Discipline Courses-I
Semester-I
Paper: Phycology and Microbiology
Unit-VIII
Lesson: Charophyceae
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Chapter: Charophyceae

Introduction

Members of Charophyceae are very closely related to the ancestory of land plants and exhibit the useful information about the evolutionary process and the pattern of extinction. It is an ancient group (known since Silurian period), that show the basic similarity in pigmentation, metabolism, cell structure, reserve food, type of reproduction and occurrence in fresh water habitat with green algae. There are six living genera and the remaining as fossils. Charophyceae includes the genus *Chara and Nitella* commonly found in fresh water bodies rich in minerals as epipelics. In this lesson the genus *Chara* is dealt in detail.

CHARA (Common name: Aquatic Horse Tail/ a mountain stream/ a stonewort)

Habit

Chara a fresh water, macroscopic, filamentous, multicellular benthonic epipelic alga.

Figure : *Chara fragilis* – W.M. of a plant collected from submerged condition.

Source: http://bobklips.com/bobs_website/CHARVULK-22Jul08-SPBI-PLE.jpg (CC-BY-SA);http://upload.wikimedia.org/wikipedia/commons/thumb/c/cf/CharaFragilis.jpg/220px-CharaFragilis.jpg

Habitat

Chara is an epipelic, gregarious alga found attached at the base with the help of root like rhizoids to the soil at the bottom of stagnant, shallow, slow running, fresh water bodies like ponds, pools, lakes and streams respectively with aerial parts free floating in submerged conditions. It is also seen growing in abundance at the banks of Hindon River (Ghaziabad, UP) in shallow water. The genus has about 117 species of which, 27 are recorded from India, 7 species are endemic eg. *Chara hatei*, *C. pashanii*, *C. handae*, *C. nuda, C wallichii , C grovesii*, and *C. vandalurensis.*

It grows in hard fresh water with organic matter (producing H_2S) Calcium and less O_2, Phosphorus 4-6 mg/l. *Chara baltica* grows in salt water (salt < 1%). It is an annual or perennial, hibernates as thick oospores in hot and dry weather and has sulphur containing compounds due to which it possesses disagreeable onion like odour.

Vegetative Thallus

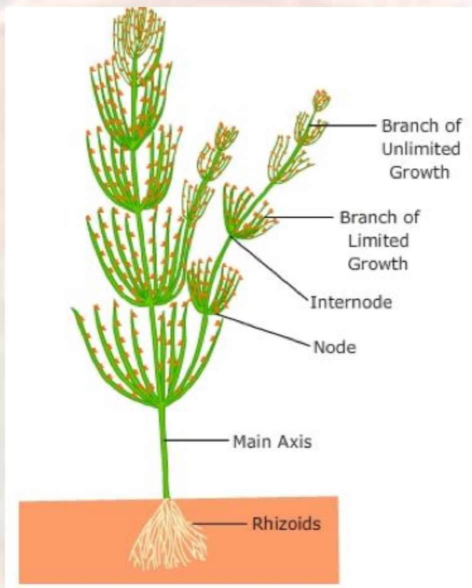


Figure : Magnified view of *Chara* Plant (Habit)

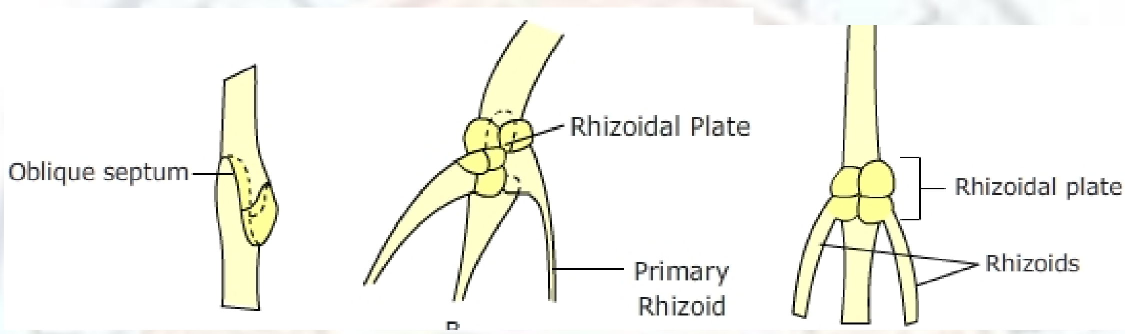
Source: Author

Chara thallus is well differentiated into basal root like creamish white rhizoids arising in bunches(like adventitious roots of higher plant), green or greyish green aerial stem like axis, surrounded by lateral branches and stipules like leaves. Thallus grows erect in submerged conditions with jointed appearance of nodes and internodes (Similar to *Equisetum* a Pteridophyte) and because of the latter trait is called the Aquatic Horsetail.

It attains a height of 1 meter with profuse lateral growth. *C. hatei* thallus has a trailing and subaerial habit and is of 20-30 cm in height. In several species of *Chara* the thallus bears rough incrustation of lime as cortical spines that makes it brittle and coarse because of which it is named as **stone wort** or **brittle wort**. Some Species of *Chara* are flexible and have mucilage sheath on cell wall, without any other matter deposition.

Rhizoids

A non-green, long, creamish white multicellular anchoring organ. The cells of which have outer and inner cell wall, nucleus, protoplasm, small solid particles present at the tip of the rhizoids function as statoliths are involved in graviperception. It arises from the peripheral cortical cells of lower nodes of main axis, grows with the apical cell and shows oblique septa.



A **B** **C**

Figure: Magnified view of rhizoids : A. An outline diagram showing oblique septum. B-C. Rhizoidal plate with two basal cells forming rhizoids.

Source: Author

Functions : Rhizoids perform the following functions:

1. Fixing the plant to the soil or substratum.
2. Absorption of minerals from the bottom sediments.
3. Reproduction and perennation by bulbils and secondary protonema.

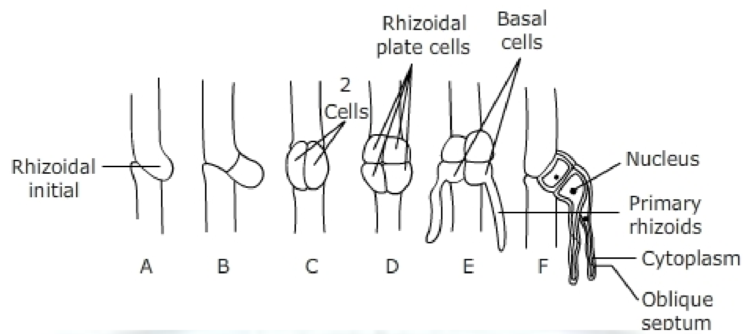


Figure : Development of rhizoidal initial from a branch of *Chara sp.* : **A-D**. Production of 4 lateral cells. **E-F**. Rhizoids produced only from basal two cells.

Source: Author

Stem

The stem like axis consists of alternate nodes and internodes.

Node: It is a short multicellular and complex structure, which consist of two central cells surrounded by 6-20 peripheral cells (Cortex).

