MODULE 1

1.1 PHYCOLOGY

CLASSIFICATION OF ALGAE

A.Basics for Classification of Algae

The primary classification of algae is based on the following five criteria:

- Photosynthetic apparatus and pigments
- Nature of reserve food
- Nature of cell wall components
- Type, number and attachment of flagella
- Cell structure

Main feature of Algae are;

- Microscopic
- Exist singly, in colonies or filamentous
- Able to photosynthesis
- Mod of nutrition Autotrophic
- Reproduction is vegetative, asexual or sexual

B. There are mainly 5 classification of algae

1. F.E. Fritsch's Classification (1935)
2. G.M. Smith's Classification (1950)
3. Round's Classification (1973)
4. Bold and Wynne's Classification (1985)
5. Robert Edward Lee's Classification (1989)

Classification of Algae proposed by *F.E. Fritsch* (1935)

- The most comprehensive and authoritative classification system of algae by ***F.E Fritsch*** (1935) in his book ***'The Structure and Reproduction of the Algae'***.

Criterion of classification;

- Pigmentation
- Types of flagella
- Assimilatory products (photosynthetic product / food reserve)
- Thallus structure
- Mode of reproduction

There are 11 classes under Fritsch`s classification system. They are;

1. Chlorophyceae - 9 orders
2. Xanthophyceae - 4 orders
3. Chrysophyceae - 3 orders
4. Bacillariophyceae - 2 orders
5. Cryptophyceae - 2 orders
6. Dinophyceae - 6 orders
7. Chloromonadineae -1 orders
8. Euglenineae
9. Phaeophyceae - 9 orders
10. Rhodophyceae - 7 orders
11. Myxophyceae - 5 orders

Classes and important features:

Class	Common name	Pigment	Flagella	Cell wall	Reserve food
Chlorophyceae	Green algae	chl a & b, xanthophyll &carotenoid	2 or 4, equal	Cellulosic	Starch
Xanthophyceae	Yellow green algae	chl a & e, beta carotene, xanthophylls	2 unequal	Pectic with little cellulose	Oil
Chrysophyceae	Golden brown algae	chl a & c, phycochrysin	2 equal or unequal	Silicified/ calcified, non cellulose	chryso laminarian, leucosin
Bacillariophyceae	Yellow or golden brown algae	chl a &c, fucoxanthin, diatoxanthin, diadinixanthin	single flagellum	pectic, silicified& variously orname nted	fat and volutin
Cryptophyceae	Brown or red algae	xanthophyll	2 unequal	Cellulosic	starch and oil
Dinophyceae	Dinophlag ellata	chl a &c beta carotene, xanthophyll	2	Cellulosic	starch and fat
Chloromonadineae	Bright green	xanthophyll	2 almost equal	No cell wall	fat and oil

Euglenineae	Euglenoids	chlorophyll a & b, beta carotene, xanthophyll	1 or more, tinsel type	No cell wall	polysaccharide paramylon
Phaeophyceae	Brown algae	chlorophyll a &c, beta carotene, xanthophyll, fucoxanthin.	2 lateral or sub apical, unequal	cellulosic with alginic & fucinic acid.	mannitol (alcohol), laminarian (polysaccharide)
Rhodophyceae	Red algae	chlorophyll a & d, beta carotene, xanthophylls, r-phycocyanin and r - phycoerythrin	Absent	outer cell wall pectic and inner cellulosic	floridian starch
Myxophyceae/ Cyanophyceae	Blue green algae	chlorophyll a &c, beta carotene,phycobilins, c-phycocyanin, c-phycoerythrin, myxoxanthin and myxoxanthophyll	Absent	Peptidoglycan	cyanophycean starch

Reproductive character and thallus structure:

- Thallus is unicellular, colonial, filamentous, thalloid or siphonaceous (thallus is not divided up by septa) in both **Chlorophyceae** and **Chrysophyceae**.
- Reproduction is seen generally as vegetative, asexual and sexual forms.
- Sexual reproduction rare **Chrysophyceae , Cryptophyceae, Dinophyceae, Euglenineae,** if present it is isogamous type.
- In **Chlorophyceae** sexual forms forms occurs as isogamous, anisogamous & oogamous, where as isogamous and oogamous in **Phaeophyceae**.
- In **Bacillariophyceae** sexual reproduction by fusion and by formation of gametes or auxospores.
- In **Chloromonadineae** and **Cyanophyceae** sexual reproduction absent.
- In **Rhodophyceae** reproduction is advanced oogamous type.

* In **[Cyanophyceae / Myxophyceae](#)** asexual reproduction by fragmentation, fission, akinetes, hormogonia.

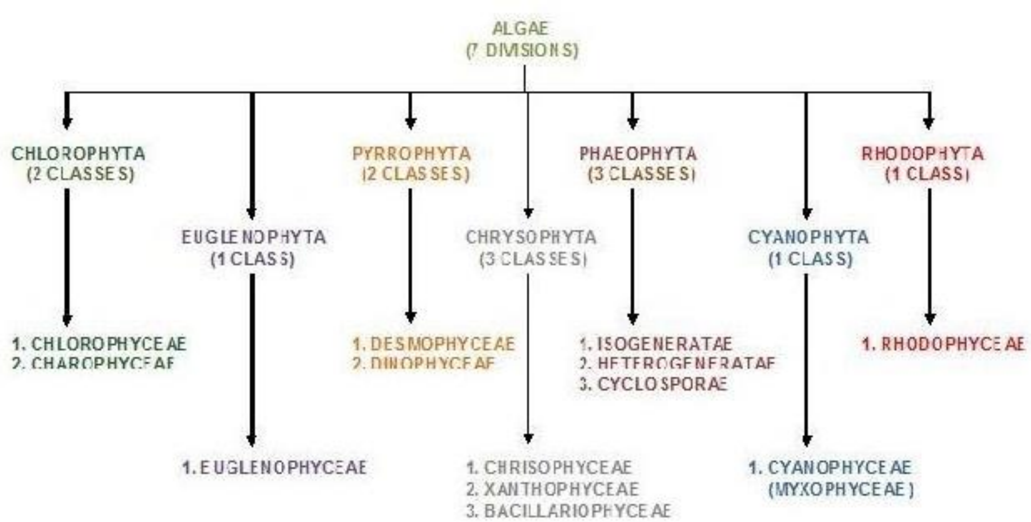
Smith's Classification

* *GM Smith* (1950) classified algae into seven divisions. These divisions include one or more classes.
* He included certain algae of uncertain position into Chloromonadales & Cryptophyceae.

There are 7 divisions in Smith`s classification:

1. **Chlorophyta**: Chlorophyceae & Charophyceae
2. **Chrysophyta**: Chrysophyceae, Xanthophyceae & Bacillariophyceae
3. **Pyrophyta**: Dinophyceae & Desmophyceae
4. **Euglenophyta**
5. **Phaeophyta**
6. **Rhodophyta**
7. **Cyanophyta**

SMITH'S SYSTEM OF CLASSIFICATION OF ALGAE



ENTRI

Modern Trends in the Classification of Algae

- The classification of algae has continually been modified since its beginning in the 1753 edition of Linnaeus` *Species Plantarum.*
- In natural or phylogenetic systems (which represent real evolutionary relationships) of classification, alterations in the classification of algae are made as a result of augmentation of our knowledge.
- This has resulted in the present, largely polyphyletic system (the system having many distinct lines of evolutionary history) in which the algae are grouped in seven to eleven categories of divisional rank.
- The criteria on which the classification is based on pigments, reserve food and flagellation.
- The comparative chemistry of the several pigments and storage products is fragmentary, especially in relation to the genetics and evolution of the organisms.
- Thus it is quite possible our current polyphyletic groupings may be modified into a more monophyletic system in the future.

At the levels of orders, families and genera it has been noted that;

(1) In the Chlorophycophyta and Phaeophycophyta; the orders are delimited largely on vegetative or somatic characters, variation in reproduction being treated as of secondary importance. In the division Rhodophycophyta, in contrast, the orders are at present delimited on the basis of the organization of the female reproductive branch, vegetative attributes being secondary.

(2) Among the Chrysophycophyta, the families of certain orders are at present delimited on the basis of flagellar numbers while the same criterion is used at the generic level in the unicellular motile Chlorophycophyta. These examples indicate that modern classifications are, at least approximations of relationship.

- Like all plants, the algae are classified in accordance with the recommendations and prescriptions of the International Code of Botanical Nomenclature.

- This code recognizes the individual organism as belonging to a species, the species to a genus, the genus to a family, the family to an order, the order to a class and the class to a division.
- The classification of algae have been recommended the use of suffixes by the International Code of Botanical Nomenclature

The suffixes are:

- Division-phyta
- Class-phyceae, Sub-class-phycideae
- Order-ales, Sub-order-inales
- Family-aceae, Sub-family-oideae
- Genus-a Greek name
- Species-a Latin name

The algae have been divided into 11 divisions. They are as follows:

1. **Cyanophycophyta** (Blue-green algae)

2. **Chlorophycophyta** (Green algae)

3. **Charophyta** (Stoneworts)

4. **Euglenophycophyta** (Euglenoids)

5. **Xanthophycophyta** (Yellow-green algae)

6. **Chrysophycophyta** (Golden algae)

7. **Bacillariophycophyta** (Diatoms)

8. **Phaeophycophyta** (Brown algae)

9. **Pyrrophycophyta**

10. **Cryptophycophyta**

11. **Rhodophycophyta** (Red algae)

GENERAL FEATURS OF ALGAE

THALLUS ORGANIZATION

- The plant body in algae is always a thallus. It is not differentiated into root, stem and leaves.
- Algae size vary from minute unicellular plants to very large highly differentiated multicellular forms (e.g., some sea weeds).
- Thallus may be colonial (loose or integrated by inter-connections of protoplasmic strands), filamentous (branched or unbranched).
- Thallus may be septate (branched or unbranchede), non-septate or branched, multinucleate siphonaceous tube where the nuclear division occur without usual septa formation

The range of thallus organization in algae may be classified as follows:

- Unicellular algae
- Colonial algae
- Filamentous algae
- Siphonaceous algae
- Parenchymatous algae

1. Unicellular alage

- Single cells

- Motile with flagellate (e.g., Chlamydomonas) or non motile (e.g., Diatom).

