# PERIYAR INSTITUTE OF DISTANCE EDUCATION (PRIDE)

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**B.Sc. BOTANY**

**FIRST YEAR**

**PAPER – I : ALGAE AND BRYOPHYTES**

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**UNIT – I TO V**

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**B.Sc. BOTANY – PAPER – I**

**UNIT I & II**

**INTRODUCTION :**

The algae are chlorophyll bearing thalloid organisms. The plant body is made up of single cell to many cells. They are aquatic, grow both in marine water and fresh water. They also grow on and within soil and on moist stones and wood as well as in association with fungi and certain animals. The algae are of great importance as primary producers of energy – rich compounds which form the basis of the food cycle of all auatic animal life. For this purpose the planktonic algae of special importance, since they serve as food for many animals. It is thought that 90 percent of the photosynthesis on earth is carried on by aquatic plants; the planktonic (suspended) algae are chiefly responsible for this. While photosynthesizing, they oxygenate their habitat, thus increasing the level of dissolved oxygen in their environment. Certain blue – green algae, like some bacteria, can use gaseous nitrogen from the atmosphere in building their protoplasm, and in this way they increase the nitrogenous compounds in water and soils of their habitat. This activity is called nitrogen fixation.

There are approximately 1800 genera with 21,000 species which are highly diverse with respect to habitat, size, organisation, physiology, biochemistry and reproduction. Phycology is the study of algae and those who pursue such a study seriously are phycologists. In India for the first time Ghose (1919-32) studied the Blue-green algae of the Punjab and Burma. The pioneer worker M.O.P. lyengar started his work on Indian algae in 1920. He and his students worked out the life – histories of several algae of this country. He discovered an algae Fritschiella tuberosa. Later on Biswas (1922-50) worked out the algal flora of Bengal. Dr. Y. Bharadwaj (1928-36) of B.H.U did a lot of work on Cyanophyceae of Uttar Pradesh. Later on R.N. Singh (1938-68) made a significant contribution on the study of blue-green algae. He did much work on the fixation of nitrogen in soil by blue-green algae. He also worked out the possibilities of reclamation of Usar soils in this country. Besides blue-green algae he has also contributed to Cholorophyceae (green algae) and worked out the life-histories of Fritschiella tuberosa and Draparnaldiopsis indica. Randhawa (1932-59) did extensive studies on Zygnemaceae, Oedogoniaceae and Vaucheriaceae of the Punjab and Uttar Pradesh and published his famous monograph on Zygnemaceae.

Dr. Desikachary contributed to the blue-green algae, diatoms and red algae of India, and published a monograph entitled Cyanaphyta (1959) of great importance. K.R. Ramanathan published a monograph entitled Ulotrichales in 1964. G.S. Venkataraman did much work on the fixation of nitrogen by blue-green algae. The famous monographs entitled Charophyta (1962) and Vaucheriaceae (1964) were published by G.S. Venkataraman, B.P. Pal, Kundu and Sundaralingam. Dr. Venkataraman and his students at I.A.R.I. New Delhi, have done significant work on nitrogen fixation by blue-green algae. Another monograph entitled Phaeophyceae in India has been published by J.N. Misra in 1966.

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**HABIT AND HABITAT :**

Most of the part of the land is covered over either by fresh water or sea water. Thousands of types of are found both in fresh and sea water. Besides, several other algae are found in somewhat drier conditions. They are found on the trunks of trees, on telephone wires, on rocks, on walls, in hot springs and in several other unusual habitats. Here some of the algae have been classified according to their habitats. Special emphasis has been given on the occurrence of fresh water algae

**Hydrophytes** – They are more or less completely submerged or free floating on the surface of the water. The hydrophytes may be subdivided into following heads.

**Benthophytes** – Several fresh water and marine algae are found in attached condition. The fresh water forms such as Chara, Nitella, Cladophora, Gongrosira, Chaemosiphon etc., are found attached to some substratum in the bottom of the water. Alomst all of brown algae (Phaeophyceae) are found in attached condition to some substrates in the sea.

**Epactiphytes** – Such algae grow along the shores of lakes and pounds, and may be delimited from benthophytes with some difficulty. The most important fresh water forms are – Oedogonium, Chaetophora, some species of Spirogyra, Mougeotia, some diatoms, Scytonema and Rivularia.

**Thermophytes** – Many algae are reported from hot springs. These algae may tolerate the temperature upto $70^0$ C or more than that. According to Copeland 53 genera and 153 species of Chroococcaceae may survive upto $84^0$ C. Some oscillatoriaceae may survive upto $85^0$ C. This supports that Myxophyceae (bluegreen algae) are primitive.

**Planktophytes –** The algae which float on the surface of the water are called ‘planktophytes’. They may be of two types i.e., (a) euplanktophytes and (b) tychoplanktophytes.

**(a).Euplanktophytes** – They are never attached, and from the very beginining are free floating e.g., diatoms, Cosmarium, Closterium, Microcystis, Sphaeroplea, Scenesdesmus, Pediastrum, Chlamydomonas, Volvox, other

Volvocales and some members of Chroococcales. The above given forms are fresh water in habit.

**(a)Tychoplanktophytes** – In the begining such algae are attached, but later on they become detached and free floating e.g., some species of Spirogyra, Zygnema, Cladophora, Oedogonium, Rhizoclonium, Mougeotia, Tribonema, Microspora, Cylindrocapsa, Tetraspora, Rivularia, Nostoc, Gloeotrichia, Cylindrospermum, Sargassum etc.

**(i)Halophates –** The algae occur in saline waters are known as 'halophytes'. The most striking examples are Dunaliella and Chlamydomonas which occur in salt lakes, the species of Scenedesmus, Aphanocapsa, Pediastrum, Aphanothece, Oscillatoria are found in saline waters; the species of Enteromorpha are found in inland asutaries; many species of Ulvales, Ulotrichales, Conjugales and Myxophyceae are found near the sea in astuaries.

**(ii)Epiphytes** – Many algae are found upon other living plants and bigger species of algae. Aphanochaete, Bulbochaete, Oedogonium and Microspora, grow on Rhizoclonium, Vaucheria and Hydrodictyon species. Coleochaete nitellarum is epiphytic upon species of Chara and Nitella. Some of the species of Coleochaete are epiphytic upon some grasses grown on the banks of the ponds and the hydrophytes such as – Vallisneria, Typha, Ipomoea and several other aquatic plants. Chaetonema is found epiphytic on the mucilaginous masses of Tetraspora and Batrachospermum.

**(iii)Epizoophytes –** Certain algae are found on living aquatic animals such as turtles, mollusc shells, fishes etc. Species of Cladophora grow upon mollusc shells. Protoderma and Basicladia occur on the bank of turtles. Characiopsis and Characium occur on the posterior and anterior legs of Branchipus respectively.

**(1)Edaphophytes** – Such algae are also called terrestrial algae. They are found upon or inside the surface of the earth. They can be (i) saphophytes and (ii) cryptophytes.

**(i). Saphophytes** – they are surface algae. Most of the species of Myxophyceae are found upon the surface of the soil. Besides, Mesotaenium, Botrydium, Protosiphon, Oedocladium, Vaucheria, Fritschiella and many others are met with upon the surface of the wet soil.

**(i).Cryptophytes** – Such algae are subterranean in habit and occur inside the soil. The species of Myxophyceae are found in the soil. The species of Nostoc, Anabaena and Euglena have been reported from the paddy fields, where they also fix the atmospheric nitrogen in the soil to enrich the fertility of the fields.

**(1). Aerophytes** – Such algae are aerial in habitat. They are found upon the trunks of trees, walls, fencing wires, rocks, land animals and also so many other aerial substrata.

**(i). Epiphyllophytes** – Such algae are epiphytic upon leaves of tress. Species of Trentepohilia are commonly found upon the bark of trees. They also occur upon rocks and fencing wires. They are abundanuly found on the fensing wires and fencing wires of Calcutta botanical gardens. Phycopeltis occurs upon Rubus; Phyllosipihin on Arisaema; Rhodochytrium on Asclepias and Solidago.

**(i)Epipholephytes** – These algae grow on the bark trees mixed with many mosses and liverworts. Phormidium, Scytonema, Haplosiphon and Schizotheix grow on the bark of trees mixed with liverworts.

**(ii). Epizoophytes** – These algae are found even on the bodies of land animals. Certain Chaetophorales are found even on the hairs of sloth.

**(i).Lithophytes** – Many algae grow on the rocks and walls. The species of Scytonema grow on the walls in rainy season and the whole wall becomes black spotted. Vaucheria, Nostoc and many other algae are also found on wet rocks.

**(4). Cryophytes** – These algae are found on ice and snow. These algal forms cause red snow, green snow, yellow snow, yellowish green snow and violet snow. In European countries, especially in arctic region the green snow is caused by Chlamydomonas, Ankistrodesmus and Mesotaenium; red snow is caused by species of Chlamydomonas, Scotiella, Gloeocapsa and diatoms.

Certain species of Ulothrix, Oedogonium, Pleurococcus and Nostoc cause yellow or yellow green snow.

Alaskan (1942) classified the Cryo algae in four groups :-

(i) Those algae which can grow only on ice e.g., Ancylonema, Mesotaenium.

(ii) Those algae which can occur only on snow e.g., Scottiella, Chlamydomonas.

(iii) Those algae which can grow on ice and snow both e.g., Cylindrocystis, Trochiscia.

(iv) Those algae which can grow on ice and snow. These are not true cryophytes e.g., Gloeocapsa, Phormidum.

**5. Symbiots or Endophytes** – Many algae grow in symbiotic association of other plants. The most striking example of symbiosis are lichens, here the algae are found in symbiotic association of fungi. Various Myxophyceae e.g., Chroococcus, Nostoc, Microcystis, Gloeocapsa, Scytonema, Rivularia etc., have been separated from lichens. Some green algae e.g., Coccomyxa, Chlorella, Protococcus, Palmella etc., are also found as symbionts in linchens.

Besides, several algae are endophytes in the tissues of other plants. Anabaena azollae is found inside the leaves of Azolla (a Pteridophyte). Anabaena cycadae is found in the coralloid roots of Cycas. Nostoc has been reported from the tissues of Anthoceros and Notothylas Nostoc is found in the leaves of Sphagnum (Bryophyta) and several angiosperms. Chlorochytrium is endophytic inside Lemna, Ceratophyllum and certain mosses.

**6**. **Endozoophytes** – Certain algae occur inside the body of animals. Zooxanthella is found inside Hydra viridis. According to Langeron (1923) about 14 species of Oscillatoriaceae are found in the digestive and respiratory tracts of various vertebrates.

**7. Parasites –** Certain algae are parasites upon other plants the most striking example is Cephaleuros virescens which causes the havoc of tea foliage in Assam and neighbouring areas, called ‘red rust of tea’.

**8. Fluviatile Algae** – Such algae are found in rapidly following waters; Ulothorix occurs in mountain falls. Stigeoclonium, Batrachospermum is reported from the swift running streams of Dehreadun and other hilly tracts.

**NUTRITION IN ALGAE :**

From the view point of their nutrition the algae are autotrophic. They synthesize their food from inorganic materials such as carbondioxide, water and minerals by means of photosynthesis. Chlorophyll is the most common pigment in all the algae, though in many, the green colour of the plastids is masked by other pigments, such as, fucoxanthin, a yellow pigment, which dominates in brown algae whereas phycoerythrin and phycocyanin pigments are found in red and blue green algae respectively. The algae also synthesize oil and proteins from the carbohydrates which they manufacture and soluable forms of nitrogen and other minerals available in solution in the water in which they are found. The aquatic species of algae obtain water and carbondioxide by osmosis and diffusion processes respectively from the water in which similar to those of ordinary green plants.

The alage, like other chlorophyllous plants, require C, H, O, P, K, N, S, Ca, Fe and Mg and also traces of Mn, Bo, Zn, Cu and Co. For certain algae additional elements required such as Si for diatoms and Mo for Scenedesmus.

The algae which grow in an entirely inorganic medium in the presence of light are known as photoautotrophic. In other words, using light energy, they synthesize their protoplasm from exclusively inorganic sources. Several other algae require in addition certain vitamins, usually B-12, Thiamine or biotin and such algae are known as photoauxotrophic. A number of algae are heterotrophic. The algae which do not synthesize their protoplasm solely from inorganic sources but require some of the essential elements, usually carbon and nitrogen, are known as heterotrophic. Several algae (e.g., species of Ochromonas) digest solid particles of food and are known as phagotrophic.

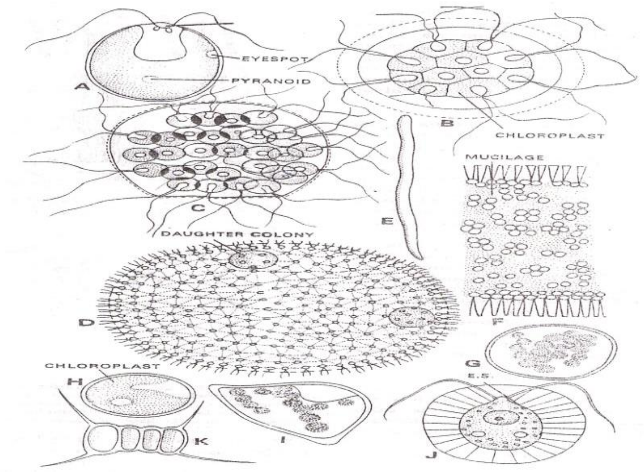
**RESERVE FOOD :**

Since the early steps in photosynthesis in all the algal groups are practically the same it is but natural that the primary products of this process must also be the same. The food materials which accumulate as food reserves in the form of polysaccharides, however, vary from group to group and thus provide useful data for preliminary classification of algae. True starch is typical of only two algal divisions, namely, Chlorphyta and Charophyta. The two other kinds of characteristic starches are the cyanophycean starch and floridean starch. The former is characteristic of division Cyanophyta and the latter of division Rhodophyta. The three other important polysaciharides which accumulate as reserve food are laminarin found in the brown algae, paramylon charcteristic of Euglenoids and leucosin peculiar to the Xanthophyta, Bacillariophyta and Chrysophyta. Besides, a proteinaceous compound cyanophycin is found only in the cells of blue – green algae. Mannitol which was formely considered to be unique to the brown algae has recently been reported to occur in a few red algae. Fats occur as reserve food in appreciable amounts in the cells of Xanthophyta, Bacillariophyta and Chrysophyta. The environmental factors which favour growth of the algae are favourable temperature, suitable light, and prope r supply of oxygen, carbon dioxide and essential elements.

**RANGE OF VEGETATIVE STRUCTURE :**

The whole range of the somatic structure of alage may be divided into following important types.

1. The motile type
2. Palmelloid and dendroid types
3. Coccoid forms
4. Filamentous habit
5. Siphonous habit
6. Advanced type.

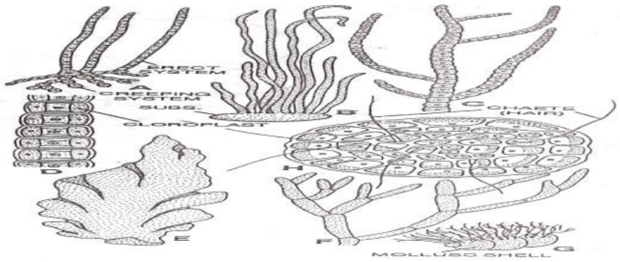



Range of vegetative structure – The motile type A-D and J; A. motile vegetative cell of Chlamydomonas; B. vegetative colony of pandorina sp; C. vegetative colony of Eudorina unicocca; D. vegetative colony of Volvox; J. motile cell of Sphaerella. The palmelloid type E and F; E. colony of Tetraspora cylindrica; F. portion of a colony of T. cylindrica; the coccoid type – G-I and K; G,H and I, vegetative cells of Chlorococcum humicola; K. colony of Scenedesmus sp.

1. **The Motile Type** – The simplest type of body is motile and unicellular. The shape varies from species to species. These bodies are flagellate. The number and type of flagella also vary. The body may be naked or with a cell wall. There are many variations in the motile type. These variations may be, amoeboid, encapsulated colourless forms, colonial forms and double individuals e.g., Volvox, Eudorina, Chlamydomonas etc.

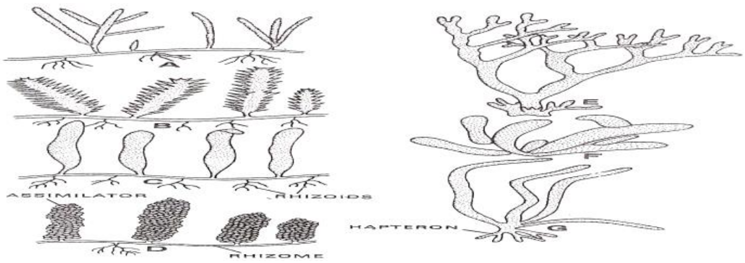
2. **Palmelloid and Dendroid Types** – For a time being palmella stage prevails in the species of Chlamydomonas. But this is a permanent feature in the case of Tetraspora, here the plant bodies are surrounded by mucilaginous covering. The dendroid type is the variant of the palmelloid type in which mucilage is produced at the base of the cell, and the dendriod colonies are resulted, e.g., Prasinocladus of Chlorophyceae.

3. **Coccoid Habit** – In coccoid forms the flagella have been lost and the plant body becomes rounded. This rounded body has no power of division and cannot reproduce vegetatively. Coccoid habit is very common in order Chlorococcales, e.g., Chlorococcum humicola.



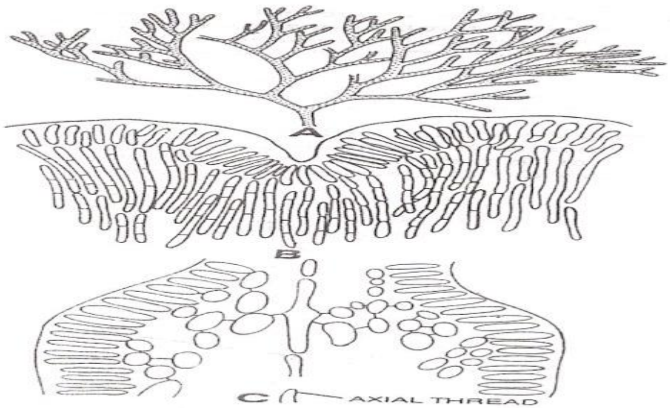

Range of vegetative structure – Fila nentous habit – A, heterotrichous thallus of Sigeoclonium ; B, tubular thallus of Enteromorpha ; C, portion of Sigeoclonium ; D, portion of the filament of Ulothrix ; E, foliaceous thallus of Ulva ; F, a part of Cladophora thallus ; G, habit of Cladophora (on mollusc shell); H, disoid thallus of Coleochaete.

4. **Filamentous Habit –** According to Blackman and Smith the filaments originate from motile unicellular forms. According to these authors the filmentous habit has been originated from motile unicellular bodies by the loss of motility and the restriction of vegetative division in one plane only. In the beginning the cells were united by mucilaginous discs (false septation) but later the transverse septa of adjacent cells decayed and union between the cells of the filament took place. This view was supoorted by Dr. F.E. Fritsch. The filamentous forms posses several variations. The filaments may be simple e.g., Ulothrix, Spirogyra; heterotrichous e.g., Stigeocleclonium; foliaceous e.g., Ulva; tubular e.g., Enteromorpha; discoid e.g., Coleochate. The filaments of Ulothrix and Spirogyra are heterotrichous i.e., the plant body consists of two systems, one erect and the other prostrate. The prostrate system is comparatively smaller and possesses many erect branches. Ulva is a good example of foliaceous structure varient. The thallus is two celled thick. In tubular variant the thallus is a hollow tube with a wall one cell in thickness, e.g., Enteromorpha. The discoid type has been evolved from heterotrichous filement. Coleochaete scutata is the well known example of this type. The cells of Coleochaete are joined end to end in branching filaments and a discoid habit is attained. The other species Coleochaete pulvinata possesses free branches.



Range of vegetative structure – Siphonouis type – A, thallus of Caulerpa cupressoides; B, thallus of C. crassifolia; C, thallus of C. prolifera ; D, thallus of Caulerpa sp. ; E, thallus of Codium sp ; F, thallus of Valonia utricularis ; G, thallus of Vaucheria sp.

1. **Siphonous Habit** – The plant body consists of branching filaments having many nuclei and no partition walls. The cross walls appear only at the time of the formation of reproductive bodies. The well known examples of this type are – Vaucheria, Codium, Caulerpa etc., of order Siphonales.
2. **Advanced Type** – The advanced types, may be uniaxial filamentous type, multiaxial filamentous type and parenchymatous type. In uniaxial filamentous type the single main axial thread has close branch systems to form more or less compact pseudoparenchymatous thallus e.g., Dumontia of Rhodophyceae. In the multiaxial filamentous type, there is a number of axial threads and the branches and all of them form a compact cortex, e.g., Scinaia furcellata of Rhodophyceae. Many advanced types are truely parenchymatous, e.g., Laminaria, Fucus, Sargassum of Phaeophyceae.




Range of vegetative structure – Advanced type – A, thallus of Dictyota sp ; B, apex of Scinaia furcellata in longitudinal section ; C, Dumontia incrassata (Rhodophyceae).

**METHODS OF REPRODUCTION IN ALGAE :**

There are three methods of reproduction found in alage – (i) vegetative, (ii) asexual, and (iii) sexual. In addition to these methods several perennating bodies also develop which face the adverse conditions.

1. Vegetative Reproduction – This may be several types.

(i) **By Cell Division** – The mother cells divide and the daughter cells are produced, which become new plants. This is exclusive type of reproduction in Pleurococcus, some desmids, diatoms, Euglena etc.

(ii) **Fragmentation** – The plant body breaks into several parts or fragments and each such fragment develops into an individual. This type of vegetative reproduction is commonly met within filamentous forms e.g., Ulothrix, Spirogyra etc. The fragmentation of colonies also takes place in several blue green algae, e.g., Aphanocapsa, Aphanothece, Nostoc etc.

(iii) **Hormogone Formation** – When the trichomes break in small pieces of two more cells, such pieces are called 'hormogones'. Each hormogone develops into a new plant e.g., Oscillatoria, Nostoc etc.

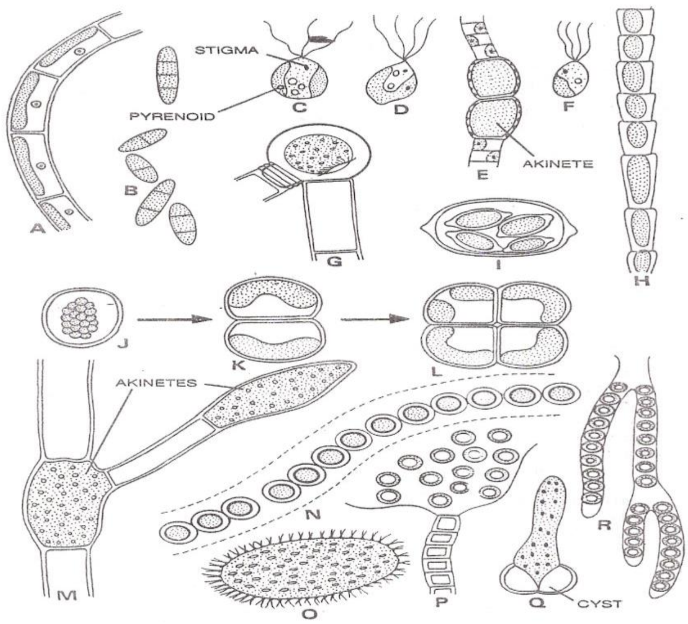
(iv) **Hormospores or Hormocysts** – they are thick walled hormogones, and produced in somewhat drier conditions.

**By Adventitious Thalli** – Certain special structures of thalli are formed which help in vegetative reproduction. The well known propagula of Bryopsis, Sphacelaria and Nereocystis are good examples.

(ii) **By primaty Secondary Protonema** – Such thread like vegetative bodies develop in the case of Chara, which help in reproduction.

(iii) **Tubers** – Usually these bodies are rounded and filled up with abundance of starch. Each body may given rise to a new plant, e.g., Chara.

(iv) **Starch or Amylum Stars** – Such special star shaped starch filled bodies give rise to new plants frequently reported from Chara.




Reproduction – Vegetative and Asexual – A filament of Hormidium; B, fragments of same; C,D and F, zoospores (swarmers) of Ulothrix ; E, akinetes of Ulothrix idiospora ; G, zoospore of Oedogonium sp ; I, autospores of Oocystis lacustris ; H, akinetes of Oedogonium ; J-L. cell division in

Pleurococcus sp ; M, akinetes of Pithophora ; N, akinetes of Ulothrix oscillarinia ; O, synzoospore of Vaucheria ; P, palmella stage in Ulothrix; Q, germination of cyst in Vaucheria ; R, akinetes of Botrydium.

(v) **Bulbils** – Small bud like structures usually develop on the rhizoids of Chara are called bulbils. Each such bulbil may develop into a new plant.

(vi) **Akinetes** – In most of the Chlorophyceae member, the akinetes are developed. Usually the protoplast of each cell converts in a single akinete. Sometimes they are formed in chains. Each akinete may develop into a new plant e.g., Oedogonium, Ulothrix etc.

2. Asexual Reproduction – Usually the protoplast of a cell divides into several prtotoplasts and thereafter they escape from the mother cell and develop into a new plants.

(i) **By Zoospores** – The zoospores are formed from certain older cells of the filaments. The cytoplasm divides to form zoospores which are escaped from the mother cell. They are always formed in favourable conditions. The zoospores are always motile. They may be (i) biflagellate, (ii) tetraflagellate, (iii) Stephanokontean type of zoospores e.g., Oedogoniales and (iv) compound zoospores e.g., Vaucheriaceae.

(ii) **By Aplanospores** – When motile phase of zoospores is estimated, the bodies are called aplanospores. The aplanospores develop in unfavourable conditions. Each such spore is surounded by a wall.

(iii) **By Hypnospores** – Actually they are very thick walled aplanospores and develop only in adverse conditions e.g., Pediastrum, Vaucheria.

(iv) **Palmella Stage** – Here the successive generations of divided cells are gelatinized and a thick mucilaginous envelope develops, e.g., Chlamydomonas, Ulothrix etc.

(v) **Autospores** – They are just like aplanospores expcept that they are smaller in size. They resemble in shape to mother cell except in size. Each autospore gives rise to a new plant. Such autospores are reported from many Chlorococcales.

(vi) **Endospores** – In many blue green algae and Bacillariophyceae the endospores are formed within the cells. On the approach of favourable conditions each endospore devepos into new individual.

(vii) **Auxospores** – In many members of Bacillariophyceae, such auxospores are produced. Each develops into new plant.

(viii) **Carpospores** – they are found in the carposporophytes of red algae (Rhodophyceae). Each such spore develops into new individual.

(ix) **Neutral Spores** – these spores are not formed within the sporangia. They are found in Rhorophyceae.

(x) **Monospores** – These spores develop within monosporangia. Each spore gives rise to a new plant e.g., many members of Rhodophyceae (Bangia, Porphyra, Porphyridium etc).

(xi) **Paraspores** – Such spores are reported from many members of Rhodophyceae. Each spore develops into a new plant.

(xii) **Statospores** – They are found in Xanthophyceae and Bacillariophyceae where they ct as perennating bodies.

(xiii) **Daughter Colonies** – In many Volvocales and Chlorococcales the daughter colonies are developed asexualy e.g., Volvox, Hydrodictyon, Pediastrum etc.

(xiv) **Gongrosira Stage of Vaucheria** – In the aseptate filament of Vaucheria, the protoplast divides into several parts, several hypnosporesd or crysts are produced, and the whole filament looks like an algal form 'Gongrosira'.

(xv) **Microspores** are produced in many Bacillariophyceae.

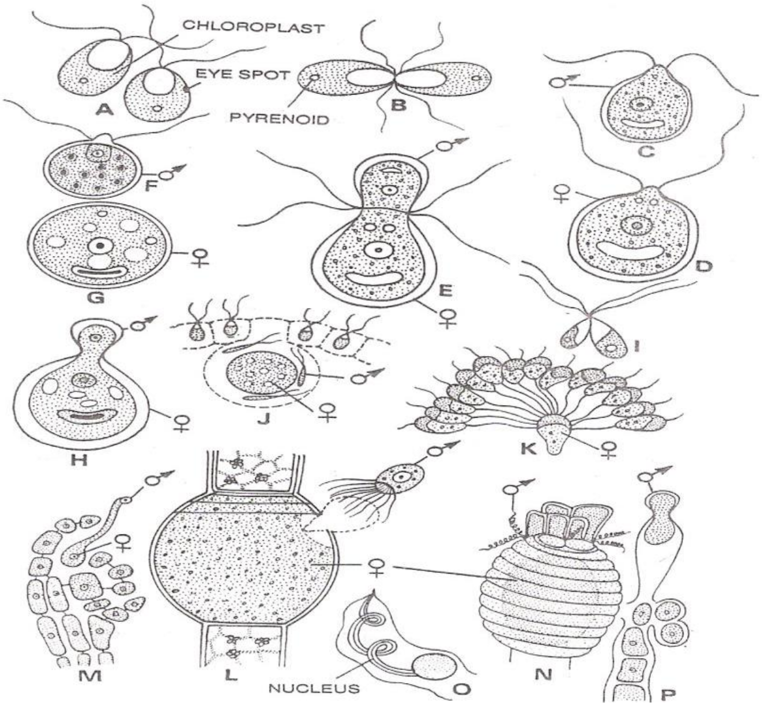
3. **Sexual Reproduction** – It is greatly advanced method of reproduction and not known in Myxophyceae (blue green algae). There are two main types, i.e., 1. isogamy and 2. heterogamy.

