B.Sc. ZBC-103

BIODIVERSITY (MICROBES, ALGAE, FUNGI, ARCHEGONIATE)

DIRECTORATE OF DISTANCE EDUCATION

SWAMI VIVEKANAND
SUBHARTI UNIVERSITY
Meerut (National Capital Region Delhi)

BIODIVERSITY (MICROBES, ALGAE, FUNGI, ARCHEGONIATE)

B.Sc. ZBC-103

Self Learning Material

Directorate of Distance Education

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PREFACE

In this course, we shall deal with various aspects of Biodiversity (Microbes, Algae, Fungi, Archegoniate)

- Limit and Continuity
- Successive Differentiations
- Partial Differentiation
- Tangent and Normal
- Curvature
- Asymptotes and Singular Points
- Differentiability
- Taylor's theorem

SYLLABUS

I Year, I Semester (Botany)

Code – B.Sc. ZBC-103

Paper I: Biodiversity (Microbes, Algae, Fungi, Archegoniate)

Unit-I **10h**

Algae: General characters, range of thallus organization, classification, ultrastructure of eukaryotic algal cell and cyanobacterial cell. Lichens: Introduction and classification. Economic importance of algae and lichens.

Unit-II **10h**

Structure and reproduction of the followings: Chlamydomonas, Volvox, Hydrodictyon, Oedogonium, Chara, Vaucheria, Spirogyra, Polysiphonia.

Unit-III **10h**

Bryophytes: introduction, general characters, classification, reproduction, affinities with algae and economic importance.

Unit-IV **10h**

Structure, Gametophytic and soporophytic organization of the followings: Riccia, Marchantia. Anthoceros, Funaria.

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UNIT I : DIVERSITY OF ALGAE AND LICHENS

UNIT III : BRYOPHYTES

UNIT–I

DIVERSITY OF ALGAE AND LICHENS

1

GENERAL CHARACTERS OF ALGAE

STRUCTURE

- Introduction
- Occurance of Algae
- *Flagella in Algae*
- Reproduction in Algae
- Comparison Between Algae and Fungi
- Algae and Bryophytes
  - Important Questions
  - Answers

• INTRODUCTION

The term 'Algae' first time introduced by Linnaeus in 1753 for class **Hepaticeae** which is now used for all class of Bryophytes. The algae comparise of a large, heterogenous group of plants whcih are diverse in habitat, size, organisation, physiology, anatomy and reproduction.

It is an important group of **Thallophyts** (*Gr. Thallos* = a sprout; *Phyton*–a plant). Members of this group are primitive, simplest division the plant kingdom. According to **Fritch** (1935) "the designation algae must include all halophytic organisms, as well as their numberous colourless derivatives that fail to reach the level of differentiation characteristics of archegoniate plants". In simple words we can define algae as the **thallose, autotrophic, non-vascular plants having unicalled sex organs and no embryo foramtion.** The branch of botany deals with study of algae is called **'Phycology'** or **'Algology'**. It is derived Greek world **'Phykos'** which means 'algae' or 'sea weed (a Latin term).

Algae along with Fungi and Bryophytes can be regarded as **Thallophytes.**

The member of algae are both prokaryotic (cyanobacteria) and eukaryotic, with a third wide range of thalli starting from unicellular (Chlamydomonas) to multicellular (*Chara*).

They are spread all over the world. They grow in many different shapes, size and colours. They can exist on their own or can grow on the surfaces of other organisms, in the soils or on rocks. Algae are extremely significant because they make much of Earth's oxygen. They are usually found in net places or water and capture light through photosynthesis (autophytic).

• OCCURANCE OF ALGAE

Though algae are found in variety of habitats but commonly grow in water and moist places. On the basis of respective occurance and habitat they are classified into following types :

(i) Aquatic algae

Aquatic algae can be (a) fresh water forms and (b) marine forms.

(a) Fresh water forms. Fresh water forms are found in fresh water of low salinity such as in ponds, lakes, rivers, ditches etc. *Cladophora. Vaucheria, Chara* and some algae found in slow running water while *Spirogyra, Chlamydomonas, Hydrodictyon* and *Volvox* are found in stagnant water of ponds etc.

(b) Marine forms. The algae found in sea water are called marine algae or seqweeds. Such algae grow in water of high salinity. Marine algae can be macroscopic and very large in size *e.g., Macrocystis* (70 meters) and *Nereocystis* (100 meters). Some other examples of marine algae are : *Ulva, Enteromorpha, Sargassum, Ascophyllum Fucus, Polysiphonia, Palmaria Gelidium* and *Gracilaria* etc.

(ii) Terrestrial algae

Terrrestrial algae growing on moist soil surface, stones and rocks are terrestrial algae. The algae growing on surface of soil are called **sapophytes** and the algae growing under the surface of soil are called **cryptophytes**. Some terrestrial algae grow on moist walls and barks of trees. These algae absorb CO_2 and water from atmosphere. Some common terrestrial algae are : *Fritschiella, Vaucheria, Chlorella,* and *Oscillatoria.*

(iii) Lithophytic algae

These algae growing on surface of rocks and stones are lithophytic *e.g., Scytonema Nostoc, Vaucheria Gloeocapsa.*

(iv) Epizoic algae

Algae growing on other animals are called epizoic algae *e.g., Cladophora crisposa* grows on snails, *Stigeoclonium* grows on gills of fishes.

(v) Epiphytic algae

Algae growing on other algae and plants are called epiphytic algae *e.g., Coleochaete Polysiphonia, Oedogonium Microspora,* are found growing on other algae, bryophytes and aquatic angiosperms.

(vi) Cryophytic algae

Cryophytic algae are occurring in snow and ice. These algae impart special colours to snow due to their pigments. **Red snow** is caused by *Haematococcus nivalis* and *Chlamydomonas nivalis.* Green snow is caused by *Chlamydomonas yellowstonensis.* **Purple brown snow** is caused by *Ancyclonema nordensklioldii.* **Black snow** is caused by *Raphidonema.*

(vii) Thermophytic algae

The thermophytic algae grow in water of high temperature upto 30°C where other plant forms can not grow. Some blue green algae are capable of growing at very high temperature because of unorganized nucleus. The thermal algae found in hot water springs are *Oscillatoria terebriformis, Heterohormogonium, Synechococcus, Scytonema* etc.

(viii) Halophytic algae

Algae growing in water of high concentration of salts as in salt lakes are halophytic algae *e.g., Chlamydomonas ehrenbergii* and *Dunaliella.*

(ix) Symbiotic algae

Some members of Chlorophyceae and Cyanophyceae are found in symbiotic association with other plants. *Nostoc* and *Anabaena* make symbiotic association with *Anthoceros* and coralloid roots of *Cycas*. Lichens are symbiotic association of algae (*Chlorella, Palmella*) and fungi.

(x) Planktons

These are microscopic algae growing on surface of water and found as free floating on surface of water are called planktons. Planktonic algae are mainly members of Chlorophyceae, Cyanophyceae and Bacillariophyceae. When planktonic algae grow fast and increase enormously in number, these algae form **water blooms.**

(xi) Endophytic algae

Algae growing inside other plants are called endophytic algae *e.g.*, *Nostoc* is found in thallus of *Anthoceros, Anabaena cycadearum* is found in coralloid root of *Cycas, Anabaena azollae* is found in *Azolla.*

(xii) Endozoic algae

Algae found inside the body of animals are endozoic algae *e.g.*, *Zoochlorella* is found in *Hydra* and sponges. Some blue green algae are found in respiratory and digestive tracts of animals.

(xiii) Parasitic algae

Some algae can be found as parasites on plants and animals *e.g.*, *Cephaleuros virescens* is found on leaves of tea, coffee and mango plants and causes **red rust**. *Polysiphonia fastigiata* is semiparasitic on algae *Ascophyllum*.

(xiv) Fluviatile algae

Such algae are found in rapidly flowing waters, *e.g.*, *Ulothrix* occurs in mountain falls. *Batrachoserpermum* and *Stigeoclonium* are reported in swift running stroms of hilly regions.

• FLAGELLA IN ALGAE

The motile members of algae, zoospores and gametes have one or more flagella for motion by beating action. Flagella are absent in members of Cyanophyceae and Rhodophyceae.

Flagella are organs of locomotion. They are filiform or lash-like protoplasmic appendages. All flagella are uniform in their internal structure. Each flagellum is made of two central tubules surrounded by nine peripheral tubules. The structure of 9 + 2 is surrounded by a membrane. In different algal groups flagella differ in number, size, location and types. The flagella can be 2, 4 or indefinite in number. All flagella of one algae can be equal in size *i.e.*, **isokontic** (Fig. 1 A, B) or unequal in size *i.e.*, **heterokontic**. The flagella can be apical, subapical and lateral in position (Fig. 1 E). The flagella can be of following types in algae :

(a) Whiplash or acronematic type

These flagella do not have hair like appendages and their surface is smooth (Fig. 1A, B).

(b) Tinsel or pleuronematic type

These flagella have hair like appendages on their surface. These appendages are called **mastigonemes** or **flimmers**. These can be of following types on the basis of arrangement of mastigonemes.

(i) Pantonematic. The mastigonemes are arranged in two opposite rows (Fig. 1C)

(ii) Pantocronematic. It is a pantonematic flagellum with terminal fibril (Fig. 1D).

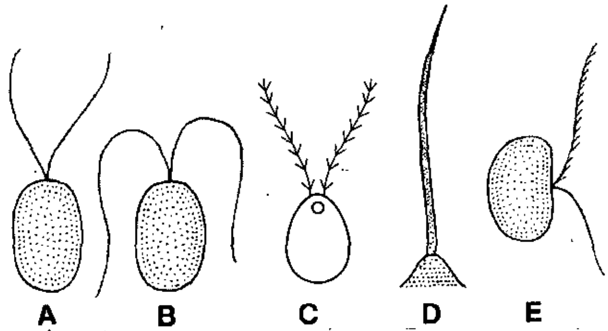


Fig. 1. (A–E) Types of flagella A, B Two equal acronematic flagella C-Pantonematic. D. Single acronematic flagellum E. Heterokontic lateral flagella.

(iii) **Stichonematic.** Mastigonemes are present on one side of flagellum (Fig. 1E).

• REPRODUCTION IN ALGAE

The reproduction in different members of algae can take place by vegetative, asexual and sexual methods :

(A) Vegetative Reproduction

In this type any vegetative part of thallug grow into a new plant.

Vegetative reproduction in algae takes place by the following methods :

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

(ii) Cell division or Fission. Fission is common in desmids, diatoms and other unicellular algae. The cell divides mitotically into two, the cells are separated by septum formation.

(iii) Bulbils or Tubers. Tubers are spherical or globular bodies formed on lower nodes and rhizoids in *Chara*. Tubers are formed due to storage of food. On detachment from parent plant, these develop into new plants.

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

(v) Hormogonia. This method found in blue green algae like *Nostoc*, *Cylindrospermum*, the main filament breaks into small fragments of varying length called hormogonia. The hormogonia may be formed at the place of heterocyst in the filaments.

(vi) Budding. In *Protosiphon* budding takes place due to proliferation of vesicles. The buds detach to make new thalli.

(vii) Amylum stars : A star shaped aggregation of starch containing cells develop on the flower node of *chara* when it detached from thallus, develops into new plant.

(B) Asexual Reproduction

Asexual reproduction takes place with the help of some spores and structures. Fertilization and fusion of nuclei does not take place. The reproduction takes place only by protoplasm of the cell. Different methods of asexual reproduction are :

(i) Zoospores. The zoospores are flagellated (motile) asexual structures. The zoospores are formed in reproductive body the **zoosporangium**. The zoospores can be biflagellate *e.g.*, *Chlamydomonas*, biflagellate and quadriflagellate *e.g.*, *Ulothrix*, *Cladophora*, multiflagellate *e.g.*, *Oedogonium*. Zoospores move in water before they germinate to make new plants. Zoospores are normally formed under favourable conditions. In *Vaucheria*, a compound zoospore called **synzoospore** is formed.

(ii) Akinetes. The akinetes are formed under unfavourable conditions as method of perennation. The akinetes are thick walled, non-motile structures like aplanospores. Akinetes, on release, form new thalli. *e.g., Anabaena, Gloeotri chia.*

(iii) Aplanospores. Aplanospores are formed under unfavourable conditions. Aplanospores are non motile structures, in which protoplasm gets surrounded by thin cell wall. The aplanospores on release form new plants. *e.g., Ulothrix, Microspora.*

(iv) Tetraspores. Tetraspores are non-motile spores formed in some members of Rhodophyceae and Phaeophyceae. In *Polysiphonia*, tetraspores are formed in tetrasporangia by reduction division on special tetrasporophytic plants.

(v) Autospores. The autospores are aplanospores like structures. These are similar to the parent cell. In *Chlorella, Scenedesmus,* autospores aquire all characteristics of parent cells before their discharge from sporangium.

(vi) Hypnospores. Hypnospores are thick walled structures. These are formed during unfavourable conditions. Under prolonged unfavourable conditions, the protoplasm of hypnospores divides to make cysts. The cysts are capable of forming new thallus. *e.g., Chlamydomonas nivalis.*

(vii) Exospores : In some algae, spores are regularly cut off a exposed distal end of the protoples and develop into new plant. eg. *Chameosphon.*

(C) Sexual Reproduction

All algae except the class of **cyanophyceae** reproduce sexually.

Sexual reproduction takes place by fusion of gametes of different sexuality. The gametes are formed in gametangia by simple mitotic division or by reduction division. The haploid gametes fertilize to make diploid zygote. Depending upon morphological and physiological characteristics of gametes, sexual reproduction can be of the following types :

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

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

(iii) Oogamy. It is the most advanced type of sexual reproduction. The motile male gametes or microgametes are formed in antheridia. The female gamete is large, usually one and formed in female structure **oogonium.** During fertilization the male gametes reach oogonium to fertilize egg and a dipolid zygote is formed. *e.g., Chlamydomonas, Vaucheria, Chara, Polysiphonia etc.*

(iv) Autogamy. In autogamy two gametes of same mother cell fuse to form diploid zygote. Since both gametes are formed by same cell there is no genetic recombination *e.g., Amphora norman* (diatom).

(v) Hologamy. In hologamy the unicellular thallus of opposite strains (–) and (+) behaves as gametes directly. The thalli fuse to make diploid zygote *e.g., Chlamydomonas.*

• COMPARISON BETWEEN ALGAE AND FUNGI

(a) Similarities

(i) Both algae and fungi are thallophytic cryptogams of plant kingdom. *i.e.*, the plant body is not differentiated into root, stem and leaves.

(ii) Vascular tissue system is absent in both group.

(iii) Algae and fungi both reproduce mainly by formation of spores.

(iv) The sex organs are not bounded by a jacket layer.

(v) Symbiotic members are present in both group.

(b) Dissimilarities

(i) Algae mostly grow in sun light and are aquatic while fungi grow in damp shady places and mostly terretrial.

(ii) Algae contain chlorophyll in the cells hence algae are **autotrophic. Th** manufacture their own food. Fungi do not contain pigments like chlorophyll! Hen fungi are **heterotrophic**, they do not manufacture their own food. Fungi are eith saprophytic or parasitic.

(iii) Algal cell wall mainly consists of cellulose and fungal cell wall is made of chit and **fungal cellulose.**

(iv) In algae cells are usually uninucleate while in fungi they may be bi multinucleate.

(v) In algal cells the reserve food material is mainly **starch**. In fungal cells t reserve food material is mainly **glycogen** and **oil**.

(vi) In algae sexual reproduction is simple in lower member and complex advanced forms while in fungi sexual reproduction is complex in lower forms a simple in advanced forms.

• ALGAE AND BRYOPHYTES

Bryophytes are most primitive land plants. Most biologist is believe that bryophyt are originated from algae due to following similarities.

(a) Similarities :

(i) In algae and bryophytes both the plant body is a thalloid *i.e.*, not differentiat into root, stem and leaves.

(ii) The cells in algae and bryophytes both contain pigment chlorophyll, they c manufacture their own food. Plants are autotrophic.

(iii) Vascular organs are absent in both groups.

(iv) Both algae and bryophytes reproduce with the help of spores.

(v) In both cases the cell wall is made up of cellulose.

(vi) The reserve food material is **starch.**

Despite of these similarities both groups have some dissimilarities as well.

(b) Dissimilarities :

(i) Algae are mostly aquatic (fresh water or marine). Bryophytes are mair terrestrial. However, only few bryophytes are aquatic.

(ii) In algae plant body may be unicellular or multicellular does not have pores stomata. In Bryophytes, plant body is multicellular and pores or stomata are present body.

(iii) In algae scales are absent on plant body, while bryophytes may have scales surface.

(iv) In algae the reproduction is vegetative, asexual and sexual. In bryophytes t reproduction is vegetative and sexual only.

(v) Every cell is capable of growth and reproduction in algae while in bryphytes or optical cells are capable to grow.

(vi) In algae the sex organs are not surrounded by jacket layer, while in bryophyt the sex organs are surrounded by jacket layer.

• IMPORTANT QUESTIONS

Long Answer Type Questions :

1. What are algae ? Give characteristics of algae.
2. What are main places of occurrence of algae ?
3. Write short note on methods of vegetative and asexual reproduction in algae.
4. What are similarities and dissimilarities between algae and fungi ?
5. What are similarities and dissimilarities between algae and bryophytes ?

Short Answer Type Questions :

1. Write two similarities between algae and fungi.
2. Write two similarities between algae and bryophytes.
3. Write two differences between algae and fungi.
4. Write two differences between algae and bryophytes.
5. Name some marine forms of algae.
6. Differentiate isogamy and anisogamy.
7. Differentiate zoospores and aplanospores.
8. Write short note on flagella in algae.

Objective Type Questions :

1. Name the book of algae written by **F.E. Fritsch (1935).**
2. Name one parasitic algae
3. Name some symbiotic algae.
4. What are acronematic type of flagella ?
5. What are panotenematic type of flagella ?
6. Name any non-motile unicellular algae.
7. Define planktons.
8. What is botanical name of 'Irish moss" ?
9. Which algae are commonly called 'kelps' ?
10. Algae of which class are called diatoms ?
11. Which is the reserve food of algae ?
12. Who is father of Algae?
13. Name any famous Indian algologist.
14. What are thermal algae ?

Multiple Choice Questions :

1. In algae and fungi sex organs are :
   (a) With jacket layer (b) Without jacket layers
   (c) Can be with or without jacket layer (d) have two jacket layers
2. In thalophytes :
   (a) The plant body is highly differentiated
   (b) Not differentiated into root, stem and leaves
   (c) Roots are present but stem and leaves are lacking
   (d) None of these
3. Algae and bryophytes are both :
   (a) Photosynthetic thallophytes (b) None photosynthetic thallophytes
   (c) Occassionally photynthetic allophytes (d) All of these

ANSWERS

Objective Type Questions :

1. The structure and reproduction of algae **2.** *Cephaleuros*
3. *Nostoc, Anabaena* **4.** Flagella are smooth
5. Mastigonemes are arranged in two opposite rows or radially
6. *Chlorella*
7. Microorganisms floating freely on surface water of oceans, lakes, seas and rivers etc.
8. *Chondrus crispus* **9.** *Laminaria* **10.** Bacillariophyceae
11. Starch **12.** F.E. Fritsch **13.** Prof. R.N. Singh
14. Algae growing in high temperature e.g., same of members of Mixophyceae.

Multiple Choice Questions :

1. (b) 2. (b) 3. (a)

2

RANGE OF THALLUS ORGANISATION IN ALGAE

STRUCTURE

• INTRODUCTION

In Algae range of thallus organisation shows a great variation. Vegetative structure of different algal members occurs from primitive microscopic unicellular (> 1 μm in diameter) form to macroscopic multicellular forms (e.g., *Laminaria*).

In Algae the plant body is always a thallus. It is not differentiated in root, stem and leaves. Their forms may be colonial (loose or integrated by inter-connections of protoplasmic strands), filamentous (branched or unbranched), septate (branched or unbranched), non-septate or branched, multinucleate siphonaceous tube where the nuclear divisions occur without usual septa formation.

Structural and cellular organizations are important characters that help in the classification of algae and in establishing the inter-relationship among them. Similarities of some morphological structures are seen among various classes of algae. The unicellular types which are seen in all groups of algae except the brown algae, are considered to be the basic type from which, through evolution, other types of thalli have developed.

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

1. Unicellular

   Motile and non-motile

2. Aggregates

   Palmelloid and Dendroid

3. Colonial

   (a) Colony motile

   (b) Colony non-motile

4. Filamentous

   (a) Unbranched

   (b) Branched

      (i) Simple

      (ii) Heterotrichous

      (iii) Pseudoparenchymatous.

5. Parenchymatous.
6. Siphonaceous.

• UNICELLULAR TYPE

The unicellular types are simplest forms seen in all groups of algae with the exception of the class Phaeophyceae. The unicellular types may be amoeboid motile or non-motile, the motility being due to the movement of the flagella attached at the anterior end. The number of flagella may be one or more, usually two or in multiples of two. The cells may have a rigid cellulose cell-wall or the outer layer of the protoplast forms the 'periplast' giving a definite shape to the cell or may allow changes in shape (rhizopodial or amoeboid type).

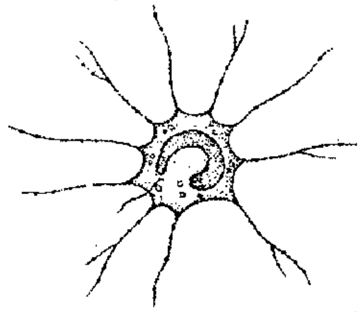


Fig. 1. *Chrysamoeba*. Unicellular amoeboid form

(a) Unicellular amoeboid forms or rhizopodial forms

These algae lack flagella, the organs of motion, but are able to perform amoeboid movement by means of cytoplasmic growth *e.g.*, *Chrysamoeba* (Fig. 1).

(b) Unicellular motile (flagelloid) forms

The unicellular motile forms of algae are the simplest type. The flagellated unicellular forms are seen in various classes of algae. The flagellated unicelled structures are distinctive of certain classes *e.g.*, Euglenineae, Cryptophyceae, Chrysophyceae and Dinophyceae. Flagellated vegetative cells are absent in Cyanophyceae, Phaeophyceae, Rhodophyceae, Bacillariophyceae. Nature of flagellation, type and number of flagella and the attachment of flagella, is an important character in classification. In most of the Chlorophyceae members, the flagella are usually two or in multiples of two in number, equal in size, of whiplash type and attached at the anterior end (Fig. 2).

The unicellular plant body may be spherical, oblong or pear-shaped and sometimes elongated and with a prominent chloroplast. In some cases, the plant body proper and peripheral layer is separated by a space. This envelope is spherical, rigid, variously shaped and is provided with apertures for the protrusion of the flagella. Such types are termed 'encapsuled' *e.g.*, *Haematococcus* etc. The common examples of unicellular flagellated forms are *Chlamydomonas*, *Chlorogonium*, (Chlorophyceae), *Ochromonas*, *Chromulina* (Chrysophyceae) etc.

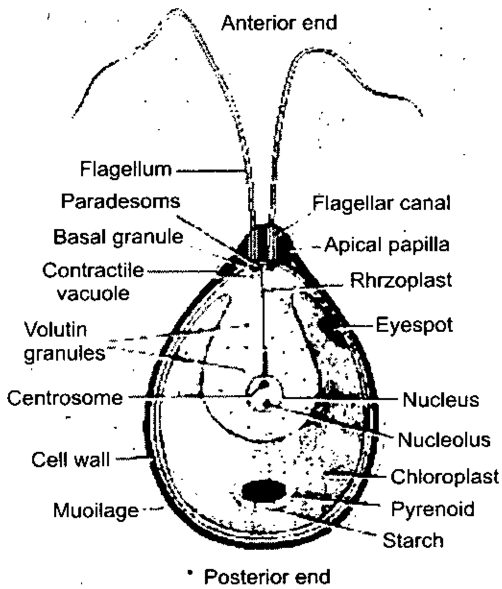


Fig. 2. *Chlamydomonas*. Unicellular Flagellated forms

The unicellular flagellated forms can be 'naked' and 'encapsuled' *e.g.*, *Cryptomonas, Euglena* (naked), and *Chrysococcus* (encapsuled). A feature common with the motile of flagellated forms is the presence of eye-spot (stigma).

(c) Unicellular Non-motile (Protococcoidal) Forms

Unicellular non-flagellated forms show many morphological variations *e.g.*, Bacillariophyceae (Diatoms), in many Chlorophyceae (*Chlorella, Cosmarium*) Cyanophyceae (*Synechococcus*), and in some forms of Xanthophyceae, Dinophyceae and Rhodophyceae (*Porphyridium*). They are simple spherical or elongated cells *e.g.*, *Microcystis, Cylindrocystis, Pinnularia* (Bacillariophyceae); triangular as i *Tetragonidium* (Cryptophyceae) and *Triceratium* (Bacillariophyceae). The epiphytic o attached forms have a basal disc (Fig. 3).

Cell-wall ornamentations of various types may occur due to the poroid nature of their siliceous wall *e.g.*, in the Desmids (Conjugales), they are in the form of ribs, spines or warts and more complex among the Diatoms (Bacillariophyceae).

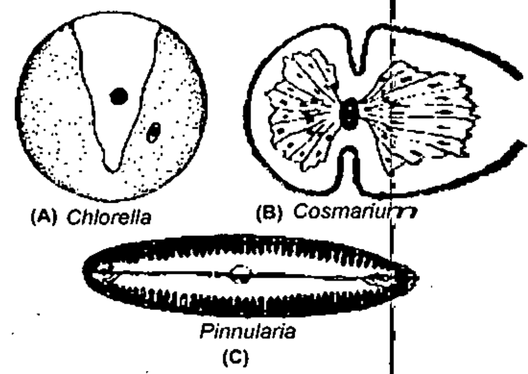


Fig. 3. Various. Non-motile Unicellular forms

Usually non-flagellated, various diatoms various be motile by the extrusion of mucilage through the pores, some Desmids and Cyanophycean members also show slight motility.

During a period of rest in the change over from vegetative phase to reproductive phase. A very large number of cases the motile flagellated types, at times, lose their flagella and become non-motile. This feature get further elaborated in many forms where the vegetative phase is completely non-motile They are motile in the reproductive phase only. Such developments ultimately lead t palmelloid, dendroid and coccoid forms.

• AGGREGATES

Aggregates are formed by the assemblage of many single cells to make thallus Unlike the coenobium the aggregation of cells do not have fixed number of cells shape c size. The cells are aggregated into more or less irregular colony like mass. When th cells divide, the daugther cells remain in same gelatinous mass. Thus there is increas in the number of cells after division. The agregates can be **palmelloid, dendroid an rhizopodial** types.

(a) Palmelloid Habit

In various genera this habit is a permanent one *e.g.*, *Tetraspora* (Chlorophyceae *Phaeocystis* (Chrysophyceae) or is a temporary phase, in the life-cycle *e.g* *Chlamydomonas* (Chlorophyceae) *Chromulina*, (Chrysophyceae). The habit is name after the genus *Palmella* (Palmellaceae, Chlorophyceae) (Fig. 4). The individua non-flagellated cells have mucilaginous sheaths around them and are enveloped in common gelatinous matrix of indefinite shape which may be microscopic or macroscop

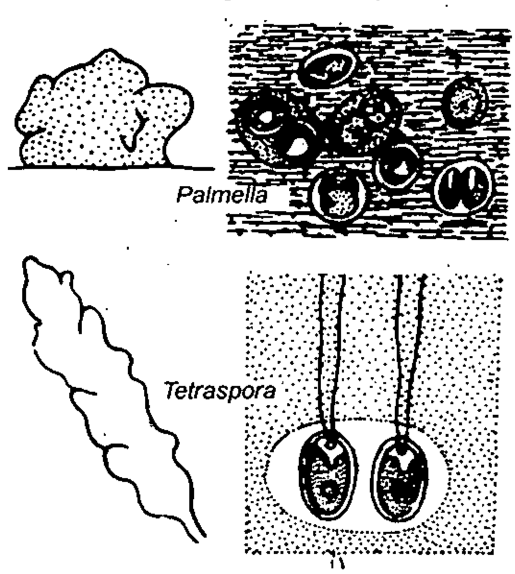


Fig. 4. Different Palmelloid forms

n size. Such 'colony' like or 'filamentous' structures (*e.g.*, *Hydrorus*) in which the individual cells are loosely aggregated in a common gelatinous matrix and behave independently, are termed Palmelloid. ('Palmelloid-stage' means temporary phase and 'palmelloid-habit' or 'palmelloid-form' denotes permanent habit).

(b) Dendroid forms

The palmelloid condition develops some variation in the form of dendroid colonies. Here the mucilage is produced locally, generally at the base of the cell. This polarity differentiates the two habits. Dendroid forms are seen *e.g.* *Prasinocladus* (Chlorophyceae), *Mischococcus* (Xanthophyceae) and in Chrysophyceae and Euglenineae (Fig. 5 A, B).

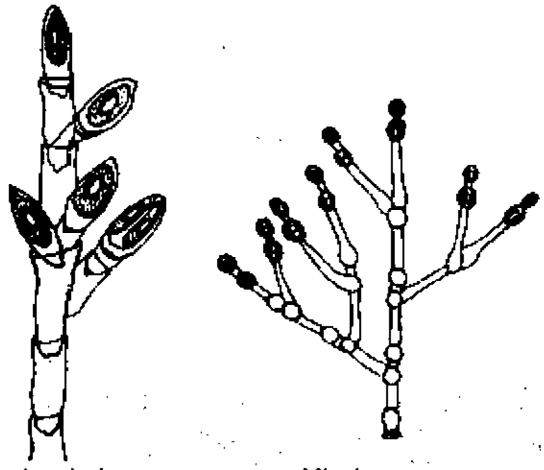


Fig. 5 (A–B). Different Dendroid forms

(c) Rhizopodial forms

Various amoeboid cells formed together by cytoplasmic projections give the shape of roots or rhizoids *e.g.*, in *Chrysidiostum* (Chrysophyceae).

• COLONIAL FORMS

During evolution of the unicellular types from occasional and indefinite type of colony like structures—with independent individual cells inside it to a well defined colony with interlinks among the cells results in a true **colonial habit**. Here varying numbers of unicells aggregate together in different ways, often within a mucous envelope. Colonial forms are seen among Chlorophyceae, Chrysophyceae, Bacillariophyceae, Dinophyceae, Xanthophyceae etc. The colony may be (a) motile or (b) non-motile type.

(a) Motile colonial forms

Here cells aggregate together to form motile colonies of various shape and size. The movement of the colony is effected by the conjoint and uniform flagellar action by all the cells. In Chlorophyceae, the colony is made up of *Chlamydomonas* like cells and the cells are arranged just below the mucilaginous surface. The colonies are either "plate-like" (*e.g.*, *Gonium*) or spherical (*e.g.*, *Volvox*). The cells may be connected by cytoplasmic strands. (*e.g.*, *Volvox*). Though in the majority of cases all the individual cells are alike, a few forms have some larger cells for reproductive functions; the rest of the cells being purely vegetative (*e.g.*, *Volvox*) (Fig. 6). Mostly they are **coenobia** (sing. **coenobium**) *i.e.*, colonies composed of definite number of cells arranged in a defined manner.

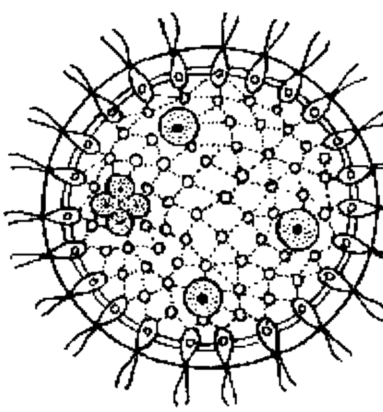


Fig. 6. *Volvox*. Motile colonies

Hence, a clear advancement in the organization of the thallus is seen in the sequence gradually from unicellular motile types to aggregates in a colony with a regular pattern, where the cells are inter-connected and behave as a single unit (multicellular organism).

(b) Non-motile colony

Aggregation of non-motile cells in the form of a colony (non-motile) are commo in Chlorophyceae, where cells are, more or less, fused together (*e.g.*, *Hydrodicty* connected by mucilaginous threads (*e.g.*, *Dictyosphaerium*) and the colony may various shapes (Fig. 7) *e.g.*, *Scenedesmus* or net-like as in *Hydrodictyon.*

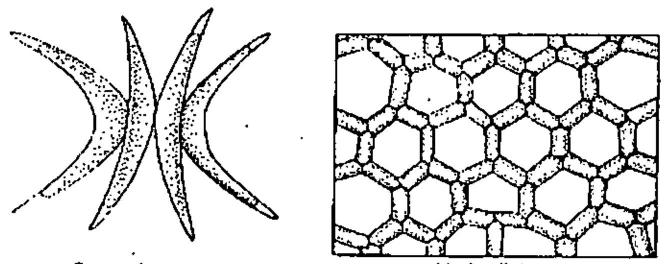


Fig. 7. Different. Non-motile colonies

• FILAMENTOUS FORMS

Colony from further developed into a more closely knit structure, *i.e.*, the divis the single cell into many daughter cells with septa between the divided cell common lateral walls derived from the mother cell. If the plane of cell divis transverse to the long axis of the thallus *i.e.*, elongation followed by divis filamentous type of construction would be formed. This type of multicellular th organization is, common to most of the algae which may be branched or unbranc

Unbranched Filaments

Simple unbranched filaments are found in many forms. They are either free- *e.g.*, *Spirogyra* or attached, at least initially *e.g.*, *Oedogonium* (Fig. 9 A), or aggre in colonies *e.g.*, *Nostoc* (Fig. 8 B). The most simple type of filament construction is seen among Ulotrichales. The filament is the most elementary type of thallus as seen in genera *Ulothrix*, *Spirogyra* (Chlorophyceae) (Fig. 9 A,C), *Tribonema* (Xanthophyceae), *Nematochrysis* (Chrysophyceae). In many Cyanophyceae it consists merely of a row of cells connected closely (*e.g.*, *Oscillatoria*) (Fig. 8 A). In the simpler forms *e.g.*, *Ulothrix*, *Spirogyra*, there is no division of labour. All cells are alike, structurally and functionally, may take part in growth and cell division and in reproduction. The cells of filaments may be uninucleate (*e.g.*, *Spirogyra*) or multinucleate (*e.g.*, *Cladophora*).

