CHAPTER 1

Algae: General Characters

Algae comprise a group of chlorophyll containing thalloid plants of the simplest type, having no true roots, stems, leaves or leaf like organs. They are placed in the Division **Thallophyta** along with fungi. They differ from fungi in the presence of photosynthetic pigment - **chlorophyll** and in their mode of nutrition. Although most of the algae are **autotrophic**, i.e., they synthesize their food by themselves, yet heterotrophic and holozoic forms are not uncommon. The important distinguishing features of algae are as follows:

(1) They are mostly chlorophyll containing autotrophic thalloid plants.
(2) They occur in a variety of habitats, but majority of them are aquatic.
(3) The plant body does not show differentiation into various tissue systems.
(4) They have mostly unicellular sex organs without a jacket of sterile cells around them. Jacket cells, if present, have different initials. There is a progressive complexity in reproduction.
(5) Embryo is not formed after gametic union.
(6) They show distinct alternation of generation.

OCCURRENCE

Algae are of universal occurrence and they are found in a variety of habitats, such as freshwater, sea water, on snow, on rocks and on/or within the plant and animal bodies. Of these, aquatic forms are most common. On the basis of habitat, they may be classified into the following three groups:

(1) **Aquatic algae**
(2) **Terrestrial algae**
(3) **Algae of unusual habitats**

[I] Aquatic algae

Aquatic forms are found in fresh water or in saline water of the sea.

1. Fresh water forms. These forms occur in fresh water (low salinity water) of ponds, pools, lakes, rivers, etc. Some fresh water forms like *Cladophora*, *Oedogonium*, *Ulothrix* and *Chara* are found in slow running water, whereas others like *Chlamydomonas*, *Volvox*, *Hydrodictyon* and *Spirogyra* occur in stagnant water.

2. Marine forms. These forms occur in saline water of the sea and are represented by the members of Phaeophyceae (e.g., *Ectocarpus*, *Sargassum*, *Fucus*) and Rhodophyceae (e.g., *Polysiphonia*).

The aquatic algae are either free-floating (e.g., *Chlamydomonas*, *Volvox*, *Spirogyra*) or are attached to a substratum with the help of an attachment disc, known as **holdfast** (e.g., *Oedogonium*, *Ulothrix*). Many free-floating algae, together with other similar organisms, form colonies on the surface of water which are called **water blooms** or **phytoplanktons**.

Algae like *Dictyosphaerium*, *Fragilaria*, *Cosmarium*, *Volvox*, *Asterionella* and *Golenkinia* are commonly found in fresh water planktons, whereas *Actinocyclus*, *Chaetoceros* and *Coscinodiscus* are common in marine planktons.

During night planktons utilize oxygen dissolved in water and as such submerged aquatic organisms do not get sufficient oxygen for respiration. Besides, phytoplanktons also prevent atmospheric oxygen from dissolving in water, thus making the habitat unsuitable for submerged aquatic life.

Many algae are found attached to rocks along the edges of lakes and seas and these forms are called **phytobenthos**.

[II] Terrestrial algae

Some algae are found in terrestrial habitats like soils, rocks, logs, etc. Forms like *Vaucheria*, *Botrydium*, *Fritschiella* and *Euglena*, which are found on the surface of the soil, are known as **saphophytes**, whereas many blue-green algae (e.g., *Nostoc*, *Anabaena*), which occur under the surface of the soil, are called **cryptophytes**.

Some algae are also found on tree trunks and moist walls, and they absorb carbon dioxide and water from the atmosphere (e.g., *Protococcus*, *Scytonema*).

[III] Algae of unusual habitats

In addition to aquatic and terrestrial habitats, some algae also occur in uncommon habitats.

1. Halophytic algae. There are many algae which occur in saline water of seas, but some others can withstand high concentration of salts and occur in salt lakes. They are called **halophytes**, and include *Chlamydomonas ehrenbergii*, *Dunaliella* and *Stephanoptera*.

2. Epiphytic algae. They grow on larger algae or on bryophytes and angiosperms. For example, species of *Bulbochaete*, *Oedogonium* and *Microspora* are found attached to the larger species of *Cladophora*, *Rhizoclonium* and *Vaucheria*. Bryophytic and angiospermic flora of rivers and lakes harbour many algal members on their surface. Algae with mucilagenous thalli like *Chaetophora*, *Oedogonium* and *Zygnema* are epiphytic on *Achnanthes*, *Eunotia*, *Synedra*, etc.

3. Epizoic algae. Many algae grow on animals like snails, fishes and tortoise, and they are known as **epizoic**. For example, *Cladophora crispata* grows on snails, and species of *Stigeoclonium* are found in the gills of fishes. Similarly, species of *Characiopsis* and *Characium* are found on the legs of *Branchipus*.

4. Endozoic algae. Algae which occur in the tissues of animals are known as **endozoic**. For example, species of *Zoochlorella* are found in *Hydra viridis*. Besides, several species of the family Oscillatoriaceae (blue-green algae) occur in the respiratory and digestive tracts of vertebrate animals.

5. Symbiotic algae. Several members of Chlorophyceae and Cyanophyceae form symbiotic association with fungi, bryophytes, gymnosperms and angiosperms. Lichens are important example of symbiotic life and their algal components belong to Cyanophyceae (e.g., *Nostoc*, *Gloeocapsa*, *Microcystis*) or Chlorophyceae (e.g., *Coccomyxa*, *Chlorella*, *Protococcus*). Colonies of *Nostoc* and *Anabaena* are found in symbiotic association in the thallus of *Anthoceros* and the coralloid roots of *Cycas*.

6. Cryophytic algae. Algae growing on ice or snow are called **cryophytic**. These algae provide attractive colours to snow covered mountains. The alpine and arctic mountains become red due to the growth of *Haemotococcus nivalis*. Green snow in Europe is due to *Chlamydomonas yellowstonensis* and species of *Mesotaenium*.

Sometimes snow becomes black due to *Scotiella nivalis* and *Raphidonema brevirostri* and brownish purple due to *Ancyclonema nordenskioldii*.

7. Lithophytic algae. Algae growing on moist rocks and stones are known as **lithophytic**. Many blue-green algae like *Nostoc*, *Rivularia* and *Gloeocapsa* commonly grow on moist and shady rocks. *Scytonema* is common on moist walls during rainy season.

8. Parasitic algae. Algae also grow as parasites on many plants and animals. *Cephaleuros virescens* (Chlorophyceae) causes **red rust** in tea and coffee plantations. *Phyllosiphon* (Chlorophyceae) is a parasite on the leaves of *Arisarum vulgare*. *Polysiphonia fastigiata* (Rhodophyceae) is a semiparasite on *Ascophyllum nodosum*.

9. Thermophytes (Thermal algae). Many blue-green algae (e.g., *Oscillatoria brevis*, *Synechococcus elongatus*, *Heterohormogonium* sp., *Haplosiphon lignosum*) are found in hot water springs (50-70°C). They are able to survive such high temperatures due to the absence of well organised nucleus. Since most hot springs are alkaline, some algologists believe that tolerance to high temperature is also associated with this factor.

RANGE OF THALLUS STRUCTURE

The vegetative structure of algae shows a wide variety and it ranges in form from unicellular to complex multicellular thalli. Their size ranges from one micron to several meters. On the basis of thallus organisation, algae are divided into the following five groups:

(1) **Unicellular forms**
(2) **Colonial forms**
(3) **Filamentous forms**
(4) **Siphonaceous forms**
(5) **Parenchymatous forms**

Multicellular forms have been derived by repeated divisions of unicellular forms. Colonial forms are developed by the aggregation of the products of cell division within a mucilage mass. Filamentous forms are formed by repeated transverse divisions of cells without separation of daughter cells. Repeated nuclear divisions, without cross wall formation, give rise to siphonaceous forms. Parenchymatous thalli are formed by the division of cells of a filament in two or more planes.

[I] Unicellular forms

Simple unicellular forms are found in all groups of algae except Charophyceae and Phaeophyceae. These forms are sometimes referred to as acellular since they function as complete living unit without any cellular differentiation. Unicellular forms can be classified into the following four sub-groups.

1. Rhizopodial unicells. These forms lack a rigid cell wall. They possess cytoplasmic projections which help them in amoeboid movement. In the absence of rigid cell wall, these forms are periplastic; e.g., *Rhizochrysis* (Chrysophyceae), *Rhizochloris* (Xanthophyceae), *Chrysamoeba* (Chrysophyceae; Fig. 1A).

2. Flagellated unicells. Flagellated vegetative cells are found in all groups of algae except Cyanophyceae, Phaeophyceae and Rhodophyceae. They vary in the number and type of flagella. For example, in Chlorophyceae, vegetative cells, zoospores and gametes have two equal flagella. Their number may sometimes vary. In Dinophyceae and Xanthophyceae there are two unequal flagella; in the former they emerge in different planes and in the latter in the same plane. In Euglenophyceae there is only one flagellum, inserted at the anterior end.

Flagellated unicells may be periplastic without cell wall (e.g., *Euglena*) or with a distinct cell wall (e.g., *Chlamydomonas*). In *Phacotus* (Chlorophyceae), there is a thick calcareous covering (capsule) around the cell wall (Fig. 1 B-D).

3. Spiral filamentous unicells. Some unicellular algae form spiral or coiled structures, e.g., *Spirulina* (Cyanophyceae; Fig. 2 A).

4. Non-motile unicells. These are non-motile coccoidal algae which do not possess flagella, eye spot, etc., meant for locomotion. The simplest non-motile forms are found in Cyanophyceae where they do not possess well organised nucleus and plastids (prokaryotic), e.g., *Chroococcus*. The non-motile unicells of Chlorophyceae possess nucleus and plastids (e.g., *Chlorella;* Fig. 1 E). The non-motile unicells of Bacillariophyceae, such as diatoms, are made up of two halves or theca, joined by a girdle band (Fig. 2B).

[II] Colonial forms

The colonial habit is achieved by aggregation of the products of cell divisions within a mucilagenous mass, by aggregation of motile cells or juxtaposition of cells subsequent to cell divisions. Therefore, all members of a colony have similar structure. These associations are usually loose, and as such a colony may break into smaller pieces. In some colonial

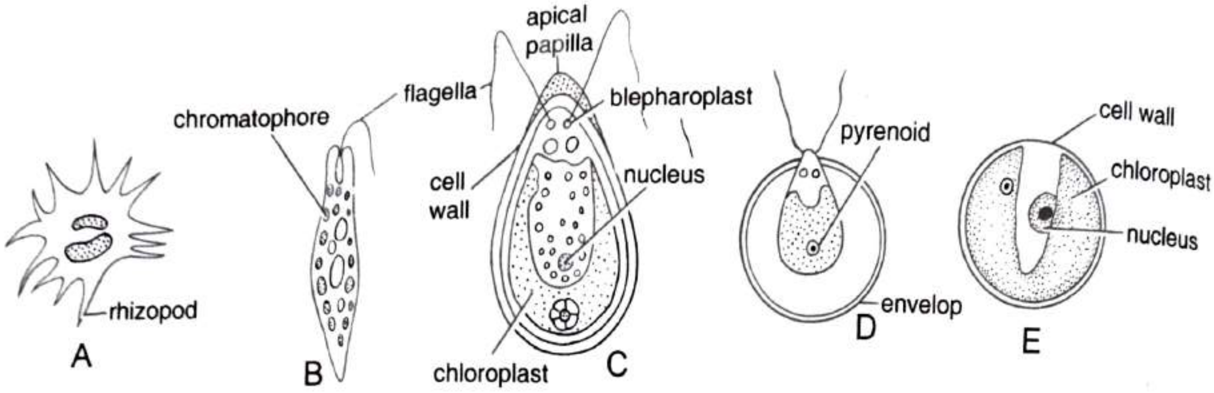

Fig. 1 A-E. Unicellular algae: A. *Chrysamoeba*, **B.** *Euglena*, **C.** *Chlamydomonas*, **D.** *Phacotus*, **E.** *Chlorella*.

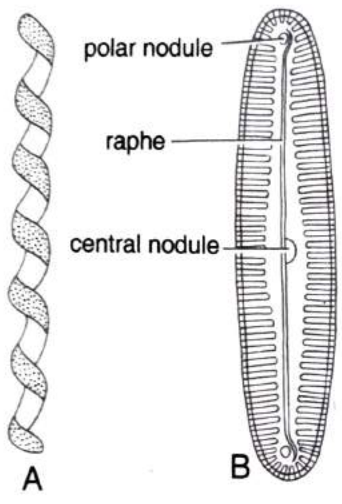

Fig. 2 A-B. Unicellular algae: A. *Spirulina*, **B.** *Pinnularia*.

forms, all members of a colony are connected with each other by cytoplasmic connections, hence they cannot break into segments (e.g., *Volvox*). On the basis of morphology, colonial organisation may be divided into the following four types:

1. Coenobial. A colony with a definite shape, size and arrangement of cells is known as **coenobium**. The number of cells in a coenobium is determined at the juvenile stage and subsequently there is only increase in size. Coenobia may be **motile** or **non motile**; in the former cells are flagellated (e.g., *Pandorina*, *Eudorina*, *Volvox*; Fig. 3A-C) and in the latter without flagella (e.g., *Hydrodictyon*; Fig. 3 D).

2. Palmelloid. Unlike coenobial forms, in a palmelloid colony the number of cells, their shape and size is not definite. The cells remain irregularly aggregated within a common mucilagenous matrix, but they are independent and function as individuals. In some palmelloid forms it is a temporary phase (e.g., *Chlamydomonas*), whereas in others it is a permanent feature as in *Tetraspora* (Chlorophyceae), *Aphanotheca* (Cyanophyceae; Fig. 4 A-B).

3. Dendroid. Here the colony looks like a microscopic tree. As in palmelloid colony, the number, shape and size of the cells is also indefinite in dendroid colonies. A mucilagenous thread is present at the base of each cell, and the threads of different cells are united to form a branched structure. It gives a tree like appearance to the whole colony (e.g., *Chrysodendron*, Chrysophyceae; Fig. 4 C).

4. Rhizopodial. In a rhizopodial colony the cells are united through rhizopodia (e.g., *Chrysidiastrum*, Chrysophyceae; Fig. 4 D).

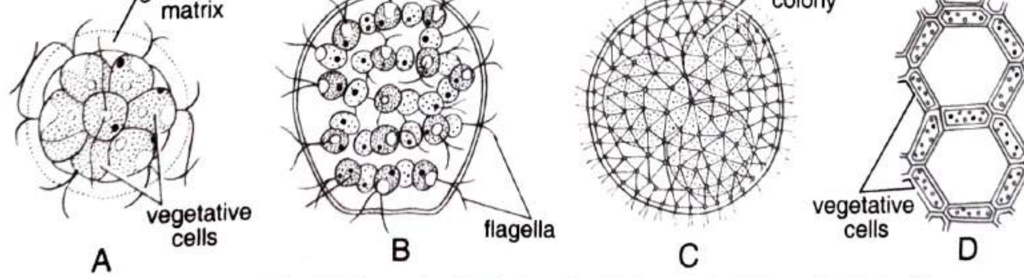

Fig. 3 A-D. Colonial algae: A. *Pandorina*, **B.** *Eudorina*, **C.** *Volvox*, **D.** *Hydrodictyon*.

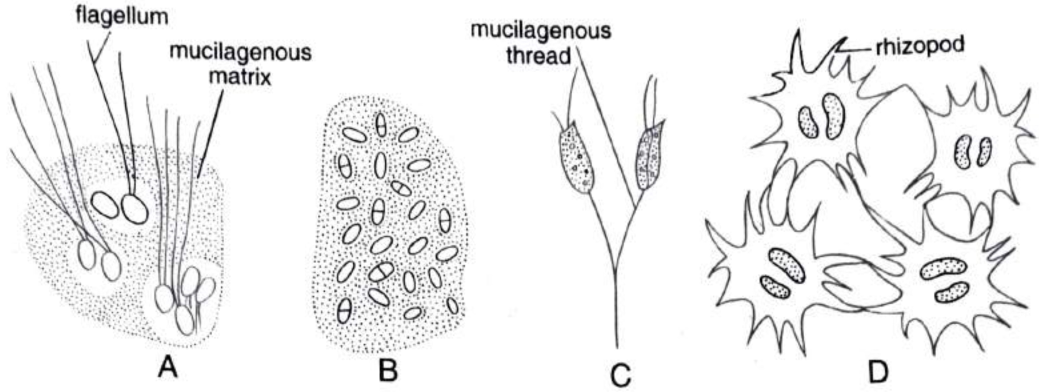

Fig. 4 A-D. Colonial algae: A. *Tetraspora*, **B.** *Aphanotheca*, **C.** *Chrysodendron*, **D.** *Chrysidiastrum.*

[III] Filamentous forms

Filamentous forms are developed by repeated transverse divisions of cells. The daughter cells do not separate and they remain attached one upon the other in a definite sequence to form a filament. The filaments may be **branched** or **unbranched**, and the cells in a filament may be arranged in a single row (**uniaxial**) or more than one rows (**multiaxial**).

1. Unbranched filaments. Simple unbranched filaments are found only in a few groups of algae. Such filaments may be free floating (e.g., *Spirogyra;* Fig. 5 A), attached to some substratum (e.g., *Zygnema*, *Ulothrix*, *Oedogonium;* Fig. 5 B-C) or form colony (e.g., *Nostoc*, *Oscillatoria;* Fig. 6 A-B).

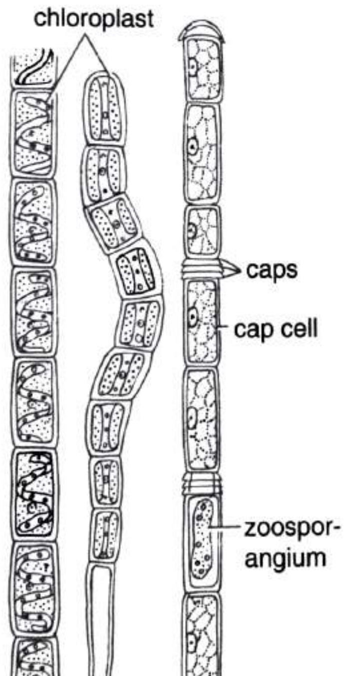

Fig. 5 A-C. Filamentous algae: A. *Spirogyra*, **B.** *Ulothrix*, **C.** *Oedogonium.*

2. Branched filaments. Branched filaments are formed by repeated transverse divisions of lateral outgrowths of cells. The branching of filaments may be **false** or **true**. A false branch does not arise as lateral outgrowth, but the trichome may break either due to death or decay of intercalary cells or at the point of heterocyst. The broken end emerges out of the mucilagenous sheath in the form of a branch, e.g., *Scytonema* (Cyanophyceae; Fig. 7 A). False branches in *Scytonema* arise almost always in pairs at some distance from the heterocyst.

True branches, which arise as lateral outgrowths, may result in the following three types of filaments:

(*a*) ***Simple filaments.*** Simple branched filaments remain attached to the substratum by a basal cell.

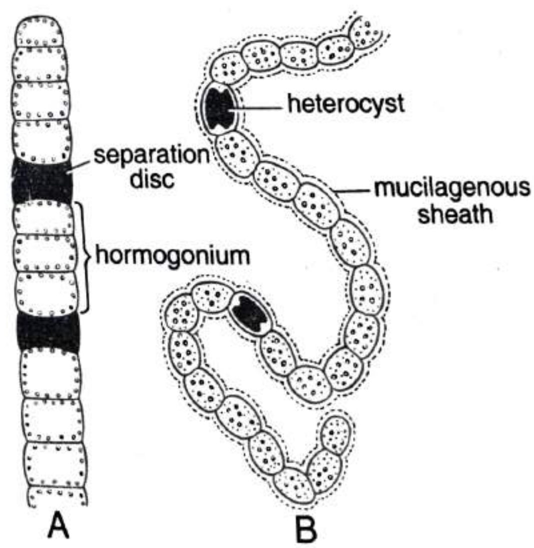

Fig. 6 A-B. Filamentous algae: A. *Oscillatoria*, **B.** *Nostoc.*

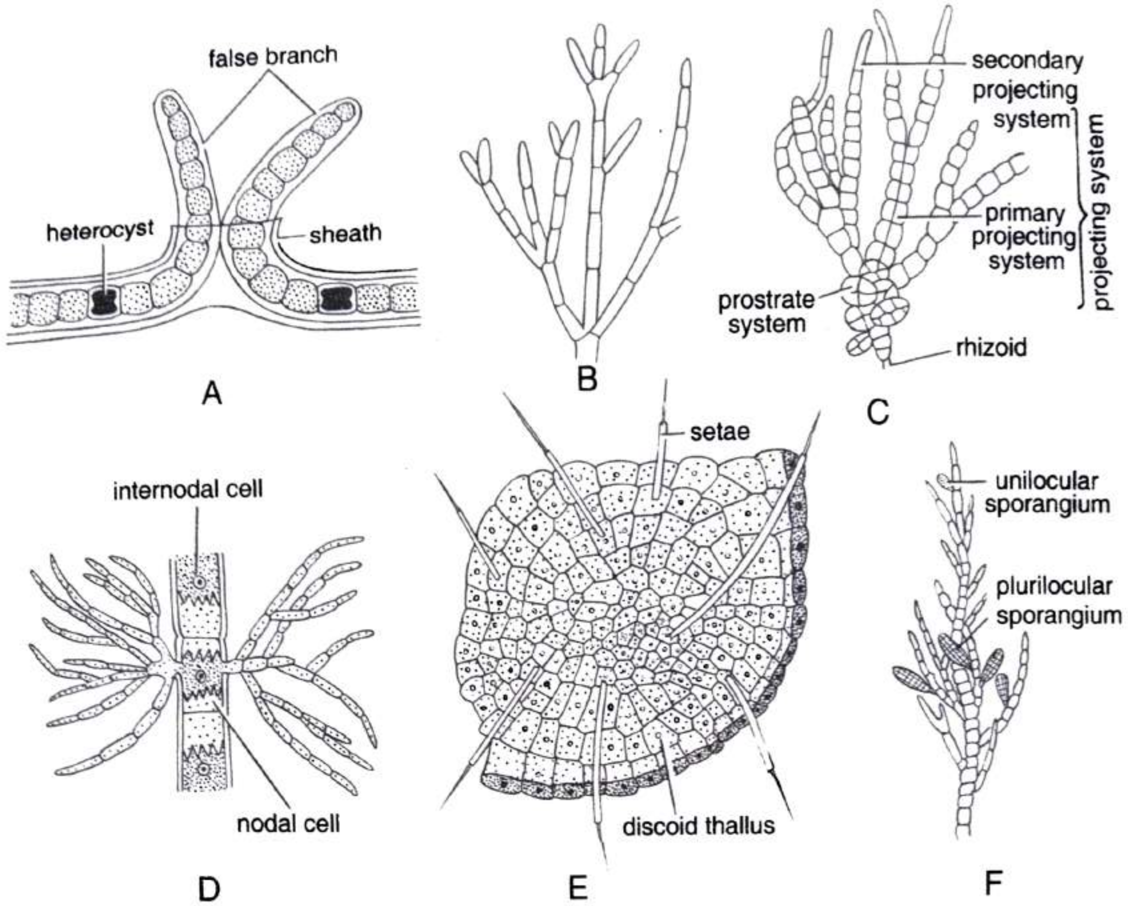

Fig. 7A-F. Branched filamentous algae: A. *Scytonema* (false branching), **B.** *Cladophora* (simple branching), **C.** *Fritschiella* (heterotrichous), **D.** *Draparnaldiopsis* (heterotrichous), **E.** *Coleochaete* (heterotrichous), **F.** *Ectocarpus* (heterotrichous).

In such filaments branches may arise from any cell except the basal cell. In *Cladophora* branches arise just below the septa between two adjacent cells (Fig. 7 B).

(b) Heterotrichous. In this type the thallus is very much evolved and differentiated into prostrate and erect systems (e.g., *Fritschiella*, *Ectocarpus*, *Draparnaldiopsis*, *Coleochaete*, *Stigeoclonium*). Both the prostrate and the erect systems may be well developed (e.g., *Fritschiella*, *Ectocarpus;* Fig. 7 C, F) or there is progressive elimination of prostrate (e.g., *Draparnaldiopsis*) or erect (e.g., *Coleochaete*) system (Fig. 7 D, E).

(c) Pseudoparenchymatous. In many filamentous forms one or more central or axial filaments, together with their branches, form a 'parenchymatous' structure. If a pseudoparenchymatous thallus is formed by the branches of only one filament, it is called **uniaxial** (e.g., *Batrachospermum*), and if branches of more than one filaments are involved, it is said to be **multiaxial** (e.g., *Polysiphonia;* Fig. 8 A-C).

[IV] Siphonaceous forms

Here the thallus is made up of branched, aseptate, coenocytic, tubular filaments as the nuclear divisions are not accompanied by wall formation, e.g., *Vaucheria* and *Botrydium* (Fig. 9 A-B).

[V] Parenchymatous forms

In this type the flat foliose or tubular thalli are formed by the divisions of cells in two or more planes. The daughter cells do not separate from the parent and give rise to parenchymatous thalli of various shapes, like flat (*Ulva;* Fig. 10 A), tubular (*Scytosiphon*, Phaeophyceae) or complex(*Sargassum;* Fig. 10 B). The growth of such thalli is apical (e.g., *Fucus*, *Dictyota*), intercalary (e.g., *Laminaria*) or trichothallic (e.g., *Porphyra*, Rhodophyceae).

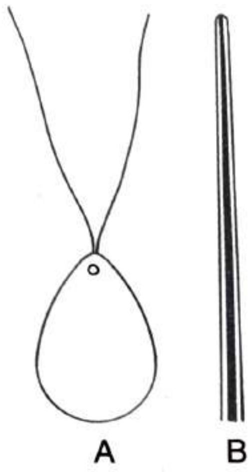

Fig. 13 A-B. Acronematic flagella: **A.** An algal cell with acronematic flagella, **B.** A single acronematic flagellum.

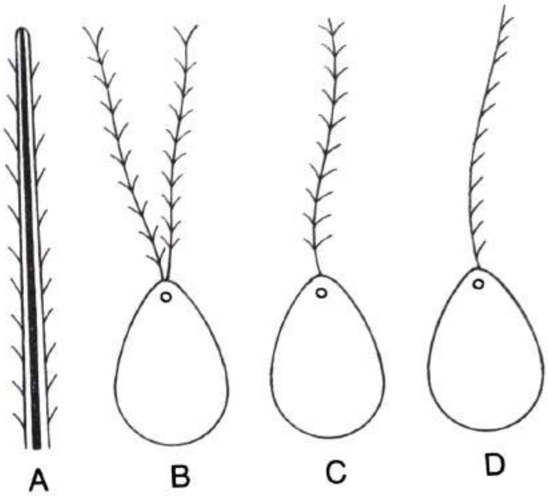

Fig. 14 A-D. Pleuronematic flagella: **A.** A pleuronematic flagellum showing mastigonemes, **B.** A cell with two pantonematic flagella, **C.** A cell with pantocronematic flagellum, **D.** A cell with stichonematic flagellum.

[II] Flagella

Motile vegetative or reproductive cells are found in all groups of algae except Cyanophyceae and Rhodophyceae. Their motility is due to small filiform (thread like) protoplasmic appendages, called **flagella**. The number of flagella varies from one to four to many (*Oedogonium*, *Vaucheria*). They are mainly of the following two types:

1. Whiplash or acronematic flagella. Such flagella have a smooth surface (Fig. 13 A, B).

2. Tinsel or pleuronematic flagella. The surface of these flagella is covered with fine filamentous appendages, known as **mastigonemes** or **flimmers** (Fig. 14 A). They are further divided into three categories on the basis of arrangement of mastigonemes.

(*a*) ***Pantonematic*.** In this type mastigonemes are arranged in two opposite rows or show radial arrangement (Fig. 14 B).

(*b*) ***Pantocronematic*.** A pantonematic flagellum with a terminal fibril is known as pantocronematic (Fig. 14 C).

(*c*) ***Stichonematic*.** Here mastigonemes develop only on one side of the flagellum (Fig. 14 D).

A motile cell may have either one or two types of flagella. It is a specific character. If all flagella of a cell are similar, it is known as **isoknot** and when dissimilar, it is called **heteroknot**.

The motile stages of Chlorophyceae possess two or four anteriorly inserted whiplash flagella of equal length; whereas the members of Phaeophyceae and Xanthophyceae have one whiplash and one tinsel flagellum of unequal length.

A transection of flagellum reveals that it consists of nine peripheral doublet and two central singlet fibrils (Fig. 15). All fibrils are enclosed within a common covering, formed by the extension of plasma membrane, but the two central fibrils have an additional covering of their own. The peripheral as well as central fibrils extend almost throughout the length of the flagellum. The nine peripheral fibrils at the proximal end are attached to a hollow basal body (which is separated from the flagellum by a diaphragm). The two central fibrils terminate just short to the diaphragm.

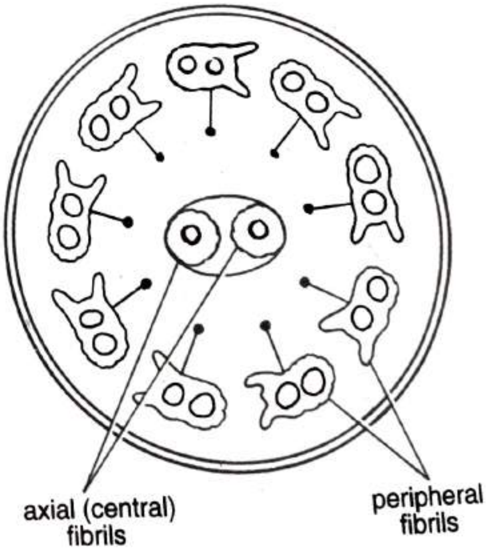

Fig. 15. Transection of a flagellum.

reservoir, and (iii) a **group of vacuoles** of varying sizes (Fig. 17). All these parts work in close coordination. These vacuoles are characteristic of Dinophyceae and Euglenophyceae.

Vacuoles act as the main osmoregulatory organ in the cell and help in regulating the absorption of water and solutes. In holozoic forms, the cytopharynx of complex vacuoles serves as gullet. Sometimes, vacuoles also store reserve food materials such as laminarin and chrysolaminarin.