(1) **Isogamy** – The fusion of similar motile gametes is found in many species. Usually the gametes taking part in the fusion come from two different individuals or filaments, sometimes these gemetes come from two different cells of the same filament. Thousands of gametes come and aggregate in clumps.

(2) **Heterogamy** – The fusion of dissimilar gametes is called heterogamy. There are variations of it.

(a) **Anisogamy -** The motile gametes taking part in fusion may either differ in size (morphological anisogamy) or physiological behaviour (Physiological anisogamy).

(b) **Oogamy** – In this case the male antherozoid fuses with the female egg. This fusion may be primitive type as found in Cylindrocapsa, or advanced type as in Oedogonium, Vaucheria, Chara, Polysiphonia etc.




Reproduction – Sexual : A, two gametes of same size (isogametes); B, fusion of same (isoagmy); C and D, two gametes of different size (male and female); E, fusion of same (anisogamy); F and G, male and female : gemeetes H, fusion of same (oogamy); I, anisogamy in Enteromorpha intestinalis ; J, oogamy in Volvox ; K, clump formation in Ectocarpus, large female is surrounded by male gametes ; L, oogamy in Oedogonium ; M, advanced oogamy in Polysiphonia : N, oogamy, in Chara ; O, autherozoid of Chara ; P, oogamy in Batrachospermum.

3. **Aplanogamy or Conjugation** – it implies the fusion of two non-flagellate amoeboid gametes (aplanogametes). they are morphologically similar but physiologically dissimilar e.g., order Conjugales.

In fresh water algae, the sexual reproduction is best means of perennation because it is followed by the formation of thick walled zygote or oospore.

**Conditions for Sexual Reproduction** – (a) The sexual reproduction takes place after considerable accumulation of food material and the climax of vegetative activity is over.

(b) The bright light is the major factor for the production of the gametes.

(c) A suitable pH value is required.

(d) The optimum temperature is necessary.

**Parthenogenesis** – The female gametes convert into zygotes without fusion. The resultants are called azygospores or parthenospores and the phenomenon ‘parthenogenesis’, e.g., Spirogyra, Oedogonium and many others.

**Antogamy** – In this phenomenon the fusion of the daughter protoplasts or of the divided nuclei of a cell without liberation takes place. This process is known in many diatoms and colourless dinoflagellates.

**CLASSIFICATION OF ALGAE :**

For the first time Aristotle (384–322 B.C) and his pupil Theophrastus (372-287 B.C) the father of Botany classified the plants into three groups. i.e. trees, shrubs and herbs. This classification was based on the form and texture of the plants. Here, they considered the trees to be highest evolved.

In eighteenth century Linnaeus (1707-1778) proposed his artificial sexual system of classification. He divided the plant kingdom into twentyfive orders or classes. In his last order Cryptogamia, he placed the plants, with concealed reproductive organs (flower etc.). Linnaeous divided his order Cryptogamia into four suborders, i.e., (1) Filices (Pteridophytes), (2) Musei (mosses and leafy liverworts). (3) Algae, (algae, lichens and thallose liver – words), (4) Fungi.

The first natural system of classification of the plants was proposed by A.L. de Jussieu (1748 – 1836) in the end of eighteenth century, who divided the plants into threee major groups, i.e, (1) Acotyledones, (2) Mono – cotyledones and (3) Dicotyledones. His classification was based upon the sexual system of Linnaeus but in improved form. His Acotyledones were like Cryptogamia of Linnaeus.

In 1880, the cryptogamic plants were divided into three major groups, i.e., (1) Thallophyta (alage, fungi and bacteria), (2) Bryophyta, and (3) Pteridophyta.

Before twentieth century only four classes were recognized among algae, i.e., (1) Chlorophyceae (2) Phaeophyceae, (3) Rhodophyceae and (5) Myxophyeceae or Cyanophyceae. Diatoms were then included in Phaeophyceae.

Formerly many zoologists placed many motile (flagellate) algae of today in the class Mastigophora of phylum Protozoa.

Rabenhorst in 1863, for the first time placed the Chlamydomonas – Volvox series in the Chlorophyceae of algae.

In the begining of the twentieth century the class Xanthophyceae was separated from Chlorophyceae and certain pigmented flagellate types were included in the class. According to Dr. F.E. Fritsch (1935, 1944, 1945) the algae have been divided into following eleven classes :-

1. Chlorophyceae
2. Xanthophyceae
3. Chrysophyceae
4. Bacillariophyceae
5. Cryptophyceae
6. Dinophyceae
7. Chloromonadineae
8. Euglenophyceae or Euglinineae
9. Phaeophyceae
10. Rhodophyceae
11. Myxophyceae

**FRITSCH'S SYSTEM**

Dr. Fritsch' classification is mainly based on the following facts –

1. Pigmentation
2. The assimilatory food products or metabolic products
3. Type of flagella.

In addition to above given facts a few minor characters may also be taken into consideration. Here we will consider the characters of few important classes, i.e., 1. Chlorophyceae 2. Xanthophyceae, 3. Bacillariophyceae, 4. Phaeophyceae, 5. Rhodophyceae and 6. Myxophyceae.

**1. Chlorophyceae (360 genera: 5,000 species)**

**Major Characteristic Features.**

(i) The pigments are just like in higher green plants i.e., chlorophyll a, chlorophyll b, xanthophyll and carotenes. These pigments are localized in definite plastids or chromatophores.

(ii) The photosynthetic food product is starch, rarely oil as in Vaucheria. Usually in the chromatophores the pyrenoids are present. They are organallae for the formation of starch. A part of pyrenoid converts into starch.

(iii) The flagellation is of isokontae type i.e., both of the flagella are equal in length.

**Minor Characteristics Features**

Vegetative body may be one to many celled.

The cell consists of cellulose

Sexual reproduction ranges from isogamy to oogamy.

The life – cycle is mostly of haplontic type.

The parenchymatous cells do not occur.

Most of the species are fresh water and few are marine.

**2. Xanthophyceae (75 genera : 675 species).**

**Major Characteristic Features.**

(i) The chromatophores are yellow green, containing chlorophyll a, carotenes (β carotene and xanthophylls in them.

(ii) The starch is not found. The pyrenoids are absent. The chief food products are oils.

(iii) The flagellation is of heterkonatae type, i.e., one flagellum is short and other long.

**Minor Charcteristic Features**

(i) The cell wall consists of pectin, and in majority of cases two overlapping halves are present, e.g., Tribonema.

(ii) The sexual reproduction is rarely found, and is doubtfully established for only one species.

(iii) The resting stages possess two pieced membranes

(vi) The walls are silicified.

(iv) The life – cycle is mostly of haplontic type.

(vi) Majority of the species are fresh water, some are marine.

**3. Bacillariophyceae (170 genera : 5,300 species)**

**Major Characteristic Features**

(i) The chromatophores are golden brown or yellow, due to the presence of a pigment called diatomin. The other pigments are chlorophyll a, carotenes (β carotene) and xanthophylls.

(i) The food products are fats or volutins.

(ii) The flagellate bodies are 1 to 2 flagellate.

**Minor Characteristic Features**

(i) Majority of them are unicellular and, some are colonial.

(ii) The sexual reproduction is of special type resulting in the formation of auxospores

(iii) They are diplontic

(iv) They are widely distributed in sea and fresh waters.

**4. Phaeophyceae (195 genera : 1,000 species)**

**Major Characteristic Features :**

(i) The chromatophores are yellowish brown in colour possessing xanthophylls in abundance in them, Chlorophyll a, and carotenes (β carotene) are also found.

(ii) The reserve food products are alcohols, mannitol and laminarin.

The motile reproductive cells are pyriform with two laterally inserted flagella; one of which is of tinsel type. In all except Fucales the anterior flagellum is longer.

**Minor Characteristic Features**

(i) The unicellular bodies are unknown

(ii) The special type of granules, which are excretory in nature are vesicles.

(iii) The sexual reproduction ranges from isogamy to oogamy.

(iv) The zygote has no resting period.

(iv) The great diversity prevails in the life cycles, possessing clear alternation of generations.

(vi) With the exception of three species, rest are marine.

**5. Rhodophyceae (400 genera : 2,500 species)**

**Major Characteristic Features**

The chromatophores possess r-phycoerythrin and c-phycocyaning pigments. The other pigments are chlorophyll a, Carotenes (β carotene) and the xanthophylls. The plants look reddish in colour.

(i) The reserve food products are polysaccharides, floridean starch and a soluble sugar called floridoside.

(ii) The flagellation is altogether absent.

**Minor Characteristic Features**

(i) The prominent plasmodesmata are present

(ii) Sexual reproduction is special and advanced

(iii) The life cycle clearly shows alternation of generations.

(iv) About 50 species belonging to near about a dozen genera are fresh water. The rest are marine.

**6. Myxophyceae (150 genera ; 1,500 species)**

**Major Characteristic Features**

(i) The pigments are not localized in definite chromatophores. The pigments are localized in the peripheral portion of the protiplast. The main pigments are chlorophyll a, carotenes (β carotene) and xanthophylls. The overmasking blue pigment is c – phycocyanin. The red pigment c – phycoerythrin is also found in peripheral regions in dispersed condition. This peripheral region with pigments is called chromatoplasm.

(ii) The reserve food products are sugars and glycogen like compounds called the 'cyanophycean starch'.

(iii) The flagella are altogether absent.

**Minor Characteristic Features**

(i) Sexual reproduction is unknown

(ii) Majority of them are fresh water forms. Some are found in sea water.

**PIGMENTATION IN ALGAE :**

Various pigments, such as red, yellow, green and blue have been found in various marine and fresh water algae. Usually these pigments are found in special plastids called chromatophores, however, in Myxophyceae the chromatophores are not found, and the pigments are dispersed in peripheral chromoplasm. Only, because of the presence of these cospicuous pigments the algae look variously coloured in their habitats. Besides, several algae are colourless and more or less saprophytic in nature. Colourless algae have been reported from several major groups. There are colourless diatoms, colourless dinoflagellates, colourless Chlorophyceae and colourless Rhodophyceae. The principal pigment chlorophyll has been reported from all major groups of algae. Besides, carotenoids, xanthophylls and phycobilins are also found in various algae.

**Principal kinds of algae pigments**

There are three main gropus of principal algal pigments. They are as follows :

1. **The chlorophylls -** They are green fat soluble pigments and universally present in green and other algae.
2. **The carotenoids -** They are fat soluble yellow pigments and present in various groups of algae. They are subdivided into three groups : (i) carotenes; (ii) xanthophylls or oxycarotenes; and (iii) carotenoid acids.

3. **The phycobilins -** They are water soluble blue and red pigments. The phycobilins are subdivided into two groups, i.e., (i) the phycocyanins and (ii) Phycoerythrins.
4. **Properties of chlorophylls -** The algal chlorophylls are (i) green, (ii) in solution the chlorophylls are fluorescent and emit red light, (iii) they are also distinguished by strong absorption of the blue – green and green colours.
5. **Properties of carotenoids -** As stated the carotenoids are subdivided into three groups, i.e., (i) carotenes; (ii) xanthophylls and (iii) carotenoid acids. The properties are as follows:
6. **Carotenes -** (i) They are unsaturated hydrocarbons; (ii) they absorb blue and green light and transmit the yellow and red; (iii) they are fat soluble and yellow in colour.
7. **Xanthophylls -** They are also named as oxycarotenes. They are oxygen derivatives of carotenes and resemble the properties of carotenes.
8. **Carotenoid acids -** They consist of a chain of carbon atoms. Their properties resemble the properties of other two carotenoids.

**Properties of phycobilins**.

The phycobilins are subdivided into two groups, i.e., (i) phycocyanins and (ii) phycoerythrins.

The phycobilins are proteins. They are soluble in water and insoluble in the fat solvents. They are strongly fluorescent and emit orange or red light.

1. Phycocyanins. They absorb green, yellow, and red light and transmit the blue.
2. Phycoerythrins. They absorb blue green, green and yellow light and transmit the red.

All the phycobilins are strongly flourescent and emit orange or red light.

| DIVISION | GreenPigments | Other Pigments | Stored food |
|---|---|---|---|
| 1. Chlorophyta | Chlorophyll –a, -b | B – Carotene and xanthophylls | Starch |
| 2. Charophyta | Chrophyll –a, -b | y – Carotene lycopene and xanthophylls | Starch |
| 3. Euglenophyta | Chlorophyll -a, -b | B- Carotene and xanthophylls antheraxanthin | Paramylum, Fats |

| | | | |
|---|---|---|---|
| 4. Chrysophyta | Chlorophyll -a | B – Carotenes, xanthophylls | Leucosin, fats, chrysolaminarin |
| 5. Xanthophyta | Chlorophyll a, e | B – Carotene and xanthophylls | Oil fat, leucosin |
| 6.Bacillariophyta (Diatoms) | Chlorophyll a, c | B – Carotene, e-carotene, xanthophylls (fucoxanthin) | Fats, leucosin |
| 7. Phaeophyta | Chlorophyll a,c | B – carotene, xanthophylls (fucoxanthin) | Laminarin, mannitol |
| 8. Rhodophyta | Chlorophyll a,d | r – phycoerythin r-phycocyanin, a- and B – Carotene, xanthophylls (lutein and taraxanthin) | Floridean starch |
| 9. Cyanophyta | Chlorophyll a | Blue c-phycocyanin, red c-phycoerythrin B- Carotene, myxoxanthin and myxoxanthophyll | Myxophycean starch and cyanophycin |

**Occurrence of principal pigments in algae -** All autotrophic algae contain chlorophylls, carotenoids and xanthophylls. The myxophyceae and Rhodophyceae contain phycobilins which overmask the other pigments. Phycobilins are always associated with other pigments such as chlorophylls and carotenoids.

**Occurrence of individual pigments in algae -** In chlorophyceae chlorophyll a (chlorophylls), β carotene (carotenoids) and lutein (xanthophylls) are present as principal pigments. Besides, other chlorophylls, carotenoids and xanthophylls are also found.

**Xanthophyceae.** Chlorophyll, a and β-carotene are found as principal pigments. In addition to these several xanthophylls have also been reported.

**Phaeophyceae** - Chlorophyll, a, β – carotene and several xanthophylls are found.

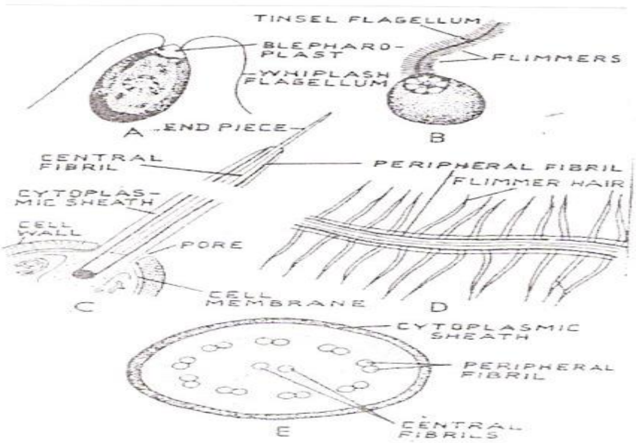
**Rhodophyceae.** Chlorophyll, a, β – carotene and r- phycoerythrin are found as principal pigments. In addition to these chlorophyll d, a carotene, lutein and r- phycocyanin are also found.

**Myxophyceae.** Chlorophyll, a, β-carotene and c-phycocyanin are principal pigments. Besides, c-phycoerythrin and xanthophylls are also found.

**FLAGELLA IN ALGAE :**

The motile cells of algae are provided with fine, protoplasmic, whip – like threads, the flagella (A). They are extremely fine and hyaline emergences of the eytoplasm. In cells possessing firm cell walls, the flagella are connected with the inner cytoplasm through small pores in the cell wall (C). There is either a single anterior flagellum (rarely posterior) or the flagella occur in pairs (A), rarely in great numbers on the cell. The flagella on the cell may be equal (isokont) or unequal (heterokont) in length. When the flagella are inserted laterally one is directed forwards in notion and the other backwards. They function as the locomotory or propelling structures of the cell. Usually there is a single granule at the base of each flagellum. It is known as the blepharoplast.

(a) **Structure of the Flagellum.** Forming the core of the flagellum is an axial or central filament called the axoneme. The latter is surrounded by a cytoplasmic membrane or sheath which terminates short of the apex (C). The naked, terminal portion of the axoneme is called the end piece. The tip of the end piece may be blunt and rounded or pointed. In cross section (E) the flagellum consists of two inner central simple fibrils forming an elastic exial thread. It is surrounded by nine united, peripheral contractile, thicker protein double fibrils. All are enclosed by a sheath which is an extension of the plasma membrane. Each peripheral fibril is composed of two thin fibrils. The two central fibrils are single. They lie side by side and are sometimes enclosed by a sheath of their own. The fibrils are hollow and extend along the entire length of the flagellum. The nine peripheral fibrils join the basal granule (C) but the two central fibrils stop short of the granule. This '9+2' pattern of component fibrils is the basic structure of the flagellum of all organisms except the bacteria.




A-E). Algae. Kinds of Flagella and their structure. A, Whiplash ; B, Tinsel ; C, L.S. Whiplash Flagellum ; D, L.S. Tinsel Flagellum ; E, C.S. Eucaryotic Flagellum.

(b) **Kinds of Flagella.** They are of two main types, whiplash (A) and tinsel (B). The whiplash flagellum has a smooth surface. The tinsel flagellum bears longitudinal rows of fine, minute flimmer hairs arranged along the axis almost to the tip of the flagellum. There may be a single row of hairs as in the Euglenophyta and Pyrrophyta or two as in Chrysophyceae and Phaeophyceae.

The hairs arise from the margins of the peripheral fibrills. The whiplash or smooth flagella are also known by other names such as acronematic or peitchgeisel. The other names for the tinsel flagella are pantonematic, flimmer or flimmergeisel. The use of an electron microscope has revealed a third kind of flagellum in which the surface of the flagellum is covered by scales (Chara) and minute, short, stiff hairs. Manton and Parke (1960) described this type of flagellum in Micromonas pusilla (Prasinophyceae). The hairs differ from those on the tinsel type. They can be easily detached.

(A-F). Algae. Flagellation. Chlorophyceae (A – C) Xanthophyceae (D); Bacillariphyceae (E) and Phaeophyceae (F).

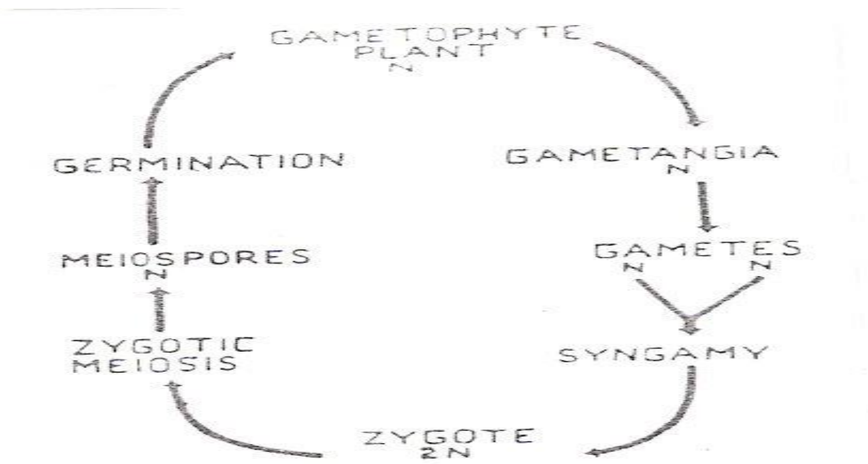
(c) **Flagellation.** The position, number and kind of flagella on the motile cells is strikingly constant in each division of algae but differs from division to division. Thus it forms an important taxonomic feature for primary classification of algae. The blue – green and red algae lack flagella. The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

**LIFE CYCLES IN ALGAE :**

The sequence of events through which an organism passes from the zygote to the zygote of the next generation constitute its life cycle. Broadly speaking at least five main types of life cycles can be distinguished among the algae reproducing sexually. They are described next :-

**Haplontic Life Cycle**. Sexual reproduction always involves a cyclic alternation between a haploid and a diploid condition. In the majority of green algae, Charophyta and Bangia in the red algae, there is a single thalloid vegetative individual in the life cycle. It is hapiloid. As it bears the gametes it is called the gametophyte plant. The latter multiplies by vegetative means and also by the formation of mitospores during the growing season. The mitospores, on germination, produce the gametophyte plants. They thus serve as additional means of multiplying the gametophyte generation which produces them and play no role in the phenomena of alternation of generations. Towards the end of the growing season the gemetophyte plant produces gametes in vegetative cells called gemetangia. These gametes fuse to form a zygospore.

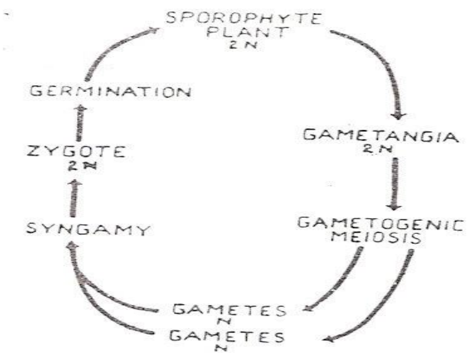
The zygote at the time of germination undergoes zygotic or intial meiosis producing 4 haploid spores called the meiospores. Each meiospore germinates to produce the gametophyte plant. The diploid condition in these algae is thus confined only to the zygospore itself. Although it gives rise to haploid spores but it can hardly be regarded as a sporophyte. In these plants, therefore, there is alternation between a prolonged, haploid vegetative gametophyte plant and a single celled diploid zygospore with meiosis occuring on germination of the zygote. This cannot be considered as true alternation of generations. There is, however, alternation of chromosome numbers from haploid to diploid and back to haploid condition but no corresponding alternation of plants with different functions. Such a life cycle is called haplontic. it is a primitive type of life cycle which is characterized by zygotic meiosis and haploid adult. Examples are Spirogyra, Ulothrix, Chlamydomonas and Oedogonium. Fritsch (1935, 1942 b) and Stebbins (1960) considered it to be a primitive type of life cycle but according to Chaodifaud (1960) it has evolved from a diplohaplontic life cycle by reduction and loss of the diploid or sporophyte generation.




**Haplontic Life Cycle**

(b) **Diplontic Life Cycle.** This type of life cycle is exhibited in many diatoms (Bacillariophyta), some of the Siphonales, Siphonocladiales and Dasycladiales among the green algae and Fucales (Fucus and Sargassum) in the brown algae. The vegetative thallus or plant constituting the dominant phase in the life – cycle, is diploid. It is the sporophyte plant but it bears the sex organs which produce the gametes. Meiosis or reduction division occurs at the time of differentiation of the gametes in the sex organs. This is known as gametogenic meiosis. In these organisms the haploid condition is limited to the gametes alone. The gamethophyte phase in such forms is thus extremely reduced. It is a brief phase represented by a few haploid cells, the gametes only. At the time of gametic fusion the diploid condition is re-established. The zygote by equational mitosis develops into the sporophyte plant. Here again the life cycle includes one vegetative adult. It is the sporophyte plant. The sporophyte plant in the life cycle alternates with a few haploid cells, the gametes. There is, therefore, no true alternation of generations in the life cycle. Such a life cycle is called diplontic. It is characterized by gametogenic meiosis and a diploid adult (sporophyte). The gametophyte is represent by the gametes, the only haploid cells in the life cycle.

Many phycologists think that a diplontic life cycle has evolved from a diplohaplontic cycle by reduction of the gametophyte but in the Bacillariophytes the diploid vegetative plant is believed to have arisen by the elaboration of the diploid zygote of the primitive haplontic cycle.

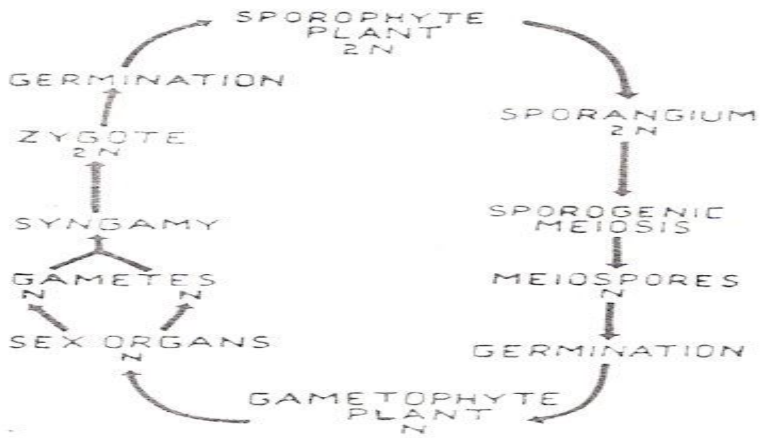



**Diplontic Life Cycle**

(c) **Diplohaplontic Life Cycle.** The third type of life cycle is typical of the Ulvales and Cladophorales in the green algae and Ectocarpus and Dictyota in brown algae. There is alternation of two district vegetative individuals having not only different chromosome numbers but different functions as well. One of thesw individuals is the haploid gametophyte. It is concerned with sexual reproduction. The other is diploid sporophyte. It produces sexual spores (meiospores). This type of life cycle which consists in the alternation of two vegetative individuals, the gametophyte and the sporophyte with sporogenic meiosis is called diplohaplontic. It is a widespread type of life cycle and is of two catagories:

(i) **Isomorphic or homologous diplohaplontic.** When the alternating vegetative individuals (the gametophyte and the sporophyte) are motphologically similar the life cycle is called Isomorphic or homologous.

Meiosis in such a life cycle is delayed so that the zygote yields a multicellular diploid plant. Meiosis takes place in the zoosporangium of Ulvales and Cladophorales, unicellular sporangium in the Ectocarpales and the tetrasporangium in the Dictyotales and red algae. It is known as sporogenic meiosis. Isomorphic type of diplohaplontic life cycle is considered to have eveloved from a haplontic life cycle by a sudden mutation which the zygote directly developed intro a new vegetative individual by mitosis. There was no zygotic meiosis.




Exploration of the seas, which are full of algae, has brought home to man the usefulness of algal flora. The algae are of impotance in the fields of agriculture and industry. In addition they are used as food, fodder and as manure. The algae are useful as the source of many commercial products. The four major products derived commercially from them are agar – agar, carrageenin, alginic acid, and diatomite. The industrial utilisation of Algae, particularly the sea weeds, dates back to many hundreads of years.

**Agar – agar**

It is a mucilage produced by certain red algae and stored along with cellulose in the cell walls. The main sources of agar – agar in Japan are the thalli of Gelidium, Gracilaria and Gigartina. Until 1939 Japan was the largest producer of agar. The other red algae used for this purpose are Camphylaephora, Eucheuma, Hypnea, Ahnfeltia and Fursellaria. Agar is a gelatinous, clear, nitrogen free extract from the above – mentioned genera of the red algae. The extract is a gel containing galactose and a sulphate. Its melting point is between 90 and $100^{0}$F. At lower temperature it changes into a solid. Agar – agar is of great value in the preparation of foodstufs and is particularly used in the articles of diet for invalids. It is insoluble in cold but should not water. It is almost a necessity to research as it is used as a base for culture media for bacteira, fungi, algae and other tissues. It is used as a laxative, culture medium, baked goods, meat industry and as an emulsifier in dairy products.

**Single Cell Protein (SCP)**

The industrial production of protein from micro organisms is called as single cell protein. Protein is extrcated from algae like chlorella, Scenedesmus and Spirulina. Protein is also extracted from bacteria like clostridium, Escherichia, Micrococcus, Pseudomonas and also from fungi like candida, Saccharomyces.

Chlorella is a very common cosmopolitan fresh water alga that may grow in brakish water and moist terrestrial habitats. The plant body is made up of single cell. It is green in colour and belongs to the family chlorophyceae. In recent years this alga has assumed great importance and it is likely to become even more important in the future. Chlorella is rich in proteins, fats and vitamins and in the presence of nutrients, $CO_2$ and sunlight, multiplies at an enormous rate. Several countries have been experimenting with the mass production of chlorella. Pilot scale chlorella farms have already been established in America, Japan, Holland, Germany and Isreal.

Chlorella has the distinction of being the most widely studied alga as a potential food source for the worlds expanding population. Each quart of a moderately thin suspension of chlorella contains twenty billion cells of the alga. Arthur D. Little has produced chlorella at the rate of 20 grams per squre metre per day in his pilot plant established at Massachusetts. This way 17.5 tons of chlorella may be produced per acre per year.