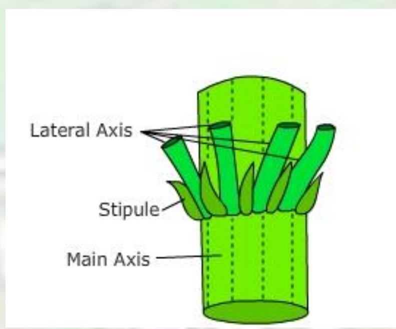


Figure: *Chara* - W. M. of main axis with lateral branches

Source: Author

The peripheral cells give rise to two types (dimorphic) of branches:

- Branchelets of limited growth (short)
- Branchelets of unlimited growth (Long)

Internode: It is of two types:

- Corticated internode- An elongated central cell of 10 cm in length surrounded by one cell thick sheath called cortex eg. *C.flaccida*. etc.

- Ecorticated internode- Central internodal cell is devoid of peripheral cortical layer of cells. eg *C. nuda*. etc

Growth: The main axis or stem grows with the help of a dome shaped apical cell. By means of transverse walls it cuts disc shaped segments at the posterior or lower end. Each segment divides further and gives rise to upper biconcave nodal initial and a biconvex internodal initial. Internodal initial elongates and continue its growth terminally. Nodal initial divides several times and give rise to 2 central cells and 6 – 20 peripheral cells, secondary branchlets and bract like stipules or bracts.

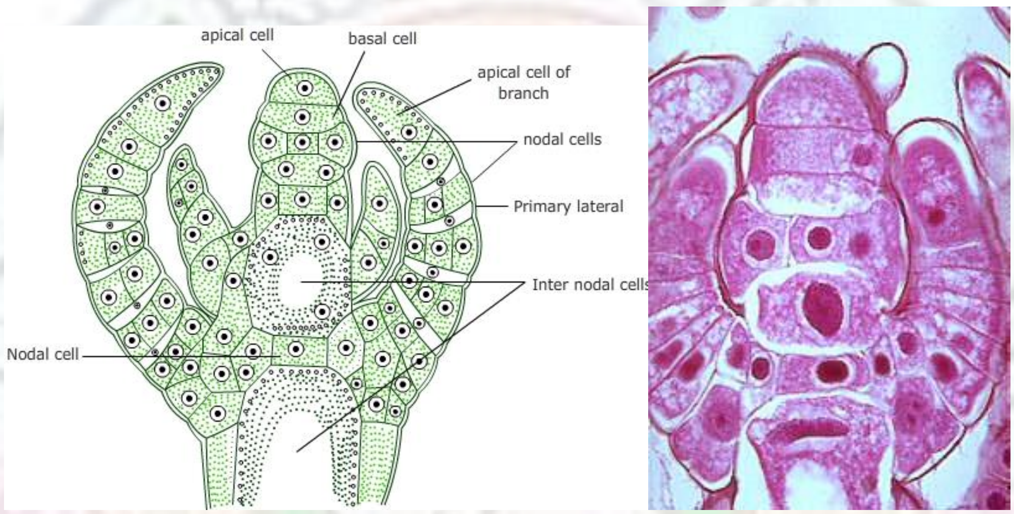


Figure: *Chara* – V.S. of apical metistematic zone***.***

Source: Author; http://www.biologie.uni-hamburg.de/b-online/fo44/chara50.jpg

The main axis or stem bears two types of lateral branches that arise from nodal region:

Short branches- Branches of limited growth or primary laterals and leaf like structures. These branches arise in whorls from each node corresponding to the number of peripheral cells at each node and limit their growth after attaining a definite length. These branches bear nodes and internodes like the main axis and end up to a long apical cell. At the nodal region whorl of one celled out growths called bracts or stipuloides or secondary laterals arise alternating to the branch. The short fertile branches bear sex organs in axil of bracts or stipuloides, or secondary laterals arise alternate to the branchlets.

Long Branches- They are also named as secondary branches or branches of unlimited growth. They arise singly or in groups from the axil of primary branchlets; hence are named as axillary long branches. They have the same structure and growth pattern as of the main axis. In corticated species these branches cause suppression of upward growth of main axis.

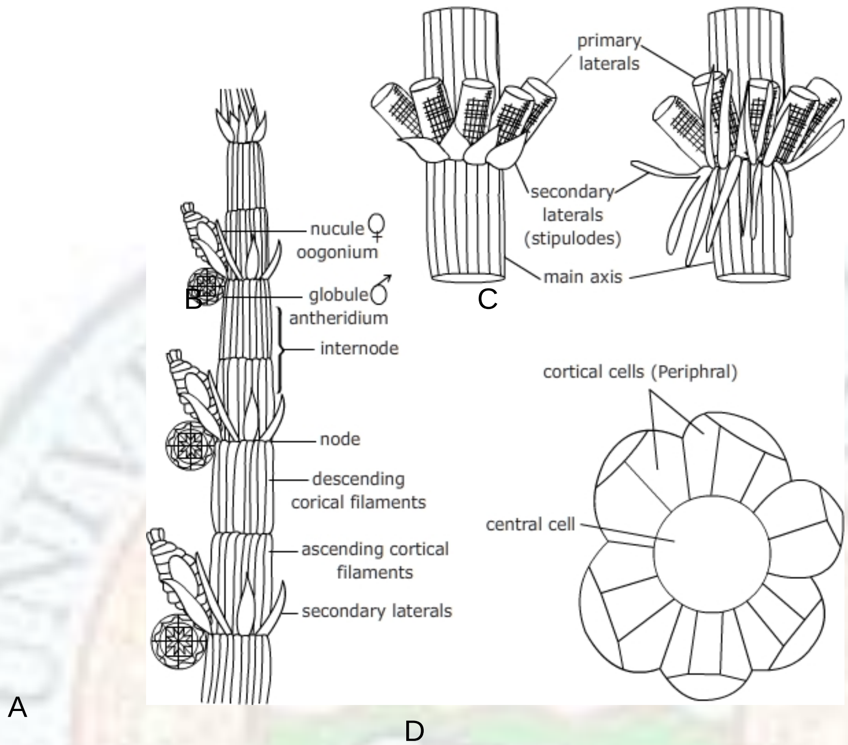


Figure: *Chara* – Magnified view of aerial axis showing **A.** W.M. of branch of limited growth with fertile lateral branches. **B.- C.** W.M. appendages at each node. **D.** Outline diagram of T.S. internode.

Source: Author

Stipulodes or stipules or bracts: These are short oval or pointed leafy one celled outgrowths developed from the basal parts of branchlets. The growth pattern shows:

(a) Haplostephanous type with one whorl of bracts on each node, unistipulate (1 bracts) eg. *C. braunii*.