2. Colonial algae

Motile or non motile algae may form a colony by aggregation of the products of cell division within a mucilaginous mass.

- Coenibial- the colony is formed with definite shape, size and arrangement of cells. E.g., Volvox
- Palmelloid- irregular arrangement of cells varying in number, size and shape. E.g., Tetraspora, Chlamydomonas.
- Dendroid- looks like microscopic tree due to union of mucilaginous threads present at the base of each cell. E.g., Chrysodendron
- Rhizopodial colony- cells are united through rhizopodia. E.g., Chrysidiastrum.

3. Filamentous algae

- Daughter cells remain attached after cell division and form a cell chain.
- Adjacent cells share cell wall.
- May be branched (regular multiseriate such as cladophora or irregular such as Frischiella) or unbranched (uniseriate such as Ulothrix).

4. Siphonaceous algae

- Siphon means tube
- One large multinucleate cell without cross wall such as Vaucheria.

5. Parenchymatous algae

- Thallus organization is a modification of the filamentous habit, with cell division in more than one plane.
- Depending upon the nature of cell divison, the parenchymatous thalli may be "leaf-like" or foliose tubular or highly developed structure.
- Flat, foliose or tubular thalli are formed by the divison of the cells two or three planes.
  - E.g., for flat and foliose structure- Viva (Chlorophyceae), Punctaria (Phaeophyceae) and Porphyra (Rhodophyceae).
  - E.g., of tubular structure – Enteromorha (Chlorophyceae).
    Lictocarpales and Sphacelariales (Phaeophyceae), the parenchymatous form develops by abundant separation of primary filament.
    In Phaeophyceae (e.g., Sargassum) cells of the thallus are differentiated into central medulla, middle cortex and outer merislodenn.

PARANCHYMATOUS FORM:

- Abundant septation of filaments in two or more planes, results in the formation of parenchymatous body in some algae.
- Such plants may ultimately be foliose and flat (Ulva) or tubular (Entermorpha)

E.g., Chara, Porphyra, Dictyota, Sargassum

PSEUDOPARENCHYMATOUS FORM:

- the term 'pseudo' = false, the plant body gives the appearance of parenchymatous construction.
- Parenchyma is a tissue composed of thin walled closely associated cells which has arisen by the division of a common parent cell. Whereas the pseudoparenchymatous structure is a secondary development, close association of cells is a result of interweaving of filaments.

REPRODUCTION IN ALGAE

There are 3 common methods of reproduction found in alage and they are:

i. Vegetative reproduction
ii. Asexual reproduction
iii. Sexual reproduction

1. Vegetative reproduction

Vegetative reproduction in algae takes place by the following methods:

(a) Fragmentation:

- Fragmentation is the most common vegetative method of reproduction.
- The filamentous thallus breaks into fragments, and each fragment is capable of forming new thallus.
- Fragmentation can take place due to mechanical pressure, insect bite etc.
- The common examples are Ulothrix, Spirogyra, Oedogoniwn, Zygnema, Oscillatoria etc.

ENTRI

(b) Fission:

- Fission is common in desmids, diatoms and other unicellular algae.
- The cell divides mitotically into two the cells are separated by septum formation.

(c) Tubers:

- Tubers are spherical or globular bodies formed on lower nodes and rhizoids in Chara.
- Tubers are formed due to storage of food.
- On detachment from parent plant, these develop into new plants.e.g., bulbils and amylum stars in Chara.
- Bulbils are small, rounded, tubular-like structure, develop on rhizoids .
- Amylum stars are star shaped aggregates of vegetative cells. Lower nodes store reserve foods detach from parent and form new plants.

(d) Adventitious branches:

- Adventitious branches like protonema develop on rhizoids of Chara.
- On detachment they form new thalli.
- Similar adventitious structures are formed on thalli of Dictyota and Fucus.

(e) Hormogonia:

- In blue green algae like Nostoc, Cylindrospermum, the main filament breaks into small fragments of varying length called hormogonia.

- The hormogonia may be formed at the place of heterocyst in the filaments

(f) Budding:

- In Protosiphon budding takes place due to proliferation of vesicles.
- The buds detach to make new thalli.
- In protosiphon bud-like structures are formed due to proliferation of vesicles delimited from the parental body by a septum, which after detachment, grow into a new plant.

2. ASEXUAL REPRODUCTION

- Asexual reproduction takes place with the help of some spores and structures.
- Fertilization and fusion of nuclei does not take place.
- The reproduction takes place only by protoplasm of the cell.
- The offsprings will be exact genetic copies of the parents, expect in the specific cases of automoxix.

Different methods of asexual reproduction are:

(i) Zoospores:

- The zoospores are flagellated asexual structures.
- The zoospores are formed in reproductive body the zoosporangium.
- The zoospores can be biflagellate e.g., Chlamydomonas, biflagellate and quadriflagellate e.g., Ulothrix, Cladophora, multi-flagellate e.g., Oedogoniwn.

- Zoospores move in water before they germinate to make new plants.
- Zoospores are normally formed under favourable conditions.
- In Vaucheria, a compound zoospore called synzoospore is formed.

(ii) Aplanospores:

- Aplanospores are formed under unfavorable conditions.
- Aplanospores are non-motile structures, in which protoplasm gets surrounded by thin cell wall.
- The aplanospores on release form new plants, e.g., Ulothrix.
- Aplanospores are produced when there is a lack of water.
- Algae like *Haematococcus pluvialis*, Chlamydomonas and Vaucheria produce aplanospores.

(iii) Akinetes:

- The akinetes are formed under unfavorable conditions as method of perennation.
- The akinetes are thick walled, non-motile structures like aplanospores.
- Akinetes, on release, form new thalli. e.g., Anabaena, Gloeotrichia

(iv) Hypnospores:

- Hypnospores are thick walled structures.
- These are formed during unfavorable conditions.

- Under prolonged unfavorable conditions, the protoplasm of hypnospores divides to make cysts. The cysts are capable of forming new thallus. e.g., *Chlamydomonas nivalis.*

(v) Tetra spores:

- Tetra spores are non-motile spores formed in some members of Rhodophyceae and Phaeophyceae.
- In Polysiphonia, tetra spores are formed in tetra sporangia by reduction division on special tetrasporophytic plants.
- Tetraspores are red algae spores produced by the tetrasporophytic (diploid) phase in the life history of algae in the Rhodophyta as a result of meiosis

(vi) Auto spores:

- An autospore is a non-motile (non-flagellated) aplanospore that is produced within a parent cell, and has the same shape as the parent cell, before release.
- Autospores occur in several groups of algae, inclusing Eustigmatophyceae, Dinoflagellates and green algae.
- In Chlorella, Scenodesmus, auto spores acquire all characteristics of parent cells before their discharge from sporangium.

3. SEXUAL REPRODUCTION

- Sexual reproduction takes place by fusion of gametes of different sexuality.
- The gametes are formed in gametangia by simple mitotic division or by reduction division.
- The haploid gametes fertilize to make diploid zygote.

Depending upon morphological and physiological characteristics of gametes, sexual reproduction can be of the following types:

(i) Isogamy:

- In isogamous reproduction the fusing gametes are morphologically similar.
- These gametes are physiologically different due to different hormones.
- The gametes are represented by (-) and (+) strains to show morphological isogamy but physiological anisogamy e.g., Chlamydomonas, Ulothrix, Spirogyra and Zygnema.

(ii) Anisogamy:

- In anisogamy the fusing gametes are morphologically as well as physiologically different.
- These are formed in different gametangia.
- The microgametes or male gametes are smaller, active and formed in large number.
- The macrogametes or female gametes are larger, less active and formed in relatively smaller number e.g., Chlamydomonas

(iii) Oogamy:

- It is the most advanced type of sexual reproduction.
- The male gametes or microgametes are formed in antheridia.
- The female gamete is large, usually one and formed in female structure oogonium.

- During fertilization the male gametes reach oogonium to fertilize egg and a diploid zygote is formed, e.g., Chlamydomonas.

ENTRY 1.docx

(iv) Hologamy:

- In hologamy the unicellular thallus of opposite strains (+) and (-) behaves as gametes directly. The thalli fuse to make diploid zygote. E.g., Chlamydomonas
- In these sex cells (gamtes) are not formed, instead, the entire unicellular organisms get fused.

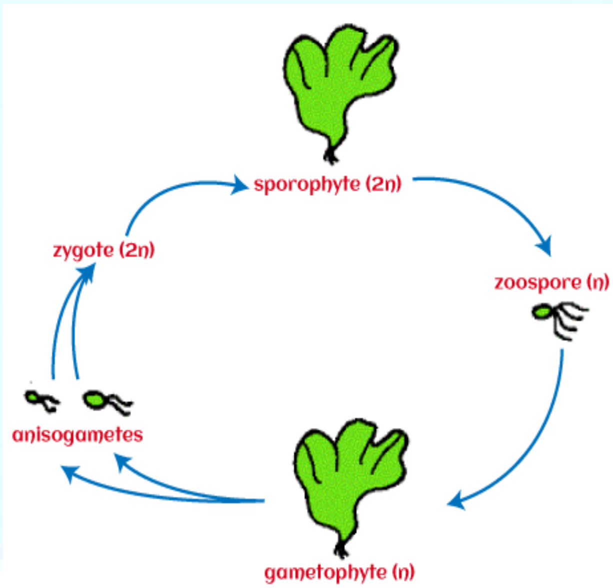
In some simplest forms of algae like Spirogyra reproduce by the conjugation method of sexual reproduction

- In this process of conjugation. Two filamentous strands of the same algae species exchange genetic material through the conjugation tube.