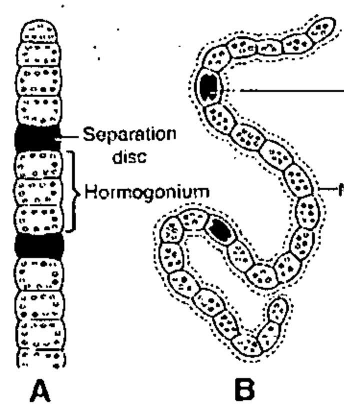
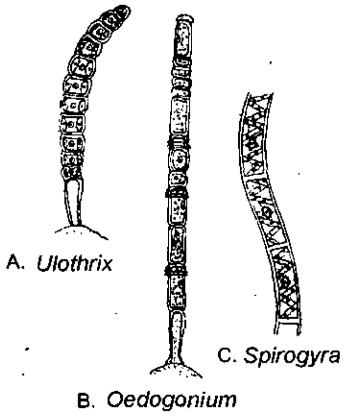


Fig. 8. Thallus organization. Unbranc filaments. A. *Oscillatoria*, B. *Nosto*

Branched Filaments

Branched filamentous structures may be categorised as—(i) Simple Heterotrichous and (iii) Pseudoparenchymatous according to the shape and nat the thalli.

(i) Branched Simple : A simple branched filament with single row of cells basal attaching cell, holdfast or hapteron is common with many types *e.g.*, *Ulc* *Oedogonium* (Fig. 9). In many, the branches arise immediately below the cross and the growth and divisions are restricted to the end-cells of the branche *Cladophora* (Fig. 10A). Simple branched filaments are also seen in Xanthoph Chrysophyceae. A peculiar form of branching, known as 'false'-branching is fou Cyanophyceae *e.g.*, *Scytonema* (Fig. 10B).



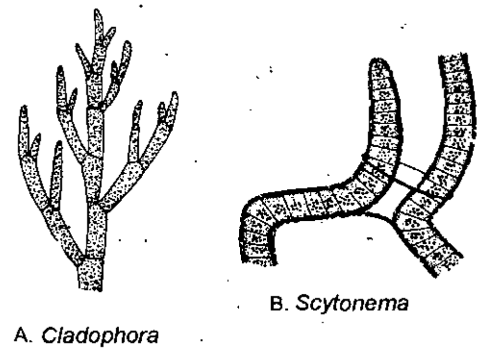


Fig. 9. Different Unbranched filaments **Fig. 10. Different Branched filamentous form.**

(ii) Heterotrichous : This is most highly evolved type of plant-body, showing a ood amount of division of labour. This is characteristic of the Chaetophorales among hlorophyceae, in many Phaeophyceae, Rhodophyceae, in some Chrysophyceae and inophyceae (*e.g.*, *Dinoclonium*). The plant-body consists of two distinct parts; (1) a asal or prostrate creeping system, and (2) an erect or upright system. The prostrate ystem is attached to some substratum, grows apically and gives rise to numerous hotosynthetic and rhizoidal filaments. Rhizoidal filaments sometimes penetrate the ubstratum (*e.g.*, *Fritschiella*) (Fig. 11A). The erect system, develops from the prostrate ystem and is composed of one or more and usually branched photosynthetic filaments. n *Stigeoclonium* and *Trentepohlia* (Fig. 11) these two systems are equally developed nd easily distinguished. Whereas in *Coleochaete* (Chlorophyceae) (Fig. 11 C) and *scocyclus* (Phaeophyceae) the prostrate system is highly elaborated and the erect ystem is reduced. This gives the body a discoid type of appearance. On the other hand, n *Draparnaldiopsis* (Chlorophyceae), in many species of *Ectocarpus* (Fig. 11 C), the rostrate system is reduced, and the erect system is well developed. This gives the body crust or cushion type of appearance. In endophytic species, *Endoderia* and in *haetopeltis* (Chlorophyceae) only prostrate system is developed while complete bsence of prostrate system is noticed in *Microthamnion*, and a comparable condition n *Drapanaldiopsis* (Chlorophyceae), *Sphacelaria* (Phaeophyceae) and *Batrachospermum* Rhodophyceae).

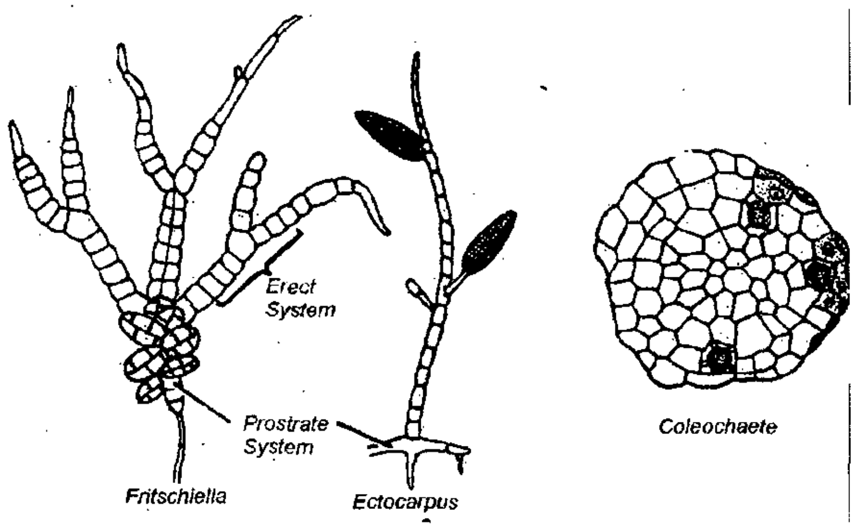


Fig. 11. Different Heterotrichous forms of Algae

The production of thread-like structures from the cells of the multicellular thallus cortication) is a method of increasing rigidity among many Phaeophyceae and hodophyceae and in some members of Chlorophyceae (*e.g.*, *Draparnaldiopsis*).

(iii) Pseudoparenchymatous forms : The term 'pseudo' means false. In algae the plant body gives the appearance of parenchymatous construc Parenchyma is a tissue composed of thin walled closely associated cells which arisen by the division of a common parent cell. Whereas the pseudoparenchyma structure is a secondary development, close association of cells is a resu interweaving of filaments. Through the establishment of secondary interce connections the cells of pseudoparenchymatous algae may be densely packed firmly coherent (*e.g.*, *Dumontia*, Rhodophyceae) or, the association may be loose an component filaments can easily be separated by pressure (*e.g.*, *Cast* Phaeophyceae). Two types of the pseudoparenchymatous thallus are recognised body may have (1) a single colourless central axial filament (uniaxial constructio (2) many filaments (multiaxial) around which photosynthetic filaments are suppo The uniaxial construction in simple form showing clearly the filamentous natu seen in *Batrachospermum* (Fig. 12). Uniaxial pseudoparenchymatous types are seen in Dasycladaceae (Chlorophyceae) and in Phaeophyceae (*e.g.*, *Spermatochnus* in *Polysiphonia* (Rhodophyceae, Fig. 13). Multiaxial construction is seen in Codi (Chlorophyceae) and in many Ectocarpales (Phaeophyceae). Such type constructions can be traced to a primary heterotrichous condition in the ontogeny o thallus, where one or many threads uni- or multi- of the erect system develop i mature thallus.

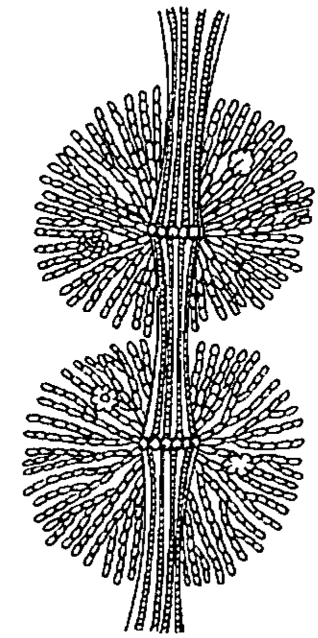


Fig. 12. Pseudoparenchymatous forms in *Batrachospermum*

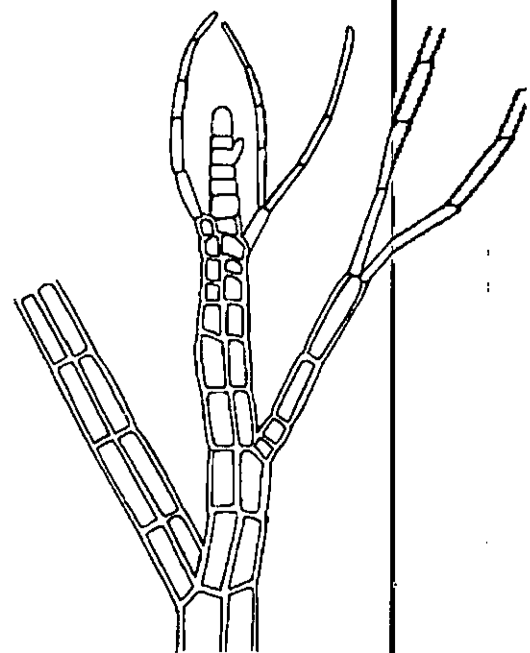


Fig. 13. Pseudoparenchymatous forms *Polysiphonia*

Secondary filamentous structures also develop in many genera either externa internally. Such internal filaments by close association give a solid core like stru in many forms. Secondary external filaments (cortication) in many cases increas thickness of the primary thallus (*e.g.*, *Desmarestia*). Besides giving rigidity to the they play a considerable role in the formation of attaching discs (Fucales) and brar haptera (Laminariales) in many parenchymatous forms (Fig. 13).

• PARENCHYMATOUS FORMS

Parenchymatous thallus organization is a modification of the filamentous h with cell division in more than one plane. Depending upon the nature of cell div the parenchymatous thalli may be 'leaf-like' or foliose *e.g.*, *Utva* (Fig. 14 A), tubul highly developed structure *e.g.*, *Sargassum* (Fig. 14 B).

Flat, foliose or tubular thalli are formed by the division of the cells two or three planes. Common examples of flat and foliose structures in *Ulva* (Chlorophyceae), *Punctaria* (Phaeophyceae) and *Porphyra* (Rhodophyceae).

The example of tubular structure is *Enteromorpha* (Chlorophyceae). In some phaeophyceae *e.g.*, in Ectocarpales and Sphacelariales, the parenchymatous form develops by abundant separation of primary filament. In Phaeophyceae (*e.g.*, *Sargassum*) cells of the thallus are differentiated into central **medulla**, middle **cortex** and outer **merisloderm.**

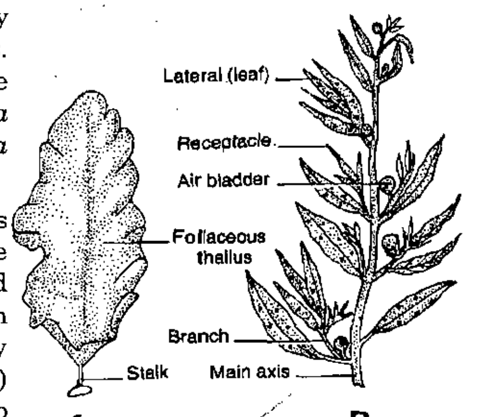


Fig. 14 (A, B). Parenchymatous forms

• SIPHONACEOUS FORMS

In various algae belonging to Siphonales *e.g.*, in *Vaucheria, Botrydium*, the growth of the plant body takes place without the usual cross-wall formation except during formation of reproductive organs. So a 'tube'-like multinucleate structure, or a **coenocyte**, is formed. This structure is interpreted as a multinucleate or coenocytic cell by some and as acellular by others. The simplest organization is in the form of a small unbranched vesicle. It contains a central vacuole with chloroplasts and nuclei in the peripheral cytoplasm. It is anchored by branching rhizoids (*e.g.*, *Botrydium*, Fig. 15B). An irregular branching system with rhizoids or haptera and occasional septa formation in cutting off old siphons and reproductive organs is found in *Vaucheria* (Fig. 15A). In other Siphonales, two basic patterns are seen. In one the siphon has become increasingly large and branched (*e.g.*, *Caulerpa*) and the other is an intricate system of interwoven vesicles and tubes (*e.g.*, *Codium*). Most of the tropical Siphonales are calcified which, provides the mechanical support to the thallus (*e.g.*, *Halimeda*).

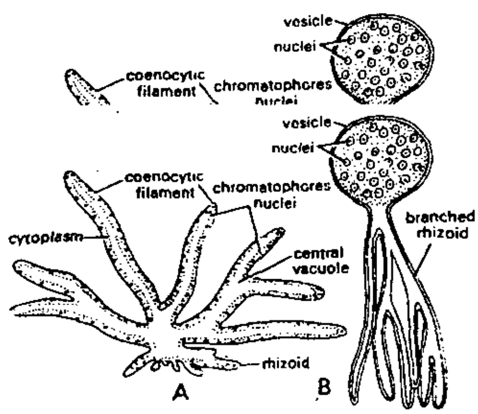


Fig. 15. (A, B). Siphonaceous forms. (A) *Vaucheria*, (B) *Botrydium*.

• IMPORTANT QUESTIONS

Long Answer Type Questions :

1. Explain in detail of range of thallus organization in Chlorophyceae.
2. Give a detailed account of range of thallus organization in algae.

Short Answer Type Questions :

1. Write note on siphonaceous forms.
2. Write note on heterotrichous habit.
3. Write note on parenchymatous forms.
4. Differentiate between siphonaceous and filamentous thallus.
5. Define coenobium.
6. Define coccoid habit.
7. Differentiate aggregates from colonies.
8. Give example of siphonaceous thallus.

Objective Type Questions :

1. Name any non-motile unicellular algae.
2. Palmelloid forms are named after which genus of algae.
3. What do you understand by dendroid forms ?
4. Name any also which show siphonaceous habit.
5. Name the algae in which cells are differentiated into medulla, cortex and meristoderm.
6. In which algae false branching is present ?
7. Name an example of non-motile colony of algae.
8. Name the group of algae that take part in the nitrogen fixation is soil.
9. Name an algae which shows multiaxial construction of plant body?
10. Define Heterotrichy.

Multiple Choice Questions :

1. Cynobacterial cell posses :
   (a) Definite nucleus and plastid
   (b) Definite nucleus but not plastid
   (c) Definite plastid but no definite ucleus
   (d) Neither definite plasid nor definite nucleus
2. In Cynobacteria, the cell around the nuceoid is called :-
   (a) Centrosome (b) Nucleoplasm
   (b) Centroplasm (d) Chromoplasm
3. In Cyanobacterial cell, flagella are :
   (a) present (b) absent
   (c) present in asexual spores (d) formed only in gametes
4. The term Cyanobacteria is applied to :
   (a) Photosynthetic bacteria (b) Nitrogen fixing bacteria
   (c) Blue green algae (d) Yeast

ANSWERS

1. *Chlorella* 2. *Palmella* 3. *Three types* 4. *Vaucheria, Botrydium*
5. *Sargassum.* 6. *Sytonema* 7. *Hydrodictyon* 8. Cyanophyceae
9. *Polysiphonia*
10. Having rhizoidal and photosynthetic branches is called heterotrichy.

Multiple Choice Questions :

1. (d) 2. (c) 3. (b) 4. (c)

3

CLASSIFICATION OF ALGAE

STRUCTURE

• INTRODUCTION

The classification of algae initially was based on the photosynthetic pigments as-green algae, red algae, broun algae and blue-green algae. Algae contain different types of pigments *e.g.*, chlorophylls, xanthophylls and phycobilins. Different classes of algae have different characteristic colours due to these pigments. Algae were first divided on the basis of colour by **Robert Brown** in groups such as Chlorospermae, Rhodospermae, and Melanospermae.

With the advancement in the field of biochemistry, physiology, culture techniques and electron microscopy, other characteristics other than pigment have been used for the classification of algae. The modern concepts of classification of algae are based on the following criteria :

1. Nuclear organization
2. Nature of cell wall components
3. Pigments and photosynthetic apparatus
4. Flagellation
5. Nature of reserve food
6. Type of life cycle and reproduction

• NUCLEAR ORGANIZATION

On the basis of nuclear organization algae can be **prokaryotic** or **eukaryotic.** Members of **Cyanophyceae** or blue green algae are not true algae but are prokaryotic in nature whereas all other classes of algae are eukaryotic. In prokaryotic *e.g.*, Cyanophyceae—nucleus is not organized as nuclear membrane is absent. DNA fibrils are free in nucleoplasm and are not associated with histones. Cell division by mitosis and meiosis is not observed. Membrane bound cell organelle like chloroplast, mitochondria and ER are also absent. Whereas eukaryotic algae have well differentiated nucleus, mitochondria, chloroplast and endoplasmic reticulum in their cell structure.

• NATURE OF CELL WALL COMPONENTS

The cell wall in algae is generally made up of polysaccharides (mainly cellulose). some cases lipids and proteins are also present in them. The inner layer of cell wall algae is generally made up of cellulose, which is insoluble polysaccharide and the outer layer is made of pectic substances.

The cell wall in Chlorophyceae is made up of cellulose. In Xanthophyceae pectic substance is more common. In Chrysophyceae cell wall is non-cellulosic which is silicified or calcified. In Phaeophyceae cell wall contains alginic acid and fucinic acid. In Rhodophyceae the cell wall is made of non-cellulosic polysaccharides like xylans and galactans. Whereas in Cyanophyceae or blue green algae the cell wall is more like bacteria and is made up of mucopeptides.

• PIGMENTATION AND PHOTOSYNTHETIC APPARATUS

One of the most important criteria used in differentiation of classes in algae is pigment present in the thallus, as algae were initially and primarily separated on the basis of colour *e.g.*, green algae, red algae, brown algae or blue-green algae. The pigments in algae can be chlorophylls, carotenoids and biliproteins.

These pigments are present in sac like structures called thylakoids. The thylakoids are arranged in stacks in granum of the chloroplasts. Different groups of algae have different types of pigments and organization of thylakoids in chloroplast.

Chlorophylls

The chlorophylls in algae are chlorophyll a, b, c, d and e types.

Chlorophyll a is present in all classes of algae.

Chlorophyll b is primary pigment of Chlorophyceae and Euglenineae.

Chlorophyll c is found in Phaeophyceae and Cryptophyceae.

Chlorophyll d is found in Rhodophyceae.

Chlorophyll e is confined to *Tribonema* of Xanthophyceae.

Carotenoids

Carotenoids are as essential component of all photosynthesis organisms.

The carotenoids are of two kinds : Carotenes (pure hydrocarbons) and Xanthophylls (are derivatives that contain one or more oxygen function).

Among the carotenoids, β carotene is found in all classes of algae.

∝ Carotene is found in Rhodophyceae.

γ Carotene and lycopene are found in Chlorophyceae.

e Carotene is present in Bacillariophyceae.

There are about 20 types of xanthophylls commonly found in algae *e.g.*, neoxanthin, neofucoxanthin, fucoxanthin, chaetoxanthin, siphonoxanthin, violaxanthin, oscillatoxanthin. As these lutein xanthophylls are restricted to certain classes, these xanthophylls are important diagnostic characteristics of algae.

Biliproteins

These are water soluble pigments and can be phycocyanin, phycoerythrin and allophycocyanin. These are common only in **Rhodophyceae** and **Cyanophyceae**.

In Rhodophyceae, R-phycoerythrin is the chief pigment and in Cyanophyceae, C-phycocyanin is the chief pigment.

The chromatophores of different classes of algae differ in number of thylakoids per granum. In Chlorophyceae there are 2–6 thylakoids per granum and the pyrenoids are covered with starch plates.

In Xanthophyceae, Phaeophyceae and Bacillariophyceae there are 3 thylakoids per granum and pyrenoids are without starch plates.

In Rhodophyceae thylakoids are single and widely separated in chromatophores and pyrenoids are naked. While in Cyanophyceae the thylakoids are free in cytoplasm as chloroplasts are not found and pyrenoids are also absent.

• FLAGELLATION

The type, number and position of flagella are important basis for classification of algae. (Fig. 1. A-D).

In Cyanophyceae and Rhodophyceae flagella are completely absent in vegetative and reproductive structures. In all other classes the basic flagellar structure is similar. The flagella show 9 + 2 pattern of component fibrils arrangement.

The flagella can be acronematic (Fig. 2B) or whiplash, pleuronematic or tinsel and prasionate.

In Chlorophyceae flagella are 2 (Fig. 2A), 4 or indefinite in number, apical or sub-apical in position and acronematic type *i.e.*, **isokontic.**

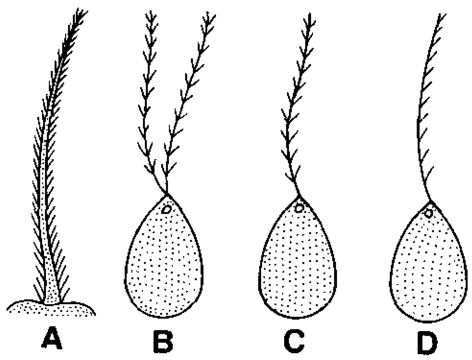


Fig. 1 (A–D). Flageltation in algae. (A) Pleuronematic flagellum with *mastigonemes*, (B) Cell with two equal pantonematic flagella, (C) Pantacronematic flagellum, (D) Stichonematic flagellum.

In Xanthophyceae flagella are two, unequal apical one acronematic and one pantonematic *i.e.*, **heterokontic.**

In Phaeophyceae flagella are two lateral, one acronematic and one pantonematic and unequal in size. In Prasinophyceae, prasionate type flagella are found. These are pantonematic and covered by minute hairs (mastigonemes).

• NATURE OF RESERVE FOOD

The primary product of photosynthesis *i.e.*, starch is same in all groups of algae but due to accumulation of food over long period the nature of insoluble reserve food may be different. The nature of reserve food can be a criterion for distinction of different groups of algae.

In Chlorophyceae the reserve food is **starch.** In Xanthophyceae **oil** and **leucosine** are reserve food material. In Rhodophyceae **rhodophycean** or **floridean starch** and in Cyanophyceae **myxophycean starch** are the reserve foods. In Phaeophyceae the reserve food material is **laminarin** or **mannitol.**

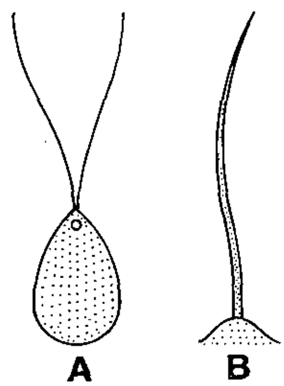


Fig. 2. (A) Equal, biflagellate, acronematic flagella, (B) Single acronematic flagellum.

• TYPE OF LIFE CYCLE AND REPRODUCTION

The presence or absence of sexual reproduction, complexity of reproductive organs, method of sexual reproduction *i.e.*, isogamy, anisogamy and oogamy are important criteria of classification in algae. **Haplontic life cycle, diplontic life cycle** and **triphasic life cycles** are characteristic of different groups. For example, sexual reproduction is completely absent in Cyanophyceae. In Chlorophyceae the reproduction can be isogamous, anisogamous and oogamous, the life cycle can be simple or complex. The reproduction is oogamous and life cycles are usually complex in Rhodophyceae and Phaeophyceae.

Table 1. Diagnostic Features of Different Classes of Algae

Division	Nuclear organization	Cell wall	Photo-synthetic apparatus	Storage product	Flagella-tion	Pigments
Chloro-phyceae	Nucleus with nucleolus, centromeric chromosomes made up of protein and DNA fibrils along with histones protoing.	Cellulosic	Chloroplasts with 2-6 thylakoids in a granum, pyrenoids with starch sheath	True starch	1, 2 or 4 (or more), equal, anterior, acronematic, smooth	Chlorophyll a, b β carotene, lutein
Xantho-phyceae	Similar to Chlorophyceae	Either pectinaceous or cellulosic	Chromatophores with 3 thylakoids in a granum, naked pyrenoids	Oil and leucosin	2, unequal, anterior, 1 acronematic and 1 pantonematic	Chlorophyll a, e, β carotene
Bacillario-phyceae	Similar to Chlorophyceae	Silicified, in two pieces forming valves	Like Xanthophyceae	Leucosin or chrysolamanain	1, anterior, pantonematic	Chlorophyll a, c, β-carotene, Fucoxanthin diatoxanthin
Phaeoph-yceae	Similar to Chlorophyceae	Cellulosic with alginic and fucinic acids	Like Xanthophyceae, pyrenoids naked and projecting	Lamanarin, mannitol and leucosin	2, unequal lateral, 1 acronematic and 1 pantonematic	Chlorophyll a, c, β-carotene, Fucoxanthin violaxanthin
Rhodop-hyceae	Similar to Chlorophyceae	Non cellulosic polysaccharides or with xylan, galactose and xylose, occassionally cellulosic	Chromatophores with single and widely separated thylakoids, naked pyrenoids	Floridean starch, floridioside and galactan sulphate polymers	Absent	Chlorophyll a, d, β-carotene lutein, *r*-phycocyanin, *r*-phycoerythrin
Cyanophy-ceae	Nucleus absent, naked DNA fibrils and not associated with histones, present in nucleoplasm	Mucopolymeric	Chromatophores absent, single thylakoid occurring, pyrenoids absent.	Proteinaceous cyanophycin and cyanophycean starch	Absent	Chlorophyll a, β-carotene, myxoxanthophyll *c*-phycocyanin *c*-phycoerythrin

Classifications of Algae

Important classifications of algae as proposed by some scientists are following :

Fritsch's Classification of Algae

F.E. Fritsch (1935, 1945) in his book **"The Structure and Reproduction of the Algae"** proposed a system of classification of algae. He treated algae giving rank of division and divided it into 11 classes. His classification of algae is mainly based upon characters of pigments, flagella and reserve food material.

Eleven classes proposed by **Fritsch** are as follows :

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

G.M. Smith (1955)

Classified algae into following and divisions and 15 families.

1. **Chlorophyta**
   (i) Chlorophyceae
   (ii) Charophyceae
2. **Euglenophyta**
   (i) Euglenophyceae
3. **Pyrrophyta**
   (i) Desmophyceae
   (ii) Dinophyceae
4. **Chrysophyta**
   (i) Chrysophyceae
   (ii) Xanthophyceae
   (iii) Bacillariophyceae
5. **Phaeophyta**
   (i) Isogenerateae
   (ii) Heterogenerateae
   (iii) Cyclosporae
6. **Cyanophyta**
   (i) Myxophyceae
7. **Rhodophyta**
   (i) Rhodophyceae
8. **Algae of uncertain position**
   (i) Chloromonadales
   (ii) Cryptophyceae

V. J. Chapman (1962) proposed another system of classification of algae based *on pigmentation, biochemical differences are morphological characters* :

1. Euphycophyta
   (a) Charophyceae
   (b) Chlorophyceae
   (c) Phaeophyceae
   (d) Rhodophyceae
2. Myxophycophyceae
   (a) Myxophyceae
3. Chrysophycophyta
   (a) Chrysophyceae
   (b) Xanthophyceae
   (c) Bacillariophyceae
4. Pyrrophycophyta
   (a) Cryptophyceae
   (b) Dinophyceae

Stanier Van Niel (1962), **Christensen** 1962, 64 and **Round** (1965) proposed the latest system for classification of algae. They are other modern algologists gave the classification as follows :

This sub kingdom *Eucaryota* also include other plants—Fungi, Bryophyta, Pteridophyta, Gymnosperms and Angiosperms) and animals.

The Prochlorophyta a novel division has been established by **Lewin** (1976–77) to accommodate certain unicellular green procaryotic algae associated with marine didemined ascidians.

- Living Organisms Kingdom
  - A cellular organisms e.g., virus
  - Cellular organisms
    - Sub-kingdom
      - Procaryota
        - Phylum
          - Schizomycophyta *e.g.*, Bacteria
          - Cyanophyta *e.g.*, Blue green Algae
      - Eucaryota
        - Phylum — Class
          - Chlorophyta — Chlorophyceae (Green algae), Charophyceae
          - Xanthophyta — Xanthophyceae (Yellow algae)
          - Chrysophyta — Chrysophyeae
          - Bacillariophyta- — Bacillarphyceae
          - Pyrophyta — Bacillariphycaeae (Diatoms)
          - Cryptophyta — Pyrrophyceae
          - Euglenophyta — Cryptophyceae
          - Pheophyta — Euglenophyceae
          - Rhodophyta — Phaeophyceae (Brown Algae), Rhodophyceae (Red Algae)

However most of the algologists classify algae into following eight divisions. The classes, order, families of some division are also given.

Division	Class	Order	Example
1. Cyanophyta	1. Cyanophyceae	1. Chlorococcales	
		2. Chamaesiphonales	
		3. Pleurocapsales	
		4. Nsotocates	*e.g.*, *Oscillatoria*
			e.g., *Scytonema*
			e.g., Nostoc
		5. Stigonemtatales	*e.g.*, Rivularia
2. Chlorophyta	1. Chlorophyceae	1. Volvocales	1. Chlamodomonceae
			e.g., Chlamydomonas
			2. Volvocaceae
			e.g., *Volvax*
		2. Chlorococcales	*e.g.*, *Chlorella*
			Hydrodictyon
		3. Ulotricales	*e.g.*, *Ulothrix*
		4. Oedogoniales	e.g., Oedogonium
		5. Cladophoroles	*e.g.*, *Cladophora*
		6. Caetophorales	*e.g.*, *Drapernaidiopsis*
		7. Zygenmales	*e.g.*, *Spirogyra*
		Zygnema	
		8. Siphonales	*e.g.*, Caulerpa

3. Charophyta	2. Charophyceae	1. Charales	*e.g.*, Chara
4. Euglenophyta	Euglenophyceae	Euglenates	*Euglena*
5. Pyrrophyta			
6. Chrysophyta	1. Chrysophyceae	Heterosiphonales	*Vaucheria*
	2. Heterogenerate	fctocarpales	*Ectocarpus*
	3. Cyclospore	Fucals	*Fucus, Sargassum*
8. Rhodophyta	1. Rhodophyceae	1. Nemalionales	*Batracho spernum*
	2	2. Ceraminales	*Polysiphonia*

• MODERN SYSTEMS OF CLASSIFICATION

The gradual recognition that all organisms need to be reclassified into five kingdoms had its effect on the systems of classification of algae also. Blue green algae with prokaryotic organisation came to be recognised as a group much different from algae, many biologists even transferring then to bacteria under the name 'Cyanobacteria'.

(A) F. E. Round (1973) classified algae into two major groups :

Gp 1. Procaryota–Phylum Cyanophyta

Gp 2. Eucaryota 12 Phylum (Euglenophyta, Chlorophyta, Charophyta, Prasinophyta, Xanthophyta, Haptophyta, Dinophyta, Bacillariophyta, Chrysophyta, Phaeophyta, Rhodophyta, Cryptophyta).

(B) H. C. Bold and M. J. Wyne (1978), following the suggestions of **Papenfuss** (1946) for using the suffix 'phy cophyta' divided algae into 9 divisions. However, to be *non-committal* with respect to blue-green algae (with regard to their algal or bacterial ancestory), they gave the name Cyanochloronta to the division of which these were consigned. The nine divisions cf algae as per classification proposed by them, are :

1. Cyanochloronta
2. Chlorophycophyta
3. Charophyta
4. Euglenophycophyta
5. Phaeophycophyta
6. Chrysophycophyta
7. Pyrrhophycophyta
8. Cryptophycophyta
9. Rhodophycophyta.

(C) K. R. Mattox and K. D. Stewart (1984) revised the classification of green algae on the basis of comparative cytology (mitochondrial phylogeny).

They divided green algae into five classes -

(i) Micromonadophyceae (formerly Prasinophyceae-Tetraselmis)

(ii) Charophyceae

(iii) Ulvophyceae

(iv) Pleurastrophyceal

(v) Chlorophyceae.

However, among the above all classification the classification provided by **Fritsch** *is more simple, convenient, accurate and reasonable.*

• CHARACTERISTICS OF DIFFERENT CLASSES OF ALGAE

(1) Chlorophyceae (Green algae) [430 genera, 1500 species]: These are unicellular, colonial or multicellular green plants, generally with simple structure, principal pigments are chlorophyll a and b, carotenes and xanthophylls as in higher plants, contained in plastids. Prominent reserve food is starch and sometimes fat, frequently aggregates around the pyrenoids. Reproduction is by asexual and sexual means. Zoospores biflagellate or quadriflagellate, flagella anterior isokontae, whipl type, cell wall of **cellulose** and **pectin**, fresh water or marine.

(2) Xanthophyceae (Yellow green algae) : Mostly unicellular, most advan forms have a simple filamentous habit, principal pigments are chlorophyll a an β-carotene and xanthophylls, reserve food mostly fat, sexual reproduction rare isogamous, cell wall frequently consists of two overlapping halves, constitutents pectin and silica, sometimes cellulose, the motile cells with two unequal flagella at anterior, one tinsel and the other whiplash type, most abundant in fresh water, but are marine.

(3) Phaeophyceae (Brown algae) [195 genera; 1000 species] : Brown algae the most complex algae, simple filaments to massive plant bodies. Pigments incl cholorophyll a and c, β-carotene and xanthophylls, stored food in the form of lamina (polysaccharide) and mannitol form of alcohol, cell wall constitution algin, fucoidin cellulose, sexual reproduction ranges from isogamy to oogamy, motile-cells only swarmers, two unequal flagella attached laterally, one tinsel and the other whipl type, most of the species are marine.

(4) Rhodophyceae (Red algae) [4000 genera, 2500 species] — Red algae mostly multicellular (complex), pigment contents are chlorophyll a and d, α- β-carotene and xanthophylls, phycobilins—r-phycoerythrin and r-phycocyanin, rese food in the form of **floridean starch**, cell wall constitution polygalactose sulph esters and cellulose, motile cells at any stage of the life history are unknown, sex reproduction advanced oogamous type, mostly marine, a few are fresh water.

(5) Chrysophyceae (Golden algae) : Mostly unicellular, colonial and filament forms rare, principal pigments are chlorophyll a, β-carotene and xanthophylls, stor product fat, sexual reproduction rare, specialized resting cells known as cysts produ endogenously, flagellated forms have either one flagellum tinsel type or when two tinsel and one whiplash type, cell wall consists of pectin and silica, fresh water marine.

(6) Bacillariophyceae (Diatoms) genera 5300 species : Diatoms are mo unicellcular or colonial, principal pigments are chlorophyll a and c, β-carotene xanthophylls, storage product in the form of fat, sexual reproduction is of widespr occurrence, cell wall of pectin and silica, silicified cell wall, precise nature of mo bodies not known, fresh water, marine and terrestrial.

(7) Cryptophyceae (Brown or red) : Unicellular flagellated forms scar represented group, principal pigment nature not definitely known, except phycobilins, reserve food a form of starch, cell wall of cellulose, two unequal flage sexual reproduction rare and isogamous, fresh water and marine.