Chlorella contains a high percentage of protein of about 50 percent, fat about 20 percent and carbohydrates about 20 percent. It is also enriched with most of the vitamins such as thiamin, Vit A, Vit B12, riboflavin, niacin, pantothenic acid, choline, biotin,and lipoic acid.

The amino acids of dried chlorella one :

| | | | |
|---|---|---|---|
| Crude Protein | 44.00% | Methionine | 0.36% |
| Arginine | 2.06% | Phenylalanine | 1.81% |
| Histidine | 0.62% | Threonine | 2.80% |
| Leucine | 3.79% | Valine | 2.47% |
| Isoleucine | 1.75% | Trptophan | 0.80% |
| Lysine | 2.06% | | |

It is for this season that posssibility of chlorella for human consumption as food is being explored througout the world.

The biologists have given a serious thought to construct a biological system in which there would be a complete recycling of the biological materials. This biological system will be used during a space flight trip lasting over 30 days. The spaceman will need a device to get rid of carbon dioxide and other body wastes and will also require sources of oxygen and food. It has been considered baneficial to use microscopic, Unicellular, algae such as Chlorella pyrenoidosa and Synechococcus as a possible food source in anticipated space flight. It multiplies rapidly and thus will synthesise a rich harvest of food utilizing carbondioxide and liberating sufficient of nitrogen for protein synthesis it will assist in the decomposition of human wastes.

**Role of Algae in Medicine**

Many sea weeds contain a high percentage of iodine content and thus are employed in the preparation of various goiter medicines or are administered directly as a powdered weed. Laminaria sp such as L. japonica and L. religiosa have a high value of iodine. Among the green algae Codium intricatum contains a considerable quantity of iodine. Red algae such as Gelidium and Grateloupia contain a medium amount.

A patient suffering from prolapsed stomach is fed on a diet containing dried agar – agar and asked to drink a lot of water. The stomach gets distended and regains its normal condition. A few algae are a source of antibiotics which inhibit the growth of other bacteria. Chlorellin from Chlorella is one such antibiotic. It has also been reported that extracts of Cladophora and Lyngbya possess antiviral properties and kill strains of certain bacteria (Pseudomonas and Mycobacterium). The Charles have been claimed to possess larvicidal properties. Caballero (1919) considered Charales useful in the destruction of mosquito larvae.

Agar – agar is an important algal product used in the manufacture of pills and ointments. Besides it forms a base for many kinds of medicines used as laxatives.

Carrageenin extract, which is another product of algal origin, acts as a blood coagulant. Alginic acid stops bleeding.

An effective vermifuge is obtained from the extracts of Digenea, Codium, Alsidium and Durvillea. Many algae are used in the treatment of lung, kidney and bladder ailments by unanihakims.

**Role of Algae in Agriculture**

Soil is a living mass. Apart from the soil particles it harbours bacteria fungi, algae and other micro – organisms. The algae occupy a volume three times that of the bacteira. Of the soil algae the blue greens are the most important. They are capable of fixing atmospheric nitrogen in their bodies. Upon liberation, nitrogen is usable form increases soil fertility and improves the growth of crop plants. P.K. De (1939) has furnished a conclusive proof that the blue – green algae are the cheif agents for nitrogen fixation in rice fields. They increase the fertility of the soil by fixing atmospheric nitrogen. Some of the important nitrogen fixing blue – green algae are Oscillatoria princeps, O. formosa, species of Anabaena, Spirulina, Nostoc and Cylindrospermum. The practical application of these algae as fertilizers is the seeding of rice fileds with nitrogen – fixing species to increase the nitrogen content of the soil.

Another important use of the blue – green algae is in the reclamation of barren, alkaline soils (R.N. Singh 1961). Such soils have been reclaimed and brought to a productive state by inducing a proper growth of certain cyanophyceae. Successive crops of these neutralize the alkalinity and increase fertility of the soil.

The algae are also used as fertilizers particularly the sea weeds. The agricultural utilisation of sea weeds as manure is chiefly confined to the farm land near the coastal regions. Large brown and red algae are used as organic fertilizers. They are richer in potassium but poorer in nitrogen and phosphorous than the farm manure. The sea weed may be used direct and ploughed. The direct application of sea weeds in vogue close to the sea in some countries such as France, Irelane and Sri Lanka, for earth vegetables such as potatoes, and turnips, and also for coffee plantations. In Japan they are used in the rice fields whereas in China for groundunts and sweet potatoes. In India Turbinaria is used as a fertilizer around palm trees. In Rajasthan Anabaena and Spirulina which are produced in enormous quantities in the Sambhar salt lake are employed as green manure by the local farmers. The sea weeds are also used as compost. Sometimes they are burnt and ashes scattered over the farm lands.

The sea weeds are processed into a sea weed meal for transport inland. Concentrated liquid extracts of sea weeds are sold as liquid fertilizers and also as insecticides. The sea weed products aid in binding sandy soils. They also help to break down clayey soils and thus promote a good crum structure.

In some countries there is a practice to grind up Lithothamnion and Lichophyllum and use it in place of lime. Similar use is made of species of Chara which are encrusted with calcium carbonate.

The algae such as Chlorella also help to aerate water by removing carbon dioxide and restoring supply of oxygen in photosynthesis. This is important to the fish. Their growth is encouraged in the sewage disposal plants. They take up nitrates and phosphates for their metabolism and liberate oxygen in photosynthesis which helps the aerobic bacteria to decompose raw sewage.

**Use of Algae as food**

The algae are important as a source of food of the fishes, aquatic amphibia, mammals and other animals. Man's dependence on fish and other aquatic animals to supplement his diet is a well known fact. Indirectly, therefore, the algae are of great value to man. Some biologists, however, suggest that algae might be raised by man as a source of food. Miller (1972) believed that the algae can play an important role in the production of protein for human food. In fact in some coastal parts of the world they are used directly as human food. In the Pacific islands and orient the red, brown and green algae form a regular portion of diet. Over a hundred species appear on the diet list. In this respect Spirogyra and Oedogonium are valuable genera in India and Ulva in Europe. The former two are dried, put up in small packets and sold on the market in India to be made into soup. The colonies of Nostoc are boiled and used as food in Brazil. In the Pacific islands raw alage (sp.of red, and brown algae) are chopped and added to other dishes. The young stipes of Laminaria and sporophylls of Alaria are also eaten. The laminarian food from stipes is called Kombu and from Alraia as sarumen in Japan, Durvillea and Ulva are dried, salted and sold. Ulva lactuca was formely used in salad soups in Scotland. Porphyra (laver) is considered a tasteful dish in England and is a common item of diet in korea, Japan and China. It is rich in Vitamins B and C. A red algae Rhodymenia palmata is used as food and also as a salty confection named dulse. Large quantities of Durvillea antartica and some species of Ulva lactuca are consumed in Chile. The prolific users of seaweeds as food are the coastal people in China and Japan. The commonest species used are Porphyra tenera (Amanori), Laminaria and a green alga Monostroma. Undaria and Sargassum are also used for this purpose. Caulerpa recemosa is cultivated in Phillippines as a source of food. In China and Japan some sea weeds are regularly harvested as food for man. In Japan many of them are cultivated in bamboo frames in water to meet their demand. It has been estimated that nearabout 25% of the daily diet of Japan consists of sea weeds. The total food production by marine algae is estimated to be eight times that by the land plants.

The algae are considered rich in proteins, fats and vitamins A,B, C and E. The vitamin A and D which are commercially obtainmed from the livers of shark and similar frish originally come from synthesis by the plankton algae particularly which form the food of the fish. Diatom Nizschia is rich in vitamin A. Vitamin B is found in Ulva, Enteromorpho, Laminaria, Alaria valida, Porphyra, Nereocystis and Chondrus crispus. Ulva, Enteromorpha, Alaria valida and Undaria also contain vitamin C. Dulse contains half as much vitamin C as oranges. Fucoids and Porphyra are even richer.

**Use of Algae as Fooder**

The sea weeds are used as a fodder for animals with beneficial effects. Norway, France, U.S.A. Denmark, and New Zealand are the countries where it is a common practice to use sea weeds as fodder for the cattle. In Great Britain, France, Scandinavia and Pacific coasts of U.S.A. kelps are chopped for sheep and chickens. Some countries have even developed small industries for processing the weeds such as Ascophylluem. Fucus and Laminaria into suitable cattle feed. The processed food is given to cattle, poultry and pigs. Egg – yolks of fowls fed on chopped sea weeds have increased iodine and carotene content. The egg laying capacity of the poultry increaes. Mactrocystis sp is also used being rich in vitamins A and E. A red alga Rhodymenia is used as a cattle fodder in France. The milk –yielding capacity of the cattle is enhanced when dried sea weeds such as Pelvetia forms an ingredient in cow feed. Similarly increased butter and fat content of milk is reported from cattle whose diet is supplemented with sea weed meal. In China Sargassum is used as fodder.

**Algae in Sewage Disposal**

Sewage is the foul domestic and industrial liquid waste which is deficient in oxygen but abounds in dissolved and suspended organic and inorganic materials. It harbours microorganisms of decay and decomposition. The use of small green algae such as Chlamydomonas, Chlorella and Euglena in large, shallow tanks of effluent (sewage oxidation ponds) has proved a rapid, cheap and effective menas of converting the dangerous and expensive waste into an odourless and valuable fertiliser. These tanks promote growth of the algae which flourish at the expense of the mineral nutrients present in the sewage. The rapid photosynthetic activity of the algae products abundant oxygen which is used by the micro – organisms responsible for decomposition of remaining organic matter in the sewage.

**NOTES**

# UNIT - III

## NOSTOC

**Structure :** The colonies *of Nostoc* are very much contorted and are embedded in a mucilaginous envelope. The mucilaginous sheath is more or less firm. Innumerable *Nostoc* threads lying irregularly are present within this sheath. Each thread has cells more or less spherical which are moniliform (beaded) in appearance. The colonies are spherical but as the development proceeds, their shape does not remain as such. They may become globular, ellipsoidal and sometimes may reach the size of a hen's egg, *e. g.*, *N. punctiforme.* Each colony may later, on break up, or may remain solid or hollow. The colony has irregular outgrowths or becomes flatly lobed as in ***N. commune*** and ***N. linkia***. Young colonies are microscopic but according to **Setchell** (1889), colonies of *N. amplissimum* reach to a size of 60 by 30 centimeters. Each cell of the colony is typical Cyanophycean in structure.

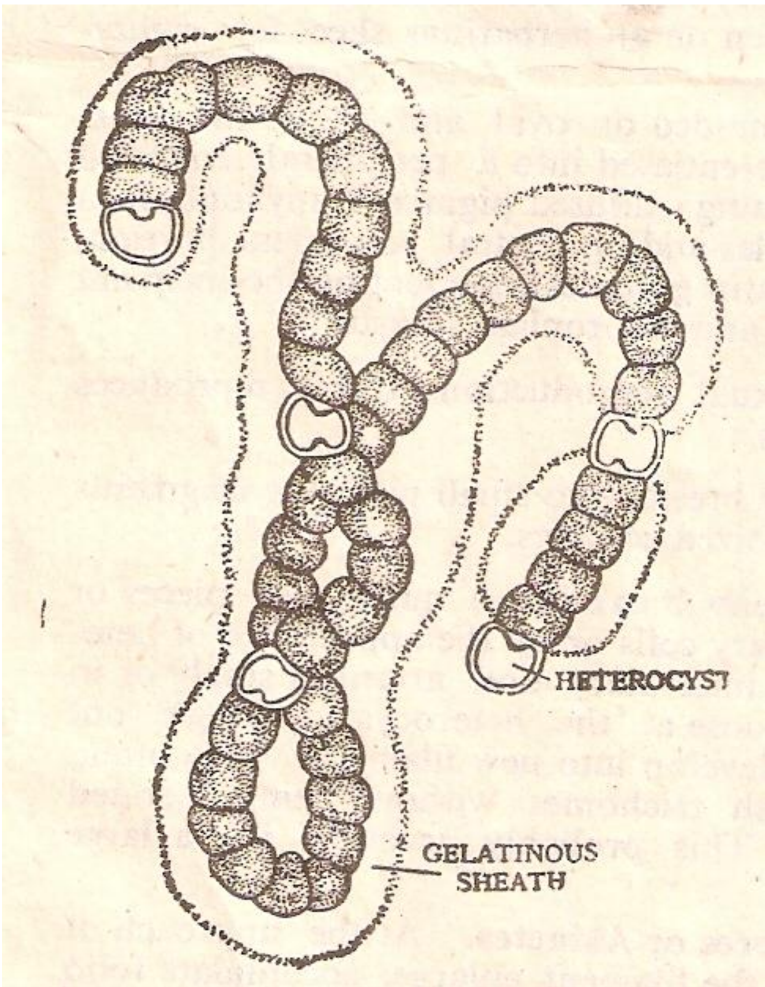
**Reproduction** : It is only vegetative and is brought about with the help of hormogones, heterocysts and akinetes.

**Hormogonia:** The trichomes generally break from the place where a heterocyst is united with a vegetative cell. After breaking up, these hormogonia form new colonies. According to Smith, this method is so much prevalent that colonies go on multiplying by this means within the gelatin ous sheath without being liberated.

**Heterocysts:** They are intercalary in origin and are generally isolated. They may be of the size of a vegetative cell or slightly larger. They have a thick wall and occur at intervals. The heterocysts germinate to form new trichomes which are finally liberated by the breaking up of the wall as in *N. commune*.

**Akinetes :** They are formed when a colony is mature. They occur in between two heterocysts. In some species *of Nostoc,* all the cells between two heterocysts may get transformed into akinetes and thus they form a continuous chain.

The akinetes are resistant and tide over unfavorable periods. They have thick wall and reserve food material. They are viable even after many years. On the return of favorable conditions, they germinate. According to Fritsch, some species of *Nostoc* produce a primary hormogonium after the germination of their akinetes. Whatever may be the case, on germination, a new trichome is formed.




**CHLAMYDOMONADACEAE**

The members of this family are mostly fresh water, though some may be terrestrial or marine also. Sometimes, they grow in such abundance that the whole water which they inhabit turns green and emits a bad odour. The family has many genera but only *Chlamydomonas,* ***Eudorina*** and Pandorina will be discussed.

*Chlorophyceae*

*Volvocales*

*Chlamydomonadineae*

*Chlamydomonadaceae*

*Chlamydomoas*

**Occurrence**. It is a primitive unicellular green alga and includes 325 species. It occurs in ditches, pools, ponds and lakes and even on moist places. Sometimes, it is found in such great abundance that the whole water.

It appears green in colour, but at such occasions other algae may also be associated with it. Generally, it occurs in ,water, rich in ammonium salts.

Some of its species are found even at unusual places *Chlamydomonas ehrenbergii* is found in the salt lakes of Crimea and Sambhar while few species are marine. *Chlamydomonas yellowstonensis* is found in Yellow Stone National Park of America on snow to which it imparts a yellow green colour. Two Indian species, *Chlmydomonas grandistigma* and *Chlamydomonas eugametos,* have been reported by **Mittra** from Allahabad *(1951).*

**Structure.** It is a unicellular organism and is usually spherical or ovoid but may be pyriform or ellipsoidal also. Its anterior end is pointed. At this end papilla may or may not be present. The cell remains surrounded by a cell wall made up of cellulose. *C. gloeocystiformis* has an outer firmer and an inner mucilaginous portion. At the anterior end, there are two thread-like structures arising from two basal granules called cilia or flagella.

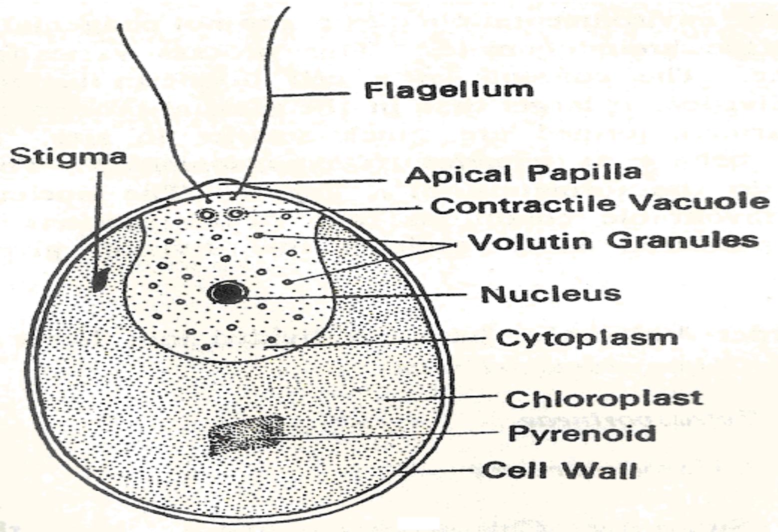



Fig. A *Chlamydomonas* cell.

The flagella originate from a flagellar apparatus or neuromotor apparatus. The two basal granules from which the flagella arise are connected by a transverse fibre, the paradesmos while one of the granules is connected to intra-nuclear centrosome by a thread-like structure called the rhizoplast. The centrosome is linked with nucleolus through another delicate fibre. According to **Fisecher** and **Petersen**, the flagella are thick at base, taper towards apex and 'finally end in whip-like processes. They help in movement. The cell moves by its anterior end forwards. There are two contractile vacuoles at the anterior end just beneath the basal granules but their number and position may vary in different species.

The most prominent structure in the protoplast is a single massive chloroplast which is horse-shoe shaped in vertical view. It is thick at bottom and thin at periphery and anterior ends. (The cells of C. *basistelata* and C. *viridemaculata* lack chloroplast and are colourless). Its shape may very in different species, *e. g.*, reticulate in C. *reticulata,* axile or almost stellate in *C. arachne* and C. *eradians* and stellate in case C. *steinii* if viewed from the front end.

A single pyrenoid is embedded in the chloroplast which is very prominent. It is generally situated in the posterior region of the cell but it may be on one side as in *C. parietaria* and C. *mucicola.* In the former species, the chloroplast remains basin shaped while in the latter it is pushed to one side. In C. *sphagnicola,* the pyrenoids are many and scattered throughout the chloroplast. In few species however, the pyrenoid is completely wanting.

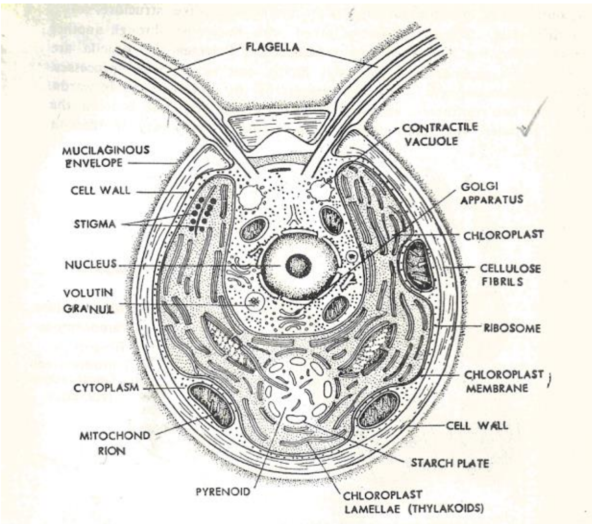



Fig. A cell of *Chlamydomonas* under electron microscope.

Just beneath the cell-wall there is a thin layer of cytoplasm which is called outer cytoplasm or plasma membrane. The stigma or eye spot is one (more than one stigma in *C. pluristigma)* and is located in the thickening of the plasma membrane. However, the position of stigma varies in different species. There is a single nucleus in the inner cytoplasm where volutin grains may also be present. Under electron microscope a cell of *Chlamydomonas* appears.

**Reproduction**. The reproduction in *Chlamydomonas* is of two types.

***1 Asexua***

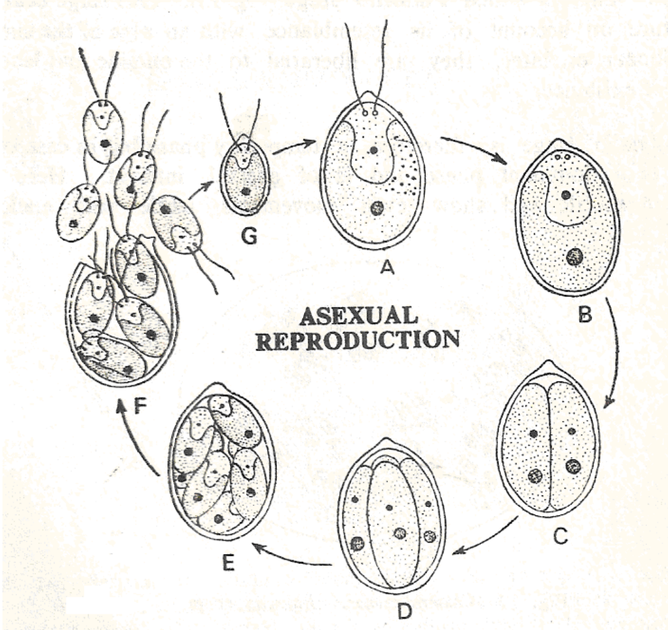
*2.* ***Sexual***

**Asexual reproduction.** This type of reproduction takes place till the conditions are favorable. During this process, the cell with-draws its cilia

Thus becomes nd non-motile. The contents of the cell undergo divisions. The plane of division is longitudinal but in some species there is rotation of the protoplast. In C. *braunii,* it rotates at right angles during division. In *C.angulosa* it rotates at right angles after the division. In C. *gigantea* no such rotation takes place. Thus, from one, two and from two, four cells are formed. Occasionally third division may also follow resulting in the formation of eight cells. The cells so formed are called zoospores. In structure they are exactly similar to the parent cell but much smaller in size. They remain surrounded by the parent cell-wall. In the beginning they are naked and are devoid of cilia, but before their liberation to the outside they develop both these structures. They are liberated to the outside by the dissolution of the parent cell-wall.

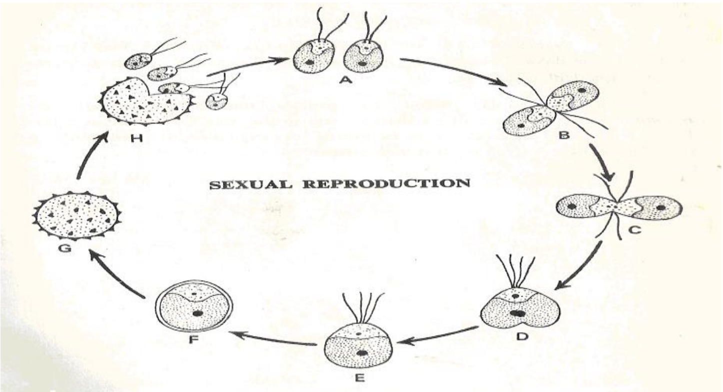
Each zoospore now is a new *Chlamydomas* cell. Thus, in case of *Chlamydomonas* asexual reproduction or cell division is the same thing. Sometimes, the zoospores are not liberated to the outside but get surrounded by a gelatinous matrix and divide repeatedly. Thus, it looks like a small colony, but it cannot be called so, as it is only a temporary association. This is called *Palmella* stage. This stage bears its nomenclature on account of its resemblance with an alga of the similar name. Sooner or later, they are liberated to the outside and lead an independent existence.

*Palmella* stage is, therefore, a temporary phase but in case of C. *kleinii* it is a dominant phase and is of special interest. Here the cells remain motile and show even movements while still enclosed within the gelatinous matrix. *Palmella* stage is occasionally seen in *C. franki* Pascher. Under some adverse conditions, *Chlamydomonas* may also reproduce by aplanospores *(C. caudata)* and hypnospores (C. *nivalis).*




**Asexual reproduction** in *Chlamydomonas*. *A*, normal cell. *B*, cilia withdrawn. *C—E*, formation of zoospores. *F*, liberation of zoospores. *G*, offspring.

**Sexual reproduction.** According to **Smith** (1955), most of the isogamous species do not give rise to gametes. The vegetative cells as such, at the time of sexual reproduction, behave as gametes. The two Cells come near and finally unite by their anterior ends. Their old cell walls (gametes are naked in C. *de baryana)* are cast off and new walls make their appearance. Finally, the two cells fuse resulting in the formation of a zygote. It remains quadriflagelate for sometime with two pyrenoids, two stigmas and two nuclei.




Sexual reproduction in *Chlamydomonas*. A, two vegetative cells. *B—C*, fusion. *D*. tetraflagellate zygote. *E*, motile zygote. *F*, thick-walled non-motile zygote. *G*, Thick-walled zygote during rest. *H*, liberation of offsprings.

According to **Strehlov** (1929), the zygotes in certain species may remain motile even for fifteen days. However, the zygote sooner or later becomes spherical, loses its cilia and comes to rest. Its wall becomes thick to tide over drought and desiccation.

On the return of favourable conditions, the diploid nucleus divides twice, first being a reduction division (**Moewus**, 1936, 1938, 1939) resulting in the formation of four offsprings. They are liberated to the outside by the breaking up of the zygote wall.

The zygote in case of C. *pertusa* and C. *botryotdes* may remain motile for ten days. The zygote of C. *variabilis was* taken to be *Carteria ovata (a* quadriflagellate genus).

The new cells formed are usually four in number but in C. *reinhardi*, there may be a third division and so the number of cells is eight. In C. *interniedia* there may be a fourth or even fifth division resulting in the formation sixteen or thirty two off springs.

**CLADOPHORACEAE :**

The members of this family have cylindrical multinucleate cells placed one above the other. They may form simple or branched filaments. Cell division has nothing 'to do with nuclear divisions and is quite independent. Pyrenoids are surrounded by a sheath of starch plate.

Asexual reproduction by quadriflagellate zoospores is common in all the genera except *Pithophora.* Sexual reproduction takes place by means of biflagellate gametes.

*Chlorophyceae*

*Cladophorales*

*Cladophoraceae*

*Cladophora*

**Occurrence :**

It includes about 160 species which are all widely distributed. It is found in fresh water, both running and stagnant, while a few species are marine. In running water, the plants are attached to some substratum by means of branched septate rhizoids, while in stagnant water, they are either free floating or in symbiosis with snails or sponges. During symbiosis, they make up the deficiency of oxygen by the movement of their symbionts. Many species are epiphytic and few are found in salt waters.

Sometimes, the individual filaments of *Cladophora* unite together to form big ball like structures. It happens in slowly running streams when the threads roll down along with the water currents and aggregate in the form of balls. Such species are called aegagrophilous forms. Schiller has mentioned one such species C, *trichotoma* from Adriatic. *C. glomerata is* a common Indian species while C. *crispata* is attached to the shells of snails.

*C. fracta* is another Indian species found in lakes while a few are found in the sea at Rameshwaram (collected by the authors).

**Structure :**

The plant remains attached to the substratum by means of branched septate rhizoids. It is made up of a number of branched septate filaments. The latter have many cylindrical cells joined end to end. The length of cell is three to twenty times more than the breadth. Each cell is multinucleate with cytoplasm and many pyrenoids. There are contradictory opinions regarding the nature of the chloroplast. The latter is said to be single having a parietal reticulum placed in the cytoplasmic lining of the cell. Sometimes the chloroplast develops processes which move inward into the cytoplasm and vacuoles. During unfavourable circumstances the chloroplast may break up into single discoid parts each having a pyrenoid. On account of this fact many workers are of the opinion that chloroplast is not single but is made up of many discoid choloplasts. However, this is not regarded to be a correct view.

According to Wurdack (1923), a cell has three layers of walls, an outer chitinous layer, a middle one having- pectic substances and an inner layer of cellulose. The mucilages is completely absent and that is why the plants are covered with epiphytic algae. The branching in *Cladophora is* noteworthy. The branches originate laterally from the upper end of the cells of the tip although apparently they give an idea of dichotomy. The latter notion is on account of evection (pushing aside of original axis and by the deposition of cellulose material on one side).

**Reproduction :**

It takes place by the following methods

*1. Vegetative*

*2. Asexual*

*3. Sexual*

**Vegetative reproduction :**

The vegetative reproduction is common in perennial species of the alga. The rhizoids become swollen owing to the formation of reserve food material. The upper part of the plant dies out during unfavourable conditions and on the return of favourable period, the rhizoids germinate giving rise to new plants. Sometimes, the separated branched rhizoids spread out as stolons. The latter give rise to erect branches at their tips or may divide-into a number of cells which are later on separated. When they fall at suitable place they give rise to a new plant.

**Asexual reproduction.** It takes place with the help of zoospores which are formed as a result of division of the cell contents, but according to Zempyrek and Schussing, they are formed owing to the aggregation of cytoplasm- round the nuclei. All the cells of a filament, except the lowermost attaching one, are capable of forming zoospores but usually they are formed in vigorously growing cells of the tip.

When they are being formed, the walls of the zoosporangium swell up, the contents divide and pear-shaped bodies are formed. Pyrenoids do not disappear during this process. It has been shown that meiosis takes place prior to the formation of zoospores. Each zoospores is uninucleate and possesses usually four but sometimes two cilia (C. *glomerata* and C. *suhriana* respectively) at its anterior end. The chloroplast is cup-shaped and the stigma is one. The zoospores are discharged through a pore in the upper part of the cell (may be terminal or lateral). They swim about for sometime and finally come to rest by their anterior end. Their cilia are lost at this stage. Each zoospore then elongates vertically, its nucleus divides into a number of nuclei and finally it divides ; transversely into two. The lower one is the rhizoidal cell while the upper one divides and redivides forming a new filament.

