then, a cardinal temperature is a range rather than a fixed point on the temperature scale, and with plants growing in natural environments, it follows that the optimal temperature conditions for the successful completion of the life cycle embraces a range set by particular maxima and minima which may limit development only at one or two points during the cycle. Thus the temperature requirement of different functions at each stage of development must lie within the variations in temperature which prevail during the season corresponding to that stage of development. At each phase of development there is, for the organism as a whole, an optimum range which is most conductive to the harmonious interaction of all physiologic processes.

Beneficial (Stimulating) effect of Low Temperatures:

- Many plants native to cool and cold climates must each year undergo a rest period that is not enforced primarily by low temperatures. After growing vigorously for a time they become dormant even though external conditions remain favorable for growth.
- Ordinarily this dormancy is broken only by temperatures below about 5 to 8^{o}C, the effect of short periods of exposure below this level being cumulative, yet susceptible of being nullified by subsequent high temperatures.
- If a plant is moved too far in a pole-ward direction, its chilling requirement is satisfied early in winter so' that growth is resumed before the end of winter. If moved too far in equatorial direction the chilling requirement may not be met by the end of winter- the dormant buds will not open promptly with the arrival of warm weather and the development of leaves, flowers and fruits is repressed, e.g. peaches require 400 or more hours of temperature at or below 7^{o}C, the length of time varying with the variety.
- Winter stimulation accordingly has been found to set the lower altitudinal and latitudinal limits of profitable culture of these plants. An example of this is illustrated by trials to introduce pistachio trees into the coastal Mediterranean area of the western desert in Egypt. The trees could give vigorous and healthy vegetative growth but failed to flower and subsequently to give a crop.
- This was primarily due to the unfulfilled chilling requirements of the plants since the temperature in winter seldom falls below 7^{o}C. Laboratory experiments could prove this to be the case. Low temperatures are often necessary to stimulate the formation of flower buds. In ***Senecio***, for example, the flower buds are not formed if the plant was kept under a temperature above 15.5oC. In most herbaceous plants the temperature level necessary to stimulate the formation of flower is lower than that favors rapid flower development, whereas very high temperatures repress flowering.
- The seeds of many plants of cold regions require chilling under moist conditions for a period after apparent maturation if they are to germinate vigorously. The common practice of supplying these conditions artificially is called “**Stratification**" and

temperatures varying from 1 to 2^{o}C for one to several months are used, depending on the species.

- Certain plants, although they do not have a rest period the breaking of which requires a low temperature, need low temperature during or shortly after germination in order to complete their life cycles quickly. For example, winter wheat sown in spring does not flower before the plants are subject to the following dry summer, but if soaked grains are subjected to a temperature just above freezing for a period, it can be sown in spring and a crop quickly produced.
- Since cold treatment is effective through promoting the formation of an essential metabolite, the stimulus derived from chilling is retained even if the seed is subsequently dried. Thus, if seed wheat is moistened to 50% of the dry weight, then chilled at 2^{o}C for about two weeks, it can be dried again and sown many weeks later.

Cold (Chilling) Injury and Frost (Freezing) Injury

- The migration of plants from their ancestral environment of the seas onto the land necessitated marked adaptation for enduring the wide variations in temperatures that characterized the newer environment. Although there is no region on earth which is so cold or, so hot but that some plants live there, plant adaptations are not so perfectly adjusted but that temperature extremes frequently cause injury or death.
- Moreover, the absolute extremes that result in the immediate death of protoplasm are much farther apart than those extremes that are determined by inhibiting growth and other functions. When temperature drops below the minimum for growth a plant' becomes dormant, even though respiration and sometimes photosynthesis slowly continue.
- **Chlorosis** likewise may result from such chilling. With further loss of heat a point is usually attained below which the protoplasm is fatal injured. Molisch (1897) has called low temperature damage, in the absence of freezing, "**Chilling Injury**" as opposed to "**Frost Injury**" caused by freezing. Three main phenomena appear to be involved in killing by low temperature:

a) proteins may be precipitated directly, especially in plants that are killed before temperatures drop to the freezing point of water.
b) b-At lower temperatures, intercellular ice commonly forms, drawing water out of the protoplasts. This causes a dehydration which, below a certain critical temperature or after a prolonged period, allows irreversible precipitations in the protoplasm. Possibly mere deformation of the shrinking cell may be lethal. Also, when the ice crystals melt rapidly the cell walls may expand more rapidly than the protoplasts can swell, and thus may tear the two apart.
c) Rapid freezing causes ice to form within the protoplasts. This ice formation is nearly always fatal presumably because crystal growth disrupts protoplasmic organization. The ability of plants to endure low-temperature extremes varies widely among species.

- Certain plants of tropical affinity such as cotton, sudan-grass etc. are injured to exposure by temperatures which are low but yet above the freezing point (5ºC) Other plants are not injured until they are frozen; still others native to cold climates can endure periods when the tissues are frozen solidly and the temperature drops to -62ºC.
- The freezing point of plant sap, because of its solute content, usually lies several degrees below 0oc, but certain plants, mostly cryptogams and seeds, cannot be frozen at any temperature (even -270ºC)rand these are immune to low temperature injury.
- A plant is not equally resistant to low temperatures at all stages of its life cycle. Seeds and spores are generally the most resistant stages. Among trees seedlings are commonly more sensitive to cold than older plants, but with grasses the relationship may be reversed.
- Even for the same plant, the frost killing temperature may vary widely with the manner of the temperature change, the season and the physiological state of the plant. Killing may occur at higher temperatures if the freezing is rapid, rather than gradual. Greater injury to the plant may occur after long continued freezing than that after short freezing periods at the same temperature.
- Injury may also occur after two or more freezing's that failed to injure the plant in one. Freezing**-** some plants that survive the cold in winter may be killed by a very slight freezing during spring.

Adaptive resistance to low-temperature injury:

The degree of injury that plants suffer from low temperature depends upon:

1- The degree and duration of minimum temperatures

2- The suddenness of change.

3- The previous physiologic conditioning by the level of mineral nutrition, moisture content of tissues, and the length of day.

4**-** The adaptational characteristics.

- Adaptations that permit plants to endure low temperature successfully are mostly protoplasmic. The principal exception to this is that plant organs the surfaces of which are covered with a waxy bloom or with dense pubescence can endure freezing temperatures for a relatively long time without ice formation inside the tissues' Also, small cells are correlated with old resistance' Temporary protoplasmic adaptation affording a measure of immunity to low temperature injury is called "**hardening**".
- It can be induced artificially by most conditions that result in a sudden checking of growth, especially by chilling to within a few degrees of freezing for at least a few hours, or by drought. The lower the temperature used in hardening the greater the resultant degree of cold resistance.
- Glass house grown seedlings are generally hardened by placing them temporarily in a cold frame and watering them but lightly. In irrigated orchards the trees can be hardened against early autumn cold temperatures simply by withholding water. These

practices lower the injurious temperature level a few to many degrees, depending on the species and on the duration of the hardening period.

- If a plant endures the first frost without injury, its resistance increases with each subsequent exposure. Several interrelated physiologic changes are known to take place during hardening. The protoplasm develops a low structural viscosity and therefore is better able to accommodate deformation.
- The free water content decreases, and at the same time soluble proteins and sugars increase. Both changes, which are especially pronounced in aerial organs, lower the freezing point of tissues. The importance of abundant carbohydrates is shown by the fact that defoliation or any other condition which prevents their accumulation renders plants more susceptible to cold injury.
- In general, small increases in osmotic pressure of the cell sap are associated with considerable margins of resistance to low temperature. Most of the factors that make a plant frost resistant also render it less susceptible to drought injury.

Winter Drought Injury:

- On account of the slowness with which the temperature of the soil changes, the temperature of the air is alternately higher and lower than that of the soil. At these times during the cold season when air temperature is the lower, cold injury is the chief hazard to plants; but when the air becomes warmer than the soil, plants have great difficulty in replacing water lost by the shoots in transpiration.
- With a drop in temperature from 25 to 0^{o}C, the viscosity of water is doubled. Therefore even when there is an abundance of growth water, low temperature greatly reduces the ability of the soil to supply water to the roots, as shown in the following table showing the amount of water absorbed by a pottery (porous) surface at different temperatures:

Water absorbed (mg/cm2 /hr)	Temp. °C.
57.2	0.0
96.6	8.2
132.2	24.0
171.8	34.8

- The optimum temperature for absorption by roots is generally around 30^{o}C or higher, and soil temperatures in the root horizons are usually lower than this even in summer. The fact has long been known that plants can be wilted by cooling the soil about their roots.
- It has been shown experimentally that cold soil induces the same structural modifications as drought, thus demonstrating the correctness of the application of the term physiologic drought to this phenomenon.

High temperature Injury:

- Aside from its role in desiccation, and in bringing about a dis-balance between respiration and photosynthesis the high temperature can injure and kill the protoplasm. When temperature rises above the maximum for growth, the plant enters a quiescent state, sometimes accompanied by **chlorosis** and, with further heating, a lethal level is eventually attained.
- The thermal death point usually is a few degrees above the optimal temperature for growth. It is believed by some that the first decrease in physiologic activity above the optimum is due to an inactivation of enzymes. The principal adaptational features which protect plants against high temperature injury are:
    1. Thinness of leaf blades coupled with high transpiration, which prevents leaves exposed to the sun from becoming more than about 5oC warmer than air, and possibly account for the fact that they are seldom injured by heat.
    2. Vertical orientation of leaf blades which always reduces the tissue temperatures at least 3 to 5^{o}C below that of leaves turned at right angles to sun's rays.
    3. Whitish colour of surfaces which reflect rays that would otherwise be absorbed and become heat energy.
    4. A covering of dead hairs or scales which shades living cells.
    5. A thick corky bark which insulates the phloem and cambium.
    6. A low, moisture content of the protoplasm, and a high carbohydrate content.
- Any development of resistance to frost or drought usually involves an increase of resistance to heat injury.

Temperature efficiency:

- Because heat energy increases the kinetic activity of molecules, the higher the temperature the more rapid is the rate of chemical reaction and, consequently the physiologic processes. The ratio of a rate of reaction or function at a given temperature to its rate at temperature 10^{o}C lower is called the "**temperature coefficient**" and is designated by Q.
- The temperature coefficient usually varies between 2 and 3, depending on the particular reaction, but in a single complex organism function the coefficient varies from zero above and below the maximum and minimum temperatures' respectively, to very high values on approaching the optimum temperature.
- Ecologists have long been interested in evaluating temperature data in terms of efficiency in allowing plants to grow and reproduce vigorously, but the problem is very complex.
- Trials have been made in several directions to reach a quantitative evaluation of temperature efficiency to plants. Coefficients and indices are calculated from the temperature records obtained from meteorological stations in the field. Some of these indices and coefficients are as follows:

The plant zero:

- The activity and growth of any plant depend upon its receiving the requisite amount of' heat during the growing period. The influence of temperature on the size of the plant is very great because of its control over growth. The sum of the temperatures that act upon a plant is of the first importance in determining its general appearance.
- The effect may be produced either by temperatures that are more or less constantly too low or by shortness of season, which is equally effective in reducing the total amount of heat available for the use of the plant. Since temperature is one of the most influential of all climatic factors affecting plant growth, it has received much attention in connection with crop production.
- In spite of much study, very little is known about the relationship between air temperature and the development of any crop. Could the heat requirement of various crops be stated in terms of temperature and times, it would be of immense importance to agriculture.
- For many years, an effort has been made to determine the total of the affective heat units necessary to grow various crops to maturity. Since all temperatures below the minimum are ineffective in promoting growth, it was first necessary to select a plant zero, i.e. a temperature above which growth begins.
- Since this varies for different crops and, to some extent, with other conditions such as latitude and altitude, length of day, etc. different plant zero points have been suggested. This is about 3^{o}C for spring wheat, 13^{o}C for corn, and 17^{o}C for cotton. It varies but little, regardless of where the crop is grown.
- The plant zeros most used, however, have been 43 and 40^{o}F (4.5^{o}C) and three summation processes have been employed to determine the effect on plant growth of temperature sums above this point.