(8) Dinophyceae (Dark yellow or Brown) : Majority with motile unicel structure, principal pigments are chlorophyll a and c, β-carotene and xanthophy reserve food starch or fat, sexual reproduction rare and isogamous, mostly marine a are fresh water, many colourless forms.

(9) Chloromonadineae (Bright green algae) : Unicellular, chromatoph bright green with excess of xanthophylls, reserve food is fat, motile cells biflagellate, only fresh water.

(10) Euglenineae : Simple unicellular or colonial motile organisms, pigme chlorophyll a and b, β-carotenes, xanthophyll, reserve food a polysaccharide paramyl related to starch, and fats, sexual reproduction not proved definitely, no cell w motility by flagella, usually one or sometimes more, tinsel type.

(11) Cyanophyceae or Myxophyceae (Blue-green algae) [150 genera, 115 species] : These are primitive simple unicellular, colonial or multicellular boc lacking true nucleus, histoneproteins, mitochondrial and chloroplast dou membranes, pigments not in organized bodies as in other cases, principal pigments chlorophyll-a, β-carotene, xanthophylls and phycobilins, c-phycoerythrin a c-phycocyanin, reserve food in the form of cyanophycean or myxophycean starch, wall mainly composed of mucopeptides, most forms are embedded in mucilaginous or gelatinous sheaths, no motile cell has been observed at any stage, reproduction of the bacterial type, 'false' branching and special types of cells called 'heterocysts' are characteristic features in many, most diverse in distribution, almost, ubiquitous.

• IMPORTANT QUESTIONS

Long Answer Type Questions :

1. Name the classes of algae proposed by **Fritsch**. Give some important characters of each class.
2. Describe the main features of class Rhodophyceae and Cyanophyceae.
3. Describe the main features of class Phaeophyceae and Xanthophyceae.
4. What are the main criteria of algae used for classification ?
5. Give main characteristics which distinguish Chlorophyceae from Myxophyceae, Rhodophyceae and Phaeophyceae.
6. Write note on important characters of Phaeophyceae.

Short Answer Different Questions :

1. Give name of different pigments found in algae.
2. Give names of characteristic pigments of class Rhodophyceae and Cyanophyceae.
3. What types of the flagella are found in algae ?
4. Name the chemical nature of reserve food in different classes of algae.
5. Write short note on class cyanophyceae.

Objective Type Questions :

1. Name the book of alage written by **F.E. Fritsch (1935).**
2. In classification of algae proposed by **F.E. Fritsch,** give the number of classes.
3. Give name of main pigment of Rhodophyceae.
4. Give main pigments of Cyanophyceae.
5. Which class is known as brown algae ?
6. Name the type of food stored in Rhodophyceae.
7. Name the class of algae that lack sexual reproduction.
8. Name the book written by **Fritsch.**
9. Chapman divided the algae into how many phyla ?
10. Who is the father of Indian Algology ?

ANSWERS

1. The structure and reproduction of the algae.

2. 11 **3.** *r*-phycoerythrin, **4.** C-phycocyonin

5. Phaeophyceae **6.** Floridean starch **7.** Cyanophyceae

8. The structure and reproduction of the Algae

9. Four **10.** M.O.P. Iyenger.

4

ULTRASTRUCTURE OF EUKARYOTIC ALGAE CE AND CYANOBACTERIAL CE

STRUCTURE

• INTRODUCTION

There are two basic types of cells in the algae—Prokaryotic (*e.g.*, cyanobacteria) Eukaryotic (*e.g.*, *Chlamydomonas*), Prokaryotic algae members are lacking membr bounded organelles such as nucleus, mitochondria, plastids, Golgibodies and flag while eukaryotic algal cells possess all these organelles.

• ULTRASTRUCTURE OF EUKARYOTIC CELL

Unicellular algae *Chlamydomas* represents an eukaryotic cell. It has following n structural components.

A. Cell wall

B. Plasmolemma

C. Protoplast

D. Chloroplast

E. Flagella

F. Stigma or Eye spot.

A. Cell wall

The cell is bounded by two-three layers of cellulose. Cellulose layers are fi striated with parallel cellulose fibrils (Fig. 1). In many species there is a pectose la external to it which dissolves in water and forms a mucilaginous pectin layer. Accor to **Roberts** *et. al.* (1972), **Hills** (1973) the cell wall in *C. reinharditii* consists of se layers gap junctions are absent in algal cells.

Plasmalemma : It is present just below the cell wall and consists of two opa layers which remain separated by less opaque zone (Fig. 1). It is different permeable memberane.

Protoplast : It is bounded by plasmalemma. It is differentiated into cytopla nucleus, chloroplast with one or more pyrenoids, mitochondria, Golgibodies, contractile vacuoles, a red eye spot 80 ribosomes, and lipid bodies.

Chloroplast : In majority of the species of *Chlamydomonas*, cytoplasm contain a single, massive cup shaped chloroplast which almost fills the oral or pear shaped b of the cell. It is surrounded by a double-layered unit membrane. It bears numbe photosynthetic lamellae (disc or thylakoids). The lamellae are lippoproteinaceou nature and remain dispersed in a homogeneous granular matrix (stroma). About

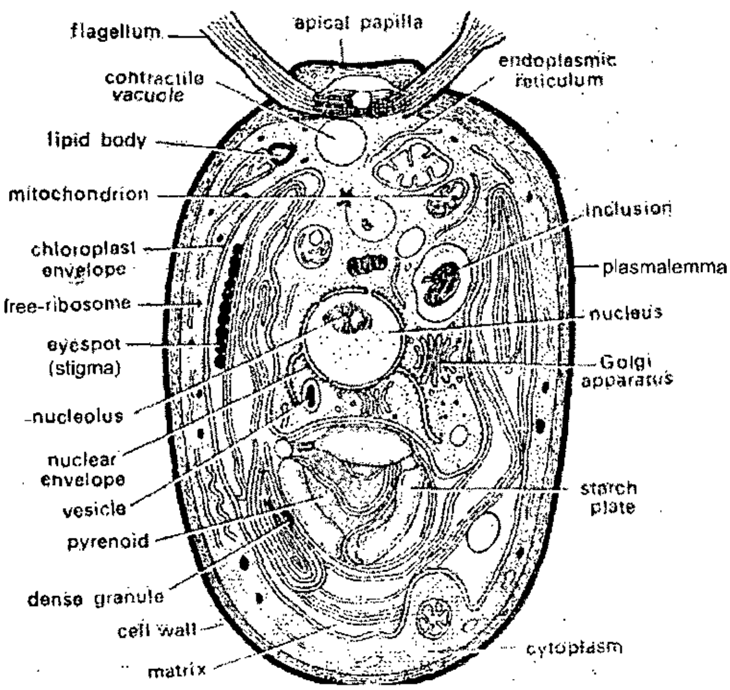


Fig. 1. *Chlamydomonas.* Ultrastructure of eukaryotic algae cell.

thylakoids bodies fuse to form grana like bodies. Matrix also contains ribosomes, plastoglobuli, microtubules and many crystal like bodies.

Flagella : The anterior part of thallus bears two locomotory flagella. Both the flagella are whiplash or **acronematic** type, equal in size. Each flagellum originates from a **basal granule** or **blepharoplast** and comes out through a fine canal in cell wall. It shows a typical 9+ 2 arrangement. Fibrils remain surrounded by a peripheral fibril. 2 central ones are singlet fibrils surrounded by 9 peripheral doublet fibrils (Fig. 2). Flagella, propel the cell through the medium by their beating movements.

Stigma or Eyespot : The anterior side of the chloroplast of algae contains a tiny spot of orange or reddish colour called **stigma** or **eyespot**. It is photoreceptive organ receives light stimuli and helps the *Chlamydomonas* to stwim towards the light. The eye spot is made of curved pigmented plate. The plate contains 2-3 parallel rows of droplets or granules containing carotenoids (Fig. 3). Each granule is about 75 mm in diameter.

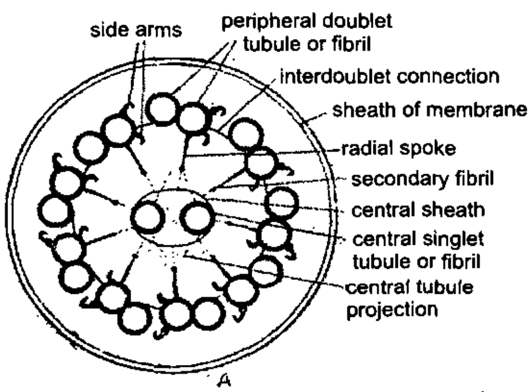


Fig. 2. Ultrastructure of flagellum of *Chlamydomonas.*

The other structures such as mitochondria, Golgi bodies, endoplasmic reticulum and nucleus are also bounded by double-layered unit membrane. Nucleus possess chromatin network and nucleolus Pyrenoides act as storage of starch. Mitochondria are

the site energy (ATP) production. Ribosomes provide site for protein synthes
Golgibodies acts as storage of various products of metabolite activators.

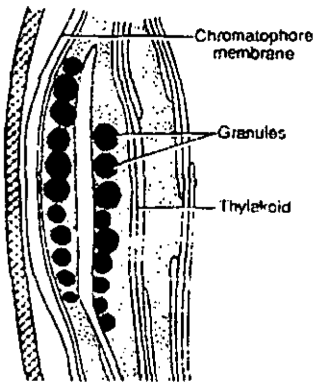


Fig. 3. Ultrastructure of eyespot.

• ULTRASTRUCTURE OF CYANOBACTERIAL CELL

Cyanobacterial (Blue-green algae) cell exhibits a typical prokaryotic structure. can be differentiated into two parts :

1. Outer Cellular Covering 2. Cytoplasm

1. Outer Cellular Covering

It can be differentiated into following parts :

A. Slime layer or mucilaginous sheath : Presence of mucilaginous sheath is t characteristic feature of cyanobacteria. It may be thin (Analystis) or thick (*Anabaena* It consists of fibrils reticulately arranged within the matrix to give a homogeneo appearance (Fig. 4 A). Fibrils are made up of peptic acids and mucopolysaccharides. retains the absorbed water and protects the cell against dessication.

B. Cell wall : Thin and firm cell wall is present between the slime layer a plasmamembrane. It is a rigid and complex structure and resembles the cell wall bacteria. It is made of four layers. **Carr and Whitton** (1973) named all these four laye as L I, L II, L III and L IV (Fig. 4 A). L I is a transparent space and occurs between the

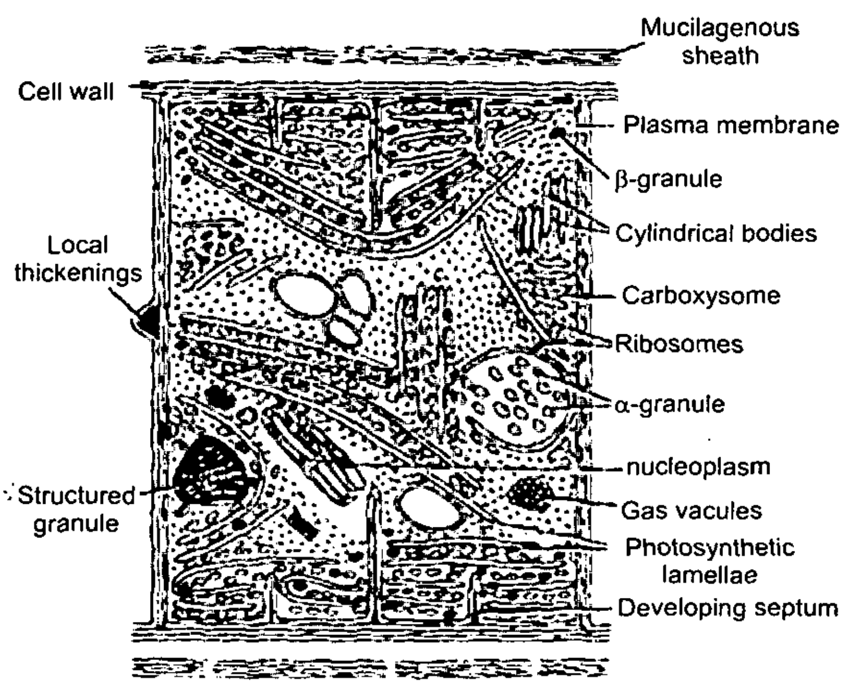


Fig. 4. (A–C). Cyanobacteria. Cell structure. Ultrastructure of a cell.

II and plasmembrane. L II and L III are mucopolymer, made up of alanine, glucosamine, peptidoglycan, muramic acid, glutamic acid and α-diaminopimelic acid. The L IV is undulating, wavy and made of liposaccharides and proteins.

C. Plasma membrane : Next to cell wall is plasma membrane. It is made up of protein-lipid-protein layers. The cytoplasmic membrane and its invaginations are the sites of biochemical functions, normally associated with the membrane bounded structures like mitochondria, endoplasmic reticulum and golgibodies of the eukaryotic cells.

2. Cytoplasm

It is differentiated into two regions (Fig. 4B) :

(1) Chromoplasm

(2) Centroplasm

(3) Cytoplasmic inclusions

(1) Chromoplasm : It is the outer or peripheral pigmented region of protoplasm. This region consists of flattened vesicle like structures called **thylakoids** or **photosynthetic lamellae**. These lamellae contain cholorophyll *'a'*, carotenoids and three phycobilins—C-phycocyanin, allophycocyanin and C-phycoerythrin. Photosynthetic lamellae are arranged in parallel rows close to the periphery of the cell or they are distributed irregularly throughout the cell. In between the lamellae, occur certain granules of 400 A° diameter. These granules contain phycobilin pigment and are called **cyanosomes** or **phycobilisomes**. It also contain polyphosphate bodies called volutin granules and gas vesicles.

(2) Centroplasm : It is the inner or central colourless region also called nucleoplasm. It is often called **nucleoid** or **incipient nucleus**. It consists of DNA fibrils. DNA is not surrounded with protein materials (histones). Like bacteria, small circular DNA segments occur in addition to nucleoid. These are known as **plasmids** or **transposons**. 70S ribosomes are also present in this region (Fig. 4 C).

(3) Cytoplasmic Inclusions : The membrane bound organelles such as the plastids, endoplasmic reticulum, vacuoles, mitochondria and the dictyosomes are absent. However, the chromoplasm contains a large number of inclusions. These are ribosomes, α-granules, β-granules, structural granules, polyhedral bodies, gas vacuoles and vacuoles like inclusions (Fig. 4 C). α-granules are also called mitochondrian granules and are said to be the region of storage. β-granules are thought to be equivalent to cyanophycin (cyanophycean) granules. Structural granules are considered as modified β or cyanophycean granules. Polyhedral bodies associated with genetic material are also found in the central region. In some cyanobacteria e.g., *Oscillatoria*, gas filled vacuoles (pseudovacuoles) are present in the peripheral part of the cell. A gas vacuole is made up of a large number of units called vesicles. Gas vacuoles provide a **buyoancy regulating mechanism** to the organism.

• IMPORTANT QUESTIONS

Long Answer Type Questions :

1. Explain the ultrastructure of algal cell with the help of suitable diagram.
2. Give ultrastructure of the cyanobacterial cell.

Short Answer Type Questions :

1. Differentiate between eukaryotic and prokaryotic cell.
2. Describe ultrastructure of cell wall of eukaryotic cell.
3. Describe ultrastructure of chloroplast of eukaryotic cell.
4. What are cyanobacteria ?

Objective Type Questions :

1. Where are plastids found ?

2. What type of ribosomes are found in cyanobacterial cell ?
3. Name the flattened vesicle like structures in which photosynthetic pigments present.
4. Name the pigments present in the prokaryotic cell.
5. Is flagellum present in cyanobacteria ?
6. Which layer covers a cyanobacterial cell ?
7. *d*-granules are also known as—
8. Which unique pigments present in cyanobacteria.

ANSWERS

1. Plant cell 2. 70S 3. Thylakoids
4. Chlorophyll '*a*', *C*-phycocyanin, allophycocyanin and C-phycoerythrin.
5. No 6. Mucilagenous sheath 7. Mitochondrion
8. Phycobilin.

5

ECONOMIC IMPORTANCE OF ALGAE

STRUCTURE

- Beneficial Aspects
- Harmful Aspects
  - Important Questions
  - Answers

Algae are economically important in various ways are intimately connected to human beings from prehistoric times. Algae can be both beneficial and harmful to mankind. Algae are primary producers of food in a very large ways and are used as food, fodder and manures. Many industrial products *e.g.*, agar-agar, carrageenin, iodine are obtained from algae. Algae can sometimes be harmful to man by causing damage to ships, buildings and by causing diseases in plants and animals.

The beneficial and harmful aspects of algae may be discuss as follows:

• BENEFICIAL ASPECTS

(i) Food

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

Commonly used algal species, are mostly marine, and they belong to Chlorophyceae [*Ulva lactuca* (Sea lettuce), *Enteromorpha compressa, Caulerpa racimosa*], Phaeophyceae (*Laminaria saccharina, Alaria esculenta, A. fistulosa, Sargassum* sp., *Durvillea* sp.), Rhodophyceae [*Porphyra tenera, P. umbilicalis, P. laciniata, Rhodymenia palmata,* (Dulse), *Chondrus crispus* (Irish moss), *Gigartina stellata, Gracilaria* sp.] and Cyanophyceae (*Nostoc* sp.).

In country like Japan, about 20 different kinds of algae are being harvested and eaten. 'Aonori' is a preparation of *Monostroma*, 'Kombu' of *Laminaria* and 'Asakusa-Nori' of *Porphyra tenera*. Every year 4000-5000 metric ton of dry weight of the algae is produced and it fetches more money than any other marine products including whales, fish etc.

Another important algae, *Laminaria* is widely cultivated in Japan and China. It is cultivated more like a crop plant which has resulted in the development of a more stable economic crop.

With the development of the techniques of mass culturing of algae, specially with *Chlorella* and *Scenedesmus*, there are probabilities of solving the problem of food deficiency. The salient feature of *Chlorella* is that the cell is rich in protein (about 30%) carbohydrates (30%), lipids (15%) and vitamin contents (Single cell protein, SCP). It contains all the essential aminoacids for the nutrition of human being. It cont vitamins C, provitamin A, thiamine, riboflavin, pyridoxine, niacine, pantothenic a folic acid, inositol and *p*-amino benzoic acid. Important minerals present, in ord contents, are phosphorous, potassium, magnesium, sulphur, iron, calcium, mangan copper, zinc and cobalt etc. *Rodomenia* and *Plamata* is chewal like tobacco in Scotla

Fodder

Certain brown species (sea weeds) have been widely used in Norway, Swe Denmark, Scotland, America, China and New-Zealand or fodder. In Nor *Rhodymenia palmata* has come to be known as 'Sheep's weed' since sheep are very of this particular alga. *Laminaria saccharina, Ascophyllum* sp., *Sargassum* sp. *Fucus* sp., are equally liked by the cattle. In many countries factories have b established to process the seaweed into suitable cattle-feed Sea-weed meal. Eggs, f hens fed on sea weed meal, have an increased iodine content while increased butte content of milk is reported from cattle.

Pisciculture

Plank tonic algae, both floating and attached forms, provide the primary food for and other aquatic animals. The great fishing grounds of the seas are found where t are present in large numbers. In many countries pond culture for fishes has been ta up and they are fed with various forms of algae. It appears that the Green algae, Diatoms and some Blue-greens are most widely eaten up by the fishes (Singh, 19 Fish food is mainly the planktons (the floating forms), phytoplanktons zooplanktons. Zooplanktons develop by feeding upon the phytoplanktons. It is known that several vitamins found in fish can ultimately be traced to phytoplanktons on which they feed. So, directly or indirectly, the algae form the so of food for fishes. At the same time, these algae keep the water habitable for fishe absorbing the carbon dioxide and enriching water with oxygen through photosynthe

Fertilizers

Various species of large Brown and Red algae are used as organic fertiliz especially on land close to the sea. The weed is used either directly or as a seaw meal. A concentrated extract of seaweed is also sold as a liquid fertilizer. Coral algae *Lithothamnion calcareum* and *Lithophyllum* sp. are used profusely for liming soil. Similar is the use of *Chara* which becomes encrusted with calcium carbonate.

Some common forms belonging to family Cyanophyceae help in atmosph nitrogen fixation and thus enriching the soil.

In the paddy fields they have been seen to produce an effect almost similar to tha manuring with 30 kg. of ammonium sulphate per acre (**Watanabe**, 1959). *Aulo fertilissima*, the common Blue-green algae of the Indian rice fields is found to add 4 lb. of nitrogen fixed /acre/crop (**Singh**, 1962). At the same time there is a considera increase in the total organic matter content of the soil. In India, the nitrogen-fix blue-green algae play a part of tremendous importance in maintaining the fertilit the rice fields and also help in **soil reclamation.**

Reclamation of alkaline, 'usar' land

In India, vast tracts of land hot suitable for cultivation of crops due to high alkali of the soil, commonly known as 'usar' soil. The 'usar' lands would be cultivable, if th pH could be lowered, and organic contents and the water holding capacity of the increased. Exactly all these functions are carried out by the blue-green algae. Dur the rainy season the blue-green algae, notably species of *Nostoc, Scytonema, Anaba* and *Aulosira*, grow in plenty. According to **R. N. Singh** (1950), these algae can be of in the reclamation of the 'usar' lands. The process involves a series of successive gro of the algal crop in a water-logged condition. After a year of such reclamation, the fell from 9·5 to 7·6, organic contents increased from 36·5% to 59·7%, nitrogen conte from 30% to 38·4%; exchangeable calcium from 20% to 33% and water holding capa of the soil is also increased by 40%. In such a 'reclaimed' land, the transplanted pa crop grew with a yield of about1576-2000 lbs/acre.

Binding of Soil Particles

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

Commerical Products

Many forms of marine algae, Phaeophyceae and Rhodophyceae, are highly valuable for certain commercial products, chiefly agar-agar, algin or alginic acid and carrageenin.

Agar-Agar (Agar)

Agar-agar power is obtained from various species of red algae for *e.g.*, *Gelidium corneum, G. cartilageneum, Gracilaria lichenoides,* and species of *Chondrus, Gigartina, Furcellaria, Phyllophora, Pterocladia, Ahnfeldtia* and *Gampylaephora* (**Round**, 1966). It is a non-nitrogenous extract obtained almost in a pure mucilaginous form. The chief constituent of agar is a carbohydrate **galactan.** The algae are collected, bleached and the mucilaginous matter is extracted with water under pressure. The purified agar is sold in the form of flakes, granules or strips which are brittle when dry but become tough and resistant when moist.

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

Carrageenin

This is a metabolic product similar to agar, obtained from *Chondrus crispus, Gigartina stellata* and *Iridaea laminaroides.* The mucilage has several important industrial applications for *e.g.*, in textile industry, in paper making to give body to the paper, in the manufacture of straw and felt hats as a stiffening agent; as an ingredient in cosmetics, shoe-polishes, hand lotions, tooth paste etc., as an emulsifying and suspending agent, in the baking, dairy industries and in clarifying liquors.

Algin and Alginates

Algin is a calcium magnesium salt of alginic acid present in the intercellular substance of the Phaeophyceae. Its salts are used in the manufacture of variety of goods ranging from ice-cream, salad cream, custard and jams to cosmetics, films, fabrics, ceramics and textiles, because of its special colloidal properties. They are also used as a suspending agent in compounding drugs, lotions and emulsions; in the rubber industry in latex production; as an insulating material and as dental impression powder, as a gel in the freezing of fish and in the medicinal antibiotic capsules.

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

Medicinal use

Alaria was once used for strengthening the stomach and restoring the appetite after sickness. Alginates are used for their haemostatic nature; fucoidin and sodium lamanarin sulphate are used as 'blood anticoagulant'. *Digenia simplex,* a Rhodophycean alga, provides an antihelmnitic drug. Agar-agar, for its absorptive and lubricating action, is used medicinally in the prevention of constipation.

Antibiotics

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

Sewage Disposal

Proper Sewage disposal is one of our main defences against those diseases which are spread by the agency of human waste. There is only one way of sewage disposal and that is into water, streams, rivers, lakes or the sea. Sea side towns can dispose the sewage directly into the sea but in other cases the sewage should be treated before disposal. Essentially, there are two phases of sewage treatment—the physical and biological. The most important and common physical processes are straining and tedious. The biological process *i.e.,* sewage disposal is simple and less expensive.

Sewage disposal treatment is essentially a process of biochemical oxidation and its basic requirement is oxygen. The parts or amount of oxygen needed for the purification of 100,000 parts of sewage by weight is called the Biochemical Oxygen Demand (B. O D.). In other words, we may say that the ever present bacteria break down the sewage into its components complex organic compounds into such simple inorganic compounds as ammonia, carbon dioxide etc. and water with the needed amount of oxygen. This oxygen demand may be supplied artificially which is quite expensive or through the agency of the photosynthetic algae which grow in sewage disposal ponds. The most common algal species present in the sewage oxidation ponds are *Chlamydomonas Scenedesmus, Chlorella, Euglena, Eudorina* and *Pandorina.*

Bacterial species belonging to different genera and other microbes breakdown products of sewage, from complex organic substrates into simple inorganic products fulfil the primary requirements of these photosynthetic algae and in return the bacteria receive the necessary oxygen for their activity. Moreover, ammonical wastes have a high oxygen demand and these algae which are the effective photosynthetic oxidizers use ammonia to build up their protein. The relationship existing between algae and bacteria in a stabilization oxidation pond is summarized in the following figure (Fig. 1).

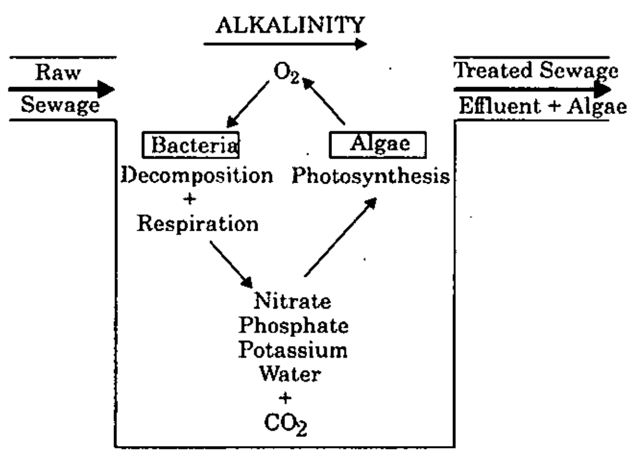


Fig. 1. Algal-bacterial inter-relationship in a sewage treatment and other Microbes

Raw sewage which enters the pond is immediately acted upon by bacteria and the sewage breakdown starts. As the algae utilize the minerals and carbon dioxide, made available by bacterial activity, the sewage becomes more and more alkaline.

Now-a-days, sewage is regarded as a raw material carrying some basic requirements for fertility—nitrogen, phosphorous, potassium and water. The yield of algae, with the nutrients tied up in the protoplasts, may also be very high; annual yield from a population of 1,000 may be as much as 4 tons in dry weight. Tests have shown that the algae recovered can be used as animal food and in certain regions it may be a valuable source of fodder (**Round**, 1966). Partially purified sewage from such ponds is led into fish pond where it stimulates a larger growth of algae beneficial to fish. Algal cells along with the effluents are also used to enrich the soil, in the cultivable lands as manure to enhance cropyield.

Funori

Adhesive product similar to agar obtained from a red algae *Gloiopeltis furcata* and from species of *Chondrus, Ahnfeldtia, Iridaea* and *Grateloupia*, is chiefly used as a glue and as a sizing agent (Round, 1973).

Diatomite (Kieselguhr)

Fossil forms of diatoms in various marine regions are found in large deposits which are called 'Diatomaceous earth' or 'kieselguhr'. Silica, the basic constituent of glass and granite rock, is deposited on the cell walls of the diatoms. Because the silica walls are hard and chemically inert, the sediments accumulate in marine and fresh water basins. Deposits of fossil marine diatoms over 1,200 feet thick are known. Because of its hard and chemically inert nature, kieselguhr is mainly used in insulation, as a filtering agent and as an abrasive, in the industrial filtration processes of sugar refining, brewing and wine making, in the recovery of chemicals and for removing waste mycelium in the production of antibiotics. It is used as an industrial catalyst, as filler in paints and varnishes, in paper industry; and in insulation materials for use at extremes of temperatures (**Round**, 1966). It is also used widely to absorb coloured substances from oils and other liquids; as a cleaning powder in soaps and in metal polishes etc.

Other Products

Some members of Phaeophyceae, provide two important products **mannitol** and **fucoidin**. Mannitol is used in food and medicinal products, inks and plastics etc. and fucoidin is used as a mucilage and in medicines.

The burnt 'ash' of larger Brown algae, specially the Kelps e.g. *Laminaria*, has been used for the extraction of minerals (sodium sulphate, potassium chloride and potassium sulphate), iodine and bromine. It is also used as a source of soda in the manufacture of soaps, glassware and alum etc.

• HARMFUL ASPECTS

The excessive growth of algae, specially the planktons or floating ones, cause undesirable effects. They form the water-bloom which may be harmful to the fish and other animals; or in water-reservoirs may cause pollution and hinder the process of filtration. Some may grow in abundance even in the salt beds and affect the quality of salt, in the crystal formation and in imparting a pink or red colour to it.

Water-blooms (Algal-blooms)

Excessive growth of phytoplankton is often responsible for the water assuming distinct colours like green, yellow-green, yellowish brown, dark or dirty brown, reddish brown, bluish-green etc. The Red Sea has been named after the Blue-green algae, *Oscillatoria erythraea, Trichodesmium* sp. which gives a red coloration to the sea at the bloom stage. The green, brown and red tides in the sea are caused mostly by the Dinoflagellates. In fresh water, water blooms fairly common in ponds and lakes and rarely in rivers, are caused by a number of classes of algae (Chlorophyceae, Xanthophyceae, Chrysophyceae, Bacillariophyceae, Dinophyceae, Cryptophyceae, Euglenineae and Cyanophyceae), each imparting a colour of its own. However, the most common forms belong to Cyanophyceae (*Microcystis, Aphanizomenon, Anabaena, Anabaenopsis, Spirulina, Oscillatoria, Nodularia, Nostoc, Coelosphaerium* etc.). Light, temperature, a high pH (7·8-11·0), dissolved organic matter and low redox-potential supports the growth of the bloom. Algal blooms may be 'mixed', constituted by several species, or more rarely 'pure', constituted by a single species.

The blooms may be temporary or seasonal occurring in November-December and in June or may be permanent.

Besides imparting colour to the water the blooms cause unpleasant smell and taste to the water making it unfit for drinking purposes. In fish ponds, they may cause physical choking of the gills and depletion of oxygen during cloudy weather. Large scale mortality among fishes may also result during their decomposition. Very strong poisons or toxins have been extracted from algae causing water-blooms (**Round, 1966**) and reports of death of cattle and birds drinking such water. Algal bloom may cause death of fishes (Prescott, 1989).

Water Pollution

Excessive growth of algae in water reservoirs for drinking and other purposes causes two undesirable effects, (i) by giving a bad taste from their decomposition products and (ii) by interfering with the filtration process. Various filamentous and unicellular forms belonging to Chlorophyceae, Cyanophyceae, Bacillariophyceae etc. cause water pollution. To some degree the presence of certain specific algae indicates the nature of pollution and water condition. Chemical algicides, specially copper sulphate with intermittent chlorination are usually employed in small doses as a check to the growth of the algae.

A beneficial effect of the algal growth, specially the attached forms, in the reservoirs with hard or calcareous 'water is the precipitation of carbonates and reduction in the hardness of water.'

Disease Producing Algae

Certain economically plants such as Tea, Coffee, Citrus etc. are sometimes seriously affected by the parasitic alga. *Cephaleuros. C. virescens* causes the **red-rust of tea**, one of the most serious diseases of tea-plant (*Thea sinesis*). The parasite is most destructive as a stem parasite and can cause damage when the host is growing slowly. Another species of *Cephaleuros*, *C. coffea* is parasitic on coffee plants.

• IMPORTANT QUESTIONS

Long Answer Type Questions :

1. Write an essay on economic importance of algae.
2. Give an account of harmful effect of algae to man.

Short Answer Type Questions :

1. Discuss the use of algae in medicines.
2. Describe the use of algae as manure.
3. Describe the use of algae as food and fodder.
4. Describe use of algae in industry.
5. Write note on water blooms.
6. Write note on nitrogen fixation by algae.
7. Give some harmful aspects of algae.

Objective Type Questions :

1. Define planktons.
2. Algae of which class are called diatoms ?
3. Name algae used as source of agar-agar.
4. Which algae are commonly called **kelps** and are used as source of iodine ?
5. Name one algae rich in proteins.
6. What is botanical name of "Irish moss" ?
7. Which algae is an important source of carragienin ?
8. What is furari ?

9. What is chlorellin ?
10. What is carrageenin ?
11. What is Kieselguhr ?
12. For which algae is salty confection called dulse is obtained ?
13. Name four algae used as food.
14. What is water bloom ?

Multiple Choice Questions :

1. Which of the following statements about lichens in wrong :
   (a) Some of the species are eaten by reindeers
   (b) These are pollution indicators
   (c) They grow very rapidly
   (d) They show symbiotic association between algae and fungi.
2. Lichens from first community in :
   (a) Psammosere (b) halosere
   (c) Xxeosere (d) Hydrosere
3. Cyphellae in lichens are analogous to which of the following structure of the higher plants :
   (a) Stomata (b) Palisade tissue
   (c) Mesophyll (d) Bundle sheath
4. The source of litmus is :
   (a) *Indigofera tinctoria* (b) Rubia tinctorium
   (c) *Roccella tinctoria* (d) None of these
5. Which of the following was considered as an excellent drug for epilepsy :
   (a) *Cetraria* (b) *Pertusaria*
   (c) *Usnea* (d) *Parmelia*
6. The term lichen was first used by :
   (a) Aristotle (b) Theophrastus
   (c) De Bary (d) Bonnier
7. In majority of the lichens, there is association of
   (a) Green algae and Basidiomycetes (b) Green algae and Ascomycetes
   (c) Cyanobacteria and Basidiomycetes (d) Cyanobacteria and Ascomycetes.
8. The term ascomata in lichens is applied to
   (a) Ascogenous hypage (b) Ascus zone
   (c) Ascus mother cell (d) Ascocarp

ANSWERS

1. These are microalgae ploating free on water syurface of ocean, lake, sea etc.
2. Bascillariophy ceal 3. *Gelidium* 4. *Laminaria*
5. *Chlorella* 6. *Chondrus crispus*
7. *Chondrus* 8. It is an adhesive material used in paper industry
9. An antibiotic obtained from *Chlorella*.
10. A product from red algae 11. Cell wall material of diatoms.
12. *Rhodymenia*
13. *Ulva, Porphyra, Chlorella* and *Sargassum*
14. Excessive growth of algae.