Akinetes are also formed in this genus. Generally, the unbranched erect branches become quite thick and contain reserve food material. On the return of favourable conditions, they form new plants without being detached (Choloky, 1930). Sexual reproduction. It is brought about by gametes. The filaments *of Cladophora* are monoecious as well as dioecious. In the latter species, gametes produced by two different filaments unite. The gametes are formed exactly in the same way as zoospores. They are isogametes. They are also similiar to zoospores in their structure except that they are always biciliate. After their liberation from the parent cell they unite in pairs and form zygotes. A zygote germinates without rest and gives rise to a new plant without its nucleus undergoing any reduction division. The filament so formed is therefore diploid.

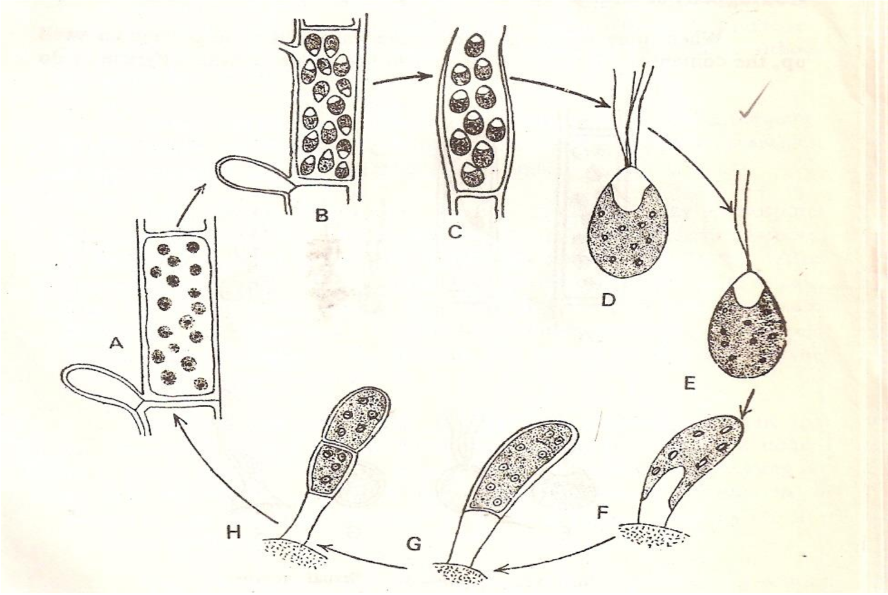



Fig. A sexual reproduction, A – formation of zoospores, B,C – liberation of zoospores, D,E – tetraflagellate and biflagellate zoospore, F – germination of zoospore, G,H – formation of new filament.

**Alternation of generations:**

It has been proved beyond doubt that in *Cladophora* there is a clear alternation of generations between asexual and sexual phases. As has already been mentioned while discussing the asexual reproduction, meiosis takes place before formation of zoospores and the latter therefore give rise to haploid filaments which in their turn produce gametes. As the gametes are produced on the haploid plants they contain X number of chromosomes. These gametes unite and form zygote which gives rise to the plants direct without the intervention of redaction division. The resulting plants, therefore, are diploid in nature. They in their turn, again form zocspores and so the life-cycle is completed.

The life-history of C. *glomerata is* quite different from other species of *Cladophora* because here no reduction division takes place during zoospore formation. It takes place during gametes formation. Hence, *C.glomerata* has all its stages diploid except the gametes.

**ORDER 4: CHARALES**

It is the highest Order of Chlorophyceae. It has a single family Characeae with *Chara* as one of the genera. The members of this group have very complicated and highly evolved sex organs. The plant body is differentiated into nodes and internodes. At nodes, "leaves" or branches of limited growth are present. In short, the complicated structure of plants and sox organs are the characteristic features of this group.

The members of this Order are found in quiet but clear water and they need little oxygen for their growth. They are rough in touch as they have a deposit of calcium carbonate over their body. The work on *Chara* started in the 19th century. Braun (1852), Sachs(1882) and Allen (1882) were the first to study the morphology of this alga. Giesenhagen (1896-9S) and Kuczenski (1906) did some detailed work

*Charales*

*Characeae*

*Chara*

**Occurrence :**

It is widely distributed and includes about 117 species. It is a fresh water alga found in quiet and clear water. It is found at the bottom of shallow pools and ponds. It is rough in touch owing to the deposit of $CaC0_3$ and therefore, also called stone-wort. One of its species C. *baltica is* found in salt water. *C. zeylanica is* an Indian species. The continuous presence of *Chara* for long periods way result in the formation of marl.

**Structure :**

The plant body is made up of erect branches having nodes and internodes. At the nodes are present the so-called "leaves", or branches of limited growth. From their axil come out other branches which continue their growth and are, therefore, known as branches of unlimited growth The plant remains attached to the substratum by means of rhizoids.

**Rhizoids :**

These are white thread-like structures coming out from and base of the plant or from the lower nodes. These are multicellular and possess oblique septa. They are branched and perform the same function as roots in case of higher plants.

**Main axis :**

It is the axis which possesses nodes and internodes and on which branches of limited and unlimited growth are present. The mode of growth of the main axis and the branches is the same. The growth takes place by means of a single cell which is domeshaped. The latter divides into two cells-a biconcave nodal initial and a biconvex internodal initial below. The latter does not divide but simply elongates many times forming the internodal cells. The former divides first into two by a longitudinal division. More divisions follow lengthwise and finally two central cells are formed rounded by many peripheral cells. The central cells remain as such while peripheral cells of the margin protrude outwards thus giving rise to apical cells of the laterals of limited growth.

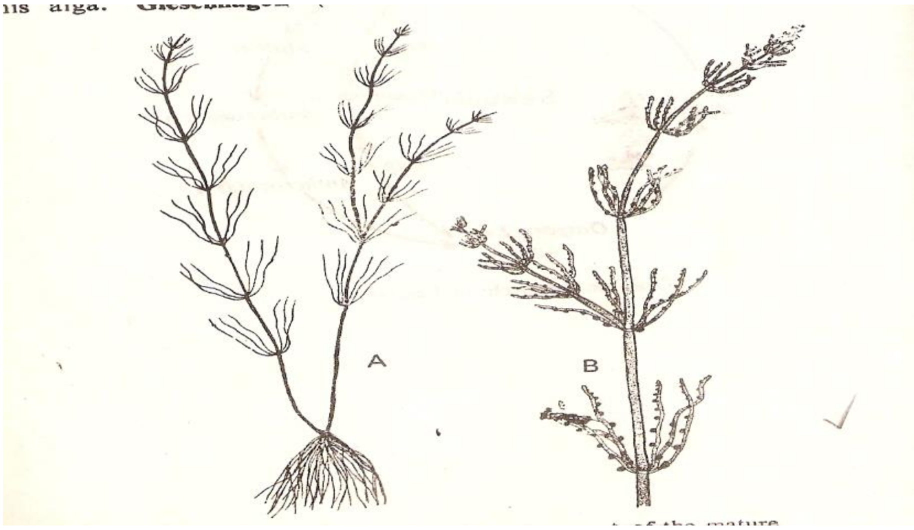



Fig. A – Habit. B – a part of matured plant showing sex organs.

As already stated, the laterals have the same method of segmentation except that internodal cells remain comparatively short and their peripheral cells do not become apical cells. At the same time, their apical cell sooner or later stops its growth and becomes elongated and pointed. They also possess nodes and internodes. Some cells of the basal node give rise to one thread growing in the upward as well as in the downward direction. They keep pace with the developing internodal cells and called cortical cells. So in a transverse section, the intemodal cell is one and surrounded by a sheath of cortical cells while the nodal cell has two cells.

**Cell structure :**

The structure of a cell in *Chara* varies according to its position and age. Each cell has a cell wall made up of cellulose and some deposite of $CaC0_3$. The young cell contains a single nucleus lying generally in the middle. There is a dense cytoplasm with many small discoid chloroplasts. In the cells, big central vacuoles appear and nucleus also divides amitotically to give rise to many nuclei. The latter possess, large nucleoli, scanty chromatin and become irregular. The cytoplasm in vacuolated cells shows an interesting type of motion. On the side of the vacuole it moves in an ascending fashion while on the other side there is a descending stream. The two streams of the cytoplasm are laterally separated by another cytoplasm which does not move at all and is devoid of chloroplast.

**Reproduction :**

It takes place by the following two methods : *1. Vegetative* and *2. Sexual*

(1) Vegetative reproduction :

It may take place by any of the following methodlks :

(a) Amylum stars. Some of the cells of the lower nodes form a mass of special type of cells which are star-shaped and are called amylum stars. (As they contain amylum starch in their cells). They give rise to new plants.

(b) Some of the rhizoids may form bulbils which also- give rise to new plants, when detached.

(c) Sometimes, protonema like branches develop on the nodes and they also give rise to new plants.

**(2) Sexual reproduction** :

It is highly oogamous and takes place w it h the help of male and female organs of reproduction. The former are Yellow or red, spherical and are known as antheridia or globule. The latter are oval in shape and. are called oogonia or nucule. The nucule possesses crown of cells above with a sheath of bright green threads alround its body. According to Smith and Sachs, terminology describing, male as globule, and female as nucule is more appropriate.

**Development and structure of sex organs :**

As already stated, the plant has nodes and internodes. From the nodes come out branches of limited growth. The latter also possess nodes and internodes. (See under the heads, main axis). The sex organs develop on the nodes of these branches. The development of the sex organs was studied by Braun (1852) and Sacks (1832). Sundaralingam (1954) worked out the development of the male and the female organs of reproduction in *C. zeylanica.*

**Antheridium or globule :**

A superficial nodal cell on the adaxial side of a fertile leaf behaves as an apical cell, The latter cuts off two cells one above the other. The cell below divides again and again and forms a node while the upper cell divides into two. The lower cellforrns the pedicel cell of the globule and the upper cell then enlarges, becomes spherical and lays down the foundation of a globule. According to Campbell and Sacks, first it divides twice vertically to give rise to four cells which are quadrately arranged. There is one transverse division and so an octant is formed.

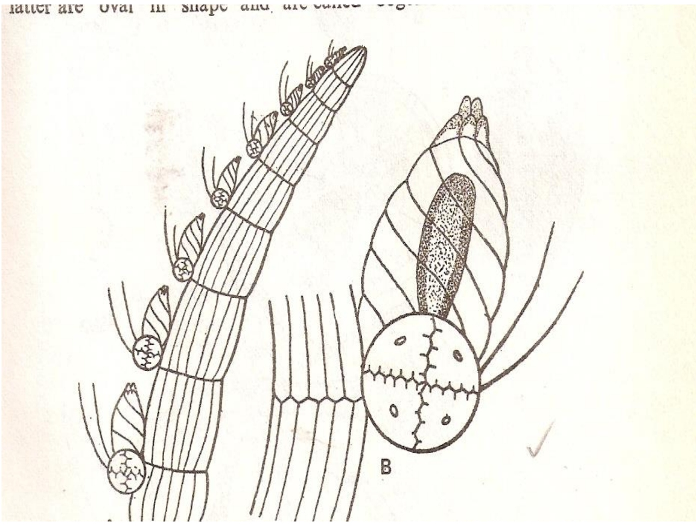



Fig. A – Branch of limited growth showing acropetal arrangement of sex organs. B – globule and nucule enlarged.

Now each cell of the octant divides by a periclinal division into -in outer and an inner cell. The outer cell, according to Sundaralingam (1954), divides once again by a periclinal division but according to Sacks (1882) and Migula (1897), it is the inner cell, which divides in this fashion. Anyway, eight diagonal series are formed. Each series consists of three cells-an outermost cell called shield cell, a middle cell known as manubrium cell and an innermost cell termed primary capitulum cell. The shield cell expands laterally forming a curved plate-like structure with the convex side outwards. It is multicellular. The manubrium cell elongates radially without undergoing any division and becomes rodlike. The primary capitulum cuts off secondary or tertiary capitula. According to Karling, the latter may or may not cut off secondary or tertiary capitula.

The secondary capitula then cuts, off initials of antheridial filaments though, the latter may be cut from primary tertiary or even quaternary ones also. These initials give rise to filaments known as spermatogenous filaments. They are multicellular and, according to Karling, the number of cells in each filament varies from 50-150 but, according to Sundaraliogam, the number in C. *zeylanica* is 60-75. The protoplast of each cell now gets converted into a single antherozoid, which is uninucleate and biflagellate. The flagella being situated slightly away from the tip. The pedicel cell at this stage moves deeper into the globule.

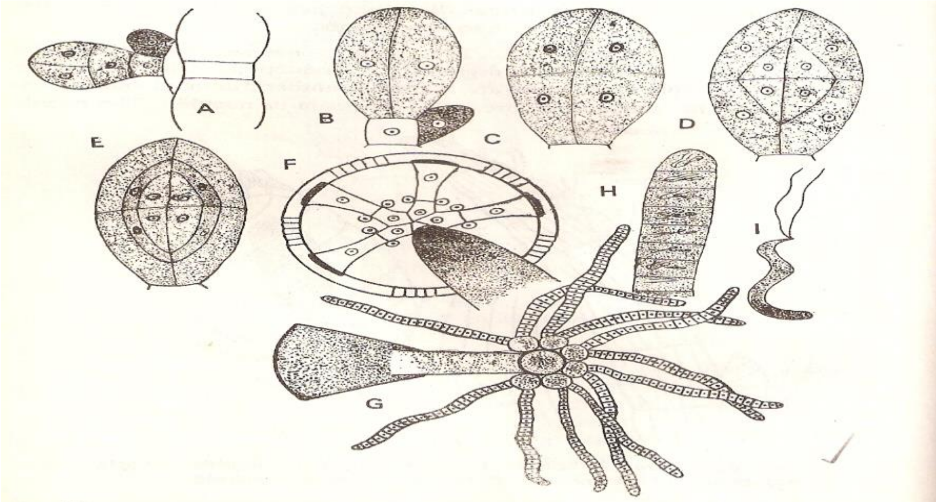



**Fig. A – F, development of globule, G – shield manubrium capitulum, sub-capitula and spermatogenous filaments, H – single spermatogenous filament, I – an antherozoid.**

When the globule is ripe, shield cells separate from each other by the pressure of the pedicel cell. The antherozoids are liberated to the outside through a pore in the wall. According to Sachs, they are liberated in the morning and swim about for nearly twelve hours, The globule, at maturity, is yellow or red.

**Oogonium or nucule :**

Adaxial cell of the basal node of the globule acts as a nucule initial. According to Campbell, it undergoes two transverse divisions forming a row of three cells. The terminal cell acts as oogonial mother cell which finally divides into an oogonium and a stalk cell. The lower cell does not divide, merely elongates and forms the pedicel. The middle cell divides vertically and gives rise to five lateral or peripheral cells which elongate considerably encircling the oogonium and forming a sheath round it.

These five cells now divide transversely forming five tube cells below and five corona cells above. Out of these, the former keep pace with the developing oogonium and elongate very much while the latter remain small. The result is that the corona cells reach at the top of the oogonium where they form corona or crown of the nucule). The oogonium now rotates and the tube cells coil round it in a clockwise fashion and invest it with five green threads. Therefore the nucule, at maturity, remains surrounded by spirally coiled cells and possesses a crown of five cells at its top. It is uninuclease, the nucleus being situated near its base, if the young oogonium is seen in a longitudinal section, but in the mature oogonium the nucleus lies in the middle. It contains a lot of starch and oils but its apical portion remains somewhat hyaline and represents the receptive spot.

**Fertilization :**

According to De Bary, at maturity, prior to fertilization, the tube cells separate sightly below the corona cells thus making five small slits. The apex of the nucule also gelatinizes at this stage. According to Suodaralisgam; the spirally coiled cells elongate more and thus slits are formed. Though he failed to see the entry of the spermatozoids into the nucule, yet it is a fact that the spermatozoids pass through these slits. Finally, only one finds its way inside. Ultimately, the male and the female nuclei unite resulting in the formation of an oospore. The latter secretes a thick wall round itself and settles down at the bottom of the pond. It rests for a few weeks.

Germination of the oospore. At the time of germination, the nucleus of the oospore comes to lie in the upper region. According to Oehlkers, the neucleus divides twice resulting in the formation of four nuclei. One of the divisions is reductional. Sooner the nuclei arrange themselves in two groups separated by a wall. One distal group consists of a single nucleus while the basal group has three nuclei. The latter degenerate after sometime and have nothing to do with the formation of the embryo. The germination of the oospore in *C. fragilis* was studied by Pringsheim (1869).

De Barv (1875) studied the germination of the oopores of *C. faestida, C. fragilis, C. contrarie* and C. *scoparia.* Sundaralingam's observations on the germination of the oospore of C. *zeylanica* are noteworthy. According to him, the oospore divides by a transverse wall into two-an upper small cell and a big lower cell. The upper cell divides vertically into two. (He does not mention further about the ultimate fate of the lower cell). One of them is rhizoidal cell and the other one is a protonemal initial. The former gives rise to the first rhizoid having nodes and internodes. From nodes come out secondary rhizoids in whorls. The primary protonemal cell forms a new filamentous protonema. The latter also possesses nodes and internodes. From its first basal nodes came out rhizoid', or secondary protonema or both while the upper node gives rise to branches of limited growth thus initiating the formation of a new plant.

**Position of Chara** : The position ˉof *Chara* and the group to which it belongs has been most puzzling and debatable. The very early writers included it in Charophyta which in its turn was included in Pteridophyta near *Equisetum.* At a latter stage, Charophyta was placed in Naiadaceae (Bryophyta) but finally it found its place in algae. Strasburger included it in a separate class of Thallophyta but Sachs elevated Charophyta and gave it a rank equal with Thallophyta. Engler and Prantle (Charophyta) and Oltmann

(Charales) treated Charophyta, as a separate group nip of algae while Pascher included *Chara* in Characeae of the Charophyta. Fritsch included *Chara* in the Order Charales of the class Chlorophyceae, but Smith puts it in Charophyceae, a class equal in rank with Chlorophyceae. The tendency of certain phycologists is to place Charophyta in between Thallophyta and Bryophyta. This chequered career of *Chara's* groups (Charales, Characeae, Charophyta) is based on the comprehensive study of many genera of this group by various workers.

In 19th century, the outstanding work was done by Braun (1877-1879) published in Robenhorts's "Kryptogamentlora". Grove and Bullock Webster'd "The British Charophyta" (1920-1924) is also a well known contribution. In fact the plant material being too delicate and soft there is not much fossil record at the disposal of the phycologists to trace its exact position- and affinities. It is yet to be seen whether there is any justification or not in elevating the Order Charales of the Chlorophyceae to the rank of a division or a phylum. The organization of the plant body of *Chara*, the complicated structure of its sex organs and structure of blepharoplast in its antherozoids all go to show its advanced nature and its similarities with the Bryophyta. But at the same time, there are many important feature which favour its inclusion in the Order Charales of the Chlorophyceae. These points may be summarized as follows :

(i) Pigments are exactly like the one found in Chlorophyceae.

(ii) Starch as food material which is a very important feature of Chlorophyceae.

(iii) The structure of the sex organs is only apparently complicated. In fact, they are quite simple when interpreted correctly. In case of globule, for example, each cell of the octant may be regarded as a secondary lateral branch of an antheridial axis which has divided into three parts-one called basal node, the shield : the internodal cell which has elongated and given rise to manubrium and an upper nodal cell, the primary capitular cell. The spermatogenous filament may be considered as single-celled antheridia like the ones found in *Oedogonium.*

## ULVA

**Systematic Position**

| | |
|---|---|
| Division | Thallophyta |
| Sub-division | Algae |
| Class | Chlorophyceae |
| Order | Ulotrichales |
| Sub-order | Ulotrichineae |
| Family | Ulvaceae |
| Genus | Ulva |

**Occurrence**

*Ulva,* commonly known as "sea lettuce" is a marine alga, which grows attached to rocks and wharves or to other marine algae. It grows along sea-coasts between the high and low-tide lines. *U. lactuca* var. *latissima,* very often grows in great profusion in water, polluted by sewage. *U. fasciata,* and *U. Indica* are reported by Anand from Kemari harbour and rocky ledge, Manora beach, Karachi.

**Ulva lactuca (sea lettuce). A plant showing habit (After Thur)**

**Plant Body**

The plant body consists of an erect, irregularly wrinkled blade that may reach a length of 30 cm. or more. It is attached to rocks and other objects in the sea by means of a basal holdfast consisting of long colourless rhizoids. The vegetative body or the thallus is thin, never becoming more than two ceils in thickness.

**Internal structure of thallus**

A cross-section of the thallus shows the cells to be isodiametric or vertically elongate to the thallus surface. Their walls are more or less confluent with one another to form a tough gelatinous matrix. Each cell is uninucleate and contains single cup-shaped chloroplast with a pyrenoid on the side towards flat surface of the blade. There is no large vacuole.

In the lower portion of the thallus certain cells send out long colourless rhizoids which pass down between the two layers of cells and interwine freely with one another. They pierce through the thallus near the point of attachment to the substratum and form a pseudo-parenchymatous holdfast getting closely appressed to one another. The loose protruding portions of the rhizoids are green, septate and **multi** nucleate.

**Reproduction**

The plant reproduces vegetatively : -

i) By its perennial holdfast from which arises a new blade each spring (Delf, 1962).

ii) By fragmentation, when growing in quiet waters of estuaries only.

**Asexual Reproduction**

Asexual reproduction takes place by quadri-flagellate **zoospores** which are produced from 16 to 32 in a single parent cell. They may be produced in any cell of the plant except the lowermost. They are at first formed in the cells near the margin; later on, however, they are produced in other cells also, which are more remote from the margin. The zoospore production continues until all the cells are used and nothing remains of the blade but a filmy mass of empty cell walls. Zoospores escape through a pore in parent cell-wall. Liberation of zoospores usually takes place at a time when the plant is reflooded by an incoming tide and they may be liberated in such a large quantity that the water appears green. After swimming for an hour or so, a zoospore comes to rest on some solid body, withdraws its flagella and secretes a wall. A transverse wall soon appears, the lower cell developing into a rhizoidal holdfast and the upper into the blade. The new plant thus formed though similar of that which produced the zoospores is haploid as there is meiosis during zoospore formation (Foyn, 1929, 1934).

**Sexual Reproduction**

The sexual reproduction takes place by the fusion of biflagellate isogametes produced from the cells of the sexual plants to an extent of 32 to 64 in a cell. They are smaller than the zoospcres, pyriform in shape, with a single chloroplast and an eye-spot.

They show a marked periodicity in that they are discharged during the low spring tides of each lunar month through a terminal pore in a nipple-like protrusion that develops in the gametangium and the surface of the thallus.

Gametic union takes place while the gametes are swimming about in the water, and in most of the species investigated, fusion takes place only between two gametes produced by different plants which have been therefore, described as bearing + and — strains. Although most species of *Ulva* are isogamous, U. *lobata* seems to be anisogamous as the gametes differ in size; one of a uniting pair is double the size of the other. The gametes are positively phototactic before fusion but the ,zygote is negatively phototactic and this change in behaviour causes it to descend and attach to a suitable substrate.

After fusion the quadriflagellate zygospores (zygote) continues to swim for a few hours. Eventually, it comes to rest on a firm object, loses its flagella and secretes a wall. Within a day or two, the zyospore divides and by succeeding divisons a new diploid plant is developed which though similar to gamete-producing plant produces only the zoospores and not gametes. This is because the division of the diploid nucleus is equational (mitotic) and not reductional (meiotic). One of the two cells formed in the first division of zygote develops into a rhizoid, the other eventually develops into the blade. At an early stage in its development the blade resembles an ordinary filamentous alga.

**Parthenogenesis**

Sometimes gametes fail to fuse, function as zoo-spores and develop into haploid plants. These are termed as azygo-spores or parthenospores.

**Alternation of generations**

*Ulva* illustrates the phenomenon of alternation of generations. Two separate plants are involved in the life-Graphic life-cycle of *Ulva.*

History, one producing the zoospores/and the other gametes. Both of them, though vegetatively alike, are different cytologically, i.e., in their chromosome numbers. The/gamete-producing plants are diploid and the zoo spore-producing plants are diploid. The reduction of chromosomes, resulting from the fusion of two gametes, is carried over to the cells of the spore-producing plant. The reduction of chromosomes takes place when the zoospores are produced. The haploid zoospores give rise to the gamete-producing plants. The haploid plants are called *gametophytes* and the diploid plants *sporophytes.* Because the two kinds *of* plants are alike' vegetatively, *ulva* displays an isomorphic alternation of generations.

## NOTES

## UNIT - IV

## CAULERPA

**Systematic Position**

| | |
|---|---|
| Division | *Thallophyta* |
| Sub-division | *Algae* |
| Class | *Chlorophyceae* |
| Order | *Siphonales* |
| Family | *Caulerpaceae* |
| Genus | *Caulerpa* |

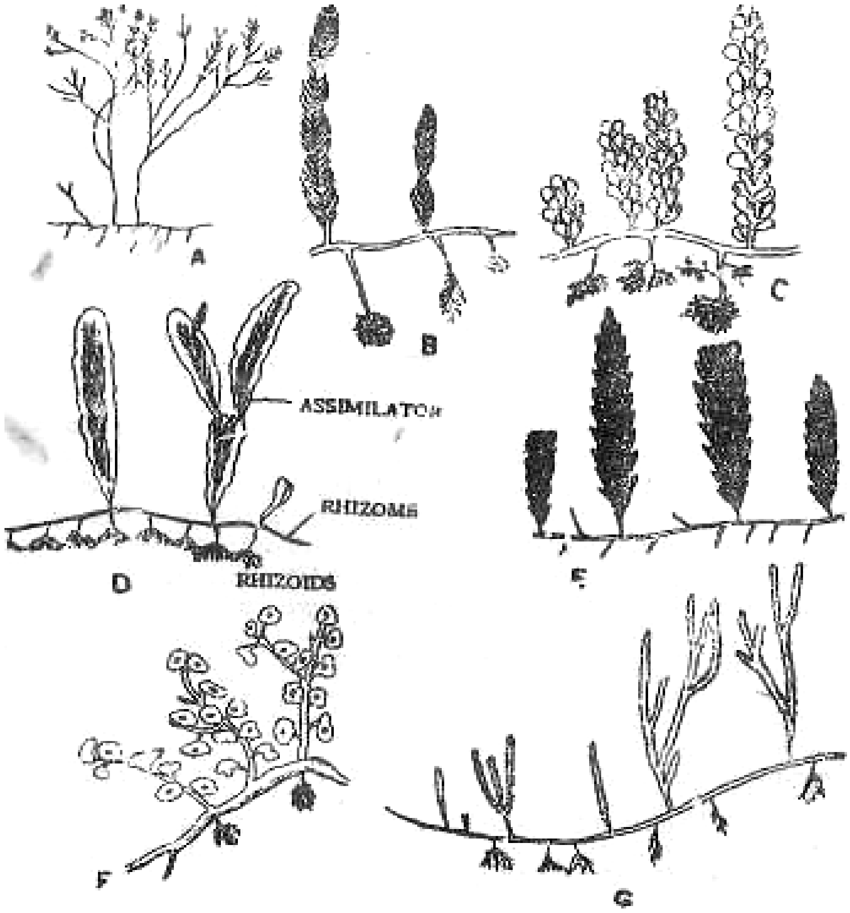



***Fig. Caulerpa.* Various species illustrating the remarkable tleeree of differentiation. A, C. *fastigata* ; B, *C. taxifolia ;* C, C. *racemosa* ■ D, C. *pwlifera :* E, C. *scalpelliformis :* F, *C. peltata ;* O, C. *cnpressoldes.***

**Habit and Habitat**

There are about 60 species of *Caulerpa*, all of which are marine and are confined to the quiet, shallow waters of the warm (tropical) seas, where they are often rooted in sand or mud. Several species are met with in the Indian sea and can be collected during the winter months at rocky ledge and along with the drift algae from the sandy beach at Manora, Karachi. Several species have been found growing at a depth of 75 to 80 metres. The common Indian species collected by the author from Manora island, Karachi, are : *Caulerpa racemosa, Caulerpa peltata, Caulerpa taxifolia* and *Caulerpa scalpelliformfc. Cmilerpa prolifera* and *Caulerpa olivieri* are the common Mediterranean species.

Ecologically, the various species of *Caulerpa* are classified into the following three categories :

(i) Mud-collecting species, growing as epiphytes on the roots of mangroves.

(ii) Sand and mud bottom species, growing in shallow or deep waters covering extensive tracts of the sea-floor, *e.g., C.prolifera,* and *C. crassifolia.*

(iii) Species growing on rocks and coral reefs, *e.g., C. racemosa, C. taxifolia,* etc.