Remainder Indices:

- By the process of remainder indices of temperature efficiency for plant growth; which has been used most frequently, all mean daily temperatures above the plant zero during the life of the crop have been added together. This would be 100^{o}F for one day with a mean temperature of 53^{o}F (plant zero of 43^{o}F). In this way, the RI = Mean daily temperature - plant zero.
- However, with terrestrial plants this method of expression is subject to the criticism that normal functioning may be more closely governed by day than by night temperatures and in other plants, nocturnal temperature levels are very critical. The mean temperature values obviously cover up the differences in day and night temperatures.

Exponential Indices:

- Exponential indices of temperature efficiency for plant growth are based on the fact that the physiological processes of plant metabolism are chemical and physical in nature and follow the principle of **Vantt Hoff and Arrhenius**, which states that the chemical reaction velocity approximately doubles for each rise in temperature of (10^{o}C).

– On this basis, indices of temperature efficiency have been calculated, assuming that general plant activity occurs at unity rate when the daily mean temperature is 5^{o}C (plant zero) and that this rate is doubled with each rise of 10^{o}C in the daily mean. Thus, with a daily mean of 15^{o}C, the rate becomes 2, with a mean of 45^{o}C it becomes 4, etc,.
– Hence, the index efficiency "I" may be found for any temperature "t" by substituting in the formula:

$$I= 2^{[t-s/ 10]}$$

e.g. a temperature of 35^{o}C gives $I = 2^3 = 8$

– Increasing temperature is not accompanied by increased growth through the range of the growth rate from the minimum to the maximum. Instead of the growth of wheat, for example, doubling at 100^{o}F that which occurred at 82^{o}F it actually decreases.
– An optimum can always be found above which the previously increasing growth rate begins to decrease.

Physiological Indices:

– Physiological indices of temperature for plant growth take into account the optimum temperature. The method is of such a nature that both low and high temperature values give efficiency indices of zero, and intermediate temperature values give indices whose graph shows a well defined maximum.

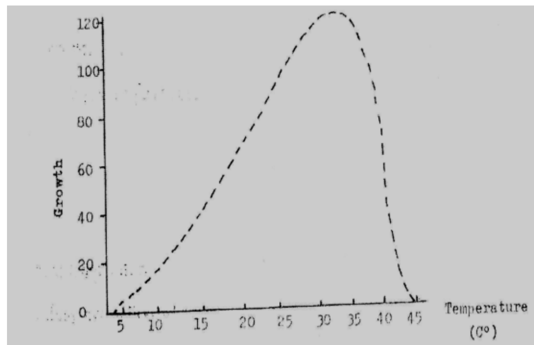


Fig.: Variation of the growth rate of corn seedlings with temperature.

Effect of temperature on the geographical distribution of plants:

– Temperature is the most important factor in determining the general distribution of vegetation. Grassland forest, and desert all occur in each of the great temperature zones of the earth, but the component species of forest, for example in each zone is different. Temperature also is the most important factor in determining the distribution of crop plants. The northern limit of the successful commercial production of cotton is determined almost entirely by temperature conditions.
– The isotherm of 10^{o}F for the daily minimum temperatures of January and February, for example, coincides, in general, with the northern boundary of winter wheat culture in the northern hemisphere. This boundary is taken as the line beyond which spring wheat is grown more commonly than winter wheat.
– Potatoes, on the other hand, give the highest yield in regions with lower summer temperatures, since tuber growth is retarded by high temperatures. Temperatures of the growing season alone limit the growth of certain crops such as corn, while other, e.g. grapes, and are limited by the temperature of the non-growing season as well.

Temperature and plant diseases:

- The ability of a parasitic fungus to gain entrance into as well as to develop within a host organism is often strongly conditioned by temperature. For example, at temperatures below 13ºC the seedlings of most strains of maize become very susceptible to disease whereas flax becomes susceptible to ***Fusarium*** wilt only at temperatures above 14ºC. Host plants commonly extend into climates where temperature restricts their parasites and it is often possible to subject a diseased plant to temperatures lethal only to its parasites.

Temperature and Transpiration:

- Transpiration, which is the loss of water vapour from the plant leaves through the stomata, increases directly with the magnitude of the difference in temperature between the leaf surface and the adjacent air. Temperature also changes the ratio of cuticular to stomatal transpiration.
- Therefore, the higher the temperature the greater cuticular transpiration is. Thus, at a temperature of 49ºC the nocturnal (night time) rate of transpiration in ***Helianthus annuus*** was observed to rise to 91% of the diurnal (day time) rate, even though the stomata remained closed at night.

II - LIGHT

- Wavelengths between 750 and 400 mp are called light or "luminous energy" because these wavelengths alone out of the total range of wavelengths of radiant energy can be seen with the eye. This is likewise almost the entire range of wavelength involved in photosynthesis, and green plants grow normally only when exposed to a combination of most of the wavelengths in this range. Approximately 50 oh of the total energy of solar radiation lies within this narrow range. When sunlight is passed through a prism it is dispersed as follows:
- All these colours making up the spectrum affect photosynthesis, but yellow and green are utilized very little, the principal wavelengths absorbed are in the violetblue and orange-red regions. Phototropism is governed chiefly by blue-violet wavelengths.

Units of measurement of lisht:

- We learned before that radiant energy (which includes both invisible radiation and light) is measured in terms of Gram calories or calories.
- 1 gram calorie =4.18 joules =41.8 x L06 ergs.
- Measurement of the intensify of light alone is based on the illumination produced by a ”standard candle”.
- I foot-Candle F.C. = light intensity at 1 foot from a standard candle.
- 1 Lux (meter-candle) =The intensity of light at 1 m from a standard candle.

- 1 foot-Candle = 10.764 L.
- By common agreement of world scientists the lux has been accepted as the standard international unit for expressing light intensity.

The role of Infra-red radiation:

- Infra-red light comprises all the radiations of wavelength greater than 800 nm. And these. are invisible. Here we are considering only the near infra-red, i. e. of wavelengths between 800 and 2000 or 3000 nm. A little more than half of the solar radiation is in this region, most of the remainder being in the visible range. Incandescent lamps, which are the most common artificial light sources, radiate about nine-tenths' of their power as infra-red radiation. It is therefore important to know the particular action of these radiations, both for plants grown in natural daylight and for those which are bound to increase in number cultivated wholly or partially in artificial light.
- In practice, the chemical activity of infra-red radiation is not strong enough to disturb chemical structural it causes oscillations of the atoms around their positions of equilibrium without destroying the molecules. These oscillations are solely heat manifestations and we may expect that the special action of infra-red will be to heat up the bodies that absorb it. on the contrary, although, by the same process' the visible and ultra-violet also have a heating effect on the substances that absorb them, these radiations can, incertain cases, particularly the ultra-violet, transmit to the molecules enough energy of excitation to make chemical reactions possible'

It is necessary to distinguish two principal zones in the infra-red:

1. The wavelengths shorter than 1400 nm which represents the major part of the solar infra-red and is relatively little absorbed by the leaf'
2. The wavelengths greater than 1400 nm relatively less abundant in solar radiation

- But proportion ately to the visible, very abundant in the radiation from incandescent lamps. This zone is strongly absorbed by leaves' As a result, when plants are cultivated under incandescent lamps, the action of the infra-red is inordinately increased for two reasons:
- a) because the incandescent lamp supplies much more infra-red than the sun (proportionate to the same power in the visible spectrum), and
- b) because this infra-red is situated particularly in the region where it is mot strongly absorbed by the water vapour in the leaf'
- Due to the heating effect of infra-red radiation, it is possible that plant transpiration, which is a physical phenomenon of evaporation of water from the plant leaf surface, is favored by the fact that the molecules of water are capable of absorbing infra-red energy. The leaf subjected to infra-red radiation finds itself in exactly the same conditions as the substances exposed to drying in an oven' and one of the results must certainly be an evaporation of water or a transpiration in proportion to the illumination received or, more exactly, absorbed. It is rather

surprising that the opening of stomata, this is controlled completely by visible ray so increases the transpiration by only 14 per cent. The stomata open in visible rays, but they remain closed when the incident radiation comprises only infrared The L4 per cent increase in transpiration by the opening of stomata may be due probably to the facilitation of interchange of gases between the tissues of the plant and the atmosphere.

- In open-air cultivation in natural daylight, when the visible always accompanies the infra-red, the opening of the stomata coincides with the arrival of the whole range of radiation and the beginning of the phenomena of transpiration.
- It may be concluded that the preponderant action of infra-red radiation is to provide heat inside the leaf and thus to stimulate the evaporation of water in the process of transpiration. The question of whether transpiration is beneficial or harmful to plants cannot be easily answered, since it depend on the individual plant and the circumstance under which it is growing. It is well known that the quantity of water lost by plants in transpiration is very large. A plant may evaporate several hundred times of its weight in water.
- This might indicate a protective mechanism to the plant against heating since the evaporation process of these large amounts of water consumes a large proportion of the heating effect of the infrared portion of the light spectrum received by the plant. At the same time the transpiration process leads to the flow of water from the soil through the plant root, stem and leaves; and then again to the air in a continuous stream. This current of liquid is necessary for good growth of the plant. The abundance of infra-red radiation normally provokes intense transpiration. However, it becomes very harmful when the amount of water available to the plant is insufficient. The leaves become damaged and the plant withers (wilted).

The role of ultra-violet (U.V.) radiation:

- Wavelengths less than 390 nm are too short to be seen, but they are very active in certain chemical reactions. Plants do not require these wavelengths for normal growth and in general are not injuriously affected by them. Owing to the screening effect of ozone in the atmosphere they comprise about 2 o/o of radiation at the earth's surface
- Also, the epidermis of plants is essentially opaque (un-penetrable) to these rays. For these reasons ultraviolet radiation is not particularly important except to certain of the lower forms of plants.
- Ultra-violet tends to promote the formation of anthocyanins, is responsible in part for phototrophic phenomena, and by inactivating growth-promoting hormones, checks stem elongation.

The Role of Visible Light

- The most interesting characteristic of the effects of visible radiations is linked with their power of chemical activation. This activation is actually and excitation of the chemical molecule capable of absorbing light is a contribution of energy in quantities, which is proportional to the frequency of the luminaries vibration (Wave length).

- The quantum, or photon, transports an increasing amount of energy as we go from the infra-red towards the ultra-violet, passing through the visible. In the infrared the quanta are individually weak but numerous; they make the molecules vibrate without chemically activating them, heat them up and evoke the evaporation of water. In the visible, the heating up and the evaporation are produced in the same way, but in addition the quanta are capable of chemical actions, which become extremely important. The visible radiations are unique in being absolutely indispensable to plant life. In the ultraviolet, we should expect an increase in the chemical activity of photons of more and more concentrated energy, but the plant seems to defend itself from this action by them with an opaque epidermis. In the extreme ultra violet (W.L. shorter than 28.9 ,nm) ![e chemical activity becomes so great that the photons destroy the molecules of the epidermal cells and cause injury to plant. The part played by visible light, of wavelengths between 400 nm and 750 nm is certainly more complex than that of all the other radiations.