[IX] Gas vacuoles

These gas containing cavities are characteristic of the mature healthy cells of Cyanophyceae. They occur as stacks of small transparent cylinders of uniform diameter. Their walls are freely permeable to gases. They render buoyancy to planktonic forms. They also act as a screen against intense light.

[X] Pigments

Algal cells have a characteristic colour due to the presence of a combination of pigments, specific to each class. In all classes, except Cyanophyceae, these pigments are present within membrane bound organelles, known as **plastids**. In blue-greens, the pigments are concentrated in the peripheral cytoplasm, known as **chromoplasm**. Plastids are of the following two types:

1. Leucoplast. These are colourless plastids.

2. Chromoplast. These are coloured plastids; those containing both chlorophyll *a* and chlorophyll *b* are called **chloroplasts** and those lacking chlorophyll *b* as **chromatophores**.

Different forms of chromatophores occur in algae. The following are the main types:

(1) **cup-shaped**, e.g., *Chlamydomonas* and *Volvox*.
(2) **discoid**, e.g., *Vaucheria*, *Chara* and centric diatoms.
(3) **girdle-shaped**, e.g., *Ulothrix*.
(4) **reticulate**, e.g., *Oedogonium*, *Hydrodictyon* and *Cladophora*.
(5) **spiral**, e.g., *Spirogyra*.
(6) **stellate**, e.g., *Zygnema*.

The various types of pigments found in the algal cell are given below.

1. Chlorophyll. There are five types of chlorophylls, viz. chl *a*, *b*, *c*, *d* and *e*. Of these, chlorophyll *a* is present in all groups of algae, chlorophyll *b* only in Chlorophyceae and Euglenophyceae, chlorophyll *c* largely in algae of marine habitats (Phaeophyceae, Cryptophyceae, Bacillariophyceae and Chrysophyceae), chlorophyll *d* in some red algae only as a trace constituent and chlorophyll *e* in certain Xanthophyceae such as *Vaucheria hamata* and *Tribonema bombycinum*.

2. Xanthophyll.* More than 20 types of xanthophylls are known. They are formed by the incorporation of molecular oxygen into carotene molecule. Many xanthophylls, common in higher plants (lutein, violaxanthin, and neoxanthin), are found in the members of Chlorophyceae and Phaeophyceae. Fucoxanthin is the main xanthophyll pigment of Phaeophyceae and diatoms whereas myxoxanthophyll, myxoxanthin and oscilloxanthin are found only in Cyanophyceae.

3. Carotenes. These are oxygen free alicyclic compounds, composed of isoprene units. The five types of carotenes occur in algae are: *a* **-carotene** in Chlorophyceae; Cryptophyceae and Rhodophyceae; **β-carotene** in all algal groups, except Cryptophyceae, **c-carotene** in Chlorophyceae; **E-carotene** in Bacillariophyceae, Cryptophyceae, Phaeophyceae and Cyanophyceae and **flavacene** in members of Cyanophyceae.

4. Phycobilins. These are water soluble complexes of protein and bile pigments, present in the photosynthetic tissue of plants. Phycobilins are red (phycoerythrin) and blue (phycocyanin) pigments which are confined to Rhodophyceae and Cyanophyceae respectively. They act as light harvesting pigments in photosynthesis and the light absorbed by them is transferred to chlorophyll *a*. Thus, like carotenoids, phycobilins are also accessory pigments.

[XI] Pyrenoids**

Pyrenoids are proteinaceous bodies present in chromatophores. These organelles are considered to be associated with the synthesis and storage of starch. In members of Chlorophyceae, pyrenoids are surrounded by starch plates. But in some algae such as diatoms, they accumulate lipids instead of starch.

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* Carotenes and xanthophylls together are known as carotenoids. Carotenoids are accessory pigments.

** Pyrenoids may arise *de novo* or by the division of pre-existing pyrenoids. They are absent in blue-green algae.

REPRODUCTION

The propagation in algae takes place by **vegetative**, **asexual** and **sexual** methods.

Vegetative Reproduction

The vegetative reproduction includes all those processes of propagation in which portions of the plant body become separated off to give rise to new individuals without any obvious changes in the protoplast or in other words, it does not involve rejuvenation of the protoplasts. It is the most common method of reproduction in algae and takes place by the following means:

1. Cell division or fission. It is the simplest method of propagation and is commonly found in unicellular algae (e.g., *Euglena*, *Chlamydomonas*), desmids and diatoms. In this process, the unicellular algal cell divides mitotically to form two daughter cells, each eventually grows into an independent organism.

2. Fragmentation. In filamentous forms like *Ulothrix*, *Oedogonium*, *Spirogyra* and *Zygnema* the thallus often breaks into small fragments. Each fragment has the capability to grow independently and forms a new thallus. The fragmentation of filaments may be due to mechanical pressure, dissolution of transverse walls or difference in turgor pressure between adjoining cells. In colonial blue-green algae, vegetative propagation takes place by fragmentation of larger colonies.

3. Hormogonia. It is a characteristic method of reproduction in blue-green algae. Under unfavourable conditions the trichome breaks into motile segments of varying length, called hormogonia. The fragmentation of parent filament into hormogonia may be due to the formation of intercalary heterocysts, specialized separation discs or necridia or due to death and decay of intercalary cells of the trichome. Hormogonia are commonly found in *Nostoc*, *Oscillatoria* and *Cylindrospermum*.

4. Formation of adventitious branches. Adventitious branches are formed in some large thalloid forms of algae. These branches, when get detached from the parent thallus, develop into new plants (e.g., *Dictyota*, *Fucus*). Adventitious branches like protonema, formed on the internodes of *Chara* or stolon of *Cladophora glomerata*, are found.

5. Tubers. On the rhizoids and the lower nodes of *Chara* some tuber like structures are formed due to storage of food material. When detached from the parent plant, the tuber produces an independent plant. Similar structures are also found in *Cladophora*.

6. Budding. In some algae (e.g., *Protosiphon*) vegetative propagation takes place by budding. Bud like structures are formed due to proliferation of vesicles. They eventually get separated from the parent plant by the formation of the septum, and have the capacity to form plants.

Asexual Reproduction

Asexual reproduction involves rejuvenation of the protoplast and the reproductive bodies are either naked or provided with a newly synthesized wall of their own. Further, it is accomplished by using specially differentiated cells that are capable of multiplying directly the alga without fusing with other cells. In some aspects, it is very similar to vegetative reproduction as both are accessory means of propagation and are not concerned with bringing together in one cell lineage the genes from different cell lineages. In general, it is a process whereby the protoplast is released from the algal cell and germinates to form a new plant. Asexual reproduction takes place by a variety of motile or non-motile spores (cells that germinate without fusing and form new individuals). These spores may be differentiated into the following broad categories on the basis of their structure.

1. Zoospores. These are motile, naked structures with two (e.g., *Chlamydomonas*, *Ectocarpus*), four (e.g., macrozoospores of *Ulothrix*) or many (e.g., *Oedogonium*, *Vaucheria*) flagella. The flagella are usually inserted anteriorly, but are lateral in some brown algae. The zoospore has a bit of chloroplast and an eye spot. The cell forming zoospore is known as zoosporangium. The protoplast of zoosporangium may form a single zoospore (e.g., *Oedogonium*, *Vaucheria*) or undergoes repeated divisions and each segment forms a zoospore (e.g., *Cladophora*). Zoospores are haploid or diploid. They are liberated by dissolution of parent cell wall or through a terminal pore. They are usually formed during the night and are liberated early in the morning. After liberation, they rest for sometime and then germinate to form new individuals.

2. Aplanospores. These are non-motile spores, commonly found in terrestrial algae, but some aquatic algae (e.g., *Ulothrix*, *Microspora*) also form them during drought conditions. They differ from zoospores in having a distinct wall and in the absence of flagella. Each cell may form a single aplanospore or its protoplast may divide to form many aplanospores.

3. Hypnospores. Aplanospores of some algae like *Pediastrum* and *Sphaerella* secrete thick walls to overcome prolonged period of desiccation. Such thick walled aplanospores are called **hypnospores**. Under favourable conditions, hypnospores germinate and grow into new individuals or their protoplast may form zoospores. The hypnospores of *Chlamydomonas nivalis* are red in colour due to the deposition of a pigment, haematochrome, in their walls.

4. Tetraspores. Diploid plants of some algae (e.g., *Polysiphonia*) form non-motile spores which are called **tetraspores**. They are formed within tetrasporangium, usually by meiosis, and are haploid. They germinate to form haploid plants.

5. Autospores. The aplanospores with a structure similar to the parent cell are called **autospores**. In *Scenedesmus* and many members of the order Chlorococcales (e.g., *Chlorella*) the aplanospores acquire all distinctive features of the parent cell before their liberation from the sporangium. The so formed autospores are infact replica of the parent cell, the only difference is that they are smaller in size.

6. Akinetes. In some algae vegetative cells develop into thick walled spore like structure with abundant food reserves. These are called **akinetes**. Unlike aplanospores, akinetes always have additional wall layers around the protoplast which are fused with the parent wall. They are resistant to unfavourable environmental conditions. The formation of akinetes, besides other factors, is affected by the availability of carbohydrates and light. They are found in many blue-green and green algae.

7. Exospores and endospores. In many blue-green algae the protoplast divides to form special type of non-motile spores, known as **exospores** and **endospores**. The cell that produces endospores becomes somewhat enlarged and its contents divide successively in three planes, forming four to many endospores (e.g., *Dermocarpa*). The exospores are formed externally; the protoplast of the cell comes out through a terminal pore and successively cuts spherical spores (e.g., *Chamaesiphon*).

Sexual Reproduction

All groups of algae, except Cyanophyceae, reproduce sexually when gametes fuse to form zygote. In contrast to vegetative and asexual reproduction, it leads to the creation of new combinations of genes by pooling together in one line of descent, the genes derived from the different parents, thus resulting in a reshuffling of the gene material. On the basis of the structure and physiological behaviour of sex organs and their complexity, the following six types of sexual reproduction are recognised in different groups of algae.

1. Autogamy. When two gametes of the same mother cell fuse to form a diploid nucleus, it is called **autogamy**. In this process there is only karyogamy (fusion of two gametic nuclei). The autogamy lacks incorporation of external genes. Hence, plants developing as a result of autogamy do not show new characters. Diatoms are the common example of autogamy.

2. Hologamy. In some unicellular forms (e.g., *Chlamydomonas*, *Dunaliella*) the vegetative cells of different strains (+) and (-) (female and male) behave as gametes and fuse to form zygote. From evolutionary point of view hologamy is more advanced than autogamy, as it involves fusion of two cells having different genetic constitution. But hologamy is an inefficient process from the point of view of propagation, as two vegetative cells fuse to form only one zygote.

3. Isogamy. In isogamy the two gametes which fuse to form zygote, are morphologically and physiologically similar. Such gametes are called isogametes, as they are indistinguishable into plus and minus strains. They are usually motile and flagellate. Isogametes are found in *Ulothrix*, *Chlamydomonas eugametos*, etc.

4. Physiological anisogamy. In some algae like *Spirogyra*, *Zygnema* and *Ectocarpus*, though gametes are similar in morphological characters, they show physiological variation with plus (+) and minus (-) strains.

5. Anisogamy. In anisogamy fusion takes place between morphologically and physiologically distinct gametes **(anisogametes)**. The male or microgametes are smaller and more active, whereas the female or macrogametes are larger and sluggish. *Chlamydomonas braunii* and *Pandorina* are common examples of anisogamy.

6. Oogamy. This is the most advanced type of sexual reproduction. In this process a large non-motile egg or ovum fuses with a small motile sperm or antherozoid (in Rhodophyceae, sperms are non-motile). Egg is formed within the oogonium and sperms within the antheridium. *Volvox*, *Oedogonium*, *Chara*, *Vaucheria*, *Sargassum*, *Batrachospermum* and *Polysiphonia* are common examples of oogamy.

TYPES OF LIFE-CYCLE

The growth and development of an alga passes through a number of distinct morphological and cytological stages. The sequence of these orderly changes is said to be **life cycle** or **life history**. In other words, the sequence of all the different phases or events, through which an organism passes from the zygote of one generation up to the zygote of next generation, is known as its life-cycle. The union of male and female gametes results in the formation of **zygote**. As there is doubling of chromosomal complement in zygote, it represents diploid state.

In some groups the original chromosome number is achieved by meiotic division of the zygote nucleus. Thus on germination the zygote produces haploid plants. In others, the zygotic nucleus divides mitotically and the resulting cells form a diploid phase, which later produces cells which are capable of meiotic division.

The various types of life-cycle met among algae can be broadly classified into the following five categories.

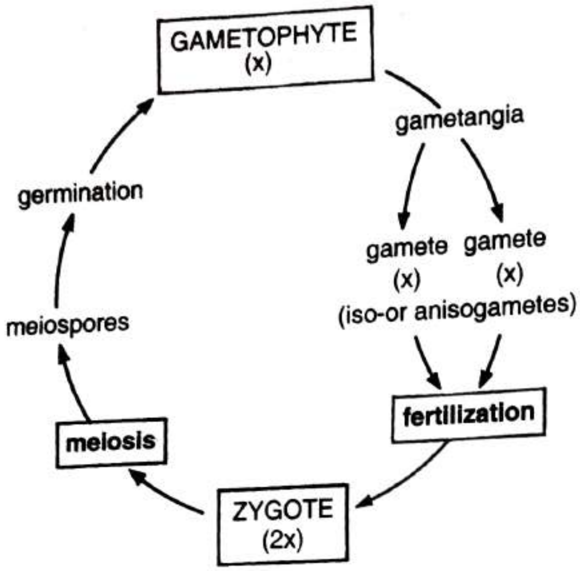


Fig. 18. Life-cycle pattern: Haplontic type.

Haplontic Type

In this type, plant is **haploid** and bears haploid gametes in the gametangium. The gametic fusion results in the formation of a **diploid** zygote which is the only diploid phase in the life cycle. The zygote nucleus divides meiotically to produce four meiospores, each of these develops into a new individual. Thus there is an alternation of a haploid plant with a diploid zygote. This type of life-cycle occurs in the motile unicellular forms (e.g., *Chlamydomonas*) and most multicellular green algae like *Ulothrix*, *Oedogonium*, *Spirogyra*, *Zygnema* and *Chara* (Fig. 18).

Diplontic Type

Here the plant is **diploid** and it bears sex organs (gametangia) which are also diploid. The reduction division takes place at the time of the formation of gametes and as such the gametes are haploid. After gametic fusion diploid stage is re-established in the form of zygote (Fig. 19). The zygote does not undergo any reduction division and it gives rise to a diploid plant body. Thus, there is an alternation of a diploid plant with haploid gametes. The gametes represent the only haploid stage in the life cycle of the plant. This type of life-cycle is found in some members of Chlorophyceae (e.g., *Cladophora glomerata*) and Phaeophyceae (e.g., *Fucus*, *Sargassum*) and nearly-all Bacillariophyceae (diatoms).

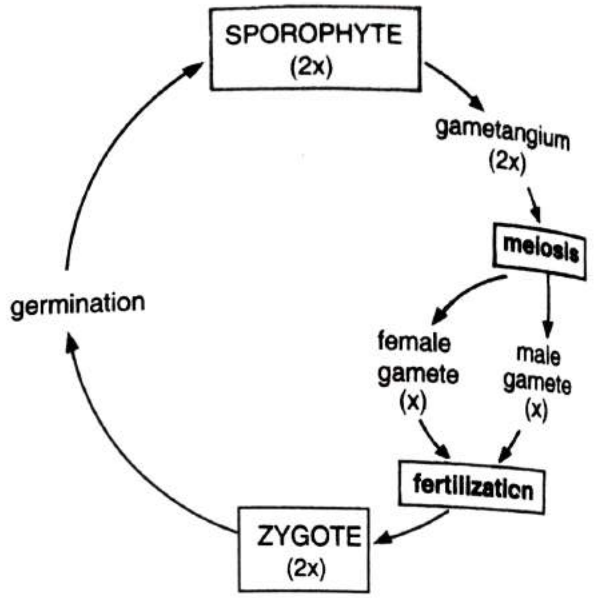


Fig. 19. Life-cycle pattern: Diplontic type.

Isomorphic Type

In this type of life-cycle, there is an alternation of two generations which are externally similar, but one is haploid (gametophyte) producing gametes and the other diploid (sporophyte) producing zoospores. The zygote germinates directly into a diploid plant without undergoing reduction division. Sporangia develop on the diploid plant body and reduction in the number of chromosomes takes place prior to the formation of zoospores. The haploid zoospores thus formed grow into haploid plants. Sex organs develop on the haploid plants and these give rise to haploid gametes. The haploid gametes fuse to form diploid zygote (Fig. 20). Isomorphic life cycle has

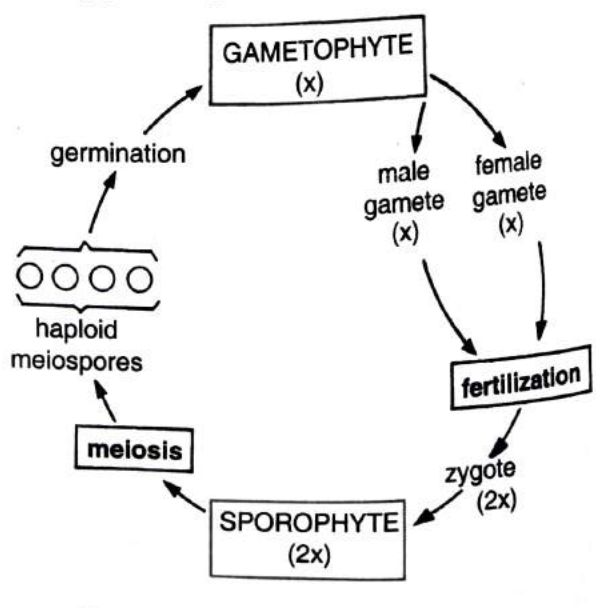


Fig. 20. Life-cycle pattern: Isomorphic type.

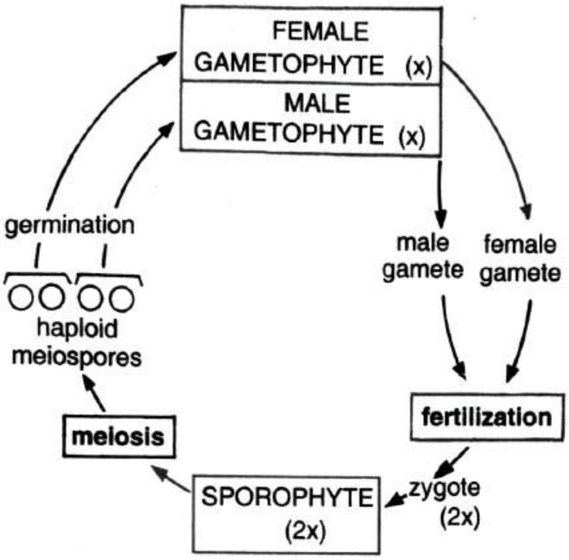


Fig. 21. Life-cycle pattern: Heteromorphic type.

been reported in a number of green algae (e.g., *Ulva, Enteromorpha, Cladophora, Draparnaldiopsis, Fritschiella*) and brown algae (e.g., *Ectocarpus*).

Heteromorphic Type

In this type of life-cycle, both **diploid** (sporophytic) and **haploid** (gametophytic) plant bodies are morphologically distinct (heteromorphic) and they alternate with each other. Mostly the sporophyte is large and the gametophyte small. Heteromorphic life cycle is seen mainly amongst brown algae (e.g., *Dictyota, Laminaria*, etc.). In *Dictyota*, there is a difference in cell size between the gametophyte and sporophyte, whereas in *Laminaria*, the haploid plant body consists of minute filaments which produce gametes, whilst the diploid plant body is a large macroscopic plant (attaining a length of several metres) bearing zoosporangia which produce zoospores after reduction division. The haploid zoospores germinate and produce haploid gametophytic plants. Haploid gametes are produced in sex organs formed on gametophytic plants. The gametes fuse to form a diploid zygote, which directly germinates into a diploid sporophytic plant. Besides heteromorphism of gametophyte and sporophyte generations, there is also slight heteromorphism of the male and female gametophytes, expressed as a difference in cell size and degree of branching (Fig. 21).

In genera like *Cutleria* and *Urospora*, haploid gametophytic plants are larger whereas diploid sporophytic plants are smaller in size.

Triphasic Type

In triphasic life-cycle, there is a succession of three generations. It may be of the following two types:

[I] Haplobiontic

In some Rhodophyceae like *Batrachospermum* and *Nemalion* two well developed haploid phases are present in the life-cycle. This type of life cycle is called **haplobiontic triphasic**. The diploid phase is represented only by the zygote. The plant body of *Batrachospermum* is gametophytic which bears sex organs (i.e., spermatangia and carpogonia). Haploid gametes (spermatium and egg) are formed in these sex organs. A diploid zygote is formed by the fusion of two gametes.

Gonimoblast filaments are formed from the basal part of the carpogonium; the uppermost cell of these filaments functions as carposporangium. The first division in the zygote nucleus is meiotic and as such the gonimoblast filaments are haploid. The haploid carposporangium bears a haploid carpospore. The gonimoblast filaments, carposporangia and carpospores are enveloped by numerous sterile filaments, and together represent carposporophyte generation which is haploid. On liberation, carpospores germinate into heterotrichous **chantransia stage**. The projecting filaments of the latter develop into new gametophytic plant body (Fig. 22).

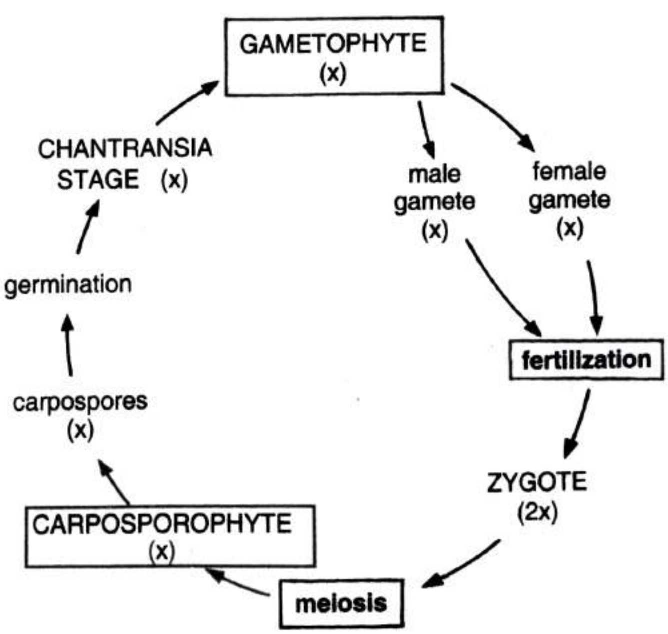


Fig. 22. Life-cycle pattern: Triphasic haplobiontic type.

[II] Diplobiontic

In **diplobiontic triphasic** life-cycle there are two diploid phases (carposporophyte and tetrasporophyte) alternating with haploid gametophytic phase. This type of life-cycle is well exemplified by *Polysiphonia* (Rhodophyceae). Here, the haploid phase is represented by male and female gametophytic plants, sex organs and gametes. The male and female gametes fuse to form a diploid zygote. The zygote produces **gonimoblasts** which represent an additional diploid phase (carposporophyte). Diploid carpospores are formed in the carposporophyte. On liberation, the carpospore germinates to produce a diploid tetrasporophytic plant. The tetrasporophytic plant produces diploid tetrasporangia. Four haploid tetraspores are formed in a tetrasporangium by reduction division. Tetraspores give rise to haploid gametophytic plants. The life cycle is thus completed (Fig. 23).

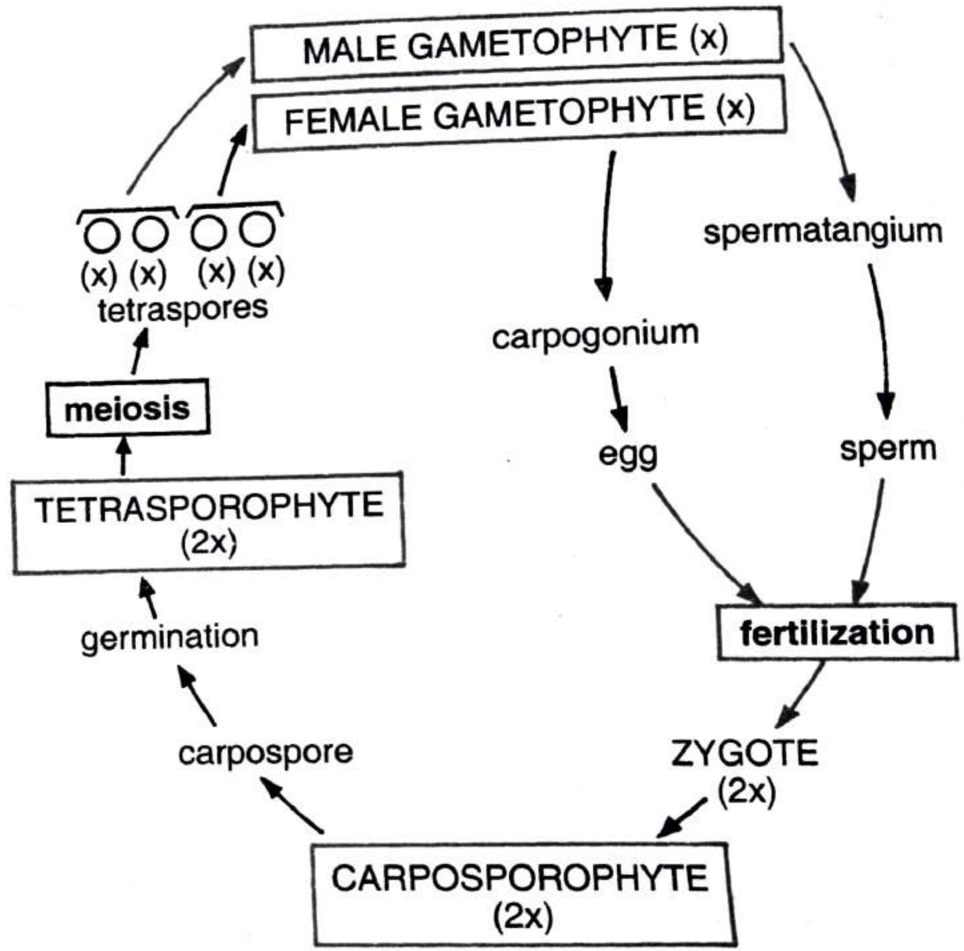


Fig. 23. Life-cycle pattern: Triphasic diplonbiontic type.

[II] Classification proposed by Smith

The classification of algae proposed by Smith (1933, 51, 55) is based on the physiological characteristics of vegetative cells and the morphology of motile reproductive cells. He divided algae into **seven divisions** and then related classes were included in each division.

The seven divisions of algae recognised by Smith are as follows:

Division 1. CHLOROPHYTA. This division includes about 6,750 species, of these 90% are fresh water and the remaining 10% are marine. Chlorophyll *a* and *b* are the dominant pigments; the reserve food is starch. Motile reproductive cells are usually bi- or quadriflagellate; flagella are equal, of whiplash type and anteriorly inserted.

The following **two classes** were included in this division.

Class 1. Chlorophyceae (grass-green algae; e.g., *Volvox*, *Ulothrix*, *Oedogonium*).

Class 2. Charophyceae (stoneworts; e.g., *Chara*).

Division 2. EUGLENOPHYTA. There are 450 fresh-water or terrestrial species in this division. The dominant pigments of these algae are chlorophyll *a*, *b* and β-carotene, and their reserve food is paramylum and fats. Motile cells may be uni-, bi-, or triflagellate; flagella anterior, inserted into a narrow gullet. Multiplication takes place usually by cell division. This division has only **one class**.

Class Euglenophyceae (euglenoids; e.g., *Euglena*).

Division 3. PYRROPHYTA. There are about 1,030 species, mainly unicellular and rarely colonial forms. The pigments are chlorophyll *a*, chlorophyll *c*, β -carotene and xanthophylls; the food reserve is starch and/ or oil. The cell wall is cellulosic. Motile cells are usually with two anteriorly inserted unlike flagella. Sexual reproduction is rarely present.

This division has been divided into the following **two classes**.

Class 1. Desmophyceae (dinophysids; e.g., *Exuviaella*).

Class 2. **Dinophyceae** (dinoflagelloids; e.g., *Dinophysis*, *Dinastridium*).

Division 4. CHRYSOPHYTA. This division is represented by more than 6,000 species, about three-fourth of which are fresh-water and one-fourth marine. These algae are characterised by the predominance of carotenes and xanthophylls. The food reserve is **leucosin** and oil. The cell wall is usually composed of two overlapping silicified halves. Sexual reproduction is iso-, aniso- , or oogamous.

This division includes the **three classes**:

Class 1. Chrysophyceae (golden brown algae; e.g., *Chromulina*).

Class 2. Xanthophyceae (yellow-green algae; e.g., *Botrydium*).

Class 3. Bacillariophyceae (diatoms; e.g., *Pinnularia*).

Division 5. PHAEOPHYTA (brown algae). There are about 1,000 species of brown algae, mostly marine. The dominant pigments are phycophein and fucoxanthin; the assimilatory products are **laminarin** (polysaccharide) and **mannitol** (alcohol). The cell wall is cellulosic with fucinic and alginic acids. Motile reproductive cells are pyriform with two laterally inserted flagella, one of which is of tinsel type. Sexual reproduction is iso-, aniso-, or oogamous type.

This division has been divided into the following **three classes**.

Class 1. Isogeneratae (e.g., *Ectocarpus*, *Sphacelaria*, *Dictyota*).

Class 2. Heterogeneratae (e.g., *Myrionema*, *Laminaria*).

Class 3. Cyclosporeae (e.g., *Sargassum*, *Fucus*).

Division 6. CYANOPHYTA (blue-green algae). This division is represented by 1,500 species, mostly fresh water. Some species are free-living, while others grow on larger algae or within the tissue of other plants. The cell is prokaryotic; the nucleus lacks nuclear membrane and nucleolus. In addition to other pigments, they contain a blue (c-phycocyanin) and a red (c- phycoerythrin) pigment. The food is stored in the form of cyanophycean starch. Motile stages are absent but vegetative filaments of some forms show gliding movements. Sexual reproduction is absent; asexual reproduction takes place by hormogonia, fragmentation, akinetes, etc.