**Plant Body**

The one-celled thallus of *Caulerpa* bears close resemblance in its external form and size to a vascular plant with a creeping rhizome. It consists of a prostrate, more or less branched cylindrical rhizome which in forms inhabiting mud, e.g., *C. prolifera* and *C. crassifolia* may be as much as a metre in length bearing numerous well-branched anchoring rhizoids below and a number of upright assimilatory shoots, sometimes, reaching a length of 30 cm. on its upper surface. This structure is applicable to all species, except in the form of the erect branches, the "leafy shoots[1]' or the assimilators which show great variation-in different species so that they are named according to their resemblance to cacti, mosses and lycopods as *C. prolifera, C. taxifolia, C. hypnoides* and *C. selago,* etc. respectively. For example, in *C. prolifera,* the assimilators are flat, leaf-like and shortly stalked structures like phyiloclades of *Opuntia,* while in *C, selago* they are long, subulate and imbricate like the leaves of *Lycopodium selago.*

The form of the thallus is .largely dependent upon the conditions of the habitat and is well illustrated in plastic species, *e.g., C cupressoides* and *C. racemosa :-*

(i) In exposed situations, the plants are small and stoutly built.

(ii) In more sheltered habitats, the shoots are longer and branched.

(iii) In deep water, the plants are very large with richly branched flgellate shoots.

**Internal Structure**

There is no septation. The cell-wall is chiefly made of cellulose and pectin, instead of cellulose. Inner to the cell-wall is a layer of cytoplasm containing several diploid nuclei and disciform chloroplasts (devoid of pyrenoids) showing streaming movement. The central vacuole, according to Spratt, contains colloids, and is transversed by numerous, more or less cylindrical skeletal strands or **trabeculae.** These are arranged perpendicularly to the surface and are most highly developed in the rhizome, where' they form an almost radial system, often knotted together in a prominent manner in the centre, whilst in the flat assimilators, they run irregularly ; they are absent or poorly developed in rhizoids.

The trabeculae arise from rows of structures termed as **microsomes** which at first are either free in the interior of coenocyte or else connected with the wall, although in the adult state, they are always fused with the walls. They gradually thicken by the apposition of successive layers of callose.

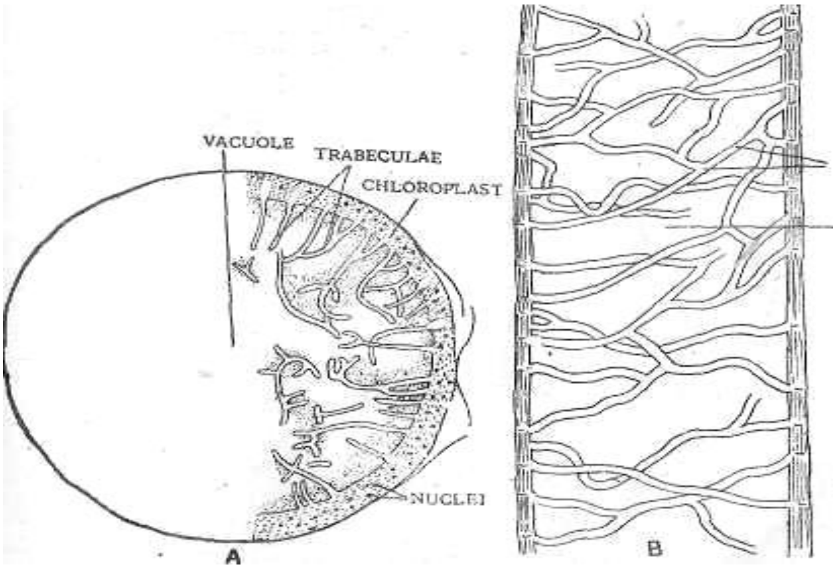



**Fig. *Caulerpa.* A, *T-S.* rhizome ; B, *L.S.* rhizome.**

The function of the trabeculae is highly problematical and may be :-

(i) *Mechanical,* providing resistance to turgor pressure due to the occasions! high osmotic value of the sap.

(ii) *To enlarge protoplasmic surface* since the trabeculae are enveloped on all sides by cytoplasm.

(iii) *To facilitate diffusion of mineral salts,* which is more rapid through these strand-, than through the cytoplasm.

**Reproduction**

*Vegetative reproduction* was the only method reported in *Caulerpa* till recent times. This takes place abundantly by gradual dying away of older parts of the rhizome, whereby the branches become independent plants. Dispersal is attained by detached fragments which are readily able to heal any exposed surface and possess a remarkable power of generating new plants when lodged in suitable position.

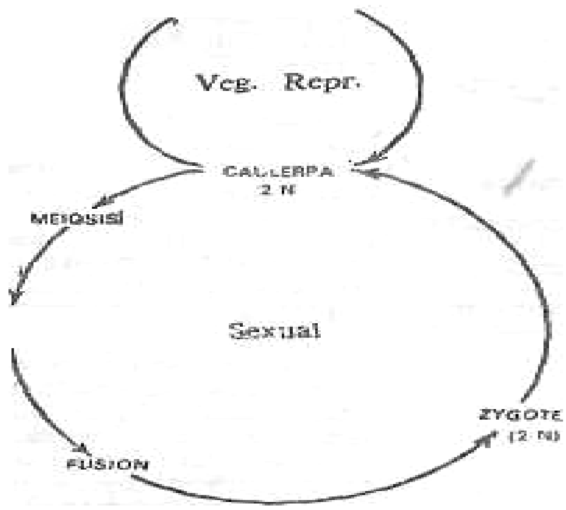
**Sexual Reproduction**

In 1928, Postal reported the discovery of the presence of elongate **extrusion papillae** in C. *prolifera,* during the autumn, more commonly on the assimilators and rarely on the rhizome. These he interpreted as possible **garnetangia,** because of the presence of a large number of biflagellate swarmers (gametes), in the abundant mucilage exuding from the apex of some of these papillae. Subsequently, he showed that the swarmers are formed within the assimilators and the papillae only serve for their liberation. Prior to the formation of the papillae, the fertile assimilators acquire a variegated appearance, showing yellow and green patches. In the green regions the cytoplasm shows reticulate arrangement and it is here that the uninucleate swarmers are formed. Formation of gametes is preceded by reduction division. They are liberated rapidly through the apices of the papillae shortly after day-break, sometimes, in such a quantity that small green clouds appear in the water around a plant. The swarmers arc pyriform, biflagellate and have a single chloroplast and a red eye-spot.

Sexual reproduction is isogamous and most species are heterothallic. Ernst and Schussnig (1930—32), distinguished two kinds of swarmers. In *C. clavifera,* there is a distinct differentiation into the smaller, bright-green, active microswarmers and the large, brownish-green, sluggish, **megaswarmers.** It is very probable that these swarmers are gametes, but so far gametic union between these has not been observed in *C. prolifera*. Fusion between the swarmers has been observed in *C. racemosa,* an Indian species by Iyenger (1933). Germination of the zygote has not yet been followed. The empty portion of the thallus Graphic life-cycle of *Caulerpa* soon disintegrates and disappears after the liberation of the gametes.

**Fragementation**

GAMETES
(ISO OR ANISO)
(1 N)




## SARGASSUM

**SARGASSUM** *(sargazo,* Spanish, for sea-weed) *(250 spp.)*

**Systematic Position.**

| | |
|---|---|
| Division | *Thallophyta* |
| Sub-division | *Algae* |
| Class | *Phaeophyceae* |
| Sub-class | C*yclosporae* |
| Order | *Fucales* |
| Family | *Sargassaceae* |
| Genus | *Sargassum* |

**Habit and Habitat**

The genus *Sargassum* includes about 250 species. Unlike most other brown algae all the species of *Sargassum* are principally limited to the tropical seas althotugh fragments are occasionally carried by ocean currents across the Atlanic to the cooler coasts of Europe. The genus is especially abundant along the coasts of Australia, India, Ceylon and is to be found as far north as Japan, where some of the more tender plants. *(S. enrve)* are used for food and decoration. *S. enerve,* the so-called Sargasso weed has been found from times immemorial, forming large floating masses in the "Sargasso Sea," a part of Pacific ocean, covering an area of about a quarter million square miles, east of Florida and the West Indies. Thick vegetative growth of *Sargassum* in Sargasso sea was a terror for his men, when Columbus passed through this sea in 1492, as his ships were held fast by the entangling sea-weeds. At one time it was thought that plants of *S. natans,*

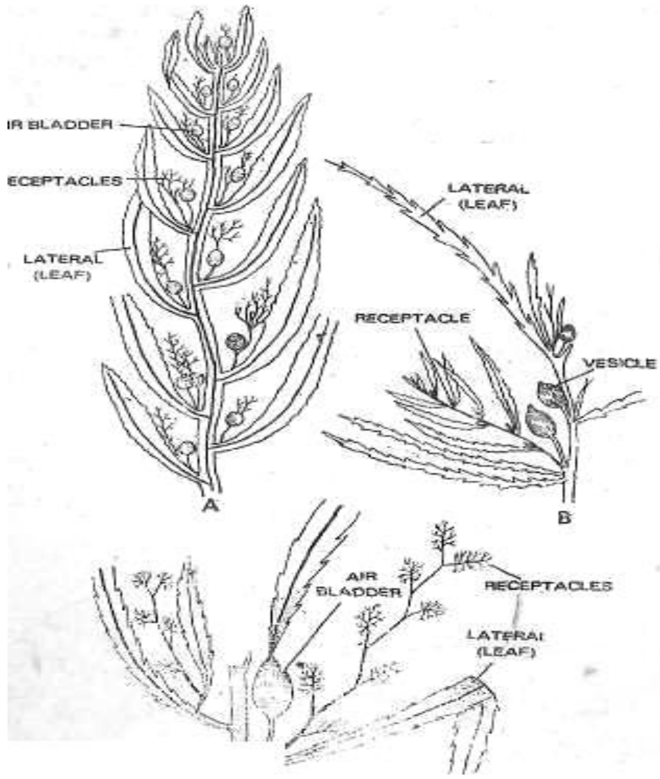



**Fig. A, *Sargasumperonii* B S*argassum enerve ; C, Sargassum hngifolium. {After Oltmaims and Setchell)***

together with one or two other species, *e.g., S. bacciferum* were attached in the early stages, but there is enough evidence to believe now that they remain entirely free-floating throughout their life-cycle and multiply continuously by fragmentation, never producing any gametes. According to Boergesen, these perennial pelagic species arose from attached forms such as S. *vulgare* and *S.filipendula,* etc. *S. filipendula,* is a large kelp with a long, slender stem, sometimes a metre or more in length.

J. Agradh (1948), Boergesen and R.K. Griville have listed a number of species from Indian coasts, *e.g., S. tennerimum. S. cinerum., S. wightii, S. ilicifolium, S. plagiophylum, S. myriocystum* ana *S. cristaefolium,* etc.

Plant Body. *Sargassum* like *Fucus* is diploid (sporophyte) and has essentially the same type of flat, branching thallus but most species show a more marked differentiation into stern-like and leaf-like branches, resembling very much the "stems and leaves of the angiosperms. The plants when young are anchored by means of more or less irregular, warty, solid, parcnchymatous base, the holdfast or else numerous, stolon-like structures grow out from the main axis and help to anchor the plants. The main axis or stem is erect, cylindrical or flattened and Shows nodes and internodes. It may be a meter or more in length as in *S. filipendula.* It bears richly-branched primary laterals or long shoots of unlimited growth.

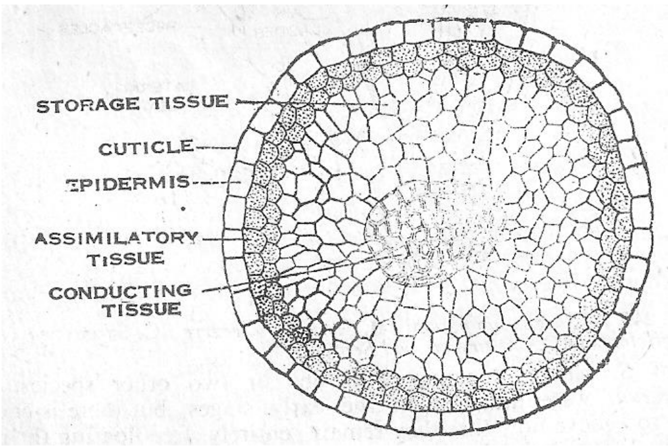



**Fig. Sargassum T.S. main axis**

The main axis and primary laterals bear conspicuous phyllodades or leaf-life branches which are modified secondary laterals of limited growth. They may be narrow or expanded with serrate, denote or entire margin and a conspicuous mid-rib. They are sterile and bear minute dots, the cryptostomata, leading into barren conceptacles or cryptoblasts. The lower "leaves" on the primary laterals bear rudimentary axillary branches but in the upper portion of a mature plant the "leaves" bear condensed axillary branch systems, each showing differentiation into air-bladder and receptacle. The air-bladder helps to buoy the plant when attached, and float it when torn free. In some species lower secondary laterals of a primary lateral is modified into an air-bladder. An air-bladder may be terminated by a "leaf" *e.g, S. longifolium.* All the subsequent branches are fertile and cylindrical or finger-like in appearance. These are the receptacles. They contain conceptacles.

**Structure of the thallus**

A cross-section of the stem or main axis reveals the following structure from without inwards **1. Epidermis or raeristoderm**

This is the outermost layer, often covered by a mucilaginous **cuticle.** The component cells are columnar and closely packed without any intercellular spaces. They contain a large number of plastids and fucosan granules and are mainly concerned in photosynthesis. This layer is also meristematic, hence called meristoderm.

**2. Cortex**

It is many-layered and consists of thick-walled poly gonal cells. It is mainly concerned in storage of reserve food as also a mechanical tissue. The innermost cortical cells gradually merge into the central zone and, like the latter, have gelatinized walls. The cortical cells, below the epidermis, contain plastids and constitute assimilatory tissue concerned in photosynthesis.

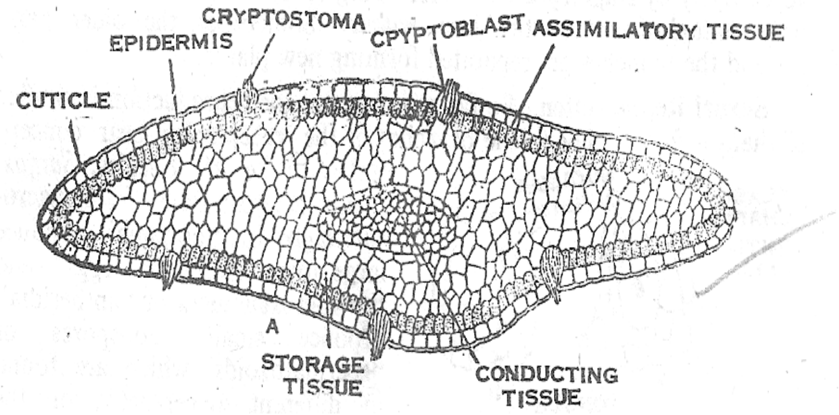



***Fig. Sargassum.*** **A, *T.S.* of a "leaf" showing embedded barren conceptacles ; B,**

***V.S.*** **sterile conccptacle.**

**3. Medulla**

The central zone or medulla consists of loosely-arranged, narrow and elongated cells. The outer medulla consists of thick-walled cells while the inner cells have compartively thinner walls. Hanstein has reported the presence of scalariform thickenings on the walls of the medullary cells. The medulla serves as a sort of conducting and supporting tissue.

Thus, we see that the thallus shows not only a great degree of tissue differentiation but also a well-marked physiological division of labour as. it contains specialized tissues which carry on assimilation, storage, support and conduction.

The internal structure of the leaf-like branch is similar to that of the stem' or main axis as a rule. The difference lies only in the outline and the presence of' cryptostomata. The outline of the leaf-like branch is more or less elliptical and it bears a large number of cryptostomata leading into flask-shaped cryptoblasts or barren concepta-cles, which contain numerous sterile hairs or paraphyses. The cryptostomata are few or absent on the main axis.

**Reproduction**

*Asexual reproduction by means of zoospores.* The plant is a sporophyte and it reproduces vegetatively by **fragmentation.** According to Collin (1917), this is the only method of reproduction in *S. natans.* Sometimes, the older parts die and the branches get separated forming new plants.

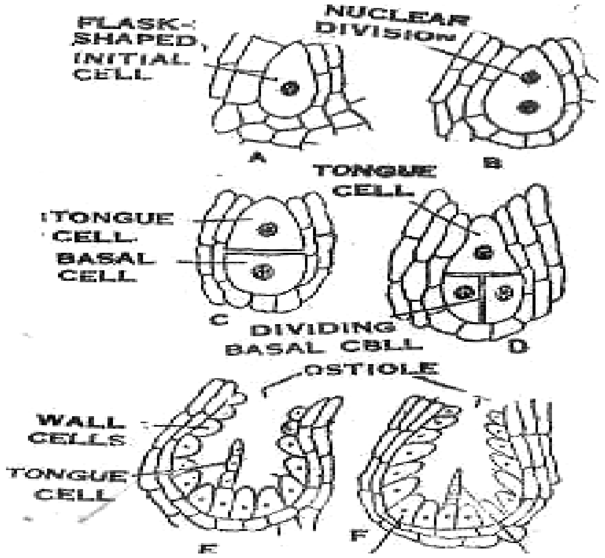



**Fig. A, Sargassum, stages showing development of conceptacle.**

**Sexual reproduction**

So far as is known, the reproduction is similar to that of *Fucus.* The fertile branches or the **receptacles** ' bear conceptacles. Like all Fucales, *Sargas-sum* is heterosporous. The **macro-sporangia** or "oogonia" produce large aplanospores or "eggs" and the **microsporangia** or "antheridia" produce small zoospores or "spermatozoids" which are found in different conceptacles on the receptacles of one plant (monoecious) or on different plants (dioecious). Monoecious species, are more common. A conceptacle opens on the surface by a minute aperture called the ostiole. Hermaphrodite conceptacles are rare in *Sargassum.* In dioecious species, the male plants bear smooth receptacles while in the female plants the receptacles are spinous. In sonic species as reported in *S, Horneri,* the male receptacles are more slender and longer in size than the femaic ones.

**Development of a conceptacle**

A conceptacle develops from a flask-shaped superficial initial cell (Oltmanns, 1889 ; Grauber, 1886 ; Simons, 1906). Nienburg (1906), Bower (1880), and Valiante (1885), however, hold that superficial initial cell is not concerned in the development. The conceptacle-initial cell can be distinguished from the adjoining cells by its larger size, prominent nucleus and comparatively slower rate of division. It soon under- goes division by a curved septum into an upper longer and a lower smaller cells. The former is called **tongue** cell and the lower **basal cell.** The tongue cell elongates and divides to form a row of cells. It may persist or disappear. The basal cell, gradually sinks down due to the division and overgrowth of the adjoining cells. The basal cell then. divides vertically a number of times and lines the base of the conceptacle, except its upper narrow region which is formed from 'the adjoining cells only. The sex organs are produced only from the cells at the base of the conceptacle.

**Antheridia**

The microsporangia or "antheridia" develop in large number on the lower branches of copiously branched paraphyses, which arise from the wall of the male conceptacle. They are crowded in clusters and practically fill up the conceptacle. A mature **antheridium** is an ovoid structure, has a two-layered wall and contains 64 sperms, which, are more or less pear-shaped and bear two unequal cilia laterally. On maturity the outer wall gelatinizes, and the masses of sperms still enclosed by the inner wall are extruded through the ostiole in sea-water. Finally, the enclosing wall also gelatinizes at one or both ends and the sperms are released in the sea-water.

**Development of antheridium**

An antheridium develops from a cell of the wall of the male receptacle. It forms a papilla-like outgrowth and divides into two by a transverse wall. The upper cell is called the **autheridial cell** and the lower the **stalk cell.** The antheridial cell develops into an antheridium, which later on, is shifted to one side by the growth of the stalk cell from below. The branch-like stalk cell may again divide forming a terminal antheridium and a stalk (branch) cell. This process may be repeated indefinitely, resulting in the formation of a much-branched paraphysis bearing a number of antheridia. The upper branches of the paraphysis are, however, devoid of antheridia and remain sterile.

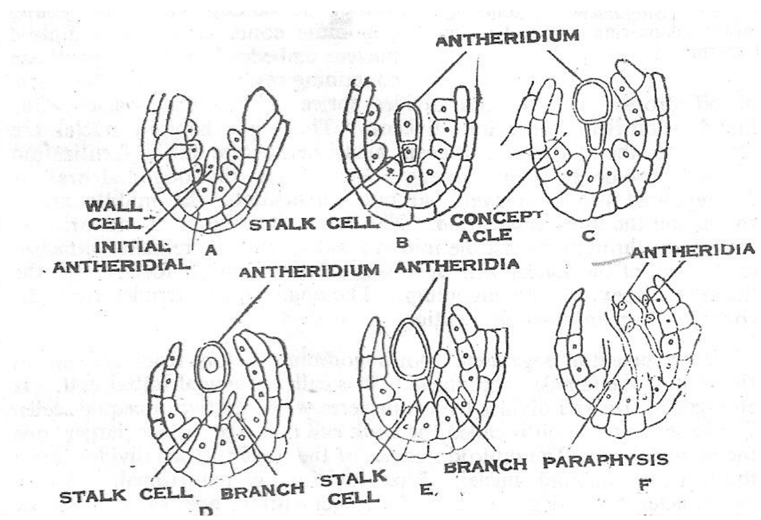



**Fig. Sargassum. Stages showing development of antheridium.**

A young antheridium contains a single diploid nucleus, which soon undergoes reduction and divides repeatedly to form 64 haploid nuclei, which are surrounded by small pieces of cytoplasm and are metamorphosed into small pear-shaped sperms, bearing two laterally inserted unequal cilia.

**Oogonia**

The megasporangia or "oogonia" develop in the female conceptacle. They are sessile and lie embedded to a large extent, in the wall of the conceptacle. The young oogonium contains a single diploid nucleus embedded in dense cytoplasm containing reserve food in the form of oil drops. The nucleus divides thrice to form eight nuclei. The first division is the reduction division. The eight haploid nuclei are shifted to the periphery. Seven nuclei degenerate during fertilization and only one develops into an egg. the oogonial wall is differentiated into three layers—an outer exocbiton, the middle meso-c(iiron and the inner endochiton. The entire oogonium at maturity is discharged through the ostiole into sea-water, but it remains attached *to* the wall of the conceptacle by a long gelatinous stalk formed by the thickened apex of the oogonium. The oogonia are extruded from the conceptacle in an inverted position.

**Development of oogonium.**

An oogonium develops from any cell in the wall of the female conceptacle. It is called oogonial initial ceil. It enlarges in size and divides by a transverse wall into two unequal cells. The lower smaller cell is called the stalk cell and the upper larger one the oogonial cell. The diploid nucleus of the oogoniai cell divides thrice to form eight haploid nuclei. First division is reductional. Out of eight nuclei, Seven degenerate and the remaining one surrounded by oogonial protoplasm forms a single egg.

**Fertilization**

Large numbers of sperms surround the extruded oogonium, which is still attached to the wall of the female conceptacle by a gelatinous stalk. The sperms attach to the oogonial wall by their anterior flagella, while the posterior ones keep lashing in water. One of the sperms penetrates through the oogonial wall and its nucleus fuses with the egg nucleus to form the zygote nucleus. Fertilization takes place while the ova are still contained in the oogonia and not discharged in water.

**Germination of the zygote**

The zygote germinates immediately without any period of rest. The germination starts while the zygote is still enclosed in the oogonium which is attached to the wall of the conceptacle. After some time, the oogonial wall gelatinizes and the zygote is liberated in water. It divides by a transverse wall into two. The lower cell forms the rhizoids while the upper cell after undergoing a number of anticlinal and periclinal divisions develops into a branched diploid *plant.*

## POLYSIPHONIA

Only polysiphonia which is included in polysiphonieae will be discussed.

Florideae

Ceramiales

Rhodomelaceae

Polysiphonieae

Polysiphonia

**Occurrence.** It is a common red alga on sea coasts. It is found in Atlantic and Pacific Oceans. It is alos found in India Anand reported *P.platycarpa, P.ferulacea* and *P.variegata* from Karachi (Pakistan). The latter species, according to Fritschi, is common in polluted water and roots of Mangroves. *P.urceolata* is an epiphyte on Laminaria. *P.elongata* is a lithophytes and is nearly 30cms. In length. *P.fastigiata* is a semiparasite on Ascophyllum nodosum although Rattaray has reported the same species growing on stones in an independent state. But it is said that the species growing independently are not so healthy as those growing on the brown sea weed.

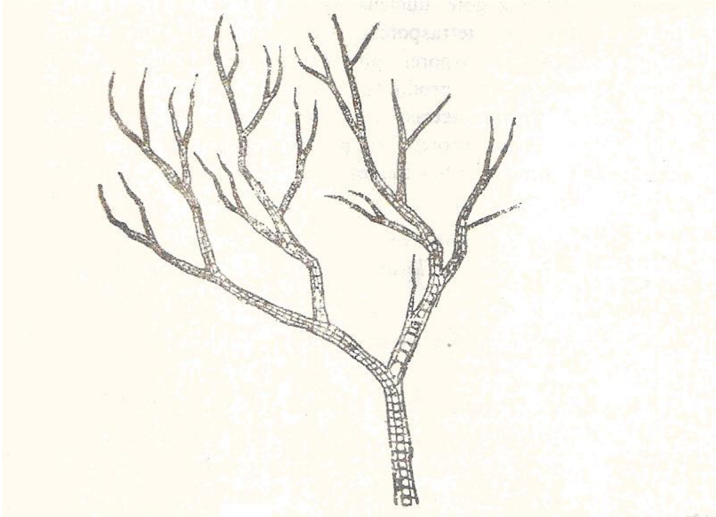
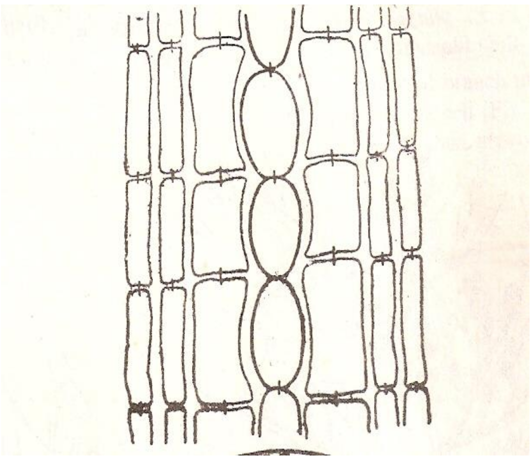
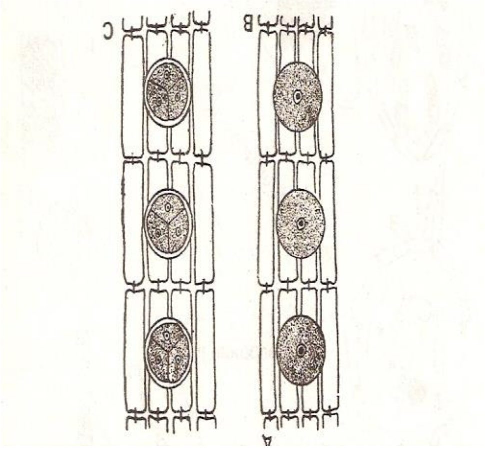


Fig. *Polysiphonia.* Habit.

**Structure.** The plants of Polysiphonia exihibit a varity of colorus. They may be red, brownish red or even darker in colour. The plants form thick tufts and are attached to the substratum plant by means of long unseptate rhizoids. The thallus is laterally and dichotomously branched and is made up of filaments placed parallel to each other. They are called siphons and if seen in a microscope, the c ells of the central siphon are look large and elongated. On either side of the central siphon are situated pericentral siphons which are narrow. The number of siphons varies from four to twenty (***P. spiralis,*** *5;* ***P. elongata, 4****:* ***P. variegata, 6****:* ***P. nigrescens*** *upto 20:* ***P. brodiaei,*** **6-8**). These pericentral siphons in older branches may further cut off smaller siphons on either side which are called cortical siphons. However, the tip of the thallus always consists of the cells of the central siphon. Some pericentral cells cut off small branches from their upper ends. They are of limited growth, monosiphonous and are called trichoblasts. The cells are connected by protoplasmic strands. Each vegetative cell has s single nucleus, usual chromatophores and floridean starch as food material.



B



A

**Fig. A – Siphones** **B – Tetra spores**

**Reproduction:** it is vegetative, sexual and asexual.

**Sexual reproduction:** the sexual reproduction is oogamous and is brought about with the help of male, female and tetrasporic plants. The male and the female organs of reproduction are known as antheridia and carpogonia respectively.