Light affects a number of plant functions:

1- Photosynthesis:

- The basic pattern of the plant shoot is directed toward efficiency in photosynthesis. The stem of the plant functions as a support enabling leaves to be exposed advantageously to light, and the large surface of the thin photosynthetic organs favors the absorption of light energy. The structure of the spongy mesophyll and the stomatal apparatus allows rapid gas exchange.
- Even the fact the photosynthesis utilizes the visible wavelengths of radiation most heavily is significant, for this is the region of the spectrum with the greatest energy values' Despite this apparent efficiency, full use is never taken of all the light energy, and under full insulation (radiation) there is a tremendous excess of unused light' On the average actively growing land plants use only about 1olo of visible radiation in photosynthesis. Respiration is a never-ending process in every protoplast, by which carbon compounds are oxidized to liberate energy for the maintenance of the plant's vital activity. whenever a plant is not carrying on photosynthesis its dry weight progressively decreases as a result of respiration. The amount of light required for photosynthesis to equal the respiratory use of carbon compounds, i.e. for coz to be neither absorbed nor evolved, is called the "compensation point". This value is always higher than the absolute minimum for photosynthesis, varying from about t 27 to 4,200 L in higher plants.-With tree seedlings the value usually lies between 2 and 30% of full sunlight. During long cloudy weather photosynthesis may lag behind respiration needs and food reserves decline.
- Growth obviously demands synthesis in excess of respiration, so that the Minimum requirements for this function are met only when light intensity exceeds

or has exceeded the compensation point. For example, the compensation point for seedlings of ***Pinus strobus*** is 1.,830 L, but twice this amount of energy is required to maintain growth. With equal energy, the monochromatic radiations of the visible spectrum are not equally effective for photosynthesis. It is already known that the orange yellow and the red have the maximum efficacy. This region of the spectrum, near 650 nm coincides with an absorption band of Chlorophyll. More recent. research has revealed a second, but lower, maximum of efficacy in the blue, in the neighborhood of 430 nm or 440 nm. In this region there is also an absorption band of chlorophyll. Between these two maxima, the efficacy of the monochromatic radiations is a little less, but is still considerable.

2- Phototropism:

- Everyone has noticed that an indoor plant placed near a window grows towards the light and that it has to be turned everyday to keep the growth symmetrical. A simple experiment can be made with oats sown in a box receiving the daylight laterally. The seedlings shoot easily and instead of growing vertically are all inclined towards the direction from which the light comes. Light therefore has a considerable influence on the growth of plant cells.
- These facts may be compared with the great difference in appearance between plant seedlings (for example, potato shoots) kept in the light and those kept in the dark; In the light, they remain short and coloured, in the dark, they stretch out into thin stems and have the characteristics known as "***etiolation***", although there is no lack of nutritive substance in the soils (in case of potato, the tuber from which the seedlings grows is full of nutrients). But among the many phenomena distinguishable in etiolation we are concerned here only with the rapid growth in darkness. When a plant is illuminated on one side only, this side grows less quickly than the other which is in the shade, hence a curvature is produced which directs the tip of the stem towards the light. This influence of light on the inclination of the tip of the stem is called **"Phototropism"**.
- Owing to phototropism, plant stems are directed from regions with less illumination toward those with more. Thus, parts of the same plant, like the branches of a tree, or different plants in a group, like the blades in a field of corn do not group themselves together in the same place, but, on the contrary space themselves out with a certain regularity to make the best use of tight. Phototropism is therefore a very important factor in agriculture.
- Phototropism is initiated by certain wave lengths of light and not by the whole spectrum of visible light. We already know that white daylight is a mixture of radiations of different wavelengths. Have all those monochromatic radiations the same influence on growth?
- Thuson's experiments in 1934 showed that the blue and the violet of the spectrum are the only radiations really effective for phototropism In his experiments, he illuminated a young "oat" plant on one side with green spectral light and on the

other with blue spectral light. When the plant inclined towards the source of blue light he concluded that the blue has a greater retardate influence than the green.

- What is the process of this particular action of blue light? Light can only cause the activation of certain chemical molecules which absorb a light quantum. These activated molecules then become capable of entering into certain reactions which otherwise would be impossible for them, so that light may have the effect, either of starting a chain of new chemical transformations, or of transforming the sequence of reactions at one of its stages and modifying the result. An action similar to that of phototropism is produced by a substance' or a class of substances, called ***auxin***, which behaves like a growth hormone. It is present in the coleoptiles of young oats, principally at the tip. If the tip is cut off and placed on a piece of gelatin, the gelatin collects a small quantity of auxin, as is shown by experiment. The piece of gelatin is placed on the side of an oat stem from which the upper part of the coleoptiles has been removed. The growth of the stem then becomes asymmetrical; it grows more on the side which has received the gelatin and bends. With this substance' therefore, the reverse effect of the relative action of light is obtained. Apparently' light checks (stops) either the production, or the transport, or the activity, of auxin.

3- Germination:

- The seeds of most plants become sensitive to light When wetted. In certain instances germination is benefited; in others, it is retarded. ***Verbascum***, ***Lactuca*** sativa will not germinate without light stimulation, and ***Daucus carota***, ***Rumex***, and ***Picea abies*** germinate better with exposure to light. In contrast' plants such as ***Vanilla***, many Liliaceae, and ***Primula*** require darkness" ***Bromus tectorum*** and ***ulmus***, and many cacurbitaceae germinate better in darkness. The amount of light needed for stimulation of bluegrass (Poe) is considerable, but for tobacco even 0.01- second exposure allows more germination. Seeds requiring light obviously must, not be completely covered with soil when planted, but it has been found that, if seeds are soaked, given adequate light treatment, then dried again, light stimulation is retained and germination will take place even if the seeds are completely covered with soil.
- Recently, it became known that red light promotes germination whereas far red (Infra-red light) prevents it. For example l when moist seeds of the plant known as peppergrass (***Lepidium***) are exposed to red light before being planted in the dark, they germinate, but if they are exposed to far red, they do not'

% Germination	Final treatment	Numberof Irradiations	
		Far-red	red
45	Red	0	1
0	Far-red	1	1
48	Red	7	8
0	Far-red	8	8
0	---	0	0

- Effect of red and far-red light on the germination of seeds of ***Lepidium virginicum***. When both red and far-red are present at the same time they do not germinate. If they are exposed eight or more times to red and far-red light alternately, they will respond according to the irradiation they last received. It was red; they germinate; if it was far red they do not.

4- Photoperiodism:

- This term means the effect of the daily period of light on illumination. Light, which is the principal nourishment of green plants must: (1) be given to them in sufficient quality and not in excess. (2) It must be of suitable composition, without injurious ultraviolet and without too much infra-red. Natural daylight is in general well adapted to them. There remains a third factor which is extremely important. (3)The length of the day and night.
- The same quantity of light may be offered each day in a number of different ways. either by strong illuminations for a few hours followed by a long night, or by lower illuminations spread over a longer "period" and followed by a short night. The development of the same plant under these varying conditions may be profoundly different. With a certain period of daylight, a plant may be incapable of producing either buds or flowers or fruit; one species of onion will not form a bulb; another tuberous plant will remain without a tuber; a tree may remain in leaf until the winter and may be kilted by the frost, while the same plants, supplied with the same quantity of light, on the same ground and at the same temperature, but with suitable periods of daylight and darkness, will flower, produce seeds, bulbs and tubers and resist the winter frost. These curious consequences of day length, which were called "***photoperodism***" by the two Americans, Garner and Allard (1920)' are of considerable economic importance. For example, a species adapted to the long summer days of northern climates may be incapable of developing at lower latitude, even if the temperature is the same, because the summer days are shorter.
- ***Chrysanthemums*** may be made to. flower earlier or later, by artificial lengthening of the day with electric light, or, by shortening it with opaque material covering the plants' photoperiodism is still rather mysterious. It is strange, for example, that a very low illumination, of 5 to 10 Lux, 10000 times lower than the maximum illumination from the sun-given at night fall for a few hours to lengthen the day, is sufficient to produce a fundamental, change in the development of the plant. It

cannot be said that chemical substances elaborated by the plant, necessitating a luminous activation .for their synthesis, will be produced in sufficient quantify only after a rather long period of day light, for them the quantity of light would be important and not its duration.

- Perhaps certain slow syntheses are possible only when the action of light is sufficiently prolonged, perhaps others go beyond the stage of their accomplishment to give other combinations if darkness comes later. Although a number of species are evidently not sensitive to this factor, the length of day determines .for, the majority whether the plants will produce flowers or remain vegetative indefinitely. Long day plants flower only under day lengths longer than fourteen hours. plants in their response to the length of day are categorized into 4 groups:

1- Long-day plants:

- Some plants require long days for successful flowering and fruiting, although they make a vigorous vegetative growth during short days. There is a marked tendency for plants of temperate climates to flower and fruit at only certain periods of the year' some plants, e.g. violet, blossom early in spring. others such as ***Iris*** and **Poppy** begin to bloom at the start of summer, whereas ***Dahlia*** and ***Chrysanthemums*** are characteristic of fall (autumn). These differences in time of reproduction are not related to temperature but to the daily duration of light and darkness. Typical examples are the radish' iris, red clover, small cereals and spinach. These flowers regularly during the long days of late spring and early summer. All may be brought into blossom and fruitage in midwinter, however, if artificial light is used to prolong the daily illumination period to 15 or 16 hours.

2- Short-day plants:

- short-day plants flowering is induced by short period, of less than 12 hours' Plants such as tobacco and ***Dahlia*** continue to develop only vegetatively under a long-day illumination. The blossom normally only when short days occur. This is true of a large group of plants including most late-blooming summer annuals.

3- Day-neutral Plants:

- These plants can form their flower buds under any period of illumination. They apparently have no critical length of day for reproduction and under suitable conditions for growth they tend to flower at ail seasons of the year. Example of this category of plants is the cultivated sunflower which is not influenced in time of flowering by length of the day.

4- Intermediate Plants:

- These plants flower at a day length of twelve to fourteen hours but are inhibited in reproduction by day lengths either above or below this duration' plants within the same group may also differ in their response to day length' subsequent to flower initiation. For example, the strawberry is a short day plant for floral initiation, but it is a long-day plant for fruit formation. Other short-day plants such as the soybean prefer a short photoperiod through.

- Later experiments, however, turned up a surprising fact' If a plant requires a certain length of the day to flower, darkening the plant for a part of the day did not interfere with its flowering on the other hand, illumination at night affected the plant's flowering. Thus the critical factor in photoperiodism is not the length of the day but the length of night; strictly speaking, plants should be classified as long-night and short-nigh rather than long day and short-day'

Photoperiodism as a factor in plant distribution:

- photoperiodism is an important factor in the natural distribution of plants' In general plants that have originated in low latitudes require short days for flowering' while those of high latitudes are long-day plants when the latter are moved to low latitudes, they will not produce blossoms when low-latitude plants are grown in the long photoperiod of high latitudes they will continue to grow vegetatively until killed by frost. some wild varieties of sugar-cane flower only in the tropics' spinach, on the other hand; never flowers in the tropics, because it requires fourteen hours of daylight for at least two weeks. Maize is a short day plant that has difficulty in adapting to the long photoperiods.

Practical significance of photoperiodism:

- Among field and garden crops, some plants are grown for their vegetative parts alone, others for their fruit or seeds, and in still others maximum yields of both vegetative and reproductive parts are desired' Two or more weeks in time of planting may definitely determine whether the plant activities will be directed toward the purely vegetative or the reproductive from of development. These facts strongly emphasize the importance of accurately knowing the correct time for planting each crop in order to secure the highest yield. Even different varieties and strains of the same species differ markedly as to the particular length of day most favorable for flowering or for vegetative development' Failure of acclimatization of many species believed due to unfavorable temperature may actually have resulted from an unsuitable length of day. **Radisheso** for example, do not blossom in the tropics and the biennial beets of temperate regions become annuals in Alaska' Knowledge of photoperiodism, as these responses to length of day are called Should aid the plant breeder to secure for any particular region earlier or later varieties, more fruitful or larger growing forms. The problem of extending the northern or southern range of crop plants is also more clearly defined' In middle and high latitudes, certain long-day plants will not flower in due time when they are most needed If they are exposed to artificial illumination for a proper length of time' the flowering date can be specified. This is used in Netherland, where artificial light is used to hasten the blooming of tulip and to retard the sprouting of seed potatoes. In the field of breeding, flower initiation has greatly reduced the time span from germination to maturity. New varieties can be developed more rapidly. The artificial flower induction also makes it possible to cross plants that flower at different seasons in natural conditions.