Multiple Choice Questions :

1. (c) 2. (c) 3. (a) 4. (c) 5. (d) 6. (b) 7. (b) 8. (d)

External Form

On the basis of growth forms, and nature of attachment to the substratum lichens are divided into following three main types :

(1) Crustose lichens (encrusting lichens). These lichens occur as thin or thick crust over rocks, soil or tree barks. The thalli may be wholly or partially embedded so that only fruiting bodies are visible above the surface of the substratum *e.g.*, *Lecanora, Graphis, Rhizocarpon, Ochrolechia* etc. (Fig. 2).

(2) Foliose lichens (leafy lichens). These lichens are variously lobed, leafy structures attached to the substratum by rhizoid like outgrowth called the **rhizines** *e.g.*, *Xanthoria, Parmelia, Physcia, Anaptychia* etc. (Fig. 3).

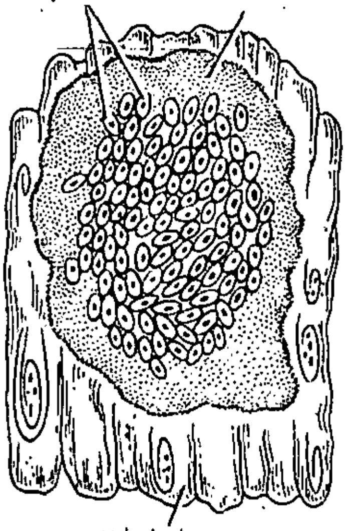


Fig. 2. Lichens : A crustose lichen

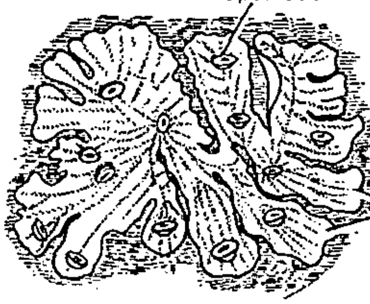


Fig. 3. Lichens : A foliose lichen

(3) Fruticose lichens (Shrubby lichens). Fruticose lichens are the upright or hanging lichens (pendant forms) attached only at the base by a flat disc. These are cylindrical, flat or ribbon like, well branched and resemble with little shrubs *e.g.*, *Cladonia, Usnea, Alectoria* etc. (Fig. 4).

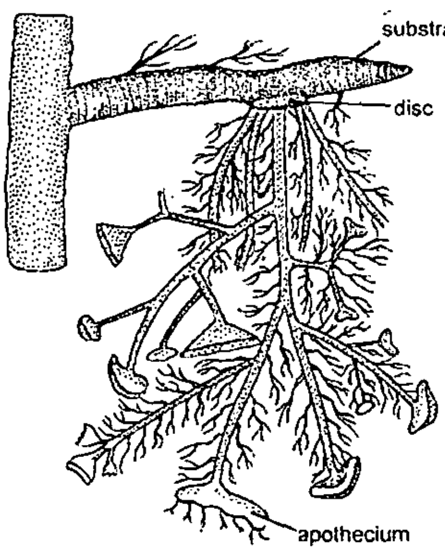


Fig. 4. Lichens : A fruticose lichen

A **fourth type** of lichen called **leprose** has also been differentiated. It has some fungal hyphae surrounding one or more algal cells. A distinct fungal layer envelops the algal cells all over. It appears as a powdery mass over the substratum *e.g., Leparia incana.*

Internal Structure

Internally the thallus is composed of algal and fungal components. Scuh type of thallus is known as **consortium.** On the basis of internal structure the lichens are divided into two groups :

(A) Heteromerous lichens

(B) Homoiomerous lichens.

T. S. Heteromerous Lichens

A transverse section of the heteromerous (foliose) lichen can be divided into following 4 distinct zones (Fig. 5) :

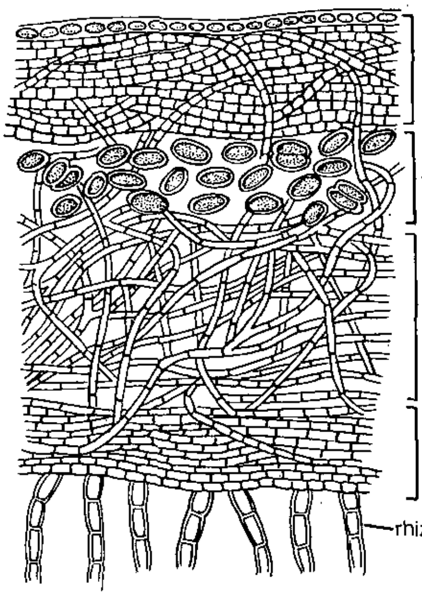


Fig. 5. *Lichens* : Transverse section of heteromerous (foliose) lichen thallus

(1) Upper cortex,

(2) Gonidial layer,

(3) Medulla and

(4) Lower cortex.

(1) Upper cortex. It is the upper-most protective layer made up of compactly interwoven fungal hyphae. The compactly interwoven hyphae produce a tissue like layer (plectenchyma or pseudoparenchyma) called the **upper cortex.** The intercellular spaces are absent, if present, they are filled with gelatinous substances. In some species of foliose lichens this layer is interrupted by **breathing pores** that serve for aeration. In addition to these certain other structures are also present for gaseous exchange. These are called **cyphellae.**

(2) Gonidial layer. This layer consists of loosely interwoven hyphae intermingled with algal cells. This region is the photosynthetic region of the thallus. This layer is also called **gonidial layer** because of the earlier concept that these cells have reproductive function.

(3) Medulla. It is present just below the algal cells and is made of loosely interwoven hyphae of fungus. Medulla forms the middle portion of the thallus.

(4) Lower cortex. Like the upper cortex, it is the lower-most layer. In some lic the layer is absent *e.g., Lobaria pulmonaria.* This layer gives rise to bundles of hy (rhizines) which penetrate the substratum to function as anchoring organs.

Different types of lichens particulary the foliose and fruticose remain attached t substratum by a variety of structures such as **rhizinose strand** (thick strands *Buellia pulchella*), **hyphal nets** (fungal hyphae forming net like structures, *e.g.*, *F decipiens*), **hypothallus** (thick, black, spongy, algal free tissue *e.g., Anzia*) holc (basal, algae free region, *e.g., Usnea, Letharia*), **hapters** (short, penetrating bran *e.g., Alectoria*) and medullary hyphae.

The above structure of a lichen shows that the algae cells are restricted or con. to form a distinct layer. Such type of lichens are called **heteromerous** (Fig 6).

T. S. Homoiomerous Lichens :

In some lichens for example, *Collema, Leptogium,* the thallus shows a si. structure with little differentiation. The algae cells and fungal hyphae are unifo distributed. Such type of lichens are called **homoiomerous.** (Fig. 6).

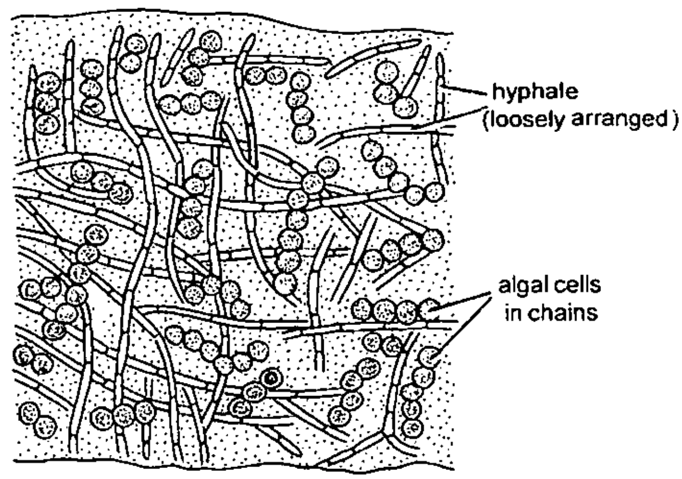


Fig. 6. Lichens : Transverse section of homoiomerous lichen

Special Structures Associated with Lichens

(1) Cyphellae and Pseudocyphellae. When observed under the microscope appear as small, hollow, circular, white cavities are seen. From these cavities me is exposed and hyphae protrude out. If these cavities are of a definite form with a distinct border, these are known as **cyphellae** (Fig. 7) *e.g., Stricta.* If the distinct border is absent and there is only distinct roundish opening in the cortex, looser hyphal medullary tissue comes out in the form of discrete patches, these are known as **pseudocyphellae** *e.g., Alectoria, Bryoria, Coelocaulon* etc. The function of these structures is to allow free passage of air to the algal cells.

(2) Cephalodia. These are dark coloured, small wart or gall like abnormal structures which develop on the upper surface or within the thallus *e.g., Peltigera aphthosa, Lobaria pulmonaria* etc. The cephalodium contains the same fungal hyphae but the algal component (generally Cyanophceae *e.g., Nostoc*) is always different from the parent thallus.

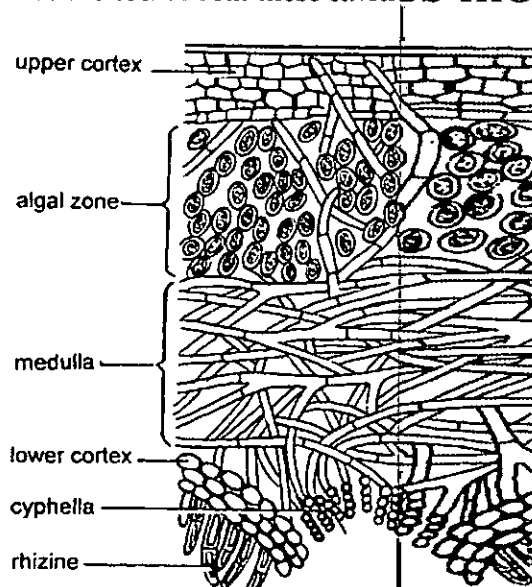


Fig. 7. Lichens : Cyphellae. Vertical sect thallus passing through a cyphella

Such lichens, having three membered symbiosis (2 algae + 1 fungus), are called **diphycophilous lichens.** The cephalodia help in retaining the moisture in thallus (Fig. 8A, B).

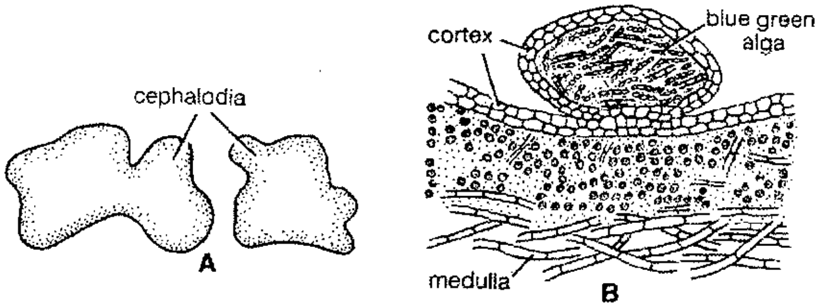


Fig. 8 (A–B). Lichens : Cephalodia. (A) Surface view of Cephalodia, (B) Vertical section of thallus passing through Cephalodium

• REPRODUCTION

Lichens reproduce by Vegetative, asexual and sexual methods.

(1) Vegetative Reproduction

(a) By Fragmentation. Death and decay of older parts of the thallus produce smaller pieces (fragments) which, develop into new thalli, provided they contain both the algal and fungal components.

(b) By Soredia. It is the most common method of vegetative reproduction. These are small protuberances, produced on the upper surface by the thallus. They may either occur within definite pustule-like compact structures called **soralium** (Fig. 9 D) or may arise so abundantly as to spread up like a thin greyish layer of dust. Each soredium consists of a few algae cells surrounded by a mass of hyphae. (Fig. 9 A–C).

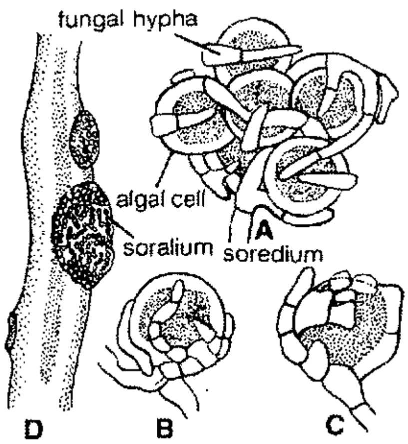


Fig. 9 (A–D). Lichens : Soredia. (A) Single soredium, (B–C) Stages in the formation of soredium, (D) Soredia on thallus.

Soredia are very light in weight and are easily disseminated by wind or rain wash. After falling on suitable substratum, they develop into a new lichen *e.g.*, *Parmelia, Bryoria* etc.

(c) By Isidia. These are the stalked, undetachable outgrowths produced by the thallus on its upper surface (Fig. 10). Like soredia, the isidia are also composed of both fungal and algal components but differ from them in being covered with a definite cortex. The algal component is of the same kind as in thallus. The isidia may be rod shaped (*Parmelia sexuatilis*), coralloid (*Umblicaria postulata*), cigar shaped (*Usnea comosa*) or scale shaped (*collema crispum*).

The main function of the isidia is to increase the photosynthetic surface of the thallus. Sometimes these also act as organs of vegetative propagation.

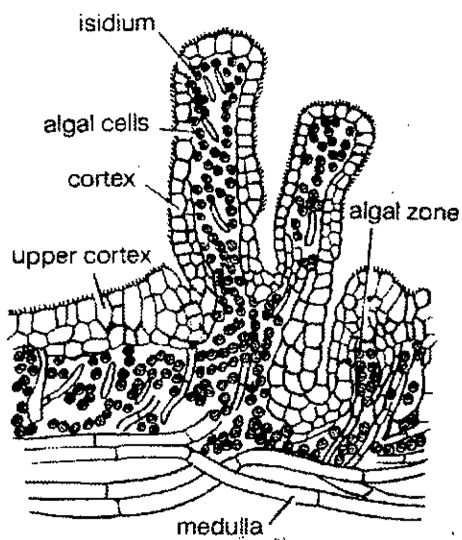


Fig. 10. Lichens : Isidia. Vertical section of thallus passing through isidia

(d) By lobules. Lobules are dorsiventral outgrowths that produced on the margins of the thallus of *Parmelia* and *Peltigera* lichens and act as organs of vegetative propagation.

Some lichens by forming propagules of different kinds such as **phyllidia** (leaf or scale like dorsiventral portions *e.g., Peltigera*), **blastidia** (yeast like, segmented *e.g, Physcia*), **schizidia** (scale like *e.g., Parmelia*), **hormocyst** (algae hyphal and fungal hyphae grow together in a chain like manner *e.g., Lempholema*), **goniocysts** (unsorallium like structures), etc.

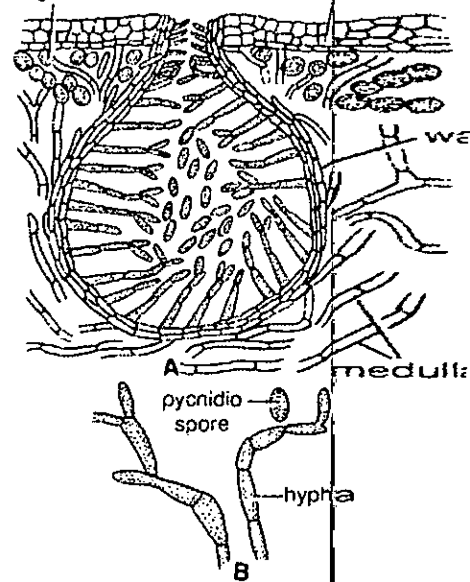


Fig. 11 (A–B). Lichens : Pycnidiur (A) Vertical section of thallus passing through pycnidium, (B) Pycnidial hyphae bearing pycnidiospores

(2) Asexual Reproduction

By Sporulation. Rarely certain lichens may also reproduce asexually by means of **conidia** (***e.g., Arthonia***), **oidia** and **Pycniospores** or **pycnidiospores** (Fig. 11 A, B). In some cases hyphae break down into small pieces known as **oidia** while pycniospores are produced within the flask shaped structures known as **pycnidia**.

Each pycnidium opens through **ostiole.** The pycnidial wall is made up of sterile fungal hyphae. Inside the pycnidia fertile hyphae obstruct sexual spores (pycnidiospores) at their tips. After falling on suitable substratu pycnidiospores germinate and coming in contact with appropriate alga, they devel further into a new lichen.

(3) Sexual Reproduction

The sexual reproduction in Ascolichens and Basidiolichens is like class Ascomyce and Basidiomycetes respectively. In Ascolichens the male reproductive organ is cal the **spermogonium** and the female is known as **carpogonium.** They develop eith on the same hypha or on two different hyphae of the same mycelium.

Spermogonium. The spermogonia are flask shaped structures embedded in the upper surface of the thallus. They open outside by **ostiole**. The fertile hyphae in the cavity of the spermogonium abstrict minute rounded cells at its tip. These male cells are known as **spermatia.** In some species of lichens, however, the pycnidia like structures also function as spermogonia (Fig. 7).

Carpogonium. A carpogonium consists of two parts (Fig. 12) *i.e.*, lower coiled multicellular portion called **ascogonium** and the upper long, straight, thread like portion called **trichogyne.** The ascogonium lies deep in the medullary portion while trichogyne emerges out of the thallus and receives spermatia.

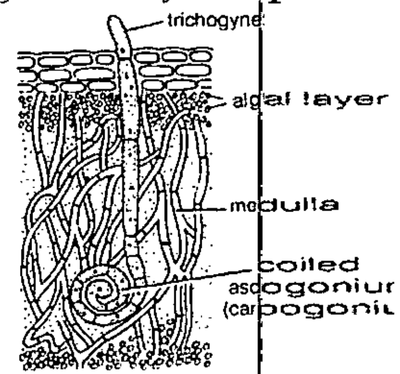


Fig. 12. Lichens : Carpogonium. Vertical section of thallus passing through Carpogonium

Fertilization. On being disseminated, the spermatia have been found sticking the protruding tip of trichogyne. This is the only evidence that spermatia function male gametes. However, **Morean** and **Morean** (1928) opined that there is never a fertilization of the protruding trichogyne by spermatia.

After fertilization trichogyne withers. The ascogonium produces freely branch **ascogenous hyphae.** These hyphae produce asci at their ends.

All the structures after fertilization (*i.e.*, developing asci, ascogenous hyphae a ascogonium) are surrounded by the sterile hyphae. It results in the formation fruiting body which is either a **apothecium** or **perithecium** type.

• STRUCTURE OF APOTHECIUM

It is round and cup-shaped structure (Fig. 13 A). If the apothecium consists only the fungal component, it is known as **lecideine** type (*e.g., Lecidea, Cladonia, Gyrophora*) and if it consists both algal and fungal components it is known as **lecanorine** type (*e.g., Lecanora, Parmelia*). It can be divided into two parts :

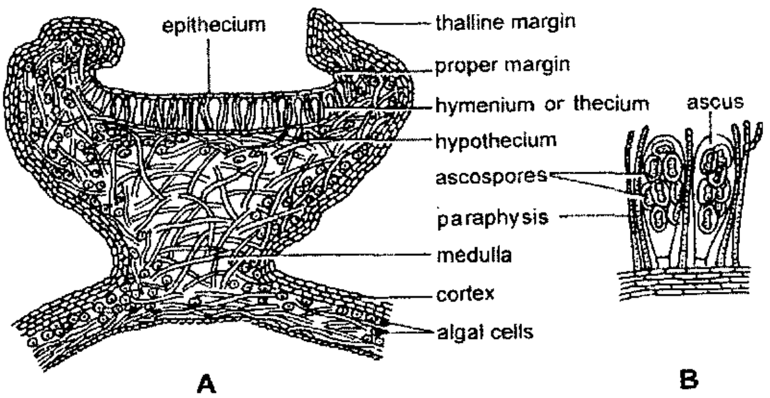


Fig. 13. Lichens : (A) Apothecium. Vertical section of apothecium, (B) Highly magnified portion of hymenium

(1) Disc of the Apothecium

(a) Hymenium (Thecium). It is the upper-most fertile layer of apothecium consisting of a closely packed, palisade like layer of sac-like **asci** and sterile hair like fungal hyphae known as **paraphyses.** This layer is also called **hymenial layer** or **hymenium.** Each ascus contains 8 ascospores. Ascospores are of various shapes and size, multicellular uni- or bitunicate and uni- or multinucleate.

The sterile tissue that separates the asci is called **hamathecium.**

(b) Sub-hymenium. The region consists of the closely interwoven sterile hyphae. It is present just below the fertile layer.

(2) Margin of Apothecium :

This part surrounds the disc and also forms the edge of the apothecium.

Germination of ascospores. The ascospores may be simple or septate. They are very light in weight and easily disseminated to a long distance by wind. After falling on suitable substratum it germinates and produces fungal hyphae. The hypha grows into a new lichen thallus, if it comes in contact with an appropriate algal component.

• NATURE OF ASSOCIATION

The nature of association of algae and fungi in a lichen is quite debatable. Following three different explanations have been given for the nature of association :

(1) Mutualism or Symbiosis. According to some botanists the association in lichens is of symbiotic type because both the components (alga as well as fungus are mutually benefited).

The fungal component absorbs water and minerals from the substratum as well as absorbs moisture and provides protection to the algal partner. In return the fungal component derives food from the algal cells.

2. Helotism. The fungal component in the lichen association is the dominating partner. The algal component lives as a prisoner or as a subordinate partner. Some workers have suggested the term **helotism** for such type of association.

3. Parasitism. Workers like **Fink** (1913) have suggested that the fungus lives as a parasite on the algal partner. According to **Geitler** (1937), fungal hyphae give out **haustoria** and **appresoria** to absorb the food material from the algal cells but the algal partner is able to survive as an independent individual, if separated artificiall from the fungal partner.

• ECONOMIC IMPORTANCE OF LICHENS

Many different uses of lichens can be studied under the following heads :

(1) Useful Aspects

(a) Ecological significance :

(i) Pioneer colonizers. Lichens are said to be the pioneers in establishin vegetation on bare rocky areas (lithosere). They are the first members to colonize th barren rocky area. During development they bring about the disintegration of roc stones (biological weathering) by forming acids *e.g.*, oxalic acid, carbonic acid etc. Thu they play an important role in nature in the formation of soil (a phenomenon calle pedogenesis).

(ii) Role in environmental pollution. Lichens are very sensitive to atmospher pollutants such as sulphur dioxide. They are unable to grow in towns, cities and aroun industrial sites such as oil refineries and brickworks. So, the lichens can be used a reliable **biological indicators** of pollution. By studying lichens on trees, a qualitativ scale has been devised for the estimation of mean SO_2 level in a given season. Thu lichens are used as **pollution monitors.**

(b) Food and Fodder. The lichens serve as important source of food fc invertebrates. A large number of animals for example, mites, caterpillars, termite snails, slugs etc. feed partly or completely on lichens. Lichens as food have also bee used by man during famines. They are rich in polysaccharides, certain enzymes an some vitamins. *Cetraria islandica* (Iceland moss) is taken as food in Sweden, Norwa Scandinavian countries, Iceland etc. *Lecanora esculenta* is used as food in Israel an *Umbilicaria esculenta* in Japan. Species of *Parmelia* (known as rathapu or 'rock flowe in Telgu) are used as curry powder in India. In France the lichens are used i confectionary for making chocolates and pastries.

Cladonia rangiferina (Reindeer moss) is the main food for reindeers in pol countries. *Cetraria islandica* is also used as fooder for horses. Species of *Stereocaulo* *Evernia, Parmelia* and *Lecanora* are also used as fodder.

(c) Source of Medicines. Since very early times the lichens are used to cur jaundice, fever, diarrhoea, epilepsy, hydrophobia and various skin diseases. Variou lichens are of great medicinal value :

(i)	*Lobaria pulmonaria* and *Cetraria islandica*	In respiratory diseases particularl tuberculosis.
(ii)	*Usnea barbata*	For strengthening hair and fo uterine ailments
(iii)	*Xanthoria parietina*	For jaundice
(iv)	*Cladonia* spp.	For whooping cough
(v)	*Peltigera canina* (dog lichen)	For hydrophobia
(vi)	*Roccella montagnei*	In angina, a serious heart disease
(vii)	*Parmelia saxatilis*	For epilepsy
(viii)	Species of *Evernia, Cladonia* and *Roccella*	To control fever

A broad spectrum antibotic **usnic acid** is obtained from species of *Usnea* an *Cladonia*. It is effective against gram positive bacteria. Some lichen compounds *e.g* **lichenin, isolichenin** have anti-tumour properties. **Protolichesterinic acid,** compound obtained from some lichens, is used in preparation of anti cancer drug **Erythrin** obtained from *Roccella montagnei*, is used to cure angina. Many antisept creams such as **Usno** and **Evosin** are available in the market and are well known for their antitumour, spasmolytic and antiviral activities.

(d) In industry :

(i) Tanning and dyeing. Some lichens are used in leather industry. *Cetraria islandica* and *Lobaria pulmonaria* show the astringent property. This astringent substance is extracted from the thallus and is used in tannin industry. Lichens are also used in preparing natural dyes. **Orchil,** a blue dye obtained from *Roccella* and *Leconara,* is used to dye woollen articles and silk fabrics. It is purified as **orcum** and used as a biological stain. A brown dye is obtained from *Parmelia* spp. whereas *Ochrolechia* spp. yield a red dye. **Litmus** used as a acid-base indicator, is also a dye and is obtained from *Roccella tinctoria* and *Lasallia pustulata.*

(ii) Cosmetics and perfumes. *Evernia, Ramalina, Pseudorina* are reported to have perfumed volatile oils. Due to the aromatic substances present in the thallus, the lichens are used in the preparation of various cosmetic articles, perfumery goods, dhoop, hawan samagari etc.

(iii) Brewing and distillation. Some species of lichen for example, *Cetraria islandica* contain carbohydrates in the form of **lichenin.** In Sweden and Russia alcohol is produced from these lichens. These lichens are also used in confectionary.

(iv) Minerals. *Lecanora esculenta,* is found in lime stone deserts and yields large amount of calcium oxalate crystals. These are 60% of its dry weight.

(e) Natural products : Lichens are known to produce over 550 natural products. Some important natural products are :

Product	**Produced from**
Salazinic acid	*Ramalina siliquosa*
Squamatic acid	*Cladonia crispata*
Lecanoric acid	*Parmelia subrudecta*

(f) Poison from Lichens : Some lichens are poisonous due to presence of various substances in them :

Lichen	**Poisonous due to**
Letharia vulphina (wolf moss)	Vulpinic acid (used as poison for Wolves)
Cetraria juniperina	Pinastrinic acid
Parmelia molliuscula	Selenium
Xanthoria parietina	Beryllium
Everina furfuracea	Chlorine

(ii) Harmful Effects :

(a) Lichens growing on young fruit trees and sandal trees are harmful to the plant.

(b) During hot season some species of lichens (*e.g.*, *Usnea barbarata*) become so dry and inflammable that they often help in spreading forest fire.

(c) Some lichens act as allergens.

(d) The commercial value of glass and marble stone is reduced because of itching of their surface by lichens.

(e) Some lichens *e.g.*, *Cladonia rangifera, Cetraria islandica* accumulate large quantities of radioactive strontium (Sr^{90}) and Caesium (Cs^{137}) from atomic fall-outs. These may be incorporated in the food chain, leading to their accumulation in human tissue systems.

• ECOLOGY OF LICHENS

The ecology of lichens refers to the place they hold in ecosystem. It is estimated that mainly 8% of the earth's terrestrial surface is covered by lichens. Ecologically the lichens are very important because they are **pioneer colonizers** and helps in s **formation.**

(a) Pioneer colonizers : They can grow on those surfaces where noting else grow for e.g., the only plants growing on a bare rock will be crustose lichens : It is du the facts that :

- Lichens can tolerate irregular and extended period of severe desiccation. They **poikilohydric** (pioilo-variable, hydric-related to water) meaning that they h little control over the status of their dehydration. They can tolerate irregular extended periods of severe desiccation.
- In this cryptobiotic state lichens can survive under extremes of temperatu radiation and drought in the harsh environments they often inhabit.
- Lichens do not have roots and do not need to top continuous supply of water.
- Lichens are smaller in size and have slow growth rate.

(b) Soil formation : During their growth, lichens slowly decompose substrate forming acid. Crustose lichens patienty collect around and beneath itself tiny amou of moisture, minerals and organic matter. When freezing temperature come, the wa collected by lichens expands as it form ice and the expanding action again helps in weathering of rocks. Over a period of perhaps many years, even centuries, the lich gathers an extremely thin layer of soil around it.

• IMPORTANT QUESTIONS

Long Answer Type Questions :

1. Where are lichens found ? Describe the structure and reproductive bodies in liche
2. Describe the structure of the lichens.
3. Give a brief account of various methods of reproduction met with in the lichens.
4. Give an account of economic importance of lichens.

Short Answer Type Questions :

1. Classification of lichens
2. Economic importance of lichens
3. Transverse section (T.S.) of lichen
4. Structure of lichens
5. Reproduction in lichens
6. Soredia
7. Relative importance gained by the fungi and algae in a lichen.
8. Habitat of lichens
9. Cyphellae
10. Cephalodia
11. Isidia
12. Spermogonium
13. Carpogonium
14. Nature of association in lichens
15. Apothecium
16. Ecological significance of lichens.

Objective Type Questions :

1. Name the composite plant consisting of a fungus living symbiotically with an alga
2. Name the vegetative reproductive body of lichens consisting of a few algal c surrounded by fungus hyphae.
3. What is the name of an outgrowth arising from the thallus of a lichen wh includes both algal and fungal cells ? Can it detach from the main body of lichen a serve as the structure of vegetative reproduction ?

4. Name the circular depressions formed in the under surface of lichens that serve as aerating organs.
5. What is the name of female reproductive organ in lichens ?
6. *What is the type of apothecium when it consists only the fungal components ?*
7. Name the tissue that originates from the base of the ascocarp, grows upwards and separates the asci.
8. Name the association in which one partner is dominant and other partner lives as a prisoner or as a subordinate partner.
9. Name the member of green algae (phycobiont) commonly present in lichens.
10. Name the three genera which belong to Basidiolichens.
11. What is the botanical name of 'Reindeer moss' ?
12. Name the acid secreted by lichens to initiate the biological weathering.
13. Name the fertile zone of an apothecium.
14. Name the pustule like structures in which soredia are formed.
15. Name the lichen which is useful for curing hydrophobia.

ANSWERS

Objective Type Questions :

1. Lichen	2. Soredium	3. Isidia, Yes	4. Cyphellae
5. Carpogonium	6. Lecideine type	7. Paraphyses	8. Helotism
9. *Trebouxia*	10. *Cora, Corella, Dictyonema*		
11. *Cladonia rangifera*		12. Carbonic acid/oxalic acid	
13. Thecium	14. Soralium	15. *Peltigera canina.*	

UNIT–II

CHARACTERISTICS AND LIFE CYCLE OF SOME ALGAL MEMBERS

7

CHLOROPHYTA

STRUCTURE

• INTRODUCTION

Chlorophytr is a largest and most diversified division of green algae including 429 genera and about 7000 species. These algae are mostly aquatic, photosynthetic and eukaryotic plants. They cantain chlorophyll 'a' and 'b' in their chloroplast and store food as starch. The cells wall consists of mainly cellulose. Most of the species are fresh water forms with few are marine. Members exhibit wide range of form structures, habit habitat.

Fresh water found in ponds, lakes, ditches canol rivers etc.

Majority of Volvocales, Chlorococcales are planktonic forms.

Many Chaetophorales *e.g.*, *Coleochacte*, *Protococcus*. *Trentepohlia* are epiphytic algae.

Many species of *Cladophora* and *Characium* are epizoic algae.

Some green algae like *Trebouxia*, *Chlorella* form symbiotic associationship with animals like *Zoochlorella* and *Hydra*.

Scotiella spp. grow on ice or snow.

Some green algae form symbiotic association with fungi to form lichens.

Cephaleuros and Sphagnum are parasitic algae on leaves of tea, coffee, *Piper* and Magnolia plants. *Cephalcuros* causes **red rust** of tea.

Chlamydomonas nivalis causes **red snow** and *Chlamydomanas yellowstonensis* causes **green snow**. Some *Chlamydomonas* species are thermophilic.

The range of thallus structure of class **Chlorophyceae** is as follows :

(i) Unicellular motile forms—*e.g.*, *Chlamydomonas*.

(ii) Unicellular non-motile forms—*e.g.*, *Chlorella*.

(iii) Colonial motile form—*e.g.*, *Volvox*, *Eudorina*, *Pandorina*.

(iv) Colonial coccoid forms—*e.g.*, *Hydrodictyon, Pediastrum.*

(v) Palmelloid forms—*e.g.*, *Tetraspora.*

(vi) Dendroid forms—*e.g.*, *Prasinocladus.*

(vii) Unbranched filaments—*e.g.*, *Ulothrix, Oedogonium.*

(viii) Branched filaments—*e.g.*, *Cladophora.*

(ix) Heterotrichous forms—*e.g.*, *Coleochaete.*

(x) Siphonaceous forms—*e.g.*, *Vaucheria.*

(xi) Parenchymatous forms—*e.g.*, *Ulva, Codium, Enteromorpha.*

Important Features

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

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

(iii) The chloroplasts are well organized, the main pigements are **chlorophyll a** and **b**, the other pigments are α and β **carotene** and **xanthophylls.**

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

(v) The reserve food is in form of starch and its formation is associated with pyrenoids.

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

(vii) The sexual reproduction can be **isogamous, anisogamous** or **oogamous**.

Classification

Fritsch (1915) divided class Chlorophyceae into nine orders on the basis of morphology and reproductive structures :

Class. Chlorophyceae

Orders :

1. Volvocales 2. Chlorococcales 3. Ulotrichales 4. Cladophorales
5. Chaetophorales 6. Oedogoniales 7. Conjugales 8. Siphonales
9. Charales.

Smith (1955) divided division **Chlorophyta** into two classes—Chlorophyceae and Charophyceae. The Chlorophyceae was divided in ten orders and Charophyceae has only single order:

Division. **Chlorophyta**

I. Class. **Chlorophyceae**

Orders :

1. Volvocales 2. Tetrasporales 3. Ulotrichales 4. Oedogoniales
5. Ulvales 6. Schizogoniales 7. Chlorococcales 8. Siphonales
9. Siphonocladales 10. Zygnematales.