**Development of antheridia:** They develop on male plants in clusters near the tip of the main filament. Generally, a single cluster develop on a trichoblst but occasionally two cluster may develop as in P. platycarpa (Iyengar and Balkrishnan, 1950). In the beginning the filament develop antheridium is monisiphonous that very soon it becomes polysiphonous. Sooner or later as a result of these divisions a central axis of elongated cells is differentiated, surrounded by pericentral cells. From these pericentral cells, primary antheridial mother cells are developed which in their turn cut off secondary antherifial cells as in P.platycarpa (Smith has not reported the presence of such secondary cells in P.flexicaulis). So each pericentral cell bears a number of antheridial mother cells. According to Grubb (1925) and kylin (1923) these mother cells bear two, three or four antheridial cells, depending upon the species. The formation of antheridial cells is very regular in P.platycarpa. Lyengar and Balkrishnan have given a simple clear and well illustrated account of their development. According to this workers, the second antheridium is cut just opposite to the first. Third and the fourth are cut in between first and the second. So far as the development of antheridium is concerned, it is more or less identical in the different species of polysiphonis. The whole male cluster is surrounded by a gelatinous investment. From the antheridia, spermatia are liberated, which are subspherical or ovoid, uninucleate, nonmotile with a delicate wall.

**Development of carpogonium:**

It arises from a fertile pericentral cells. This cell divides into two – an upper carpogonial branch initial and a basal cell which is called bearing cell or supporting cell. The carpogonium branch initial further divides and thus a fow of three cells is formed. So carpogonial branch in P.platycarpa is three celled wheras in P. nigrescence and P. flexicaulis it is four celled. The uppermost cell of the carpogonial branch now elongates and forms trichogyne while its basal region broadens into carpogonium where the female nucleus is located.

**Pre-fertilization changes:**

There are certain developments in the carpogonium before fertilization. The basal cell or the bearing cell cuts off a cell towards it base, which is called the basal sterile cell. Soon afterwards another sterile cell is cut towards the side of the bearing cell which also divides into two. These two cells are called the sterile cells. The pre-fertilization developments in the Indian species P.playcarpa and the other species *P.flexicaulis* are identical upto this stage.

**Fertilization :**

In some species like ***P. violacea*** the carpogonium nucleus divides at the time of fertilization and one of the nuclei passes into the trichogyne (Yamanouchi). However, the division of the carpogonium nucleus has not been observed in ***P. nigrescence*** (Kylin). *P. platarpa* (Iyengar and Balkrishnan) and ***P. brodiaei*** (Rosenberg).

At the time of fertilization, the spermatium adheres to the trichogyne. Finally, wall between the two dissolves. More than one spermatium has also been noticed attached to the trichogyne in case of *P.platycarpa* (**Iyengar** and **Balkrishnan**). The nucleus of the male then passes downwards through the trichogyne into the carpogonium. The two nuclei unite resulting in the formation of a zygote.

**Post-fertilization changes:**

After fertilization, many changes take place within and around the carpogonium. First the basal sterile cell divides and thus two basal sterile cells are formed (P.platycarpa and P.nigrescence). The lateral sterile cells also divide and thus many lateral sterile cells are formed (4 in ***P. platycarpa*** and 4-10 in ***P. flexicaulis***).

The bearing cell now enlarges and cuts off a cell above which is an important cell and is called the auxiliary cell. In ***P. platycarpa*** the auxiliary cell cuts off another small cell known as the connecting cell because it connects the

the carpogonium to the auxiliary cell. Such connection is, however, lacking **P.nigrescence.** The zygote nucleus now divides by mitosis and and one of the nuclei passes into the auxiliary cell. The carpogonium is now cut off by a wall and finally degenerates. During all these changes, the bearing cell, the auxiliary cell and the sterile cells become interconnected and open communications are established between them. The function of the sterile cells is supposed to be nutritive (**Iyenger** and **Balkrishnan, 1950**). All these cells so intergrated form a central mass called the fusion cell or the placental cell.

The fusion cell now cuts off gonimoblast mother cell or gonimoblast initial. The zygote nucleus also divides and one of the nuclei passes into the gonimoblast mother cell. The latter immediately cuts off a number of gonimoblast cells. Every time a new cell is cut, the zygote nucleus divides and its derivative enters the newly formed cell. These gonimoblast cells at later stages are known as carpospores. All these carpospores are enveloped within the well of the fruit body which is called cystocarp or caryposporophyte. The wall of the carposporophyte is double layered in the beginning (**Iyenger** and **Balkrishnan, 1950**) in ***P. platycarpa*** but as the development proceeds, the wall become single layered. The inner layer shrivels and finally disappears, thus indicating its nutritive value. The carposporophyte has a pore.

The carpospores are finally liberated through this pore and on reaching a suitable place they germinate. According to **Lewis** (1912, 1914), they give rise to tetrasporic plants. As they are diploid in nature the plants developed as a result of their germination are also sporophytes although apparently they resemble the normal gametophytic plants.

**Asexual reproduction:**

These tetrasporic plants, sooner or later, give rise to tetrasporangia which formed in many successive tiers although only a single pericentral cell of the tetrasporic plant gives rise to a tetrasporangium. The fertile pericentral cell first divides longitudinally forming an inner half and an outer half. The outer half develops cover cell or two cover e.g. ***P. nigreacence*** or two cover cells and a small peripheral cell eg., ***P. violacea.*** whatever may be the case, the inner half divided transversely giving rise to a lower small stalk cell and an upper tetrasporangium. The latter elongates and increases in size. According to Yamanouchi (1906), finally, its nucleus divides twice and the first division is reductional. Thus, within a single tetrasporangium, four haploid spores are formed. The spores are liberated from the tetrasporangium by the rupture of its wall. In ***P. playcarpa,*** the tetraspores escape from the sporangium 'by squeezing themselves out through the amoeboid movement' (**Iyengar** and

**Balkrishnan,** 1950). On reaching a suitable place, they germinate and give rise to normal gametophytic plants of **polysiphonia.**

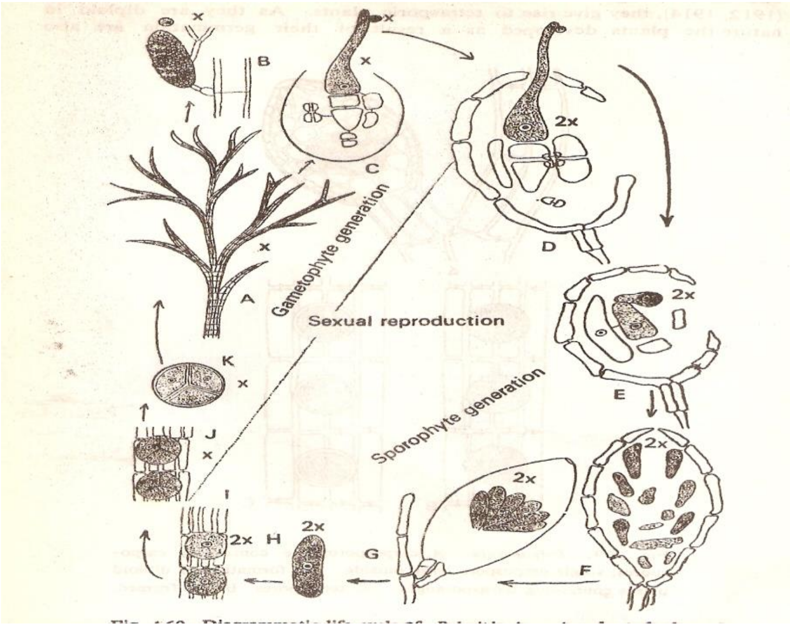



**Fig. Life cycle of Polysiphonia. A – plant body, B, antheridium and spermatia, C- carposonium and its fertilization, D – Zygote, E- formation of fisrt gonimoblast, F- carpospores, G – carpospores ready for liberation, H- single carpospores, I – tetrasporangia, J – Tetrasporic plant, K – single tetraspores.**

## NOTES

## UNIT – V

## GENERAL CHARACTERS OF BRYOPHYTES

1. Mostly amphibious, few aquatic; grown in bog's (wet and soft ground); in xeric conditions (Polytrichum); epophyllus;saprophytes; grow on rocks and barks.
2. The plants show two morphologically distinct heteromorphic generations i.e. gametophyte and sporophytic generations.
3. The plants body is gametophyte and it is the dominant phase of life cycle.
4. The gametophyte (plant body) is well developed, green and autotrophic.
5. The sporophyte is entirely dependent on the gametophyte.
6. The plant body is thalloid (Riccia & Marchantia) or differentiated into rhizoids, stem (axis) and leaves.
7. Unicellular, multi cellular rhizoids and multicellular scales are present.
8. The plant body consists of simple parenchy matous cells,xylem,phloem and lignified cells are completely absent.
9. Vegetative reproduction largely takes place by means of tubers and gemmae.
10. The sexual reproduction is oogamous type.
11. The male reproduction organ is called antheridium. The consist of a central mass of androcytes enclosed by a single layer sterile jacket cells. Each androcyte produces a single biflagellate spermatozoid.
12. The female reproductive organ is called archgonium. It is a multicellular flask-shaped structure. The basal swollen portion is called Venter and the elongated narrow portion is called neck.
13. Fertilization takes place in presence of water.
14. The zygote does not undergo any resting period.
15. Embrogeny is exoscopic (The division of zygote is transverse and the embryo proper develops from the outer cell).
16. The embryo is retained within the archegonium where it develops into a sporophyte.
17. Except in a few cases, the sporopytes consist of foot, seta and capsule.
18. Spores are formed after meiosis in the capsule, they are homosporus.
19. The spores germinate directly into the new gametophytic plants. In mosses, the spores germinate into filamentous protonema from which are produced that give rise to a new plant.

**Classification**

The bryophyta represents 960 genera and 24,000sp. Brown (1864) introduced the term bryophyte Schimper (1879) assigned bryophyta a rank of division. Eichler (1833) divided bryophyte into two classes, the Hepaticae and music Engler (1892) divided each class into three orders.

Div. Bryophyta

| | |
|---|---|
| Class I. Hepaticae | Class II : Musci |
| Order I Marchantiales | I Sphagnales |
| II Jungermanniales | II. Andreales |
| III Anthocerotales | III. Bryales |

Howe (1879) has modified it by raising anthocerotales to the rank of a class.

Class I. Hepaticae II. Anthocerotes III. Musci.

Takhlajan (1953), Samith (1955), wardlaw (1955, 62) and Schuster (1958, 66) have modified it by using the term anthocerotae.

According to the recommendation of ICBN (International code of Botanical Nomenclarture) and Bryosida. Proskauer (1957) suggested to use the term Anthocerotopside.

Div: Brooplyta le : Hepaticosids or : Marchantialses Fa : Marchantiaceae genus : Marchantia.

**RICCIACEAE**

The family includes three genera and about 140 species. It has the simplest type of sporophyte which is nor differentiated into foot, seta and capsule. The spores are not mixed with elaters. The gametophytic plant body is simple with the ventral parenchymatous region and dorsal assimilatory portion where cells form longitudinal filamentous chains. Out of the three genera (Oxymitra, Ricciocarpus and Riccia), only Riccia will be discussed.

- **Bryophyta**
- **Hepaticopsida**
- **Marchantiales**
- **Ricciaceae**
- **Riccia**

**Occurrence.** It is a common widely distributed genus and includes about 130 species. All the species are terrestrial except the one, R. fluiatans which is aquatic and is found in free floating condition. Other species inhabit moist places like banks of streams, tree trunks, wet walls, rocks and beds of rivers from where water has receded.

In undivided India, Kashyap reported a number of species from Lahore, Pathaokot, Manali, Kulu, Simla and various other regions of Western Himalayas. Rangachariar and Tirunarayanan reported R. himalayensis from Tinnevelly Hills and Darjeeling respectively. This species can be found up to a height of 9,000 feet. R. robusta is traceable up to 13,000 feet and has been reported by Pande and Singh. Some other species have been reported by Qizibash from Peshawar, by Hora from Manipur and by Iyengar from Madras. Chopra reported 14 species of Riccia from India. Recently, there has been more addition in the new species of Riccia from this country. There are, R. kashyapii by Kachroo (1954), R. personii, R. benghalensis by Khan (1957), R. aravaliensis, R. tuberculata by Pande and . Udar (1957, 1958), R. Pandei by R. Udar (1958) and R. pimodii by Kachroo (1959).

S. Ahmad (1942) reported three species – R. orientalis Ahmad (a ciliated species), R. gangetica Ahmad (a monoecious species) and R. mangalorica. The latter species, according to the same author, may be a variety of R. plana Tay.

Ricciocarpus natans is an allied genus and is found in free floating condition This species, as well as aquatic species of Riccia, may grow in terrestrial habitats also, but under such conditions, their shape changes so much that it is rather difficult, though not impossible, to recognize them.

**Structure.** The plant body is in the form of a delicate, ribbon-lime dichotomously branched thallus. The aquatic species are thin, membranous and light green while the terrestrial ones are comparatively thick and dark green. The thallus often becomes rosette-shaped on account of repeated dichotomy. It is prostrate and dorsiventrally differentiated. On the dorsal surface, the thallus exhibits a thick and very conspicuous mid-rib. There is a depression in the apical portion which forms a notch, where the growing point is located.

Scales and rhizoids are present on the ventral surface. The scales are multicellular and violet in colour. They are crowded near the growing apex, and are meant for its protection. These are marginal in position. the scales may disintegrate in aquatic species while they may be persistent in case of terrestrial ones.

The rhizoids are situated on the ventral side of the thallus. They are analogous to the roots of higher plants, that is, their function is also that of fixation and absorption. They are of two types-smooth and tuberculate. The former are long unicellular structures while the latter have outgrowths arising from the inner surface of their walls. The hygrophilous species may be devoid of such structures.

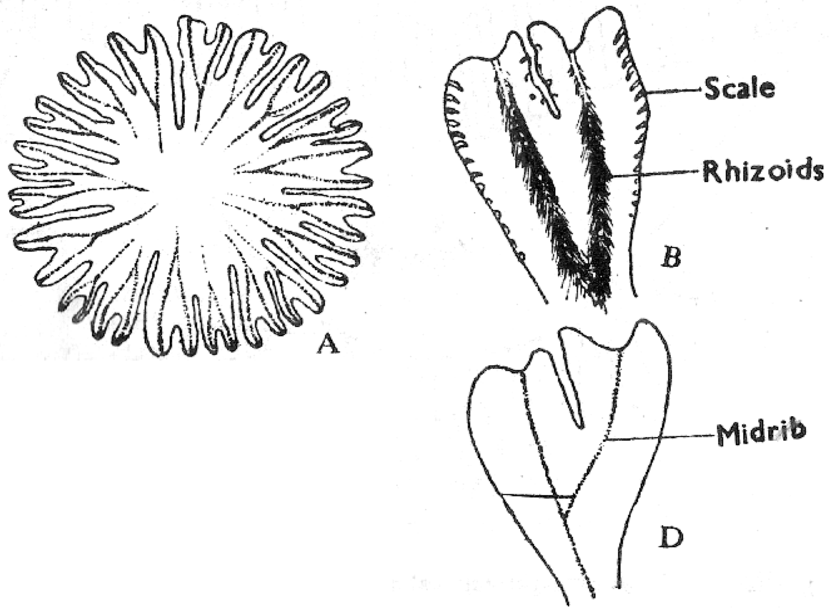



**Fig. Riccia: A, Thalli forming rosettes. B, ventral side of the thallus showing scales and rhizoids. C, D, dorsal side of the thallus showing clear mid-rib.**

The detailed anatomical study may be made in a vertical cross section of the thallus. It is differentiated into two clear regions - a colourless parenchymatous region on the ventral side and a chlorenchymatous portion on the dorsal side. The former consists of compact parenchymatous cells having starch with no intercellular spaces and is called storage region while the latter has vertical rows of chlorophyllous cells separated by air chambers and is known as assimilatory region. The epidermis of the ventral surface is continuous having rhizoids. The epidermis on the dorsal side is discontinuous and is single-layered. The air pores are meant for the exchange of gases.

In aquatic species, like R. fluitans, the epidermis may be continuous. The growth of the thallus takes place by a single apical cell situated in the apical notch.

**Reproduction**

It takes place by two methods:

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

**1. Vegetative reproduction**

The vegetative reproduction takes place by any of the following methods:

a. As the plant matures, there is death and decay of the older parts. The decay continues till it reaches dichotomy, when the surviving branches separate and grow as two new individuals.

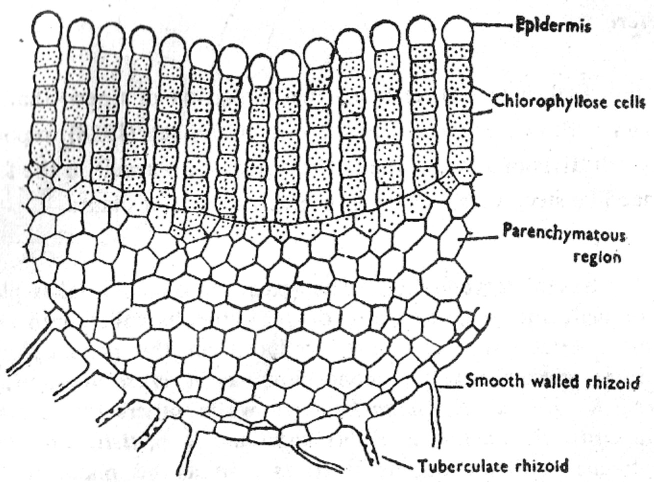



**Fig. Vertical cross section of Riccia thallus showing detailed anatomy.**

b. According to Smith, the plants cannot withstand the summer drought and during this period, they are killed except their growing apices. On the return of favourable conditions, these apices again grow out into new plants.

c. According to Cavers (1903), many species grow by adventitious branches which may be formed on the ventral surface of the thallus. On being detached, these branches give rise to new plants, e.g., R. fluitans.

d. According to Goebel, in certain species, tubers also help in vegetative reproduction. These tuber-like structures have been observed is R. bulbifera.

e. Fellner (1875) reported the formation of a new thallus from the apex of a rhizoid incase of R. glauca. Campbell (1928) reported that there are cell division in the apex of rhizoids which result in the formation of gemmae-like structures. They also give rise to new plants.

**2. Sexual reproduction**

The sexual reproduction takes place with the aid of male and female organs of reproduction called antheridia and archegonia respectively. They are produced on the gametophytic plant body. Some species may monoecious as *R. crystaillna, R. robusia, R. frostit, R. glauca, R. pathankotensis* while others like *R. discolour, R. himalayensis, R. sanguinea, R. bischoffii* and *R. curtisii,* are dioceious. The development of sex organs starts as soon as the plants are mature. They are produced on the dorsal side of the thallus and are arranged in acropetal, succession. Side by side, there is also an activity in the neighbouring vegetative tissue which surrounds the sex organs. It results in the formation of chamber, and each sex organ lies enclosed at the bottom of such a chamber. However, the archegonia are never completely surrounded by this tissue, as their necks always protrude out from the chamber.

**Development of antheridium**

Black (1913) and Campbell (1918) investigated the development of the antheridium and, according to them, it develops from a single superficial cell, which forms the antheridial initial (Fig.A). The latter lies slightly away (hardly two or three cells away) from the apical initial. It now enlarges and then divides transversely into two, a basal cell and an outer cell (Fig., B). The former remains embedded in the vegetative tissue, while the latter emerges out from the thallus, though slightly. The basal cell further divides and finally forms the embedded portion of the stalk of the antyheridium, while the antheridium proper is formed by the outer cell. The latter divides and gives rise to a row of four cells which are more prominent than the basal cell

(Fig. C).

Of these four cells formed, the two upper ones are called primary antheridial cells and the lower ones are known as primary stalk cells. As the name suggests, the primary stalk cells develop the stalk and the primary antheridial cells give rise to the antheridium. Now, two successive vertical walls are laid down in both the primary antheridial.

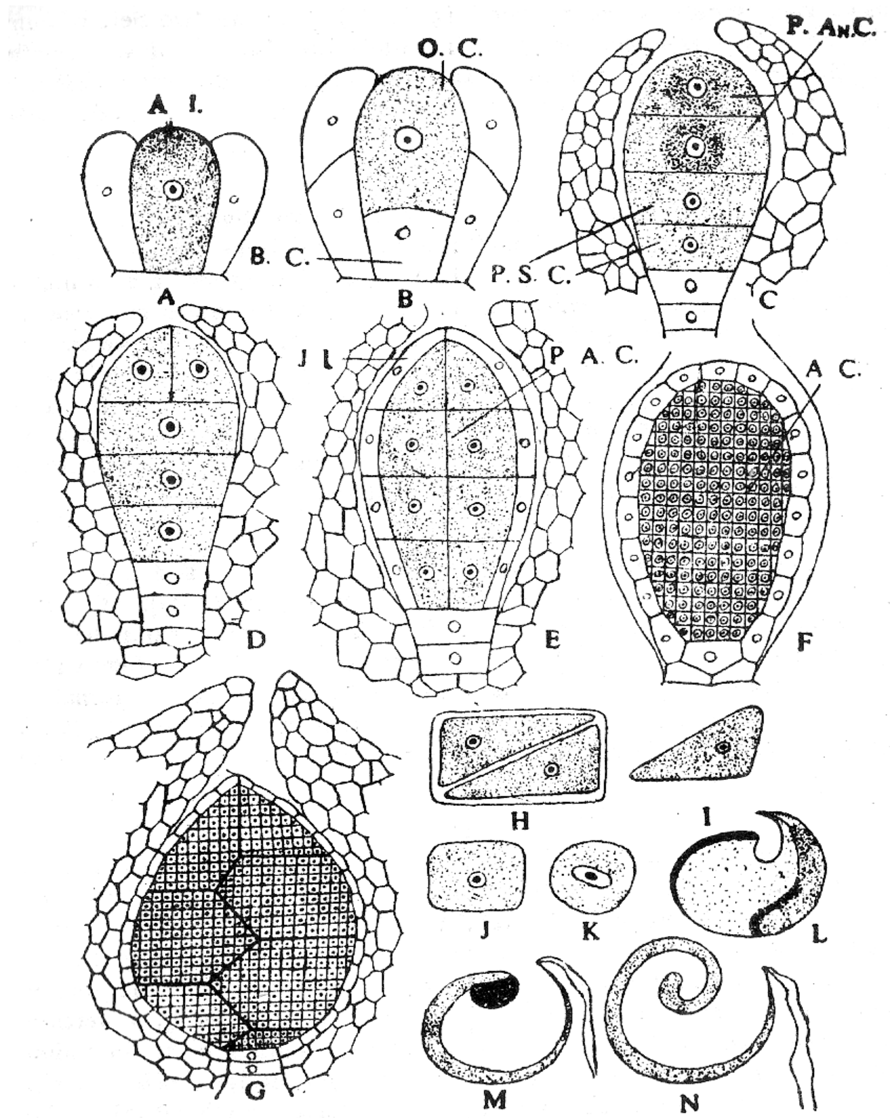



**Fig. Development and structure of an antheridium of Riccia. a, antheridial initial. B, transverse division of the antheridial initial. C, four-celled antheridium. D, E, appearance of vertical wall and periclinal divisions forming the antheridium and jacket layer, F, antheridium with a. short stalk and androgonial cells. g, antheridium, fully mature containing antherozoids. H-N, stages in the development of an antherozoid from and androcyte. A.C. androgonial cells. A. I. antehridium initial. B, C basal cell. O. C, outer cells, P.A.C, primary androgonial cell. P.An.C., primary antheridial cells, P.S.C., primary stalk cells. cells at right angles to each other (Fig. , D), forming two tiers of four cells each. At this stage, the periclinal walls are also laid down in both these tiers of four cells with the result that eight sterile jacket cells are formed, which surround a group of eight fertile primary androgonial cells (Fig. , E).**

The jacket cells further divide by anticlinal divisions resulting in the formation of a single-layered multicellular sterile jacket which surround the developing antheridium (Fig., F). In the meantime, the primary androgonial cells undergo many divisions giving rise to smaller androgonial cells. The last generation of the latter cells is termed the androcyte mother cells (Fig. G). These mother cells divide diagonally and finally each androcyte mother cell gives rise to two androcytes (Fig, H, I). the latter are triangular in shape in the earlier stages, but later on they become spherical (Fig. I-M). Each androcyte forms a single antherozoid (Fig. N, O) which is uniuncleate and biciliate.

A mature antheridium consists of a small stalk and a globular or club-shaped body with a round or conical apex (Fig. G). The cell walls within it also disintegrate and finally all the antherozoids lie in a single cavity surrounded by the cells of the sterile jacket. When water enters the cavity, it softens. The cells of the sterile jacket ultimately break down and antherozoids come outside alond with the mucilaginous substance. The antyherozoids find their way outside on the dorsal surface of the thallus.

**Development of archegonlum**

It also develops from a superficial cell which lies slightly away from the apex (hardly two or three cells away). This cell forms the archegonial initial (Fig. A). Soon it divides into two by a transverse division, a basal cell and an outer cell (fig. B). The latter gives rise to the body of the archegonium while the former develops only its embedded portion. The outer cell divides by a vertical divisions followed by two more such divisions resulting in the formation of four cells, of which three are peripheral and one is median (Fig. C). These cells are placed in such a way that the three peripheral initials lie lateral to the fourth one which is called the primary axial cell. The four cells can be seen in a cross-section (Fig. J). Each peripheral cell now divides vertically to form six jacket initials (Fig. I), while primary axial cell divides to give rise to an upper primary cover cell and a lower central cell (Fig. D).

Now, the six jacket initials divide transversely to form two tiers of six cells each. The upper tier is called the neck initial and the lower tier is known as venter initial. The neck initials divide transversely to form a neck six to nine cells in height. The number of vertical rows of neck cells is an important feature of this order. There are six rows of neck cells in Marchantiales. On the other hand, the six initials divided repeatedly forming a venter of twelve to twenty cells. The divisions are both transverse and vertical.

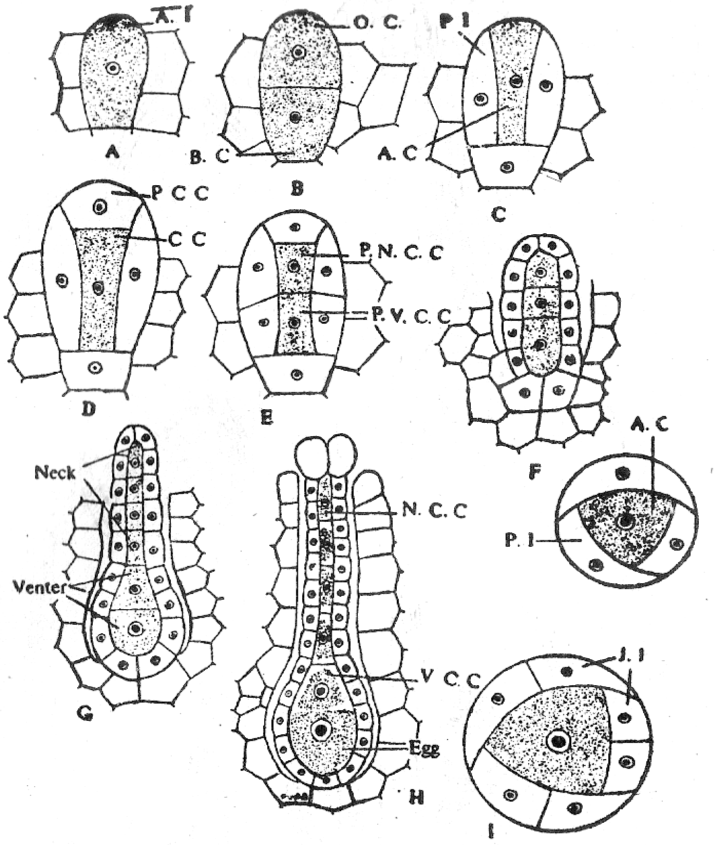



**Fig. Development and structure of an archegonium of Riccia. A, archegonial initial. B, transverse division of the archegonial initial. C, formation of three vertical walls and appearance of primary axial cell in a L.S.D, F, stages in the development of a mature archegonium. G, a mature archegonium with a swollen venter and a long neck. H, six neck initials surrounding sixial cell in a T.S.I, primary axial cell surrounded by three peripheral cells in a T.S.A.C. axial cell. J.I. jacket initials. N.C.C. neck canal cells. O.C. outer cell. P.C.C. primary cover cell. P.I. peripheral initial. P.N.C.C. primary neck canal cell. P.V.C.C. primary ventral canal cell. V.C.C. ventral canal cell.**

At the same time, primary cover cell also divides by two vertical divisions at right angels to each other and gives rise to four cover cells. The central cell divides by a transverse wall to form an upper primary neck canal cell and a lower primary venter cell (Fig., E). The former further divides transversely to form four neck canal cells usually, while the latter divides by a transverse division to give rise to a venter canal cell and an egg cell (Fig., F).