Effect of light on plant structure:

- All green plants require tight, although bacteria and fungi may flourish even in dark caves and in the depths of oceans. In fact many species of saprophytic plants are kiiled by exposure to light, a fact well known in sanitation. Many saprophl'tic and parasitic fungi that can grow vegetatively in the dark require light for reproduction' Exposure of bacteria to direct sunlight kills the cells. Lethal effect is due chiefly to the ultraviolet rays between 254 and280 nm although violet and blue light have some effect. The same wavelengths have an inhibitory effect upon fungi' when disease producing, fungi are more sensitive to ultraviolet than their hosts, irradiation can be used in controlling them.
- Light influences the whole course of higher development of the plant, exerting a profound effect upon its characteristic form and structure. It affects plants in many ways. Through its action chlorophyll and many other pigments, growth substances or hormones as well carbohydrates are synthesized. Light influences the position of the chloroplasts, the opening and closing of stomata, and has a profound effect upon transpiration.
- Light is necessary for the production of chlorophyll. A primary response of the plant to light is the formation of chlorophyll. This response does not occur in plants such as bacteria and fungi. Plants with plastids produce chlorophyll only in light' and the chlorophyll practically always disappear in continued darkness; chlorophyll cannot function in synthesis of carbohydrates without light.
- Light influences the position and number of chloroplasts in the leaf. In the upper part of the leaf which receives full sunshine, and where chloroplasts are much more abundant, they are arranged in line with direction of light and thus screen each other from the full effect of the radiant energy. It has been shown that a single layer of chloroplasts absorbs about 30% of the light falling upon it. Absorption in the second layer is reduced to 2loh, in the third to 15%, and in the fourth to l0% but deeper layers of the chloroplasts absorb very little' In the shade, there is a need to obtain all the light possible. Accordingly' the plastids, which are fewer in number, are arranged at right angles to the light rays' thus increasing the surface for absorption. Shade results in thin leaves often with a single layer of palisade cells and loosely arranged **chlorenchyma**. A variety of plants growing under low light intensities (in forests or shaded places) develop only are layer of palisade tissues those under strong light intensities (in desert or exposed places) had two or more distinct layers.
- Thickness of the leaf increased with increasing light intensify. The sponge cells elongate more or less parallel to the surface, thus increasing the light absorbing surface. Palisade tissue is found in nearly all leaves where the light is diffuse. The cells that normally form palisade in the sun develop into sponge cells in the shade. Conversely, sponge cells under strong illumination develop into palisade' In places where the under (lower) surface of the leaf is also highly illuminated, for example by the reflection of light from white sand, palisade also develops in the lower part

- The total absence of light results in greatly attenuated, weak stems with tissues weakly differentiated and little mechanical tissue. There are few or no branches and the leaves fait to expand. The root system is poorly developed. The plant is pale yellow or whitish in colour, due to the lack of chlorophyll and is said to be "etiolated". while diffuse light promotes the development of vegetative structures, intense light favors the development of flowers, fruits, and seeds. under extreme sunlight intensities, transpiration becomes excessive. Structural changes occur which protect the plant from excessive heating and desiccation. The vegetation is often characterized by plants with low stature and small leaves of considerable thickness.
- Rapid transpiration is promoted by an increase in water-conducting tissue. Many crops grown for their vegetative parts, such as potatoes, carrots, turnips, and garden peat's, yield best where there is a high percentage of cloudy days. Conversely, the greatest grain-producing areas are in regions where there is a high percentage of bright sunny days. Fruit is likewise produced in great quantities where the light intensity is reduced only slightly by clouds or atmospheric moisture during the entire growing season. The yield of cotton is greatly reduced during unusually cloudy days in the growing season, although the plants make an excessive vegetative growth.

Effect of light on transpiration:

- The detrimental effects of high light intensities include their influence in promoting rapid, transpiration. Light stimulates the guard cells to open' as well as increases the permeability of the plasma membranes. The stomata of all plants remain open all day and close at night. Transpiration increases rapidly at daybreak and slows to a very low level at sundown, if not earlier, owing to a tissue developing water deficit. Although algae may use as much as25% of CO_2 supply, water deficit, etc. Of the remainder approximately one third is reflected back from the leaf or is transmitted through it, and about 2/3 is absorbed, changed into heat energy' then lost by radiation or used up in the vaporization of water. Since some of the light rays that penetrate tissues are always changed into long heat rays, it is apparent that light effects can never be completely separated from heat effects, and because heat influences transpiration and other physiologic processes, the investigation of light as an ecologic factor is very complicated.

Modifications of the effect of light by temperature and other factors:

- Temperature and light influences are inextricably related in their influence on plants. Suitable intensities in one compensate in part for deficiencies in the other. For example, photoperiodism can be altered somewhat by the intensity or quality of light' and it can be reversed by the manipulation of temperature. Thus, verbalization allows winter wheat to flower during long photoperiods, whereas without temperature stimulation these varieties are distinctly short-day plants. Also, if moistened grains of sorghum and millet are kept in darkness for 5 to 10 days at temperatures between 27 and 29^{o}C, the need for short photoperiods of the plants produced is removed. Soil fertility is also known to effect light relations. The less fertile the soil' the lower the chlorophyll content of the leaves and the less their photosynthetic efficiency under a given amount of light. There are, however, definite limits to the extent to which fertility can compensate for inadequate light energy.

III.WATER

Importance of water to Plants:

- In the physiology of plants water is of extreme importance in many ways:

1. Being a universal solvent, dissolves all minerals in the soil. It is the medium by which solutes enter into the plant & move about through the tissues.
2. It is a raw material in photosynthesis.
3. It is essential in maintaining the turgidity without which the cells cannot function actively. It is important for the activity of the protoplasm. Very few tissues are able to survive if their water content is reduced to about l0%.
4. Acts as a thermal regulator in the plant tissues. This is due to its high heat capacity' being capable of absorbing large amounts of heat with relatively little change in temperature.

- The water in the soil is continuous with that in plant, and the entire system is constant upward movement since the shoot loses water to the atmosphere at almost all times. Nearly all this water moving upward in the plant is lost in transpiration.
- Only about 0.1 - 0.3% of it being tied up in chemical compounds. The intake of water by plant roots from the soil and its loss to the atmosphere are strongly controlled by the factors of the environment.

Atmospheric moisture

- The water in the atmosphere which supplies the soil, and consequently the plant, takes different forms:

1- Invisible vapor (Humidity):

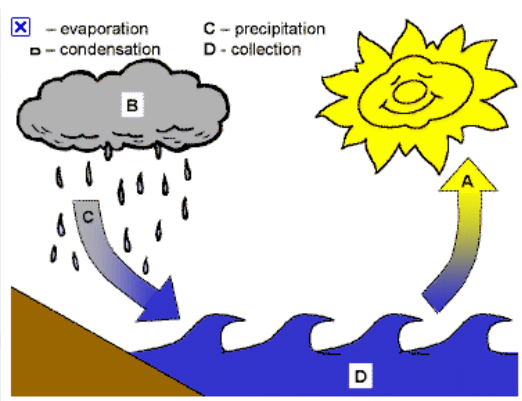
- The invisible water vapour in the air is referred to as "***humidity***".
- Its amount in the air depends to a great extent on air temperature. Warm air can hold more water vapour than cold air.The capacity of air for holding water vapour doubles with each increase of 20^{o}F (11.1^{o}C) in temperature.
- The amount of water vapour held by air at a given temperature is called its ***"absolute humidity"***.
- Air humidity is usually expressed as "***relative humidity***" which is an expression of the air humidity as a percentage of the maximum amount it can hold at a given temperature.
- ***Dew point*** : It follows that, when a body of moist, warm air is cooled, the relative humidity approaches 100% (even though the actual water-vapour content of the air

remains constant), and if further cooling takes place, the "***dew point***" is reached and the excess vapour is condensed into droplets of liquid.

- Thus, a cubic meter of saturated air (R.H. = 100%) at 80°F, when cooled down to 60°F, will lose by condensation half its water content as visible droplets. At the changed temperature, with only half its former absolute humidity, the relative humidity is still 100%.

Vapour Pressure

- Relative humidity normally undergoes a daily rhythm, changing from low during the day to high at night when the air cools'
- Since the relative humidity of the air is changed by temperature, the effect of atmospheric humidity on plants will be always inseparable from temperature effect. For this reason, atmospheric humidity is better expressed as the "***vapour pressure***".
- This expression is a statement of the activity of water vapour in the air under the influence of temperature. More significant to the plant is the difference between the water vapour pressure inside the leaf tissues, always assumed to be near saturation (exactly the relative humidity inside the tissue is 99.8%) and that of the air adjacent to the leaf. This is called the "vapour saturation deficit" of the air.
- ***2- Visible vapour: (Cloud and fog):***
- Cloud and fog consist of water droplets, or sometimes minute ice crystals which result from the cooling of air to a temperature below its dew point. They differ only in location. The first forms at high altitudes above ground and the latter in the air layers near the ground surface.
- When further, cooled both cloud and fog condense into particles or droplets large enough to precipitate out of the atmosphere. On the other hand, should clouds be forced downward to warmer levels of the atmosphere, or foggy air be warmed up, the visible vapour evaporates into the invisible from after which the relative humidity begins to drop.



- Water vapour in the atmosphere intercepts much of the solar radiation energy before it reaches the earth's surface. With all other factors remaining constant, an increase in atmospheric humidity reduces the rates of evaporation and transpiration because the vapour-pressure gradient between the atmosphere and moist surfaces is lowered .

- Moisture precipitation from cooled fogs may be absorbed directly by plants. In some rainless coastal areas, e.g. the coast of **Peru in the western part of South America**, it serves as the sole source of water for plants.

- In less arid regions the water is deposited conspicuously in the form of drops on the leaves in large amounts. Sometimes this amount of water condensed is so great that it falls to the ground, materially increasing the supply of soil moisture. When this takes place, its effect on the distribution of annual and low plants.
- Some plants are capable of absorbing atmospheric moisture directly from the atmosphere. For example desiccated dry mosses and lichens absorb moisture from a humid without preliminary condensation. In general the abundance of these plants is in direct proportion to the humidity of the climate.
- some desert plants can take up water directly from the air when the relative humidity rises above 85%.
-

3- Dew

- Whenever loss of heat by radiation cools a surface below the dew point, water vapour from the air will condense on it as a film of dew, even if relative humidity at a height of l.2 m is no more than 60%. Turbulent air prevents the required temperature gradient, but gentle air currents thicken dew films by bringing fresh supplies of air into contact with the surfaces.
- Such dew forming in leaves may be absorbed through the cuticle of normal epidermal cell, or through specialized cells. Shallow-rooted desert annuals may depend more upon dew condensed on the soil than upon rain. Larger desert plants have been found to suffer a marked reduction in growth when covered at night. At the very least, dew shortens the diurnal period of transpiration, and thus conserves soil water.
-

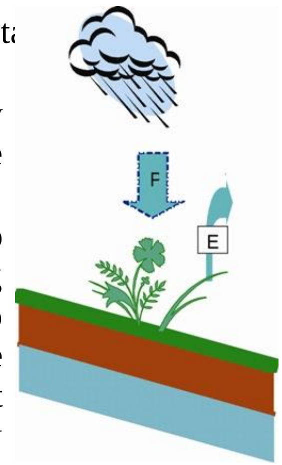
4- Precipitation:

- There is always sufficient water vapour in the air to be precipitated in different forms, but the proper meteorological conditions to cause this precipitation is frequency absent. precipitation of atmospheric moisture takes different forms, according to the prevailing climatic factors according to the prevailing climatic factors prevailing at or before the times of occurrence of precipitation:

1. **Rain**: Although rain is of tremendous importance to plants as a source of moisture, in general it is of little direct importance.
2. **Snow**: precipitation of atmospheric moisture in the form of snow caused damage (mechanical) to the plants as a result of its heavy weight resulting on accumulation on plants.

- Very often large trees are bent prostrate or their branches are broken off. In areas of rough topography, snow accumulation on slopes facing the north affects the distribution of plants and the types of plants on the slopes. Deep snow cover may press seedlings down to the ground so as to favor their parasitism by fungi which are active at the ground surface' Snow when melts at times and to the supply of soil water.