LIFE CYCLE OF ALGAE

Life Cycle of Algae:

- The life cycle of algae varies depending on the species, and there are four basic life cycle patterns in algae.
- There is an alternation of generations in all four patterns, indicating different haploid and diploid stages.
- In all life cycles, the haploid stage indicates gametophyte, while the diploid stage indicates sporophyte.
- Haploid refers to a cell or organism that contains a single set of chromosomes. Moreover, the organisms that reproduce asexually are called haploids.
- On the other hand, the organisms that reproduce sexually are called diploids, having two sets of chromosomes.



Types of Life Cycle in Algae:

1. **HAPLONTIC LIFE CYCLE**
2. **DIPLONTIC LIFE CYCLE**
3. **DIPLOHAPLONTIC LIFE CYCLE**
4. **TRIPHASIC LIFE CYCLE**

1. HAPLONTIC LIFE CYCLE

- The plant body is gametophyte (haploid) and sporophyte (diploid) stage is represented only by zygote.
- The gametophytic plant develops haploid gametes in the gametangium.
- The fusion between gametes results the formation of zygote, the only diploid stage i.e., sporophytic phase of the life cycle.
- The zygote undergoes meiotic division and forms four meiospores. These meiospores develop into haploid plants.
- The alternation of generations can be interpreted by chromosome number.

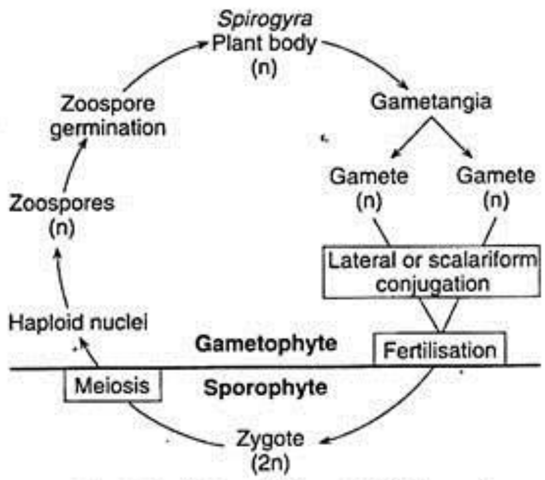


Fig. 3.19 : Haplontic life cycle (*Spirogyra*)

- This life cycle is also known as monogenic life cycle.
- The majority of Chlorophyceae, such as Chlamydomonas, Ulothrix, Oedogonium, Spirogyra, Chara, and others, as well as all members of the Xanthophyceae, have this type (haplontic) of life cycle.

2. DIPLONTIC LIFE CYCLE

- The plant body is sporophyte and develops sex organs. Sex organs produce gametes by meiosis.
- The gamete only represents the gametophytic stage. The gametes undergo fertilization immediately and form zygote.
- The zygote does not undergo meiosis and give rise to new sporophytic plant body.

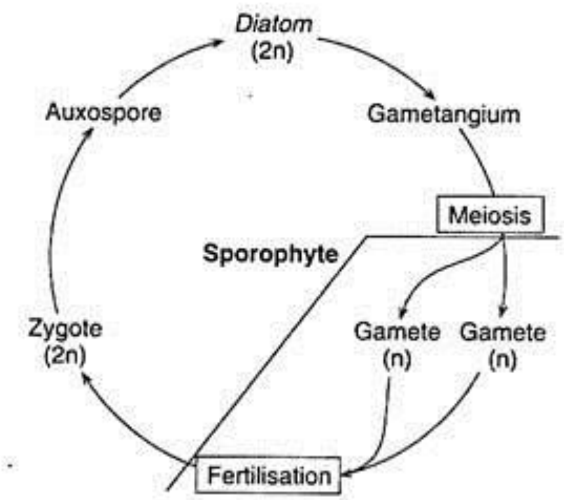
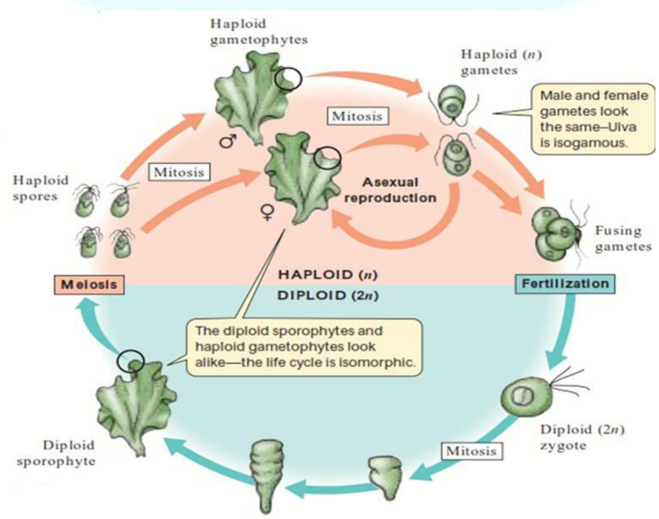


Fig. 3.20 : Diplontic life cycle (Diatom)

- This type of life cycle is found in majority of the members of Bacillariophyceae, some members of Chlorophyceae like Cladophora glomerata.
- Fucus and Sargassum of Phaeophyceae also show this type of life cycle.

3. DIPLOHAPLONTIC LIFE CYCLE

- In this type the haploid and diploid phases are equally prominent and are represented by two distinct vegetative individuals.
- They differ only in chromosome number and function. The haploid gametophytic plant reproduces by sexual method, while diploid sporophytic plant by asexual process.
- In this life cycle alternation of two Vegetative individuals occurs by sporogenic meiosis and fusion of gametes.



An Isomorphic Life Cycle The life cycle of Ulva lactuca is an example of isomorphic alternation of generations.

Types of Diplohaplontic Life cycle are as follows:

A. Isomorphic or Homologous Diplohaplontic Type:

- In this type both sporophytic and gametophytic plants are morphologically similar and free living.
- The gametophytic plant (haploid) produces gametes, undergo sexual reproduction and form zygote.
- The zygote germinates directly into a sporophytic (diploid) plant.
- The sporophytic plant forms haploid zoospores by meiosis. These zoospores can develop new gametophytic plant.
- This type of life cycle is found in Cladophora, Ulva, Draparnaldiopsis of Chlorophyceae and Ectocarpus of Phaeophyceae.

B. Heteromorphic or Heterologous Diplohaplontic Type:

- In this type both sporophytic (diploid) and gametophytic (haploid) plants are morphologically dissimilar.
- Generally the sporophyte is complicated and much elaborate, but the gametophyte is simple and small as found in Laminaria of Phaeophyceae.
- In some cases like Cutlaria (brown algae) etc. gametophyte is dominant over sporophyte.
- In Laminaria the gametophytic plant body is made up of minute filaments which produce gametes.
- The gametes undergo fusion and form zygote, which germinates directly into a sporophytic plant. The sporophytic plant body is macroscopic and several meters in length.
- The sporophytic plant bears zoosporangia and produce zoospores after meiotic division. The haploid zoospores on germination produce haploid gametophytic plant.

4. TRIPHASIC LIFE CYCLE

Algae have two different types of Triphasic life cycles:

a) **Haplobiontic**
b) **Diplobiontic**

a) Haplobiontic Type:

- In this cycle the gametophytic (haploid) phase is elaborate, dominant and persists for long time than sporophytic (diploid) phase which is represented only by zygote.
- That is haplobiontic type and two successive haploid generations are interrupted only by diploid zygote stage indicate its triphasic nature.
- This type of life cycle is found in the primitive members of Rhodophyceae like Batrachospermum and Nemalion.
- In Batrachospermum the gametophytic plant body develops sex organs and produces male (spermatium) and female (egg) gametes.
- The gametes by fusion form zygote. The zygote immediately undergoes meiosis and produces another haploid gametophytic plant, the carposporophyte.
- The carposporophyte develops carposporangium which produces haploid carpospores.
- The carpospores germinate and develop new free-living gametophytic plant.

Three phases are there in this cycle:

1. Haploid carposporophyte
2. Haploid gametophyte
3. Diploid zygote

b) Diplobiontic Type:

- In this type there is one gametophytic phase and two sporophytic phases indicate its triphasic nature and the sporophytic phase is more elabo rate and persists for long duration than the gametophyte i.e., diplobiontic type.
- This type of life cycle is found in Polysiphonia, a member of Rhodophyceae.
- In Polysiphonia, the gametophytic phase is represented by two types of gametophytic plant i.e., male and female plant, those bear spermatangium and carpogonium respectively.
- Later, the spermatangium and carpogonium develop sperms and egg respectively.
- The male and female gamete i.e., sperm and egg undergo fusion and form zygote.
- The zygote (2n) develops into a diploid carposporophytic phase. The diploid carpospores are formed in the carposporophyte.
- The carpospores on germination develop the diploid tetrasporophytic plants.
- The tetrasporophytic plant develops diploid tetrasporangia each of which produce four tetraspores (n) by meiotic division.