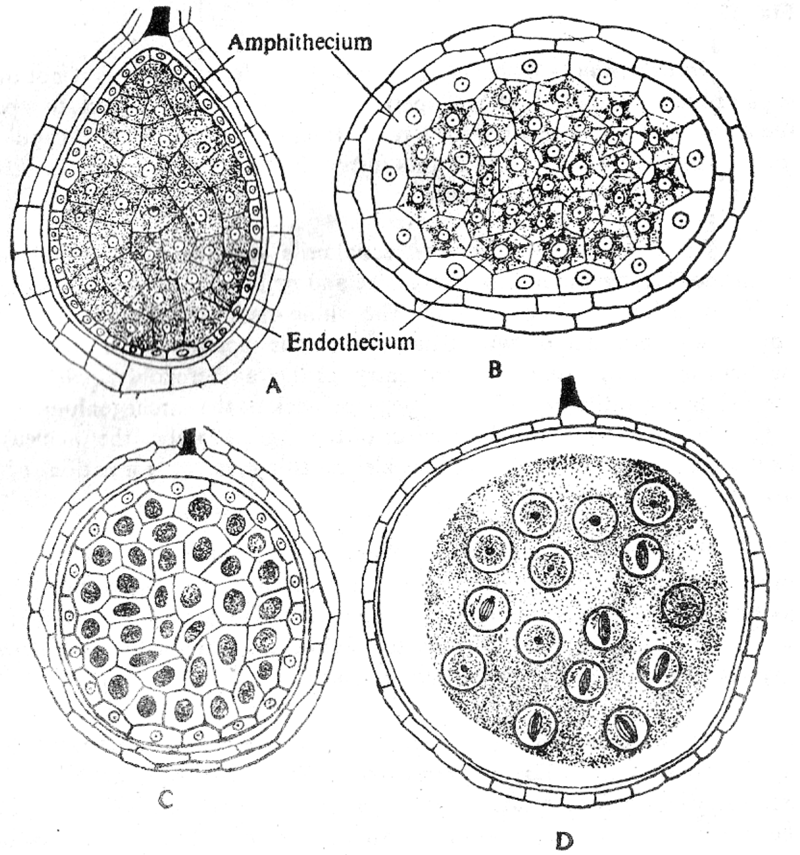



**Fig. Riccia, a, B, differentiation of amphithecium and endothecium. C, spore mother cells. D, reduction division in spore mother cells.**

Thus, an archegonium, when fully mature, is a flask-shaped structure with a long neck and a swollen venter. At the top of the neck, there are four ocver cells which are broader than the neck cells. The neck has six to nine tiers of cells arranged in six vertical rows. The swollen venter is composted of twelve to twenty cells. Within the neck are four neck canal cells and the venter consists of one venter canal cell and an egg (Fig. ).

**Fertilization**

Water is indispensable for fertilization as it not only helps in the transference of the sperms but also causes the neck to open. The dorsal furrow which contains rain water or dew, acts as a capillary tube. The presence of water in this furrow is quite sufficient to facilitate the movement of the antherozoids.

At the same time, the neck canal cells and the venter canal cells within the archegonium also disorganize and mucilaginous mass is formed which absorbs water (Fig. . The whole mass now swells and creates a pressure on account of which the cover cells separate from each other, thus leaving a clear passage for the entry of the antherozoids. Now, the free swimming antlierozoids move near the near the neck of the archegonium, pass downwards and reach near the nucleus of the egg. Finally, the nucleus of the male unites with that of the female resulting in the formation of an osspore (Fig. ) .

**Post-fertilization changes**

Soon after fertilization, the oospore forms a wall round itself, enlarges in size and finally occupies the whole cavity of the venter. simulataneously, the cells of the venter undergo periclinal divisions. Anticlinal divisions also follow and ultimately a two-layered calyptra is formed enclosing the young sporpohyte (Fig. C, D).

At the same time, the oospore also divides into equal cells (Fig. C). It is soon followed by a second division at right angles to the first resulting in the formation of a quadrant (Fig., D). Occasionally, the second division may also be parallel to the first and so instead of a quadrant a filament or a linear four-celled embryo is formed. According to Lang (1905), both types of embryos may be found in the same genus. One more vertical division, at right angles to the already formed walls, gives rise to an eight-celled embryo.

Many more divisions follow but they are all irregular. (Fig. E, F). When the embryo consists of 20-40 cells divisions are laid down. This results in the formation of an outer layer called amphithecium and an inner layer known as endothecium (Fig. A, C). The former is merely a sterile jacket meant for the protection of young embryo while the latter is the archesporium which divides repeatedly forming sporogenous cells. The last generation of the letter cells is called spore mother cells or sporocytes (Fig., C and B).

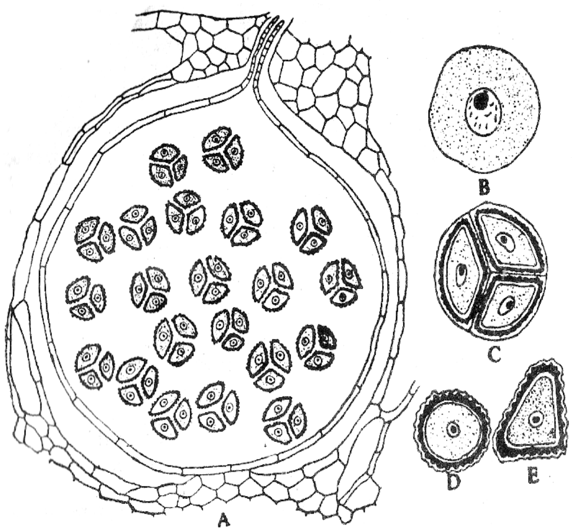


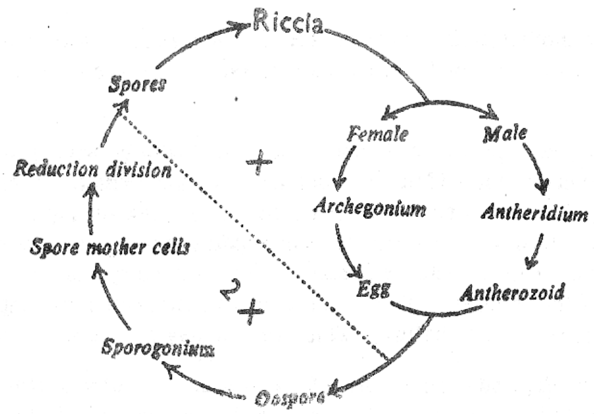
**Fig. Riccia, A, mature capsule or sporogonium containing tetrads of spores, B, spore mother cell. c, a spore tetrad. d, a spherical spore. E, a spore showing thick-walled exosporium.**

The mother cells sooner or later divide twice to form spores. The first division is reductional, which puts an end to the sporophyte generation (Fig. D).

The four spores so formed are tetrahedrally arranged (Fig. A, C) and remain embedded in a common sheath which is more or less spherical. The spores remain in it till maturity. According to McAllister (1916). in *R. curtisit* the spores may not separate at all even after maturity and so they are disseminated en masse. There is no special method for the liberation of the spores. They are set free to the outside simply by the death and decay of the thallus. This process may take a long time.

Structure and germination of the spore. A fully mature spore is uninucleate and is more or less pyramidal in shape. It has irregular thickening and is made up of three layers of walls which are easily distinguishable (Fig. D, E). According to Beer (1906), the outermost layer is exosporium which is highly cutimized, the middle layer, mesoporium which has three concentric layers, is also cutinized and the innermost endosporium is made up of pectose and cellulose.

The germination of the spore begins with the rupture of the two outermost layers-exosporium and mesosporium. The endosporium protrudes in the form of a tube called the germinal tube (Fig. a, B). The first rhizoid also comes out more or less at the same time and nearly from the same place (Fig. C, D). There are divisions in the germinal tube and when eight-celled it is called protonema (Leitgeb 1879). But most of the workers do not agree with this nomenclature. Anyhow, sooner or later, a new thallus is formed from it (Fig. E).



**MARCHANTIA**

**OCCURRENCE:**

65/11, 6-Hills of south India or 2 plains. M. polymorpha and M.indica are the most common species. Vegetative thallus with gemmae cups throughout the year. The sexual plants are comparatively rare. They occur abundantly in the month of Feb & Mar. in Himalaya and in Oct 8, Nov. in south Indian Hills. The genus grows luxuriantly in moist shardy places.

**The plant Body – Gametophyte**

**The external features**

The plant body is a dark green, fleshly thallus. It is dorsiventrally flattened, prostrate and dichotomously braced. A notch is present at the apical region of the thallus. The growing point is situated in between the two lobes of the notch. A shallow midrib is present on the dorsal surface and a low ridge on ventral surface.

Cup shaped structures are present along the midrib. They are called gemma cups. They are asexual reproductive structures. They close asexual reproductive bodies called gemmae.

The ventral surface of the thallus is brownish in colour. It has scaled and rhizoids. There are two types of rhizoids. 1. Simple rhizpoids 2. Tuberculate rhizoids. The simple rhizoids fix the thallus to the subrstractum. The tuberculate rhizoids are thick walled and narrow. The pge-like invaginations are present on the inner wall of the rhizoids. But the donot form complete partitions. They function as a capillary conduction of water. The scales are usually arranged in two to four rows on either side of the midrib. The scaled help to retain the moisture below the thallus.

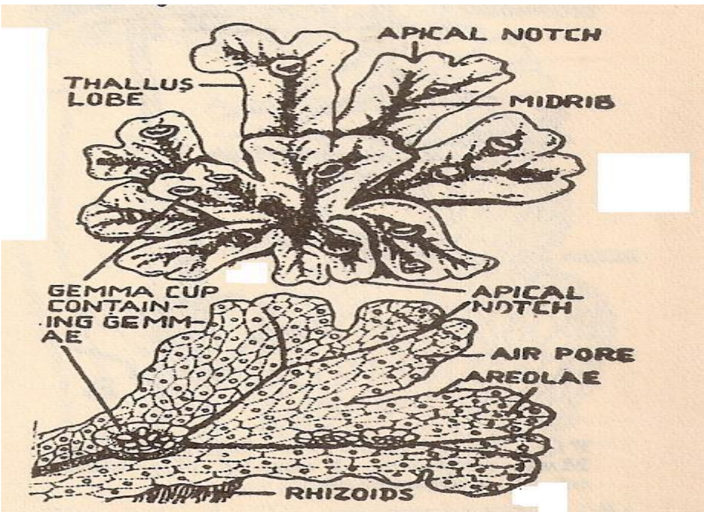



**Fig : Habit**

**Internal structure**

In vertical section the thallus shows three district regions namely the epidermal region, the photosynthetic region and the storage region.

**Epidermal region:**

This region consists of on upper epidermis and lower epidermis. They form surface layers. Each epidermal layer consists of a single layer of cells. The epidermal cells contain few chloroplasts.

The upper epidermis consists of many chimney like air pores. Each air pore is surrounded by 4-8 tiers of 4-5 cells each. These tiers form rings of cells one above the other. They enclose a passage which is broad in the middle and narrow above and below. The pore wall lies half above and half below the epidermis. Each pore leads into an underlying air chamber. The presence of air pores in the epidermis facilitates gaseous exchange.

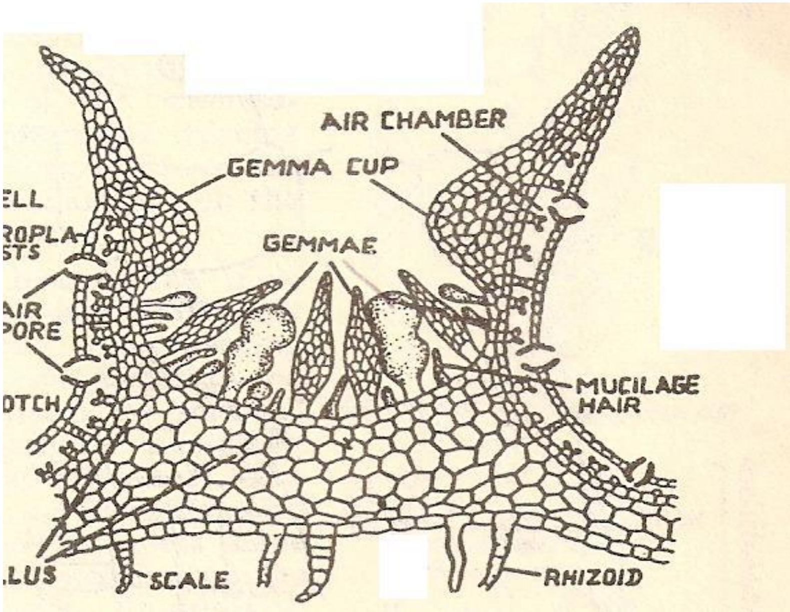



**Fig : Vertical trasverse section of the thallus lobe passing throw the gemma cup.**

**Photosynthetic region**

Below the upper epidermis, air chambers are present. Air chambers are separated by one cell layer thick partitions. A number of short simple or branched filaments are arised from floor of the chamber. They are known as assimilatory of photosynthetic filaments. All the cells of this region contain numerous ovoid chloroplasts. The cells are photosynthetic in function.

**Storage region**

Storage region lies fast below the photosynthetic region. It is made up of uniform, large, colourless, thin walled polygonal parenchymatous cells. Most of the cells contain starch and proteins grains. Few oil cells with oil bodies and mucilage cells with mucilage are also present.

**The lower epidermis**

The lowermost layer of the storage region is the lower epidermis scales and rhizoids are developed from the lower epidermis.

**REPRODUCTION**

Marchantia reproduces vegetatively, asexually and sexually.

**Vegetative reproduction**

Vegetative reproduction takes place the death and decay of order parts and by the fragmentation of the thallus.

**Asexual Reproduction**

Asexual reproduction takes place by special structures called gemmae. The gemmae are produced in gemmae cup.

**Development**

The gemmae are formed from the epidermal cells within gemma cups. One of the epideram cells acts as gemma initial. The gemma initial divides transversely to form the basal stalk cell and an upper primary body cell. The stalk cell does not divide further. The body cell divides transversely to form a 4-5 celled filament. Again these cells divide vertically and transversely to produce a one cell thick discoid body. Then periceinal divisions take place in the central cells. So the central region becomes several cells thick. In the mean time, an enveloping outgrowth of the thallus developed. It is known as cupule or gemma cup. It surrounds the group of gemmae.

**Structure of gemma**

Each gemma consists of a small stalk and a discoid body. The stalk is one celled. The body is multicellular. The central region of the body is several cell thickness. The remaining region is single cell thickness. The body has two notches at its middle region one on each lateral margin. Apial cells and the growing region lie at these notches. Most of the cells of the body contain chloroplasts. Few cells are large and filled with rich protoplast. They are called rhizoidal cells. Few others cells contain oil bodies and are called oil cells. A number of mucilage hairs also arise in the gemma cup. The are intermingled with the gemmae.

**Dispersal of gemma**

The mucilage hairs absorbe water. They swell and create a pressure upwards. Due to the pressure, the gemma breaks away from the stalk and dispersed. Sometimes, the formation of new gemma causes the liberation of old gemma.

**Germination of gemma**

Each gemma, on favourable condition germinates to produce two new plants in the soil. The rhizoidal cells develop rhizoids. The rhizoids are absorbtive in function the apical cells at the notches become active and produce two new independent thallus. These new thalli grow in opposite directinons. The central mass of gemma disintegrates.

**SEXUAL REPRODUCTION**

Except few all plants are dioecious. The sex organs of marchantia are borne on special crect and stalked branch. The stalked branch bering male sex organs, the antheridia is known as antheridiophore. The stalked branch bearing female sex organs, the archegonia is called archegoniophore. The antheridiophore and the archegoniophore are the prologations of the thallus. Each has a slender stalk. The stalk has 8-12 lobed flat disc at it tip.

**Stalk**

The structure of the stalk of the antheridiophore and archegoniophore is similar.Intransverse section, assimilatory zone with epidermis is present in oneside. Hence epidermis has many airpores. Has many airpores. The air pores open into the air chambers. Few branched photosynthetic filaments are present in the chambers. It denotes the dorsal surface. In continuation with the assimilatory zone, the storage zones is present. It is formed by a mass of parenchymatous cells. The central part of the stalk is composed of vertically elongated narrow cells. It is conduction in function. There are also two deep rhizoidal furrows containing rhizoids and scales. These denote ventral surface.

**THE ANTHERIDIUM**

The antheridiophore has a slender 1-3cm long stalk. It has an eight lobed flat disc at its tip. The disc is convex on its upper surface. It is s modified branch of the thallus. Epidermal region has two types of openings namely the air pores and ostioles. Airpores are the opening of the airchambers and the ostioles the the openings of antheridial chambers. Branched assimilatory filaments are present in the air chambers. A single sthor stalked antheridium is present chamber. The oldest antheridia lie towards the centre of the disc and the youngest towards the periphery of the lobe. Two rhizoidal furrous with scales and rhizoids are also present.

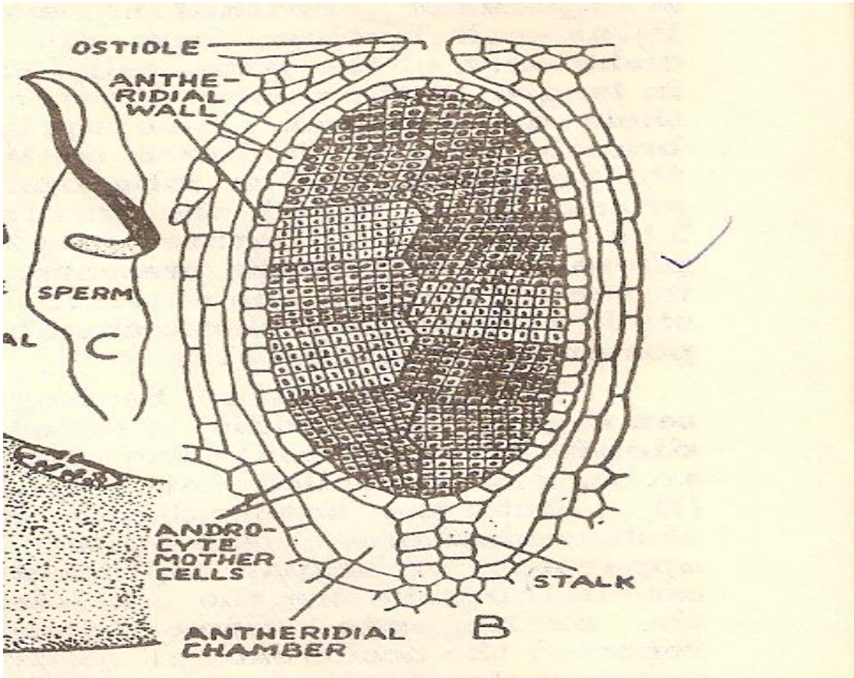



**Fig. Matured antheridium**

**Development of antheridium** :

A superficial cell of the antheridial disc functions as the antheridial initial. It divides transversely to produce an upper primary antheridial cell and a lower primary stalk cell. The primary stalk cell on irregular divisions forms a multicellular stalk of the antheridium. The primary, antheridial cell on transvers, vertical and periclinal divisions, produces an outer layer of primary jacket cells on repeated anticlinal divisions form one cell thick anteridial jactket. Primary androgonial cells on repeated divisions form one cell thick antheridial jacket. Primary androgonial cells on repeated divisions produce a large number of androgonial cells. They give rise to androcyte mother cells. Each androcyte mother cell produces two androcytes. Each androcyte metamorphose into an anterooid. The anterozoid is a small, coiled, uninucleate and biflagellate structure.

**Structure of mature antheridium**

A mature antheridium is oval in shape. It has a short stalk. The stalk attaches the antheridium with the base of the antheridial chamber. The antheridium has a single layered jacket. The encloses a mass of androcyte cells.

**Dehiscence of the antheridium**

The antheridium ruptures due to the pressure caused by the neighbouring cells by absorbing water. The mass of androcytes comes out and becomes antherozoids.

**THE ARCHEGONIUM**

The archegoniophore consists of a slender stalk surrounded by a small lobed disc. Archegonia are produced on the dorsal side of the each lobe. Before fertilization, the necks of the archegonia direct upwards. After fertilization, the stalk begins to elongate. Due to this, the archegonia from dorsal surface are shifted to ventral surface. So that, the necks are pointing downwards. Usually 12-25 archegonia occur in a group. They are surrounded by a common involucres known as perichaetium. From the upper surface of the disc, long, stout, green cylindrical structures ae developed. They are generally nine in number and known as rays.

Upper epidermal regions with air pores, air chambers, assimilatory filaments are also present in the archegoniophore.

**Development of Archegonium**

The development of archegonium begins from a single superficial dorsal cell of the female receptacle. It is called the archegonial initial. It divides to forman outer primary archegonial cell and an inner primary stalk cell. The primary stalk cell on further divisions produces the stalk of the archegonium. The primary archegonial cell divides to produce three peripheral initials and a primary axial cell. The primary axial cell gives rise to an upper, smaller primary cover cell and an inner (lower) central cell. Primary cover cell divides to form four cover cells. The central cell divides transversely into an upper primary neck canal cell and a lower central cell. The primary neck canal cell gives four neck canal cells and the ventral cell divides to produce an upper ventral canal cell and an egg cell.

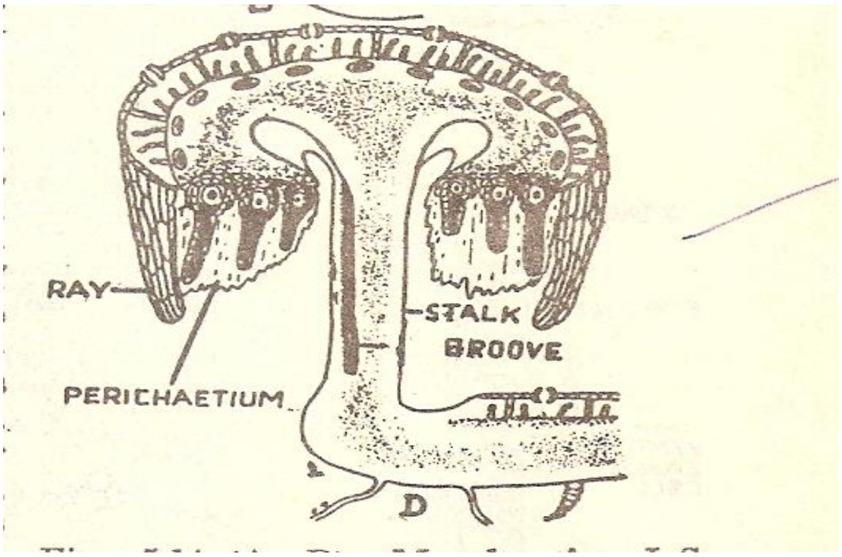



**Fig. LS of Archegoniophore**

**Structure of mature archegonium**

A mature archegonium is a flask shaped structure. It has a short multicellular stalk. The archegonium is differentiated into a basal round structure called venter and a long slender structure called venter and a long slender structure called neck. The venter encloses a single large egg and a ventral canal cell. The neck is madeup six vertical rows of cells. The neck canal is filled with 4 to 6 neck canal cells. The tip of the neck is protected by four cover cells.

**Fertilization**

At the time of fertilization, the neck canal cells and the ventral canal cell distintegrate. In the present of water, antherozoids reach the archegonia and finally only units with the egg.

**THE SPOROPHYTE**

**Development**

The venter enlarges. Zygote secretes a wall arround it. The first division of the zygote results an upper and a lower cell. The next division gives rise to either a three celled filamentous embryo. The upper cell in filamentous embryo develops into the capsule and the lower cells into foot and seta. In quadrant embryo, the upper cells produce the capsule and a part of seta and the lower cells produce the foot and remining part of the seta. Further irregular divisions take place to form multicellular structure which is differentiated into the morphologically, physiologically and cytologically distnict zones.

**The foot**

The foot is situated towards the base of the archegonium. It is make up of thin walled parenchymatous cells without intercellular spaces. The foot anchers the sporophyte in the tissue of the archegoniophore and absorbs the nutrients from the gametophytic tissue for developing sporophyte.

**The seta**

The cells in the seta are rich in vacuolated cytoplasm. The seta develops below the capsule. In the earlier stage, the cells are isodiametric and in the latter stage, they become elongated. Thus the seta increases in length, ruptures the ealyptra and pushes the capsules out through the surrounding calyptras, perigynium and perichaetium.

**The capsule**

The cells of this zones are arranged in a globular structure. The outer layer of this zone is called amphithecium or the capsule wall. The inner mass of cells is called endothecium. The cells of the endothecium undergo a number of divisions and produce sporogenous cells. It is known as the archesporium.

Among these cells, 50% are fertile and the remaining 50% are sterile. The fertile cells are broader with dense cytoplasm and prominent nuclei. The sterile cells are narrow and elongated. The fertile cells, on repeated transverse divisions, form a row of cells. Each cell in the row is know as a spore mother cell. Each spore mother cell undergoes meiotic division to form spore tetrad. Spores are separated at maturity. The elongated, non-protoplasmic, diploid sterile cells are known as elaters. The elaters are spirally thickened and hygroscopic. They are helpful in the dispersal of the spores.

Due to the rapid divisions of the cells of the venter and base of the archegonium, the developing sporophyte is surrounded by calyptras, perigynium and perichaetium. They are peotective in function.

**Dehiscence of capsule**

The capsule comes out of the protective layers and splits irregularly. The movement of the elaters is helpful for the dispersal of spores.

**The spores**

The spores are small and spherical with two wall layer namely the exine and the intine.

**THE YOUNG CAMETOPHYTE**

Spore is the first stage of the gametophytic generation. 50% of the spores develop into male and the remaining 50% develop into female plants. The spore divides and produces a large cell and a small cell. The large cell divides irregularly to form a 6-8 celled filament. The small cell forms the rhizoid. The 6-6 celled filament becomes a new thallus.

**POLYTRICHIDAE – FUNARIA**

Order . (Reihe) **Polytrichales.**

Order. (Reihe) **Dawsoniales.**

The Order Funariales comprises five families, 206 genera and about 356 species.

The Families are:

1. Gigaspermaceae
2. Funariaceae
3. Discelioceae
4. Oedipodiaceae
5. Splachnaceae

Only Funaria belonging to the family Funariaceae will be discussed.

1. Bryopsida
2. Eubrya
3. Funariales
4. Funariaceae
5. Funaria

**Occurrence**

The first reference of Funaria was made in the appendix to Ray's Synopsis in 1860. To Linnaeus it was known as Minium hygrometrica. It was discovered in 1791 by Schreber and appeared in the 8$^{th}$ Edition of Linnaeu's "Genera Plantarum". The word Funaria is derived from a Latin term 'Funis', means a rope and it refers to th characteristic twisting of seta in the moss when it is dry. The name Funaria hygrometrica was first coined by Sibthorp in his "Flora Oxomensis" (1794). Hedwid (1801) used the same term in his "Species Muscorum".

It has the distinction of being cosmopolitan in distribution and includes about 117 species. It is found on soil, on walls, and on the lands which have been burnt by fire. It grows vigorously in compact masses and within a very short period it occupies a vast area. However, the colonization depends upon the various habitats and accordingly it may be rapid or slow. For example, growth of the moss may be rapid on moist bare soil and on a ploughed field, while it is slow on the rocky surface. The fact has been demonstrated experimentally true by Sharp (1939). F. fascicularis is found in fallow fields, F. muehlenbergii occurs on rocky ledgesand F. attenuate and F. obtuse are common in peaty banks. F. hygrometrica is a common moss on Indian Hills, Bruhl reported 15 species of Funaria from the country.

**Structure :** The short erect bright green coloured plants of Funaria are differentiated into rhizoids, stem and leaves (Fig. )

**Habit of Funaria**

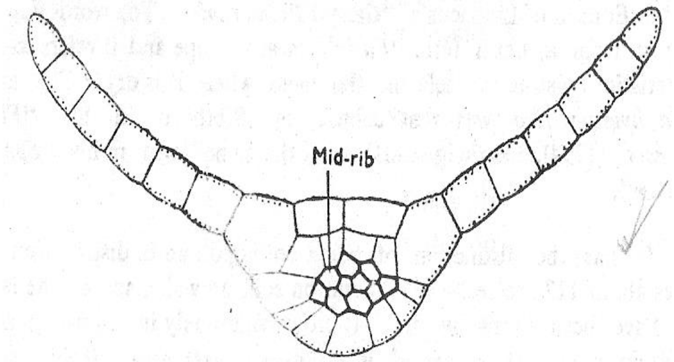
**Rhizoids**

They are hyaline or whitish, branched multicellular thread-like structures arising from the base of the plants. The septa are oblique. The colour of the rhizoids in the later stages becomes brown or red. Their function is the same as those of roots in Phanerogams i.e., fixation of the plant and absorption of food.

**Leaves**

The bright green membranous ovate leaves are spirally arranged on the stem. Each leaf is more or less sessile and possesses a well defined and distinct mid-rib.

In a transverse section, the leaf shows two wings on either side and a central strand. The so-called wings on either side contain chloroplasts middle carry on conduction (Fig. 980. A very interesting phenomenon of division of the chloroplast can easily be seen in the leaves of this moss. Here the chloroplast undergoes divisions even when the leaves reach complete maturity.




**Stem**

It is green, delicate and branched (not very often). In a transverse section it exhibits the following structure (Fig. ).