The members of this division are placed in a single class, **Myxophyceae** or **Cyanophyceae** (e.g., *Nostoc*, *Anabaena*, *Oscillatoria*).

Division 7. RHODOPHYTA (red algae). This division includes about 2,500 species, mostly marine. They have a predominance of r-phycoerythrin which masks the other pigments to give them a distinctive red colour. They store food in the form of **floridean starch**. The thallus is non-motile and complex. Sexual reproduction is oogamous; motile reproductive cells are not found.

This division contains only **one class**, **Rhodophyceae** (e.g., *Batrachospermum*, *Polysiphonia*, *Chondrus*, *Gracilaria*).

5 Chlamydomonas

Class	:	*Chlorophyceae*
Order	:	*Volvocales*
Family	:	*Chlamydomonadaceae*
Genus	:	*Chlamydomonas*

Chlamydomonas is a ***green alga***. It is included in the class ***Chlorophyceae***. The plant body is ***motile*** and ***unicellular***. *Ehrenberg* named the genus *Chlamydomonas*.

Occurrence

Chlamydomonas is a ***free-floating, freshwater green alga.***

It is found in stagnant freshwaters of ***ponds, lakes, pools***, etc.

It is common in ***polluted water*** rich in ***organic matter*** and ***ammonium compounds***. It provides ***green turbidity*** to the ponds and lakes.

Some species are ***marine***. Eg. *Chlamydomonas halophila*.

A few species are ***terrestrial***.

Some species grow in ***snow fields*** and give the snow a characteristic colour. Eg. *Chlamydomonas nivilis* and *Chlamydomonas yellow stonensis*.

Chlamydomonas is ***world-wide*** in distribution. It includes about 500 species. 18 species of *Chlamydomonas* are found in India.

Examples

Chlamydomonas braunii
Chlamydomonas coccifera
Chlamydomonas grandistigma
Chlamydomonas eugametos
Chlamydomonas moewusii
Chlamydomonas monadina
Chlamydomonas subcaudata
Chlamydomonas iyengarii

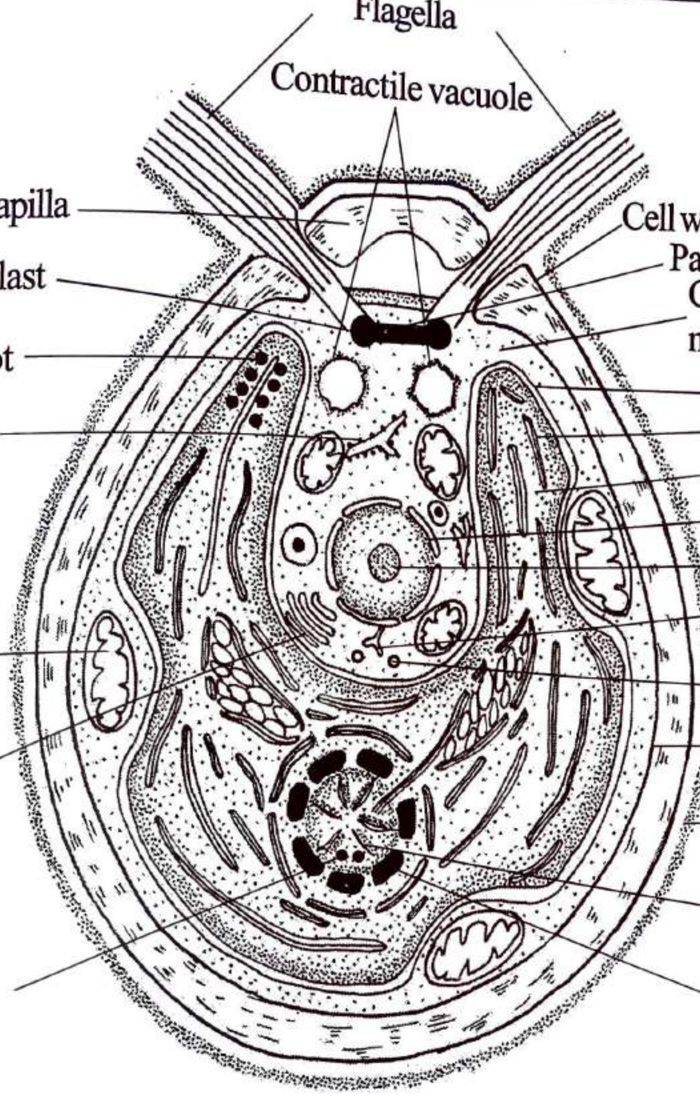


Fig. 5.2: Chlamydomonas - Electron Microscopic view.

Pyrenoid is the ***site of starch formation***. It functions as a ***temporary storage*** for early products of ***photosynthesis***, that are converted into starch.

Towards the anterior end, on one side of the chloroplast, there is a photo-receptive organ called ***eye-spot*** or ***stigma***. It governs the movement of the cell towards light.

There is a single large ***eukaryotic*** nucleus in the cytoplasm lying above the chloroplast.

Highlights

Pyrenoids

- *Pyrenoid is a protein granule surrounded by a starch sheath present inside the chloroplast of **Algae** and **Bryophytes**.*
- It is ***spherical*** in shape.
- It has a central ***proteinaceous core*** surrounded by ***starch plates***.
- The number of pyrenoids is one or more. In some species it is absent.
- In some species, the ***thylakoid membrane*** extends into the pyrenoid.

Functions

- Pyrenoid is the center of ***carbondioxide fixation.***
- It is the site of ***starch formation***.

- ***Microtubular roots*** originate from the paradesmose. They are distributed to the different parts of the body.

Nutrition

Chlamydomonas is ***autotrophic*** in nutrition.

It synthesizes its food from the carbondioxide dissolved in water using the sunlight. This process is called ***photosynthesis***. This mode of nutrition is known as ***photoautotrophic***.

The excess of food materials is stored as ***starch plates*** around the pyrenoid.

C.dysosoms is a facultative heterotroph and can grow in dark in the presence of acetate as a carbon source.

Highlights

Chlamydomonas

- *Chlamydomonas* is a ***motile, free- floating, unicellular green alga***.
- It is included in the class ***Chlorophyceae***.
- It is ***eukaryotic***.
- *Chlamydomonas* is a ***haploid gametophyte.***
- It is found in stagnant ***freshwaters*** of *ponds, rivers, slow running streams,* etc.
- It is ***pear-shaped***.
- It is narrow at its anterior end and broad at the posterior end.
- The anterior end bears two whiplash-type ***flagella***.
- It consists of an outer ***cell wall***, a middle ***plasma membrane*** and an inner ***protoplasm***.
- The ***cell wall*** is made up of ***cellulose***.
- The ***plasma membrane*** lies below the cell wall.
- The ***protoplasm*** contains a single cup-shaped *chloroplast, a nucleus, two contractile vacuoles, endoplasmic reticulum, ribosomes,* etc.
- ***Chloroplast*** contains ***pyrenoid, lamellae, stroma, chlorophyll*** and an ***eye - spot***.
- It is ***autotrophic*** in nutrition.
- Reproduction is of ***two*** types. They are:
    - *Asexual reproduction*
    - *Sexual reproduction.*
- Asexual reproduction takes place by-
    - *Zoospores*
    - *Aplanospores*
    - *Palmella stage.*
- Sexual reproduction involves the fusion of two haploid cells.
- There are ***four*** kinds of sexual reproduction -
    - *Isogamy*
    - *Anisogamy*
    - *Oogamy*

Reproduction

The reproduction in *Chlamydomonas* is of ***two*** types. They are:

- *Asexual reproduction*
- *Sexual reproduction.*

Asexual Reproduction

The asexual reproduction in *Chlamydomonas* takes place by

1. *Zoospores*
2. *Aplanospores*
3. *Palmella stage.*

1. Zoospores

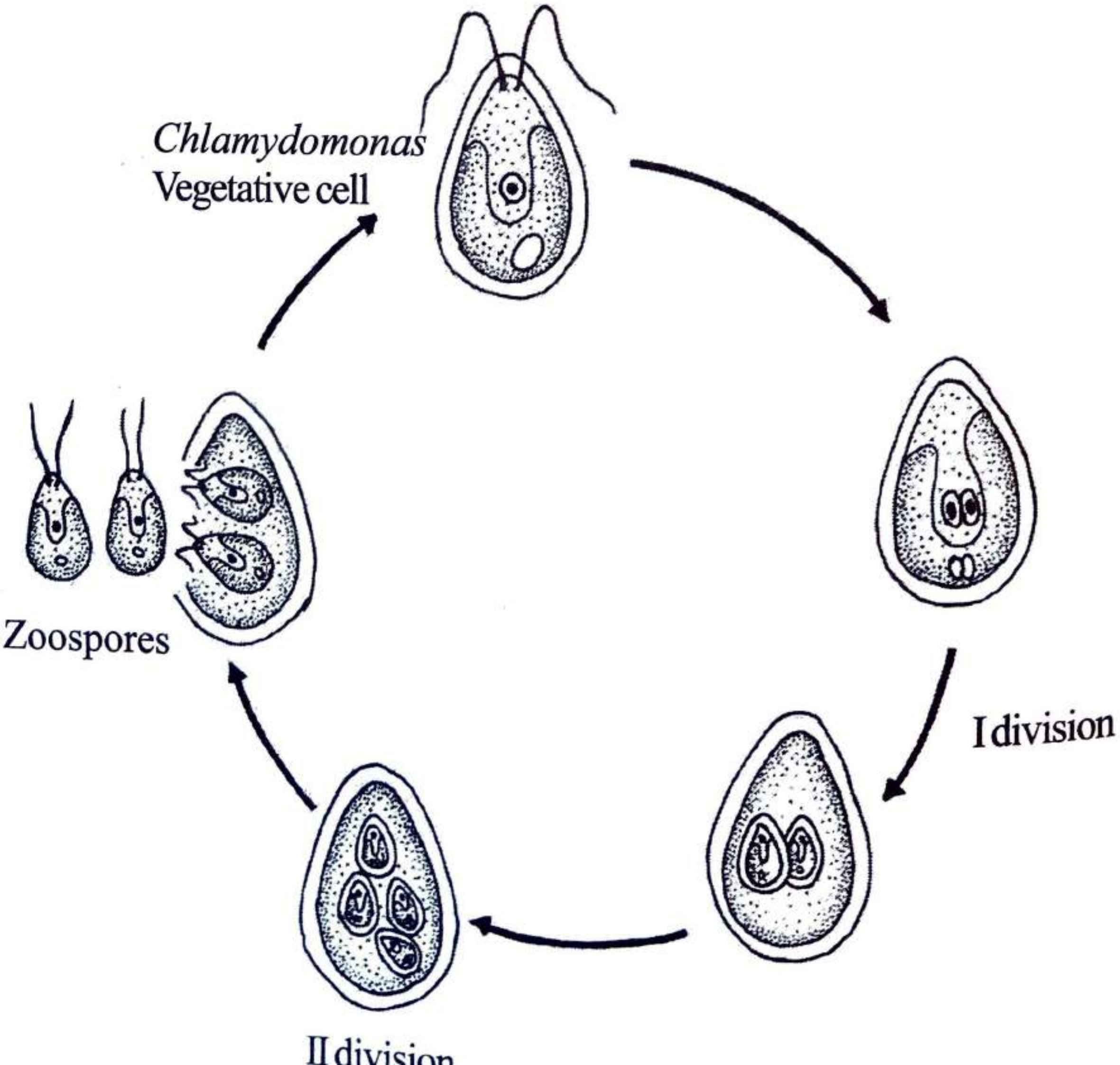
Zoospores are ***motile, biflagellate*, *asexual spores***.

They are usually produced during the ***favourable conditions*** when water is abundant.

The vegetative cell first comes to rest by dropping its flagella and becomes non-motile.

The protoplast of the cell then divides repeatedly to form 2, 4, 8 and16 daughter protoplasts.

Each daughter protoplast develops two equal flagella at its anterior end to become a ***zoospore***.



The mature zoospores are released free in the water by the rupture or gelatinisation of cell wall of the parent cell.

The liberated zoospores grow into new vegetative cells.

2. Aplanospores

Aplanospores are ***non-motile***, ***non-flagellate, asexual spores***.

They are produced during the ***dry season***. Here, protoplasm of a vegetative cell undergoes repeated divisions to form 8 or 16 daughter protoplasts. Each daughter protoplast then metamorphoses into a non-motile, non-flagellate, cell called ***aplanospore***.

When ***favourable*** season comes, it develops two flagella at its anterior end and grows into a new vegetative cell. Eg. *Chlamydomonas caudata*.

3. Palmella Stage

During ***unfavourable season*** non-motile *Chlamydomonas* cells remain embedded in an

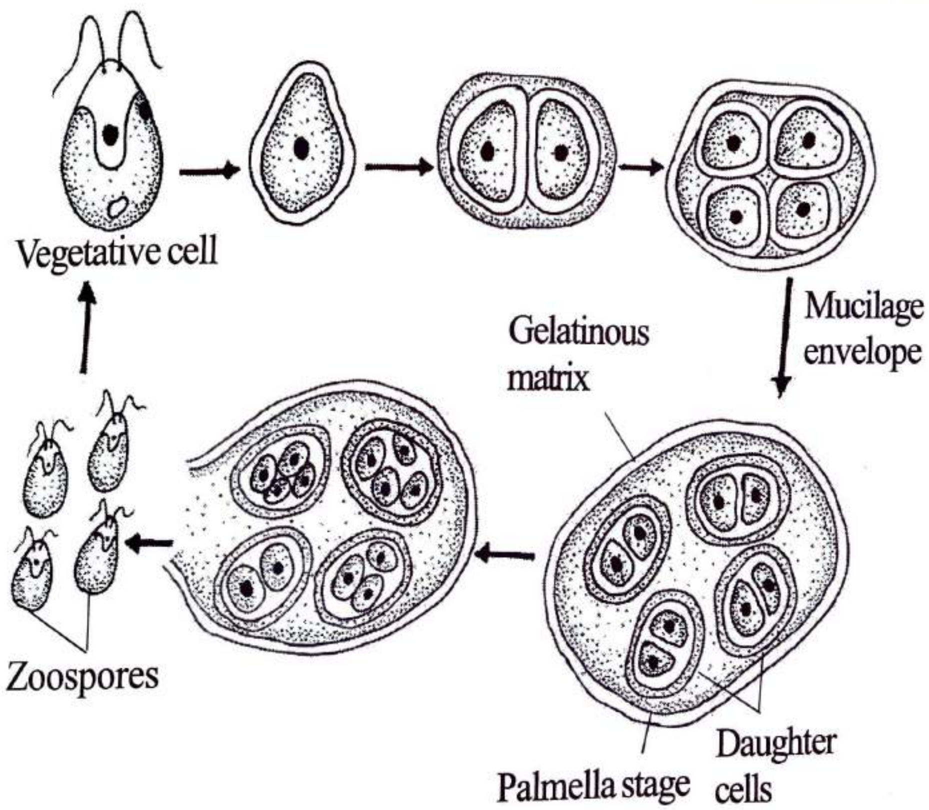


Fig. 5.5: Chlamydomona - Development of Palmella stage.

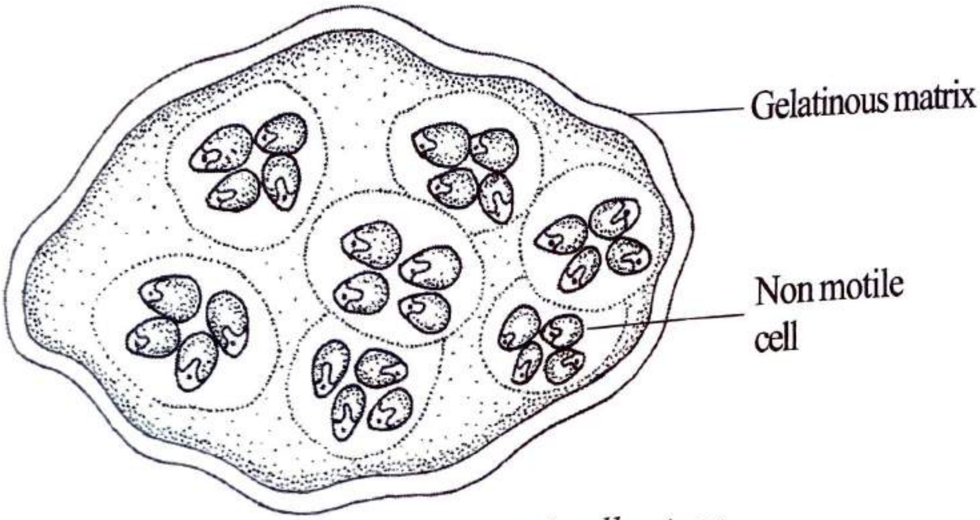


Fig. 5.6: Chlamydomonas - Palmella stage.

amorphous gelatinous matrix. As this stage resembles a colonial green alga ***Palmella***, this is known as ***Palmella stage***.

Palmella stage develops when conditions are ***unfavourable***.

The vegetative cell drops its flagella and its protoplast then divides repeatedly to form groups of 2-4 cells. These daughter cells do not develop flagella and lie within the parent wall.

The parent cell wall and the wall of the daughter cells become gelatinous and hence non-motile cells remain embedded in a common ***gelatinous matrix.***

In the next favourable season, these non-motile cells develop flagella and escape from gelatinous matrix to grow into new adult cells. Eg. *Chlamydomonas nivalis.*

Highlights

Palmella Stage

- Groups of non -motile *Chlamydomonas* cells remaining embedded in a common gelatinous matrix constitute ***Palmella stage.***
- As this stage resembles a colonial green alga *Palmella*, it is named so.
- It develops during ***unfavourable season***.
- It is involved in ***asexual reproduction***.
- ***Flagella*** is absent in the cells.
- During unfavourable season, the *Chlamydomonas* drops its flagella.
- The cell divides repeatedly to form groups of cells.
- The cells are surrounded by a ***gelatinous matrix***.

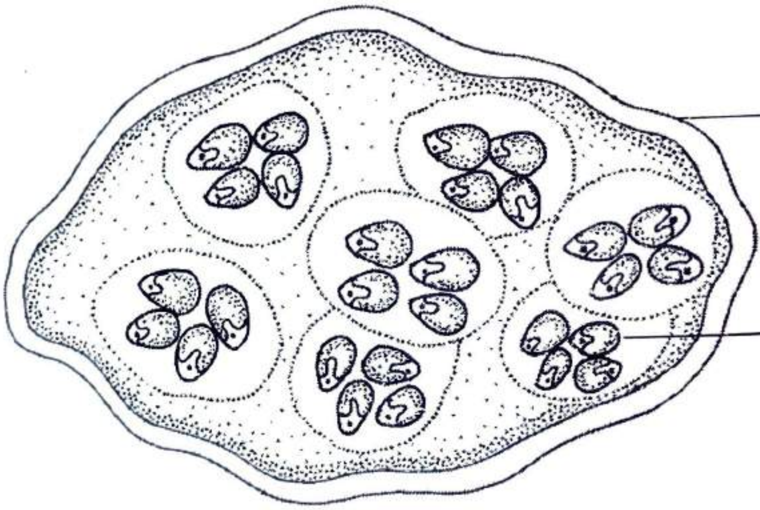


Fig. 5.7: Chlamydomonas - Palmella stage.

- During favourable condition, these non-motile cells come out from the gelatinous matrix and grow into new ***vegetative cells.***
- It helps in the ***multiplication*** of *Chlamydomonas*.

Sexual Reproduction

The sexual reproduction involves the fusion of two haploid cells. It takes place during ***unfavourable conditions***, such as *low nitrogen, high content of CO_2, bright sunlight, deficiency of nutrients, etc.*

Chlamydomonas is a ***haploid gametophyte***.

Most of the species produce male and female gametes in two separate individuals, and are known as ***heterothallic*** species. Eg. *Chlamydomonas moewusii.*

Some species are ***homothallic***. They produce gametes of two opposite strains in the ***same individual.*** Eg. *Chlamydomonas media.*

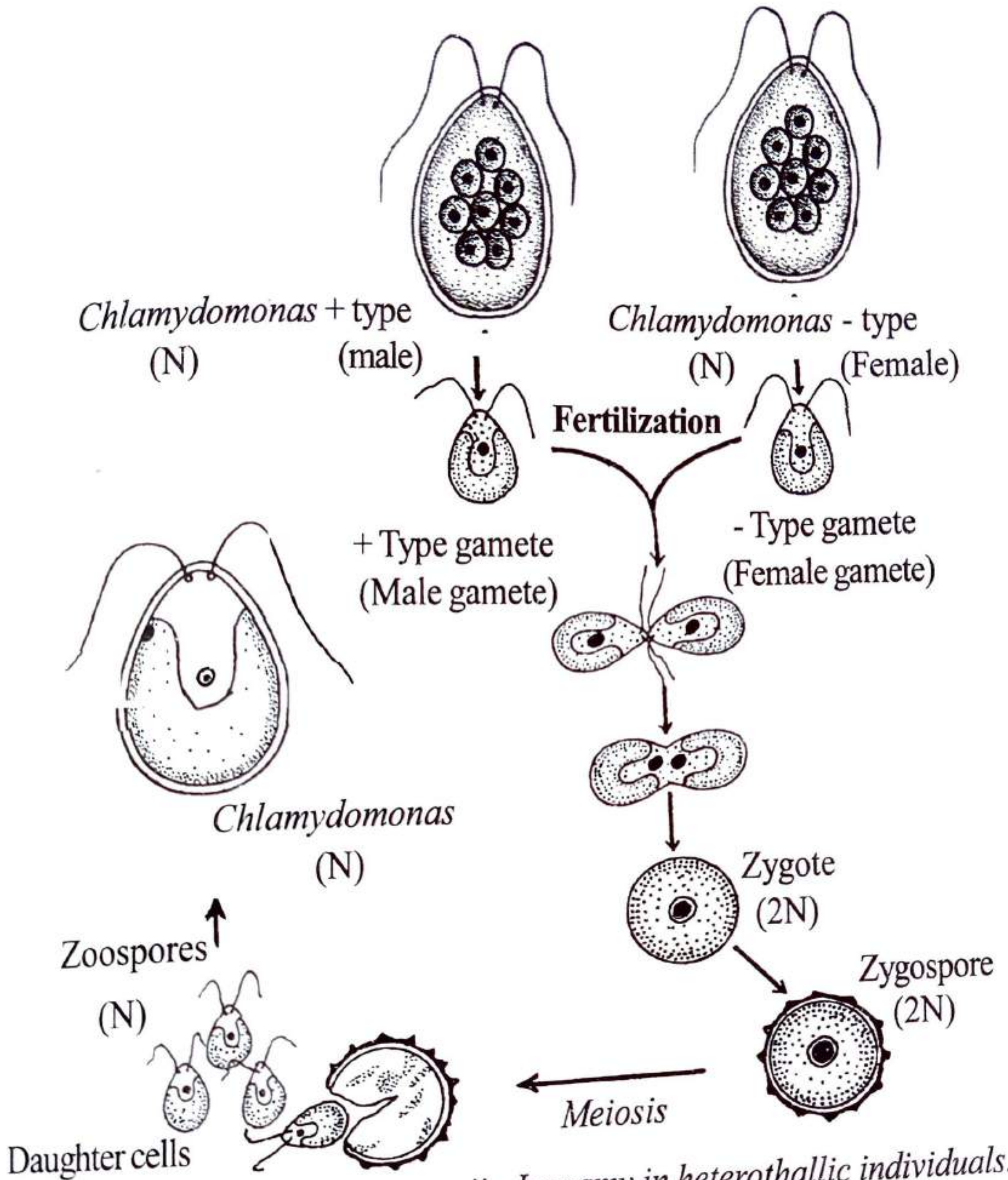


Fig.5.8: Chlamydomonas moewusii - Isogamy in heterothallic individuals.

There are four kinds of sexual reproduction in *Chlamydomonas*. They are:

1. *Isogamy*
2. *Anisogamy*
3. *Oogamy*
4. *Hologamy.*

1. Isogamy

Isogamy is a sexual reproduction where similar motile gametes fuse together to form a zygote. It takes place both in ***homothallic*** *and* ***heterothallic individuals.***

In ***heterothallic individuals***, the two fusing gametes are produced from two different parent cells. Eg. *Chlamydomonas moewusii*. The vegetative cells first lose their flagella and their protoplast undergoes repeated mitotic divisions to produce 16-64 daughter protoplasts.

Each daughter protoplast develops two equal flagella at its anterior end to form a ***gamete***.

The gamete of one parent is called + ***type*** (male) and that of the other parent is called - ***type*** (female). The flagella of gametes are covered by agglutinins, the chemical substances involved in the recognition of gametes of the opposite strains. These substances are not present in the flagella of the vegetative cells.

The flagella of two gametes of opposite strains adhere because of agglutins.

The gametes are released free in water.

A + type gamete (male) fuses with a -type gamete (female) to form a ***diploid zygote***.

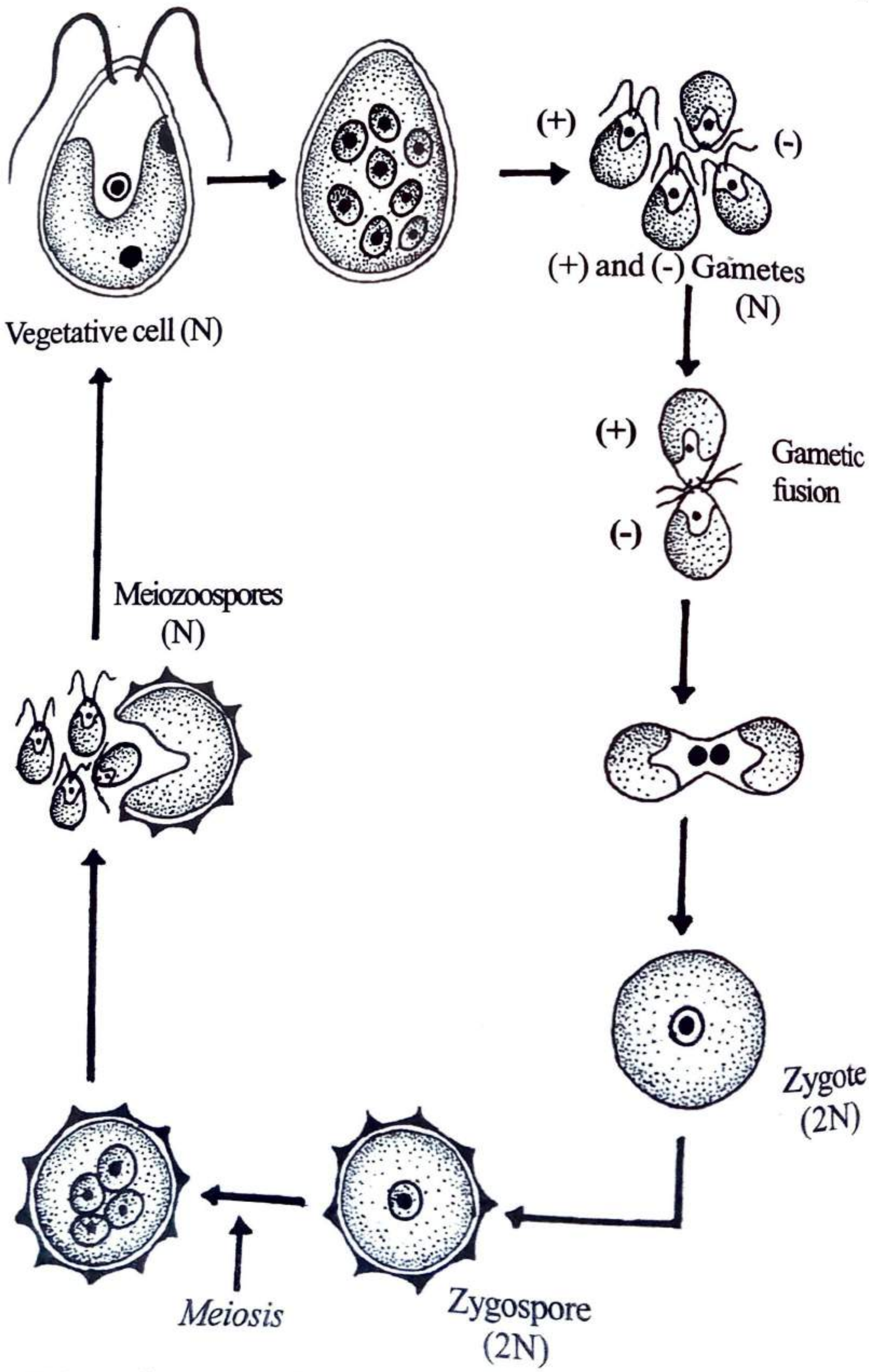


Fig. 5.9: Chlamydomonas - Isogamy in homothallic individuals.

The diploid zygote enlarges in size and secretes a thick wall around it. This thick-walled zygote is known as ***zygospore***.

After a period of rest, the zygospore starts germination during the favourable season.

The diploid nucleus of the zygospore undergoes a ***reduction division*** (***meiosis***) to form ***four haploid nuclei***.

Then the cytoplasm divides into four pieces, each of which collects around a nucleus to form a haploid protoplast.

Each protoplast develops two equal flagella to form a motile cell called ***meiozoospore***.

Thus four meiozoospores are formed inside a zygospore wall.

The wall of the zygospore ruptures and the zoospores are released in the water. These zoospores grow into new adult cells.

In ***homothallic species***, the gametes of two opposite mating types are produced by the same parent cell. Eg. *Chlamydomonas media.*

Here, a vegetative cell drops its flagella and its protoplast divides ***mitotically*** into 8 or 16 daughter protoplasts.

Each daughter protoplast develops two flagella and forms a ***gamete***. The flagella of gametes are covered by agglutinins, the chemical substances involved in the recognition of gametes of the opposite strains. These substances are not present in the flagella of the vegetative cells.

The flagella of two gametes of opposite strains adhere because of agglutinins. Two gametes fuse together by their anterior ends to form a ***zygote***.

The diploid zygote enlarges in size and secretes a thick wall around it. This thick-walled zygote is known as ***zygospore***.

After a period of rest, the zygospore starts germination during the favourable season.