(b) Diplostephanous type with two whorl of bracts on each node, Bistipulate (2 bracts) eg. *C. buramanica*

(c) Triplostephanous – Stipulodes or bracts occur it three whorls, Tristipulate (3 bracts). eg. *C. ceratophylla*

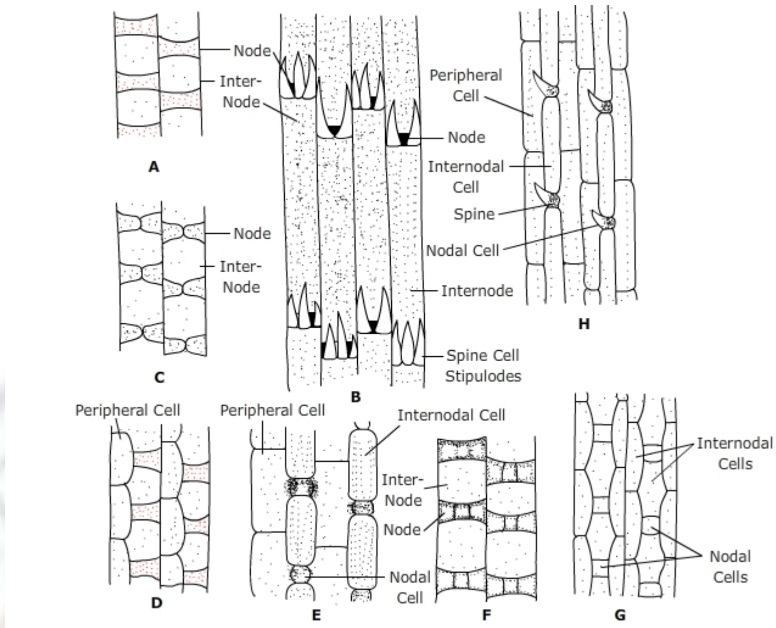


Figure: *Chara* - Outline diagram of different types of cortex:**A.**Young cortex with node and intermodal cells.**B.**W.M. of haplostichous type with spine cells (stipulodes) *C. canescens* **C-E.**Different stages of diplostichous type *C. delicatule* **F.- H.** Triplostichous type *C.fragilis*

Source: Author

In some species stipules are rudimentary eg. *C. nuda* or completely absent eg. *C. pashanii* .

Cortex-Presence of vertically elongated narrow cells around central internodal cell called cortex. Based on the series of peripheral cortical cells around inter-nodal cells. Cortex is of three types:-

1. Haplostichous - Single series of cortical cells eg. *C. canescence.*
2. Diplostichous- Two series of cortical cells eg. *C. delicatule.*
3. Triplostichous – Three series of cortical cells. eg. *C. fragilis.*

Cell Structure

Chara has two types of cells:

1. Nodal cell:- It is a small isodiametric in outline with single centrally placed nucleus and small scattered vacuoles.

2. Internodal cell – It is long and cylindrical. The adjacent cell exhibits protoplasmic continuity by means of plasmodestmata. Each cell is surrounded by:

- Outer cell wall which is made up of cellulose (found in the form of microfibrils deposited in a homogeneous matrix) .
- Inner cell membrane hyaline, selectively permeable.
- A superficial layer of mucilaginous material in some species.
- Lime in the form of calcite (Rhomboidal) deposits on the cell wall in several species.

Protoplasm contains cytoplasm, endoplasmic reticulum, mitochondria, ribosomes, dictyosomes, chloroplasts, nuclei and large central vacuole. The outer exoplasm has partially embedded chloroplasts. The inner endoplasm is more fluid than the outer exoplasm. Pyrenoids are absent. Reserve food material is in the form of starch grains. The internodal cell is multinucleated The number of chromosomes vary eg. n=12 in *C. canescense* and n=28 in *C. zeylanica*.

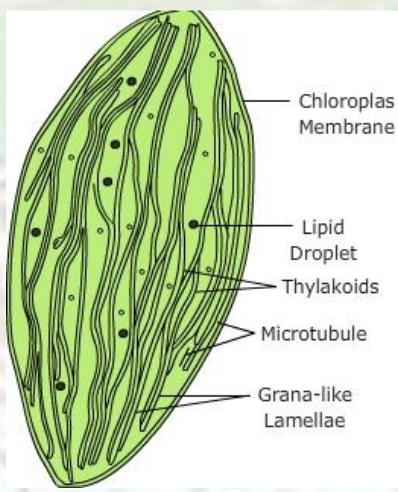
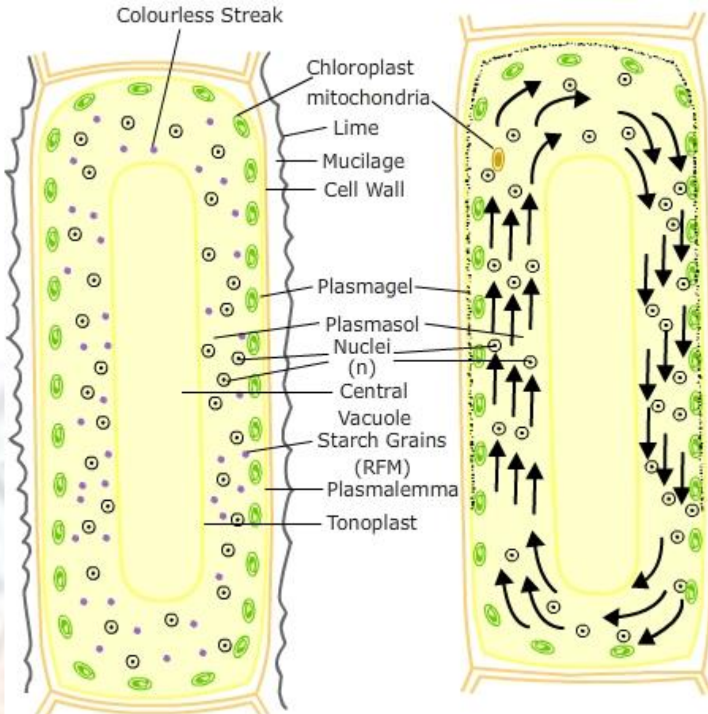


Figure: *Chara*- Magnified view of a chloroplast

Source: Author



A. **B.**

Figure: *Chara* sp. A. Magnified view of internodal cell. B. Protoplasmic streaming in a internodal cell.

Source: Author

Streaming of Protoplasm (Cyclosis): All types of cells except young show cyclosis. The endoplasm of plasmasol continually show up and down streaming in long direction, which is caused by sol-gel changes in the cytoplasm through alternate contraction and expansion of protein fibrils.

Reproduction

Asexual Reproduction

Chara reproduces asexually by vegetative means. The vegetative parts of the plant give rise to small protuberances in hot and dry weather. Asexual spores are absent.