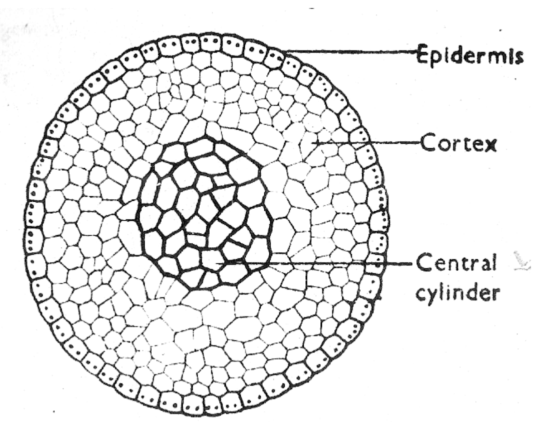



**Fig. T.S. of the stem of Funaria**

**1. Epidermis**

It is the outermost layer. Its cells are thin (may be thick occasionally). It is single- layered (May be double-layered at certain places) and contains chloroplast. It lacks cuticle and stomata.

**2. Cortex**

It is multi-layered. It is made up of parenchymatous cells which may be thin or thick. the “leaf trace” may be present which runs diagonally from the leaf to the central cylinder.

**3. Central cylinder**

The middle region is occupied by slightly smaller cells (smaller than the cells of the cortex), which are sightly thick-walled. Bower (1933). Showed that whatever may be the habitat of the moss small amount of water moves up through this region. Magdefrau (1935) and Ignold (1955) regard it as a conducting region.

**Reproduction**

It is brought about by two methods

1. Vegetative
2. Sexual.

**Vegetative multiplication**

In mosses vegetative multiplication is a very common phenomenon. According to Smith, some mosses multiply abundantly only by vegetative means.

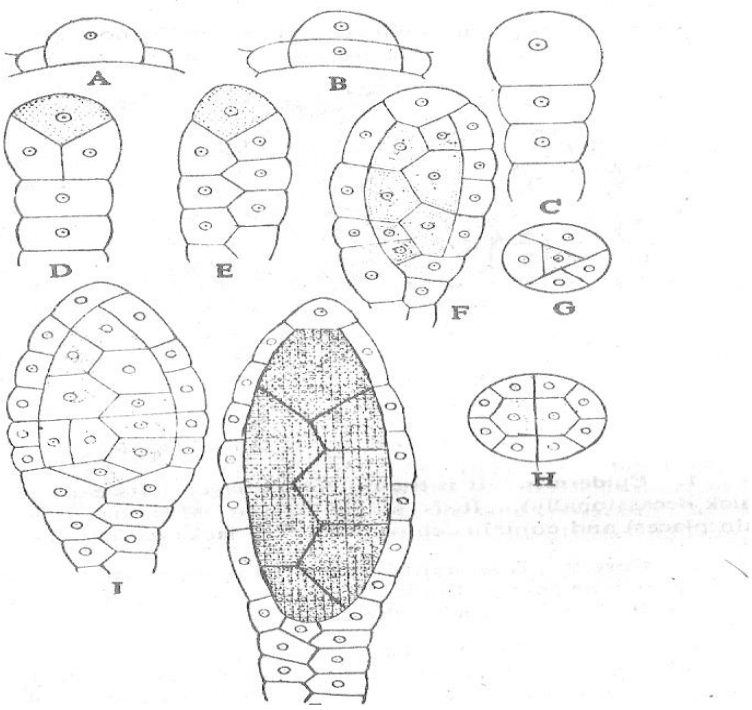



**Fig. Stages in the development of the antheridium of Funaria. A-E, formation of antheridial initial. F, very young antheridium with jacket cells and androcyte mother cells. G, H, T.S. of the antheridium. I, J, antheridia with a short stalk and sterile jacket. Inside are androcytes.**

**A. Death and decay of the rhizoids**

The rhizoids run prostrate and erect branches are given out from them. Sometimes, the rhizoids die out and erect branches constitute a single independent plant.

**B. Gemmae**

Small multicellular bodies may be formed at the tips of the leaves, at the apex of the stem and on the rhizoids. When gemmae are aubterranean, they are called bulbils. Each gemma, when detached, gives rise to a new plant. Berkeley (1941) reported formation of such gemmae at the apex of the protonemal branches.

**C. Prmary protonema**

It is formed by the germination of a spore. It consists of many buds which later on give rise to moss plants. Increase in the number of protonema increases the number of plants also. If the cells in a protonema die out, they give rise to small fragments and each fragment on germination forms a new individual.

**D. Secondary protonema**

When protonema arise from any part of the plant (but not from the spores) these are called secondary protonema. Such protonema do occur in Funaria, particularly on wounded portions. On germination, they give rise to new plants.

**1. Sexual reproduction**

The sexual reproduction is brought about with the help of male and female organs of reproduction called antheridia and archegonia respectively. Campbell's observation that the plants of Funaria are dioecious is erroneous and it is now an established fact that the plants are strictly monoecious, though autoecious (Boodle and Brown). At maturity, the male branches appear brownish in colour, if seen against light. The female branches are evergreen.

**2. Development and structure of an antheridium**

A superficial cell at the apex of the male branch acts as an antheridium initial (Fig.. A). It slightly bulges out and then divides into two-an outer cell and an inner cell (Fig., B). The former further divides and forms a row of two or three cells (Fig., C). The terminal cell in this row acts as an apical cell with two cutting faces (Fig. D). It now cuts off 5-15 segments. The inner cell finally gives rise to the lower portion of the stalk of the anthridium (Fig., E).

Before the cessation of the apical activity of the cell, divisions start in the fourth or the fifth segment and the first division is diagonally vertical. One of the smaller cells the jacket initial. The bigger one again divides and gives rise to another jacket initial and a primary androgonial cell. The latter appears triangular in cross-section (Fig., G). The upper segments (cut off by apical cell) latter on divide in the same way. Thus, the divisions which start from the lower side eventually proceed to the upper region. Finally, single and regional cell may be seen surrounded by two jacket initials.

The primary androgonial cell divides and redivides and gives rise to many androcyte mother cells (Fig. F, J). Now each androcyte mother cell forms two androcytes and according to Allen (1912), the division is not diagonal (unlike Hepaticopsida). According to the same author (1912, 1917), the formation of antherozoids from the androcyte is exactly similar as in Hepaticopsida. The jacket cells also divide but only radially and thus a single-layered wall surrounds the antheridium (Fig. J. H.).

**Liberation of the antherozoids**

The clubshaped antheridium has a short stalk and an operculum. It contains numerous antherozoids (Fig. A). Water is indispensable for the liberation of the antherozoids. The antheridium absorbs water and a hydrostatic pressure is created inside. At the same time, the jacket cells also become turgid. This pressure is sufficient to force the operculum to open. As soon as it opens, the whole mass of the antehrozoids comes outside (Fig. B). Each antherozoid is uninucleate and biciliate (Fig. C).

The antheridia are closely associated and surrounded by many sterile structures, the paraphyses. Each paraphysis is an elongated structure with four or five long narrow cells joined end to end (Fig. ).

The terminal cell of the paraphysis is globose. Goebel (1905), referred to the function of these structures. According to him, these help in water conservation and are also meant for the protection of the antheridia against external environments. Resse (1955), referred to these structures as a means of vegetative propagation. Rarely, the lowermost cell gives rise to protonema.

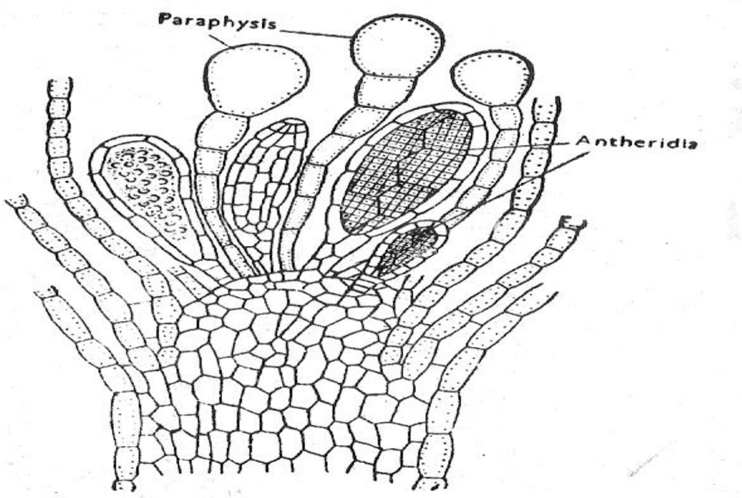



**Fig : L.S. of male branch of the moss showing antheridia and paraphyses**

**Development of the archegonium**

The archegonium develops from an apical cell, which in the earlier stages, has two cutting faces (Fig. A, C). It cuts off four to eight segments. These segments further divide and finally give rise to the stalk of the archegonium. According to Holfesty (1904), Bryan (1917) and Burr (1939), the apical cell abruptly changes and develops three cutting faces (Fig. D, E). Each face cuts off a single segment and thus three peripheral cells, now called peripheral initials, encircle the former apical cell now known as axial cell. The peripheral cells divide vertically and so six jacket initials are produced. In the meantime, the axial cell divides transversely and gives rise to a primary cover cell and a central cell (Fig. F). The latter again divides transversely and forms a primary canal cell and a venter cell (Fig. G). The former (also Jacket initial) gives rise to the median and the lower portion of the neck, while the upper portion is formed by the primary cover cell. The venter cell divides and gives rise to a venter canal cell and an egg, (Fig. I. J). Archegonium thus becomes and elongated flask-shaped structure with a long neck a swollen venter. The neck is single-layered and consists of six or more neck canal cells while the venter possesses a venter canal cell and an egg and is double-layered. At the top, there are cover cell (Fig. K).

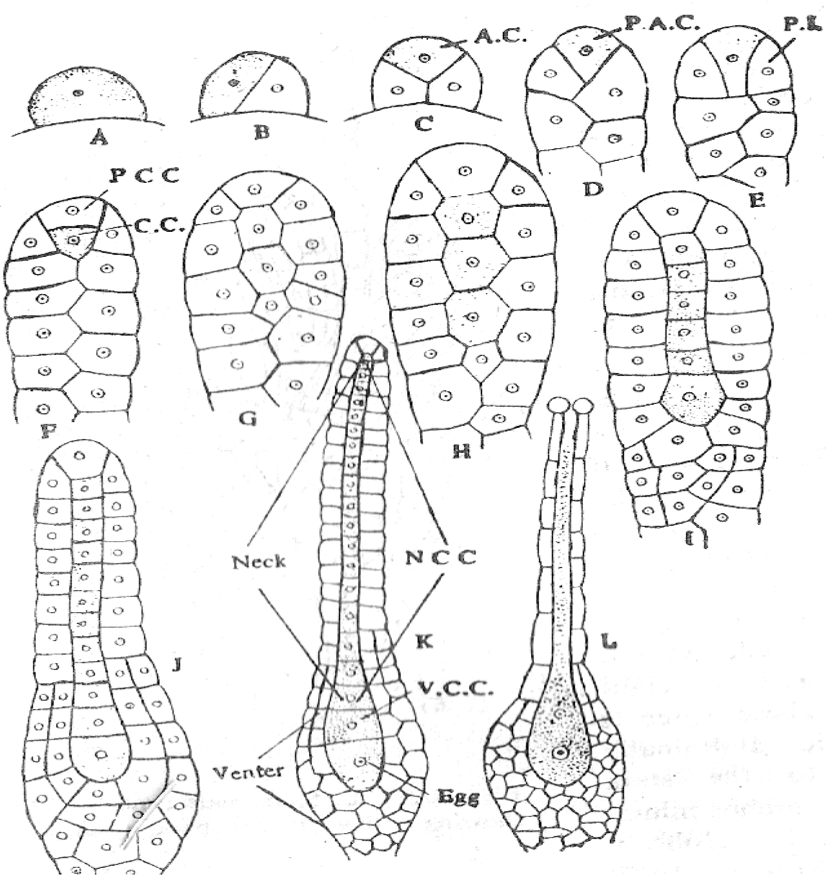



**Fig. Stages in the development of an archegonium of Funaria. A-D formation of archegonial initial. e, axial cell. F, first division of the axial cell forming primary cover cell and central cell. c, formation of primary neck canal and primary venter cell. H-K, development of fully mature archegonium, L, archegonium ready for fertilization, A, C., apical cell. C, C, central cell. N.C.C., neck canal cells. P.A.C., primary axial cell. P, C, C., primary cover cell. P. I., peripheral initial, V, C, C., venter canal cell.**

**Fertilization**

At the time of fertilization, the neck canal cells disintegrate and from a mucilaginous mass. As the water is absorbed, the mucilage swells and the neck opens. Thus, a clear passage is formed for the entry of the antherozoids.

Many such archegonia may be seen if a L. S. of the female branch is cut. along with these female organs are sterile hairs (Fig.). No doubt, water is indispensable for fertilization, the movement of the antherozoids is chemotactic. Many antherozoids are attracted but ultimately it is only the one which fertilizes the archegonium. The nucleus of the male unites with the nucleus of the female and it results in the formation of an oospore.

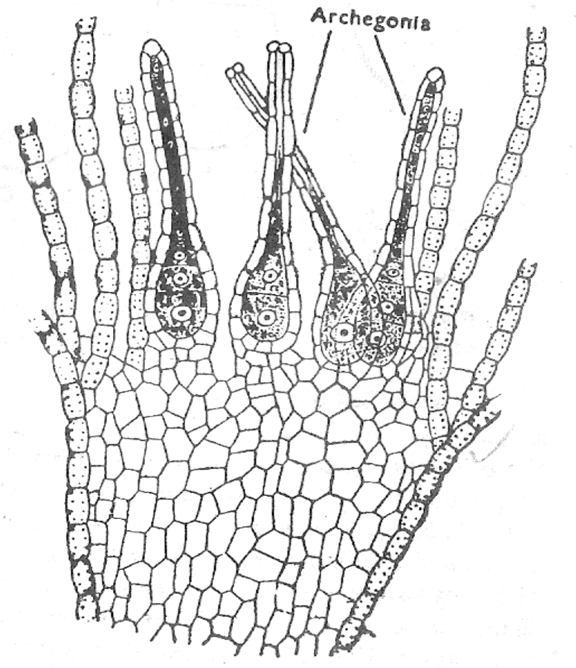



Fig : L.S. of female branch of funaria showing archegonia and sterile hairs.

**Post-fertilization changes**

Immediately after fertilization the oospore increases in size (Fig. A) and divides into two by a transverse wall forming an epibasal (upper one) and a hypobasal (lower one) cell (Fig. B). Soon afterwards, the epibasal cell divides by two diagonal divisions into an apical cell with two cutting faces. The same thing happens in the hypobasal cell. Thus, young embryo of this moss possesses two growing points (Fig. C). The apical cell in the epibasal region cuts off cells right and left and finally develops capsule and most of the portion of seta. Remaining portion of seta and foot develop from the hypobasal region (Fig. D).

In the earlier stages, the development of the embryo is accompanied by the development of the surrounding tissue which forms the calyptra. The latter structure, however, gets broken by the elongation of the sporophyte.

**Detailed account of the development of the capsule**

The capsule, as already stated, develops by the successive divisions of the apical cell in the epibasal regions of the young embryo. The first division is vertical (Fig. A). A transverse division follows and thus a quadrant iis formed (Fig. B). According to Biomquist and Robertson (1941). Burr (1939), Evans and Hooker (1915). Wenderoth (1931) and Wijk (1929), each part of the quadrant now undergoes anticlinal division in such a way that one daughter cell in each quadrant is triangular and the other is more or less rectangular (Fig. C). Now periclinal divisions follow in each quadrant and so finally four cells are differentiated in the middle surrounded by eight peripheral cells (Fig. D). The former give rise to the endothecium, while the latter constitute the amphithecium. Infact, endothecium and amphithecium are the chief constituents which ultimately form different tissues of the capsule. The further developments in different parts of the capsule are slightly complicated, though very systematic and regular. For the sake of convenience, developments in different parts of the capsule may be discussed separately.

1. Developments in the central fertile region.
2. Developments in the apical region (Thecae).
3. Developments in the lower region (Apophysis).

**1. Development in the central fertile region**

In all the four central endothecium cells diagonal or vertical (Anticlinal) divisions take place followed by periclinal divisions resulting in the formation of four inner endothecial cells and eight peripheral endothecial cells (Fig. E). The former divide twice and give rice to sixteen cells which finally constitute coloumella. The eight peripheral cells divide radially and periclinally and thus form two rings. The cells of the outer ring once again divide radially and form archesporium while the cells of the inner ring, adjacent to columella, constitute the inner spore-sac (Fig. F). The cells of the archesporium give rise to spore mother cells which finally convert into spores.

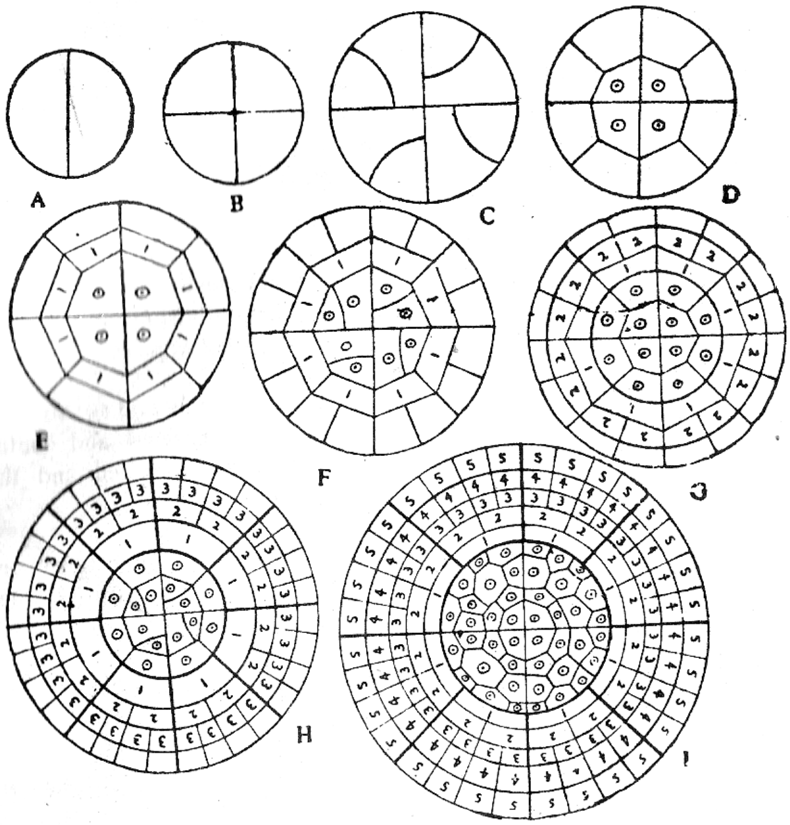



**Fig : Transverse section of the capsule of Funaria taken from different levels. A-D, differentiation of amphithecium and endothecium, H-I, development of rings.**

According to Blomquist and Robertson (1941), Burr (1939), Evans and Hooker (1913) and Wenderoth (1931), the divisions in the amphithecium are very systematic and have a definite pattern. Goebel called this pattern the "Grundquadrat" or fundamental square method. The amphithecium divides periclinally and thus two concentric rings are formed. The inner ring may be referred to as the first ring (Fig. E, F). Cells of the outer ring now divide anticlinally followed by periclinal divisions almost immediately. thus, two rings of sixteen cells are formed. The inner ring is called the second ring (Fig. G). The cells of the outer ring again divide anticlinally and periclinally and so two concentric rings of thirty two cells are again formed. The inner one is known as the third ring (Fig. H). The outer cells further divide in a periclinal fashion and so two rings of thirty-two cells are again formed. The inner one is termed the fourth ring while the outer one constitutes the fifth ring (Fig. I).

The cells of the first ring divide in an anticlinal fashion and give rise to thirty-two cells. it is followed by periclinal divisions and finally a four-laayered outer spore sac is formed, which lacks chloroplast.

The cells of the second ring elongate radially and so air-space appears in these cells. These become laterally separated and contain chloroplast. Later on there is a transverse division in each cell and thus a filament of three or four cells is formed.

The cells of the third ring remain thirty-two in number but only one cell in thickness (occasionally two cells thick). At maturity, these possess chloroplast.

The fourth ring becomes two or three-layered on account of the periclinal divisions but its cells never possess chloroplast.

Cells of the fifth divide anticlinally and the epidermis.

**2. Developments in the apical region of the capsule**

In the upper region four endothecial cells and eight amphithecial cells are present. The former divide repeatedly and give rise to thin-walled parenchyma which is continuous with the columella of the fertile region. the amphithecium, as usual, forms five concentric rings of which the first ring (32-celled) gives rise to inner peristomial layer (after anticlinal divisions) and the second ring gives rise to the outer peristomial layer. cells of the third and the fourth ring become three-layered and form operculum while the cells of the fifth ring give rise to epidermis. The cells of the epidermis at the base of the operculum enlarge radially and constitute annulus.

**3. Developments in the lower region of the capsule**

The endothecial cells in the apophysis form the conducting region. Amphithecium develops into spongy chlorophyll and epidermis. the later possess stomata.

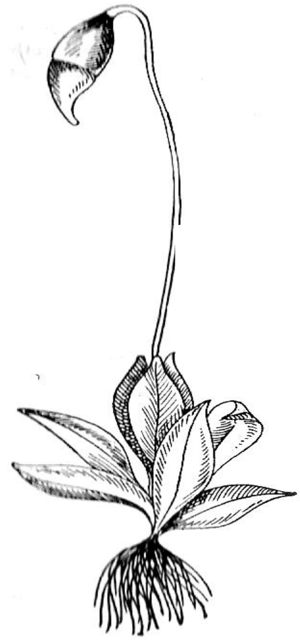


**Fig : Gametophyte of Funaria, bearing the sporophyte. Long seta and capsule with operculum are visible.**

Thus, the sporophyte of *Fumaria* is differentiated into foot, seta and capsule. The foot is small and not very well developed. Its function is to absorb water and other food materials.

The seta is an elongated thread-like structure, the function of which is more or less mechanical. The pear-shaped capsule with a hood of broken calyptra is carried above by seta. The essential parts of capsule are, operculum, the cap-like structure which in the later stages is replaced by peristome or peristomial teeth which bring about dispersal of the spores (Fig. A, B). There is columella on either side of which are two elongated spore sacs containing spore mother cells or spores. Adjacent to the spore sacs are air spaces while the outermost layer is epidermis. The lower portion or apophysis has conducting strand and in this region the epidermis possesses stomata (Fig., ).

**Dispersal of the spores**

The spore mother cells undergo meiosis and give rise to haploid spores. The latter are more or less spherical and possess two walls – an inner one, the endosporium and an outer one, the exosporium. The spores are dispersed gradually by the activity of the peristomial teeth. The latter are hygroscopic in nature (Fig. A). In moist conditions they remain inside and their tips remain in touch with the spores (Fig. B). When the conditions are dry, they come outside, their tips laden with spores (Fig. C). Movement of wind or even the mild breeze is quite sufficient to dislodge these spores (Fig. D) and thus they are taken of far-off places. The peristomial teeth remain active till the spores are dispersed (Fig. A, E).

**Germination of the spores**

The first account of the germination of the spores was given by Hedwig in 1782. Further investigations on this juvenile phase of the moss were carried out by Muller (1874).

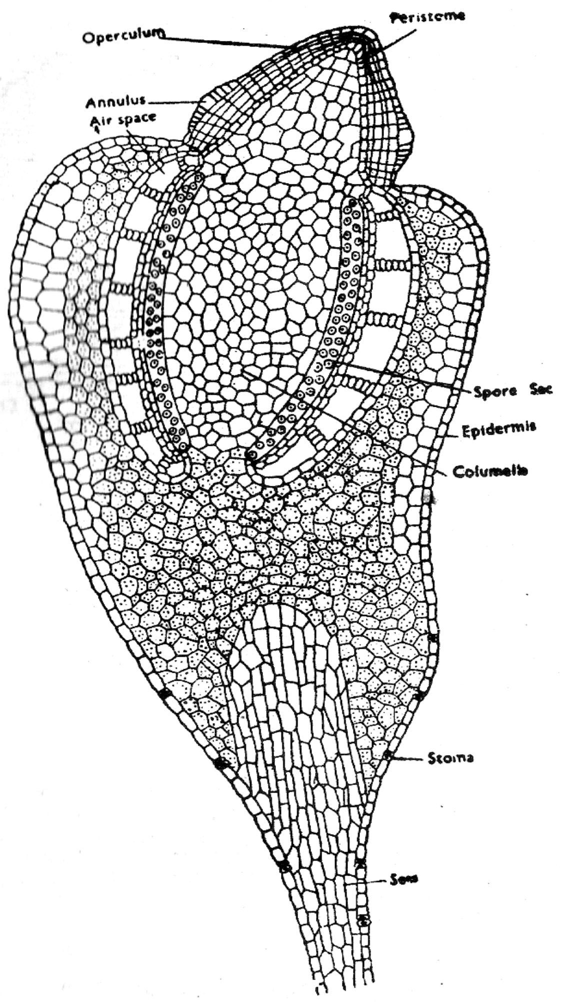



Fig : L.S. of the capsule of the Funaria showing detailed anatomy.

Sachs (1875) and Goebel (1882). According to these workers, the spore germinates into a primary protonema which has green filaments containing chlorophyll and pale or brown rhizoids. They regarded these two filaments as morphologically homologous. Correns (1899), accepted this view but he called the green filaments chloronema. According to Nemec (1904), Bischoff (1922), E. & O. Pringsheim (1935), Hetiz (1942) and Fitting (1950), the rhizoids are positively geotropic.

According to Sironval (1947), there are two protonemal stages. First is just after germination when green filaments are produced which he called chloronema and the second he termed caulonema. The latter, according to him, has rhizoidal characters. Bopp (1952, 1954, 1955), supported Sironval. Van Andel (1952) could not see caulonema of Sironval. According to Allsopp and Mitra, there is "no indication of the distinct stage 'chloronema' and 'caulonema' identified by Sironva (1947)." According to the same workers, "the characteristic of caulonema as described by Sironval are clearly those of the normal well-grown protonema. They are certainly not associated with a distinct morphological phase, but are probably indicative of a certain nutritional status of the protonema." The bud formation, according to these workers, is not restricted to the caulonema alone.

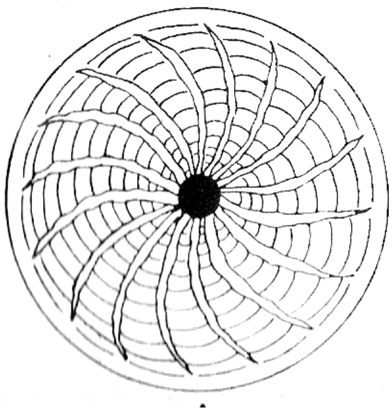


Fig : Peristome of Funaria

Anyhow, during germination, the spore sends out filamentous multicellular branches, the primary protonema (Fig. A-D). The protonema then gives rise to two types of branches – the prostrate and the upright (heterotrichous) green branches with cross wall (transverse), the chloronema and the branches which go into the soil, possess little chloroplast or leucoplast and have oblique walls. The protonema develops buds which finally give rise to new moss plants (Fig. E). After many buds have developed and leafy gametophytes are produced, the primary protonema degenerates.

**Alternation of generations**

The moss plant belongs to the gametophyte generation. It bears sex organs, the antheridia and the archegonia. Both the sec organs are haploid in nature. The antheridia gives rise to the antherozoids while the archegonia possess an egg. At the time of fertilization, the male and female nuclei unite resulting in the formation of an oospore. The formation of the latter structure is the end of the gametophyte generation. An altogether new generation starts with the formation of the diploid oospore and it is called the sporophyte generation. During post fertilization stages, the sporogonium or the capsule possesses spore mother cells. The latter after two successive divisions (one of the divisions is reductional) give rise spores, which are haploid in nature (See life-cycle of Funaria at the end).

Thus, the life-history of moss exhibits two clear and very distinct phases. The haploid phase which is before fertilization and after reduction division and diploid phase which is after fertilization and before reduction division. The former (haploid phase) constitutes the gametophyte generation and the latter (diploid phase) corresponds to the sporophyte generation. The gametophyte generation gives rise to the sporophyte generation and the latter in its turn gives rise to the gametophyte generation again. That is, the two generations succeed each other and this is called the alternation of generations.

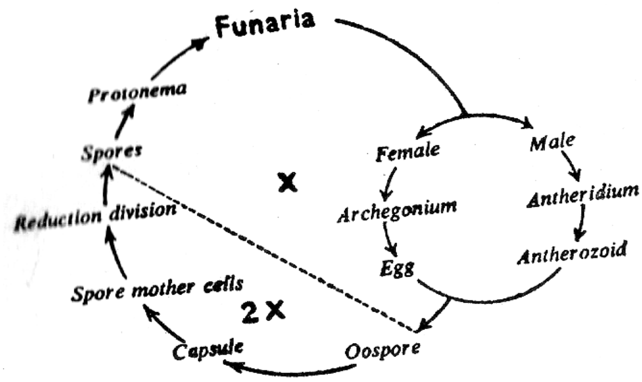



**Fig : Life-cycles of Funaria**

## NOTES

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