The diploid nucleus of the zygospore undergoes a ***reduction division*** (***meiosis***) to form ***four haploid nuclei***.

Then the cytoplasm divides into four pieces, each of which collects around a nucleus to form a haploid protoplast.

Each protoplast develops two equal flagella to form a motile cell called ***meiozoospore***.

Thus four meiozoospores are formed inside a zygospore wall.

The wall of the zygospore ruptures and the zoospores are released in the water. These zoospores grow into new adult cells.

The zygote secretes a thick wall to form a ***zygospore***. It undergoes ***meiosis*** to form haploid ***zoospores***.

The zoospores develop into *Chlamydomonas* cells.

2. Anisogamy

Anisogamy is a sexual reproduction where dissimilar gametes fuse together to form a zygote. The gametes are ***motile***. These gametes are called ***anisogametes***. Eg. *Chlamydomonas braunii.*

The protoplasts of a vegetative cell undergoes mitotic divisions to form 8 or 16 haploid daughter protoplasts.

Each daughter protoplast develops two flagella to form a small male gamete called ***microgamete***.

The protoplast of another cell divides ***mitotically*** into 2 or 4 haploid daughter protoplasts. By developing two flagella, each daughter protoplast becomes a large female gamete called ***macrogamete***.

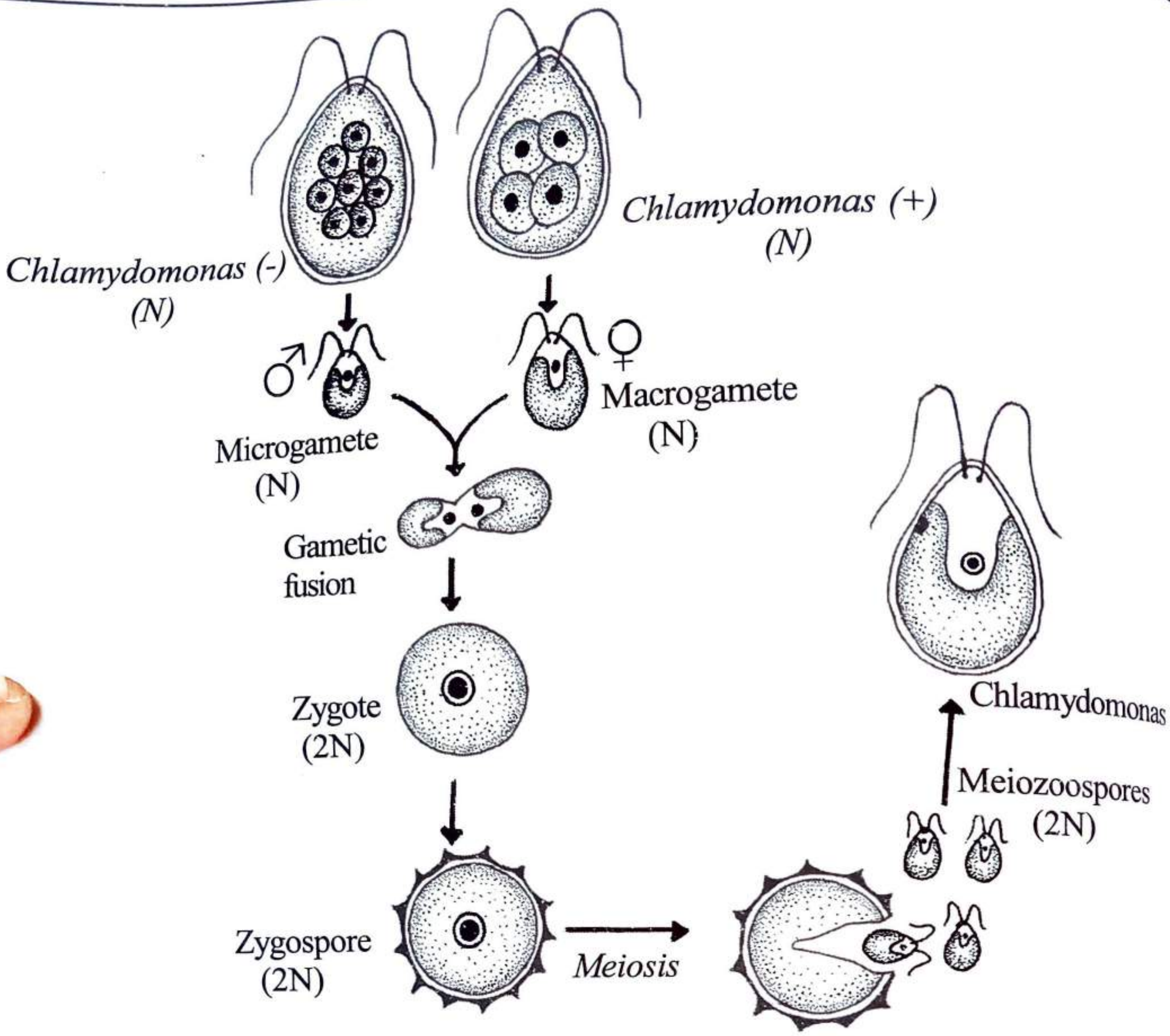


Fig. 5.10: Chlamydomonas braunii - Anisogamy.

The flagella of gametes are covered by agglutinins, the chemical substances involved in the recognition of gametes of the opposite strains. These substances are not present in the flagella of the vegetative cells.

The flagella of two gametes of opposite strains adhere because of agglutinins.

The microgamete fuses with a macrogamete to form a ***diploid zygote***.

The zygote secretes a thick wall to form a ***zygospore***.

The diploid zygote enlarges in size and secretes a thick wall around it. This thick-walled zygote is known as ***zygospore***.

After a period of rest, the zygospore starts germination during the favourable season.

The diploid nucleus of the zygospore undergoes a ***reduction division*** (***meiosis***) to form ***four haploid nuclei***.

Then the cytoplasm divides into four pieces, each of which collects around a nucleus to form a haploid protoplast.

Each protoplast develops two equal flagella to form a motile cell called ***meiozoospore***.

Thus four meiozoospores are formed inside a zygospore wall.

The wall of the zygospore ruptures and the zoospores are released in the water. The zoospores grow into new adult cells.

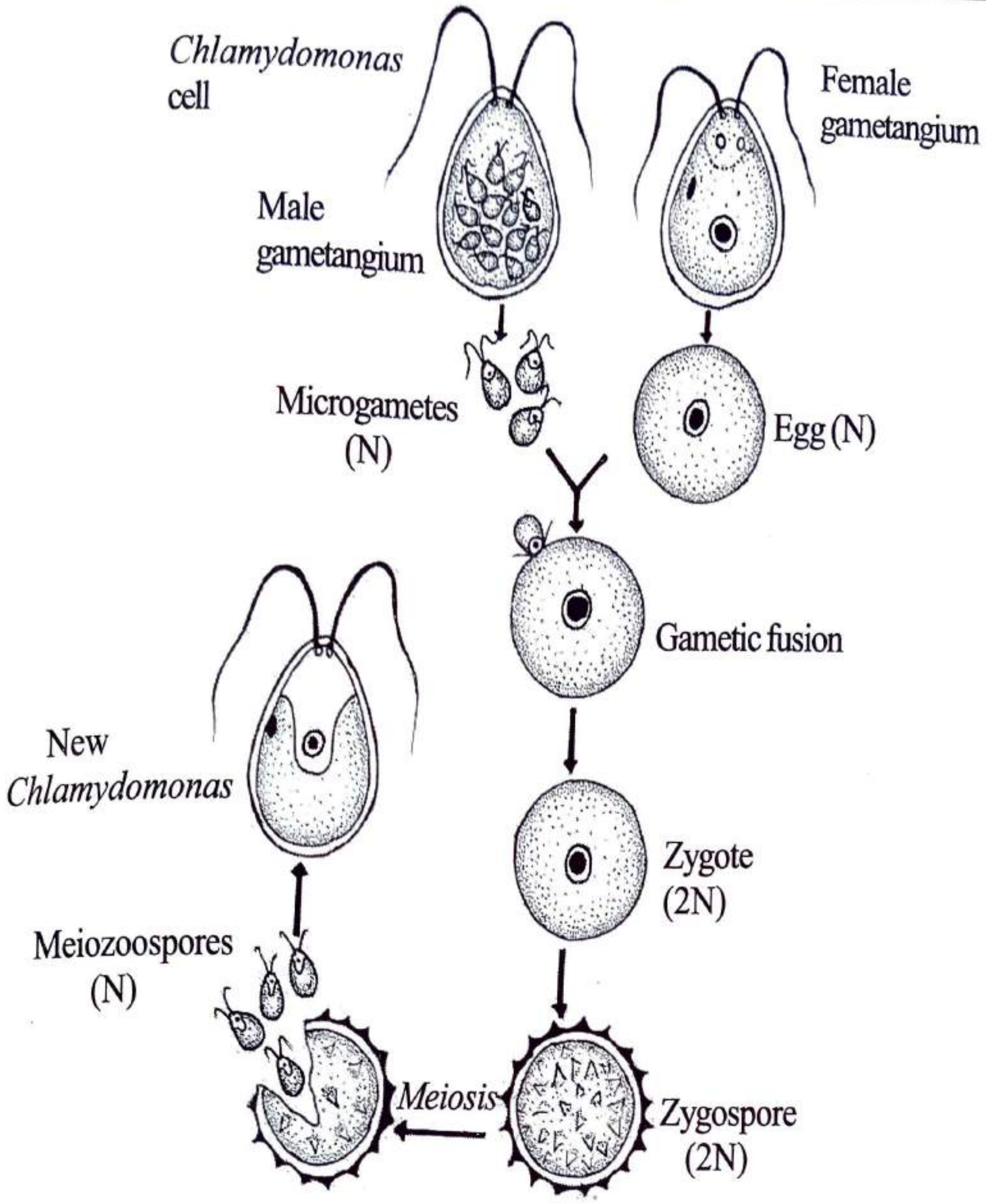


Fig. 5.11: Oogamy in Chlamydomonas oogonium.

3. Oogamy

Oogamy, is a sexual reproduction where a ***small motile*** *male gamete fuses with a larger, non-motile female gamete to form a zygote. Eg. Chlamydomonas oogamum.*

The protoplast of a vegetative cell undergoes mitotic divisions to form 16 or 32 daughter protoplasts.

Each protoplast becomes a ***biflagellate male gamete***.

At the same time, another vegetative cell drops its flagella, and becomes enlarged and rounded. This round cell is called ***egg*** or ***ovum***. It is ***non-motile*** and ***non-flagellate***.

The male gamete migrates towards the egg and fuses with it to form a ***diploid zygote***.

4. Hologamy

In *Chlamydomonas eugametos*, the vegetative cells as such function as gametes and fuse together to form a ***diploid zygote***. This type of fusion is called ***hologamy***.

Conclusion

The life cycle of *Chlamydomonas* is ***haplontic***. The vegetative cell is a ***haploid gametophyte*** (N). Asexually, it reproduces by ***zoospores***, ***aplanospores*** and ***palmella stage***.

It reproduces sexually by ***haploid gametes*** by simple mitotic division of ***gametophytic cell***.

The gametes may be ***isogametes*** or ***anisogametes*** or ***oogametes*** or ***holo gametes***. Two haploid gametes fuse together to form a ***diploid zygote*** (2N). This zygote undergoes ***meiosis*** to form four ***haploid meiozoospores***. The haploid meiozoospores develop into ***haploid gametophytes*** (N).

Here, the haploid phase is dominant and the diploid phase is represented only by the zygote. Hence the life cycle is known a ***haplontic type.*** There is ***no alternation of generation.***

Life Cycle of *Chlamydomonas*

Chlamydomonas is a ***motile, free-floating, unicellular green alga.*** It is found in stagnant freshwaters of *ponds, lakes, pools*, etc. Some species occur in seas and even in snow-fields.

The plant body is a ***haploid gametophyte*** (N). It is ***microscopic*** and usually ***pear-shaped.***

The cell consists of a ***cell wall***, a ***plasma membrane*** and ***protoplasm***.

The ***cell wall*** is composed of ***cellulose***. At the anterior end of the cell, the cell wall forms a small projection called ***papilla***. Inner to the cell wall is a ***plasma membrane*** enclosing the ***protoplasm***.

There is a large cup-shaped chloroplast at the posterior part of the protoplasm. It contains ***chlorophyll-a*** and ***b, γ - carotenes*** and ***xanthophylls***.

A single ***pyrenoid*** lies embedded in the chloroplast. It consists of a central ***protein core*** surrounded by ***starch plates***.

Towards the anterior end, on one side of the chloroplast, there is a photo-receptive organ called ***eye-spot.***

There is a large ***eukaryotic nucleus*** in the cytoplasm lying above the chloroplast.

Two ***contractile vacuoles*** are present just below the papilla.

The ***cytoplasm*** contains small *endoplasmic reticulum, dictyosomes, mitochondria* and *starch granules*.

The cell has two equal, ***whiplash type flagella*** at its anterior end. They are connected with the nucleus by ***neuromotor apparatus***.

Chlamydomonas synthesizes its food from ***carbondioxide*** and ***water*** using sunlight. Hence it is ***photoautotrophic*** in nutrition. ***Starch*** is the ***reserve food*** material.

Chlamydomonas reproduces by two methods, namely :

Asexual reproduction

Sexual reproduction.

The asexual reproduction takes place by means of ***zoospores, aplanospores*** and ***Palmella stage.***

The zoospores are ***motile, biflagellate*** asexual spores. They are produced when there is abundant water.

The vegetative cell drops its flagella and then its protoplast divides ***mitotically*** to form 8 or 16 daughter protoplasts.

Each protoplast develops two equal flagella at its anterior end and becomes a ***zoospore***.

The zoospores are released free by the rupture of parent cell wall. The zoospores grow into new vegetative cells.

The aplanospores are ***non-motile, non-flagellate*** asexual spores. They are produced in some terrestrial species during the dry season. The protoplast of a vegetative cell divides ***mitotically*** into 8 or 16 daughter protoplasts. Each daughter protoplast develops into a non-flagellate ***aplanospore***.

During the favourable season, the aplanospores develop two equal flagella, come out of the parent cell and grow into new vegetative cells. Eg. *Chlamydomonas caudata*.

During unfavourable season the vegetative cell, drops its flagella and its protoplast divides ***mitotically*** so as to form 2-4 cells. They do not develop flagella and lie within the parent cell wall.

The cell wall of the parent cells and daughter cells get gelatinised so that many non-motile cells lie embedded in a gelatinous matrix. As this stage resembles a green alga *Palmella*, it is known as ***Palmella stage.***

In the next growing season, the cells of Palmella stage develop two flagella and grow into new vegetative cells. Eg. *Chlamydomonas nivalis*.

The ***sexual reproduction*** involves the fusion of two haploid gametes. Most species of *Chlamydomonas* are ***heterothallic*** so that they produce male and female gametes in two separate individuals. Eg. *Chlamydomonas moewusii*. Some species, however, are ***homothallic*** so that they produce male and female gametes in the same individual. Eg. *Chlamydomonas media*.

The sexual reproduction is of ***four*** types :

1. Isogamy

2. Anisogamy

3. Oogamy

4. Hologamy.

In isogamy, the two fusing gametes are ***morphologically alike*** and ***motile*** and the gametes are known as ***isogametes***.

In ***heterothallic*** species the gametes are ***self-incompatible***, so fusion takes place between gametes of two different parents.

In ***homothallic*** species, the gametes are ***self-compatible,*** so that fusion takes place between two gametes of an individual.

The vegetative cell loses its flagella and its protoplast undergoes mitotic divisions to form 16 to 64 daughter protoplasts. These daughter protoplasts develop two equal flagella to form gametes.

The gametes are released by the rupture of parent wall. Two gametes fuse together to form a diploid ***zygote*** (2N). The zygote secretes a thick wall to become a ***zygospore***. Eg. *C. media.*

In anisogamy the two fusing gametes are ***dissimilar*** and ***motile***. The gametes are known as ***anisogametes***.

The protoplast of one cell undergoes ***mitotic*** divisions to form 8 or 16 daughter protoplasts. Each daughter protoplast develops into a biflagellate male gamete called ***microgamete***.

The protoplast of another cell divides into 2 or 4 daughter protoplasts. They later become biflagellate female gametes called ***macrogametes***.

A microgamete fuses with a macrogamete to form a diploid ***zygote*** (2N). Eg. *Chlamydomonas braunii.*

In Oogamy, the ***male gamete is small*** and ***motile*** due to the presence of flagella and the ***female gamete*** is ***larger*** and ***non-motile.***

The protoplast of a vegetative cell divides into 16 or 32 daughter protoplasts. They develop two flagella to form small biflagellate ***male gametes***.

At the same time, a vegetative cell loses its flagella and becomes enlarged and rounded. This round cell is called an ***egg*** or ***ovum***. It is ***non-motile.***

The male gamete moves towards the egg and fuses with it to form a diploid ***zygote.*** Eg. *C.Oogamum.*

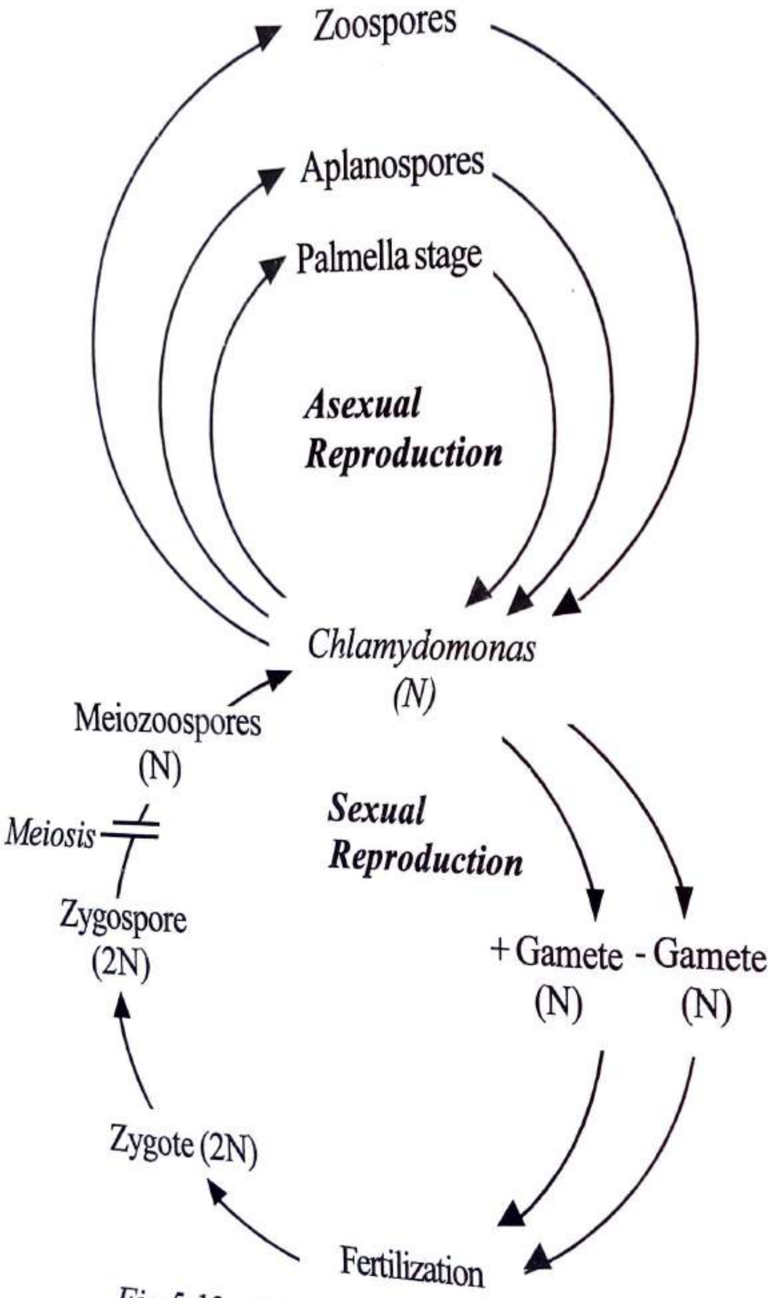


Fig.5.12: Chlamydomonas - Graphic life cycle.

The zygospore, after a period of rest, starts its germination. The diploid nucleus first divides ***meiotically*** into four ***haploid nuclei***. This is followed by ***cytokinesis*** to form four ***haploid protoplasts.*** These haploid protoplasts develop cell wall and two flagella to form ***meiozoospores***.

The meiozoospores come out by the rupture of zygospore wall and grow into new ***haploid gametophytic cells*** (N).

In *Chlamydomonas eugametes*, the haploid vegetative cells as such act as gametes and fuse together to form a ***zygote***. This type of fusion is called ***hologamy***.

Conclusion

The life cycle of *Chlamydomonas* is ***haplontic***.

The vegetative thallus is a ***haploid gametophyte*** (N).

Asexually it produces new gametophytes by means of haploid ***zoospores***, ***aplanospores*** and ***Palmella stage***.

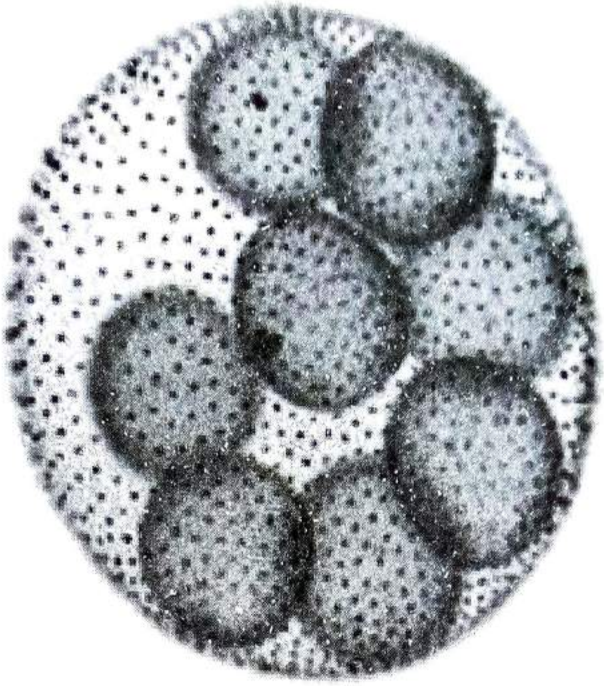
It produces sexually haploid gametes (N) by simple ***mitotic*** division. Two haploid gametes fuse together to form a ***diploid zygote*** (2N). The zygote undergoes ***meiosis*** to form four ***haploid meiozoospores***. The haploid meiozoospores develop into ***haploid gametophytes*** (N).

In the life cycle the ***haploid*** phase is dominant and the diploid phase is represented only by the zygote. Hence the life cycle is known as ***haplontic type.***

Highlights

Life Cycle of *Chlamydomonas*

- *Chlamydomonas* is a ***motile, free - floating, unicellular green alga***.
- It is included in the class ***Chlorophyceae***.
- It is found in stagnant ***freshwaters***.
- *Chlamydomonas* is a ***haploid gametophyte***.
- It is ***eukaryotic.***
- It is ***pear - shaped.***
- The cell consists of ***cell wall, plasma membrane*** and ***protoplasm***.
- It consists of an outer ***cell wall***, a middle ***plasma membrane*** and an inner ***protoplasm***.
- The ***cell wall*** is made up of ***cellulose***.
- The ***plasma membrane*** lies below the cell wall.
- The ***protoplasm*** contains a single cup-shaped *chloroplast, a nucleus, two contractile vacuoles, endoplasmic reticulum, ribosomes,* etc.
- ***Chloroplast*** contains ***pyrenoid, lamellae, stroma, chlorophyll*** and an ***eye - spot***.
- It is ***autotrophic*** in nutrition.
- It reproduces by ***two*** methods namely:
  - *Asexual reproduction*
  - *Sexual reproduction.*
- Asexual reproduction takes place by -
  - *Zoospores*
  - *Aplanospores*
  - *Palmella stage.*
- ***Zoospores*** are motile, biflagellate asexual spores. They are liberated from the parent cell and grow into new vegetative cells.
- ***Aplanospores*** are non-motile, non-flagellate asexual spores. They come out of the parent cell and grow into new vegetative cells.
- In ***Palmella stage***, cells remain embedded in an amorphous gelatinous matrix. During ***favourable*** season, these non-motile cells come out from the gelatinous ***matrix*** and grow into new vegetative cells.



6 *Volvox*

Class	:	*Chlorophyceae*
Order	:	*Volvocales*
Family	:	*Volvocaceae*
Genus	:	*Volvox*

Volvox is a ***green alga.*** It is included in the class ***Chlorophyceae. Linnaeus*** named the genus, *Volvox*.

Occurrence

Volvox is a ***colonial green alga***.

It is a ***freshwater alga***. It is found in *ponds, lakes, tanks, pools, ditches,* etc. During favourable season, it grows vigorously to form ***water blooms*** and gives ***green colour*** to the water. *Volvox* colony floats during bright light and goes deep during night.

Volvox includes about 20 species. There are five species of *Volvox* in India.

Volvox africanus *Volvox prolificus* *Volvox merelli.*
Volvox globator *Volvox rousseletii*

Structure of *Volvox*

Volvox is a ***colonial green alga***. It is included in the class ***Chlorophyceae***.

It is a ***freshwater*** alga.

It is a ***free-floating*** form. It is ***spherical*** in shape.

It is ***macroscopic***. It is visible to the naked eye in the size of a ***pin-head.***

Volvox colony is 1to1.5mm in diameter. The colony of *Volvox* consists of 500 to 50,000 *Chlamydomonas*-like cells.

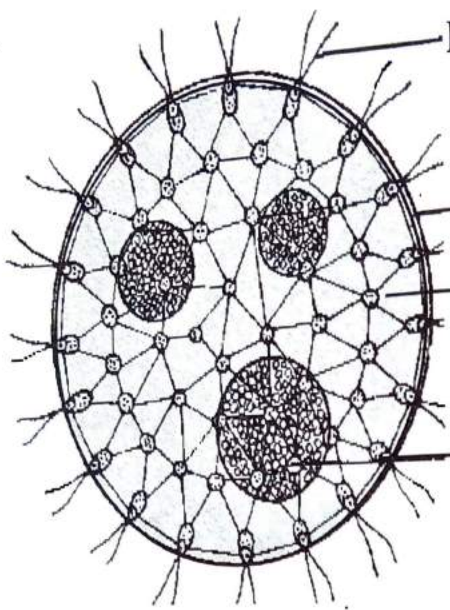
Volvox is an assemblage of similar and independent cells.

Each cell functions like an individual, carrying out its own nutrition, respiration and excretion.

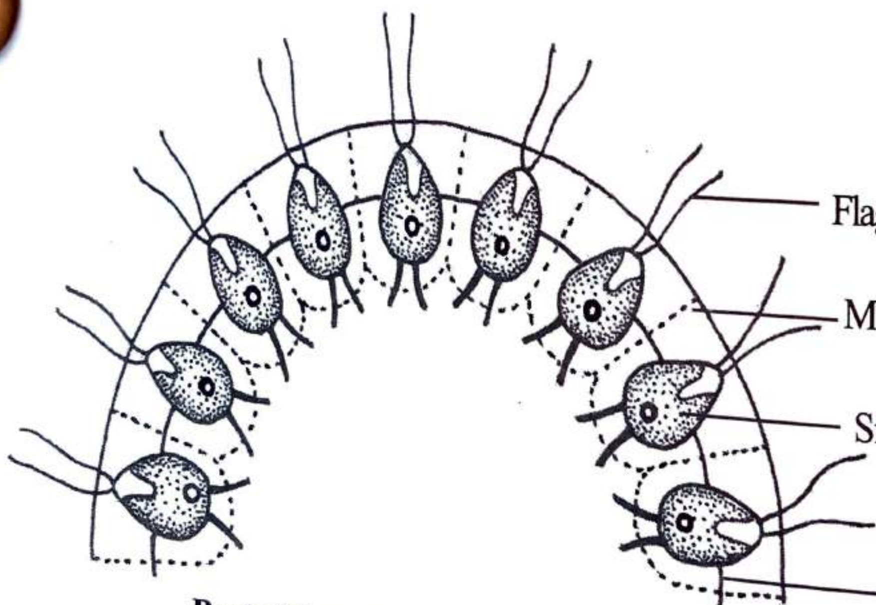
Volvox is a ***haploid gametophyte***. It is a ***colony***. The colony is ***spherical*** in shape.

The colony is made up of *Chlamydomonas*-like cells. The ***number*** and ***arrangement*** of cells in a ***particular*** colony are definite. Hence the colony is called a ***coenobium***.

The cells of the colony are embedded in a mass of ***mucilage.*** Each cell is also surrounded by a ***mucilage sheath.*** The cells are interconnected by protoplasmic strands called ***plasmodesmata.***



An entire colony



Part of the colony showing detailed structure

Fig. 6.1: Volvox colony.

The cells are arranged as a ***single layer*** along the periphery of the colony. The centre of the colony is ***hollow*** and it is filled with ***mucilage.***

The colony has a ***polarity.*** It has an ***anterior*** side and a ***posterior*** side.

At the posterior side of the colony, there is a perforation called ***phialopore***.

The cells of *Volvox* resemble a *Chlamydomonas*. They are ***green*** in ***colour.*** Each cell is ***oval*** in shape. Its anterior end is ***pointed*** and the posterior end is ***rounded***. The anterior end faces outwards.

The cell is surrounded by a ***cell wall*** made up of ***cellulose***. A thin ***plasma membrane*** lies below the cell wall. The plasma membrane surrounds the ***protoplasm.***

The anterior end has a ***thickening of cell-wall*** called ***papilla.*** The anterior end bears two ***flagella.*** The flagella arise from ***basal granules***. The flagella are ***equal in length***. They bring out the movement of the colony.