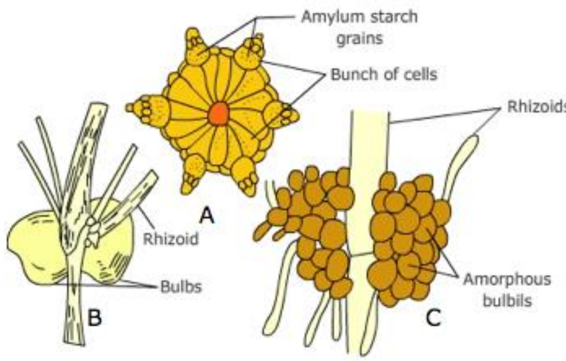


Figure: *Chara* W. M. of asexual (veg.) reproductive bodies. **A.** Amylum stars, **B.** Root bulbs, **C.** Amorphous bulbils

Source: Authors

- **Tubers and Bulbs :** The small outgrowths that arise from the lower nodes and rhizoids. These outgrowths are oval or spherical in shape and rich in food eg *C. aspera.*
- **Amorphous and spherical bulbils**: These are aggregated small and swollen cells that are formed by irregular division of all peripheral cells of stem or all the four cells of the rhizoidal joint. Tubers and Bulbils perennate during unfavourable conditions and grow in next favourable season to form new plants.
- **Amylum Stars:** The multicellular star shaped aggregates develop by proliferation of nodal cells at lower nodes and are filled with abundant amylum starch as reserve food. These stars when detached can give rise to a new plant. eg. *C. stelligera.*
- **Secondary Protonema**: The protonemal structures arise from several parts of the plant which later give rise to adult plants:
  - Rhizoidal node of Primary protonema.
  - Basal node of Primary rhizoids
  - Dormant apical cells.
  - Nodal cells of axis or stem.
  - Buried nodes of older plants

Sexual Reproduction

Sexual reproduction is oogamous. In submerged habitats when temperature rises, water recedes, minerals increase and pH changes (drying up conditions), these conditions hasten the formation of sex organs. The well-differentiated complex and macroscopic antheridium and oogonium are borne on the adaxial surface of lower branchlet nodes.

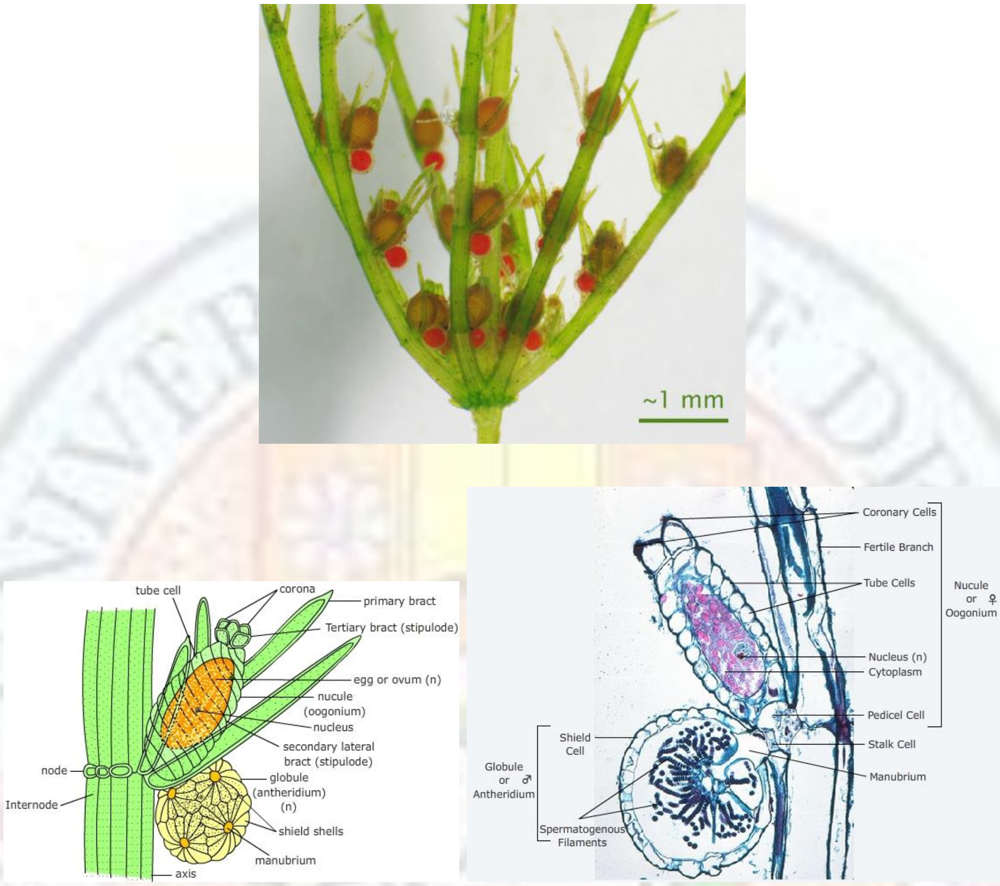


Figure: *Chara* sp. Magnified view of a fertile branch to show the position and details of nucule and globule.

Source: http://upload.wikimedia.org/wikipedia/commons/2/26/CharaV3.jpg;Author; http://facultyweb.berry.edu/mcipollini/bio311/files/chara.jpg

Majority of species are monoecious or homothallic and bear both the sex organs on the same thallus eg. *C. zelanica*. A few species are dioecious or heterothallic and bear both the sex organs on different thalli eg. *C. wallichi* etc. In monoecious species the oogonium lies above the antheridium at the same branchlet node. In some species the monoecious habit changes to dioecious habit by change in day length eg. *C corallina.* Sex organs are considered to be condensed branches and are quite similar to sex organs of bryophytes .

Antheridium or globule

It is a globose, green at young stage and turns yellow, orange or reddish in colour towards maturity. It is borne at the top of a branch of second order and replaces a bract. It has a large pedicel cell lying partly embedded inside the body of antheridium. The basal node contains five peripheral cells. Two of the lateral peripheral cells produce one celled bracteoles, the lower two peripheral cells grow into cortical filaments in corticated forms. In monoecious species the upper peripheral cell gives rise to oogonium or nucule.

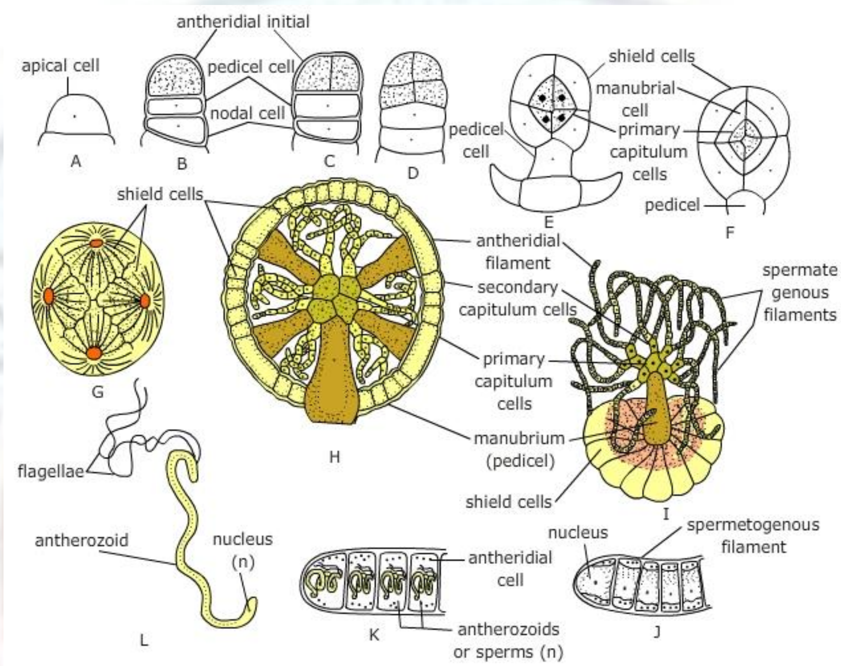


Figure: *Chara*- **A-F.** Developmental stages of globule from apical lateral cell; **G**- Whole mount of mature globule; **H**. V.L.S. of mature globule; **I.** W.M. of sheild cell, Manubrium and Anthredial filaments; **J.** Magnified view of spermatogenous cells; **K.** Single antherozoid; **L.** W.M. of Antherozoid (sperm).