II. Class. **Charophyceae**

Order. Charales.

Order : *Volvocales*

(i) The order Volvocales includes about 60 genera and 500 species.

(ii) The algae of this order are mainly fresh water forms.

(iii) The thallus may be unicellular *e.g.*, *Chlamydomonas* or motile colony *e.g.* *Volvox, Eudorina* and *Pandorina*.

(iv) The members are characterized by presence of flagellated motile vegetative cells. The flagella can be two or four, equal, apical and acronematic. The cells have large cup shaped chloroplast with single pyrenoid covered with starch plate.

(v) The asexual reproduction takes place by biflagellated zoospores, aplanospores or by palmella stage.

(vi) The sexual reproduction can be isogamous, anisogamous and oogamous.

Family : Chlamydomonadaceae

(i) Algae of this family are mostly unicellular.

(ii) The members are motile. Flagella are generally two or four.

(iii) The asexual reproduction takes place by zoospores or palmella stage.

(v) The sexual reproduction can be isogamous, anisogamous or oogamous.

CHLAMYDOMONAS

• SYSTEMATIC POSITION

Class	:	Chlorophyceae
Order	:	Volvocales
Sub-order	:	Chlamydomonadineae
Family	:	Chlamydomonadaceae
Genus	:	*Chalmydomonas*

• OCCURRENCE

Chlamydomonas is a large genus and is found almost in all places. It is represented by about 400 species (**Prescott**, 1969). *Chlamydomonas* is simple, unicellular, motile fresh water algae. It is mainly found in fresh water rich in nitrogen salts and organic matter. It is also found in stagnant water of ponds, pools, ditches, water tanks, sewage tanks and in slow running water. *Chlamydomonas* is planktonic algae and make surface of water appear green. Some species of *Chlamydomonas* are terrestrial, they grow on moist soil surface, in rice fields and on banks of rivers and lakes. Palmella stages of genus make scum on soil surfaces. Some species are found in salty brackish water *e.g.*, *C. halophila, C. ehrenbergii. Chlamydomonas* is also found as **cryophytes** *i.e.*, growing on snow *e.g.*, *C. nivalis* causes **red snow** due to presence of red pigment haematochrome and *C. yellowstonenris* imparts green colour to snow.

• STRUCTURE

Chlamydomonas is unicellular, motile green algae. The thallus is represented by a single cell. It is about 20 μ-30μ in length and 20 μ in diameter. The shape of thallus can be oval, spherical, oblong, ellipsoidal or pyriform. The pyriform or pear shaped thalli are common, they have narrow anterior end and a broad posterior end (Fig. 1).

The structure of thallus can be divided into following parts:

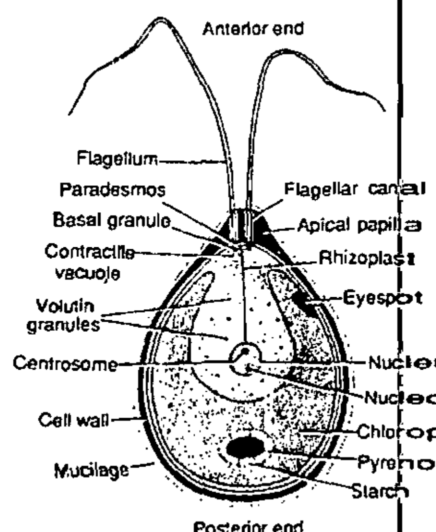


Fig. 1. Thallus of *Chlamydomonas*

• CELL WALL

The cell is surrounded by a smooth, thin and firm cell wall made of cellulose. The cell wall at the anerior end is extended to make

apical papilla. In some species the outer pectose layer dissolves in water medium to make gelatinous layer outer to cell wall. The detailed structure of cell wall shows that it is multilayered and is made of cellulose fibrils. Inner to the wall lies the **plasmalemma** (plasma membrane).

Cytoplasm : The cytoplasm is present in thallus between the cell wall and the chloroplast. The cytoplasmic structure includes the nucleus, mitochondria, endoplasmic reticulum, dictyosomes, ribosomes (80 S) etc. The thallus contains single large, dark nucleus lying inside the cavity of the cup shaped chloroplast. The dictyosomes or Golgi bodies are found near the nucleus and they do not possess large vesicles.

Each cell contains two **contractile vacuoles** located at the base of flagella in a plane at right angle to them. The contractile vacuoles are **excretory** or **osmoregulatory** in function.

Flagella : The anterior part of thallus bears two flagella. Both the flagella are whiplash or acronematic type, equal in size. The flagella are mostly longer than the thallus but in some species they can be equal or shorter than the thallus. Each flagellum originates from a **basal granule** or **blepharoplast** and comes out through a fine canal in cell wall.

Neuromotor apparatus. In some species of *Chlamydomonas e.g., C. nasuta,* a sensitive neuromotor apparatus is present. It controls movement of thallus in response to light, chemical and other stimuli. The neuromotor apparatus consists of two basal granules or blepharoplasts from which the flagella originate, a transverse cytoplasmic fibre **paradesmos** which connects two blepheroplasts.

Chloroplast : In *Chlamydomonas* generally a large, cup shaped parietal chloroplast is present in cytoplasm (Fig. 2 A). But the chloroplasts can be of various shapes in different *Chlamydomonas* species (Fig. 2 B,C). The chloroplast is 'H' shaped in *C. bicilliata,* reticulate in *C. reticulata*, parietal in *C. mucicola* stellate in *C. arachne* and axile in *C. steinii,* the chloroplast is generally associated with pyrenoid covered with starch plates, but sometimes pyrenoids can be more than one. The pyrenoids are two in *C. debaryana* and many in *C. gigantae.* The pyrenoids are concerned with synthesis of starch.

Stigma or Eyespot : The anterior side of the chloroplast contains a tiny spot of orange or reddish colour called **stigma** or **eyespot**. It is photoreceptive organ concerned with the direction of the movement of flagella.

Reproduction :

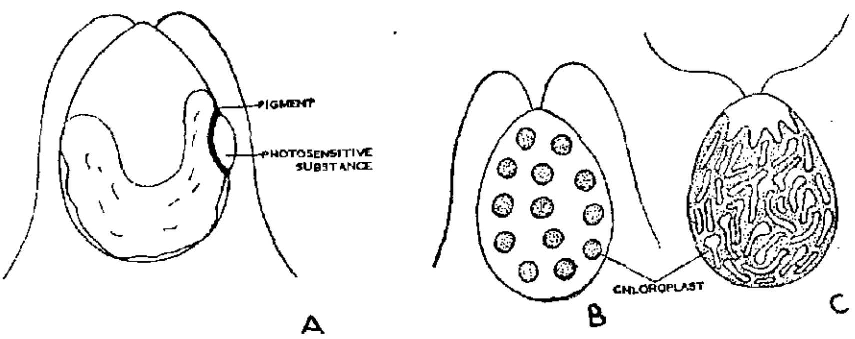


Fig. 2. Different type of chloroplast in *Chlamydomonas*

The reproduction in *Chlamydomonas* is both asexual and sexual.

Asexual Reproduction :

It takes place by following methods :

(A) By zoospores. The notice zoospore formation takes place during favourable conditions. The zoospore formation takes place as follows :

The protoplast contracts and gets separated from the cell wall. The parent cell los flagella or in some species of *Chlamydomonas* flagella are absorbed. The contracti vacuoles and the neuromotor apparatus disappear. The protoplasm divid longitudinally by simple mitotic division forming two daughter protoplasts. The secor longitudinal division of protoplasm takes place at right angle to the first, thus makir four daughter chloroplasts. Sometimes the protoplasm may further divide to mal 8–16–32 daughter protoplasts. Each daughter cell develops cell wall, flagella ar transforms into **zoospore** (Fig. 3).

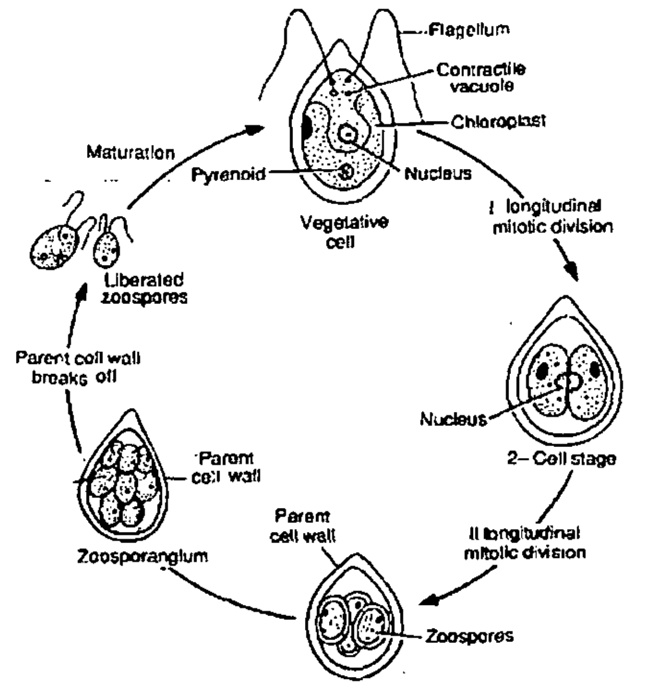


Fig. 3. Asexual reproduction in *Chlamydomonas*

The zoospores are liberated from the parent cell or zoosporangium by gelatinizatic or rupture of the cell wall. Under favourable conditions the formation of zoospores ca take place every 24 hours.

(ii) By aplanospores. The aplanospores are formed slightly under unfavourab conditions *e.g.*, in *C. caudata*. The parent cell loses flagella. The protoplast rounds c `are called **aplanospores.** In favourable conditions aplanospores may germinate either directly or divide to produce zoospores (Fig. 4 A, B).

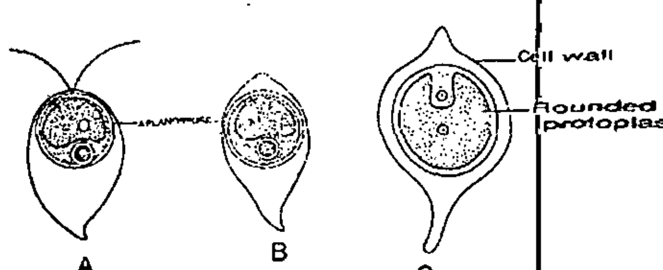


Fig. 4. (A) Parent cell, (B) Aplanospore formation, (C) Hypnospore

(iii) By hypnospores. In extreme unfavourable conditions the protoplast develops thick wall and the structure developed is called **hypnospore** *e.g.*, in *C. nivalis*. The hypnospores also germinate like aplanospores (Fig. 4 C).

(iv) Palmella stage. The palmella stage is formed under unfavourable condition as shortage of water, excess of salts etc. The protoplast of parent cell divides to mal many daughter protoplasts but they do not form zoospores. The parent cell wa gelatinizes to make mucilaginous sheath around daughter protoplasts. The daught protoplasts also develop gelatinous wall around themselves but do not develop flagell These protoplast segments are called **palmellospores.** The division and redivisions these protoplast ultimately forms amorphous colony with indefinite number of spores and it is called **palmella stage** (Fig. 5). When favourable conditions return the gelatinous wall is dissolved, palmellospores develop flagella, and the spores are released to make new thalli.

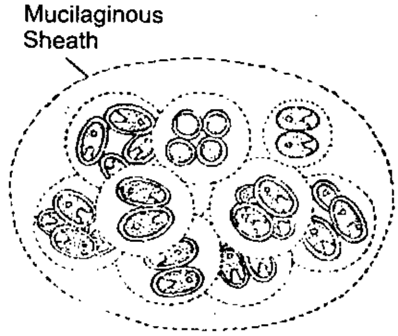


Fig. 5. *Chlamydomonas.* Palmella stage

Sexual Reproduction :

The sexual reproduction in *Chlamydomonas* can be **isogamous, anisogamous** or **oogamous**. The thallus can be homothallic *i.e.*, both types of gametes are produced in same thallus *e.g.*, *C. gynogama* and *C. media* or can be heterothallic *i.e.*, (+) and (–) gametes come from different parents. The gametes may be naked and called **gymnogametes** *e.g.*, *C. debaryana* or covered by cell wall and called **calyptogametes** *e.g.*, *C. media.*

(i) Isogamy. Most of the *Chlamydomonas* species are isogamous in nature. In isogamous reproduction the fusion of gametes, which are similar in size, shape and structure, take place. These gametes are morphologically similar but physiologically dissimilar.

In many isogamous species the vegetative cells may directly function as gametes without undergoing any division *e.g.*, in *C. snowiae* (**Smith**, 1955), this fusion is called as **hologamy.**

In *C. eugametos,* the vegetative cells do not shed their walls, after union the contents of one gamete enter into another gamete as such. According to **Chapman** (1964) the isogamous reproduction takes place by production of 8, 16 or 32 biflagellated gametes. The process takes place as follows (Fig. 6). The vegetative thallus functioning as gametangium comes to rest and loses its flagella. The protoplast withdraws itself from the cell wall. The protoplast divides by repeated longitudinal mitotic divisions to produce 8–16–32 or 64 daughter protoplasts. Each daughther protoplast develops a pair of flagella and transforms into gamete. The gametes are liberated by breaking the wall of gametangium. The flagella of gametes are covered by **agglutins** and secrete a hormone called **gamone**. These chemical substances are involved in the recognition of gametes of the opposite strains. In heterothallic species (+) and (–) strain gametes cluster together and this phenomenon is called **clumping.** The gametes of opposite strain fuse by anterior end *i.e.*, **apical fusion** or laterllay *i.e.*, **lateral fusion.** The paired gametes move away from the clump. The wall at the place of contact dissolves and fertilization takes place in two steps— **plasmogamy** and **karyogamy.** In plasmogamy the fusion of cytoplasm and in karyogamy the fusion of nuclei takes place. After fetilization a quadriflagellate zygote is formed. The zygote later on loses flagella and gets covered by a thick wall and is now called **zygospore.**

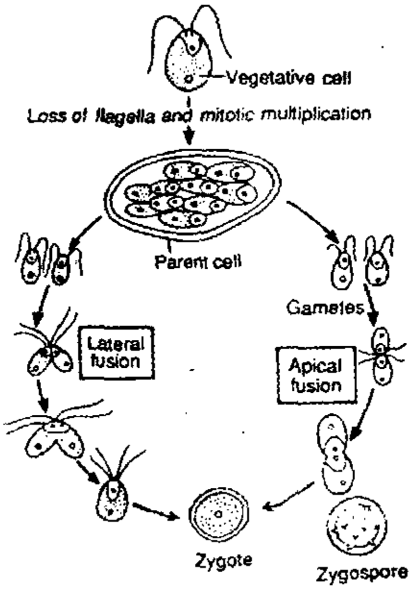


Fig. 6. *Chlamydomonas.* Isogamous reproduction.

(ii) Anisogamy. In anisogamous reproduction the gametes are unequal in size. The male gametes or **microgametes** are smaller, the female gametes or **macrogametes** are larger *e.g.*, in *C. braunii* and *C. suboogama.* The macrogametes are formed in female gametangium in which the protoplast divides to make 2 to 4 gametes only (Fig. 7 A, C). The microgametes are formed in male gametangium where the protoplast divides to make 8–16 gametes (Fig. 7 B, D). The microgametes are more active than macrogametes. The microgametes come close to the macrogamete, the protoplast of microgamete enters into macrogamete and after fusion a diploid zygote is formed. The zygote secretes a thick wall and transforms into zygospore (Fig. 7 E-H).

(iii) Oogamy. The oogamous sexual reproduction takes place in *C. coccifera* and *C. ooganum*. The vegetative thallus functioning as female cell withdraws its flagella and directly functions as non-motile **macrogamete** or **egg.** The female gamete contains many pyrenoids (Fig. 8 A, B). The microgametes are formed by four divisions of protoplast as in case of anisogamous reproduction (Fig. 8 C, D). The microgamete reaches the female gamete and unites by anterior ends. The contact wall between the two dissolves. After plasmogamy and karyogamy a diploid zygote is formed (Fig. 8 E-G). The zygote secretes a thick wall and tranasforms into zygospore.

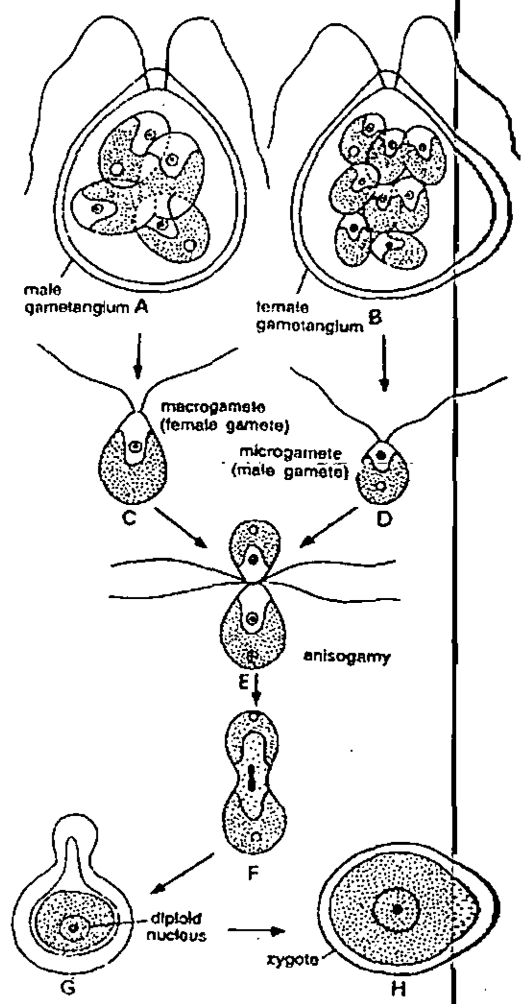


Fig. 7. ***Chlamydomonas*** **anisogamous reproduction.**

Zygote/Zygospore :

The zygote is resting diploid spore. The zygote secretes a thick wall which is smooth or ornamented. The zygote accumulates large amount of oils and starch. The zygospores are red in colour due to the presence of **haematochrome.** the zygospore survives long period of unfavourable conditions and germinates on approach of favourable season.

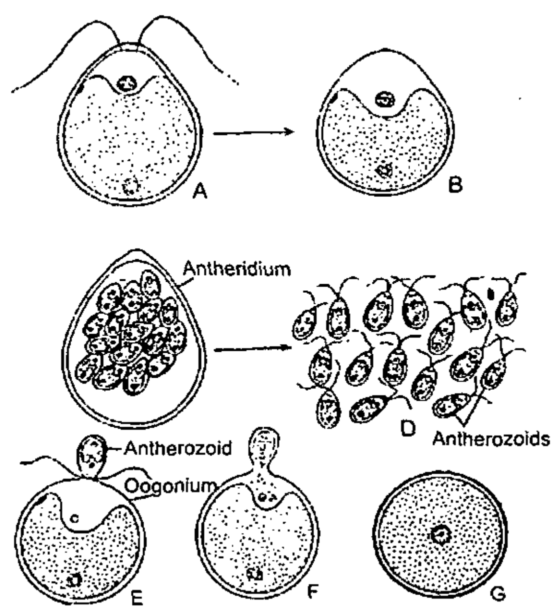
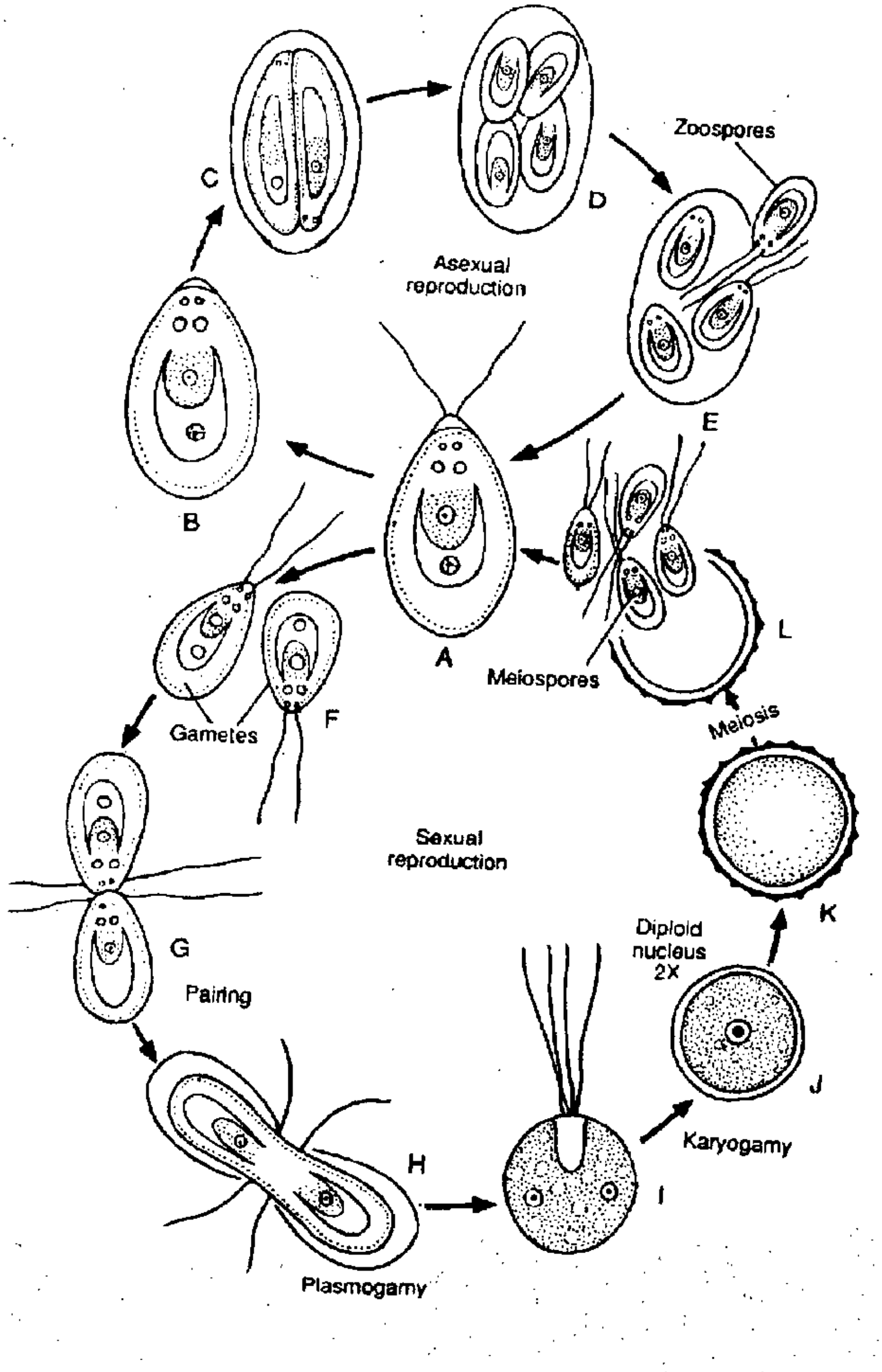


Fig. 8. *Chlamydomonas.* Oogamous reproduction


Zoospores
C
D
Asexual reproduction
E
B
A
L
Meiospores
Gametes
F
Meiosis
G
Sexual reproduction
K
Diploid nucleus 2X
Pairing
J
H
Karyogamy
I
Plasmogamy

(ii) The members are motile. Flagella are generally two or four.

(iii) The asexual reproduction takes place by zoospores or palmella stage.

(v) The sexual reproduction can be isogamous, anisogamous or oogamous.

VOLVOX

• SYSTEMATIC POSITION

Class	:	**Chlorophyceae**
Order	:	**Volvocales**
Sub-order	:	**Chlamydomonadineae**
Family	:	**Volvocaceae**
Genus	:	***Volvox***

• OCCURRENCE

Volvox is free floating fresh water green algae. *Volvox* grows as planktons on su of water bodies like temporary and permanent ponds, lakes and water tanks. D rainy season due to its fast growth the surface of water bodies become green. The V colonies appear as green rolling balls on surface of water.

Volvox is represented by about 20 species. Some common Indian species are—V *globator, V. aureus, V. prolificus, V. africanus* and *V. rousseletii.*

• STRUCTURE

Volvox thallus is a motile colony with definite shape and number of cells **coenobium**. The colony is hollow, spherical or oval in shape and the size of col about the size of a pin head. Depending upon the species of *Volvox* the cells c 500–60,000. The central part of colony is mucilaginous and the cells are arrange single layer on periphery of the colony (Fig. 1A).

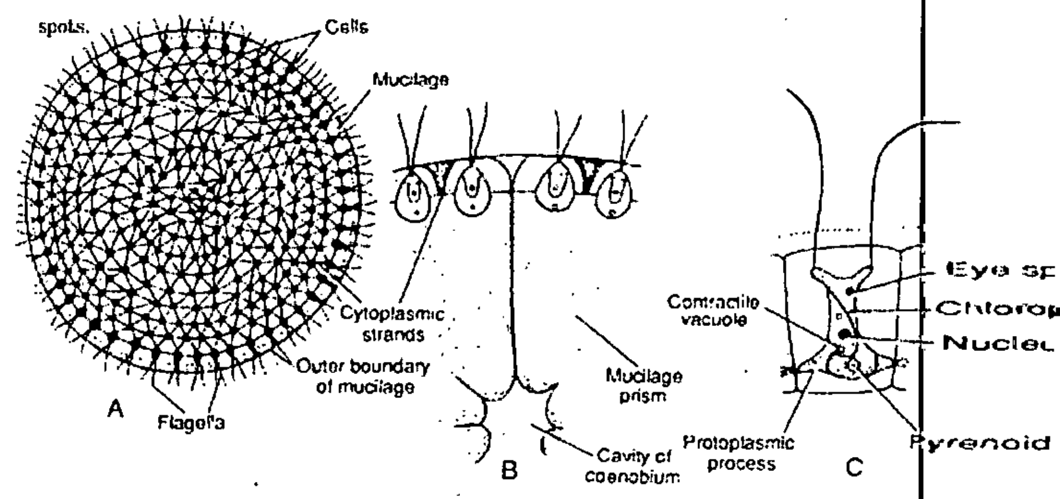


Fig. 1. (A-C) *Volvox*. A. A colony; B. A part of colony; C. Single cell.

The cells of anterior end possess bigger eye spots than those of posterior enc The cells of posterior side become reproductive on maturity. Thus, spherical or colony of *Volvox* shows clear polarity.

The cells of *Volvox* colony are *Chlamydomonas* type. Every cell has its own mu sheath (Fig. 1 B). The mucilage envelope of colony appears angular due to compr between cells. The cells are connected to each other through cytoplasmic strar some species of *Volvox* the cytoplasmic connections or strands are not present. Th of colony are usually pyriform with narrow anterior end and broad posterior en cells are biflagellate, the two flagella are equal, whiplash type and project outwards (Fig. 1 C). The protoplasm of cell is enclosed within plasma membrane. Each cell contains one nucleus, a cup shaped chloroplast with one or more pyrenoids, an eye spot and 2–6 contractile vacuoles. In some species of *Volvox e.g.*, in *V. globator* and *V. rousseletii* the cells are of *Sphaerella* type.

The cells of colony are independent for functions like photosynthesis, respiration and excretion. The movement of colony takes place by co-ordinated flagellar movement.

Reproduction

Volvox reproduces both **asexually** and **sexually**. The asexual reproduction takes place under favourable conditions during spring and early summer. In *Volvox* mostly the cells of posterior part of colony take part in reproduction. These reproductive cells can be recognized by their larger size, prominent nuclei, dense granular cytoplasm, more pyrenoids and absence of flagella.

Asexual Reproduction

During asexual reproduction some cells of the posterior part of colony become reproductive. These cells enlarge upto ten times, become rounded and lose flagella. These cells are called **gonidia** (Sing. gonidium) (Fig. 2 A). The gonidia lose eye spot. Pyrenoids increase in number. The gonidia are pushed towards interior of the colony. The first division of gonidium is longitudinal to the plane of coenobium and this forms 2 cells (Fig. 2 A). The second division is also longitudinal and at right angle to the first, forming 4 cells (Fig. 2 B). By third longitudinal division all the four cells divide to make 8 cells of which 4 cells are central and 4 are peripheral. These 8 cells are arranged in curved plate-like structure and are called **plakea stage** (Fig. 2 C, D). Each of these 8 cells divides by longitudinal division forming 16 cells arranged in the form of a hollow-sphere (Fig. 2 E). The sphere is open on exterior side as a small aperature called **phialopore** (Fig. 2 F). The cells at this stage continue to divide till the number of cells reaches the characteristic of that species. The cells at this stage are naked and in close contact with each other. The pointed anterior end of cells is directed towards inside.

The next step is called **inversion of colony** (Fig. 2 G-H). As cells become opposite in direction, their anterior pointed end has to face the periphery of colony. The inversion of colony starts with formation of a constriction opposite to phialopore. The

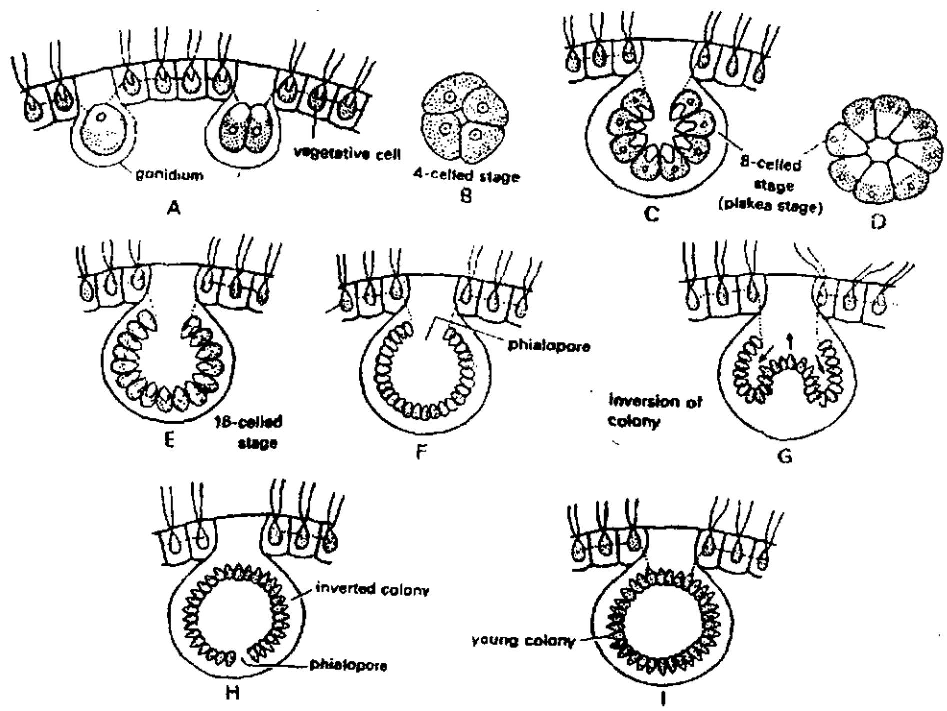


Fig. 2. (A–I) *Volvox*. Asexual reproduction in *Volvox*

cells of posterior end along with constriction are pushed inside the sphere, till the whole structure comes out of the phialopore. After inversion, the anterior pointed end of the cell faces periphery. The phialopore gets closed, and makes the anterior part of the colony. After inversion the cells develop cell wall, flagella and eye spot. The cells become separated due to development of gelatinous sheath around each cell. This newly developed colony is called **daughter colony** (Fig. 2 I). The daughter colonies initially remain attached to gelatinized wall of parent colony and later become free in gelatinous matrix of parent colony. The daughter colonies are released in water after the disintegration of parent colony or through the pores. Sometimes next generation daughter colonies develop while the colonies are still attached to the earlier parent colony.

Sexual Reproduction

The sexual reproduction in *Volvox* is **oogamous** type. Some species of *Volvox* e.g., *V. globator* are **monoecious** or **homothallic** (Fig. 3) *i.e.*, the antheridia and oogonia develop on same colony. Other *Volvox* species *e.g.*, *V. rousseletii* are **dioecious** or **heterothallic** *i.e.*, antheridia and oogonia develop on different colonies. Monoecious species are usually **protandrous** *i.e.*, antheridia mature before oogonia but some species are **protogynous** *i.e.*, oogonia develop before antheridia. *V. aureus* is mostly dioecious but sometimes can be monoecious.

Reproductive cells mostly differentiate in the posterior part of colony. These cells enlarge, lose flagella and are called gametangia. The male reproductive cells are called **antheridia** or **androgonidia** and female reproductive cells are called **oogonia** or **gynogonidia**.

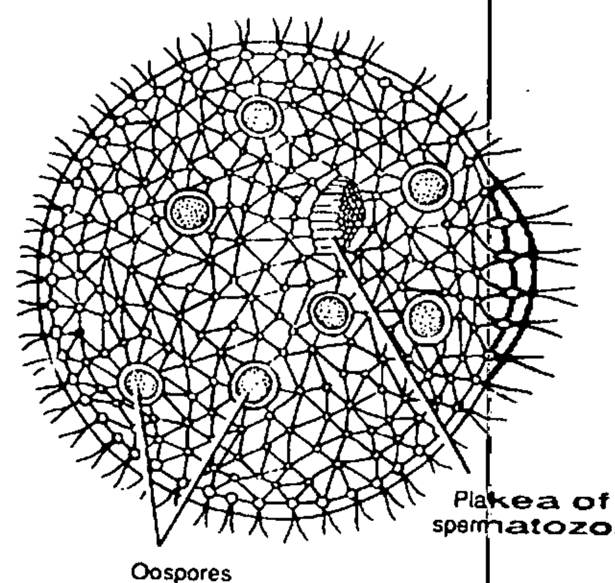


Fig. 3. ***Volvox*. Monoecious species**

Development of Antheridium

The development of antheridium starts with formation of **antheridial initial** or **androgonidial cell** mostly in posterior side of the colony. The initial cells enlarge, lose flagella, protoplasm becomes dense and nucleus becomes larger. The antheridial initial shifts inside towards cavity and remains connected to other vegetative cells through cytoplasmic strands. The protoplast of antheridial initial divides, longitudinally to form 16–512 elongated cells. Each cell differentiates in antherozoid or **spermatozoid** (Fig. 3, 4).