The protoplasm contains a pair of ***contractile vacuoles*** near the anterior end. A ***nucleus*** is present in the centre. The nucleus is ***eukaryotic*** and ***haploid.***

A large ***chloroplast*** is situated at the posterior side of the protoplasm. It is cup-shaped. The chloroplast contains pigments like ***chlorophyll-a*** and- ***b, carotenes*** and ***xanthophyll.*** The chloroplast has an ***eye-spot*** anteriorly and a ***pyrenoid*** in the centre. ***Starch*** is stored in the ***pyrenoid*** in the form of ***starch plates.***

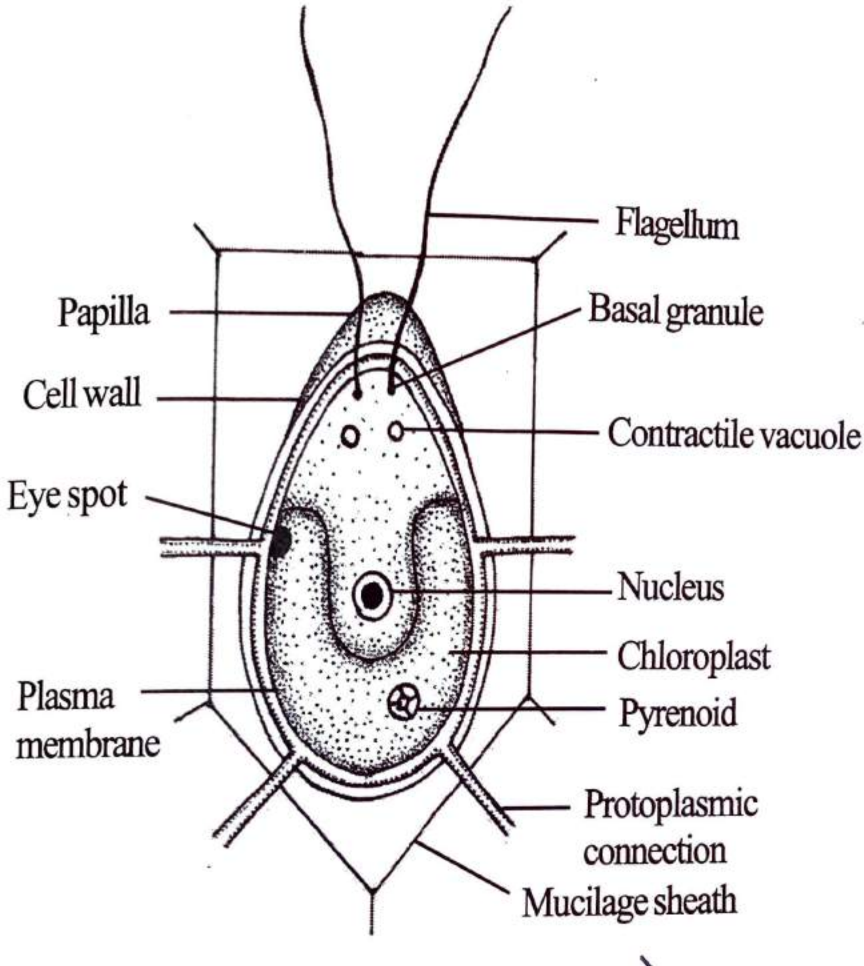


Fig.6.2: Volvox-A single cell.

Highlights

Volvox

- *Volvox* is a free ***floating, freshwater, macroscopic*** and ***colonial green alga.***
- It is included in the class ***Chlorophyceae.***
- It is a ***haploid gametophyte.***
- It is a ***colony***.
- It is a ***plant animal***.
- It is made up of *Chlamydomonas* like cells.
- Each cell of *Volvox* is covered by a ***mucilage sheath*** and the cells are inter-connected by ***protoplasmic strands*** called ***plasmodesmata.***

Nutrition and Movement

Volvox is ***photoautotrophic*** in nutrition. It synthesizes ***starch*** using CO_2 and ***sun light***. This process is called ***photosynthesis***. It moves by ***rotary*** type of movement using the flagella.

Highlights

Reproduction

Volvox reproduces by ***two methods*** -

Asexual reproduction

Sexual reproduction

Asexual Reproduction

In *Volvox*, asexual reproduction takes place by the formation of ***daughter colonies*** from ***gonidia.***

It takes place during ***favourable season.*** At the posterior part of a mature colony, ***2-20 cells*** enlarge and function as reproductive cells called ***gonidia.***

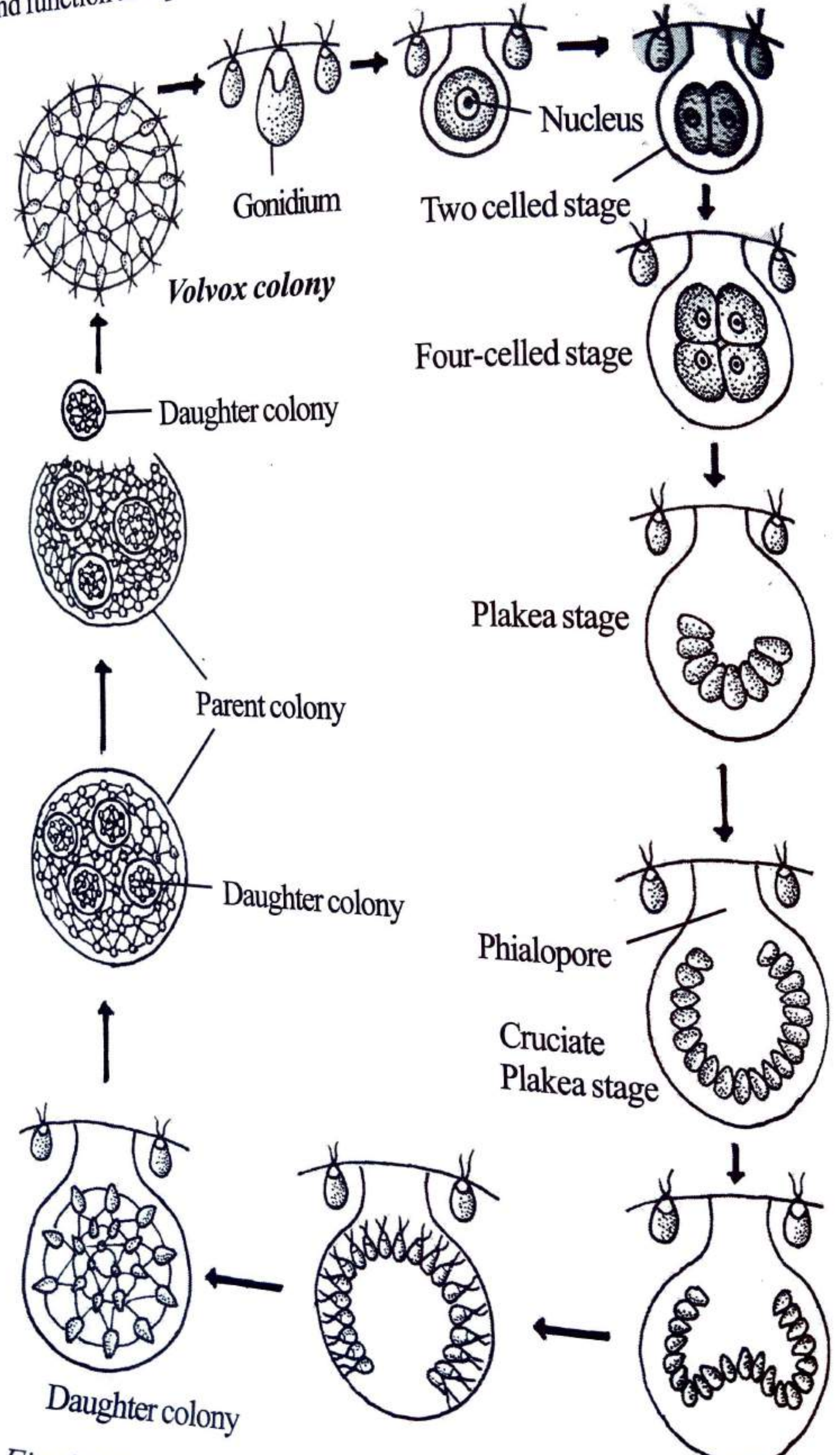


Fig.6.3: Volvox - Asexual reproduction; Stages of development of daughter colony from gonidium

The gonidia ***lack eye-spots*** and ***flagella.*** They have well defined ***nuclei*** and ***dense granular cytoplasm.***

Each gonidial cell divides 3times into 2, 4 and then into ***8 daughter cells.*** The 8 celled stage is called ***octant stage.*** The eight daughter cells are arranged in the form of a ***curved plate.*** This stage is known as ***plakea stage.***

The cells of the plakea stage divide into 16 cells. These 16 cells rearrange to form a ***hollow sphere.*** This stage is called ***cruciate plakea*** stage. It has a ***layer of cells,*** a ***terminal pore*** and a ***central cavity.*** The pore is called ***phialopore.*** The cells are arranged in such a way that the anterior ends point inwards.

Then the number of cells increases by repeated ***mitotic*** divisions.

The sphere of cells turn ***completely inside out*** through the ***phialopore.*** This process is called ***inversion.***

At this stage,the anterior ends of cells point outwards.

Each cell then develops an ***eye-spot*** and ***two flagella*** at its anterior end. In this way, a daughter colony is formed inside the ***gonidial wall.***

The daughter colonies come out by the rupture of parent colony and live as ***independent colonies.***

Highlights

Plakea Stage

Plakea stage is a curved plate of eight cells formed during the development of Volvox.

- This stage is called ***octant stage*** because it contains ***eight cells.***
- It develops from ***gonidium*** in asexual reproduction and ***antheridi. m*** in sexual reproduction.
- The cells at the posterior part of a mature colony enlarge and function as reproductive cells called ***gonidia.***
- The gonidia lack ***eye-spots*** and ***flagella.***
- Each gonidial cell divides into 2,4 and then into 8 daughter cells.
- The eight daughter cells are arranged in the form of a ***curved plate.*** This stage is known as ***plakea stage.***
- The cells of the plakea stage divides into 16 cells. These 16 cells rearrange to form a ***hollow sphere.*** This stage is called ***cruciate plakea*** stage. It has a ***layer of cells,*** a ***terminal pore*** and a ***central cavity.*** The pore is called ***phialopore.*** The cells are arranged in such a way that the anterior ends point inwards.
- The number of cells increases by ***mitosis.***
- The sphere of cells turn completely inside out through the ***phialopore.*** This process is called ***inversion.***
- The inverted sphere becomes the daughter colony.
- The cells of the antheridium develop into ***sperms*** through plakea stage.

Sexual Reproduction

The sexual reproduction in *Volvox* is ***oogamous type.*** It takes place during unfavourable season. Many species of *Volvox* are ***homothallic*** or ***monoecious.*** They produce ***male*** and ***female*** sex organs in the same colony. Eg. *Volvox globator.*

Some species are ***heterothallic*** or ***dioecious.*** They produce male and female sex organs in two different colonies. Eg. *Volvox aureus*. The plant is a ***haploid gametophyte***. The male sex organ is called ***antheridium*** and the female sex organ is called ***oogonium.***

Antheridium

The male sex organs of *Volvox* are called ***antheridia*** or ***androgonidia.*** They are produced at the ***posterior part*** of the colony.

Each ***antheridium*** develops from a ***vegetative cell.***

The ***vegetative*** cell first enlarges in size and loses its flagella to become an ***antheridial cell.***

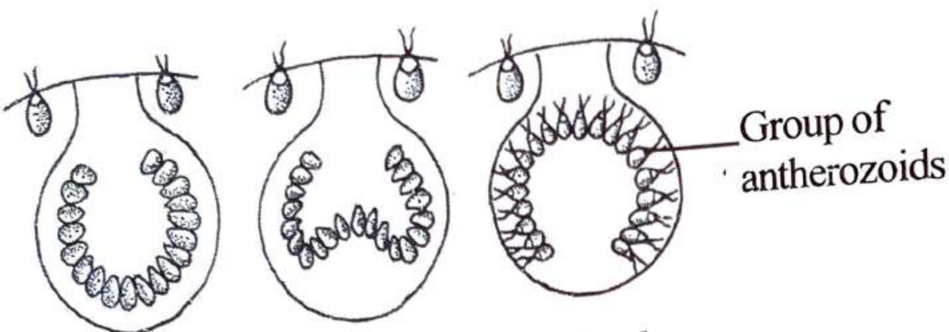


Fig.6.4: Volvox - Stages of development of antheridia.

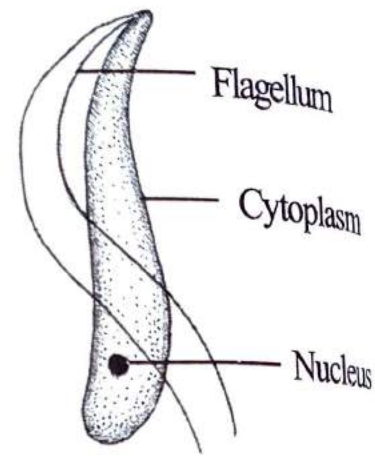


Fig .6.5: Volvox- A sperm.

The antheridial cell divides into 2, 4 and then into 8 cells. The eight daughter cells are arranged in the form of a ***curved plate.*** This stage is known as ***plakea stage*** or ***octant stage.***

The cells of the plakea stage divides into 16 cells. These 16 cells rearrange to form a ***hollow sphere***. This stage is called ***cruciate plakea stage***. It has a ***central cavity***, a ***layer of cells***, a ***terminal pore*** and a ***central cavity***. The pore is called ***phialopore***. The cells are arranged in such a way that the anterior ends point inwards.

16 to 128 cells are formed by ***mitotic*** divisions.

The sphere of cells turn completely inside-out through the ***phialopore.*** This process is called ***inversion.***

At this stage, the anterior ends of the cells point outwards.

Each cell then develops ***two flagella*** at its anterior end to become a ***sperm*** or ***antherozoi***

Mature sperms are liberated in ***water*** in a ***cluster*** or ***singly.***

The cluster of sperms gets separated, when they reach near the egg.

The sperms or male gametes are ***narrow*** and spindle-shaped. They have ***two anter*** ***flagella.*** They are ***haploid.*** They have a large ***nucleus*** and ***dense cytoplasm.*** They are y***low*** in colour. They swim freely in water towards the oogonium.

Highlights

Inversion

Inversion is the turning inside-out of the colony of some of the Volvoca
Eg. Volvox

- Inversion occurs during the development of new ***colony*** and ***sperms.***
- The cells at the posterior part of a mature colony enlarge and function as ***reproductive cells*** called ***gonidia***.
- Each gonidial cell divides into ***8 daughter cells.***
- The eight daughter cells are arranged in the form of a ***curved plate.*** This stage is known as ***plakea stage.***
- The cells of the plakea stage divides into 16 cells. These 16 cells rearrange to form a ***hollow sphere.*** This stage is called ***cruciate plakea stage.*** It has a layer of cells, a ***terminal pore*** and a ***central cavity.*** The pore is called ***phialopore.*** The cells are arranged in such a way that the anterior ends point inwards.
- The sphere of cells turns completely inside out through the ***phialopore.*** This process is called ***inversion.***
- At this stage, the ***anterior ends*** of the cells point ***outwards.***
- The inverted sphere becomes the ***daughter colony.***
- At the development of sperms also inversion occurs.
- The antheridium divides and passes through the ***plakea stage*** and ***cruciate plakea stage*** as in the development of ***gonidia.*** Here also the cruciate plakea undergoes inversion to form sperms.

Oogonium

The female sex organs in *Volvox* are known as ***oogonia*** or ***gynogonidia.***

A few ***oogonia*** develop in a colony. They are ***flask*** shaped.

They are formed in the ***posterior*** part of the colony.

Each oogonium develops from a ***vegetative cell.***

The vegetative cell enlarges in size, loses its flagella and eye-spot. The protoplast of the cell gets rounded to form a single ***egg*** or ***ovum.***

The egg contains a ***haploid nucleus*** and ***dense cytoplasm.***

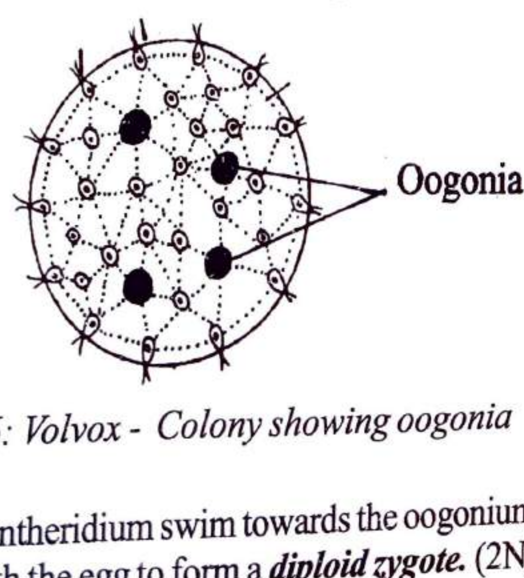


Fig. 6.6: Volvox - Colony showing oogonia

Fertilization

The sperms liberated from the antheridium swim towards the oogonium and enter the oogonium. One of the sperms fuses with the egg to form a ***diploid zygote.*** (2N).

The zygote secretes a thick three layered, smooth or spiny wall around it to form an ***oospore.*** The thick-walled oospores remain in the parent coenobium. The oospore is released by the rupture of the colony.

Germination of Oospore

The oospore *germinates* after a period of rest. The diploid nucleus undergoes ***reduction division*** or ***meiosis*** to form four ***haploid nuclei.*** Of these, ***three nuclei*** get ***disorganised*** and the remaining ***one is functional.*** At this stage, the oospore wall ruptures and the protoplast comes out in the form of a ***vesicle.*** This protoplast develops into a ***biflagellate zoospore.***

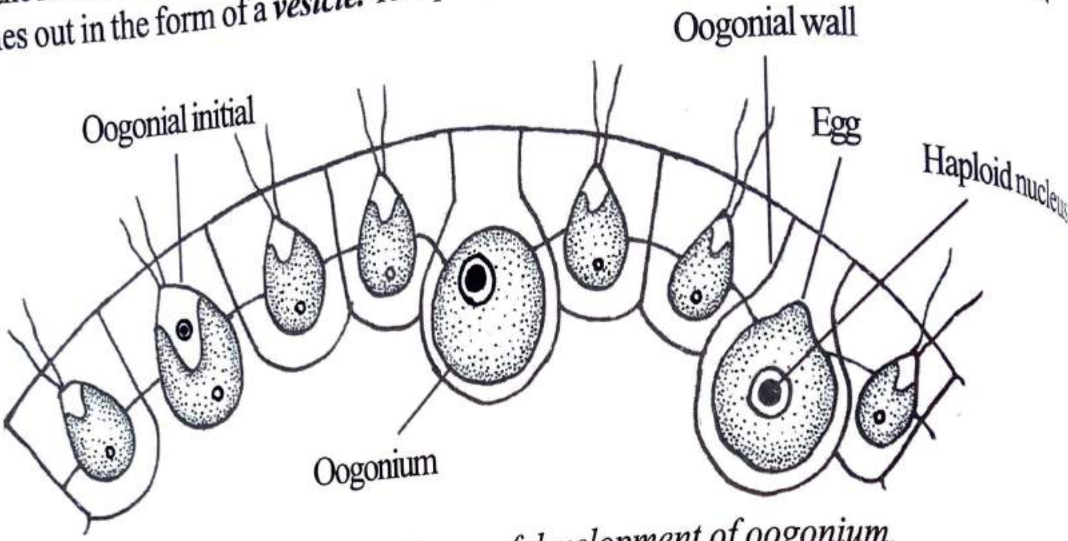


Fig. 6.7: Volvox - Stages of development of oogonium.

The zoospore swims in water and divides mitotically into 2,4,8 and then into a mass of cells. These cells are arranged in a single ***layer*** to form a ***hollow sphere.*** The anterior end of the cell faces inwards. The hollow sphere has a pore called ***phialopore.***

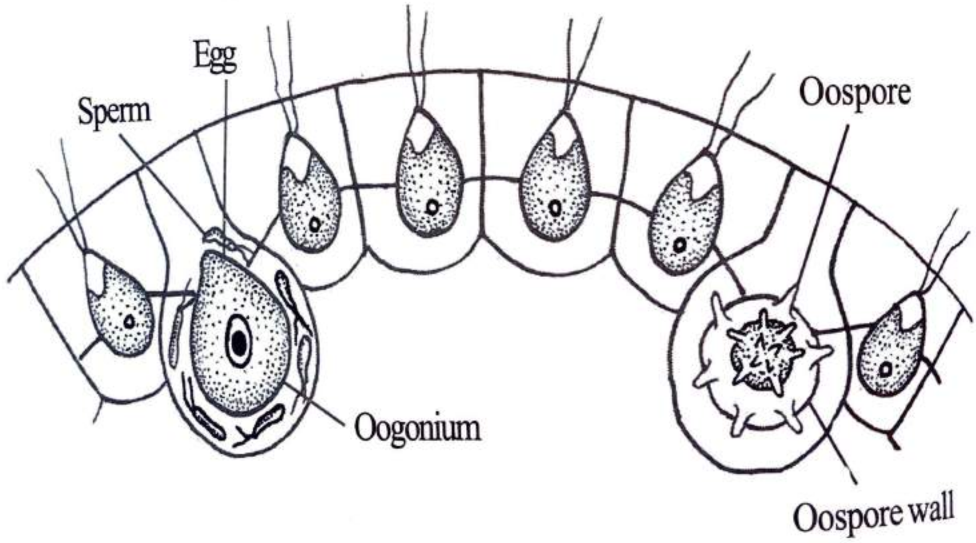


Fig.6.8: Volvox - Fertilization and oospore formation.

Then the sphere of cells turns completely inside out by a process called ***inversion.*** Now the anterior ends of the cells face outwards. Each cell then develops a pair of ***flagella.*** In this way, the hollow sphere develops into a ***daughter colony.***

Conclusion

The life cycle of *Volvox* is ***haplontic type.*** The plant is a ***haploid gametophyte*** and reproduces ***asexually*** by ***daughter colonies.***

It produces sexually, a ***diploid zygote*** by the fusion of two gametes. The zygote under-

In the mature colony, a few cells in the posterior end enlarge in size and function as ***gonidial cells***. The gonidia are ***reproductive*** in function.

The cells of *Volvox* colony are ***oval in shape***.

The posterior end of the cell is ***broader*** and the anterior end is ***narrow***.

The anterior end faces outwards. The anterior end of the cell has ***two equal flagella***. The cell has a cell wall made up of ***cellulose***.

At the anterior end, the cell wall forms a thickening called ***papilla***. A thin plasma membrane lies below the cell wall, surrounding the protoplasm. The protoplasm contains a large ***cup-shaped chloroplast***, an ***eukaryotic nucleus***, a few ***mitochondria, endoplasmic reticulum*** and two ***contractile vacuoles***.

The chloroplast has a ***single pyrenoid*** and an ***eye-spot.*** It contains pigments like ***chlorophyll-a, chlorophyll-b, carotenes*** and ***xanthophylls. Starch*** is the ***reserve food material***. The cells of the colony are interconnected by ***plasmodesmata***. Each cell is surrounded by a ***mucilage envelope.***

The colony is ***motile***.

Volvox reproduces by two methods -

Asexual reproduction

Sexual reproduction

The asexual reproduction takes place with the help of ***gonidia***. Some cells at the posterior part of the colony enlarge, lose their flagella and act as ***asexual reproductive cells*** called ***gonidia***.

The contents of each of the gonidia divide ***mitotically*** into 2,4 and then into ***8-daughter cells***. This stage is called ***octant stage.*** These 8 cells arrange to form a curved plate. This stage is called ***plakea stage***. These cells become a spherical mass called ***cruciate plakea.*** The cruciate plakea has a ***small pore*** called ***phialopore***.

The cells then undergo repeated ***mitotic*** divisions to form a ***hollow sphere of cells***. The cells of the hollow sphere turn completely inside out by ***inversion***. At this stage, the anterior ends of the cells point outwards. Each of these cells develops two ***equal flagella*** at its anterior end. In this way a daughter colony is formed inside the ***gonidial wall***.

The daughter colonies come out by the rupture of the parent colony and live as ***independent colonies***. Sometimes, the daughter colonies persist within the parent colony for a long time and produce grand daughter colonies also.

The sexual reproduction is ***oogamous type.*** It takes place during ***unfavourable*** conditions. The plant is a ***haploid gametophyte*** (N). The male sex organs are called ***antheridia*** and the female sex organs are called ***oogonia***. Many species are ***homothallic*** or ***monoecious***. They produce antheridia and oogonia in the same colony. Eg. *Volvox globator*. Some species are ***heterothallic*** or ***dioecious***. They produce antheridia and oogonia in separate colonies.

The antheridia are produced at the posterior part of the colony. They develop from enlarged vegetative cells called ***antheridial cells***.

The antheridial cell divides ***mitotically*** into 16-128 haploid ***daughter cells***. These cells rearrange in the form of a ***hollow sphere***.

Each ***cell*** develops two flagella to form a ***sperm*** or ***antherozoid***.

The mature sperms are released as a mass in the water by the gelatinisation of the antheridial ***wall***.

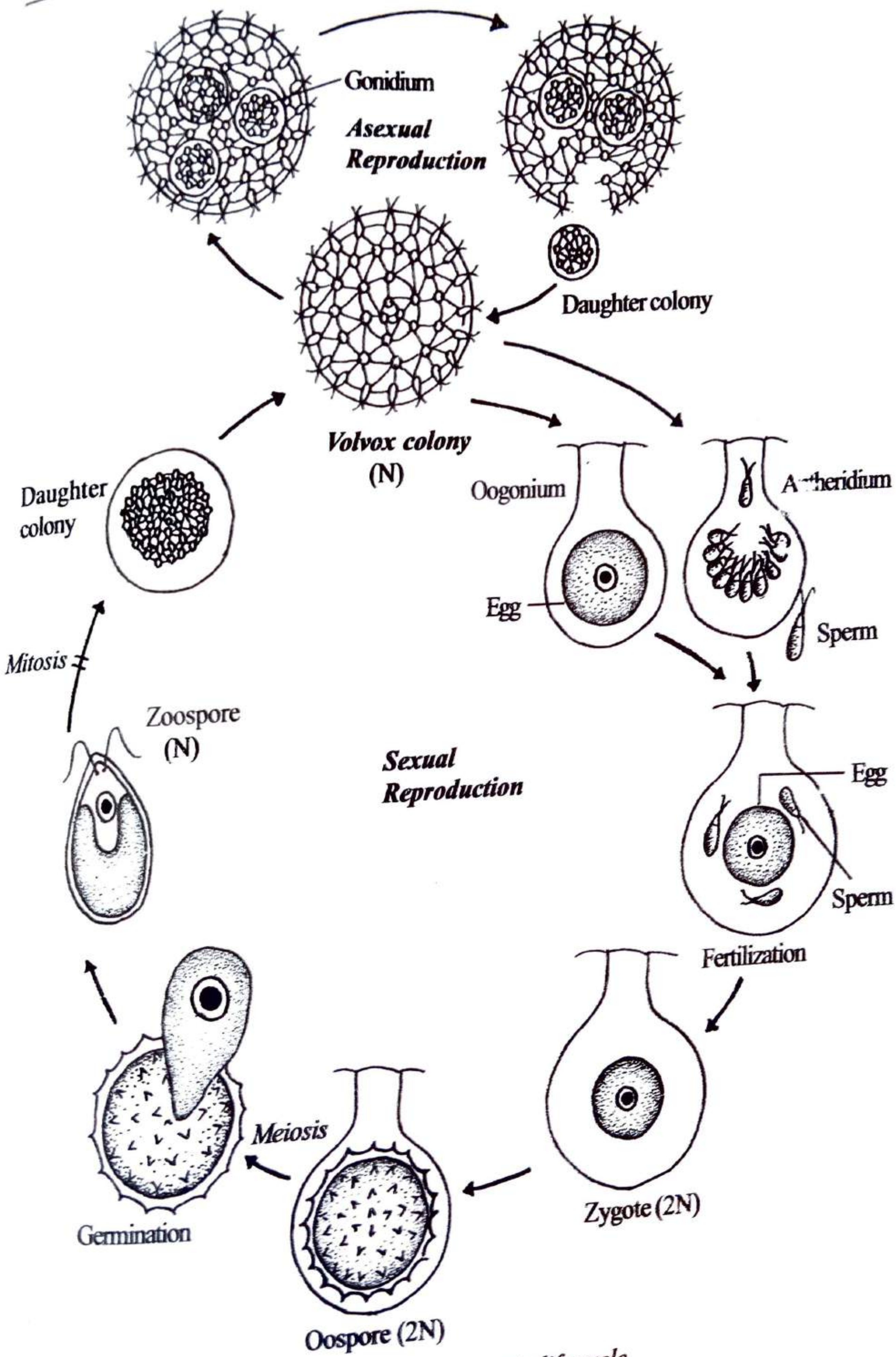


Fig.6.10: Volvox - Diagrammatic life cycle.