- They are liberated by splitting of sporangial wall. Out of four tetraspores two produce male gametophyte and the other two into female gametophyte.

Three phases are there in this cycle:

1. Haploid gametophyte
2. Diploid carposporophyte
3. Diploid tetrasporophyte.

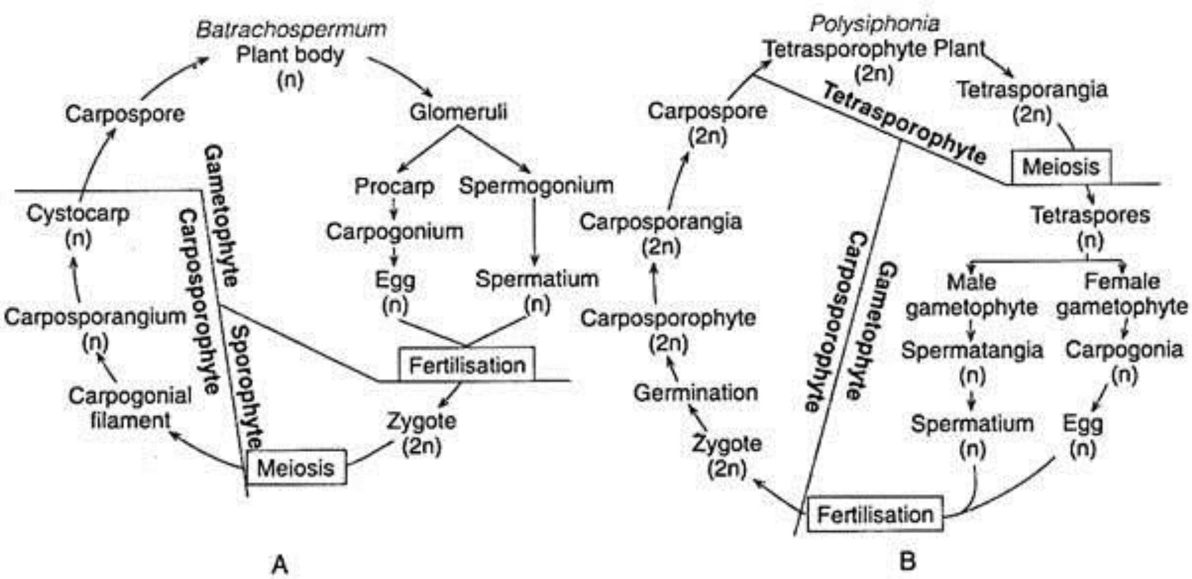


Fig. 3.22 : Triphasic life cycle : A. Haplobiontic type (*Batrachospermum*). B. Diplobiontic type (*Polysiphonia*)

ENTRI

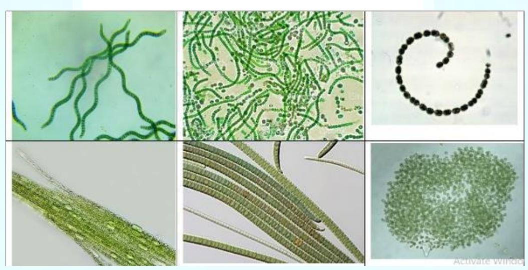
ALGAL CLASSIFICATION

1. **CYANOPHYTA**
2. **CHLOROPHYTA**
3. **XANTHOPHYTA**
4. **BACILLARIOPHYTA**
5. **PHAEOPHYTA**
6. **RHODOPHYTA**

The pattern of life cycle and salient features:

CYANOPHYTA

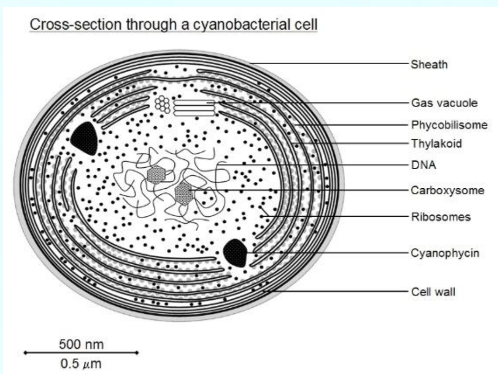
- The division Cyanophyta or Myxophyta, commonly known as blue-green algae.
- It consists of a single class Cyanophyceae or Myxophyceae or Schizophyceae whose plants are extremely simple in several respects.



- It is a primitive group of algae, consists of 150 genera and about 2,500 species.
- In India, the division is represented by 98 genera and about 833 species.
- Members of the class Myxophyceae (Cyanophyceae) are commonly known as blue green algae. The name blue green algae is given because of the presence of a dominant pigment c-phycocyanin, the blue green pigment.
- In addition, other pigments like chlorophyll a (green), c-phycoerythrin (red), B-carótene and different xanthophylls are also présent.
- The members of this class are the simplest living autotrophic prokaryotes.
- First algae to appear fossil history 3.5 billion years. Fossils of cyanobacteria stromatolite

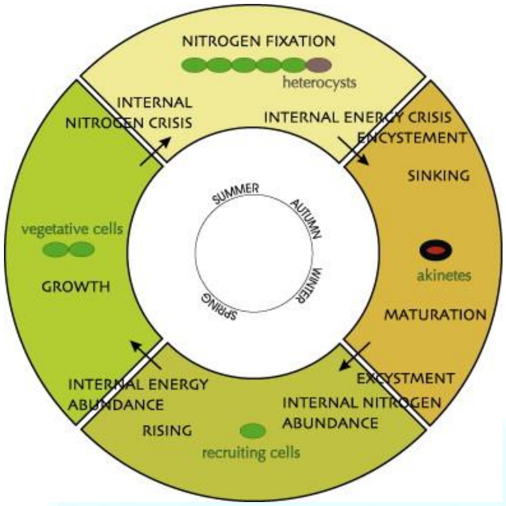
Salient features of Cyanobacteria:

1. The individual cells are prokaryotic in nature. The nucleus is incipient type and they lack membrane bound organelles.
2. Both vegetative and reproductive cells are non-flagellate.
3. Cell wall is made up of microfibrils and is differentiated into four layers. The cell wall composed of muçopeptides , along with carbohydrates, amino acids and fatty acids.
4. Locomotion is generally absent, but when occurs, it is of gliding or jerky type (oscillatoria).
5. The principal pigments are chlorophylls a (green), c-phycocyanin (blue) and c-phycoerythrin (red). In addition, other pigments like B-carotene and different xanthophylis like myxoxanthin and myxoxanthophyll are also present.



6. Membrane bound chromatophore are absent. Pigments are found embedded in thylakoids. The protoplasm is differentiated into central region called centroplasm and peripheral region bearing chromatophore called chromoplasm.
7. The reserve foods are cyanophycean starch and cyanophycean granules (protein).
8. In some forms a upid drolet Nuceid (dircular DNA) large colourless cell is found in the terminal Protein Granule Ribosome or intercalary position called heterocysts. They are involved in nitrogen fixation.
9. Reproduction in Cyanophyceae: The blue green algae (Cyanophyceae) reproduce by both vegetative and asexual means. Sexual reproduction is absent.

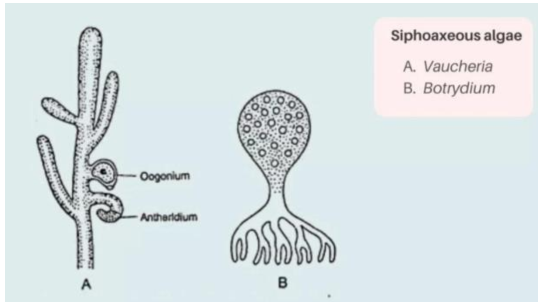
- The vegetative reproduction performs through fission (Synechococcus), fragmentation (Oscillatoria, Cylindrospermum muscicola), hormogonia formation (Oscillatoria, Nostoc), hormospores (Westiella lanosa).
- During asexual reproduction various types of asexual spores are formed. These are akinetes (Anabaena sphaerica, Gloeotrichia natans, Calothrix fusca), endospores (Dermocarpa), exospores (Chamaesiphon) and nannocyte (Microcystis).
- True sexuality does not exist in the blue-green algae, but a kind of parasexual phenomenon designated as genetic recombination has been demonstrated in Anacystis nidulans by gene transfer and gene recombination through blue-green algal virus.
- Genetic recombination differs from true sexuality in that it is not through syngamy or meiosis, and yet the function of true sexuality is achieved.
- Genetic recombination has also been reported in Cylindrospermum majus and Anabaena doliolum.
- It is likely that genetic recombination is brought about by conjugation between donor and recipient cells, as in bacteria.
- It is also possible that gene recombination may be caused by transduction, a process in which the virus acts, as a vector of certain genes transferring them from donor to recipient cells.
- Large number of blue-green algal viruses have already been discovered to play the above role, of which mention may be made of the blue-green algal virus, cyanophage LPP-1 having host range (Lyngbya, Plectonema and Phormidium). (The type specimen of cyanopodovirus is Cyanophage LPP-1, which infects Lyngbya, Plectonema and Phormidium).
- The Cyanobacteria Life Cycle (CLC) model was introduced by Hense and Beckmann (2006) and includes, in its original design, four life cycle stages representing a vegetative non-nitrogen-fixing stage, a vegetative nitrogen-fixing stage, a resting stage (akinetes), and a non-growing recruiting stage.