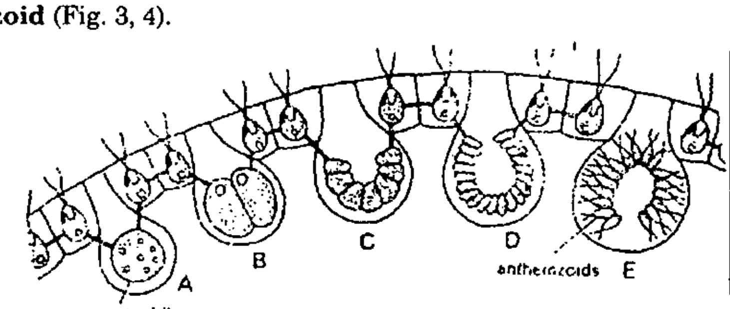


Fig. 4. (A–E). ***Volvox*. Development of antherozoids**

The antherozoid is spindle shaped, elongated, biflagellated structure containing two contractile vacuoles, nucleus, cup shape chloroplast, pyrenoid and eye spot. It is pale yellow or green in colour. The antherozoids are released individually or sometimes in groups.

Development of Oogonium

The oogonia also differentiate mostly in posterior side of the colony. The oogonial initials enlarge, nucleus becomes larger, protoplast becomes dense, flagella are lost, eye spot disappears and many pyrenoids appear. The mature **oosphere** or **ovum** is round or flask shaped structure. The egg is uninucleate structure, the beak of flask shape oogonium functions as receptive spot (Fig. 5 A, B).

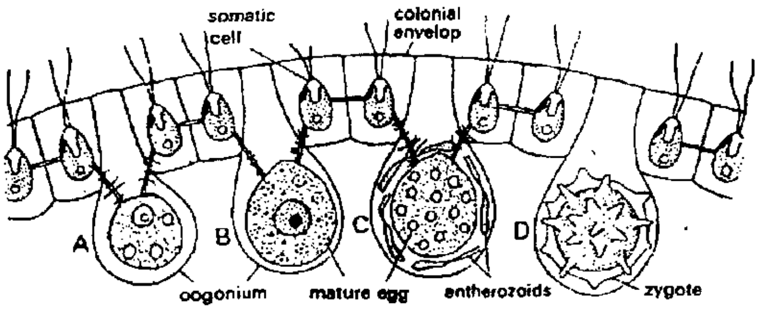


Fig. 5. (A–D). *Volvox*. Oogonium and fertilization

Fertilization. After liberation from antheridium, the antherozoids swim freely on surface of water. Due to chemotactic response the antherozoids reach the oogonia. Some antherozoids enter each oogonium. Only one antherozoid enters inside the oogonium through receptive spot. After this **plasmogamy** *i.e.*, fusion of male and female cytoplasm and **karyogamy** *i.e.*, fusion of male and female nuclei take place. This results in formation of diploid **zygote** (Fig. 5 D).

Zygote

The diploid zygote secretes a three layered thick wall. The layers of the wall are **exospore, mesospore** and **endospore** (Fig. 6 A, B). The outer exospore is thick. It may be smooth *e.g.*, *V. aureus* (Fig. 6 A) or spiny *e.g.*, *V. globator* (Fig. 6 B). The mesospores and endospores are thin and smooth. The walls contain pigment **haematochrome** which imparts red colour to the zygote. The zygotes are released by the disintegration of parent colony. Then zygotes undergo a period of dormancy.

Germination of Zygote

The dormant zygote germinates on approach of favourable climatic conditions. The diploid nucleus of zygote undergoes meiotic division forming four haploid cells. The outer two layers of zygote burst and the inner layer comes out as vesicle. The four haploid cells migrate with the vesicle (Fig. 6 C, D). The development of new colony from zygote differs in different species of *Volvox*. In *V. aureus* and *V. minor* the protoplasm of zygote divides repeateadly until the cell number of colony is reached and new colony is formed as in asexual reproduction process. In *V. campensis* the protoplast of zygote divides to make many

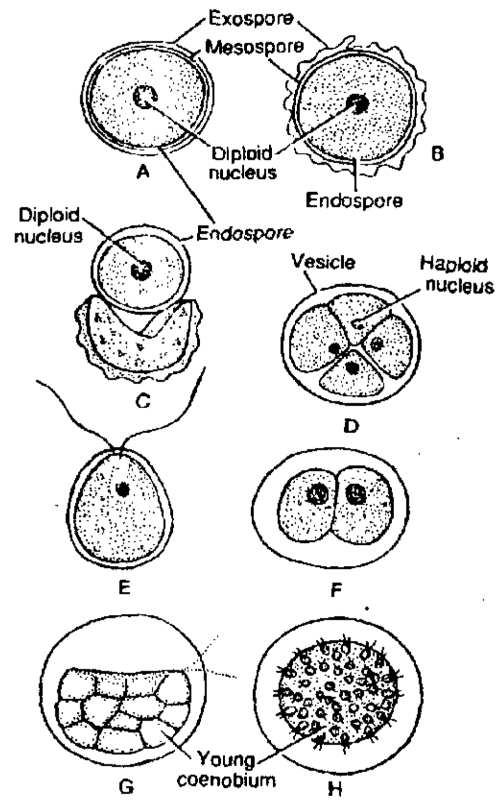


Fig. 6 (A–H). *Volvox*. Gemination of zygote and formation of young coenobium.

biflagellate zoospores. Only one zoospore survives and all other degenerate. This survived zoospores comes out of the vesicle and divides to make may cells which arrange the form of **colony**.

Hydrodictyon

• SYSTEMATIC POSITION

Class	:	**Chlorophyceae**
Order	:	**Chlorococcales**
Family	:	**Hydrodictyaceae**
Genus	:	***Hydrodictyon***

• ORDER : CHLOROCOCCALES

(i) Members are exclusively fresh water.

(ii) Thallus consists a single cell or coenobium.

(iii) Vegetative cells are non-motile, either uninucleate or multinucleate.

(iv) Vegetative cells generally lack flagella, contractile vacuoles and eyespot.

(v) Asexual reproduction occurs by flagellate zoospores, or autospores or aplanospores or hypnospores.

(vi) Sexual reproduction is isogamous anisogamous or oogamous.

• FAMILY : HYDRODICTYACEAE

(i) Members are mostly non-motile coenobia.

(ii) Asexual reproduction takes place by the formation of zoospores.

(iii) Zoospores remains motile within the parent cell and get themselves arrange into a peculiar fashion.

(iv) Sexual reproduction is isogamous.

(v) Gametes are motile.

• OCCURRENCE

Hydrodictyon, a non motile coenobium is macroscopic and beautiful alga. Due to its net like plant body, it is commonly known as **'water net'**. It is represented by 5 species. Only two species of *Hydrodictyon i.e., H. reticulatum* and *H. indicum* are reported from India. *H. reticulatum* is cosmopolitan in distribution. The species are commonly found between spring and rainy season in slow running water or still water of ponds, pools and lakes. It generally floats on the surface of the water but may also lie on the bottom. Very often due to profuse growth, the nets assume big size and cover the entire pond.

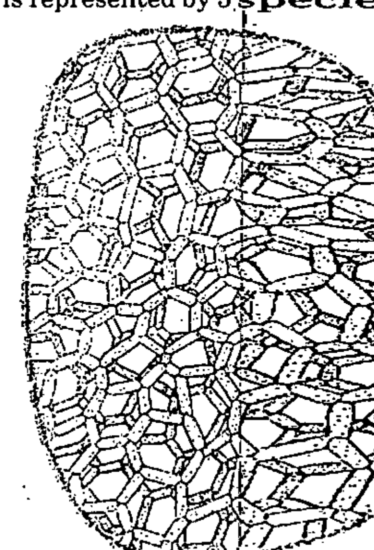


Fig. 1. ***Hydrodictyon*. A coenobium.**

Thallus structure

A mature coenobium consists of a hollow cylindrical network which is closed at both the ends (Fig. 1). It is flat and saucer shaped and its maximum size is generally 20-30 cm. Rarely it may reach upto a length of 60 cm. The mature net of coenobium is made up of a few hundred to several thousand cells. These cells are joind at the end and form pentagonal or hexagonal structures. These structures are called **meshes**. Each mesh interspace is generally bounded by 5-6 or rarely three cells. At each angle of the net or mesh meet three cells (Fig. 2 A, B).

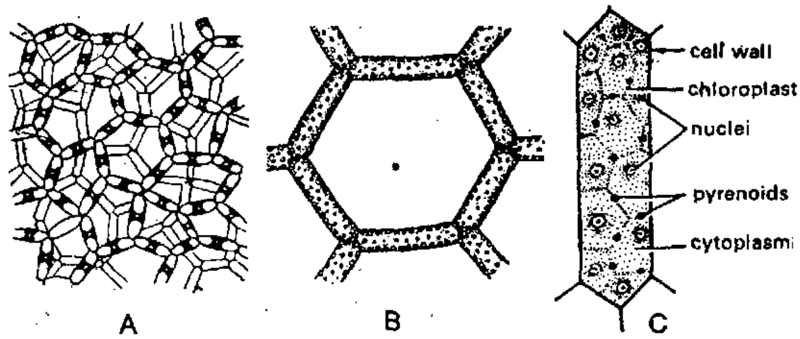


Fig. 2 (A—C). ***Hydrodictyon.*** **Vegetative structure. A. A part of the net; B. Hexagonal mesh; C. A cell.**

Cell structure

Each cell is long, cylindrical or ovoid in shape. Its internal structure can be differentiated into two parts: **cell wall** and **protoplasm.** Cell wall is two layered and is made up of cellulose. It encloses protoplasm. When young, the cells are uninucleate, but at maturity they become multinucleate (coenocytic). Cells contain reticulate chloroplast with many pyrenoids (Fig. 2C). All the typical structures of green algae like a central vacuole ribosomes, mitochondria, dictyosomes are also present. As the cell matures.

REPRODUCTION

It is of three types : **Vegetative, asexual** and **sexual.**

Vegetative reproduction

It takes place by fragmentation. Coenobium breaks up into small pieces called **fragments.** Which have capibility to grow into new colonies.

Asexual reproduction

It takes place by the formation of **autocolonies** or **daughter colonies** (Fig. 3 A–G). These colonies are formed by the biflagellate, uninucleate zoospores. Under

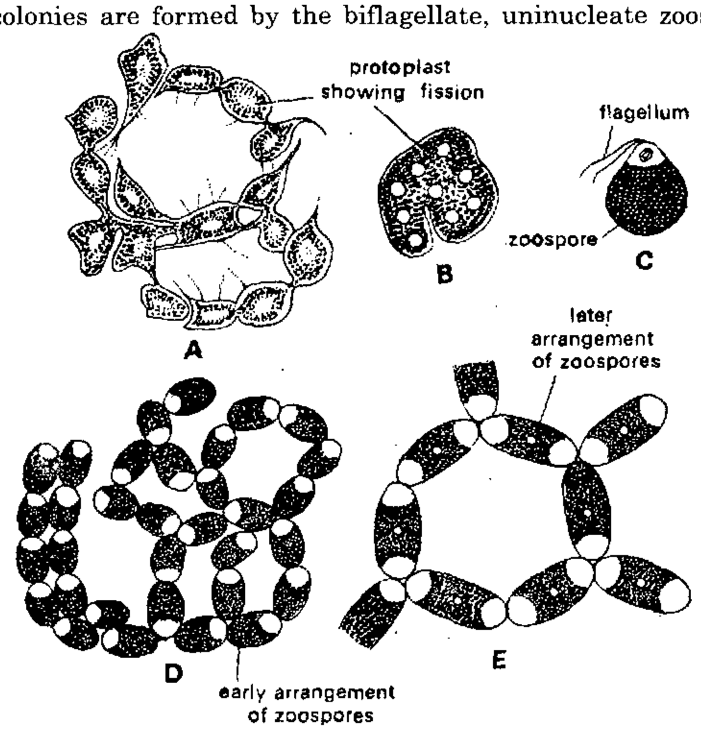


Fig. 3 (A—G). ***Hydrodictyon.*** **Asexual reproduction. (A, B). Zoospores formation. C. A zoospore; (D, E). Arrangement of biflagellated zoospores into a net;**

favourable conditions each coenocytic cell behaves as **zoosporangium.** Its nu undergo mitotic divisions to form a large number of nuclei (7000-20000). Protopla gets segmented into as many segments as there are nuclei. Each segment surrounded by small amount of cytoplasm, a limiting membrane and develops whiplash type equal flagella and represents biflagellate **zoospore** (Fig. 3 A—C) *Hydrodictyon* a peculiar phenomenon is observed. The zoospores thus formed are ne liberated outside the parent cell. They remain motile within the restricted region within the cell. After swimming inside the cell, they ultimately withdraw their flag and get themselves arranged into characteristic hexagonal or pentagonal fashio form a new net (Fig. 3 D, E). This new net is called **autocolony** or **daughter colon**

Sexual reproduction

It is **isogamous.** Any vegetative cell of the coenobium can function gametangium. The biflagellate gametes are produced by the cleavage of the protopl of the gametangia like that of zoospores (Fig. 4A, B). They are produced in large num and are smaller in size than the zoospores. They are liberated individually throug hole in the parent cell wall and swim freely in water. The gametes are uninucleate biflagellate. *Hydrodictyon* is **monoecious.** The gametes from the same or diffe coenobia after liberation fuse to form quadriflagellate zygotes (Fig. 4C). Soon they their flagella and settle down. The immobilised zygote enlarges in size, beco spherical and develops thick wall to form **zygospore**. First it is green but it beco red because of the development of a red pigment **haematochrome**.

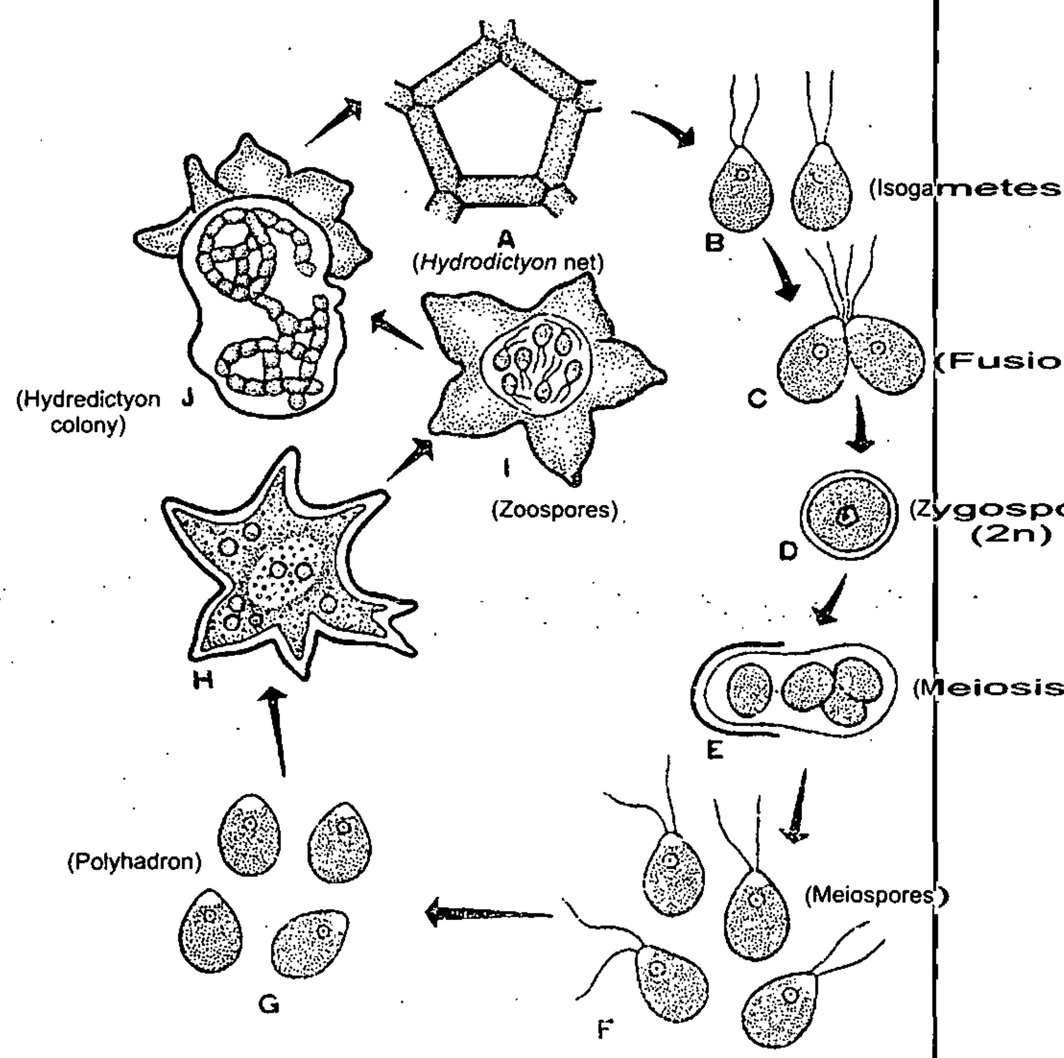


Fig. 4 (A—J). *Hydrodictyon.* Sexual reproduction.

Germination of zygospore : Zygospore is capable to tide over the low winter temperature. At the onset of the spring season, its diploid nucleus undergoes zygotic meiosis to form four, haploid uninucleate, biflagellate **gonozoospores meiospores** (Fig. 4 D-F). The zygospore wall bursts and the meiospores are liberated in the surrounding water. After swimming for some time these meiospores come to rest. They retract their flagella, enlarge and form the thick walled angular cells called **polyhedrons** or **polyeders** (Fig. 4 G, H). This stage is known as **polyhedron stage**. The single nucleus of the polyhedron divides and redivides several times and ultimately forms the **second generation of zoospores** (Fig. 4 I). These zoospores are also uninucleate and are anteriorly biflagellate. The wall of the polyhedron cracks down and the zoospores emerge into a thin vesicle (Fig. 5 J). These zoospores do not escape outside in the water but actively swim within the vesicle for sometime. They withdraw their flagella and arrange themselves in the form of a net of *Hydrodictyon*. It is a **daughter** or **juvenile colony**. It is released in water by the dissolution of the vesicle. Its cells grow in size and produce new coenobium.

OEDOGONIALES

OEDOGONIACEAE : *Oedogonium*

• ORDER : OEDOGONIALES

(i) This order is essentially a group of fresh-water green algae.

(ii) Members prefer to grow in quieter situations and shun flowing waters.

(iii) They often occur attached by a special hold fast cell.

(iv) Plant body is unbranched (*Oedogonium*) or branched (*Oedocladium*, *Bulbochaete*). Filaments are made up of uninucleate, cylindrical cells.

(v) Each cell is greater in length than in breadth and contains a well developed reticulate chloroplast enclosing many pyrenoids.

(vi) Cell division is unique. It is accompanied by the formation of cap of cell wall material.

(vii) Reproductive structures like zoospores, androspores and male gametes possess a ring of numerous flagella around the anterior end. Such a type of flagellation is known as **stephanokont.**

(viii) Asexual reproduction takes place by the formation of multiflagellate zoospores produced singly per zoosporangium.

(x) Species are homothallic as well as heterothallic.

• FAMILY : OEDOGONIACEAE

(i) The order oedogoniales includes a single family Oedogoniaceae.

(ii) The family contains only three genera-*Oedogonium*, *Oedocladium* and *Bulbochaete*.

(iii) *Oedogonium* is terrestrial while *Oedocladium* and *Bulbochaete* are aquatic.

Oedogonium

• SYSTEMATIC POSITION

Class	:	**Chlorophyceae**
Order	:	**Oedogoniales**
Family	:	**Oedogoniaceae**
Genus	:	***Oedogonium***

• OCCURRENCE

The genus *Oedogonium* (*Oedos*–swollen, *gonos*–reproductive) structure is the only genus of the family with unbranched filaments. It is represented by about 400 species. The common Indian species are : *O. cardiacum, O. elegans, O. obolongellum* and *O. tenuis*. *Oedogonium* occurs as the fresh water filamentous alga found in ditches, ponds, pools and lakes. It occurs as **epiphytic** alga found attached on leaves and twigs of other plants. It is also found attached on other algae such as *Cladophora*. Some species of *Oedogonium* are terrestrial, found growing on moist soils. It is common in stagnant water and less common in running water.

Thallus. The thallus is made of green, multicellular, unbranched filaments. The filament is made of three types of cells (Fig. 1) :

(i) The lower-most basal cell or **holdfast**.

(ii) The intercalary cells.

(iii) The upper–most apical cell.

(i) Hold fast. The filament is attached by means of specially differentiated basal cell. The holdfast is found in aquatic species and it rarely occurs in terrestrial forms. In terrestrial forms it may give out rhizoid like outgrowths. The hold fast or basal cell is club shaped, broad, round in upper part and narrow in lower part. The lower terminal part of basal cells is multilobed, disc like or finger shaped which attaches the filament to substratum. Chloroplasts are absent or poorly developed in basal cell.

(ii) Intercalary cells. All cells of the filament in between apical cell and the basal cell are intercalary cells. The intercalary cells of filaments have base-apex polarity. All intercalary cells are alike, only some cells after division develop cap in upper part. Such cells are called **cap cells.**

(iii) Apical cell. The terminal cell of the filament called apical cell. It is round or dome shaped. In some species *e.g.*, *O. ciliata*, the apical cell is tapering and gives rise to narrow hair like structure. The apical cell is green due to chlorophyll.

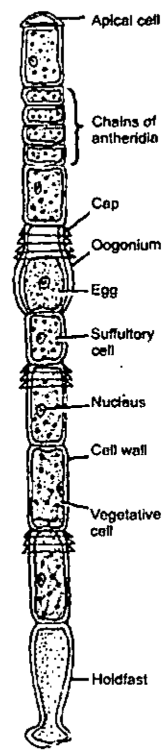


Fig. 1. ***Oedogonium.*** **A filament**

Cell Structure

The cells are elongated and cylindrical. The cell wall is generally thick, rough and rigid. It is made up of three concentric layers, the inner **cellulose,** middle **pectose** and the outer layer is **chitinous** in nature.

The protoplasm consists of thin plasma membrane, cytoplasm, central vacuole, reticulate chloroplast and the nucleus. The centre of the cell is occupied by a large **central vacuole** which contains the cell sap. The cell sap contains excretions, secretions and inorganic compounds. The protoplast occurs as thin layer between the central vacuole and the inner cell wall. The chloroplast is characteristically reticulate, extending or covering the whole cell and encircling the protoplast (Fig. 2 A, B). The strands of reticulum may be broad or narrow depending upon the species. In most of the cases the strands are parallel to the long axis of the cell. Many pyrenoids, Pyrenoids single

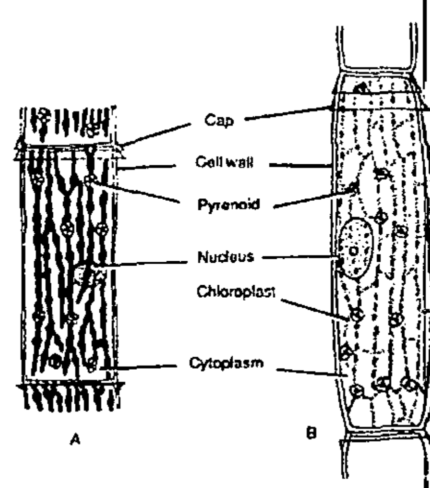


Fig. 2 (A, B). ***Oedogonium*** **(A). Young cell; (B) Mature cell.**

large nucleus, mitochondria, Golgi bodies, endoplasmic reticulum and the other cell organelles are present in the cell.

Growth

The growth of *Oedogonium* filaments takes place by cell division in intercalary cells but sometimes the apical cell also divides and takes part in the elongation of filaments.

The method of cell division and growth of cell wall is unique and peculiar in *Oedogonium*. The cell wall does not elongate in the usual way. The process of cell division in *Oedogonium* takes place in following stages:

(i) The nucleus from periphery moves towards the centre and slightly towards the upper part of the cell (Fig. 3 A).

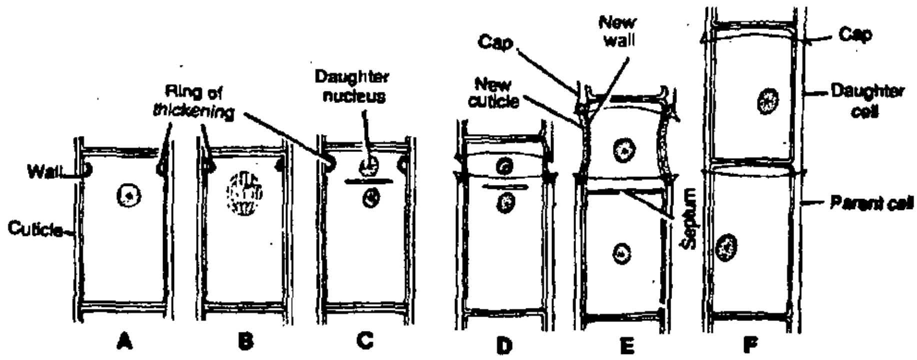


Fig. 3. *Oedogonium*. Cell division

(ii) Since the wall does not elongate in the usual manner, the cytoplasmic wall material gathers in the form of a "ring" round the inner wall at the upper end of the cell (Fig. 3 A).

(iii) The nucleus divides mitotically and there is formation of a groove in the ring (Fig. 3B, C).

(iv) The next stage is the elongation or stretching of the daughter cells by breaking up of the wall layers round the groove of the ring. The lower daughter cell elongates to the former level of the ring. The upper one also elongates to the same extent. The process of elongation is completed within 15 minutes (Fig. 3 D).

(v) Along with the completion of elongation, a transverse wall formation between the two is also completed. The distal end of the upper cell contains a small portion of the old parent wall which appears as the **apical cap**. It is evident that the outer wall of the newly divided upper cell with the "cap" is derived from the ring except the "cap" which belongs to the old parent wall, whereas, in the lower daughter cell laterals wall are those of the old parent cell.

"Cap cells" usually divide repeatedly showing as many caps as there have been divisions and the position and number of such cells in a filament are specific characters. The cell divisions are generally intercalary and sometimes terminal.

• REPRODUCTION

The reproduction in *Oedogonium* takes place by **vegetative**, **asexual** and **sexual** methods.

(i) Vegetative Reproduction

Vegetative reproduction takes place by **fragmentation** and **akinete formation**.

(A) Fragmentation : *Oedogonium* filament breaks into many small fragments which have capability to grow into complete filaments under favourable conditions. Fragmentation takes place due to any of the following reasons :

(a) accidental breaking of the filaments.

(b) dying or dehydration of intercalary cells.

(c) disintegration of intercalary cells due to conversion in sporangia.

(d) mechanical injury to the filament.

(e) change in the environmental conditions.

(B) Akinete formation : The akinetes are formed under unfavourable conditions. Akinetes are modified vegetative cells which become swollen, round or oval, reddish brown and thick walled. These are rich in reserve starch and orange-red coloured oil. Akinetes are formed in chains of 10 to 40 (Fig. 4). Akinetes germinate directly under favourable conditions.

Fig. 4. *Oedogonium*. Chain of akinetes

(ii) Asexual Reproduction

Asexual reproduction takes place by means of multiflagellate zoospores produced singly in intercalary cap cell. Mostly the newly formed cap cell functions as the **zoosporangium**. Several factors control zoospore formation of which high pH and CO_2 concentration of medium and a diurnal rhythm of light and darkness are significant. The cell which functions as zoosporangium gets filled with abundant reserve food and a slight contraction of the protoplast from the cell wall takes place (Fig. 5 A, B). The central vacuole disappears, the chloroplast frees itself from one end of the cell and becomes conical. The nucleus comes to lie near this chloroplast. A small lens shaped hyaline region is formed between the wall and the nucleus. This hyaline **bald spot** later forms the anterior end of the zoospore.

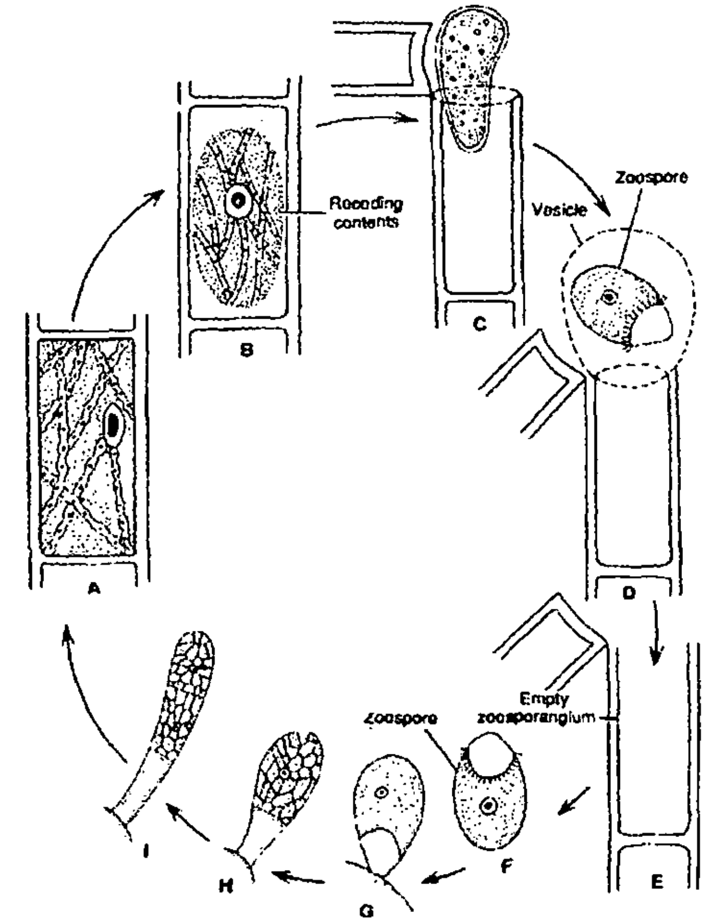


Fig. 5. (A–I). *Oedogonium*. Asexual reproduction in *Oedogonium*.

At the base of this hyaline area a ring of basal granules appears and from each basal granule or blepharoplast a flagellum arises. The basal granules are connected to each other by fibrous strand. A crown of about 30 flagella is formed around the hyaline spot (Fig. 5 C).

The mature zoospore is oval, spherical or pear shaped structure. The zoospore is uninucleate and contains a ring shaped chloroplast. The zoospore is dark green in colour except at the hyaline pointed apical end. A subapical ring of flagella is present and such flagellation is called **stephanokontic type** (Fig. 5 F).

When the zoospore is mature, the wall of the zoosporangium splits near the apical region and the adjacent cell moves apart to make a gap for the liberation of zoospore (Fig. 5 D). The mucilage substance is secreted at the base of the zoospore which helps in the liberation of zoospore. The zoospore comes out of the zoosporangium in a delicate mucilaginous vesicle which soon gets dissolved and the zoospores are liberated in water (Fig. 5 D, E).

Germination of zoospore. After liberation, the zoospore swims for about an hour. Then it settles and attaches itself to a solid substratum with its anterior end downwards. After attachment flagella are withdrawn and it starts elongation. The lower hyaline part elongates to make holdfast and the upper part divides repeatedly to make new filament (Fig. 5 G–I).

• SEXUAL REPRODUCTION

The sexual reproduction in *Oedogonium* is of advanced **oogamous** type. Sexual reproduction is more frequent in still waters than in running water. The factors influencing sexual reproduction are alkaline medium, deficiency of nutrition, light and dark periods and increased temperature. The genus *Oedogonium* exhibits **sexual dimorphism** because the male and the female gametes differ morphologically as well as physiologically. The male gametes are produced in **antheridia** and the female gametes are produced in **oogonia.**

Depending upon the nature of antheridia producing plants, *Oedogonium* species are of two types:

(i) Macrandrous. If antheridia are produced on normal size plant, *Oedogonium* forms are called **macrandrous.** Macrandrous species may be **monoecious** or **dioecious.** In monoecious macrandrous species antheridia and oogonia are produced on the same plant *e.g.*, *O. fragile, O. hirnii, O. kurzii* and *O. nodulosum.* In dioecious macrandrous species antheridia and oogonia are produced on separate male and female plants of normal size.

(ii) Nannandrous. The female or oogonia bearing plants are normal. The antheridia are produced on special type of small or dwarf plants, known as **Dwarf males** or **Nannandria**. The dwarf males are formed by **androspores** which are produced in **androsporangia.**

If androsporangia and oogonia are formed on same plant, the *Oedogonium* forms are called **gynandrosporous** *e.g.*, *O. concatinatum.* If androsporangia and oogonia are formed on different plants, *Oedogonium* forms are called **idioandrosporous** *e.g.*, *O. confertum*, *O. iyengarii* and *O. setigerum*. According to some algologists, nannondrous species are more primitive.

Antheridia

(i) In macrandrous forms. The antheridia develop on normal filaments, terminal or intercalary in position. The initial cell which gives rise to antheridia is called **antheridial mother cell.** It is normally a cap cell. The antheridial mother cell divides by transverse division to form an upper smaller cell called **antheridium** and a lower larger cell called **sister cell.** The sister cell divides repeatedly to form a row of 2–40 antheridia (Fig. 6 A). The antheridia are broad, flat, short cylindrical, uninuleate cells.

The two antherozoids are positioned side-by-side or one above the other if divisions are longitudinal and transverse respectively. The antherozoids are liberated in the

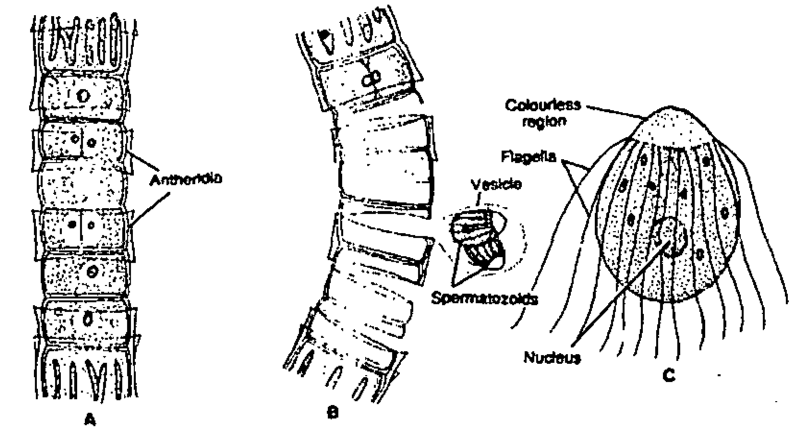


Fig. 6. (A–C). *Oedogonium*. (A) Chains of Antheridia, (B) Liberation of antherozoid or spermatozoid, (C) Antherozoid.

same fashion as zoospores (Fig. 6 B). The liberated antherozoids or spermatozoids o sperms are pale green or yellow green, oval or pear shaped. The antherozoids are moti about 30 sub-apical flagella present at the base of beak or hyaline spot (Fig. 6 C). Th flagella are sometimes longer than the body of spermatozoid *e.g.*, in *O. crassum* and O *kurzii*. The antherozoids swim freely in water before they reach oogonia and take pa in fertilization.