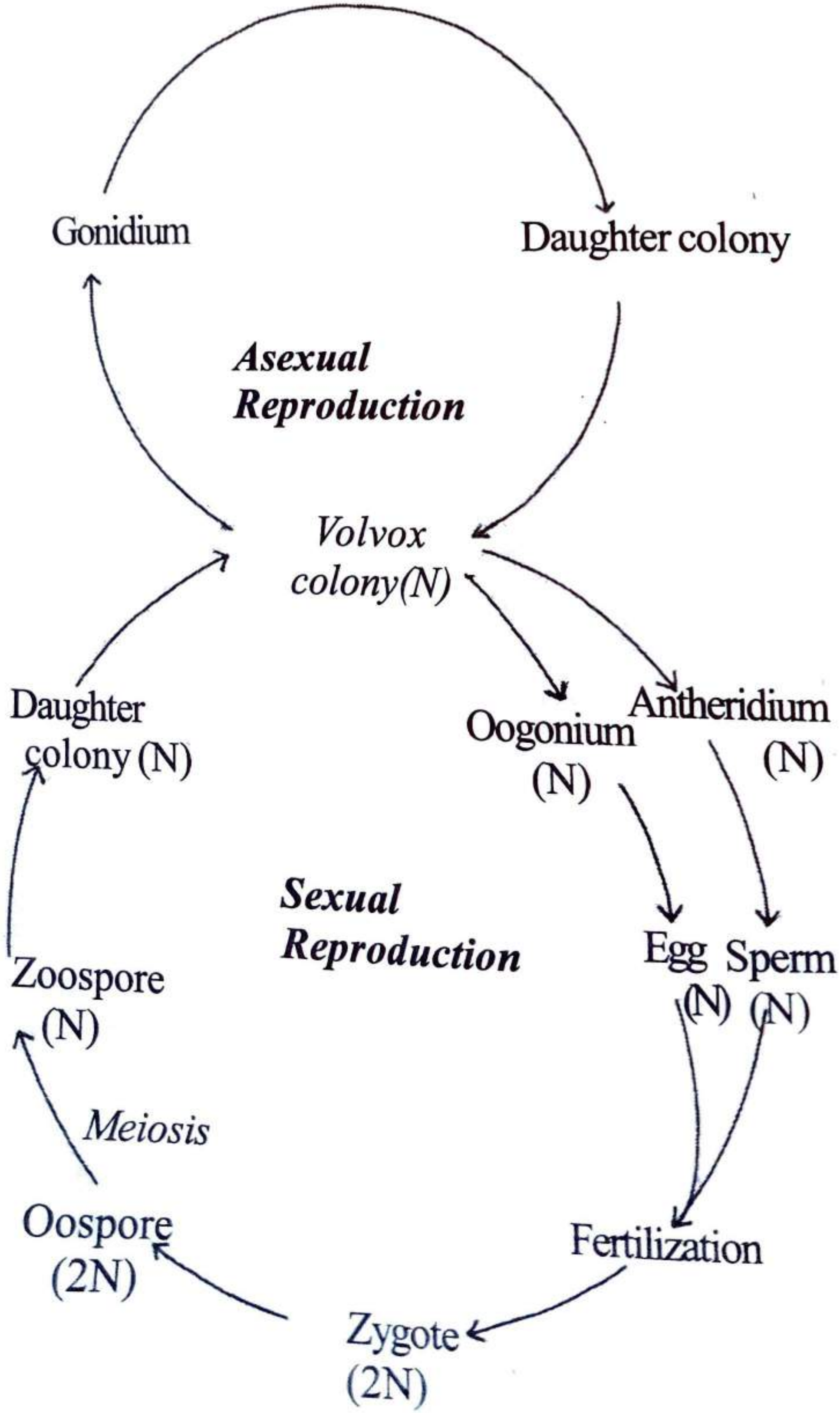


Fig. 6.11: Volvox - Graphic life cycle.

11 Caulerpa

Class	:	*Chlorophyceae*
Order	:	*Siphonales*
Family	:	*Caulerpaceae*
Genus	:	*Caulerpa*

Caulerpa is a ***green alga***. It is placed under the class ***Chlorophyceae. Lamouroux*** named the genus, *Caulerpa*. It belongs to the monogeneric family ***Caulerpaceae.***

Caul means ***stem***; *erpa* means ***creep***.

Caulerpa has about 73 species. All the species are ***marine***. The common Indian species are -

Caulerpa racemosa
Caulerpa taxifolia
Caulerpa scalpelliformis
Caulerpa prolifera
Caulerpa peltata

On the basis of habitat, various species of *Caulerpa* are classified into three categories:

1. Species growing in ***mud*** or ***sandy bottom***. Eg. *Caulerpa prolifera.*
2. Species growing on ***rock*** and ***coral reef***. Eg. *Caulerpa taxifolia.*
3. Species growing as ***epiphytes*** on the ***roots of mangroves*** or ***epiphytic species***. Eg. *Caulerpa verticillata.*

Thallus Structure

Caulerpa is a ***tubular green alga.***

The plant body is a ***diploid sporophyte.***

It is ***unicellular*** and ***multinucleate***.

It looks like a ***vascular creeping plant***. It consists of a horizontal ***rhizome,*** erect ***branches*** and ***rhizoids.***

The rhizome is ***cylindrical*** and ***branched.***

It grows ***horizontally*** over the substratum.

From the lower surface of the ***rhizome***, many ***multicellular rhizoids*** arise and fix the thallus over the substratum.

From the upper surface of the rhizome arises many ***erect branches*** called ***leafy shoots*** or ***assimilatory shoots.***

The erect branches bear many ***lateral outgrowths*** called ***assimilators.***

The axis of the assimilatory shoot, in most species, is ***cylindrical*** and it is ***flattened*** in a few cases.

The assimilators are ***green*** and ***photosynthetic.***

The arrangement of assimilators on the axis is characteristic to the species :

1. In *Caulerpa verticillata,* the central axis is ***cylindrical*** and the assimilators are arranged in ***verticillate manner.***

2. In *Caulerpa taxifolia,* the axis is ***cylindrical*** and the assimilators are arranged in ***two opposite rows*** on the axis.

3. In *Caulerpa crassifolia,* the axis is ***cylindrical*** and the assimilators are arranged ***pinnately.***

4. In *Caulerpa prolifera,* the axis is ***flattened*** and ***leaf-like*** and has ***no assimilators.***

Internal Structure

The entire thallus is a ***long,one-celled, branched, non-septate, tubular cell.***

It is bounded by a ***cell wall*** made up of ***callose, pectin*** and ***pentose sugar***.

Cellulose is absent. Inner to this is a thin ***plasma membrane.*** The plasma membrane surrounds a dense ***protoplasm.***

The protoplasm is ***coenocytic*** and ***vacuolate.*** The ***nuclei*** are ***eukaryotic*** and ***diploid***.

There are numerous discoid ***chloroplasts*** in the protoplasm.

The chloroplasts contain ***chlorophyll-a*** and-***b, carotene, xanthophylls, siphoenin*** and ***siphonoxanthin.*** Pyrenoid is absent.

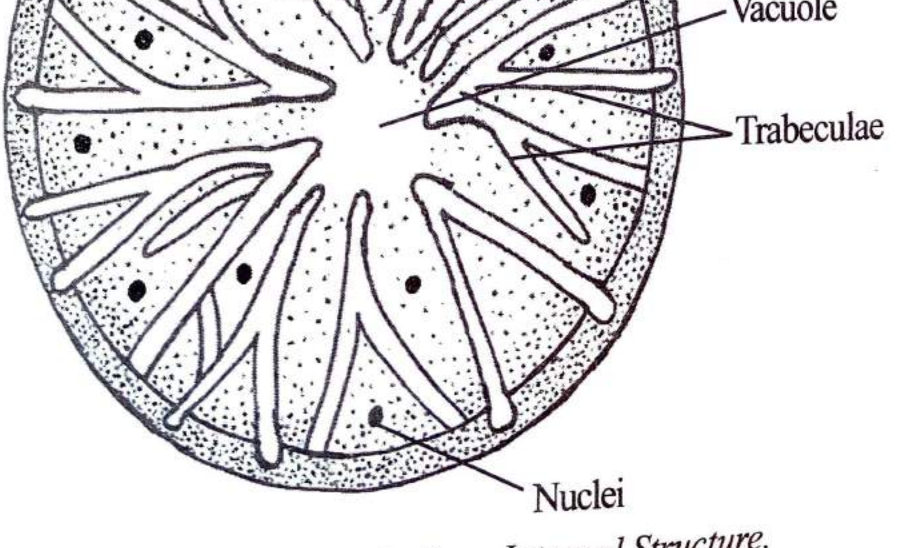


Fig.11.2: Caulerpa thallus - Internal Structure.

The nuclei and chloroplasts exhibit ***streaming movement*** along with the cytoplasm.

Starch granules are also found in the ***cytoplasm***.

There is a ***large central vacuole*** running throughout the entire length of the plant.

The vacuole is traversed by many small ***cylindrical strands***. These strands are called ***trabeculae*** or ***skeletal strands.***

The trabeculae are strongly developed in rhizomes and in the axis of ***mature assimilatory shoots***. They are ***poorly developed*** in the ***assimilators***.

They run ***irregularly*** from surface to surface.

They arise from rows of structures called ***microsomes*** and are always connected with the walls in the ***adult*** condition.

The ***functions*** attributed to the trabeculae are,

- To provide ***mechanical strength*** so as to resist high ***turgor pressure.***
- To increase the ***protoplasmic surface*** of the cell.
- To facilitate easy and quicker ***diffusion of minerals***.

However, the exact role of trabeculae is not yet clear.

Growth

The growth is ***apical.***

Highlights

Caulerpa

- *Caulerpa* is a ***green alga***.
- It is included in the class ***Chlorophyceae***.
- It is a ***branched, sedentary***, ***marine*** alga.
- The plant is a ***diploid sporophyte (2N)***.
- It is ***unicellular*** and ***multinucleate***.
- The plant body is a ***thallus***.
- It consists of a horizontal ***rhizome***, erect **branches** and ***rhizoids***.
- The rhizome is horizontal ***cylindrical*** and ***branched***.
- The upper surface of rhizome produces many ***erect branches*** called *leafy* ***shoots*** or ***assimilatory shoots***.
- Assimilatory shoots have many ***lateral outgrowths*** called ***assimilators***.
- Assimilators are ***green*** and ***photosynthetic***.
- The lower surface of the rhizome produces many branched colourless ***rhizoids***.
- Rhizoids fix the thallus on the ***substratum***.
- The entire thallus is a ***long***, ***one celled, branched, non-septate***, ***tubular***...
- The cell contains a ***cell wall***, ***plasma membrane***, ***protoplasm***, ***cytoplasm***, ***central vacuole*** and ***nuclei***.
- The cell wall is made up of ***callose, pectin*** and ***pentose sugar***.
- The plasma membrane surrounds a ***dense protoplasm.***
- The protoplasm is ***coenocytic*** and ***vacuolate***.
- The protoplasm contains ***cytoplasm***, ***discoid chloroplasts***, ***starch granules*** and ***nuclei***.

Reproduction

Caulerpa reproduces by ***two*** methods :

1. *Vegetative reproduction*
2. *Sexual reproduction*

1. Vegetative Reproduction

It takes place by ***fragmentation.***

Due to ***death*** and ***decay*** of the ***rhizome***, the erect branches get separated from the ***thallus.***

These branches later on grow into ***new plants***.

2. Sexual Reproduction

In 1928, ***Dostal*** first reported ***sexual*** reproduction in *Caulerpa prolifera*. Sexual reproduction had not been known for several years.

Caulerpa is a ***diploid sporophytic plant*** (2N).

Meiosis takes place at the time of ***gamete formation***. The sexual reproduction in *Caulerpa* is ***anisogamous,*** ie. the male and female gametes are ***unequal*** in size.

All species of *Caulerpa,* except one, are ***heterothallic*** or ***dioecious.***

The ***male*** and ***female gametes*** are produced by the ***male*** and ***female thalli***.

One species, *Caulerpa racemosa,* is ***homothallic*** (***M.O.P. Iyengar,*** 1940). Here the male and female gametes are produced by the ***same plant***.

The gametes are produced in ***fertile assimilators*** and rarely in the rhizome.

The ***protoplasm*** of the fertile assimilator becomes ***dense*** and ***dark green*** at some areas called ***fertile areas.***

The ***fertile area*** is separated from the rest of the thallus by a ***membraneous septum*** and it has a ***single diploid nucleus.***

It forms a ***small papillate projection*** on the surface of the assimilator.

Each piece of cytoplasm encloses a ***haploid nucleus*** to form a ***haploid protoplast.***

The haploid protoplast then becomes ***pear-shaped*** and develops ***two equal flagella*** at its anterior end.

These ***biflagellate cells*** are called ***gametes*** or ***swarmers.*** They contain a ***single chloroplast***, a ***haploid nucleus*** and an ***eye-spot***.

The ***mature gametes*** are released into the extrusion papilla along with a ***slimy mass.***

They are ***released out dissolving*** the ***wall*** of the ***extrusion papilla***.

The ***fertile assimilators die off*** after the liberation of gametes.

The ***male gametes*** are produced from the ***male thallus***.

They are ***smaller in size, actively motile*** and ***bright-green*** in colour. They are known as ***microswarmers*** or ***microgametes.***

The ***female gametes*** are produced from the ***female thallus***.

They are ***larger*** in size, ***slow-moving*** and ***brownish green*** in colour. They are known as ***macrogametes*** or ***macroswarmers.***

Both the male and female gametes ***swim*** in ***water*** for some time and each ***male gamete fuses*** with a ***female gamete*** to form a ***quadriflagellate diploid zygote.***

The ***zygote*** then ***loses its flagella***, gets ***rounded*** and ***secretes a wall around it***. The zygote later on ***germinates*** into a ***new diploid sporophytic plant.***

Conclusion

The plant *Caulerpa* is a ***diploid sporophyte (2N)***. It directly produces ***new sporophytes vegetatively*** by ***fragmentation***.

Sexually it produces ***haploid anisogametes*** by ***meiosis***.

The ***male*** and ***female gametes*** fuse together to form a ***diploid zygote.***

The ***zygote germinates*** into a new ***diploid sporophytic plant (2N)***.

The major part of the ***life cycle*** is ***diploid***.

Haploid stage is represented only by the ***gametes***.

Hence this type of life cycle is called ***diplontic life cycle.***

Life Cycle of *Caulerpa*

Caulerpa is a ***green alga***.

All species are ***marine***.

They are found attached to ***rocks*** or ***roots of mangroves***.

The plant body is a ***diploid sporophyte*** (2N).

It looks like a vascular creeping plant. It consists of a horizontal ***rhizome, erect branches*** and ***rhizoids.***

The rhizome is ***cylindrical*** and ***branched***.

From the lower surface of the rhizome many ***multicellular rhizoids*** arise and ***fix the thallus*** over the ***substratum***.

From the upper surface of the rhizome arise many branches called ***assimilatory shoots.*** These branches bear many ***lateral outgrowths*** called ***assimilators.***

The entire thallus is a ***long, branched, unseptate, tubular, multinucleate cell***.

It is bounded by a ***cell wall*** made up of ***callose, pectin*** and ***pentose sugar***.

Cellulose is absent. Inner to the ***cell wall***, the ***plasma membrane*** surrounds a ***dense protoplasm***.

This projection later grows into a new diploid ***sporophytic plant.***

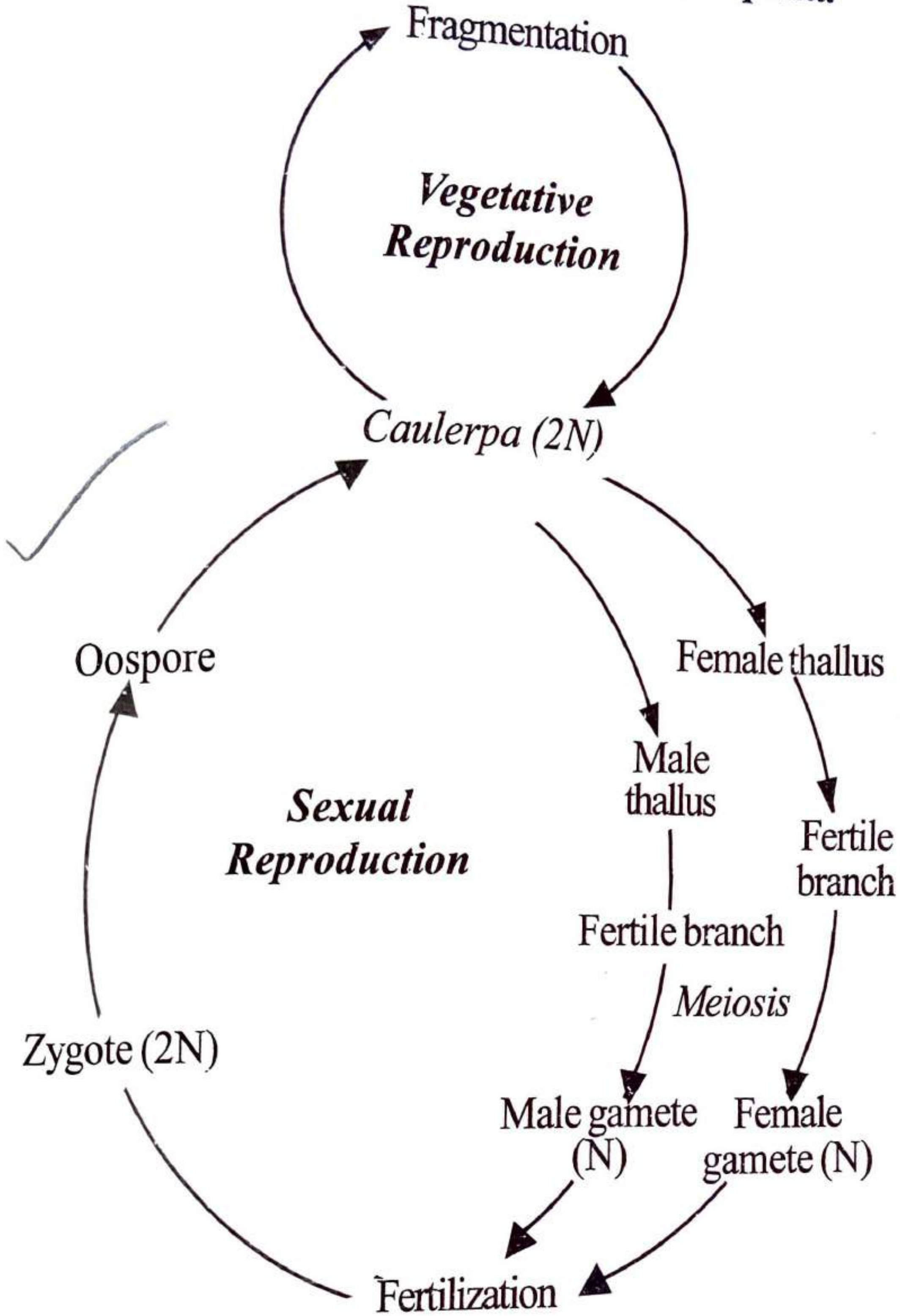


Fig.11.4: Caulerpa prolifera - Graphic life cycle.

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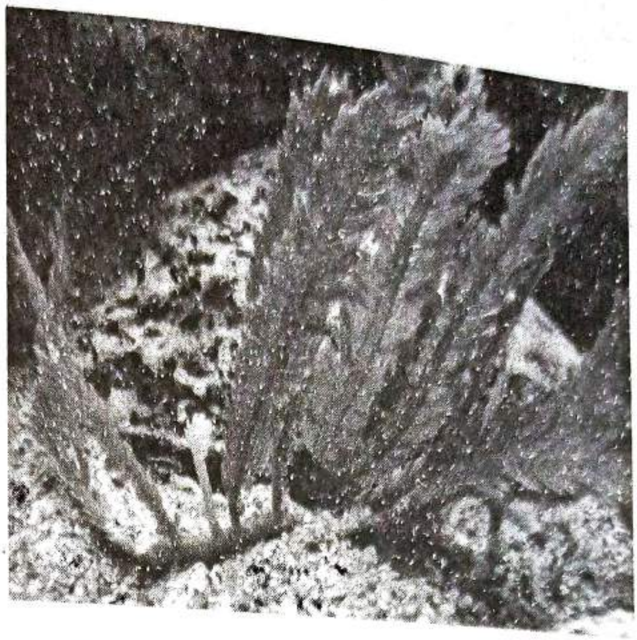

11 Caulerpa

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Order	:	*Siphonales*
Family	:	*Caulerpaceae*
Genus	:	*Caulerpa*

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Caulerpa has about 73 species. All the species are ***marine***. The common Indian species are -

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Caulerpa taxifolia
Caulerpa scalpelliformis
Caulerpa prolifera
Caulerpa peltata

On the basis of habitat, various species of *Caulerpa* are classified into three categories:

1. Species growing in ***mud*** or ***sandy bottom***. Eg. *Caulerpa prolifera.*
2. Species growing on ***rock*** and ***coral reef***. Eg. *Caulerpa taxifolia.*
3. Species growing as ***epiphytes*** on the ***roots of mangroves*** or ***epiphytic species***. Eg. *Caulerpa verticillata.*

Thallus Structure

Caulerpa is a ***tubular green alga.***

The plant body is a ***diploid sporophyte.***

It is ***unicellular*** and ***multinucleate***.

It looks like a ***vascular creeping plant***. It consists of a horizontal ***rhizome,*** erect ***branches*** and ***rhizoids.***

The rhizome is ***cylindrical*** and ***branched.***

It grows ***horizontally*** over the substratum.

From the lower surface of the ***rhizome***, many ***multicellular rhizoids*** arise and fix the thallus over the substratum.

From the upper surface of the rhizome arises many ***erect branches*** called ***leafy shoots*** or ***assimilatory shoots.***

The erect branches bear many ***lateral outgrowths*** called ***assimilators.***

The axis of the assimilatory shoot, in most species, is ***cylindrical*** and it is ***flattened*** in a few cases.

The assimilators are ***green*** and ***photosynthetic.***

The arrangement of assimilators on the axis is characteristic to the species :

1. In *Caulerpa verticillata,* the central axis is ***cylindrical*** and the assimilators are arranged in ***verticillate manner.***

2. In *Caulerpa taxifolia,* the axis is ***cylindrical*** and the assimilators are arranged in ***two opposite rows*** on the axis.

3. In *Caulerpa crassifolia,* the axis is ***cylindrical*** and the assimilators are arranged ***pinnately.***

4. In *Caulerpa prolifera,* the axis is ***flattened*** and ***leaf-like*** and has ***no assimilators.***

Internal Structure

The entire thallus is a ***long,one-celled, branched, non-septate, tubular cell.***

It is bounded by a ***cell wall*** made up of ***callose, pectin*** and ***pentose sugar***.

Cellulose is absent. Inner to this is a thin ***plasma membrane.*** The plasma membrane surrounds a dense ***protoplasm.***

The protoplasm is ***coenocytic*** and ***vacuolate.*** The ***nuclei*** are ***eukaryotic*** and ***diploid***.

There are numerous discoid ***chloroplasts*** in the protoplasm.

The chloroplasts contain ***chlorophyll-a*** and-***b, carotene, xanthophylls, siphoenin*** and ***siphonoxanthin.*** Pyrenoid is absent.

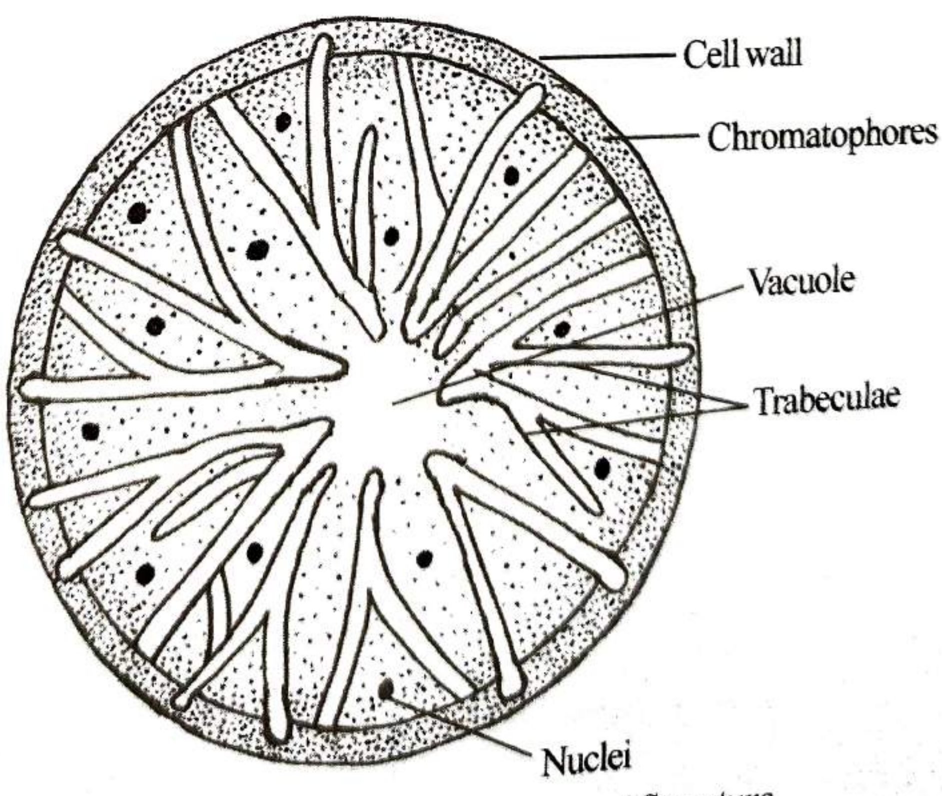


Fig.11.2: Caulerpa thallus - Internal Structure.

The nuclei and chloroplasts exhibit ***streaming movement*** along with the cytoplasm.

Starch granules are also found in the ***cytoplasm***.

There is a ***large central vacuole*** running throughout the entire length of the plant.

The vacuole is traversed by many small ***cylindrical strands***. These strands are called ***trabeculae*** or ***skeletal strands.***

The trabeculae are strongly developed in rhizomes and in the axis of ***mature assimilatory shoots***. They are ***poorly developed*** in the ***assimilators***.

They run ***irregularly*** from surface to surface.

They arise from rows of structures called ***microsomes*** and are always connected with the walls in the ***adult*** condition.

The ***functions*** attributed to the trabeculae are,

- To provide ***mechanical strength*** so as to resist high ***turgor pressure.***
- To increase the ***protoplasmic surface*** of the cell.
- To facilitate easy and quicker ***diffusion of minerals***.

However, the exact role of trabeculae is not yet clear.

Growth

The growth is ***apical.***

Highlights

Caulerpa

- *Caulerpa* is a ***green alga***.
- It is included in the class ***Chlorophyceae***.
- It is a ***branched, sedentary***, ***marine*** alga.
- The plant is a ***diploid sporophyte (2N)***.
- It is ***unicellular*** and ***multinucleate***.
- The plant body is a ***thallus***.
- It consists of a horizontal ***rhizome***, erect ***branches*** and ***rhizoids***.
- The rhizome is horizontal ***cylindrical*** and ***branched***.
- The upper surface of rhizome produces many ***erect branches*** called leafy ***shoots*** or ***assimilatory shoots***.
- Assimilatory shoots have many ***lateral outgrowths*** called ***assimilators***.
- Assimilators are ***green*** and ***photosynthetic***.
- The lower surface of the rhizome produces many branched colourless ***rhizoids***.
- Rhizoids fix the thallus on the ***substratum***.
- The entire thallus is a ***long***, ***one celled, branched, non-septate***, ***tubular***
- The cell contains a ***cell wall***, ***plasma membrane***, ***protoplasm***, ***cytoplasm***, ***central vacuole*** and ***nuclei***.
- The cell wall is made up of ***callose, pectin*** and ***pentose sugar***.
- The plasma membrane surrounds a ***dense protoplasm.***
- The protoplasm is ***coenocytic*** and ***vacuolate***.
- The protoplasm contains ***cytoplasm***, ***discoid chloroplasts, starch granules*** and ***nuclei***.

- The nuclei are ***eukaryotic*** and ***diploid***.
- Chloroplasts contain ***chlorophyll- a*** and ***b***, ***carotene, xanthophylls, siphoenin*** and ***siphonoxanthin***.
- A large central ***vacuole*** is present throughout the entire length of the plant.
- The vacuole is transversed by many small cylindrical strands called ***trabeculae***.
- ***Starch*** is the stored ***reserve food***.
- The plant reproduces by two methods.
  - *Vegetative reproduction*
  - *Sexual reproduction*
- Vegetative reproduction takes place by ***fragmentation***.
- In sexual reproduction the diploid ***sporophytic*** plant produces haploid ***gametes*** by ***meiosis***.
- The haploid gametes fuse together to form quadriflagellate diploid ***zygote***.
- The zygote develops into an ***oospore***.
- Oospore germinates into a ***diploid sporophyte***.
- The life cycle is ***diplontic type***.

Reproduction

Caulerpa reproduces by ***two*** methods :

1. *Vegetative reproduction*
2. *Sexual reproduction*

1. Vegetative Reproduction

It takes place by ***fragmentation***.

Due to ***death*** and ***decay*** of the ***rhizome***, the erect branches get separated from the ***thallus***.

These branches later on grow into ***new plants***.

2. Sexual Reproduction

In 1928, ***Dostal*** first reported ***sexual*** reproduction in *Caulerpa prolifera*. Sexual reproduction had not been known for several years.

Caulerpa is a ***diploid sporophytic plant*** (2N).

Meiosis takes place at the time of ***gamete formation***. The sexual reproduction in *Caulerpa* is ***anisogamous***, ie. the male and female gametes are ***unequal*** in size.

All species of *Caulerpa*, except one, are ***heterothallic*** or ***dioecious***.

The ***male*** and ***female gametes*** are produced by the ***male*** and ***female thalli***.

One species, *Caulerpa racemosa*, is ***homothallic*** (***M.O.P. Iyengar***, 1940). Here the male and female gametes are produced by the ***same plant***.

The gametes are produced in ***fertile assimilators*** and rarely in the rhizome.

The ***protoplasm*** of the fertile assimilator becomes ***dense*** and ***dark green*** at some areas called ***fertile areas***.

The ***fertile area*** is separated from the rest of the thallus by a ***membraneous septum*** and it has a ***single diploid nucleus***.

It forms a ***small papillate projection*** on the surface of the assimilator.