Life cycle of cyanobacteria

XANTHOPHYTA

- The Xanthophyta or Heterokontae are commonly known as yellow-green algae include only one class Xanthophyceae.
- This division has close relationship with the chlorophyta comprising both marine and fresh-water forms.
- Certain species grow on drying mud, on trunk of trees, on damp walls, and similar other habitat.
- There are varied forms of vegetative body ranging from unicellular coccoid, siphonaceous to filamentous condition.
- Each vegetative cell has a wall composed chiefly of pectic substances which, depending on species, may be impregnated with silica. The cell contains one to several discoid chromatophores.
- Except in the siphonaceous forms each vegetative cell is uninucleate. Due to the presence of excess of carotenoids, the colour of chromatophores is yellow-green. Chlorophyll a and chlorophyll e are present. But chlorophyll b is absent.

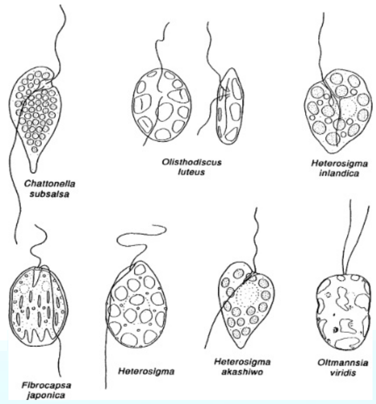


- The chromatophores lack pyrenoids. The usual food reserve is oil.
- One of the outstanding features of the Xanthophyta is the presence of motile cells bearing two flagella of unequal length.
- Asexual reproduction in most species is by zoospores with a few exceptional cases where aplanospores are formed for asexual reproduction.
- The zoospores are characterized for having two unequal flagella borne at the anterior end or are multi-flagellate.
- Sexual reproduction is isogamous and oogamous.

Salient features of xanthophyceae

1. Members of Xanthophyceae are commonly fresh water (Tribonema) and most of them are free floating. [Few members are found to grow on mud (Botrydium) and also on walls or tree trunks (Characiopsis, Ophiocytium etc.). A few members like Halosphaera are marine.
2. Plant body is unicellular (Heterochloris) or multicellular. The multicellular bodies also exhibit various forms like palmelloid (Chlorogloea), dendroid (Mischococcus), coccoid (Chlorobotrys), rhizopodial (Stipitococcus), filamentous (Heterococcus) and siphonaceous (Botrydium).
3. Cell wall contains more pectic compounds than the members of Chlorophyceae. Occasionally cellulose is also present. In some non motile forms the cell wall is silicified and made up of two halves, those overlap each other.(These cell walls may be entire or they may be formed from two H-shaped pieces).
4. The motile forms bear usually two flagella but rarely one. They are unequal and inserted at the anterior end. The flagella are of two types.The larger one is tinsel (or pantonematic or pleuronematic i.e., bearing hair-like

appendages) and the shorter one is whiplash (or acronematic i.e., without hairs and their surface is smooth) type.



5. The chromatophores are discoid in shape and are numerous in each cell.
6. The pyrenoids are absent or rarely present.
7. The plastids are yellow-green in colour. The photosynthetic pigments are chlorophyll a, chlorophyll e (very little), P-carotene (fairly high concentration) and xanthophylls. The chief xanthophyll is diadinoxanthin. The other xanthophylls are violaxanthin, lutein, neoxanthin, flavoxanthin and flavacin. The carotenoids are normally present in excess amount than chlorophyll. Chlorophyll b is absent.
8. The reserve food is chrysolaminarian, oil, lipid and lucosin. Starch is not formed.
9. Plants reproduce commonly by vegetative and asexual means. Vegetative reproduction takes place by cell division. Asexual reproduction by zoospores, aplanospores or akinetes. Sexual reproduction, though rare, may be isogamous, anisogamous or oogamous. Isogamy is common. Both iso and anisogamy are found in Botrydium.
10. Life cycle is mostly haplontic

Life cycle of Vaucheria

- Vaucheria reproduces both asexually and sexually.
- The asexual method of reproduction is by means of large multiflagellate zoospores which are formed singly in zoosporangia, cut off at the ends of the tubular thallus by cross-walls.
- The branch tip' bulges out forming a potential zoosporangium.

- A large number of nuclei and chloroplasts along with cytoplasm stream into swollen tip which is cut off a a by a cross-wall differentiating the zoosporangium from the rest of the filament.
- After a short period of motility, followed by a subsequent loss of the flagella it germinates and forms one to several tubular outgrowths that may continue to grow indefinitely to produce an adult plant.
- The protoplast of the sporangium may also divide to form many small immobile thin-walled aplanospores.
- In some terrestrial species, if exposed to greater desiccation, the threads become septate and rows of cysts are formed giving rise to what is termed Gongrosira stage.

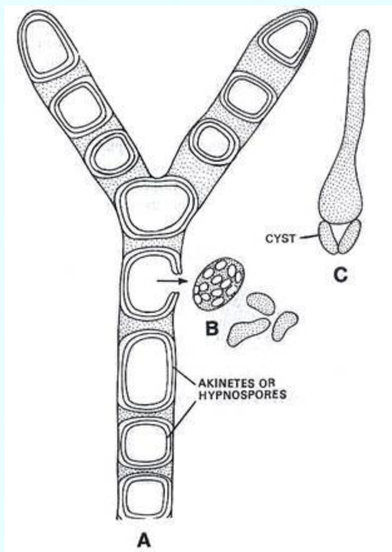


Fig. 5.5. *Vaucheria* sp. Asexual reproducion. A, formation of thick walled akinetes or hypnospores (Gongrosira stage); B, liberation of contents from hypnospore and three amoebae; C, germination of cyst.

- Under favourable conditions these cysts germinate either into new filaments or into small amoeboid structures from which new filaments are produced.
- There is a great variation in the arrangement of sex organs in the different species and even in different individuals of the same species.
- In homothallic species antheridia and oogonia are generally produced on Gongrosira stage short branches close together on the filament.
- The antheridium is a slender, curled hook-like tubular structure which is walled off from the rest of the filament. The contents of the antheridium consist of cytoplasm, numerous nuclei, and chloroplasts.

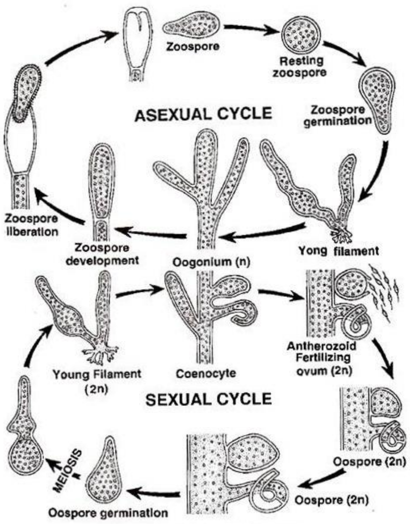


Fig. 8. *Vaucheria.* Diagrammatic life cycle.

- During development of sperms, also known as antherozoids or spermatozoids, small portions of cytoplasm surround each nucleus, thus making small pear-shaped bodies which acquire a pair of flagella. At maturity, numerous small male gametes, or antherozoids are formed.
- Each antherozoid bears two laterally inserted unequal flagella (one being whiplash, the other tinsel) and consists of a nucleus and a small amount of tri cytoplasm surrounded by a membrane.
- When the antheridium is mature, the antherozoids are set free through a terminal pore.
- The oogonium is a spherical or oval sessile or short-stalked body with a short, rounded beak which opens to receive the sperms (antherozoids).
- The oogonium appears as a globular outgrowth, usually near an antheridium; and is separated from the rest of the filament by a septum.
- The oogonium consists of cytoplasm, a single rather large nucleus, numerous chloroplasts, and stored food in the form of oil. The contents of the oogonium form a single large spherical egg, or ovum laden with much food.
- Eventually one passes in and fuses with the nucleus of the egg resulting in the formation of oospore.
- Actual fertilization, the fusion of nuclei may be delayed.

- Following fertilization the oospore secretes a thick wall and passes through a resting stage, having within it reserve food in the form of oil. The oospore germinates and directly forms a new plant.

- Cytological behaviour at the reproductive stage has been insufficiently investigated.
- It is likely, however, that meiosis is zygotic and hence the vegetative filament is haploid.
- In vacheria, asexual reproduction by means of multi-flagellate zoospores whose flagella are distributed throughout the entire body - coenozoospores.
- Sexual reproduction oogamous. The oogonium bears single large, uninucleate oosphere, while the antheridium gives rise to numerous small biflagellate sperms bearing unequal flagella.

CHLOROPHYTA

- Chlorophyta is the largest of the eight divisions of algae.
- Members of the Chlorophyta, or grass-green algae are similar to higher plants being characterized by a well-defined nucleus, photosynthetic pigments localized in chloro plastids in which usually pyrenoids are present, the food reserve is commonly stored as starch.
- The class Chlorophyceae is commonly called as green algae. Chlorophyceae is very large group of algae and is represented by about 429 genera and 6500 species.
- Chlorophyceae are mainly fresh water algae (about 90 percent species are fresh water and 10 percent marine).
- Fresh water forms are common in ponds, pools, lakes, ditches, water tanks, and in river and canals.

- Majority of Volvocales, Chlorococcales are planktonic forms. Many Chaetophorales e.g., Coleochaete, Protococcus, Trentepohlia are epiphytic algae.
- Many species of Cladophora and Characium are epizoic algae.
- Some green algae like Trebouxia, Chlorella form symbiotic association ship with animals like Zoochlorella and Hydra.
- Some green algae form symbiotic association with fungi to form lichens.

- Cephaleuros is parasitic algae on leaves of tea, coffee, pepper and magnolia plants. Cephaleuros causes red rust of tea.
- *Chlamydomonas nivalis* causes red snow and *Chlamydomonas yellowstonensis* causes green snow.
- Some Chlamydomonas species are thermophilic.