Source: Author

Structure

- Shield Cell: These are concave or convex plate like eight large curved cells initially green due to chloroplast pigments which later turns brilliant orange coloured due to gamma carotene in abundance. These cells have large number of wall infoldings which show sutures fitting into one another.

- Manubrium: It is eight in number and project towards the centre of the globule. Manubrium arises from the central part of the shield cell as an elongated club-shaped cell. Each manubrium bears a head cell or primary capitulum. The cell cuts secondary capitular cells which further divide 2-4 times to form terminal cell initials. These terminal cell initials divide mitotically to give rise to antherozoidal branched or unbranched filament at the centre called spermatogenous filaments.

- Spermatogenous filament or an antheridial filament consists of series of cells arranged in uniseriate fashion called antherozoid mother cells or sperm mother cells. Each cell of spermatogenous filament metamorphoses to give rise to biflagellate sperms or motile male gametes (n). Each globule or antheridium produces two thousand or more sperms.
- Spermatozoid: The sperm or a male gamete is narrow, elongate, spirally coiled uninucleate, unicellular, hyaline, biflagellated structure that has the cytoplasm enclosed at the posterior end. The body shows three coils or turns, the two flagella arise subterminally at the anterior end and are smooth and similar type.
- With the maturity of sperms, the shield cells separate due to internal pressure of manubria, capitular cells and enzymatic secretions. The sperms come out of the pore with body first and flagella at the end in the early hours of morning and continue to swim to reach the nucule slit till evening.

Oogonium or Nucule

It is a large ellipsoidal, oblong single celled female sex organ which encloses a single gamete or egg and is borne on the top of four celled filament. The three cells lying below the nucule are the stalk cell, nodal cell and the pedicel cell. The pedicel is connected adaxially (dorsally) with basal nodal cell of the antheridial axis (in monoecious forms) and branchlet node (in dioceous forms). The nodal cell produces five peripheral envelope cells which elongate and spread over the oogonium. These cells divide transversely into upper coronular cells (corona) and lower tube cells. The tube cells get twisted spirally in a clockwise (right to left from below) direction and are called spiral cell bracts. The ensheathing cells are green when young but after fertilization they become yellow or brown.

The twisting of spiral cells serves two functions:

- Keeping contact with oogonium.
- Exudation of chemotactic mucilaginous ooze at the time of fertilization.

Oogonium is a one celled female sex organ enclosing a single female non-motile haploid egg or ovum(n). It has a thin wall, single nucleus lying at the base, chloroplast, abundant starch grains, little cytoplasm and a receptive spot for the entry of the serms.

Fertilization : At maturity, the receptive spot or area in the apical part exudes mucilaginous (ooze) fluid. Tube cells swell below corona, elongate and separate terminally from one another to create five slit opening. Mucilage oozes out and attracts the sperms by chemotactic influence. Several sperms enter the receptive spot but only one penetrates the oosphere or ovum or female gamete and fuse to produce diploid zygote.

- **Zygote or Oospore** : During maturation of zygote the envelope cells turn yellowish brown and store a lot of lime minerals. Inner walls of tube cells thicken, suberize and silicify. Oogonial wall also thickens, develops exine (outer thick layer) , mesine (middle layer) and intine (inner layer) to enclose diploid nucleus (2n) and cytoplasm. Reserve food starch gets converted into fat (oil drops) and the oospore becomes dark brown, seed like structure. The resting oospore settles down on the soil or sand of stagnant water to perennate after the degradation of plant body. It is a thick walled unicellular, uninucleated diploid (2n), hard , ovate , ellipsoidal in outline (eg. *C nuda*), dark brown or golden brown with spiral ridges on its surface. It is a perennating structure resembling the seeds of higher plants.

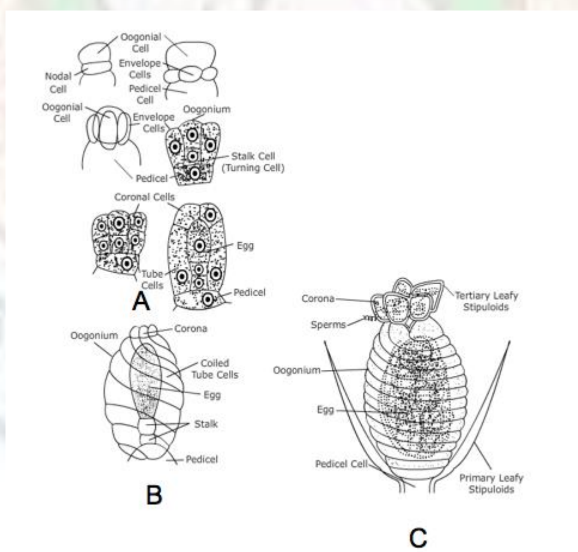
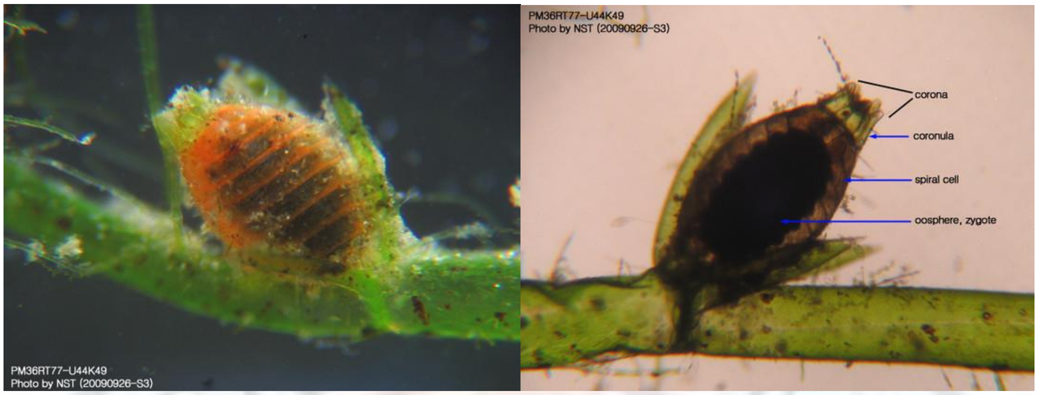


Figure: *Chara*- **A.** Developmental stages of nucule from apical oogonial cell.; **B.** V.S. of nucule showing internal structures. **C.** W.M. of nucule with primary, secondary and tertiary bracts like angiospermous female flower.

Sourec: Author



A. **B.**

Figure: A- B. *Chara* – A photograph of nucule (orangish in color) resembles the angiospermous flower.