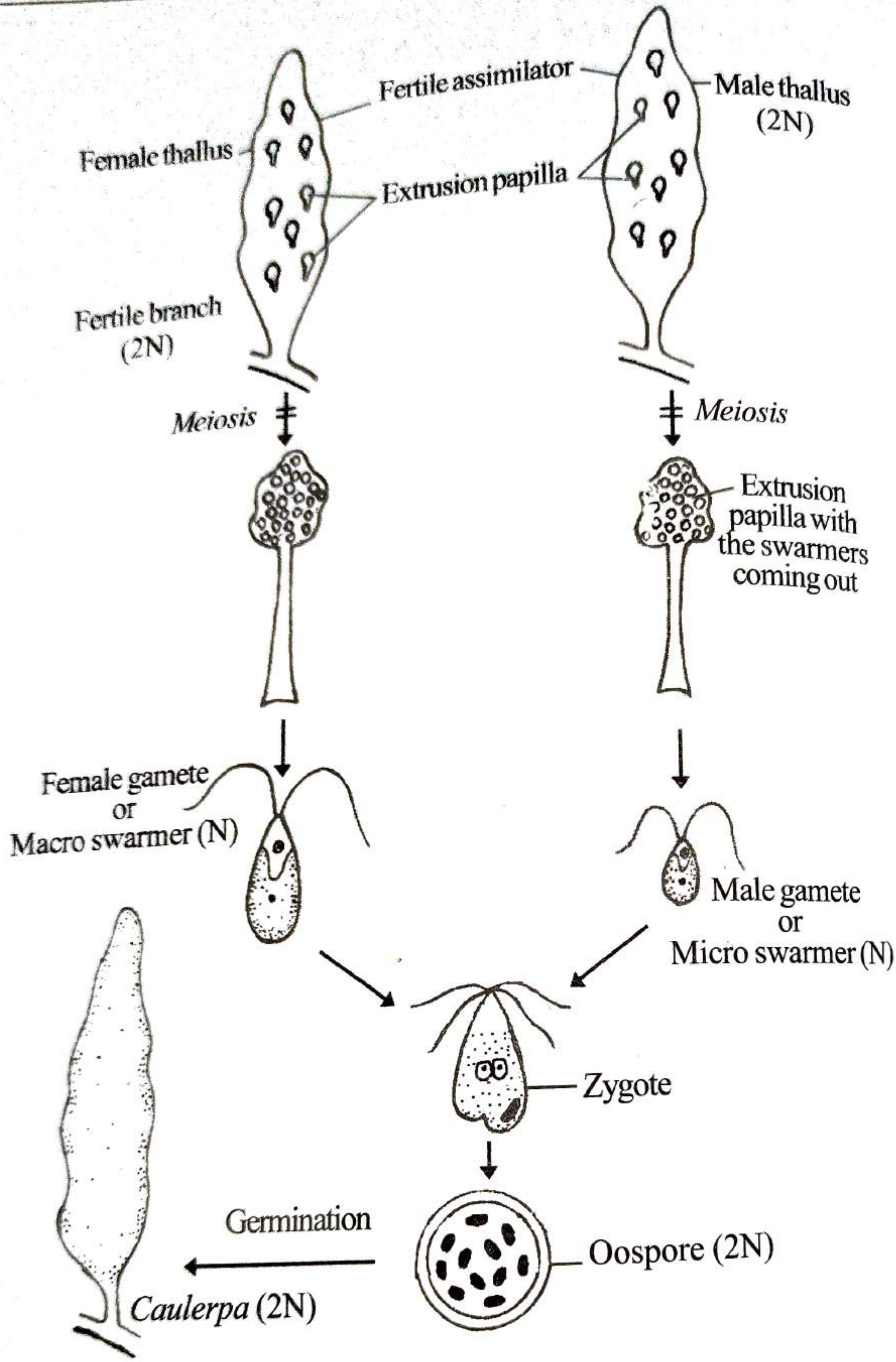


Fig.11.3: Caulerpa prolifera - Sexual reproduction.

This ***papillate projection*** is called ***extrusion papilla*** (pl:-extrusion papillae).

In the meantime, the ***diploid nucleus*** undergoes ***meiotic division*** to form ***four haploid nuclei***.

This is followed by the division of ***cytoplasm*** into ***four pieces***.

Each piece of cytoplasm encloses a ***haploid nucleus*** to form a ***haploid protoplast.***

The haploid protoplast then becomes ***pear-shaped*** and develops ***two equal flagella*** at its anterior end.

These ***biflagellate cells*** are called ***gametes*** or ***swarmers***. They contain a ***single chloroplast***, a ***haploid nucleus*** and an ***eye-spot***.

The ***mature gametes*** are released into the extrusion papilla along with a ***slimy mass.***

They are ***released out dissolving*** the ***wall*** of the ***extrusion papilla***.

The ***fertile assimilators die off*** after the liberation of gametes.

The ***male gametes*** are produced from the ***male thallus***.

They are ***smaller in size***, ***actively motile*** and ***bright-green*** in colour. They are known as ***microswarmers*** or ***microgametes.***

The ***female gametes*** are produced from the ***female thallus***.

They are ***larger*** in size, ***slow-moving*** and ***brownish green*** in colour. They are known as ***macrogametes*** or ***macroswarmers.***

Both the male and female gametes ***swim*** in ***water*** for some time and each ***male gamete*** fuses with a ***female gamete*** to form a ***quadriflagellate diploid zygote.***

The ***zygote*** then ***loses its flagella***, gets ***rounded*** and ***secretes a wall around it***. The zygote later on ***germinates*** into a ***new diploid sporophytic plant.***

Conclusion

The plant *Caulerpa* is a ***diploid sporophyte (2N)***. It directly produces ***new sporophytes vegetatively*** by ***fragmentation***.

Sexually it produces ***haploid anisogametes*** by ***meiosis***.

The ***male*** and ***female gametes*** fuse together to form a ***diploid zygote.***

The ***zygote germinates*** into a new ***diploid sporophytic plant (2N)***.

The major part of the ***life cycle*** is ***diploid***.

Haploid stage is represented only by the ***gametes***.

Hence this type of life cycle is called ***diplontic life cycle.***

Life Cycle of *Caulerpa*

Caulerpa is a ***green alga***.

All species are ***marine***.

They are found attached to ***rocks*** or ***roots of mangroves***.

The plant body is a ***diploid sporophyte*** (2N).

It looks like a vascular creeping plant. It consists of a horizontal ***rhizome, erect branches*** and ***rhizoids.***

The rhizome is ***cylindrical*** and ***branched***.

From the lower surface of the rhizome many ***multicellular rhizoids*** arise and ***fix the thallus*** over the ***substratum***.

From the upper surface of the rhizome arise many branches called ***assimilatory shoots.*** These branches bear many ***lateral outgrowths*** called ***assimilators.***

The entire thallus is a ***long, branched, unseptate, tubular, multinucleate cell.***

It is bounded by a ***cell wall*** made up of ***callose, pectin*** and ***pentose sugar***.

Cellulose is absent. Inner to the ***cell wall***, the ***plasma membrane*** surrounds a ***dense protoplasm***.

The protoplasm is *coenocytic* (multinucleate) and ***vacuolate.***

The ***nuclei*** are *eukaryotic.*

It contains numerous ***discoid chloroplasts.***

The chloroplasts contain ***chlorophyll-a*** and ***-b, carotene, xanthophylls, siphoenin*** and ***siphonoxanthin***.

The *pyrenoid* is absent. There is a ***large central vacuole*** running throughout the entire length of the cell.

The vacuole is traversed by many small ***cylindrical strands*** called ***trabeculae*** or ***skeletal strands.***

It is believed that trabeculae provide ***mechanical support*** and act as ***canals*** for ***intracellular*** *transport* of ***minerals.***

Caulerpa reproduces by ***vegetative*** and ***sexual*** methods.

The vegetative reproduction takes place by ***fragmentation.***

Fragmentation

Due to ***death*** and ***decay*** of ***rhizome*** the ***young branches*** get ***separated*** from the thallus.

These branches later grow into ***new plants***.

The sexual reproduction is ***anisogamous type.*** *Caulerpa* is ***heterothallic*** or ***dioecious.***

The ***male*** and ***female gametes*** are produced in ***separate individuals***.

But, *Caulerpa racemosa* is ***homothallic.***

The ***gametes*** are produced in ***fertile assimilators*** or ***rarely*** in ***rhizome***.

In the ***fertile assimilator***, the ***protoplasm*** becomes ***dense*** and ***dark green*** at some areas. These areas are known as ***fertile areas.***

The protoplasm of the ***fertile area*** has a ***single diploid nucleus.*** The fertile area develops a ***small papillate projection*** called ***extrusion papilla*** on the surface of the ***assimilator.***

In the meantime, the ***diploid nucleus*** divides ***meiotically*** into four ***haploid nuclei*** and the ***cytoplasm splits*** into ***four pieces***. Hence ***four haploid protoplasts*** are formed in the ***fertile area***.

Each protoplast becomes ***pear-shaped*** and develops ***two equal flagella*** at its anterior end.

The ***biflagellate cells*** are called ***gametes*** or ***swarmers.***

The ***mature gametes*** together with a ***slimy mass*** are released into the ***extrusion papilla.***

The ***wall of the papilla*** gets ***gelatinised*** by ***water*** so that the gametes are released in the water.

The fertile assimilators usually die off after the ***liberation*** of the ***gametes***.

The ***male gametes*** are ***smaller in size***, actively ***motile*** and ***bright green in colour.*** They are often known as ***microswarmers.***

The ***female gametes*** are ***larger in size, slow moving*** and ***brownish green*** in colour. They are otherwise called ***macroswarmers.***

Each gamete has a ***pear-shaped body*** and ***two anterior flagella***. It contains a ***single chloroplast***, a ***haploid nucleus*** and an ***eye-spot***.

The released ***micro*** and ***macro-swarmers*** swim in water and fuse together to form a ***diploid zygote.***

The ***zygote loses its four flagella*** and ***gets rounded***. It secretes a ***thick wall*** around it to become an ***oospore.***

The oospore produces a ***tubular projection*** by increase in the volume of ***protoplasm*** and in the ***number of nuclei*** and ***chloroplasts***.

This projection later on grows into a diploid ***sporophytic plant.***

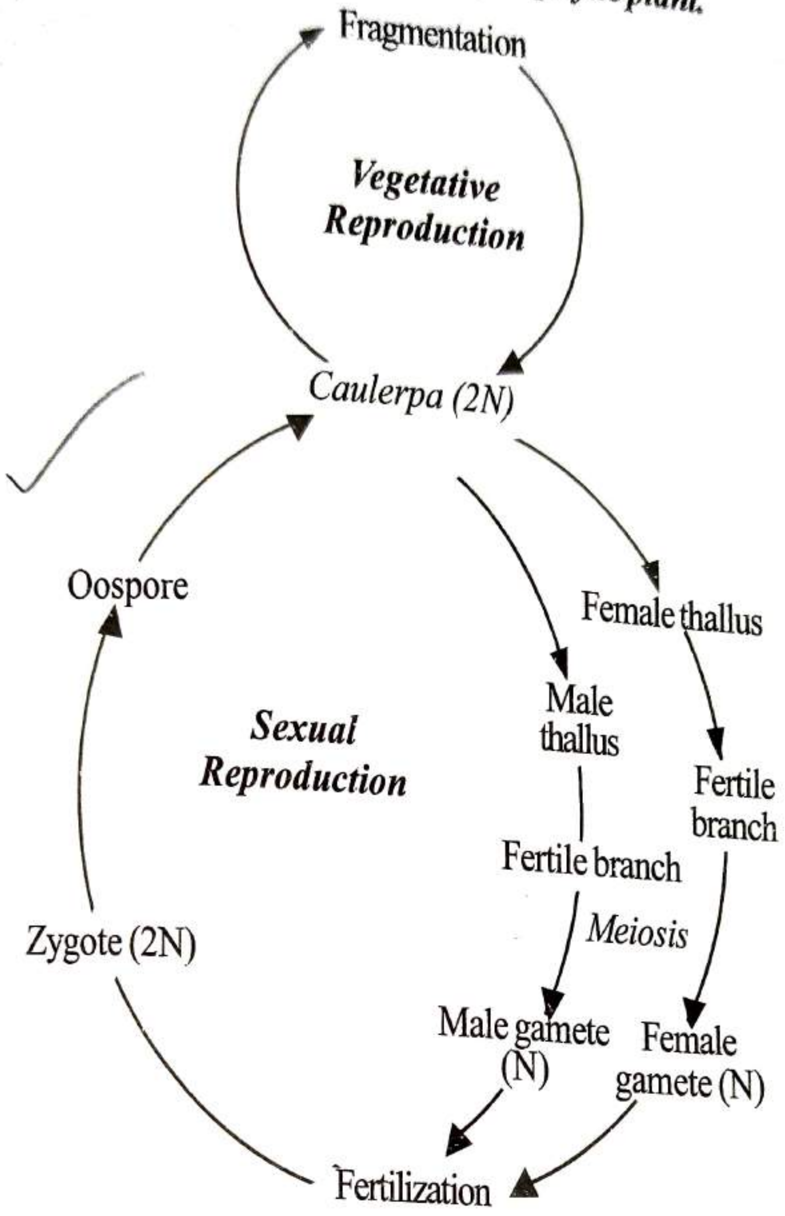


Fig.11.4: Caulerpa prolifera - Graphic life cycle.

Conclusion

Caulerpa is a ***diploid sporophytic plant*** (2N). ***Meiosis*** takes place during ***gametogenesis.***

There is ***no independent gametophytic plant***. The ***male*** and ***female gametes*** are ***haploid*** and they fuse together to form a ***diploid zygote.***

The zygote germinates into a ***new sporophytic plant*** (2N). The diploid phase is dominant in the life cycle and the haploid phase is restricted to haploid gametes. Hence the life cycle is known as ***diplontic life cycle.***

Highlights

Life Cycle of *Caulerpa*

- *Caulerpa* is a ***marine green alga***.
- It is included in the class ***Chlorophyceae***.

12 Chara

Class	:	*Chlorophyceae*
Order	:	*Charales*
Family	:	*Characeae*
Genus	:	*Chara.*

Chara is a ***green alga***. It is included in the class ***Chlorophyceae***.

It grows in ***pools, ponds*** and ***lakes***.

It is commonly known as ***stone wort*** or ***brittle wort*** because the plant body is encrusted with ***calcium carbonate***. This alga grows in clear still waters and does not grow in contaminated waters.

Chara is ***world-wide*** in distribution. It includes about 90 species. Of these 27 species are found in India.

The common Indian species are:

Chara vulgaris | *Chara nuda*
Chara zeylanica | *Chara erythrogyna*
Chara corallina | *Chara fragitis.*

Thallus Structure

Chara is a ***green alga***. It is commonly called ***stone wort*** or ***brittle wort*** because the thallus is encrusted with ***lime***.

It is a ***freshwater*** form.

It is a ***submerged attached*** alga.

The thallus of *Chara* is ***macroscopic***. It is ***erect*** and grows to a height of 20-30 cms.

The plant body is called ***thallus***.

The thallus consists of a ***main axis*** and ***rhizoids***.

The plant is a ***haploid gametophyte.***

The plant is attached to the substratum by means of rhizoids.

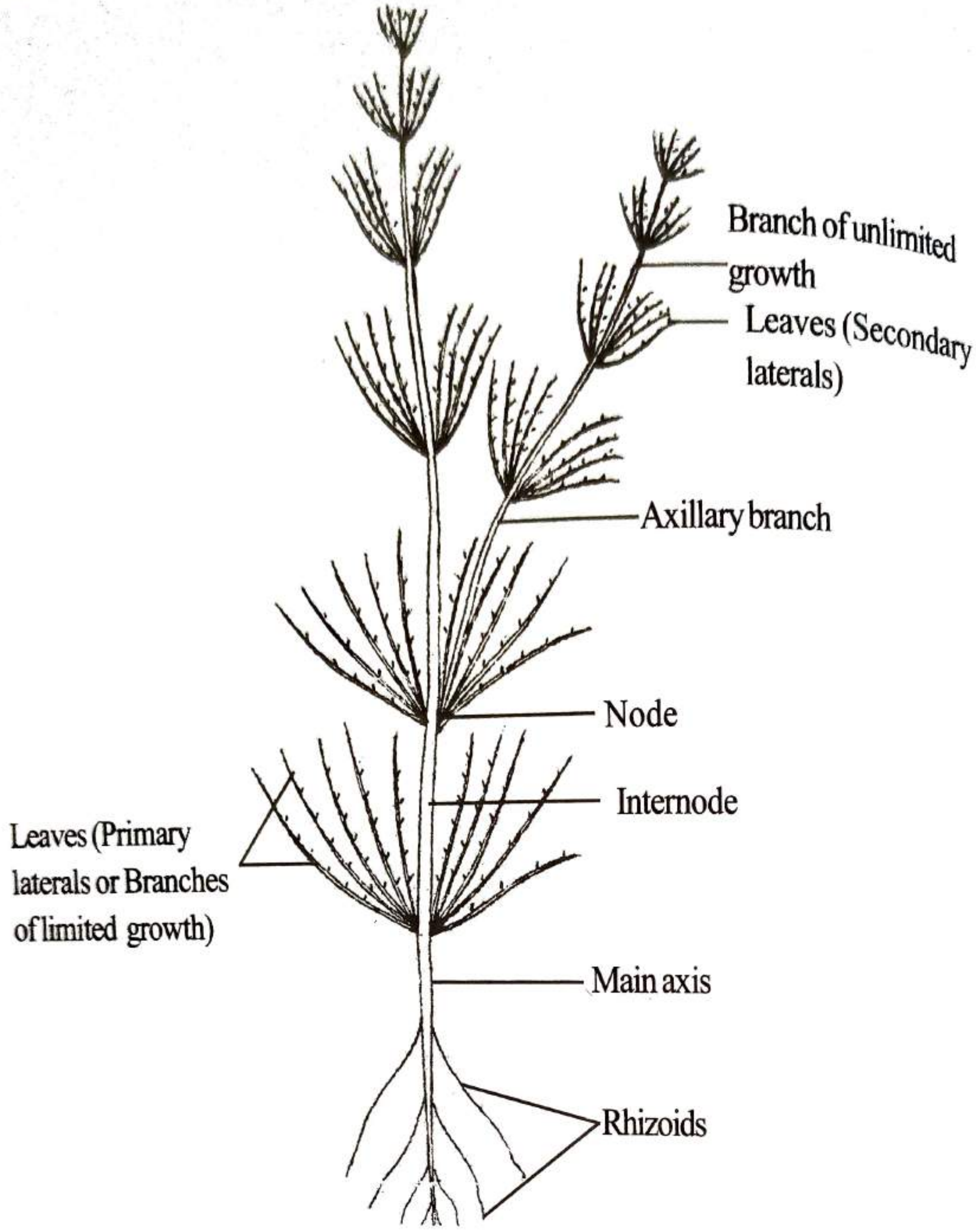


Fig.12.1:Chara-Structure of thallus.

The rhizoids are ***uniseriate*** and ***branched***.

The main axis consists of ***nodes*** and ***internodes***.

The node is made up of two ***central cells*** surrounded by 6 to 20 peripheral cells called ***cortical*** cells.

The internode is made up of a single long central cell called ***axial cell*** surrounded by many ***cortical cells***.

The node bears three types of branches namely '***leaves'***, ***stipulodes*** and ***axillary branches***.

The ***'leaves'*** arise as a whorl around the node. They have ***limited growth***. They are also called ***primary laterals*** or ***branchlets***.

The 'leaves' also contain nodes and internodes.

The nodes of leaves contain a whorl of branches called ***stipulodes***.

In addition, the nodes of 'leaves' contain sex organs such as ***nucule*** (oogonium) and ***globule*** (antheridium).

Nucule is located ***above*** the stipulodes and globule is located below the stipulodes.

Below the 'leaves' the node of the main axis bears unicellular branches called ***stipulodes***.

The stipulodes are present as a whorl around the node.

The node of the main axis bears a third branch. It grows up from the axil of the 'leaves'. nce it is called ***axillary branch***. As it grows laterally from the main axis, it is also called ral ***branch***.

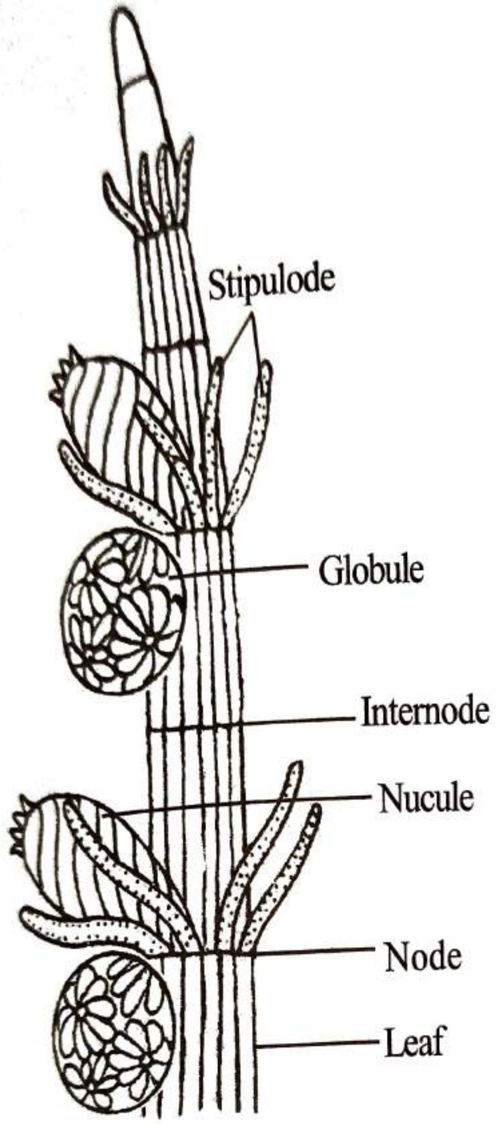


Fig.12.2:Chara-An enlarged leaf.

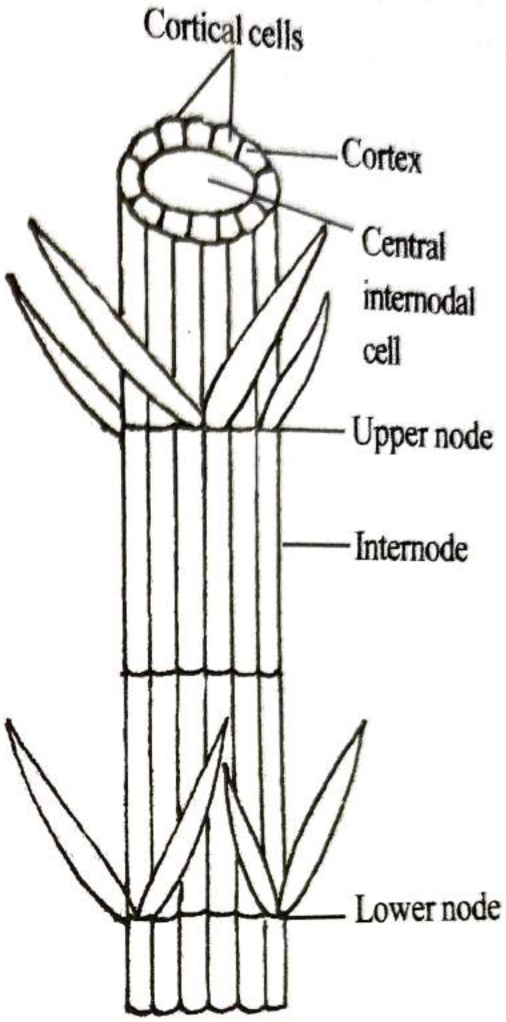


Fig.12.3:Chara-Stem structure.

It has ***unlimited growth***.

The axillary branches also contain ***nodes, internodes, 'leaves', stipulodes*** and ***sex organs*** similar to that of main axis.

The leaves of the axillary branches are called ***secondary laterals***.

The cells that surround the internodal cell constitute ***cortex***.

The process of development of cortex is called ***cortication***.

The cortex of each internode is contributed by the adjacent two nodes.

One set of cortical cells grow downwards from the upper node and the other set of cortical cells grow upwards from the lower node. These two sets of cells elongate and meet in the middle of the internode ensheathing the central internodal cell. This sheath of cortical cells constitutes the cortex.

The cortex is present in most of the species of *Chara*.

The species of *Chara* containing cortex is called ***corticated species***. Eg. *C. zeylanica*.

The species that do not contain cortex is called ***ecorticated*** species. Eg. *C. nuda*.

Cell Structure

The nodal cells are small and the internodal cells are large.

The cell has a thick ***cell wall***.

The cell wall is differentiated into an ***inner layer*** consisting of ***cellulose*** and an ***outer layer*** consisting of ***pectin*** and ***calcium carbonate*** crystals.

Inner to the cell wall is a ***plasma membrane*** around the ***protoplasm***.

The protoplasm contains a haploid ***nucleus*** and a few discoid ***chloroplasts***.

The ***pyrenoid*** is absent.

The chloroplast contains ***chlorophyll-a*** and ***–b***, ***carotenes-α, -β***, and ***-γ***, ***lutein***, ***lycopene***, ***violaxanthin*** and ***neoxanthin***.

Starch granules are the ***reserve food***.

Growth

The growth takes place by a large, dome-shaped ***apical cell*** at the tip of the growing axis.

Highlights

Chara

- *Chara* is a ***green*** alga.
- It is included in the class ***Chlorophyceae***.
- It is commonly called ***stonewort*** or ***brittle wort***.
- The plant body is encrusted with ***calcium carbonate***.
- It grows in ***pools, ponds*** and ***lakes***.
- The plant is a ***haploid gametophyte***.
- The thallus is ***macroscopic***.
- It is an ***attached submerged*** alga.
- It consists of ***main axis*** and ***rhizoids***.
- The plant is attached to the substratum by ***rhizoids***.
- The rhizoids are ***uniseriate*** and ***branched***.
- The main axis consists of ***nodes*** and ***internodes***.
- The node bears three types of branches namely ***leaves, stipulodes*** and ***axillary branches***.
- The leaves arise as a ***whorl*** around the node.
- They have ***limited growth***.
- The leaves are also called ***primary laterals*** or ***branchlets***.
- They have also ***nodes*** and ***internodes***.
- The nodes of leaves bear unicellular branches called ***stipulodes*** and ***sex organs***.
- The nodes of main axis also bear stipulodes below the leaves.
- ***Axillary branches*** arise from the axil of a leaf.

- It is also called ***lateral branch***.
- It has unlimited growth.
- It also bears nodes, internodes, leaves, stipulodes and sex organs.
- The leaves of axillary branches are called ***secondary laterals***.
- ***Sex organs*** arise from the nodes of the leaves.
- The male sex organ is called ***globule*** and the female sex organ is called ***nucule***.
- The nucule is situated ***above*** the globule.
- The cells that surround the internodal cell constitute the ***cortex***.
- The process of development of cortex is called ***cortication***.
- The cell consists of ***cell wall, plasma membrane*** and ***protoplasm***.
- The cell wall is differentiated into an inner layer of ***cellulose*** and an outer layer made up of ***pectin*** and ***calcium carbonate***.
- The protoplasm contains a haploid ***nucleus*** and discoid ***chloroplast***.
- ***Pyrenoid is absent***.
- The chloroplast contains ***chlorophyll-a***, and ***-b***, ***carotenes-α, -β***, and -γ, ***lutein, lycopene, violaxanthin*** and ***neoxanthin***.
- ***Starch granules*** are the reserve food.
- The growth takes place by ***apical cell***.
- *Chara* reproduces by ***two*** methods. They are:
    * *Vegetative reproduction*
    * *Sexual reproduction.*
- Vegetative reproduction takes place by the following methods.
    * *Amylum stars*
    * *Bulbils*
    * *Tubers*
    * *Secondary protonema.*
- The sexual reproduction is ***oogamous*** type.
- In this type of reproduction, the male sex organ ***globule*** or ***antheridium*** produces ***motile sperms*** and the female sex organ ***nucule*** or ***oogonium*** produces ***non-motile egg***.
- *Chara* is ***homothallic*** and ***protandrous***.
- Some species are ***heterothallic***.
- The life cycle is ***haplontic type***.
- The haploid phase is ***dominant*** and the diploid phase is represented by the ***zygote*** only.

Reproduction

Chara reproduces by ***two*** methods. They are:

* *Vegetative reproduction*
* *Sexual reproduction.*

Vegetative Reproduction

Vegetative reproduction takes place by the following methods:

1. *Amylum stars*
2. *Bulbils*
3. *Tubers*
4. *Secondary protonema.*

Amylum Stars

These are ***star-shaped, multicellular*** bodies.
They are produced on the ***lower nodes*** of the main axis.
Each amylum star is an aggregation of cells rich in ***starch***.
These stars get separated from the nodes and grow into new plants. Eg. *Chara stelligera*.

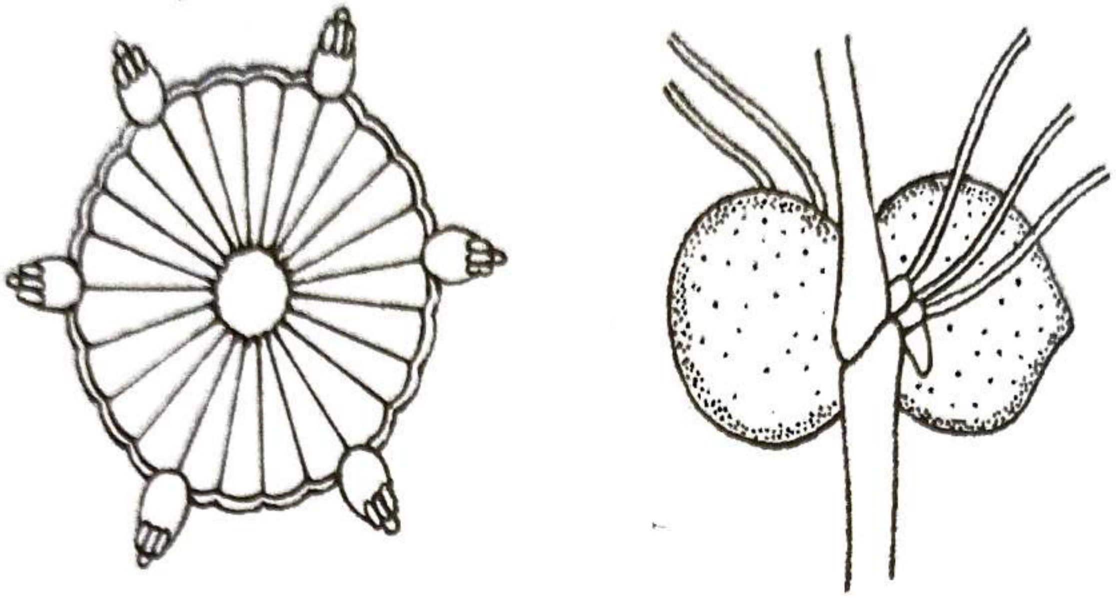


Fig.12.4: Chara-Amylum star and bulbil.

2. Bulbils

Bulbils are ***small, rounded***, tuber-like structures produced from the lower nodes and rhizoids of *Chara*. When the bulbils are detached from the nodes, they grow into new plants. Eg. *Chara aspera.*

3. Tubers

Tubers are ovoid bodies rich in ***starch***.
They are produced on the ***rhizoids***.
They are also known as ***root bulbils***.
During favourable season, they get separated and grow into new plants.

4. Secondary Protonema

The filamentous structures arising from nodes or rhizoids of old stem of *Chara* are called ***secondary protonema***.
Structurally they are similar to the primary protonema.
The secondary protonema forms nodes and internodes.
When the protonema gets detached from the axis, it develops into a new plant.