Salient features of Chlorophyta:

i) The cells are eukaryotic and contain mitochondria, Golgi bodies, plastids, endoplasmic reticulum and ribosomes.

ii) The cell wall is made of two layers, the inner layer mainly consisting of cellulose and the outer layer consisting of pectic substances.

iii) The chloroplasts are well organized, the main pigments are chlorophyll a and b, the other pigments are a and ß carotene and xanthophyll.

iv) The shape of the chloroplast is variable. It may be cup shaped e.g., Chlamydomonas, girdle shaped e.g., Ulothrix, reticulate e.g., Cladophora, stellate e.g., Zygonema, spiral e.g., Spirogyra, discoid e.g., Chara or parietal e.g., Draparnaldiopsis.

v) The reserve food is in form of starch, composed of amylose and amylopectin and its formation is associated with pyrenoids.

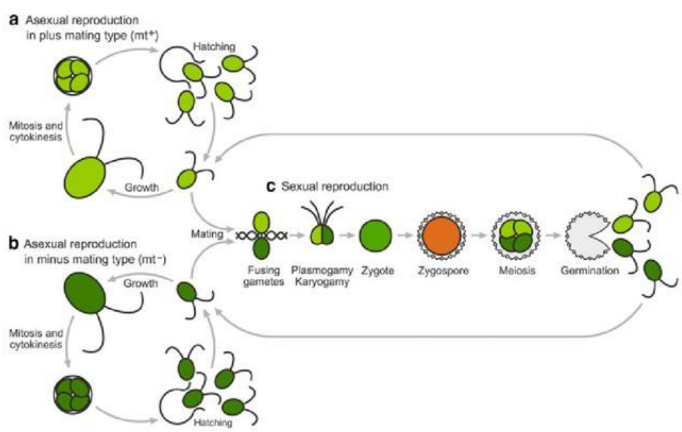
vi) The motile reproductive structures i.e., zoospores and gametes have 2,4 flagella which can be apical, sub apical, equal in size and acronematic type.

vii) They reproduce by all the three means i.e., vegetative (cell division and fragmentation), asexual (zoospore, aplanospore, akinete etc.) and sexual reproduction (isogamous, anisogamous or oogamous). The sexual reproduction is absent in some members of Chlorococcales.

Life cycle of Chlorophyta

- In lifecycle two generations alternates with each other.
- Diploid asexual phase called sporophyte and haploid sexual phase called gametophyte.
- In algae like spirogyra, zygnema thallus is haploid gametophyte, sporophyte is reduced so life cycle is called haplontic or haplobiontic.
- Cell division is longitudinal.

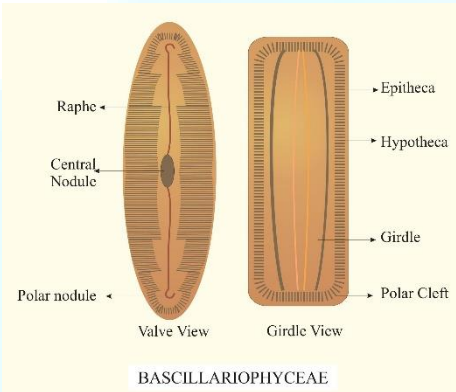
- In algae like ulva, cladophora gametophyte and sporophyte both are morphologically identical, so called isomorphic or homologous diplohaplontic type.
- Life cycle is homologous diplohaplontic type alternation of generation.
- In algae of order siphonales, thallus is diploid sporophyte, sporophytic generation is main, so called diplontic.



BACILLARIOPHYTA

- The Bacillariophyta, commonly known as the diatoms, are ubiquitous algae of both fresh-and salt-water and of damp places including aerial habitats as, old walls, rocky cliffs, bark of trees, and damp soils.
- Some are submerged in water growing attached to various substrata like aquatic algae and submerged objects.
- They play a very important role, particularly in the aquatic vegetation of the world forming an important part of the plankton, the basic food of aquatic fauna.
- Diatoms have been very appropriately named the 'jewels of the plant world', for their diverse forms and very delicately designed wall markings being the objects of great beauty.
- These are unicellular, sometimes colonial microscopic algae. They are of innumerable shapes, some being boat-like in outline, while others are rods, disks, triangles, and wedges.

- A special branch of phycology known as diatomology, the science of diatoms, has developed dealing with the various aspects of the huge number of diatom species and their unique structure.
- The diatom cell, known as frustule, is composed of two overlapping halves, or valves very nicely fitted one upon the other like an old fashioned pill-box, or a pair of petridish.
- Of the two halves, the outer one is the epitheca and the inner the hypotheca. The edges of the two halves are more or less incurved, app together forming the girdle.



- The diatom cell wall is composed of pectic substances which are impregnated with silica.
- The siliceous material instead of being deposited as a smooth layer, forms different patterns which vary according to the genus and species. But usually the ornamentation follows two general patterns.
- For example, in the centric diatoms (Centrales) radially symmetrical about a central point, or drum-like, and in the pennate diatoms (Pennales) bilaterally sym metrical with respect to the long axis of the cell.
- On the back of each valve of most elongated types there are linear perforations forming longitudinal slit, called the raphe. But when without longitudinal slit is the pseudoraphe.
- There are also structural modifications of the cell wall forming thickenings which are known as nodules, appearing at both ends of raphe - polar nodules, and interrupting it near the mid-point - the central nodule.
- The markings of the wall, raphe and nodules constitute taxonomic criteria.
- The protoplast of a diatom cell forms a lining layer closely appressed to the cell wall and generally surrounding a large central vacuole.

- Depending on species, the cell may contain one to many discoid or irregularly shaped plastids which are yellow to brown in colour.
- Pigments of a diatom cell are: chlorophylla, chlorophyll c, fucoxanthin and a special pigment - diatomin casting a golden-brown to the diatom cell.
- Starch is never formed in diatoms, the reserve foods are fats and volutin.
- Diatom cells of some species exhibit movement which is slow and jerky and confined to forward and backward directions.
- The movement may be due to the flow of currents of water or by the circulation of cytoplasm.
- After the death of diatom cells, their siliceous walls, or empty frustules drift to the bottom of the body of water in which they occur and tinder favourable conditions there accumulates a large deposit of diatom walls, known as diatomaceous earth.
- During tertiary and quaternary ages the formation of diatomaceous earth was so great that the great deposition was formed in ocean.
- Such deposition is known as diatomite or Kieselguhr. Diatomite because of its porosity, is light in weight and can stand high temperature.
- Its melting point is 175°C. Diatomite is used in various industries.

Uses of Diatomite:

  - used in polishes for silverware, metals
  - preparation of tooth powders
  - insulation of steam pipes and blast furnaces
  - to filter oils
  - used in sugar- refineries
  - in brewing industry
  - in manufacturing antibiotics to remove waste mycelium.
- At first Alfred Nobel used diatomite as an absorber of highly explosive nitroglycerine when he manufactured dynamite.

Characteristics of Diatoms:

1. They are commonly unicellular and free- living but some members form colonies of various shapes like filaments, mucilaginous colonies etc.
2. Microscopic cells are of different shapes. They may be oval, spherical, triangular, boat- shaped etc.
3. Plant bodies are either bilateral or radial in symmetry.

4. The cells are surrounded by a rigid cell wall, called frustule, consisting of upper epitheca and lower hypotheca; arranged in the form of a box with its lid.
5. The cell wall is composed of pectic substances impregnated with high amount of siliceous substance.
6. The wall may have secondary structures like spines, bristles etc.
7. Vegetative cells are diploid (2n) and so meiosis can take place, producing male and female gametes which then fuse to form the zygote.
8. The cells generally have many discoid or two large plate-like chromatophores. Some cells possess stellate chromatophore.
9. The photosynthetic pigments are chlorophyll a, chlorophyll c along with xanthophylls like fucoxanthin, diatoxanthin and diadinoxanthin. The golden-brown colour of diatom cells is due to the presence of xanthophylls like fucoxanthin, diatoxanthin and diadinoxanthin.
10. Reserve food is oil, volutin and crysolaminarin.
11. Motile structure (antherozoid) has single pantonematic flagellum.
12. Vegetative multiplication takes place by cell division, which is very common. Some of the cells become very much reduced in size.
13. They produce characteristic spore, the auxospore which develops to regain the normal size.
14. Sexual reproduction takes place by isogamy and oogamy.

Vegetative Reproduction

- Vegetative reproduction performs with the help of cell division.
- During cell division the protoplast of the cell enlarges slightly, thus the cell increases in volume and slightly separates both the theca (epitheca and hypotheca).
- Then the protoplast undergoes mitotic division and gets separated along the longitudinal axis through the median line.
- Thus one half of protoplast remains in epitheca and the other one in hypotheca. One side of the protoplast thus remains naked. Now both the theca i.e., epitheca and hypotheca of mother cell behave as epitheca of the daughter cells.
- Thus new silicious valves are deposited towards the naked sides of the protoplast and always behave as hypotheca of the daughter cells.

- Connecting bands are developed between the theca. Later on, the daughter cells get separated.