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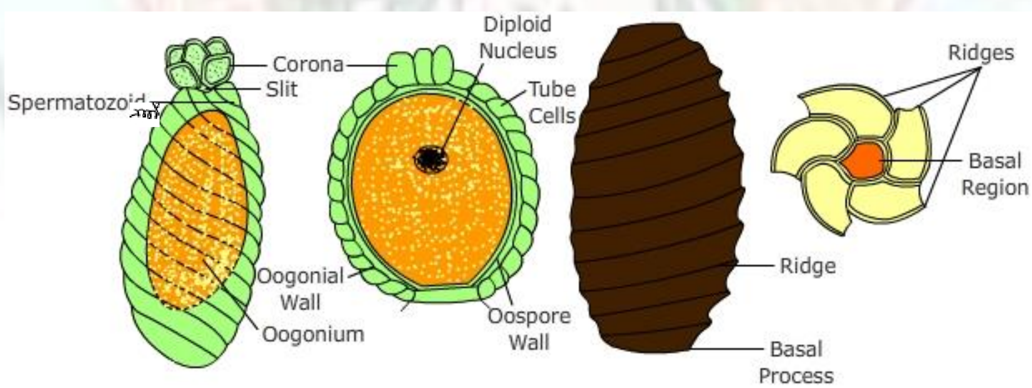


Figure: *Chara*- **A.** Spermatozoids near ostiole at the coronary ostiole. **B.** V.S. of developing oospore (2n) enclosed by oospore wall. **C.** W.M. of mature oospore or seed (2n) showing ridged exine. **D.** W.M. of ridges seen at the base of the oospore.

Source: Author

Figure: *C. fragilis* – A photograph of W. M. of zygote (2n) enclosed in nucule.

Source: http://mcgregor.sbs.auckland.ac.nz/files/2011/01/dave_082_1.jpg

Germination of Oospore or zygote : The three membranous thick walled diploid oospore germinates during favourable conditions on sand or soil in submerged habitat with the following conditions:

- sufficient light (towards red side)
- temperature 20-27±1°C
- pH 5-10
- minerals like Phosphorous 20-40 mg/l
- Less oxygen, calcium
- rich organic matter.

Oospore is a thick walled seed like structure that absorbs water, minerals and germinates. The outermost exine - thick dark brown inelastic layer cracks open by imbibition and the mesine, intine (inner layers) along with protoplasm and nucleus exude out as a small germling or germ tube at the apical tip. The diploid nucleus (2n) undergoes meiosis to form four haploid nuclei (n). A curved wall appears at the apical part. It divides the interior of the oospore into two unequal halves (cells), the smaller lenticular apical cell and the larger basal cell. Apical cell divides longitudinally into two cells, the protonemal initial and the rhizoidal initial. Both these cells grow out to form erect filamentous aerial primary protonema and basal primary rhizoids. This later gives rise to the *Chara* plant. These stages resemble with *Batrachospermum* a red alga*.* Protonemal stage is also found in some bryophytes.

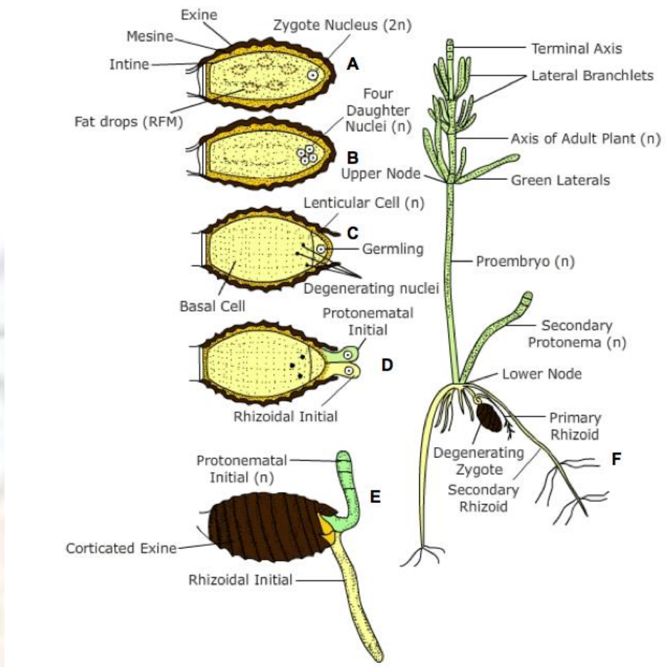


Figure: *Chara*- Different stages of germination of oospore shown in vertical section of oospore. **A.** A resting zygote; **B.** Meiosis; **C.** Cracking of outer exine and emergence of germling. **D.** Separation of upper protonemal and lower rhizoidal initial**. E.** Growth of primary protonemal and rhizoidal initials.; **F.** Young protonemal aerial plant with lower primary rhizoids.

Source: Author

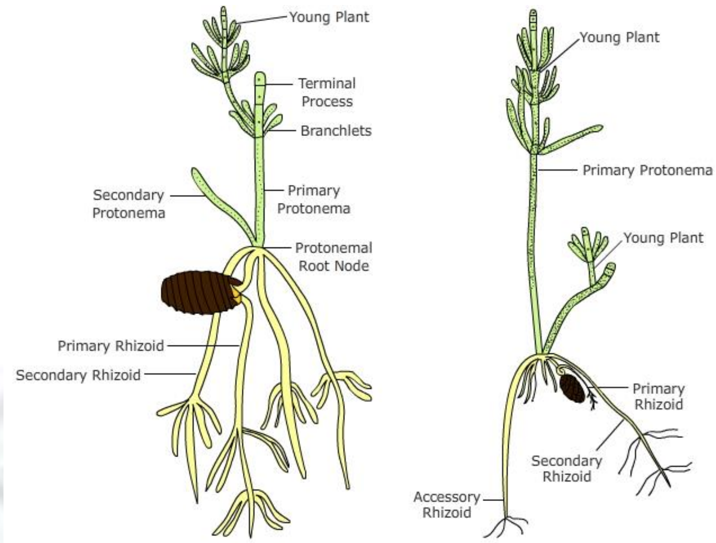


Figure: *Chara*- Young protonemal plants with aerial branching and secondary protonemal branches arising from lower rhizoidal node.

Source: Author

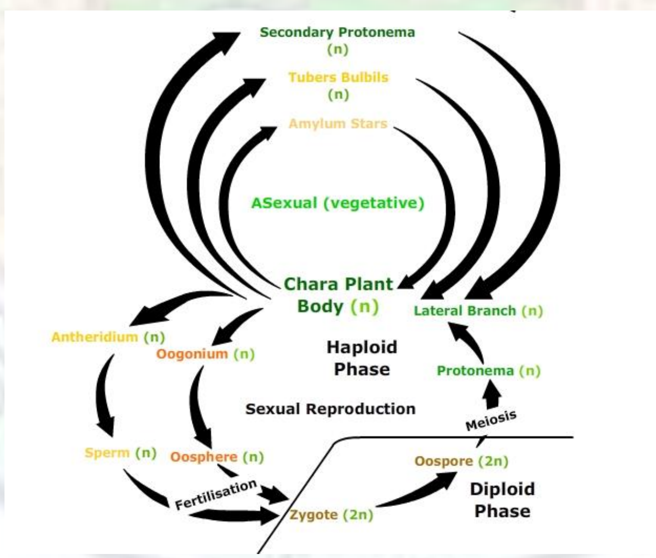


Figure: *Chara* – An outline view of life cycle.