- ***Precipitation Effectiveness: -***
- Although all soil moisture is derived from precipitation, not all precipitation is equally effective in increasing soil moisture.
  - The slower and more gentle the showers the higher the percent soaks into the soil in relation to that lost as runoff.

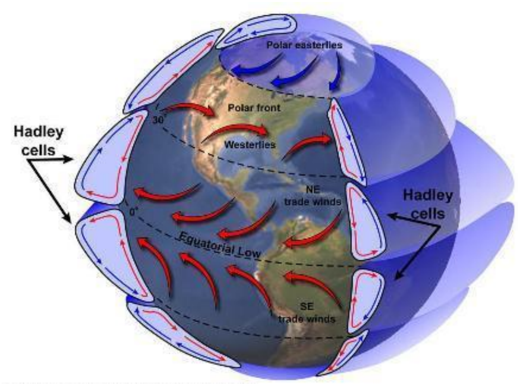


- 2. The greater the quantity of water falling during anyone rainy period, the more of it sinks below the reach of direct surface desiccation.
- Thus, in dry-climates a number of showers to falling up to several inches of rain in summer may have no effect in raising the soil moisture content because the individual rains are too light and too widely separated for successive increments to have cumulative effect' The longer and more severe the drought greater the quantity of rain fall that will be required subsequently to break it.
- The affectivity of precipitation as a source of soil moisture for plants is best measured by direct studies of the degree of penetration and duration of moisture in the soil. Efforts have been made to fined direct means of evaluating this factor by utilizing climatological data. This is based on the fact that the severity of the evaporative conditions after a rainfall affects the duration of favorably moist conditions. The more cool and humid the climate, the more effective a given amount of rain fall.
- A simple equation to determine the precipitation effectiveness is:

Pp.n. effectiveness = number of rainy days x P (mm)/T(ºC) + 10

- where P is the mean amount of rainfall and T the mean temperature.

IV. Wind



- Air moves from a region of high pressure to one of low pressure and the differences in pressure are largely the result of unequal heating of the atmosphere.
- The equatorial regions receive more heat than regions to north or south; consequently, low pressures normally exist in the lower latitudes.
- The tendency then, is for air to move the poles toward the Equator, there to rise and return toward the poles. This pattern, although true in general, is modified by the deflecting action of the earth’s rotation and by differences in

temperature resulting from oceans and land masses.

- Continents in temperate zones tend to become very hot in summer and the resulting low pressure produce winds that blow inland. The cold of winter reverses the pressure, and winds tend to out blowing. In mountain areas or along sea coasts these seasonal trends may have daily variations again produced by temperature differences.
- Mountain valley and slopes, which are often warmed rapidly during the day, produce valley breezes blowing upward. At night, the rapid cooling of bare high ridges results in a flow of cold air down the alleys. The contrast between day and night temperatures of land and water results in an offshore breeze at night as the land cools rapidly and higher pressures result.

- During the days, the land again heats up rapidly above the temperature of the sea, and an inshore breeze develops that may be noticeable for several miles inland. This brief outline of factors producing wind, although greatly over-simplified, should serve to indicate that air is almost constantly in motion. This should also indicate that, within limits, the general plan of motion is predicable for seasons and parts of the earthThe rate of movement of air is generally expressed as average velocity over an interval of time, such as **meters/ second or kilometers/ hour**. The velocity of wind is affected by the topography, vegetation masses, by position with respect to the sea shore, and by major paths of wind movement. So the rate of air movement increases regularly with increasing height above the ground.
- It is necessary to distinguish between wind in the free atmosphere and the surface wind as measured 10 m above the ground. The former is dominated by the distribution of atmospheric pressure, while the surface wind is influenced partly by the landscape on a scale up to or beyond several Kms. Below 10 m the wind speed is influenced by smaller scales of roughness consisting of the plants themselves' Within the vegetation, the air flow is much retarded by plant parts, and approaches zero near surfaces. The wind over vegetation is also influenced by local wind systems which include thermal circulations produced by a differential heating and cooling of adjacent land areas and winds influenced by topographic factors, such as the narrowing of valleys.

Effects of wind on Plants.

1-Desiccationالتجفيف:

- In still air evaporation of water from a wet surface, such as moist soil on a turgid leaf with open stomata's, is simply a process of diffusion. When air is in motion the process becomes strongly affected by **convection**. Wind causes evaporation even when the **saturation deficit** (gradient in water vapour concentration between **leaf surface** or moist soil and **air above**) is **zero**.
- Wind increases transpiration by moving layers of humid air which tend to accumulate adjacent to the plant surfaces. This action is especially facilitated by small-sized leaf blades. Wind also bends leaves, causing alternate expansion and contraction of the

intercellular space, which forces saturated air out and drier air in. At high wind velocity, the leaf tissues may therefore lose turgidity and the stomates are then forced to close. Transpiration then will take place through the cuticle, and the amount of water lost will depend largely on the thickness of the cuticle.

– **2- Dwarfing:**

– Plants developing under the influence of frequent dry winds never attain a degree of hydration, and consequently of turgidity, that enables them to expand their maturing cells to normal size. As a result of this, all organs are dwarfed because constituent cells become fixed at a small (subnormal) size.

Although dwarfing involves low dry-matter production, yet the total water utilization is not reduced in proportion, so that the transpiration efficiency is reduced' In addition, the date of maturity is advanced in some plants, and the number of secondary branches may be increased.

3- Deformation (wind-training):

– When developing shoots are subjected to strong wind pressure from a constant direction, the form and position of the shoot may become permanently altered. Deformation, when caused by moist winds, is not accompanied by dwarfing. In some instances, the side of the plant opposite to the direction of the prevailing winds (the windward side) is so desiccated that new growth is killed before it is well established.

– Lateral buds taking over the growth may or may not survive, and a scrubby matted growth develops on the windward side. To the reward (the other side similar to the direction of wind) the new shoots are protected by the trunk and the other parts of the plant, and growth continues on there.

– This result, over a period of years' in a symmetric growth forms known as '**flagging growth**' in which only the Leeward side of the plant carries normal growth. Some branches may grow completely around the trunk from the windward to the leeward side. Such type of growth is commonly found in exposed places at high altitudes in mountain areas. In these areas' plants which normally grow upright may become prostrate and form mats fitting into hollows or behind protecting rocks.

– Sometimes deformation occurs in trees that have regular seasonal active secondary thickening. secondary thickening on the windward side of these trees is suppressed to the extent that their trunks become no more of the normal cylindrical form. In cross section, the trunks take deformed **oval** shapes as a result of asymmetric secondary growth where the growth is far greater on the leeward side of the trunks than on the windward side.

4- Anatomical modifications:

- When a tree trunk becomes bent as a result of wind deformation' a dense reddish type of xylem called "**compression wood**" forms on the compressed side and this helps further bending in the same direction. In herbaceous plants wind blowing may stimulate the formation of more **collenchymas** than usually found in protected plants.

5- Lodging:

- This is a type of damage, cause by strong winds, to herbaceous plants and grasses such as wheat, maize and sugar cane. wind blowing will cause the fall down of the fleshy shoots and these tend to take a prostrate type of growth
- In case of crop plants, such as wheat, maize and barley, it may greatly reduce the yield since it affects conduction of water to the plant tops because of the mechanical damage caused to the stem tissue. It may also cause the damage of the developing inflorescences and seeds since they become located near the soil which is frequently wet.
- **6- Uprooting:**
- Trees may be uprooted even if the stems successfully resist breakage by high winds. uprooting is helped by the high moisture content (saturated soil) resulting from rainfall which usually accompany strong wind storms especially in tropical and subtropical areas.

7- Abrasions:

- When wind carries particles of ice or soil (such as the **Khamaseen** winds in Egypt); or winds blowing on coastal areas of seas and oceans cause severe abrasive damage to the soft parts of the plants. Buds may be eroded away from the windward sides of woody stems. crops growing in sandy soils are frequently damaged in windy climates.

8- Effect of soil erosion and deposition:

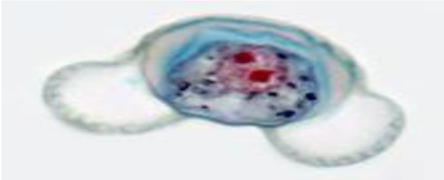
- The slightest air movement shifts dust particles from place to place, and increasing velocity results in the transport of larger particles of soil in increasing amount wind effect in this respect is noticeable in dry climates where there is a prevailing wind and a minimum of plant cover.
- Sand beaches and vast desert regions (such as the western desert in Egypt) are dry; free of vegetation, and swept by prevailing winds, which carry the soil along near the earth's surface. Any obstacle than slows down the velocity of wind causes some of its load to deposit and starts a mound or ridge called "**dune**"
- Some dunes grow, by further deposition of more sand, to a height of several hundred feet. A well developed dune attains a crescent-shape having a gentle slope on the windward direction and a sharp drop on the leeward direction' A dune is never completely stable (or fixed) unless it becomes covered with dense growth of plants.
- It always moves in the direction of prevailing winds, sometimes covering roads railways or villages in its path. This creates great problems in desert areas. In Egypt, places such as the Kharga and Dakhla oases (The New Valley Province) suffer greatly from moving sand dunes wind breaks, established by growing kinds of trees (Casuarinas-type) at close distances are effective in protecting cultivations to some

extent. Wind may also cause the soil to lose its surface layer which is usually more fertile.

- **9- Transportation by Wind:**
- Wind is an efficient agent in dissemination upon which most terrestrial plants depend to scatter their disseminules الاعضاء المتنقلة . In such cases the disseminules, which are either seeds or whole fruits, have adaptive characteristics which enable them to be carried by wind. This helps the plants to invade new areas in which they did not grow before.
- In addition, pollination in a large number of plants is carried out only by means of wind (**anemophily الهجرة بالرياح**). The pollen of grasses, willow and pine are carried in large number of distances exceeding l000 kms.
- Animophilous plants have, therefore, developed certain morphologic adaptations that facilitate wind pollination of these adaptations are the (1) long stamens extruding from the perianth and the well exposed, (2) feathery stigmas which catch pollen carried by wind.
- The flowers are typically unisexual. In certain plants, e.g. the gymnosperms' such as ***Pinus***, the pollen grain has a pair of wings which helps it to be buoyant in air.

Morphological adaptations in plant disseminules carried by wind are the following:

1- Minute seeds:



Of this type are seeds of plants belonging to families **Orchidaceae** and **orobanchaceae**, the seed weight less than 0.0002 milligram.

2- Feathery disseminules:

Such as the seeds of plants belonging to the families Salicaceae and Composite. The seed carries a large number of minute hairs which help its buoyancy in air.

3- Winged disseminules:

Seeds and fruits of many forest trees possess wings that enable them to be carried away from the trees they are produced.

4- Saccate disseminules:

Seeds of some plants belonging to family Chenopodiaceae are enclosed in inflated papery structures which can be rolled over the ground by wind.

5- Tumbling disseminules:

Whole inflorescences, and sometimes whole shoots, of some desert plants are cut off from the plant and are rolled on the ground surface by wind action' During rolling, the seeds are scattered in a large area in the path of rolling.

6- Ejaculated disseminules:

The fruits of some plants when open are able to throw the seeds to a distance way from the plant. Plants that have fruits of this type are ***Iris***, ***Papaver*** and ***Delphinium***. This is, however, a weak mechanism of dissemination.

EDAPHIC FACTORS

- Edaphic factors are those due to the soil in which the plant is rooted, and it is usually easy to draw a line between these and climatic factors, though, the characters of the soil are largely dependent upon climate.
- For example, the soils of a desert are very different from those of a region of high rainfall distributed through the year' even if they are derived from identical rocks.
- The edaphic factors would be master factors, because they would differentiate the plant communities inhabiting the soils on the different types of rocks.