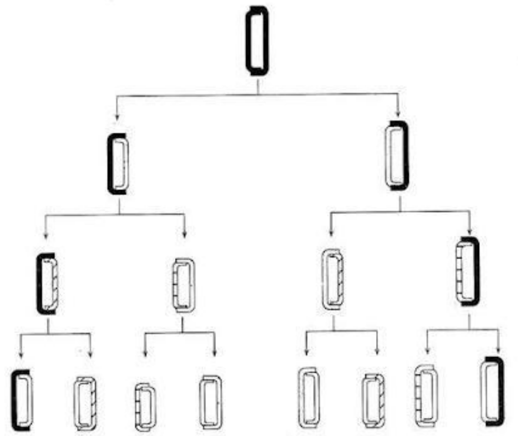


Fig. 3.102 : Cell division in diatoms (diagrammatic) showing reduction in cell size in successive generations except one (extreme right)

- During cell division, both the theca i.e., epitheca and hypotheca of the mother cell behave as epitheca of the daughter cells.
- So at the side where the hypotheca behaves as epitheca, the cell becomes reduced in size. Thus with continuous cell division some cells gradually become reduced in size.
- In general, the vegetative cell of diatom is a diploid structure and for meiosis gametes are formed.
- In anisogamy, one gamete is amoeboid while the other is non-motile.
- The amoeboid gamete (male) travels through a mucilage matrix, or a fusion tube, toward the female and nuclear fusion takes place there.
- Auxospores can also play a role in sexual reproduction in diatoms, and may be formed after haploid gametes fuse to form a diploid zygote.

RHODOPHYTA

- It is a large group of algae consisting of about 831 genera and over 5250 species.
- They are commonly known as red algae due to the presence of water soluble red pigment, r- phycoerythrin.

- r- phycoerythrin is, however present sufficiently and completely to mask the chlorophyll a, giving the characteristic red colouration.
- More than 98% members are marine and the rest grow in fresh water.
- The freshwater members grow in stagnant water (e.g., Asterocystis, Compsopogon etc.)
- They also grow in flowing water (e.g., Lamanea, Thorea, Batrachospermum etc.).
- The marine species have the ability to live at greater depth (even at 30-90 meters) than the other members of different classes.
- They also exhibits a high degree of parasitism and epiphytism.
- The parasitic members shows great reduction in their size and pigmentation.
- Some parasitic members are *Ceramium condicola* on *Codium fragile*, *Polysiphonia lanosa* on *Ascophyllum nodosum* etc.
- The epiphytic members like Rhodochorton, Ceratocolax etc. grow on other members of Rhodophyceae.
- Porphyridium, a unicellular member, is terrestrial and grow on damp soil.
- Marine members commonly grow in sublittorial zone, but a few members like Rhodocorton, Corallina and Bostrychia grow in intertidal zone.

CHARACTERISTICS OF RHODOPHYCEAE (RED ALGAE):

1. Most of the members (more than 98%) are marine and 20 species (as per report) grow in fresh water. The members may grow either as saprophytes, parasites and also as epiphytes.

2. The plant body may be unicellular (Porphyridium) or multicellular. The multi-cellular form may be filamentous (Gonio- trichum), parenchymatous (Porphyra, Crinellia), pseudoparenchymatous (Helmin- thocladia), feathery (Polysiphonia) or ribbon like (Chondrus) (Fig. 3.130).

3. They do not attain the size like that of the brown algae (Phaeophyceae), but may reach up to 2 meters in Schizymenia.

4. The flagellated motile stages are totally absent.

5. The cell wall consists of outer pectic and inner cellulosic layer. The mucilaginous material of the outer layer mainly consists of agar-agar and carrageenans and constitute major portion of dry weight of the cell wall.

6. In multicellular forms, the cell walls have pits, through which cytoplasmic connections are maintained. These cytoplasmic threads are the so-called plasmodesmata.

7. The members of Rhodophyceae show much variation in the number of nuclei in a cell. In the subclass Bangioideae, cells are uninucleate, but in the subclass Florideae most of the members are multinucleate and the number of nuclei is 3,000-4,000 in Griffithsia.

8. The cells may have one chromatophore with a central pyrenoid (Bangioideae) or many discoid and parietal chromatophores with pyrenoids (Florideae).

9. The photosynthetic pigments are chlorophyll a, chlorophyll b; α- and β-carotene; xantho- phylls like teraxanthin, lutein, violaxanthin, zeaxanthin, flavoxanthin and biliproteins such as r-phycoerythrin and r-phycocyanin. The characteristic red colouration of the algae is due to the sufficient presence of r-phycoerythrin which completely masks the chlorophyll a. [The chief Xanthcphyll is teraxanthin and chlorophyll b is absent.]

10. The reserve food is floridean starch, floridi- side and mannoglycerate.

11. Reproduction takes place by all the three means: vegetative, asexual and sexual.

a. Vegetative reproduction takes place only in unicellular form.

b. Asexual reproduction takes place by monospore, neutral spore, carpospore, bispore, and tetraspore.

c. Sexual reproduction is of advanced oogamous types.

i. The male sex organs are known as spermatangium. Single non- flagellate male gamete is produced in each spermatangium, called spermatium.

ii. The female sex organs are called carpogonia or procarp. Carpogonia are flask-shaped with a long neck, the trichogyne.

12. During fertilisation, the spermatium comes in contact with the trichogyne with the help of water current.

13. In Rhodophyceae the post-fertilization changes are highly elaborate. They develop carposporophyte. Carposporangia are developed from each carposporophyte and each carposporangium produces single carpospore.

14. Most of the Rhodophycean members show biphasic or triphasic life cycle patterns.

PHAEOPHYCEAE

- It is a large group of algae consisting of 240 genera and over 1,500 species out of which 32 genera and 93 species are reported from India.
- They are commonly known as brown algae, due to the presence of a golden brown xanthophyll pigment, fucoxanthin ($C_{40}H_{54}O_6$) in the chromatophores.
- About 99.7% members are marine and a few grow in fresh water. The fresh water members are Pleurocladia, Heribaudiella, Pseudobodanella, Lithoderma and Sphacelaria.
- Members like *Pleurocladia lacustris* grow both in fresh water and marine habitats.

THE IMPORTANT CHARACTERISTICS OF THE CLASS PHAEOPHYCEAE ARE GIVEN BELOW:

1. Plant body is immobile, multicellular and highly differentiated both externally and internally. [Unicellular, colonial (motile and non-motile) and unbranched filamentous forms are completely absent).

2. They range from simple microscopic heterotrichous filament (Ectocarpus) to largest alga (*Macrocystis pyrifera*), which attains a length of 60-90 meters. (The largest forms are known as kelps or rockweeds. Lessonia davicans reaches a length of 4 meters and looks like a miniature tree. *Nereocystis luelkeana*, the bladder kelp which attains a length of 25-30 meters. *Postelsia palmae- formis* appears like a palm tree and commonly known as Sea Palm)

3. Commonly the plant body is differentiated into hold fast, a short or elongated stipe and an expanded blade. The blade performs photosynthesis and bears reproductive structures. Many species remain afloat by having air bladders.

4. The photosynthetic pigments include chlorophyll a, chlorophyll c, β-carotene and xanthophylls like lutein, fucoxanthin, flavoxanthin and violaxanthin. The fucoxanthin is however present sufficiently which partially mask the chlorophyll and carotenoid, thereby giving the characteristic brown colouration.

5. The growth of the plant body may be apical (Fucales, Dictyotales), intercalary (Laminariales) or trichothallic (Ectocarpales).

6. The cell wall is differentiated into outer and inner layers. The outer mucilaginous layer has fucinic and alginic acid, but the inner layer is mainly cellulosic. [The alginic acid is used to manufacture artificial silk and adhesive, obtained commercially from Sargassum, Laminaria etc].

7. The cells usually have many small vesicles and white granules. The granules are called fucosan vesicles.

8. Pyrenoides are usually absent, but, if present, is of single stalk type.

9. Motile structures (zoospores and gametes) have two laterally inserted unequal flagella, of which larger one is tinsel or pantonema- tic and the smaller one is whiplash or acronematic type.

10. The reserve foods are commonly laminarin and mannitol. Sucrose and glycerol are also present in some members.

11. They reproduce by all the three means: vegetative, asexual and sexual.

a. Vegetative reproduction takes place by fragmentation. Special reproductive branches, the propagules, are developed in some members of Sphacelariales; those develop to new plants after detachment.

b. Asexual reproduction takes place by zoospores except Tilopteridales, Dictyotales and Fucales. The zoospores produced in unilocular sporangia are haploid, while in pleurilocular sporangia they are diploid.

c. Sexual reproduction ranges from isogamy (Ectocarpales and Sphacelariales) to oogamy (Fucales, Dictyotales and Laminariales) through anisogamy (Cutleriales and Tilopteridales).

12. In most of the members fertilisation is external. Zygote does not undergo meiotic division and on germination it develops diploid thallus.

13. The members show various types of alternation of generations i.e., isomorphic (Ectocarpus), heteromorphic (Laminaria) or diplontic (Sargassum).

The members of Phaeophyceae show two types of life cycle:

1. Diplontic life cycle e.g., Sargassum.

2. Diplohaplontic life cycle.

It is of two types:

i. Isomorphic type e.g., Ectocarpus.

ii. Heteromorphic type e.g., Laminaria.

ECONOMIC IMPORTANCE OF ALAGE

The following are some of the important economic importance of algae;

- ✓ Used as Food
- ✓ Used as Fodder
- ✓ Used as Fertilzers
- ✓ Used for reclamation of alkaline, 'Usar soil'
- ✓ Binding of soil particles
- ✓ Used in agar industry
- ✓ Used in algin industry
- ✓ Kelp industry
- ✓ Medicinal uses

1. ALGAE IS USED AS FOOD:

- Algae have been in use as human food for centuries in various parts of the world, including Scotland, Ireland, Norway, Sweden, France, Germany, North and South America, China, and Japan.
- Algae may be taken as a salad, cooked with meat or eaten as vegetable, sprinkled with oatmeal or fried with meat.
- Some are added for flavour to various dishes, while extract from others is taken as a beverage.
- Their nutritional value is quite high, as they contain a good amount of proteins, carbohydrates, fats and vitamins, specially A, B, C and E.
- Commonly used species, are mostly marine, and they belong to;

  Chlorophyceae [Ulva lactuca (Sea lettuce), *Enteromorpha compressa*, *Caulerpa racimosa*],

  Phaeophyceae (*Laminaria saccharina*, Alaria esculenta, A. fistulosa, Sargassum sp., Durvillea sp.),

  Rhodophyceae [*Porphyra tenera*, P. umbilicalis, P. laciniata, *Rhodymenia palmata*, (Dulse), *Chondrus crispus* (Irish moss), *Gigartina stellata*, Gracilaria sp.]