Source: Author

Also visit: http://physwiki.apps01.yorku.ca/images/thumb/5/51/02_Figure_2.5.PNG/400px-02_Figure_2.5.PNG

Parthenogenesis- This process is seen in nature in some species of *Chara.*The nucule or oogonium directly produces thick wall resting oospores without fertilization.These spores or parthenospores directly germinate in favourable conditions and produce new plants. This process is common in dioecious species like *C. canescens*.

Economic importance

Charales exhibit the dominant forms of macrophytic green algae in base rich fresh waters for some three million years earlier than embryophytes. They are important in many respects with regard to food, calcification, ecology and as experimental tools:

- Charales are used as food for aquatic animals.
- *Chara* plant supports many epiphytic herbivores being used as food for fishes.
- Bulbils are eaten by diving birds or water fowls.
- Growth of *Chara* can clear turbid water. Dried plants possess pungent odour i.e. being used as insect repellent in farmhouses.
- Charales have larvaecidal property.
- Lime deposits at the bottom of water reservoirs appear as marl and tufa. These are used in the manufacture of cement and also for soil reconditioning.
- Charales are used as manure and also to correct the acidity of soil.
- These are used as fertilizer as they form good crumb structure and aeration to clayey soil.
- Charales because of macroscopic size are a favorable material for physiologists to carry out experimental studies of:
    - Electrophysiological features of membrane functions.
    - Analysis of cytoplasmic streaming and geotropism.
- Charales due to their abundant growth in water reservoirs disrupt the proper working or supply of water.

Systematic Position and Relationship with other green plants

Charales have been considered an advanced complex, modified group amongst Chlorophyceae based on micromorphological, ultrastructure, biochemical, molecular and physiological features. Phycologists proposed a distinct position of Charales at the rank of division, class under Thallophytes.

Fritsch 1935 and Iyenger 1951 considered Charales at an order level of Chlorophyceae (green algae) based on morphological and reproductive features

- Bold 1967 classified green algae to Phyllum- Chlorophycophycophyta and the order Charales was separated and raised to the rank of Phyllum – Charophyta
- Desikachari and Sudaralingum 1962, Round 1973, and other phycologists preferred to place the stoneworts in Division – Charophyta separate and parallel to Chlorophyta.

The Characters which place Charalean algae in or near green algae:-

- Presence of green pigment chlorophyll a and b.
- Reserve food material – starch
- Haploid nature of plant body.

The features which characterize Charales as distinct group:

- Erect vegetative plant body with distinct nodes and internodes.
- Dimorphic whorled lateral branches.
- Cortication and occurrence of sex organs on the lateral branches.

These characters have formed the basis of the origin of Charales from Chaetophorales (eg. Draparnaldiopsis) or their ancestors.

Chaetophorales ⟶ Charales.

Charalean group exhibits distinct characters which brings it closer to the other plant groups – Bryophytes and Pteridophytes:

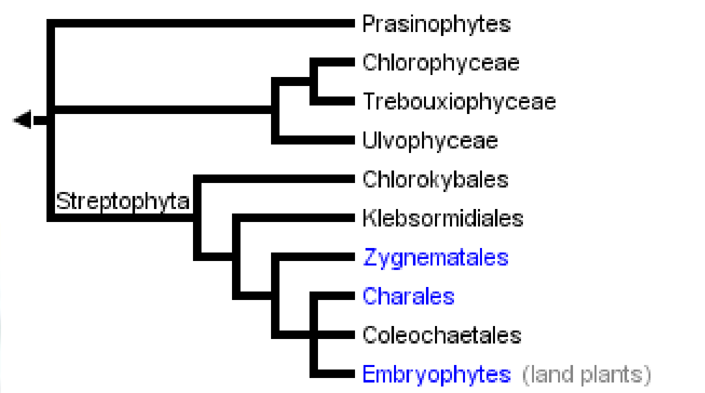
- Vegetative growth by apical cell.

- Young protonemal stage with the germination of zygote or oospore (2n) after meiosis.
- Rhizoids uniseriate, multicellular with oblique septa.
- Stem with knotted nodes and internodes (similar to *Equisetum*) and peculiar mode of branching.
- Sex organs multicellular and their developmental stages.
- A layer of sterile tissue present around the sex organs.
- The tube cells or corona of nucule or oogonium resembles the venter and neck cells of archegonium in bryophytes.
- Spirally coiled antherozoids with flagella having band of micro-tubules at their base.

Charalean green algae show affinities with embryophytes :

- Presence of discoid chloroplast.
- Multicellular complex plant body with stem like axis, root like rhizoids, leaf like stipulodes or bracts.
- Meristematic growth by apical cell.
- Asexual reproduction by vegetative structures like tubers, bulbils and protonema.
- Sexual reproduction by multicellular male gametophytic globule enclosing male unicellular motile gametes (n), and female gametangial oogonium enclosing egg or ovum (n) surrounded by three membranous structures like ovary and externally by primary, secondary bracts similar to the calyx lobes and corona like corolla of flowering plants.
- Zygote or oospore resembles a thick walled nut or seed like hibernating structure.
- Phragmoplasts (persistent spindle and glycolate oxidase) have been seen in Charales , Coleochaetales and Zygnemales (*Spirogyra*). In the dividing cells the telophasic nuclei lie far apart due to open spindle formation.
- Primary plasmodesmata (during cytokinesis) develop much like those of land plants and also is seen in one of the *Chara* species.
- The developmental and morphological features thus reveal that Charales and Coleochaetales are closely associated with embryophytes.

The Charales and Coleochaetales are considered as the closest living green algal relatives of land plants



Source:http://tolweb.org/Public/treeImages/Green_plants.png?x=1203662046

The green plants (assemblage of photosynthetic organisms, containing chlorophyll a and b, having double membrane bound chloroplasts and cellulosic cell walls) are divided into two main lineages:

- Green algal lineage that includes the Prasinophytes, Chlorophyceae, Trebouxiophyceae and Ulvophyceae.
- Streptophytes

Traditionally Charales and Coleochaetales were placed under Charophyceae, Division Chlorophyta. However ultrastructural, morphological as well as molecular studies support the fact that Charophyceae is a paraphyletic group and are most closely related to higher land plants. These orders therefore have been now placed within the Streptophyta

Lee 2008 grouped algae into four distinct groups (gene sequence, ultra structure of organalles and other molecular features taken into account)

- Prokaryotes –Cyanophyta (Cyanobacteria).
- Eukaryotic Algae (chloroplast surrounded by two membranes)
- Eukaryotic Algae with chloroplast surrounded by one membrane of chloroplast endoplasmic reticulum.
- Eukaryotic Algae with chloroplast surrounded by two membrane of chloroplast endoplasmic reticulum.

Under this system Charophyceae occupies distinct position as a class under Group 2 Division Chlorophyta.