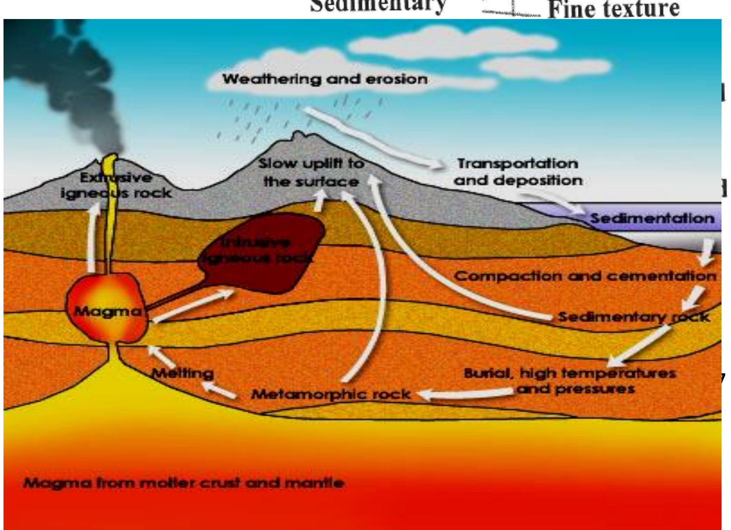
Soil

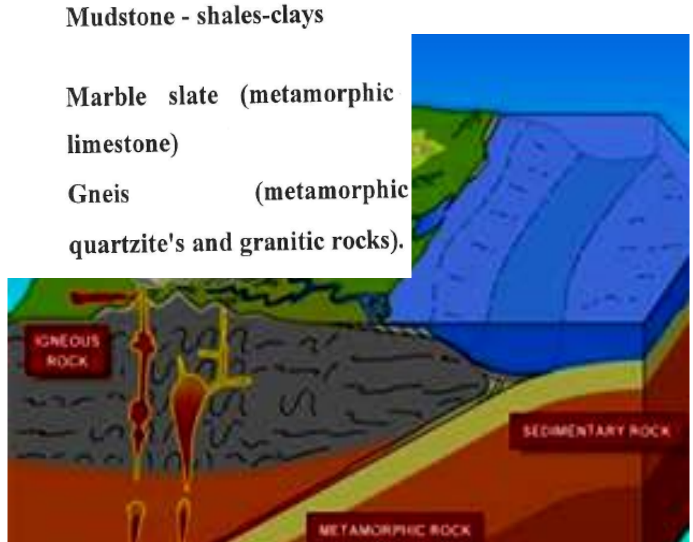
- The soil is the unconsolidated outer layer of the earth's crust, ranging in thickness from a mere film to some-what more than 10 feats, which through processes of weathering and the incorporation of organic matter has become adapted to the growth of plants. Nearly all higher plants except parasites and epiphytes are rooted in the soil.
- The soil often contain and acts upon a much more extensive portion of the plant body than does the atmosphere' Moreover, vegetation has played a remarkable role in the formation of this medium in which plants are anchored and form which they obtain their water and nutrients.
- ***Nature and origin of soil:***

  The geological formations through weathering produce the parent materials of soil. These materials constitute the bulk of the soil and for a long time determine its physical character. Thus the chief components of most soils are derived from rocks. The following table shows the soil-forming rocks and their composition:

  Rocky Example

	Rock type	Example
Igneous	Quartz rich (acidic)	Granite
	Quartz poor (basic)	Basalt
Sedimentary	Coarse texture	Sandstone - sand
	Fine texture	Mudstone - shales-clays
		Marble slate (metamorphic limestone)
		Gneis (metamorphic quartzite's and granitic rocks).





The weathering processes:

Bare rock surfaces and developing soils are exposed to a range of physical, chemical and biological processes which lead to mechanical and chemical disruption of their components which we can summarized in the following table:

Physical	Chemical
(1) Wetting - Drying - e.g. Disruption of layer lattice minerals which swell on wetting.	(1) Hydration e.g. Reversible change of hematite to limonite which is accompanied by swelling and so disrupts cementation of sandstones etc. $FeO_3 \rightarrow Fe_20_3 \cdot JH_20$
(2) Heating - Cooling e.g. Disruption of heterogeneous crystalline rocks in which inclusions have differential coefficients of thermal expansion surface flaking of large boulders, particularly in arid climates due to sun heating	(2) Hydrolysis e.g. silicate breakdown K2Al2Si6O16 → Al2Si3O8+SiO2+ KOH and surplus si are washed away in solution.

(3) Freezing

e.g. Disruption of porous, lamellar or vesicular rocks by frost shatter due to expansion of water during fre- ezing.

(4) Glaciations

e.g· physical erosion by grinding process more soluble than the carbonate.

(5) Solution

Removal of more mobile component such as Ca, S04, Cl, etc.

(6) Sand blast

e.g.· erosion of upstanding rocks in arid desert condition.

(3) Oxidation-reduction e.g. $Fe^{+} \rightarrow Fe^{++}$ causes disruption of cementat- ion as Fe^{++} is much more soluble than Fe^{+++}.

(4) Carbonation

e·g. $CaCO3 \rightarrow Ca(HCO_3)2$ leads to solution loss of $CaCo_3$ cemented rocks as the bicarbonate is

(5) Chelation

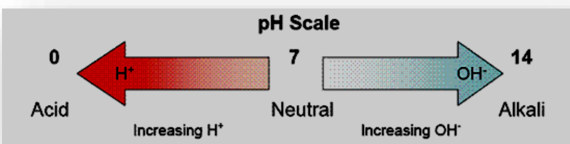
Essentially a consequence of biochemical activity, various metals being dissolved as che- lates with organic products of plant and microorganism activity.

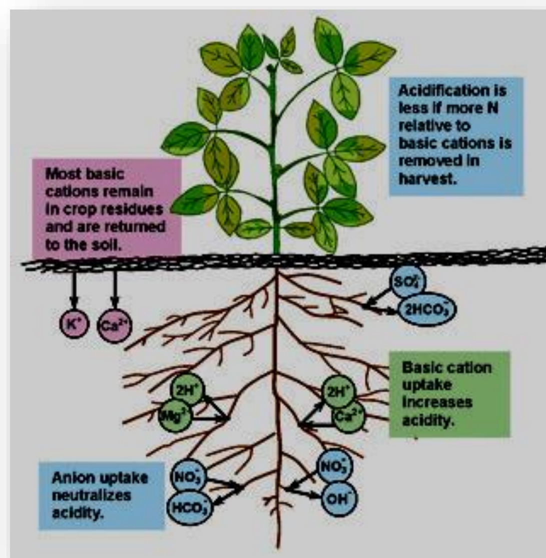
- Chemical and physical processes alone give rise to a biotic crusts of weathering products which are only the raw material of soil formation. Most rock surfaces do not remain free of life for very long and the physiochemical weathering processes are soon rein- forced by the often potent effects of numerous microorganisms.
- Lichens are able to extract nutrients which would be unavailable to higher plants. Retention of water by the thin layer of lichen, fungal and bacterial organisms on rock surfaces prolongs the period during which chemical processes can proceed colonization of a juvenile soil by higher plants adds yet another complication to the soil forming process, greatly increasing the energy fixing capacity of the surface and increasing the supply of decaying organic matter.
- Soluble organic compounds also diffuse into the rhizo-sphere zone from the roots and wash into the soil surface from leaf-drip. Deeper penetration of roots will tend to increase the depth range of cyclic processes involving nutrient elements, soluble elements leached downward being returned to the surface by transport through the plant. Rock weathering is therefore, for a short time a physiochemical process but rapidly becomes biogenic with a consequent increase in the overall rate.
- ***Pedogenesis***: a biological phenomenon by which crusts of weathered rock debris are converted to true soils comprising a complex mineral matrix in association with rang of organic compounds' very often carrying a rich microorganism population which is a reflection of the nature of the parent material and its interaction with climate, topography, plant cover and age.

Chemical characters:

- The basis of the great majority of soils is the collection of inorganic particles produced by disintegration (weathering), both physical and chemical' of the parent "**rock**" the hard rock's igneous or metamorphic, or sedimentary grits, sandstones or limestone or the softer **shales, clays and alluvia**.
- Besides these inorganic particles, an organic constituent (**humus**) is nearly always present. According to particular rock from which the soil is derived the nature of the soil particles is different, both chemically and physically, but the main in organic chemical substances forming the basis of soils are three: (**complex alumino-silicates, silica and calcium carbonate**).
- The **alumino-silicates** are ultimately derived from such rock-forming minerals as the felspars, hornblende, augite and mica of igneous rocks' which pass into the sedimentary rocks by erosion, transport and redeposit, generally through the agency of water. The **silica** comes largely from the quartz of acidic igneous rocks and form sandstones.
- **Calcium carbonate** comes mainly from limestones originally formed in bygone seas by such organisms as corals, and calcareous algae. with the alumino-silicates are associated various elements which form basic (alkaline) salts such as Ca^{+2}, Mg^{+2}, K^{+} and Na^{+} all except the last being essential elements in plant nutrition.
- **Iron** salts are practically always present (iron being an essential element in the formation of chlorophyll) and the oxidation from ferrous to ferric salts during weathering gives the brown or red colour of many soils.
- **Phosphorus and sulpher**, usually in the form of PO_4^{-3} and SO_4^{-2} or their acids, are always present and essential to plant life.
- **Nitrogen**, which is an essential constituent of plant proteins, is mainly derived from humus but also partly by fixation of the free nitrogen of the air.
- **Traces of other elements** such as Boron and manganese, which have recently been shown to play a vital part in most plant life, though in extremely minute quantities, are found in most soils, and others again are frequently absorbed by plants but probably do not affect their vital processes.
- The alumino-silicates form the center of the essential process of chemical weathering in soil.
- The originally very complex silicates are broken down, largely by hydrolysis; and the bases removed in solution, while a part of the silica is separated from the complex silicates.
- The residue is still essentially a complex alumino-silicate, which may vary considerably in chemical composition and physical properties, some of it forming the very fine particles of colloidal clay.
- This colloidal clay, together with the colloidal humus derived from the decomposition of dead vegetation and this clay humus complex is the main reactive part of the soil the i.e. part within which the main chemical processes occur.

- Calcium is the dominant basic ion in the soil and when present in quantity it imparts' physical and chemical stability to the whole weathering complex' aggregating the fine colloidal particles into compound particles and thus giving a granular or "crumb" structure to the very fine grained clays which without calcium, are unfavorable to many forms of life. While the calcium ions are thus the great stabilizing agent in soil, the free hydrogen ions, derived from the ionization of acids, promote chemical change. These are the active agents in the chemical action of acids and in soil are derived mainly from the carbonic acid dissolved in soil water, from the organic acids of humus, and from other acids produced as the result of chemical changes.
- <u>pH is defined as the negative logarithm of hydrogen ion activity where activity is understood to mean effective concentration.</u>
- Increasing acidity raises the H^+ ion concentration, lowers the OH^- ion concentration and lowers the pH value. Increasing alkalinity raises the OH^- ion concentration with a corresponding reduction in H^+ concentration and thus increases pH value.