(ii) In nannandrous forms. The antheridia are formed on short or dwarf ma plants called **dwarf males** or **nannandria** (Fig. 7 G). The dwarf male filament

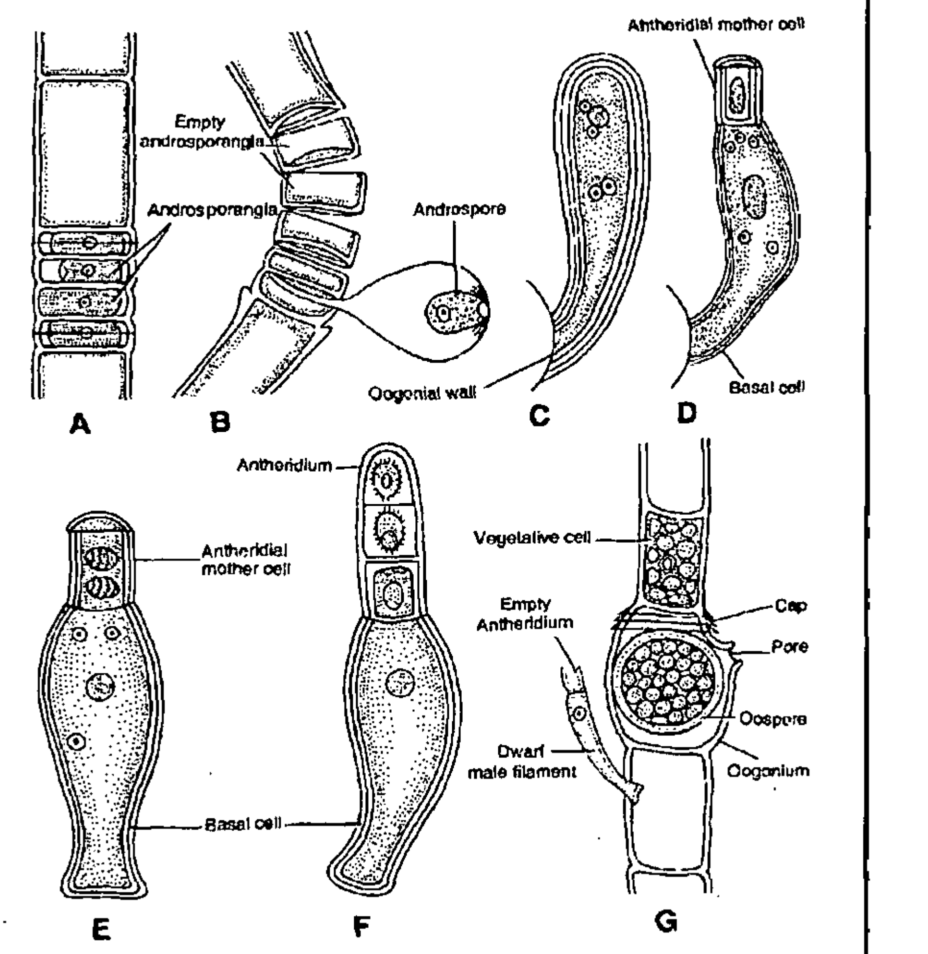


Fig. 7. (A–G). *Oedogonium*. Development of nannandrium, (A, B). Androsporangia in idioandrosporous species, (C–G). Germination of androspore on female plant.

produced by the germination of a special type of spore known as **androspore**. The androspore is produced singly within an androsporangium. Androporangia are more or less similar looking to the antheridia of macrandrous forms and are produced in a similar manner from a mother cell (Fig. 7 A, B).

The androsporangia are flat, discoid cells slightly larger than antheridia. Each androsporangium produces a single androspore just as in the case of zoospore. Liberation of androspore is similar to that of a zoospore. The androspores look similar to zoospore except for the smaller size. The androspores are motile and have a subpolar ring of flagella.

After swimming about for some time, the androspore settles on oogonial wall *e.g.*, *O. ciliatum* or on the supporting cell *e.g.*, *O. concatenatum*. The androspore germinates into a dwarf male or **nannandrium**. Germlings at one celled stage may divide and produce two antherozoids *e.g.*, *O. deplandrum, O. perspicuum* (Fig. 7 C–G).

The nannandrium or dwarf male can be a few cells long. It has a **basal** attaching cell the **stipe** and all others cells are antheridial cells. In many cases cap is present at the top of the apical antheridium. The protoplasm of each antheridial cell divides to form two sperms or antherozoids which are similar to antherozoids of macrandrous species. According to **Iyengar** (1951) the antheridium of nannandrium produces single antherozoid. The antherozoids are released by disorganization of antheridial cell or through the opening. Most phycologists consider that nannandrous species have been evolved from macrandrous species.

Oogonia

In *Oedogonium* the female sex organ **oogonia** are highly differentiated female gametangia. These are mostly intercalary but sometimes can be terminal *e.g.*, *O. palaiense*. The structure and development of oogonium is identical in macrandrous and nannandrous species.

Like antheridia any freely divided or actively growing cap cell functions as the **oogonial mother cell**. The oogonial mother cell divides by transverse division into two unequal cells, the upper cell and the lower cell. The upper larger cell forms **oogonium** and the lower smaller cell function as **supporting cell** or **suffultory cell**. In some species the oogonial mother cells directly forms the oogonium. Supporting cell is absent is *O. americanum*. If any of the two divided cells again functions as oogonial mother cell many oogonia are formed in chain. In monoecious species the suffultory cell may divide to form antheridia.

The protoplast in oogonium metamorphosises into a single **egg** or **oosphere**. The oosphere is non-motile, green due to chlorophyll and has a central nucleus. As the ovum matures, the nucleus moves to periphery, the oosphere retracts slightly from the oogonial wall and develops a **hyaline** or **receptive spot** just outside the nucleus. The receptive spoto receives antherozoids for fertilization. At receptive spot a pore is formed by gelatinisation of wall in **poriferous** species and a transverse slit is formed in **operculate** species. In both species a thin membrane is deposited on the inner node of the exit which functions as a channel leading down to ovum.

In macrandrous monoecious species, where antheridia and oogonia develop on the same plant, the *Oedogonium* species are **protogynous** *i.e.*, the development of oogonia takes place before development of antheridia to ensure cross-fertilization.

Fertilization. The mature egg secretes chemical substance or mucilage to attract antherozoids or the antherozoids may enter oogonium through the slit. The antherozoids swim through the opening of oogonial wall and enter the egg through hyaline receptive spot (Fig. 8 D–F). Only one male antherozoid is able to fuse with ovum. After plasmogamy and karyogamy the male nucleus and female nucleus fuse to form a diploid **zygote nucelus**. The zygote secretes a thick wall around itself and forms **oospore**. The colour of the oospore changes from green to reddish brown. The oospore is liberated by the disintegration of oogonial wall.

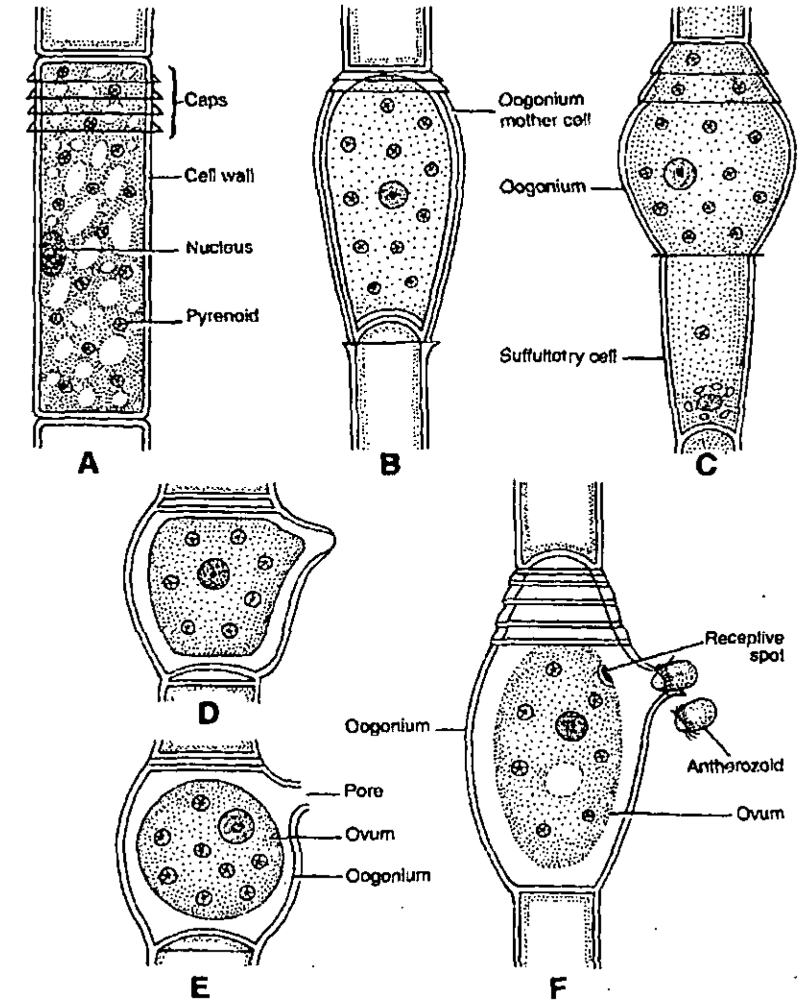


Fig. 8. (A–F). *Oedogonium*. Development of oogonium.

The ornamentation of oospore is of taxonomic importance. The oospore is red in colour due to accumulation of red oil. Oospore contains a diploid nucleus and cytoplasm rich in proteins.

Germination of oospore. Oospore is a resting spore but sometimes it can germinate directly. The period of rest for oospore may be a year or more. According to **Mainx** (1931) the zygote may require chilling before germination. The diploid oospore nucleus undergoes zygotic meiosis to form four haploid nuclei before germination. The diploid oospore divides to form four haploid daughter protoplasts. Each daughter protoplast metamorphosis into a zoospore also called as **zoomeiospore**. The zoomeiospores are liberated in a vesicle. Soon the vesicle disappears and as in asexual reproduction the zoospores develop to make *Oedogonium* plants.

LIFE CYCLE IN *OEDOGONIUM*

In *Oedogonium* the thallus is haploid and the life cycle is **haplontic type**. The diploid stage in life cycle is only zygote. It occurs for a short period. The zygote or oospore undergoes meiosis to make four meiozoospores which again form haploid *Oedogonium* thalli.

The variations in life cycles of *Oedogonium* are due to macrandrous and nannandrous nature of *Oedogonium* species.

Macrandrous Forms

Oedogonium macrandrous species can be **monoecious** or homothallic, if antheridia and oogonia are produced on same filament (Fig. 9, 10).

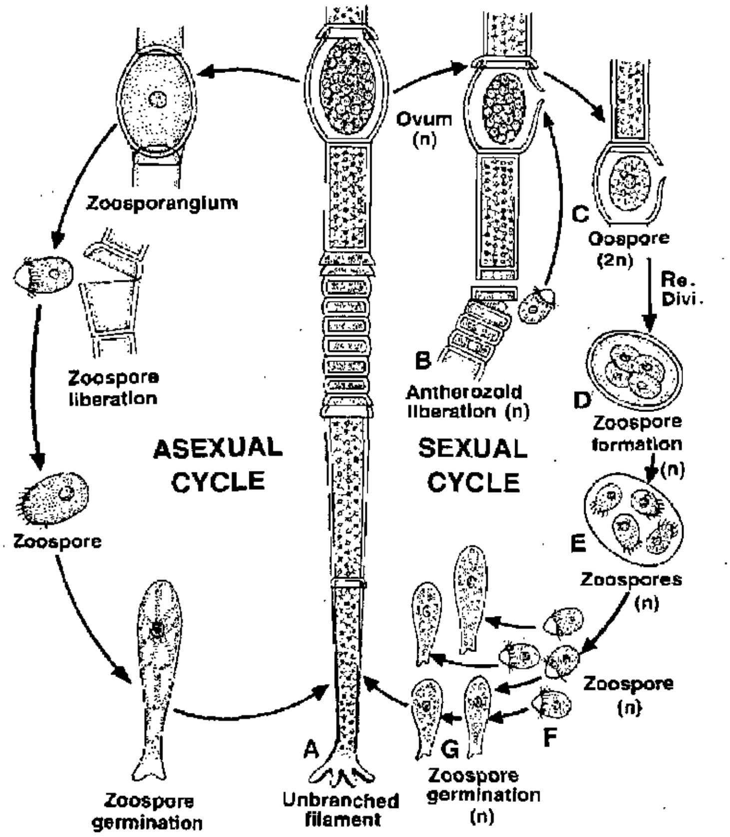


Fig. 9. (A–F). ***Oedogonium.*** **Diagrammatic life Cycle of monoecious macrandrous species.**

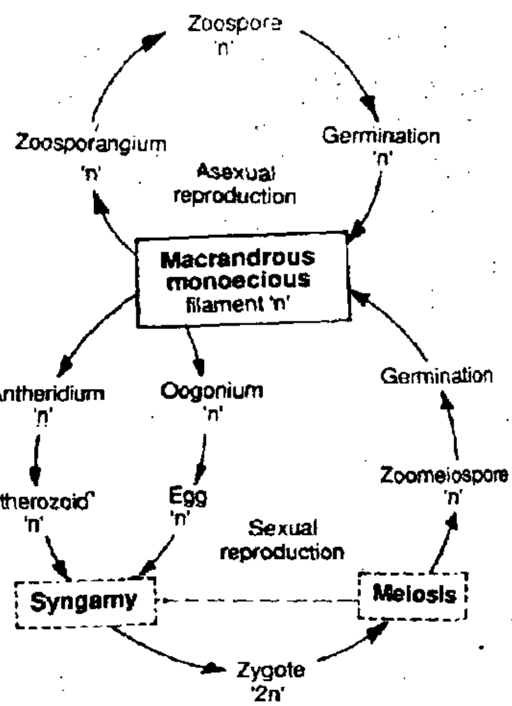


Fig. 10. ***Oedogonium.*** **Graphic life Cycle monoecious macrandrous species.**

Oedogonium macrandrous species can be **dioecious** or **heterothallic** if antheridia are produced on male plants and oogonia are produced on separate female plants. (Fig. 11).

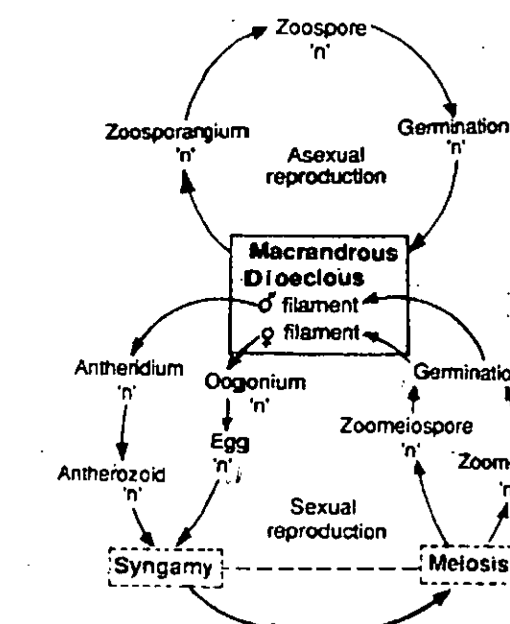


Fig. 11. ***Oedogonium*. Graphic life cycle of macrandrous dioecious species.**

Nannandrous Forms

The nannandrium or dwarf male plants are produced by germination androspores which are produced in **androsporangia**. In **gynandrosporo** nannandrium forms the androsporangia and oogonia are formed on same filamen (Fig. 12, 13).

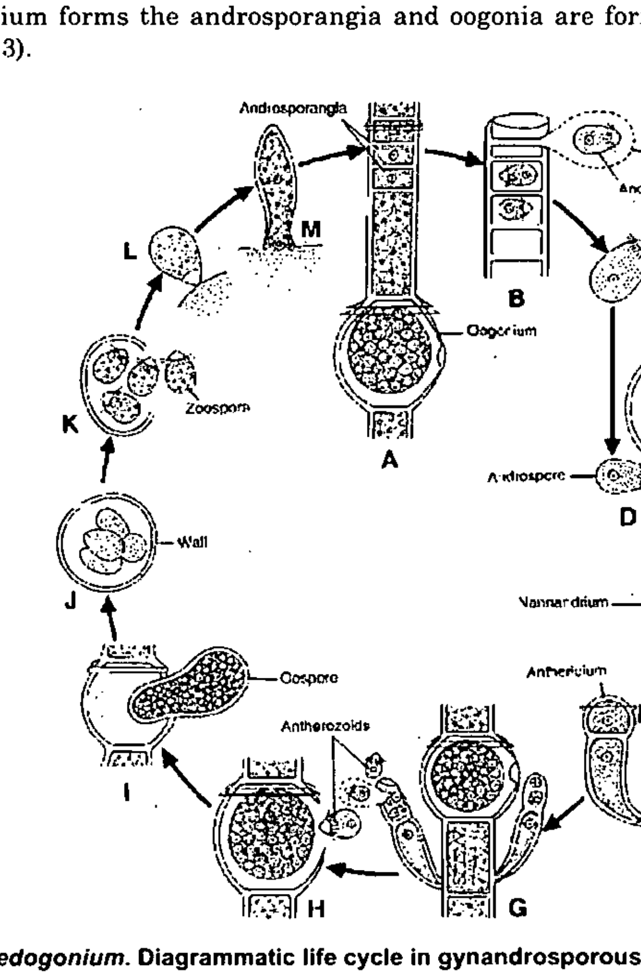


Fig. 12. ***Oedogonium*. Diagrammatic life cycle in gynandrosporous, nannandrous species.**

In **idioandrosporous** nannandrium forms, the androsporangia and oogonia are formed on different plants.

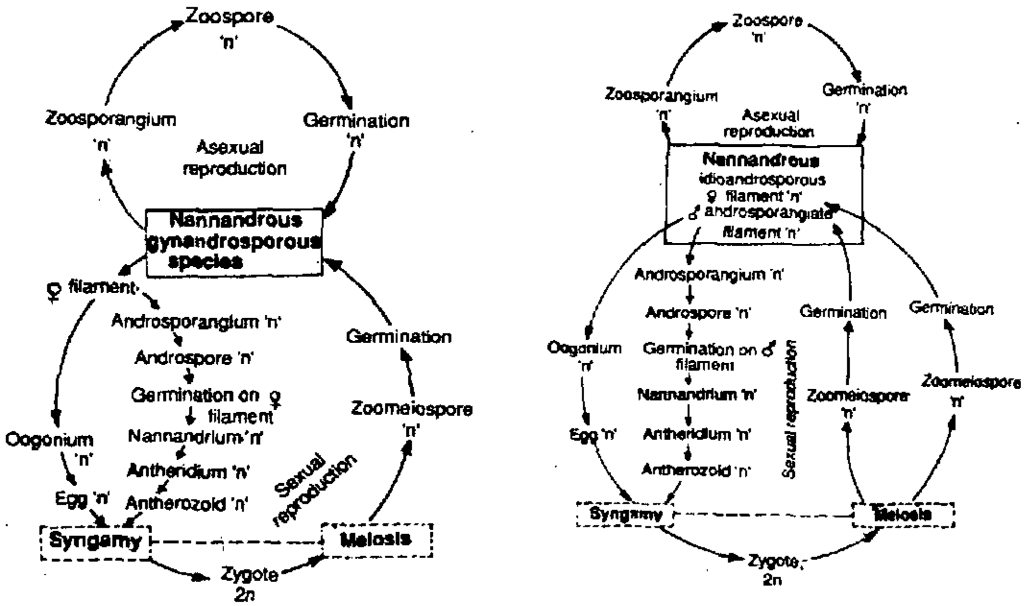


Fig. 13. ***Oedogonium*. Graphic life Cycle of nannandrous species of *Oedogonium*.**

CHARALES

CHARACEAE : *Chara*

• ORDER : CHARALES, FAMILY : CHARACEAE

(i) The systematic position of **Charales** is debated. It has been treated differently by different workers **Fritsch** (1935) included it in class Chlorophyceae. **Smith** (1938) and **Chapman** gave it the rank of class Charophyceae. **Bold** (1956), **McLean** and **Cool** (1956) considered it as a separate phylum Charaphyta, intermediate between algae and bryophyta.

(ii) The charophytes are commonly called 'stoneworts'.

(iii) The members are mostly found in shallow fresh water lakes with sandy and muddy bottom. The thallus is well organized and differentiated into **rhizoids** and **erect system**. The erect main axis is differentiated into nodes and internodes. Each node bears a **whorl of branches of limited growth**. The branches of unlimited growth arise in the axils of these branches. This habit is called **equisetoid.**

(iv) The sexual reproduction is advanced **oogamous** type. The sex organs are macroscopic. The male sex organs, antheridia are called **globule** and the female sex organs, oogonia are called **nucule**.

(v) Asexual reproduction is absent.

(vi) There is distinct protonemal stage after the germination of zygote.

(vii) The order includes only one family **Characeae**. It is represented in India by 5 genera and 65 species. These genera are *Chara, Nitella Nitellopsis, Lychnothamnus* and *Tolypella*.

Chara

• SYSTEMATIC POSITION

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

• OCCURRENCE

Chara is a fresh water, green alga found submerged in shallow water ponds, tanks, lakes and slow running water. *C. baltica* is found growing is brackish water and *C. fragilis* is found in hot springs. *Chara* is found mostly in hard fresh water, rich in organic matter, calcium and deficient in oxygen. *Chara* plants are often encrusted with calcium carbonate and hence are commonly called **stone wort.** *Chara* often emits disagreeable onion like odour due to presence of sulphur compounds. *C. hatei* grows trailing on the soil *C. nuda* and *C. grovesii* are found on mountains, *C. wallichii* and *C. hydropitys* are found in plains. In India *Chara* is represented by about 30 species of which common Indian species are : *C. zeylanica*, *C. braunii*, *C. gracilis*, *C. hatei* and *C. gymnopity* etc.

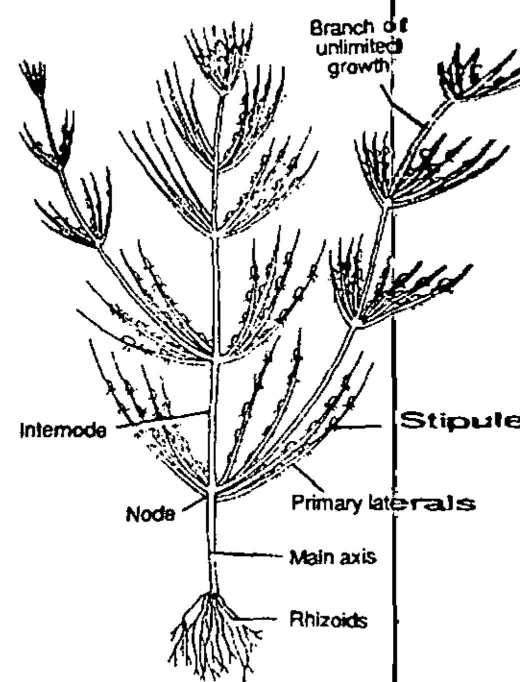


Fig. 1. *Chara*. External features.

• STRUCTURE

The thallus of *Chara* is branched, multicellular and macroscopic. The thallus is normally 20–30 cm. in height but often may be upto 90 cm to 1 m. Some species like *C. hatei* are small and may be 2–3 cm. long. The plants in appearance resemble *Equisetum*, hence *Chara* is commonly called as **aquatic horsetail.** The thallus is mainly differentiated into **rhizoids** and **main axis** (Fig. 1).

• RHIZOIDS

The rhizoids are white, thread like, multicellular, uniseriate and branched structures. The rhizoids arise from rhizoidal plates. The rhizoids show apical growth. Rhizoids help in attachment of plant to substratum *i.e.*, mud or sand, in absorption of minerals and in vegetative multiplication of plants by forming bulbils and secondary protonema.

• MAIN AXIS

The main axis is erect, long, branched and differentiated into **nodes** and **internodes.** The internode consists of single, much elongated or oblong cell. The internodal cells in some species may be surrounded by one celled thick layer called **cortex** and such species are called as **corticate species.** The species in which cortical layer is absent are called **ecorticate species** (Fig. 2 A. B).

The node consists of a pair of central small cells surrounded by 6–20 peripheral cells (Fig. 2 C). The central cells and peripheral cells arise from a single nodal initial cell. On nodes develop these following four types of appendages :

(i) Branches of limited growth. The branches of limited growth arise in whorls of 6–20 from peripheral cells of the nodes of main axis or on branches of unlimited growth. These are also called **branchlets, branches of first order, primary laterals** or **leaves.** These branches stop to grow after forming 5–15 nodes and hence are called branches of limited growth. The stipulodes and reproductive structures are formed on the node of these branches.

(ii) Branches of unlimited growth. The branches of unlimited growth arise from the axils of the branches of limited growth hence these are also called **auxillary branches** or **long laterals**. These are differentiated into nodes and internodes. At nodes they bear primary laterals and these branches look like the main axis. Their growth is also unlimited like main axis.

(iii) Stipulodes. The basal node of the branches of limited growth develop short, oval, pointed single cell outgrowths called **stipulodes. In** most of the species of *Chara e.g., C. burmanica,* the number of stipulodes at each node is twice the number of primary laterals, such species are called as **bistipulate.**

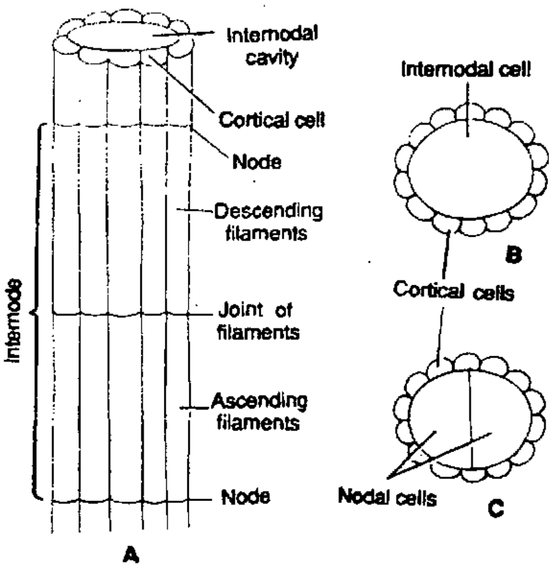


Fig. 3. (A–C). ***Chara.*** **(A) Main axis showing cortication, (B) Transverse section through internode; (C) Transverse section through node.**

(iv) Cortex. Many species of *Chara e.g., C. aspera, C. inferma* have internodal cells of main axis ensheathed by cortex cells. Such species are called **corticated** species. The cortex consists of vertically elongated narrow cells. The internode is covered upto half of its length by corticating filaments developed from upper node called descending filaments, the lower half of internode is covered by filaments developed from lower node called ascending filaments. The ascending and descending filaments meet at the middle of internode. The *Chara* species without cortex *e.g., C. corallina* are called **ecorticated** species.

• CELL STRUCTURE

The main axis of *Chara* consists of mainly two types of cells :

(i) Nodal cells

(ii) Internodal cells.

The nodal cells are smaller in size and isodiametric. The cells are dense cytoplasmic, uninucleate with few small ellipsoidal chloroplasts. The central vacuole is not developed instead many small vacuoles may be present. The cytoplasm can be differentiated in outer **exoplasm** and inner **endoplasm** (Fig. 3 A).

The internodal cells are much elongated. The cytoplasm is present around a large central vacuole. The cells are multinucleate and contain many discoid chloroplasts. The cytoplasm is also differentiated into outer **exoplasm** and inner **endoplasm**. The endoplasm shows streaming movements.

• REPRODUCTION

Reproduction in *Chara* takes place by vegetative and sexual methods. Asexual reproduction is absent.

(i) Vegetative reproduction : Vegetative reproduction in *Chara* takes place by following methods :

(a) Bulbils : The bulbils are spherical or oval tuberlike structures which develop
rhizoids *e.g.*, *C. aspora* or on lower nodes of main axis *e.g.*, *C. baltica*. The bulbils
detachment from plants germinate into new thallus (Fig. 3 A).

(b) Amylum stars : In some species of *Chara e.g.*, *C. stelligna*, on the lower nodes of main axis develop multicellular star shape aggregates of cells (Fig. 3 B). These cells are full of amylum starch and hence are called **Amylum stars.** The amylum stars on detachment from plants develop into new *Chara* thalli.

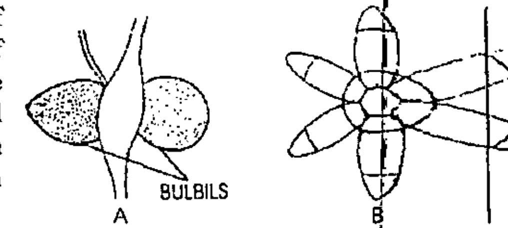


Fig. 5. (A, B). ***Chara*. Vegetative reproduction**

(c) Amorphous bulbils : The amorphous bulbils are group of many cells, irregular in shape which develop on lower node of main axis *e.g.*, *C. delicatula* or on rhizoids *e.g.*, *C. fragifera* and *C. baltica*. The amorphous bulb
are perennating structures, when the main plant dies under unfavourable condition
these bulbils survive and make *Chara* plants on return of favourable conditions.

(d) Secondary protonema. These are tubular or filamentous structure whi
develop from primary protonema or the basal cells of the rhizoids. The seconda
protonema like primary protonema form *Chara* plants.

• SEXUAL REPRODUCTION

The sexual reproduction in *Chara* is of highly advanced **oogamous** type. The s
organs are macroscopic and complex in organization. The male sex organs are call
antheridium or **globule** and the female **oogonium** or **nucule.** Most of the *Cha*
species are **homothallic** *i.e.*, the male and female sex organs are borne on the sa
nodes, (Fig. 4) *e.g.*, *C. zeylanica*. Some species *e.g.*, *C. wallichii* are **heterothallic** *i.*
male and female sexorgans are borne on different plants.

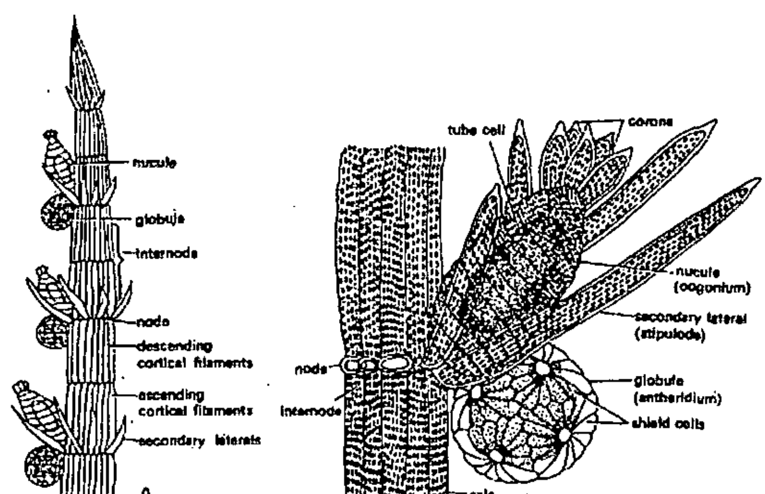


Fig. 7. (A, B). ***Chara*. Sexual reproduction. (A) A branch of limited growth with sex organs on its node; (B) Mature nucule (above), globule (below).**

The sex organs arise on the branches of limited growth or primary laterals,
nucule is located above the globule. The development of globule and nucule takes pl
simultaneously but in some species globule matures before nucule (Fig. 4 A, B).

Globule

The globule is large, spherical, red or yellow structure.

Development and Structure

The early development of globule and nucule is similar.

The pripheral cell of the lower node of the primary lateral divides periclinally to form an outer and an inner cell. The outer cell functions as antheridial initial and the lower cell again divides by periclinal division. Out of these three cells formed, the lowermost functions as **internodal cell** the middle forms **basal node**, the uppermost functions as the **antehridial initial** (Fig. 5 A, B). The middle basal node cell divides to make 5 peripheral cells. Out of these five peripheral cells, the upper one develops into oogonium, two lateral ones form unicellular bracteoles and two lower ones, one on either side of oogonium forms cortex or remains non-functional (Fig. 5 C, D).

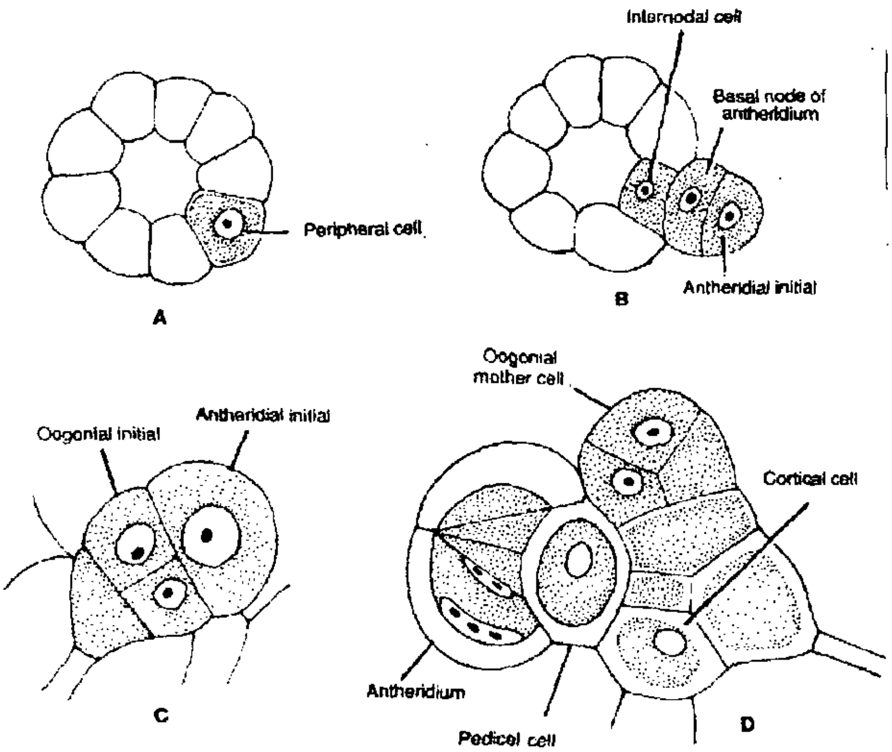


Fig. 8. (A–D). *Chara.* Early development of sex organs.