Systematic Position

Fritsch (1935)	Bold and Wynne (1978)	Lee(2008)
Division – Algae	Division - Charophyta	Phylum - Chlorophyta
Class – Chlorophyceae	Class - Charophyceae	Class - Charophyceae
Order – Charales	Order - Charales	Order - Charales
Family- Characeae	Family - Characeae	Family - Characeae
Genus –*Chara*	Genus - *Chara*	Genus - *Chara*

Summary

Chara sp. is a highly complex, well defined green alga. Its thallus is differentiated into root like rhizoids, stem like aerial axis and leaf like lateral unicellular stipulodes or bracts. It reproduces asexually by vegetative means and sexually by oogamy. This alga shows affinities with bryophytes, pteridophytes and embryophytes. *Chara* plant body and reproductive structures justify its placement as a distinct group - Charophyta at division level parallel to Chlorophyta. Charales (*Chara and Nitella*) the largest and complex group amongst Chlorophyceae with their plant body reaching one metre length along with whorls of lateral branches at each node, show the great similarity with aquatic flowering plants (eg. *Ceratophyllum* sp.) in submerged conditions. In addition, the recent studies with regard to the features like molecular sequence, architectural evidences that include intron insertion steps and movement of genes between genomes suggest that the order zygnemales of Chlorophyceae originated prior to Chaetophorales, Charales (green algae) and embryophytes (multicellular flowering plants). These features strongly represent the monophyletic relationship of this algal group with embryophytes and supports the fact that their ancestors do share features with members of Charalean green algae.

Exercises

1. Comment on the following:
    a) Germination of oospore in *Chara*
    b) Epipelic nature of stone worts.
    c) Charales resemble Chlorophyceae.
2. Write short notes on the following:
    a) Nucule.

b) Globule
c) A sexual reproduction in *Chara.*

3. Fill in the blanks.
   a) Pyrenoids are------------ in *chara.*
   b) Reserve food material of *chara* ------------.
   c) Stone worts is a name of------.
   d) Protoplasmic streaming in a cell is called -------.
   e) Male sex organs in *Chara* is called-----.
   f) Oogonium of *chara* is called---------.
   g) Root like anchoring organ in *Chara------.*
4. Draw well labelled diagrams:
   a. W.M of sex organs of *Chara.*
   b. V.L.S of Globule.

Glossary

Antheridium : A cell that undergoes internal division and for differentiation to form male gamete.

Apical cell(s) : The single apical cell or group of cells that occur at the tip of a thallus, often capable of merismatic proliferation (apical growth).

Benthic: Growing in the benthes – the bottom of a lake, stream or marine system.

Calcification: Deposition of calcium carbonate.

Cell wall: A more or less rigid enclosure surrounding the cell membrane; can be composed of various materials.

Cellulose: A **β**1➔4 linked glucose that forms micro fibrils in the cell walls of various algae and all land plants.

Embryophytes: Bryophytes and vascular plants.

Epipelics: Living on the surfaces of mud and sand (Rooted at the base and free floating arial parts in submerged conditions).

Gyrogonites: The calcified zygotes of Charalean green algae; includes those occurring in the fossil record and those in modern sediments.

Internodal cell: A cell located between nodal cells.

Brackish : Saline water with a salinity less than that of see water.

Manubria (sing.Manubrium): In Charalean green algae; columnar cells that connect the pedicel to the shield cells within male gametangia.

Oogamy: Sexual reproduction involving syngamy of a small flagellate male gamete and a larger, nonflagellate female gamete.

Oogonium: A structure that produces one or more eggs.

Parthenogenesis: Production of a new individual from an unfertilized gamete.

Plamasol: Protoplasm

Shield cells: In Charalean green algae, cells that form the outer walls of the multicellular male gametangia.

Spermatogenous threads: In Charalean green algae, filaments of cells that each produce a sperm, located within a complex antheridium.

Sporopollenin: In walls of certain green algae and spores of embryophytes a resistant biopolymer.

Systematics: The scientific study of organismal diversity and the relationships among organisms.

Taxon: A general term for any taxonomic category.

Tube cells: In Charalean green algae, elongated helically twisted tubular cells that surround oogonia.

Zygote: The product of gamete fusion (syngamy).

Amylum star: Star shaped aggregate of cells filled with amylum starch that forms new plants in the stoneworts (charales)

Plasma membrane: (Plasmalemma) The outermost living membrane of a cell.

Plasmodesmata : The minute cytoplasmic threads that extend through openings in cell walls and connect the protoplasts of adjacent living cells.

Spermatogenesis: Formation of sperm.

Sperm: Male gamete.

References/ Suggested Readings

Bold, H.C. 1967. Morphology of Plants. Harper and Row, New York.

Desikachary, T.V. and Sundaralingam, V.S. 1962. Affinities and interrelationships of the Characeae. Phycologia, 2:9-16.

Fritsch, F.E.1935. The Structure and Reproduction of Algae, Vol. 1 & 2. Cambridge University Press.

Bold, H.C. and Wynne, M.J. 1985. Introduction to the Algae: Structure and Reproduction, Second Ed. Prentice Hall, New Jersey.

Bell, P.R and Woodcock, L.F Diversity of Green plants.

Bhatia, K.N 1993, A treatise on Algae, R. Chand and Co.

Round, F.E. 1973. The Biology of Algae, 2nd Edition. St. Martin Press, New, York.

Borowitzke M.A, 1982 Morphological and cytological aspects of algal calcification Int. Rev. Cytol. 74 : 127-62.

Casanova, MT. 1997 Oospore variation in three species of *chara* (charales, chlorophyte). Phycologia, 36 : 274-80.

Goutchasov, A.A, Marin, B & Melkonian, M 2002 Molecular Phylogeny of conjugating green Algae (zygnemophyceae, streptophyta) inferred from SSU DNA sequence comparison J.Mol. Evol. 56 : 89-104.

Graham L.E. 1993, The origin of land plants. John Wiley, New York, NY.

Graham, I.E 1984 coleochaete and the origin of Land plants Am.J.Bot 71 : 603- 608.

Graham, L.E and Wilcox, L.W 2000, Algae, Prentice Hall Inc.

Hodick . D. 1994 Negative gravitropism in *chara protonemata* a model integrating the opposite graitropic responses of protonemate and rhizoides. Planta, 195 : 43-49.

Kenrick, P and Crane, P.R 1997, The Origin and Early Diversification of land plants. Smithsonion Institution Press, Washinton, DC.

Kwiatkowske, M 2003 Plasmodesmal changes are related to different developmental stages of antheridia of *chara* species. Protoplasma, 222 : 1-11.

Lee, R.E. 2008, Phycology, Cambridge univ. Press 4th Edition.

Levis I.A & Mc Court, R.M. 2004, Green Algae & the origin of land plants . Amer. J.Bot 91 : 1535-56.

Lucas W.C. 1979 Alkaline band formation in *chara coralline.* Plt.Physiol 63 : 248-54

Piickett- Heaps, J.D 1975. Green Algae. Sinauer Associates, Sunderlands, MA

Links

http://www.biologie.uni-hamburg.de/b-online/e44/chara.htm

http://taibif.org.tw/nbrpp/algae.php?select=Lychnothamnus+barbatus

http://aquaplant.tamu.edu/plant-identification/visual-index/muskgrass/

http://comenius.susqu.edu/biol/202/archaeplastida/viridiplantae/green%20algae/charophyta/charophyta.htm