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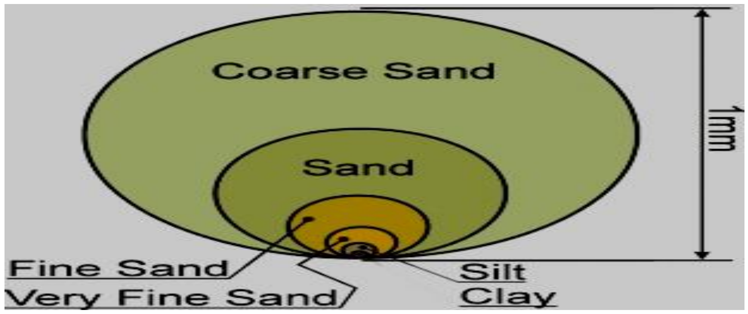
- Natural soils usually have pH values between about pH 3.0 and 8.4, the upper value being the $CaCO_3$ equilibrium with atmospheric CO_2 concentration and the lower value, the soil solution equilibrium with highly hydrogen-saturated soil. More extreme values do occur in un-usual soil types.
- Some alkali soils with high Na_2CO_3 content reach values of pH 10 - 10.5
- ***Physical characters of soils: Soil texture***
- The nature and size of the mineral particles constituting the inorganic frame work of soils not only influence the chemical, processes, but directly determine the physical nature of a soil and its effect upon plants.
- The texture of a soil depends primarily on the sizes of its mineral particles, and this feature is of great importance to plants because it controls aeration, water holding capacity and the ease with which water can traverse the soil.
- The proportion of particles of different sizes present in a soil is recognized by the procedure called **"mechanical analysis"**, in which the fractions of the soil whose particles lie between different limits of size are determined.
- The agreed international standards of size of different categories are as follows:

Gravel and stones particles →above 2mm in diameters

Coarse sand particles → from 2-0.2 mm in diameters

Fine sand Particles → from 0.2- 0.02 mm in diameters
Silt particles → from 0.02-0.002 mm in diameters
Clay particles → below 0.002 mm in diameters



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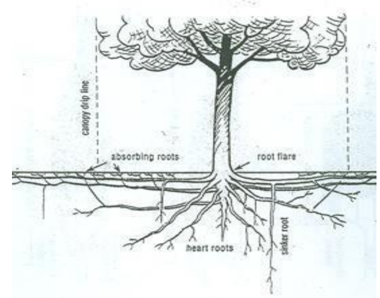
- All soils contain in fact particles belonging to more than one of these categories, the soil itself being named after the fraction which is preponderant' when soil consists of a good mixture of particles of widely different sizes with adequate humus fraction it is called loam.
- **In mechanical analysis** a sample of air-dried soil is firstly heated to 1000 C in an oven till it no longer loses water, and then heated to redness in a crucible or one a sheet of metal to burn away the humus. The mineral residue is then pounded in a mortar to reduce it to its elementary particles, and washed through a series of sieves, each with a mesh of definite diameter, to separate the coarser particles, and the successive fraction dried and weighed. This procedure of course destroys the structure of the soil, by breaking up the compound particles or "crumbs", so that it only gives information as to the proportions of the ultimate mineral particles of which it is composed .

Characters of soils of different textures:

- **Gravels**: are soils with a preponderance of large particles above 2 mm in diameter, practically always mixed with a coarse sand fraction and some finer particles as well. Aeration and percolation of water are extremely free. Gravel soils are unfavorable to plant life because of their dryness and poverty in nutrients, unless the ground water is high and carries nutrient salts. A gravel soil has the characters of coarse sand in extreme form.
- **Sandy soils**: have a preponderance of particles between 2mm. and 0.2 mm. in diameter (coarse sand) and between 0.2 - 0.02 mm. (fine sand). The particles are typically of silica (SiO_2). Percolation of water and aeration are free, the water holding capacity (in case of low humus) and power of raising water slight because the spaces between the particles are too wide. Hence sands are dry soils unless the ground water is high, and warm.
- They are light and easy to work but typically poor in nutrients because of deficiency in the finer particles with which the bases are associated, and because the free

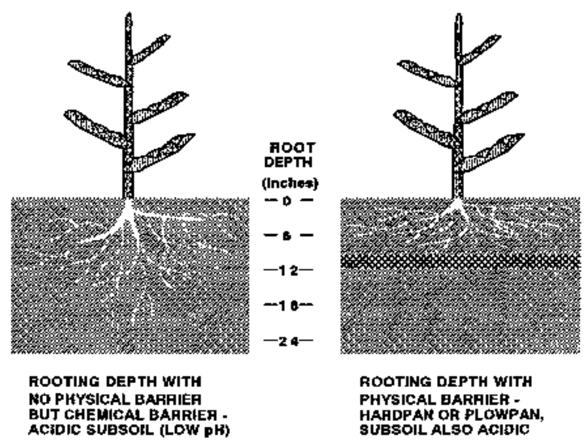
percolation of rain-water leads to very thorough leaching for this reason they are easily "**podsolised**" and quickly develop acidify.

- **Silt soils:** are intermediate between sands and clays in the size of their particles' They are favorable soils for vegetation because they have considerable water-holding capacity, while percolation, aeration and capillary rise of water are fairly free. The name is derived from the prevalent texture of alluvial soils (silts) laid down on the flood plains of rivers.
- **Clavs**: are soils in which the particles below 0.002 mm in diameter, typically of hydrated alumino-silicates, are numerous enough to give character to the soil.
- Any soil with a proportion of 30 - 40 % or more of these fine particles would be **called a clay soil**. Clay soils have all the qualities opposite to those of sand: percolation of water is very slow or almost nil غير موجود , aeration defective and water-holding capacity very high.
- Clay soils are wet, heavy, difficult to be cold and "late" because they warm up slowly owing to the high water content.
- Under continued drought the clay colloid shrinks, cracks, and eventually “bakes" hard. These characters make clay soils physically unfavorable to many plants, and root systems tend to be shallow because of the difficulty of adequate aeration at greater depths.



- This effect can be well seen on clay grassland, where the grasses are all shallower rooting species, and in clay woods, where the roots of shrubs and trees tend to be concentrated in the "improved" surface soil, while in a sandy wood the roots of the woody plants are more spaced out vertically and reach a greater depth.

- On the other hand clay soils are often chemically favorable to plants because they may be rich in bases associated with the complex silicates; the basic ions free or adsorbed by the weathering complex' Clays are, however, sometimes deficient in essential nutrients, e.g. phosphates, and sometimes in bases also.



- Clays are much improved by an abundance of mild humus (mull) which "opens" and lightens the soil, and by calcium carbonate which flocculates the clay colloids so as to form "crumb structure" and secures better aeration and free movement of water

- **Loam soils:** Consisting of a good mixture of particles of different sizes, are the most favorable soils for the great majority of plants because they tend to combine the good qualities of the extreme types. Thus the **clay and humus fractions** → give consistency and water holding power and supply plant food, **the particles of medium size** → permit of the capillary rise of water, while **the sand particles** → facilitate aeration.

- The constitution of loams has a wide range according to the relative preponderance of one fraction or another:

- Thus we have **"heavy (clay) loams"**, **"<u>medium</u> loams"**, and **"light (sandy) loams"**. With an adequate supply of bases, especially calcium, plenty or mild humus and good water supply and drainage, medium loams are the ideal soils for all plants except highly specialized types adapted to extreme edaphic conditions.

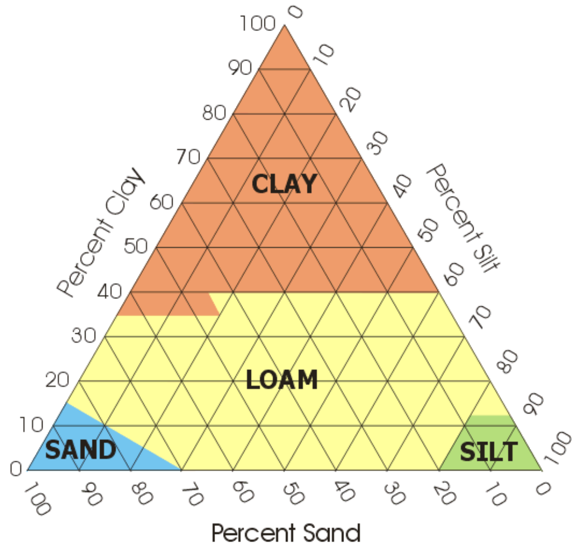
- **Limestone soils:** derived directly from lime-stones. A relatively pure limestone like the **chalk** (of 90% and in some cases nearly 100% of which consists of calcium carbonate), weathers by chemical <u>solution of the carbonate</u>, <u>not primarily by mechanical erosion</u>, though this may contribute where the rock is exposed in cliffs and scars for the most part gradual solution of the rock takes place below the carpet of vegetation and surface humus through the action of percolating rain-water containing carbonic acid.

- The result is the formation of a shallow soil consisting of the scanty residue of insoluble mineral particles and of surface humus, the whole saturated with calcium such shallow limestone soils are dry soils, because the percolating rain-water quickly escapes through the fissures of the rock below.

- They support **herbaceous plants** which can tolerate drought, including species which flourish on alkaline soils and cannot tolerate acid conditions.

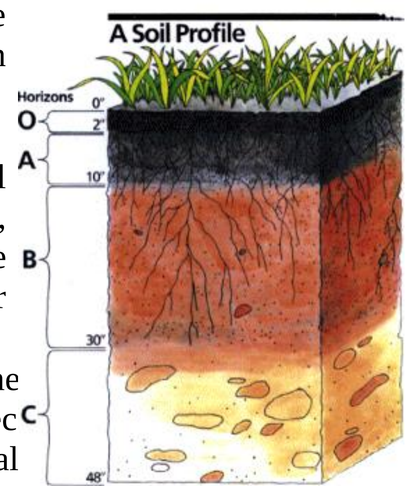
- Deeper soils are formed from lime-stones which contain a larger proportion of insoluble mineral particles and also, though much more slowly, flat horizontal surfaces of almost pure limes-tones like the chalk, where the very scanty insoluble constituents derived from a great thickness of dissolved rock have had time to accumulate in depth and are not removed by rain-wash down a steep slope.

Under such conditions the nature of the resulting soil depends on the nature of the insoluble material of which it is composed. If this is largely clay or silt, a good water-holding soil is produced, if it is largely sand, a light permeable soil.



Development of Soils

- The controlling factors in the development of soil are climate and vegetation. The features assumed by the soil in its development from infancy through youth, maturity, and old age vary with the environment.Thus, all mature soils developed on undulating or gently sloping surfaces and for long time undisturbed by injurious erosion, by deposit, or by the activities of man.
- Their characteristics not so much attributed to the kind of rock from which they originated as to the nature of the climate in which they have developed.
- Soils tend to show a similar sequence of horizontal layers, irrespective of the underlying rock, the latter causing only minor differences.
- These layers occur in a definite sequence and differ from one another in one or more easily discernible features, such as color, lime content, texture, structure, and compaction. A vertical cut through these various horizons is termed "**soil profile**".
- The nature of the several layers has a profound effect upon the water, air, and nutrient relations of the soil and consequently upon root extent and distribution and nature of the soil cover.



Soil profile:

- Most soils consist of particles of various sizes, chemical constitution and degree of solubility. During long periods of time, calcium carbonate and other soluble materials are leached from the surface soils and carried down to lower layers or to ground water and consequently out of the soil.
- The finer, insoluble soil particles (colloidal clay, etc.) are also me downward (under those types of soil formation in which they bec variable depths which depend largely upon the amount of rainfal with which the water is absorbed and transpired by the vegetation. Thus, the surface layers of a mature soil are poorer in soluble salts as a result of leaching and are coarser grained because of eluviations or washing down of the colloidal clay,

- ***These layers constitute***
- A, the zone been carried is designated
- B, the zone of concentration (accumulation).
- E, at greater depths there is third zone, where neither extraction nor accumulation has occurred it is the mother rocks zone.
- The A and B zones or horizons constitute the solute produced by soil building processes.

- The c horizon is the weathered parent material or unconsolidated rock from which (usually) the soil has developed. Each soil zone or horizon has a distinct color, texture, and structure.

Soil Horizon	***Description***	***Horizon Depth*** (Measurements are approximate)
O Horizon	Mainly twigs, leaves and other organic matter. Not all soil has an O horizon.	0.5 in. - 1 in.
A Horizon	Also known as the topsoil, essential for plant growth. The A Horizon is composed of mainly nitrogen, phosphorus and potassium. Has a dark brown color and a light texture.	1 in. - 2 ft.
B Horizon	Also known as the subsoil. Has few plant nutrients and a higher clay content. Usually the subsoil has a brighter color and a high salt content.	2 ft. - 4 ft.
C Horizon	Also known as the substrata. The C horizon (also known as the weathered parent material) is often a reddish-tan color and unaltered by rainfall or other natural conditions.	5 ft. - varies greatly
R Horizon (Bedrock)	Also known as the fresh parent material. Bedrock is usually a light tan color.	In the Central Valley, bedrock can be found as deep as 5,000 ft.