  Cyanophyceae (Nostoc sp.).

- In Japan, about 20 different kinds of algae are being harvested and eaten. **'Aonori'** is a preparation of Monostroma, **'Kombu'** of Laminaria and **'Asakusa-Nori'** of *Porphyra tenera.*
- Similarly, Laminaria is widely cultivated in Japan and China. It is cultivated more like a crop plant which has resulted in the development of a more stable economic crop. With the development of the techniques of mass culturing of algae, specially with Chlorella

and Scenedesmus, there are probabilities of solving the problem of food deficiency.

- The salient feature of Chlorella is that the cell is rich in protein and vitamin contents (Single cell protein, SCP). It contains all the amino acids known to be essential for the nutrition of human being as well as animals.
- Algae are also being used for the production of low cost protein.

2. ALGAE IS USED AS FODDER

- The sea weeds as fodder have been widely used in Norway, Sweden, Denmark, Scotland, America, China and New-Zealand. In Norway, *Rhodymenia palmate* has come to be known as **'Sheep's weed'** since sheep are very fond of this particular alga.
- *Laminaria saccharine*, Ascophyllum sp., Sargassum sp. and Fucus sp., are equally liked by the catties.
- Eggs of hens fed with seaweeds have an increased iodine content.
- Cattles supplemented with seaweeds reported increased butter-fat content of milk

3. ALGAE IS USED AS FERTILIZERS

- The large Brown and Red algae are used as organic fertilizers, especially on land close to the sea. A concentrated extract of seaweed is also sold as a liquid fertilizer. Coralline algae *Lithothamnion calcareum* and Lithophyllum sp. are used profusely for liming the soil. Similar is the use of Chara which becomes encrusted with calcium carbonate.
- The greatest utility of the algae, as a friend to the farmers, is seen in some common forms belonging to Cyanophyceae for their capacity to fix atmospheric nitrogen and thus enriching the soil.
- *Aulosira fertilissima*, the common Blue-green algae of the Indian rice fields.

- In India, the nitrogen-fixing blue-green algae play a part of tremendous importance in maintaining the fertility of the rice fields.

4. RECLAMATION OF ALKALINE, 'USAR' LAND

- In India, vast tracts of land cannot be cultivated for crops because of high alkalinity of the soil, commonly known as **'usar'** soil.
- The **'usar'** lands would be cultivable, if their pH could be lowered, and organic contents and the water holding capacity of the soil increased. Exactly all these functions are carried out by the blue-green algae.

5. BINDING OF SOIL PARTICLES

- Algae act as an important binding agent on the surface of the soil.
- Disturbed or burnt soils are soon covered with a growth of green and blue-green algae thus reducing the danger of erosion.
- The role of Cyanophycean members as a pioneer in colony formation and thus in soil formation is well known.

INDUSTRIAL APPLICATION;

6. AGAR-AGAR (AGAR):

- Agar-agar is obtained from various species of red algae for e.g., *Gelidium corneum*, G. cartilageneum, *Gracilaria lichenoides*, and species of Chondrus, Gigartina, Furcellaria, Phyllophora etc..
- The chief constituent of agar is a carbohydrate galactan.
- The algae are collected, bleached and the mucilaginous matter is extracted with water under pressure. The purified agar is sold in the

form of flakes, granules or strips which are brittle when dry but become tough and resistant when moist.

- The important use of agar is in microbiology and tissue culture (in the preparation of culture media for growing algae, fungi and bacteria in the laboratories).
- Other uses are in the cosmetics, paper and silk industries, in dentistry for making impressions, in canning fish, to prevent the soft fish from being shaken to pieces during transit, in sizing material, in clarifying liquors etc.
- It is also used as food and in the preparations of ice-cream, jellies, sweets and baking.

7. ALGIN INDUSTRY

- Algin is a calcium magnesium salt of alginic acid present in the intercellular substance of the Phaeophyceae.
- Because of its special colloidal properties alginic acid and its derivatives find considerable use in industry.
- Its salts are used in the manufacture of variety of goods ranging from ice-cream, salad cream, custard and jams to cosmetics, films, fabrics, ceramics and textiles.
- They are also used as a suspending agent in compounding drugs, lotions and emulsions; in the rubber industry in latex production; as an insulating material and as dental impression powder, as a gel in the freezing of fish and in the medicinal antibiotic capsules.
- The production of algin by the Phaeophycean members varies from species to species and genus to genus besides the seasonal variations in the contents, the values being highest in the winter and lowest in the summer.

- The harvesting of the weed depends upon the genera used and their habitat.
- Species of Laminaria, Ascophyllum, Macrocystis, Nereocystis, Ecklonia, Durvillea and Sargassum are the chief sources of commercial algin.

8. KELP INDUSTRY

- Industrial utilization of seaweeds in Europe had its principal early developed in the production of "kelp", a name that originally refered to the ash, rich in soda and potash, derived from burning marine plants.
- Kelp production was begun in 17th century by French peasants and spread to other parts of North-West Europe.
- Laminaria, Saccorhiza, Fucus, Ascophyllum are widely used for kelps.
- Himanthalia are also used in some areas.
- Kelp is used to make: toothpastes, shampoos, salad, dressings, puddings, cakes, pharmaceuticals.
- Kelp farms allow growers to make use of existing aquaculture resources in their areas.
- Kelps can have many therapeutical and nutritional benefits as it is rich in source of iodine, minerals, antioxidants, fiber, protein and healthy carbohydrates.
- Kelp may also improve diabetes, reduce blood clot, and even help to fight hepatitis and breast cancer.
- Kelp extract contains a number of chemical elements. 25% of dry weight is composed of potassium chloride.

9. MEDICINAL USE

- From earliest times the Chinese used Sargassum and various Laminariales for treatment of goiter and other glandular troubles.

- Gelidium very early became employed for stomach disorders arid for heat-induced illness.

- The gentle swelling of dried Laminaria stripes upon exposure to moisture makes them surgical tool in the opening of wounds.

- Alaria was once used for strengthening the stomach and restoring the appetite after sickness.

- Alginates are used for their haemostatic nature.

- Fucoidan and sodium lamanarin sulphates are used as “blood anticoagulant”.

- *Digenea simplex*, a Rhodo-phycean alga, provides an antihelminthic drug.

- Agar-agar for its absorptive and lubricating action, is used medicinally in the prevention of constipation.

- Gelidium employed for stomach disorders against coliforms and other related intestinal bacteria.

- Extracts from *Neorhodomela larix* and Ascophyllum nodosum are effective against both gram positive and gram negative bacteria.

- Several algae, e.g., Halidrys, Pelvetia, Laminaria, Polysiphonia, Nitzschia and Hapalosiphon have been reported to possess antibiotic or antibacterial properties which, however, need further confirmation.

10.ANTIBIOTICS

- The antibacterial product chlorellin, obtained from Chlorella is well known. The antibacterial effects are more pronounced against coliforms and other related intestinal bacteria.
- Extracts from *Rhodomela larix* and *Ascophyllum nodosum* are effective against both gram positive and gram negative bacteria. Several algae, e.g., Halidrys, Pelvetia, Laminaria, Polysiphonia, Nitzschia and Hapalosiphon, have been reported to possess antibiotic or antibacterial properties which, however, need further confirmation.

WATER-BLOOMS (Algal-blooms)

- The rapid increase or aggregation in the alage population of freshwater or marine water systems is termed an algal bloom.
- It is often identified by water discolouration due to algae's pigment.
- The term algal bloom typically refers to the rapid multiplication of microscopic algae rather than microscopic ones.
- Excessive development of phytoplankton is often responsible for water assuming distinct colours like green, yellow-green, yellowish brown, dark or dirty brown, reddish brown, bluish-green etc..
- The red sea has been named after the Blue- green algae, *Oscillatoria erythema*, Trichodesmium sp., which gives a red coloration to the sea at the bloom stage.

- The green, brown and red tides in the sea are caused mostly by the Dinoflagellates.
- In freshwater, water blooms fairly common in ponds and lakes and rarely in rivers, are caused by number of classes of algae (Chlorophyceae, Xanthophyceae, Chrysophyceae, Bacillariophycaea, Dinophycaea, Cryptophyceae, Euglenineae and Cyanophyceae) each imparting a colour of its own.
- Most common form belongs to Cyanophyceae (Microcystics, Anabaena, Spirulina etc.)
- The blooms may be temporary or seasonal occurring in November-December and in June or may be permanent.
- This bloom causes disagreeable small and taste to water making it unfit for drinking purposes.
- Very strong poisons or toxins have been extracted from algae causing water-blooms (Round, 1966) and reports of death of cattle and birds drinking such water, are also there but so far chemical analysis of Indian water bloom algae or of the water supporting them have not revealed any toxic substance (Singh, 1955) nor the drinking of such water, with moderate blooms, is known to cause any ill effect.
- Algal blooms may be used and are used as manure in certain places and light algal blooms are, in fact, induced in fish ponds by adding inorganic fertilizers, to control the submerged weeds