Sexual Reproduction

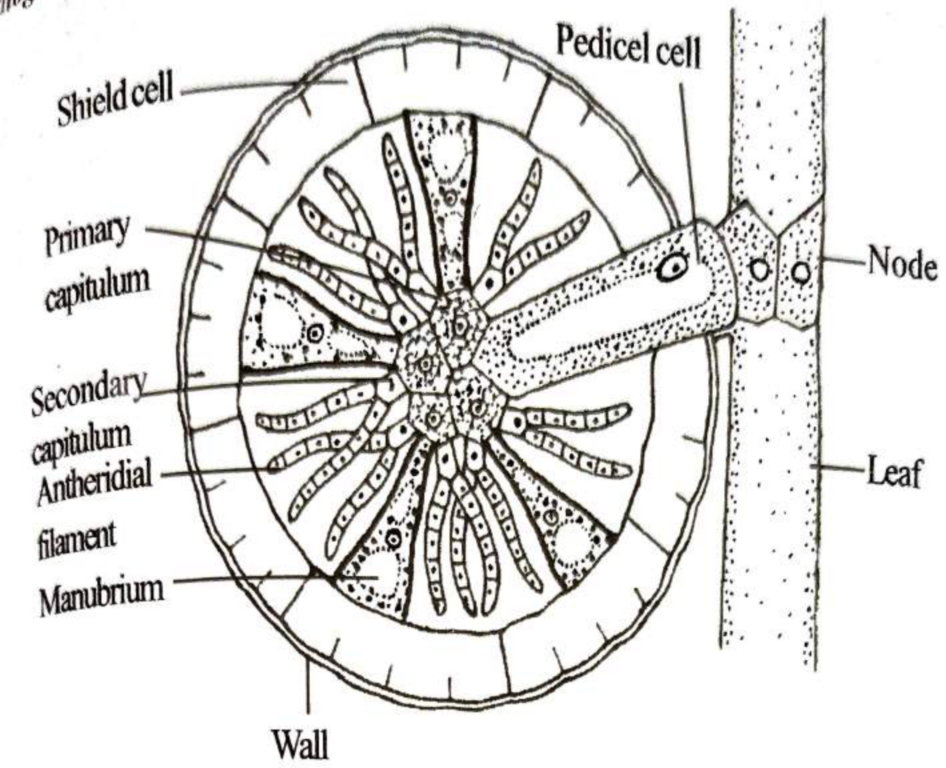
The sexual reproduction in *Chara* is ***oogamous type*** as the eggs are ***non-motile***.
Chara is a ***haploid gametophyte***.
The sex organs are ***multicellular***.
They are protected by a ***sterile envelope***.
The male sex organ is called ***globule*** or ***antheridium***.
The female sex organ is called ***nucule*** or ***oogonium***.
The sex organs are produced at the nodes of the '***leaves***'.
The globule is formed on the lower side and the nucule is formed on the upper side. They are protected by ***stipulodes***.

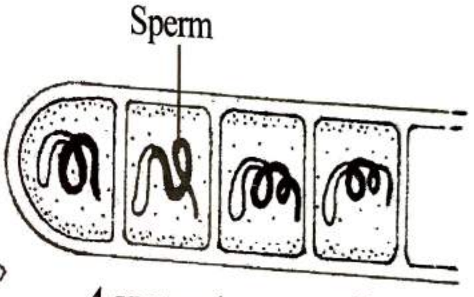
...ara is ***homothallic*** and ***protandrous***.

...wever, a few species are ***heterothallic***. Eg. *Chara wallichii*.

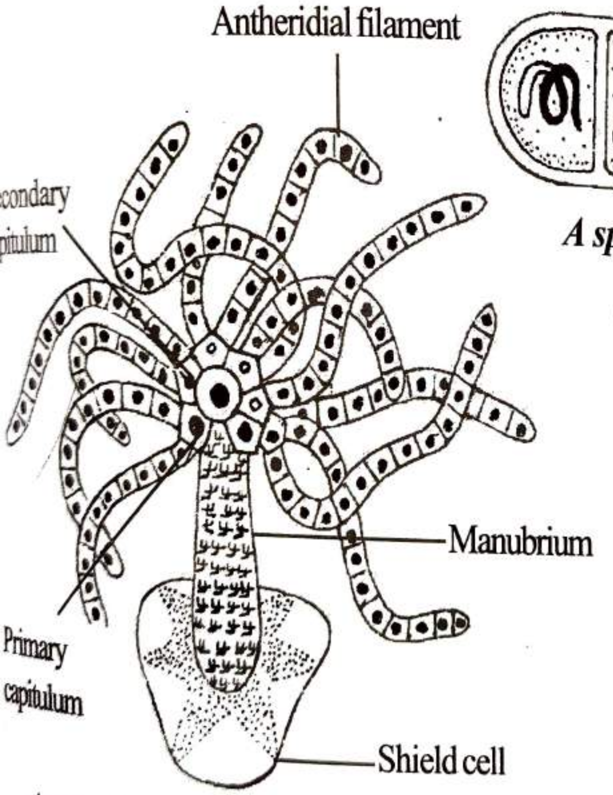
...le

...lobule is the ***male sex organ*** of *Chara*. It is also known as ***antheridium*** or ...togema or ***sperm bud***.

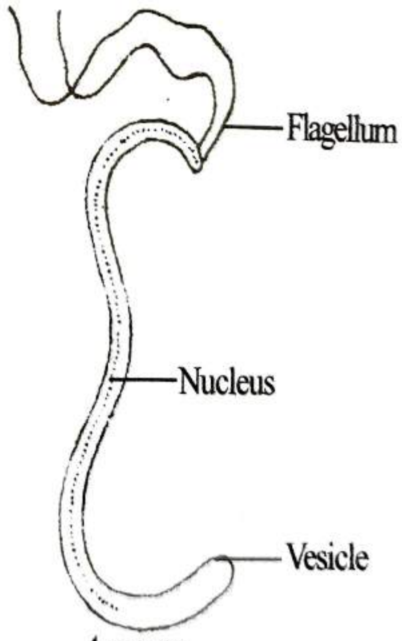




A spermatogenous filament



A shield cell with a manubrium and antheridial filaments.



A sperm

Fig.12.5:Chara-A globule and its components.

It develops at the nodes of 'leaves'. It is formed on the ***lower*** side.

The mature globule is a large, ***hollow, spherical structure***. It is ***yellow*** or ***red*** in colour.

It has a short stalk called ***pedicel cell*** which projects into the cavity.

The wall of the globule consists of 8 curved plate-like cells called ***shield cells***.

The outer surface of the shield cell is ***convex*** and the inner surface is ***concave***.

From the centre of each shield cell arises an elongated cell called ***manubrium***. Thus the globule contains ***8 manubria*** in the hollow space.

At the tip of each manubrium, there is one or two rounded cells called ***primary capitulum*** or ***primary head cell***.

Each primary capitulum produces 2-6 ***secondary capitulum*** cells or ***secondary head cells***.

Each secondary capitulum produces two long uniseriate filaments called ***antheridial filaments*** or ***spermatogenous filaments***. Each spermatogenous filament consists of 50-200 ***sperm mother cells***.

Each sperm mother cell gives rise to an elongated spirally coiled, ***biflagellate sperm*** or ***spermatozoid***.

The spermatozoid of *Chara* is ***spirally coiled*** with about three turns.

The anterior end is ***thin*** and ***pointed***.

A ***vesicle*** is present at the posterior end of the body.

Two ***flagella*** are attached at the anterior end.

Each spermatozoid has an elongated coiled ***nucleus*** and has a ***cytoplasmic sheath*** all over its body. The spermatozoids are liberated as the shield cells separate.

Nucule

Nucule is the ***female sex organ*** of *Chara*. It is also known as ***oogonium***.

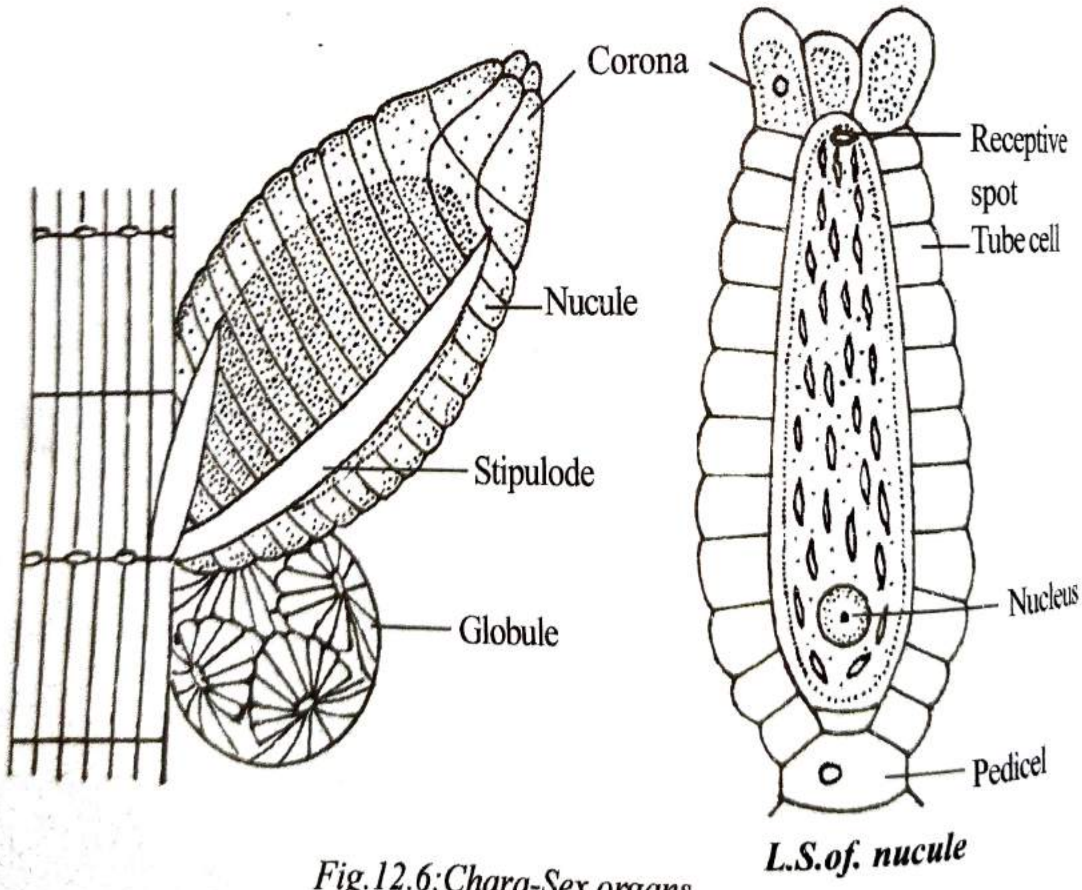


Fig.12.6:Chara-Sex organs.

It is produced at the nodes of '***leaves***'. It is located on the ***upper*** side.
The nucule is ***oval*** in shape and has a short ***pedicel***.
The mature nucule is ***black*** in colour.
It contains a single ***egg***.
The egg cell contains a single basal ***nucleus, dense cytoplasm*** and ***reserve foods*** like ***starch*** and ***oils***.
The egg is surrounded by a sterile ***protective*** envelope.
The protective envelope consists of five spirally elongated sterile cells called ***tube-cells***.
Each tube cell cuts off a small ***crown cell*** at the apex of the nucule.
These five crown cells together form a ***corona*** at the apex of the nucule.
The egg contains a colourless area at the apex called ***receptive spot***.

Fertilization

In mature nucule, the tube cells around the oogonium separate from one another. Hence narrow slits are formed in the envelope.
The oogonial wall at the receptive spot gets gelatinized.
The spermatozoids enter the nucule through the slits of the envelope.
One of the spermatozoids enters the egg cell through the gelatinized oogonial wall and fertilizes the egg.

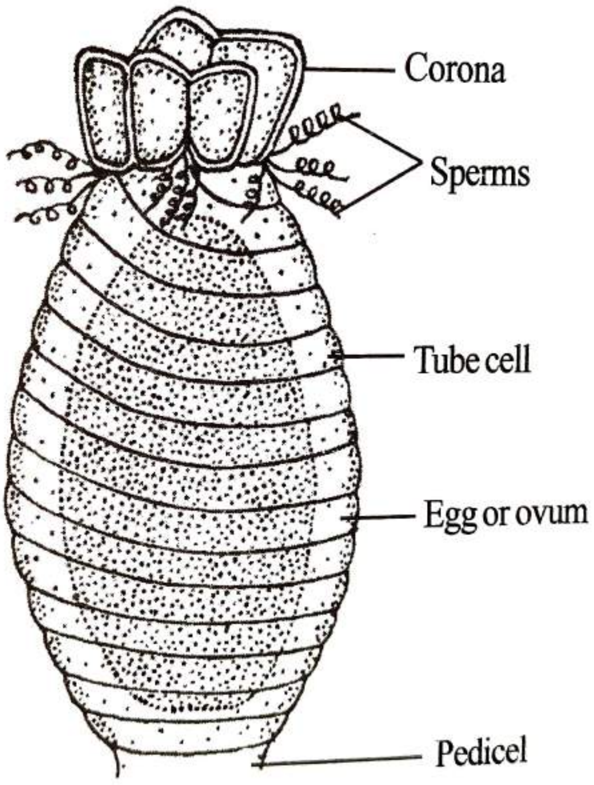


Fig.12.7:Chara-Fertilization.

As a result a diploid ***zygote*** is formed. This zygote secretes a thick wall around it to form an ***oospore***.

Germination of Oospore

After a period of rest, the diploid nucleus of the oospore undergoes ***meiotic*** division to form four ***haploid nuclei***.

A transverse septum develops between the nuclei so that an upper cell containing a single nucleus and a lower cell containing 3 nuclei are formed.

The lower cell degenerates in course of time.

The upper cell divides vertically into a ***protonemal initial*** and a ***rhizoidal initial***. By repeated divisions the protonemal initial develops into a filamentous protonema call ***primary protonema***.

It differentiates into ***nodes*** and ***internodes***. The rhizoidal initial gives rise to colourle ***rhizoids***.

The primary protonema then grows into a new plant.

Conclusion

The life cycle of *Chara* is ***haplontic type*** as the haploid phase is dominant.

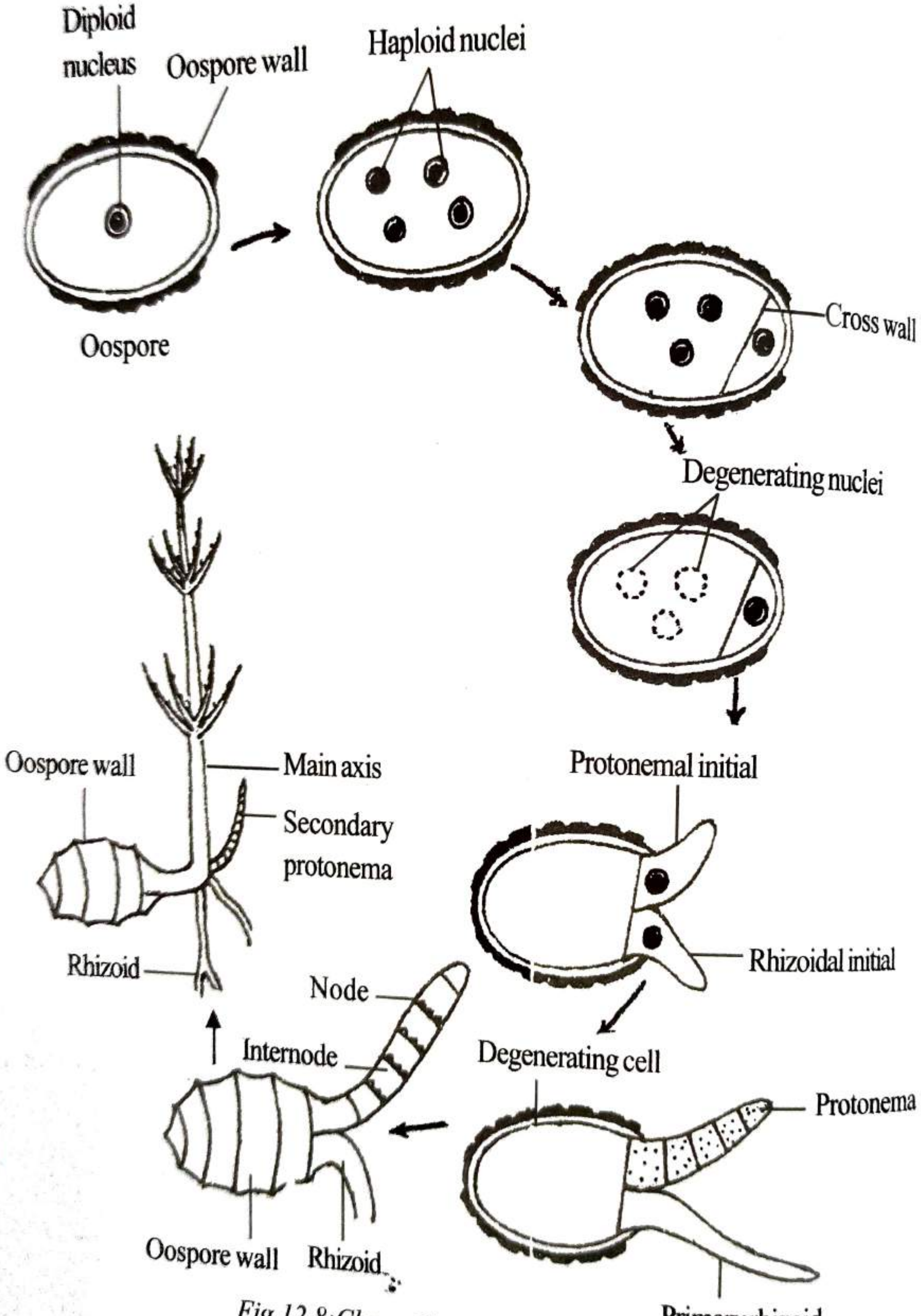


Fig.12.8: Chara-Germination of oospore.

The vegetative thallus is a ***haploid gametophyte*** (N).
It produces ***eggs*** and ***spermatozoids*** by simple ***mitosis***.
The spermatozoid fuses with the egg to form a diploid ***zygote*** (2N).
The zygote undergoes ***meiosis*** to form haploid filamentous ***primary protonema***.
The primary protonema grows into a new gametophytic plant (N).
Here the diploid stage is represented only by the ***zygote***.
There is ***no alternation of generation.***

Phylogeny and Systematic Position of Charales

The members of Charales have uncertain affinities with other groups of plants. There is also no enough fossil evidence to explain the phylogeny of Charales. So the phylogeny of Charales remains a mystery.

All evidences supporting the phylogeny of Charales are based on the characters of living specimens. There are three schools of thought on the phylogeny of Charales.

The first school of thought states that the members of Charales should be kept as a separate division between ***Thallophyta*** and ***Bryophyta***. This view was supported by ***Charles***, ***Round*** and others. They quoted the following reasons to support their view:

1. ***Equisetum-like*** plant body consisting of ***nodes*** and ***internodes.***
2. ***Whorled*** arrangement of branches on nodes.
3. Presence of ***protective*** sheath around the egg cell.
4. Presence of ***sterile wall*** around the antheridial mother cells.
5. ***Spirally*** coiled ***biflagellate spermatozoids.***
6. Presence of ***protonemal*** stage during the germination of oospore.
7. Presence of ***dominant gametophytic*** phase.

On the basis of the above features, the order Charales is elevated to the rank of a division between ***Thallophyta*** and ***Bryophyta***.

The second school of thought states that Charales should be kept as a separate ***class*** under algae. ***G.M. Smith, V.J. Chapman, T.V. Desikachary, Sundaralingam, Prescott,*** etc. are strong believers of this view. They stated the following reasons to include Charales as separate class ***Charophyceae*** under algae:

1. Absence of alternation of generation.
2. Marked differences in the structure of sex organs from those of Bryophytes.
3. Presence of ***haplontic type*** life cycle.

They believe that the differences between Charales and Chlorophyceae are insufficient to separate them from algae. The sex organs are modifications of a single cell. However, the Charales show ***Equisetoid plant body*** and protected sex organs. Hence Charales is raised to the rank of class ***Charophyceae*** under ***Chlorophyta***.

The third school of thought states that Charales should be kept under the class ***Chlorophyceae.*** This view was first proposed by ***F.E. Fritsch*** and supported by ***M.O.P. Iyengar***. They quoted the following reasons to include Charales as an order of Chlorophyceae:

1. The ***nodes*** and ***internodes*** are similar to that of Chaetophorales.
2. Presence of ***haploid vegetative thallus***.
3. Presence of similar ***pigments*** in Charales and other Chlorophyceae.

4. Presence of ***starch*** as reserve food.

5. Presence of ***haplontic type*** life cycle.

Because of the above reasons, the order Charales is included under the class Chlorophyceae. In recent years it is raised to the rank of a division and named ***Charophyta.***

Life Cycle of *Chara*

Chara is a ***freshwater, submerged green alga***.

It is ***attached*** to the muddy bottoms of ***ponds, pools*** and ***lakes***.

The plant body is hard in texture due to the deposition of ***calcium carbonate***. Hence it is called *stonewort* or ***brittle wort***.

The plant is a ***haploid gametophyte (N).***

It grows to a height of 20-30 cms. It has a branched ***main axis*** and ***rhizoids***. The thallus is attached to the substratum by means of ***rhizoids***.

The main axis is differentiated into ***nodes*** and ***internodes***. The node bears three types of branches namely '***leaves***', ***stipulodes*** and ***axillary branches***.

The 'leaves' and axillary branches contain ***nodes*** and ***internodes*** similar to that of main axis.

The node of the axillary branch also bears 'leaves' as well as stipulodes.

The node is ***corticated***.

Sex organs such as ***nucule*** (oogonium) and ***globule*** (antheridium) are located on the nodes of leaves.

Nodal cells are smaller and shorter than internodal cells.

The cell wall is thick and is differentiated into an inner layer of ***cellulose*** and an ***outer layer*** of ***pectin*** and ***calcium carbonate***.

Inner to the cell wall is a ***plasma membrane*** around the ***protoplasm***.

The ***protoplasm*** is dense and ***granular***.

It possesses a haploid ***nucleus*** and a few discoid ***chloroplasts***.

Pyrenoid is absent.

Starch is the reserve food.

The chloroplasts contain ***chlorophyll-a*** and ***–b, carotenes-β and –γ, lutein, lycopene, violaxanthin*** and ***neoxanthin.***

The growth takes place by a dome-shaped ***apical cell***. All cells of the thallus are derivatives of the apical cell.

Chara reproduces by ***two*** methods:

* *Vegetative reproduction*
* *Sexual reproduction.*

The vegetative reproduction takes place by ***amylum stars, bulbils, tubers*** and ***secondary protonema.***

Amylum stars are star-shaped bodies rich in ***starch*** produced on the lower nodes of main axis. They grow into new plants, when they get detached from the axis.

Bulbils are small round structures produced on the lower stem nodes and rhizoids. When they get detached from the stem, they germinate into new plants.

Tubers are ovoid bodies rich in starch produced on rhizoids. They germinate into new plants.

Secondary protonema are green filaments arising from basal nodes or old rhizoids of *Chara.*

They get differentiated into ***nodes*** and ***internodes***. The detached secondary protonema grows into new plants.

The ***sexual reproduction*** in *Chara* is ***oogamous type***. The sex organs are highly specialized structures and are protected by a ***sterile envelope***.

The male sex organ is called ***globule*** or ***antheridium*** and the female sex organ is called nucule or ***oogonium***.

The sex organs are produced at the nodes of ***primary laterals*** or ***leaves***.

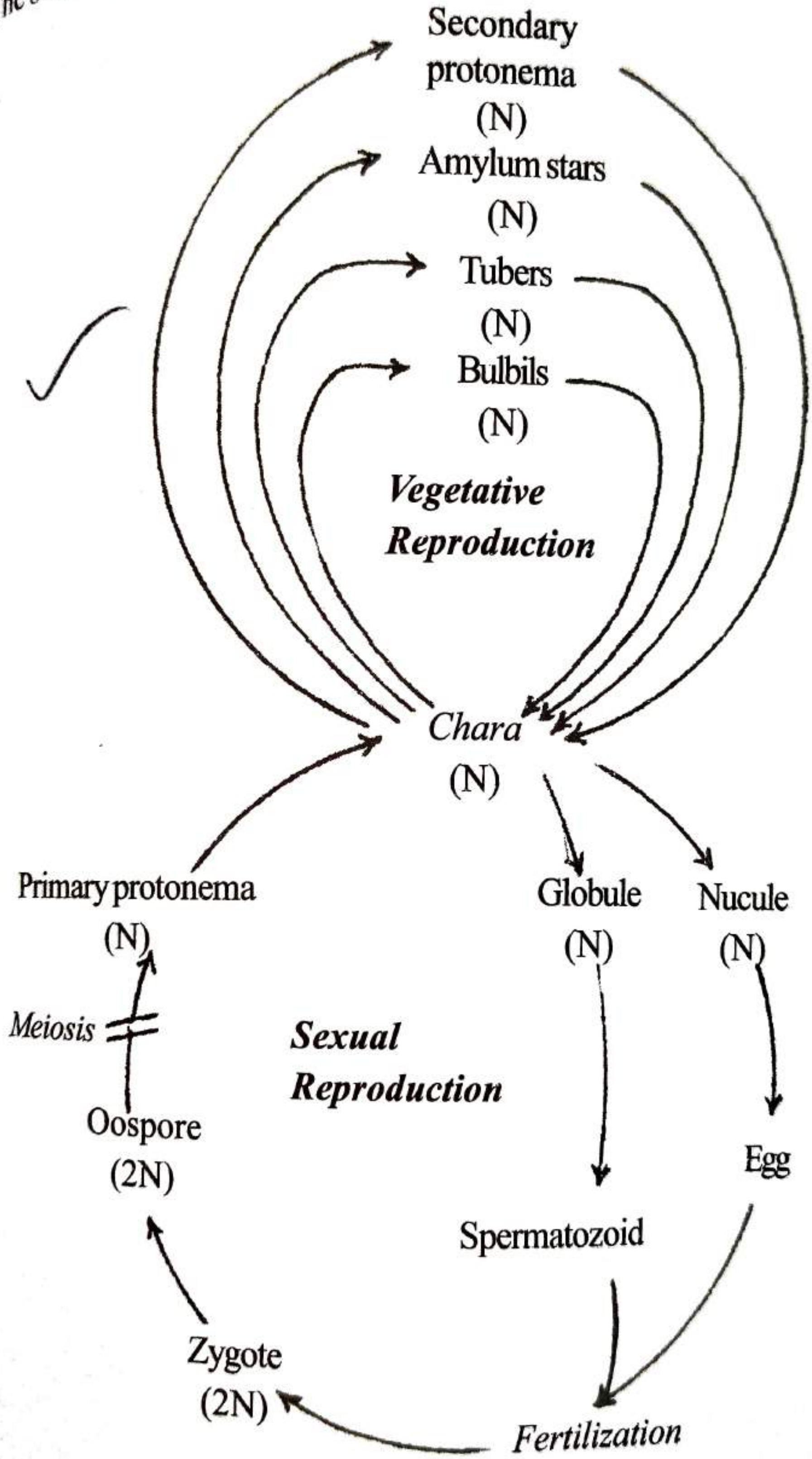


Fig.12.9:Chara-Graphic life cycle.

The globule and nucule are found in the same plant.

The globule is formed on the lower side and the nucule is formed on the upper side. Most species of *Chara* are ***homothallic*** and ***protandrous*** (ie. The globule matures first). Eg. *Chara zeylanica*. But some species are ***heterothallic.*** Eg. *Chara wallichii.*

The globule is also known as ***antheridium***.

The mature globule is a ***large, hollow, spherical*** structure with a short unicellular ***stalk***.

The globule wall is made up of 8 curved plate-like cells called ***shield cells***.

From the inner surface of each shield cell, a rod-shaped cell called ***manubrium*** arises.

The free end of the manubrium bears a few ***isodiametric cells*** called ***primary capitular cells*** and ***secondary capitular*** cells.

Two long filaments called ***antheridial filaments,*** arise from each ***secondary capitulum***.

Each antheridial filament has a single row of 50-200 ***sperm mother cells***.

Each cell produces a ***spermatozoid.***

Nucule is also known as ***oogonium***.

It develops at the node of primary laterals or leaves.

The mature nucule is oval-shaped and has a ***short stalk***.

The oogonium is surrounded by a sterile protective ***envelope***.

It contains a large ***egg cell*** containing a basal ***nucleus, dense cytoplasm, starch*** and ***oils***.

The protoplasm at the upper part of the egg is colourless and serves as ***receptive spot.***

The protective envelope consists of five spirally coiled elongated cells called ***tube cells.***

The tube cells form a five-celled ***crown*** above the oogonium. The crown is called ***corona.***

Towards maturity, tube cells of nucule get separated from one another and leave narrow slits.

The egg secretes ***mucilage*** at the receptive spot.

The spermatozoid enters the oogonium and fuses with the egg to form a ***zygote (2N).***

The zygote secretes a thick wall around it to become an ***oospore.***

After a period of rest, the diploid nucleus of the oospore undergoes ***meiosis*** to form ***four haploid nuclei.***

A cross ***wall*** develops so as to form three - nucleate cell and uninucleate cell.

The three - nucleate cell degenerates and the uninucleate cell divides into a ***protonemal initial*** and a ***rhizoidal initial***.

The ***protonemal initial*** forms a filamentous ***protonema*** with nodes and internodes and grows into a new plant.

The rhizoidal initial produces ***rhizoids***.

Conclusion

The plant is a ***haploid gametophyte (N).*** It produces sex organs.

The male sex organ is the ***globule*** and female sex organ is the ***nucule***.

The globule produces ***haploid spermatozoids*** and the nucule produces a haploid ***egg***.

A spermatozoid fuses with the egg to form a diploid ***zygote*** (2N).

The zygote undergoes ***meiotic*** division to form a ***haploid gametophytic plant (N).***

The ***haploid phase*** is dominant and the ***diploid phase*** is restricted to the zygote only.

The life cycle of *Chara*, is known as ***haplontic type***.

There is ***no alternation of generation***.