The soil is a natural body in dynamic equilibrium with its environment. Thus we have:

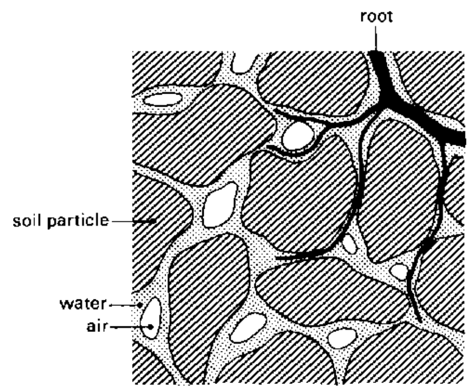
l- **Young soil**: not developed (there is unbalancing between soil and the surrounding conditions, inherited characters only)
2- **Mature soil**: developed (an equilibrium state occurs between the soil and the environment .
3- **Zonal soil**: its profile show different zones
4- **A-zonal soil**: without any zones (young soils)
5- **Transported soil**: the soil transported by wind (duns) or rivers (Nile valley)
6- **Residual soil**: formed in its place (where the parent rocks are present).

Composition of soil

<u>The components of a mature soil can be classified into four categories:</u>

1 - A matrix of **mineral particles** derived by varying degrees of breakdown of the parent material.

2- An **organic component** derived from long-and short-term additions of material from plants, animals and microorganisms above and below ground.



3- **Soil water** held by capillary and adsorptive forces both between and at the surface of the soil particles, its amount varying with the balance between precipitation, evapo-transpiration loss and drainage. Soil water is in reality a dilute solution of many different organic and inorganic compounds and forms the immediate source of plant material nutrients.

4- The **soil atmosphere** occupies the pore space between soil particles which, at any time, is not water-filled.

The organic fraction of the soil "Humus"

- Practically all soils contain organic material derived from the disintegration of plants or parts of plants such as dead leaves, roots and rhizomes, with a small addition from animal excreta or dead bodies.
- A part from highly exceptional soils, such as those accumulating below maritime "bird cliffs" or "bird rocks" inhabited by thousands of sea birds, which are largely formed of the birds droppings, the animal contribution is insignificant compared with the great bulk of plant material.
- ***The term <u>humus</u>*** is usually applied to the whole complex of disintegrating and decaying organic material in or on the soil, but sometimes it is restricted to the brown substance, soluble in acidified water, which is formed as a late result of the processes of disintegration and chemical change of the organic debris.
- The soils of habitats such as deserts, in which the vegetation is always sparse, and new soils, freshly formed from inorganic material, contain the least humus, mature well-vegetated soils the most.

- In a raw soil, freshly formed from rock or alluvium, humus begins to accumulate directly plants of any kind settle upon it, and a certain contribution may also be made by windborne particles of organic substance.
- In many soils earthworms are important agents in incorporating dead leaves and stems with the soil. They drag them down into their burrows, and constantly pass large quantities of humus through their bodies' disintegrating and partially digesting the organic matter. They are aided in the work of disintegration by other small soil animals, and also by soil fungi and bacteria.
- Eventually the disintegrated and decomposed organic substance is finally broken up by bacteria of different kinds into carbon dioxide, water and simple salts, which break up in water into **anions** (N, S, P) and **cations**, (Ca^{+2}, Mg^{+2} and K^{+},), all of which elements are necessary ingredients of plant food.
- ***Nitrification and its conditions***
- A most important chemical soil process as regards the food of the higher plants is **nitrification**, the conversion of NH_4^- salts into NO_2^- and then into NO_3^-, the last process being carried out by the so called **nitrifying bacteria**.
- The great majority of green plants absorb their nitrogen in the form of NO_3^-. These processes take place most freely and rapidly in soils with a fairly high "base status" and moderate water content, in the presence of plenty of free oxygen and at a moderately high temperature, i.e., in rich, moist, warm' well aerated soils.
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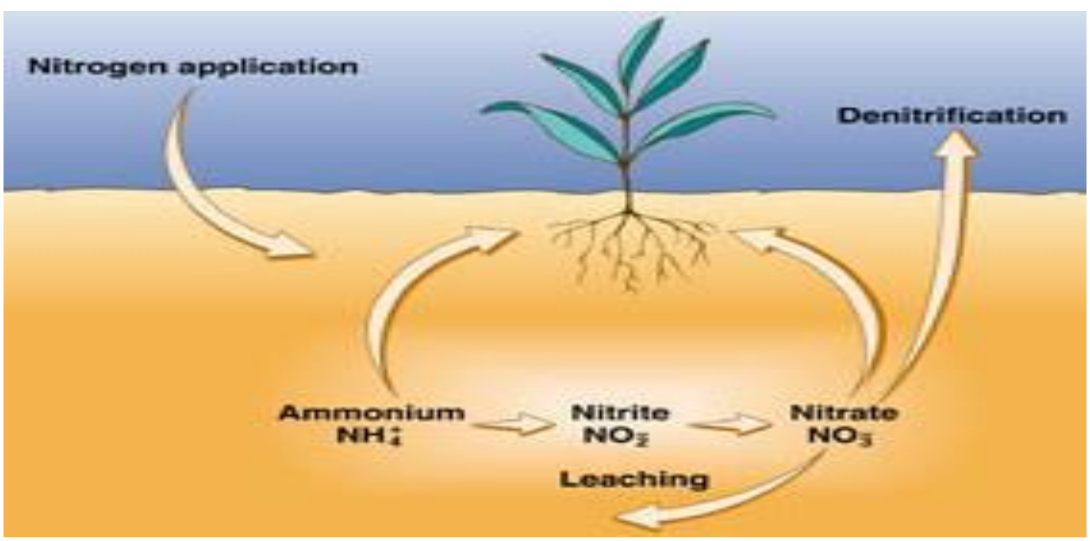
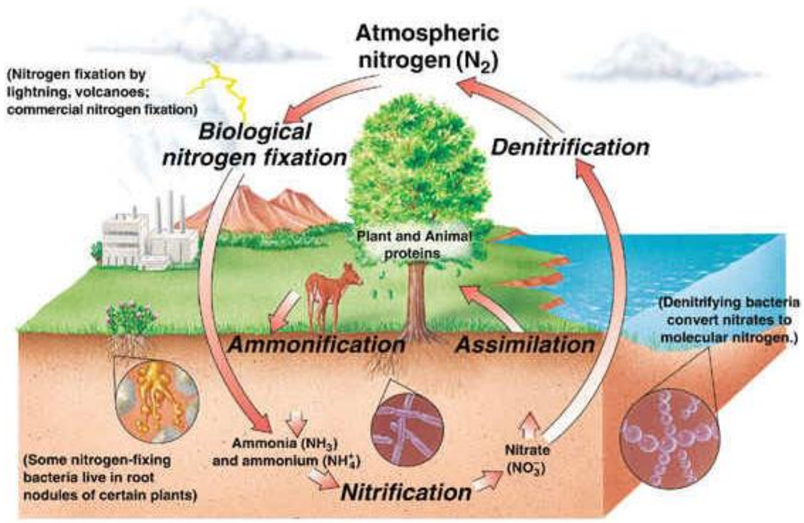


Nitrogen Cycle



Mull

- The kind of humus formed where the processes described are free is known as ***mull*** (mild humus), under these conditions the humus turnover is quick when the temperature is sufficiently high. Humus is formed in quantity, and rapidly' because the favorable conditions for the growth of plants give an abundant supply of plant material and this is rapidly decomposed because of the favorable conditions for the activity of the soil organisms.
- In this way an ample supply of the ions of the mineral salts which had been licked up in the plant tissues is set free and made available again as plant food.
- Mull is therefore characteristic of the fertile soils of high base status already described. It is well incorporated in the soil and becomes combined with the compound particles of colloid clay to form the reactive weathering complex.
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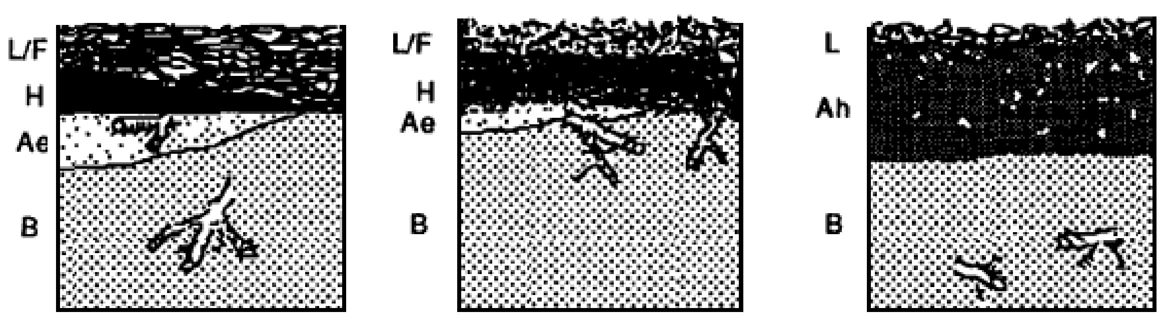

Mor
- matted F horizon
- abrupt boundary between mineral soil and organic layer

Moder
- loosely structured F horizon
- more gradual boundary between mineral soil and organic layer

Mul
- F and H horizons thin or absent
- organic enriched mineral soil horizon (Ah) present

Mor

There are several conditions leading to the production of mor.

1. **First** it tends to be formed in soils derived from rocks which are very poor in bases, such as many of the siliceous rocks and some of the sandy soils.
2. **Secondly** it is formed especially in a cold damp climate where the conditions are unfavorable for the active life of many of the mull-producing soil organisms.

- **Thirdly** high rainfall leads to through leaching of the surface layers of soil, carrying down the soluble mineral salts to lower layers, especially quickly on highly permeable soils, and thus increasing the poverty of the upper layers and leading to the formation of mor .
- Where one or more of these conditions prevails the formation of humus from litter is slowed down and partly decomposed litter tends to accumulate, becoming highly acid because the bases 'contained in the decomposing plant substances are leached out and the organic acids are not neutralized.
- The excess of hydrogen ions renders the humus substances extremely mobile and heavy rain carries them down to lower levels, especially in a permeable soil.
- The solubility, and consequent mobility of mor humus are conspicuously shown by the brown colour or moorlands streams draining from acid peaty soils, especially when the streams are in **spate**.
- In the hilly and mountainous regions, all the conditions leading to the production of mar-siliceous rocks poor in bases, a cool damp climate and heavy rain are frequently combined, so that mor soils are the prevailing type over wide areas.

The soil fauna and flora of mar are totally different from those of mull:

- Earthworms and other invertebrates active in the formation of mull are absent, and instead of the wide range of bacteria, including the nitrifying bacteria, present in mull, certain fungi especially **Hymenomycetes**, are the predominant "**saprophytic**" forms of lower plant life.
- The absence of nitrifying bacteria means that no nitrates are produced, and ammonium compounds are the main form of combined nitrogen available for the nutrition of the higher plants.
- The mor soils with complete absence of nitrates are found to have a pH value **below 3.8**, which appears to be a critical limit separating mor from mull in several soil series but there are soils less acid than this which show at least incipient mor formation and may be transitional between the two types.

- ***Soil water content***

  Water is important to plant in many ways:-

  1- It is a component of Protoplasm.

  2- Water and CO_2 are essential in building plant foods.

3- It usually constitutes 70 to 90 percent of the weight of herbaceous plants.
4- All substances that enter plant cells must do so in solution.
5- Water is the great solvent.
6- It serves as a medium of transport of nutrient and foods from place to place.
7- It keeps the cells turgid, a condition essential for their normal functioning.
8- It serves to prevent excessive heating of the plant, acting as a buffer in absorbing the heat generated by chemical reactions taking place in the plant.

The amount of water contained in a given soil at any moment depends upon several factors. We have seen that the water relations of soils of different textures are very different, the amount of water retained by the soil depending on the size of the soil particles and the amount of humus present.

With my best wishes

Prof.Dr./ Noha Ahmed El-Tayeh Ali