The **antheridial initial** divides by transverse division to make basal **pedicel cell** and a terminal **antheridial mother cell** (Fig. 6 A, B). The pedicel cell does not divide further and forms **pedicel** or **stalk** of mature antheridium. The antheridial mother cell enlarges and divides by two successive vertical division at right angle to each other to make a **quadrant** (Fig. 6 C–D). All these four cells divide by a transverse wall to make eight cells or **octant stage**. Each cell of the octant divides periclinally and forms two layers of eight cells each. The cells of inner or outer layer divide periclinally to make three radial layers of eight cells each. The outermost eight cells enlarge laterally to form a curved plate of **eight shield cells** (Fig. 6 E, F). The cells of the middle layer elongate towards centre to make eight rodshaped **manubrial cells** (Fig. 6 F).

The cells of the inner layer function as eight **primary capitulum cells.** Each primary capitulum cell divides to form six **secondary capitulum cells**. Sometimes the secondary capitulum cells divide to make tertiary capitulum cells. Each capitulum cell divides repeatedly to form 2–4 long, multicellular, branched or unbranched **antheridial filaments** or **spermatogenous filaments** (Fig. 6 G–H). The antheridial filament has upto 250 uninucleate cells. These cells funcion as **sperm mother cell** and each cell gives rise to a single spirally coiled, uninucleate, biflagellated **antherozoid** (Fig. 6 J-L).

The mature globule thus is made up of 8 curved **shield cells,** 8 elongated **manubrial cells,** 8 centrally located **primary capitulum cells** and 48 **secondary capitulum cells.** The secondary capitulum cells give rise to many antheridial filaments. Each sperm mother cell forms a single biflagellated **antherozoid** (Fig. 6 K).

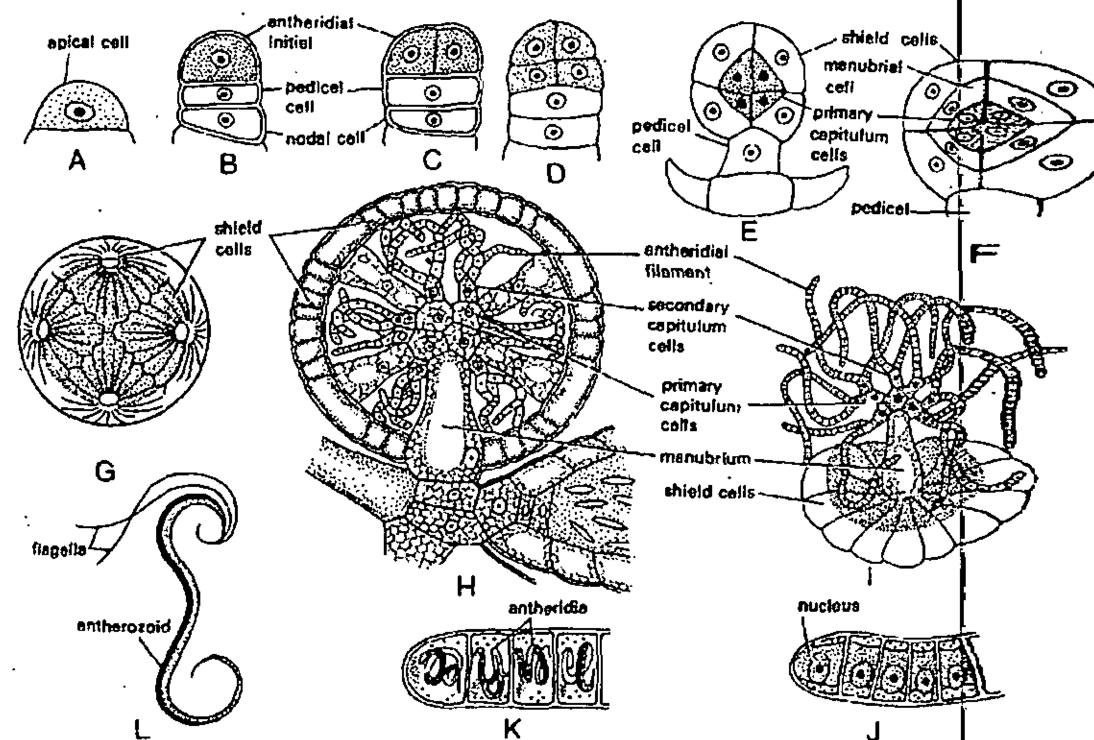


Fig. 9. (A–K). ***Chara*. Development of globule and antherozoids.**

At maturity the shield cells of antheridium separate from each other exposin antheridial filaments in water. The sperm mother cell gelatiinizes to liberate th antherozoids.

Nucule

The nucule of *Chara* is large, green, oval strucuture with short stalk. It is borne a the node of the primary lateral. It lies just above the globule in homothallic species.

Development and Structure

The upper peripheral cell of the basal node of the anheridium functions as th **oogonial initial**. The oogonial initial divides by two transverse divisions to make thre celled filament. It has lower **pedical cell**, the middle **nodal cell** and the uppe **oogonial mother cell** (Fig. 7 A–C). The pedicel cell does not divide further and make **pedicel** of the oogonium. The middle nodal cell undergoes many vertical divisions t make five sheath cells or peripheral cell which surround the central cell (Fig. 7 D–F The central cell does not divide and functions as the node of the oogonium.

The oogonial mother cell elongates vertially and divides by transverse division t make lower small **stalk cell** and an upper large **oogonium.** The oogonium contain uninucleate ovum or **egg** (Fig. 7 G, H).

The peripheral cells or five sheath initials elongate and divide by transverse divisio to make two tiers of five cells each. The five upper tier cells form **coronary cells** whic form the **corona** of nucule. The five lower tier functions as **tube cells,** the tube cell elongate and get spirally twisted in clokwise directions on oogonium. The nucleu migrates on lower side and receptive spot develops at the tip of oogonium. Larg amount of starch and oil get deposited in oogonium.

The oogonial cell possesses a **single large egg** or **ovum.** The nucule contains larg amount of starch and oil. The receptive spot is present at the upper part of nucule.

Fertilization

When the oogonium is mature, the five tube cells get separated from each othe forming narrow slits between them. Antherozoids are chemotactically attracte

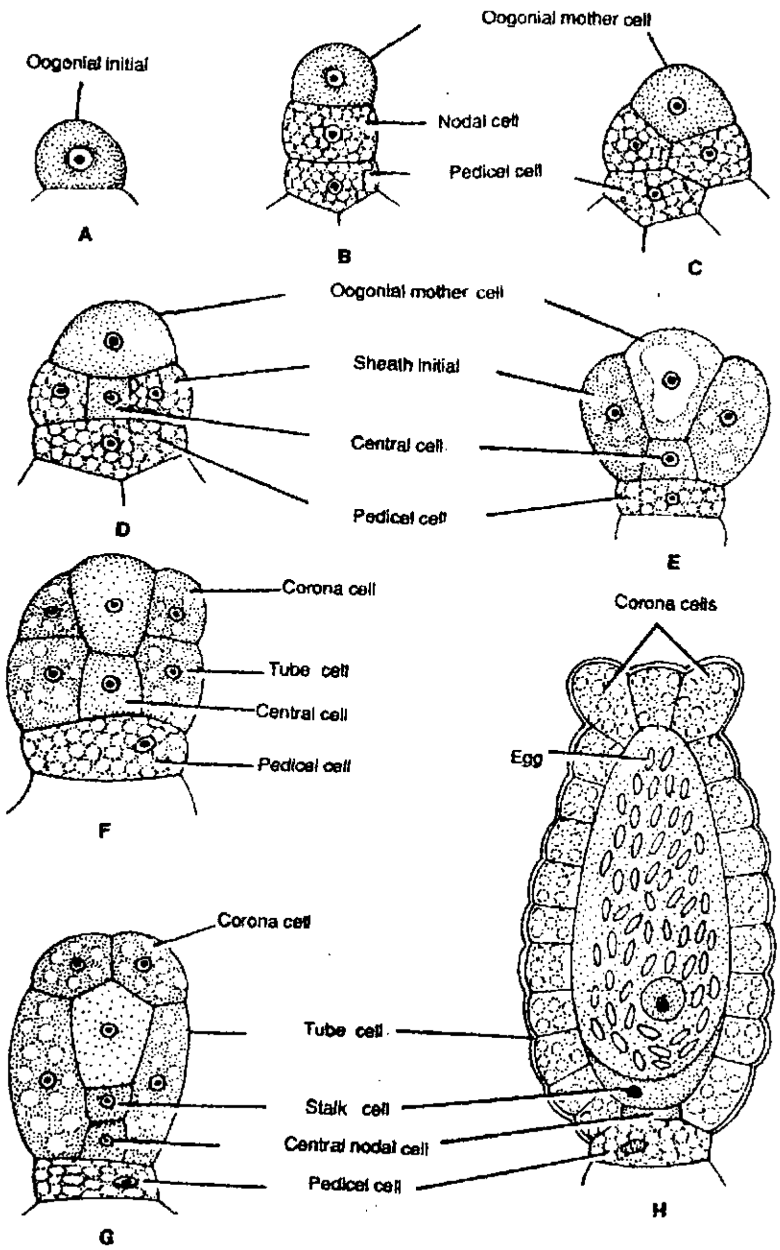


Fig. 7. (A–H). ***Chara.*** **Development of oogonium**

towards ovum. The antherozoids enter through these slits and penetrate gelatinized wall of the oogonium. Many antherozoids enter oogonium but one of those fertilizes the egg to make a diploid zygote. The zygote secretes a thick wall around itself to make **oospore.**

Oospore

The mature oospore is hard, oval, ellipsoid structure which may be brown *e.g.*, *C. inferma*, black *e.g.*, *C. corallina* or golden brown *e.g.*, *C. flauda*. The oospore inside contains a diploid nucleus and many oil globules in cytoplasm.

On maturity of oospore the inner walls of tube cells get thickened, suberised and silicified.

Germination of Oospore

The oospore germinates when favourable conditions appear. The diploid nucleus present in apical colourless region divides by meiosis forming four haploid daughter nuclei (Fig. 8 A–B). At this stage a septum divides oospore into two unequal cells. The upper smaller **apical cell,** contains a single nucleus and the large **basal cell** contains three nuclei. The three nuclei of basal cell degenerate gradually. The oospore apical cell divides by longitudinal division to make a **rhizoidal initial** and **protonemal initial** (Fig. 8 D).

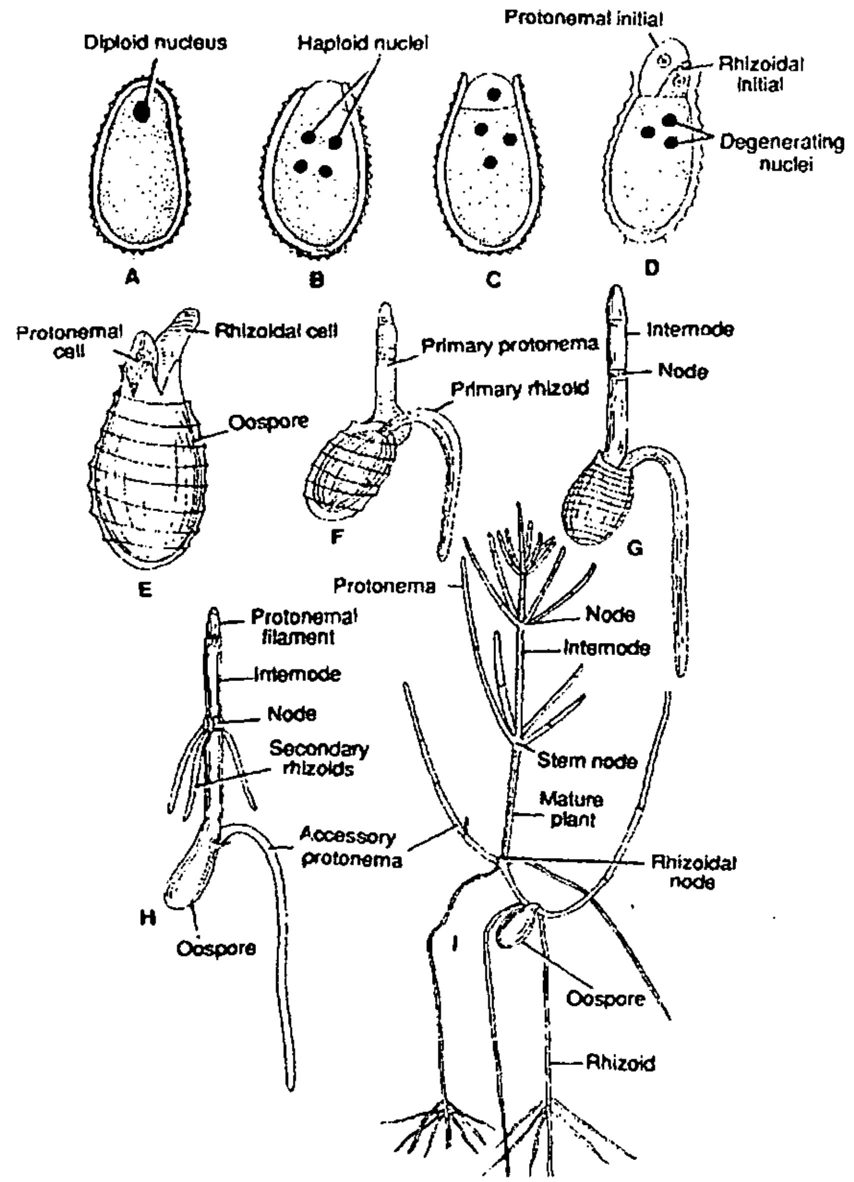


Fig. 11. (A–I). ***Chara.*** **Germination of oospore and development of new plant**

The rhizoidal initial shows positive geotropism and forms **primary rhizoid**, the protonemal initial shows negative geotropism and forms **primary protonema.** The primary protonema differentiates into nodes and internodes. The peripheral cells of the basal node give rise to rhizoids and secondary protonema. The peripheral cells of the upper nodes give rise to lateral branches (Fig. 8 E–I).

Life Cycle

The plant body of *Chara* is haploid. The vegetative reproduction takes place by the formation of amylum stars, bulbils and secondary protonema. Asexual reproduction is absent. The sexual reproduction is advanced oogamous type. The male and female sex organs are globule and nucule respectively. After fertilization a diploid spore is formed. At the time of germination the diploid oospore nucleus divides to make hapoid nuclei and haploid *Chara* plant. Thus the life cycle of Chara a predominantly **haploid type** (Fig. 9).

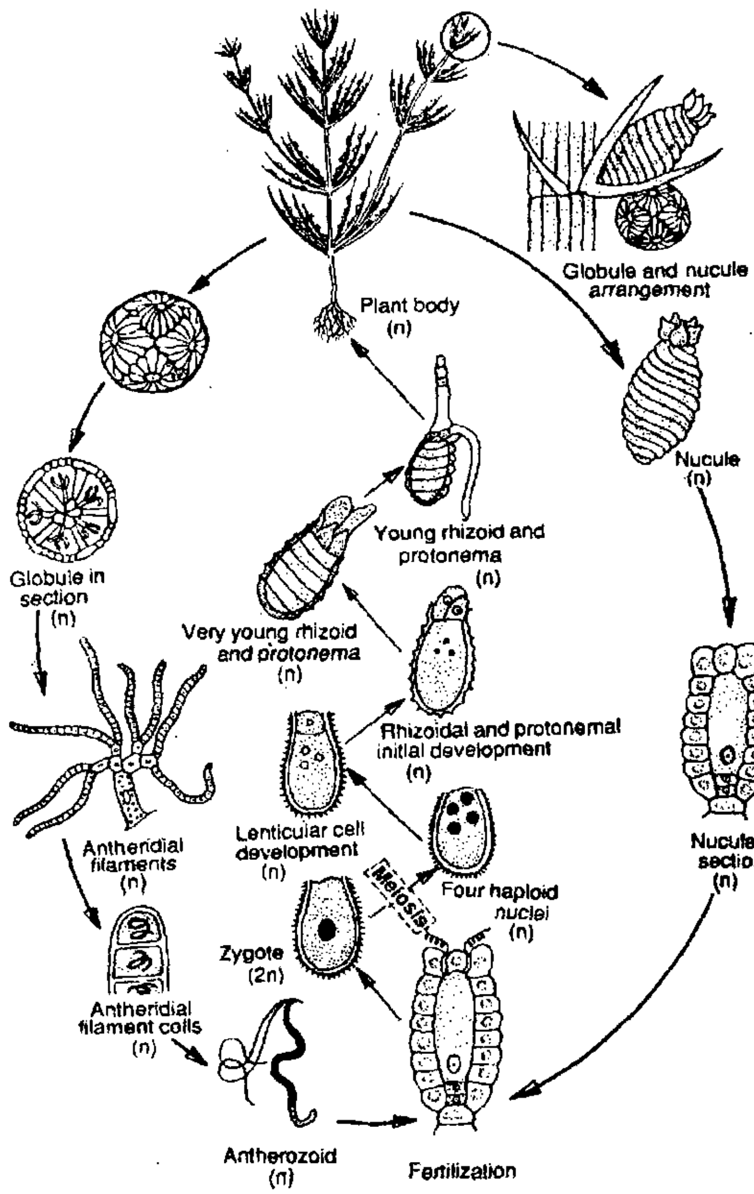


Fig. 9. ***Chara.*** **Diagrammatic life Cycle**

Spirogyra

• SYSTEMATIC POSITION :

Kingdom	:	**Plantae**
Diversion	:	**Algae**
Order	:	**Conjugales/Zygnematales**
Family	:	***Zygemataceae***
Species	:	**Karnalae**
Sub Kingdom	:	**Thallophyta**
Class	:	**Chlorophyceae**
Sub-order	:	**Zygnemideae**
Genus	:	***Spirogyra***

• OCCURRENCE

Spirogyra is a cosmopolitan, freshwater, filamentous green alga, represented b about 300 species. Most of them are green floating in stagnant ponds and pools, a few species are attached and some occur in running water (*S. adnata*). It was discovered by Link. *Spirogyra* is commonly known as **pond silk, water silk, pond scum o mermaid's trees** because of their bright green silky appearance.

Morphology

The plant body of *Spirogyra* is an un-branched filamentous thallus (Fig. 1) measuring about mt. 1 in length. The *Spirogyra* filament is very slimy due to the presence of mucilage sheath that lines the whole filament. The mucilage often holds the filaments together in a matted blanket.

Each un-branched filament of *Spirogyra* consists of a number of elongated cylindrical cells of similar type joined end to end. The terminal cell is dome-shaped. In attached species, the low non-green cell is called holdfast or hapteron (with irregular lobes, *e.g.*, *S. fluviatilis*). Presence of non-green rhizoids (branches) reported by Jac (1936) in two species, *S. rhizobra* and *S. rhizopus*.

Each cell of *Spirogyra* filament is cylindrical and consists of 2 parts cells wall and protoplast. The cell wall surrounds the protoplast, is protective and consists of two layers *i.e.*, inner cellulose layer and outer pectose layer. The pectose layer dissolves in water to form a slimy mucliage sheath covering the whole filament. The transverse wall (cross wall) between adjacent cells has middle lamella (septum). The cross wall may be plane, replicate or colligate. In repilicate type, the middle lamella forms two rings like in growths while in colligate type H-shaped pieces develop near middle lamella.

The protoplast is differentiated into many parts, from outside to inside, they are plasma membrane, primordial utricle (= peripheral cytoplasm), large central vacuole and a nucleus. The primordial utricle contains 1-16 spirally arranged ribbon-shaped chloroplasts along with various organelles such as pyrenods which is surrounded by a starch sheath.

A sigle nucleus present at the central cytoplasmic mass that held in the center of vacuole. The nucleus held in position by radiating. Except holdfast, all the cells of filament can divide and elongate to increase the length of Spirogyra filament.

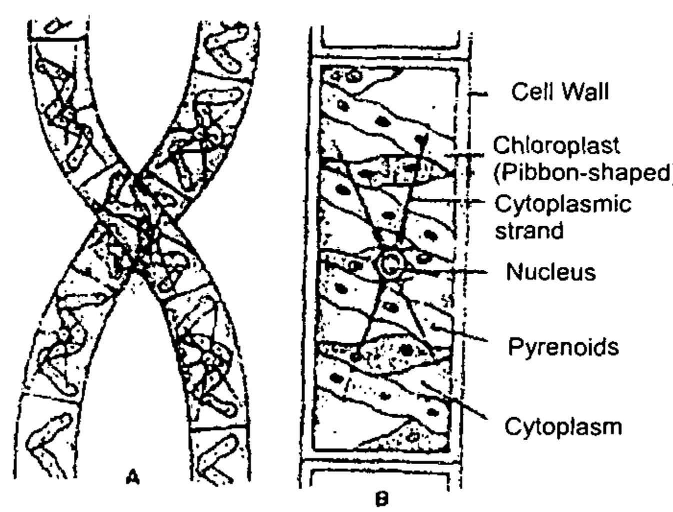


Fig. 1. *Spirogyra*. A. two algal filaments magnified. B. Cell highly magnified to show to detailed structure.

Life Cycle of *Spirogyra*

In *Spirogyra* 3 types of life cycle can be seen-vegetative and sexual cycles are most common. But asexual cycle occurs only occaisonally. Life cycle of *Spirogyra* is haploidic where the haploid vegetative filament represents a prolonged gametophyte generation and the brief sporophyte phase is represented by diploid zygospore (zygote). In the life cycle, the thalloid vegetative filametns multiples by vegetative and sexual reproductions are most common while asexual reproduction occur only occasionally.

(A) Vegetative cycle : During the growing season, the vegetative filament of *Spirogyra* undergoes fragmentation, so that each fragment independently develops into a new filament by repeated cell division and elongation. In favourable conditions, fragmentation is a most common method of multiplication. The fragmentation is caused by (i) mechanical injury (ii) dissolution of middle lamella (H_i) development of H-shaped pieces (e.g. in S. colligates).

(B) Asexual cycles : Asexual life cycle is less common and reported only in a few *Spirogyra* sp. Asexual cycles involve the formation of aplanospores, akinetes, azygospores (Fig. 2).

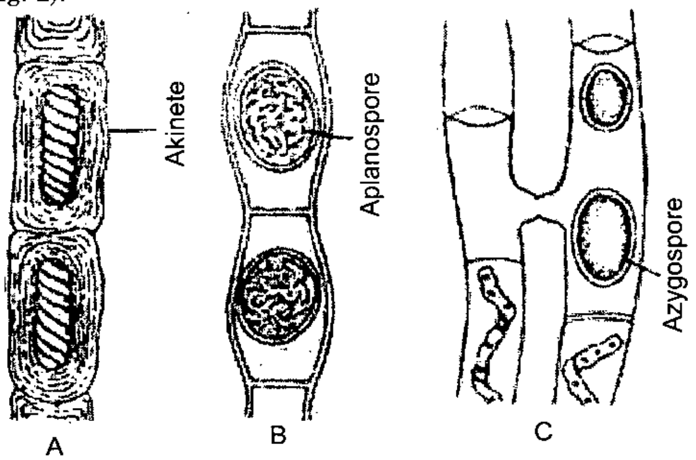


Fig. 2. *Spirogyra*. Asexual reproduction A. Akinete B. Aplaneospore C. Azygospore.

(i) Formation of aplaneospores : Under un-favourale conditions, the protoplst of each vegetative cell shrinks and develops a wall around it to form an aplanospore. Each non-motile aplanospore germinates to form a new filament. For example, *S. articulate, S. mirabilis* etc.

(ii) Formation of akinetes : Under unfavorable conditions, the vegetative cells of *S. farlowii* develop thick-walled cells called akinetes. On the return of favourable conditions each akinete germinate into a new filament.

(iii) Formation of azygospores or parthemspores : In the cycle of *S.varians* and *S. groenlandica,* sometimes the gametes fail to fuse and each get enclosed by thick cell wall to become azygospore or parthenospore. Each azygospore germinates in to a new filament.

(C) Sexual cycle : In *Spirogyra,* the sexual reproduction involves a cycle alternation between a haploid, vegetative filament (gametophyte plant and a diploid zygospore, towards the end of growing season the *Spirogyra* filament produce aplanogemates in vegetative cells called gametangia. The gametes fuse to form a zygospore (2*n*). At the time of germination, the zygospore nucleus undergoes meiosis to produce 4 haploid nuclei but only one of them survives. Thus, a zygospore gives rise to a haploid new filament.

Sexual reproduction of *Spirogyra* involves conjugation, which may be defined as a primitive type of isogamy called aplanogametic isogamy. In this type of isogamy, the entire protoplasmic contents of vegetative cells (*viz.* Gametangia) function as gametes it always involves the gametangial contact. Conjugation is of two type—Scalariform and Lateral conjugation.

(i) Scalariform conjugation : It is most common method in most heterothallic species of *Spirogyra*. It takes place in the night when two filaments come close and lie opposite and parallel to each other. Now, opposite cells develop outgrowth or protuberances called conjugation processes. At the point of contact, the tips of thes processes dissolve (by cytase) to form conjugation tube between opposite cells.

This resembles a ladder. Hence, the conjugation is called scalariform (*Gr. scala* ladder, *forma* = shape) or H-shape conjugation.

When the conjugation tube is forming, the protoplasts of conjugating cel (gametangia) recade, round up and function as gametes. The male gametes transfe through the conjugation tube into the opposite cell (female gametangia) and fuse wit female gamete to form zygote (2*n*). The zygote secretes a thick wall to becom zygosopore. Therefore, in the late stage of conjugation, male gametangia remain empt and the female gametangia cotain zygospores (2*n*) fig. 3.

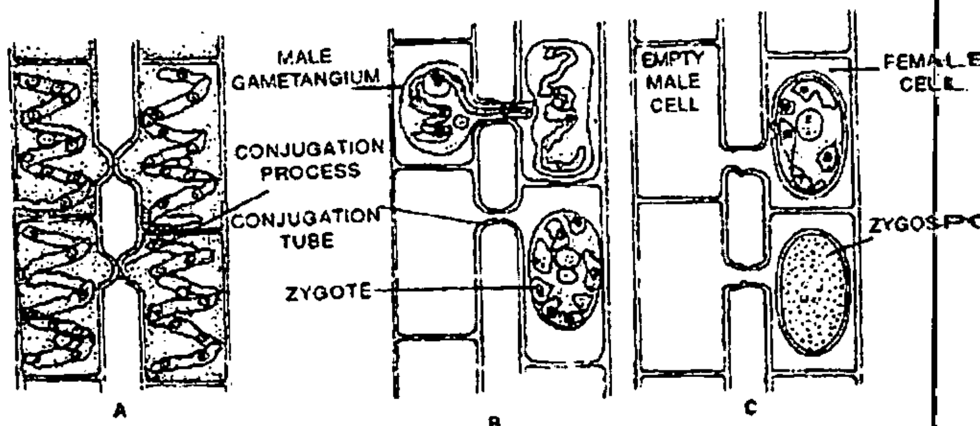


Fig. 3. Stage in scalatom conjugation of *Spirogyra*.

(ii) Lateral conjugation : It is of rare occurrence and involves the fusion gametes from two adjacent cells of the same filament in monoecious or homothall species. It is of two types. Indirect and Direction lateral conjugation.

(a) Indirect lateral conjugation : Two outgrowths emerge on both side of transverse septum of two adjunct cells and after some growth the two protuberanc unite to form a conjugation tube. Of the two adjacent cells, one behaves as ma gametangium whiles the other as female gametangium. The content (now behaving gamete) from male gametangium passes through conjugation tube and enters in female gametangium. By the fusion of male and female gametes a diploid zygospore formed. *e.g.*, *S tenuissima S. affinis.*

(b) Direct lateral conjugation : In this type of conjugation, the ma gametangium after passing through an aperture in the transverse septum of adjoini gametangium enters the female gametangium and fuses with the female gamete, and diploid zygospore is formed, e.g., *S. jogensis.*

Germination of Zygospore (fig. 4) : Zygospore is the only diploid phase in the sexual life cycle. The decay of female gametangia causes the liberation of zygospore which remains dormant in the pond bottom till the favourable conditions return. Zygospore wall is thick and differentiated in to 3-layers. Outer exosporium (cellulose), middle mesosporrium (cellulose and chitin) and inner endosporium (cellulose).

On return of favourable condition the diploid nucleus of zygospore undergo meiosis to produce 4 haploid nuclei out of

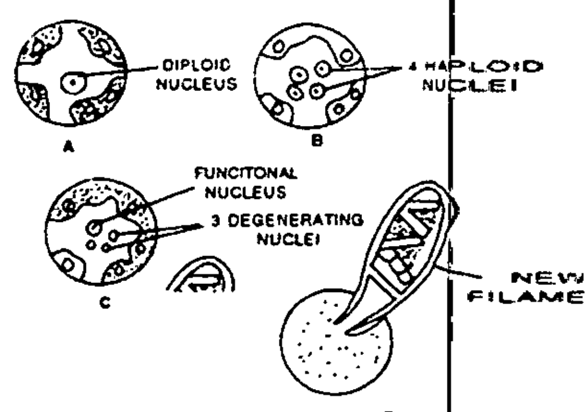


Fig. 4. *Spirogyra* : Stage in germiniation a zygoscopore.

which 3 degenerrate. The zygospore with one haploid nucleus gradually enlarges and burst open to release a germ tube. The repeated transverse division of germ tube form a new filament.

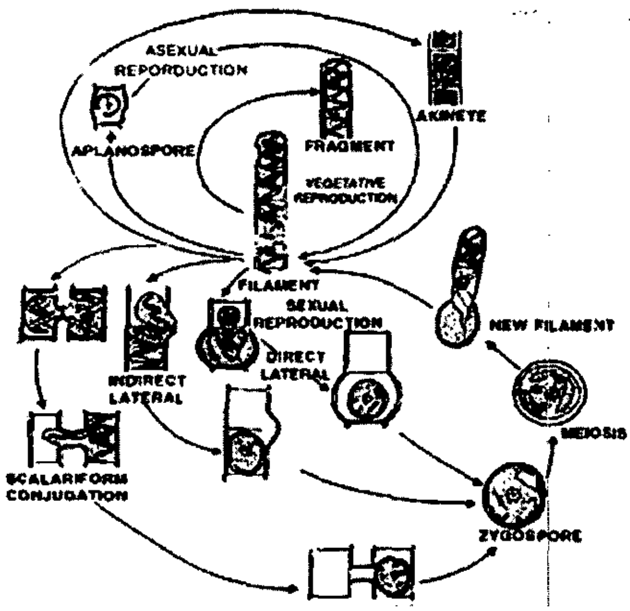


Fig. 5. Life cycle of spirogyra

• IMPORTANT QUESTIONS

Long Answer Type Questions :

1. Explain the structure of *Chlamydomonas* with help of suitable diagrams.
2. Make diagram only of ultrastructure of *Chlamydomonas*.
3. Write account of sexual reproduction in *Chlamydomonas*.
4. Give graphic representation of life cycle in *Chlamydomonas*.
5. Describe the sexual reproduction in *Volvox* with the help of suitable diagrams.
6. Give an illustrated account of the thallus structure and asexual reproduction in *Volvox*.
7. Describe the life history of *Volvox* with the help of diagrams only.
8. Describe the life cycle of *Hydrodictyon* giving suitable diagrams.
9. What is autocolony ? How it formed in *Hydrodictyon*.
10. Describe the thallus structure and method of asexual reproduction in *Oedogonium*.
11. Describe the method of sexual reproduction in *Oedogonium* with the help of diagrams.
12. Describe the different types of life cycles found in *Oedogonium* with the help of diagrams only.
13. Explain with the help of labelled diagrams the structure of globule and nucule of *Chara*.
14. Give an account of position and structure of sex organs of *Chara*.
15. Explain the structure of vegetative thallus of *Chara*.
16. Describe the method of vegetative reproduction in *Chara*.

Short Answer Type Questions :

1. Write a short note on neuromotor apparatus is *Chlamydomonas*.
2. Write a short note on development of palmella stage.
3. Show with the help of diagrams only isogamous sexual reproduction in a species of *Chlamydomonas*.
4. Draw the structure of *Chlamydomonas* cell and also give its systematic position.
5. Write in short about fine structure of flagella and pyrenoids.
6. Give a short note on anisogamy in *Chlamydomonas*.

7. Give a graphic representation of life cycle of *Volvox*.
8. Write in short about 'Plakea stage.'
9. Give 4 special features of *Volvox*.
10. Give 5 points of difference in sexual reproduction between *Chlamydomonas* and *Volvox*.
11. Give 5 similarities in sexual reproduction between *Chlamydomonas* and *Volvox*.
12. Write a short note on sexual reproduction in *Hydrodictyon*.
13. Coenobium
14. Cell structure of *Hydrodictyon*.
15. Draw a well labelled structure of an *Oedogonium* filament.
16. Write in short about akinete formation.
17. Give structure of zoospore in *Oedogonium*.
18. Write a short note on receptive spot found in ovum of *Oedogonium*.
19. Write in short about stages in life cycle of macrandrous monoecious species of *Oedogonium*.
20. Show graphically stages in life cycle of nannandrous gynandrosporous species of *Oedogonium*.
21. Draw diagrams of mature globule and nucule.
22. Give graphically life cycle of *Chara*.
23. Mention 3 points of similarity of *Chara* with Chlorophyceae.
24. Mention 3 advanced features of *Chara* over Chlorophyceae.
25. Write a note on bulbils in vegetative reproduction.

Objective Type Questions :

1. Which type of flagella are found in *Chlamydomonas* ?
2. What is the main function of neuromotor apparatus ?
3. What is the term given to the fibre which connects the two blepharoplasts in neuromotor apparatus ?
4. Pyrenoid is absent in which species of *Chlamydomonas*.
5. What is the main function of volutin granules ?
6. The phenomenon of red snow is due to which pigment.
7. What are covered gametes termed as ?
8. The number of meiospores produced per zygospore may range from 16-32 in which species of *Chalmydoamonoas*.
9. Give the sub-order to which *Chlamydomonas* belongs.
10. Which species imparts green colour to snow ?
11. Give an example of a monoecious species of *Volvox*.
12. Give an example of species, each with smooth and ornamented exospore is *Volvox*.
13. After fertilization which pigment develops in cytoplasm of ovum in *Volvox* ?
14. Which type of sexual reproduction is found in *Volvox* ?
15. To which class does *Volvox* belong ?
16. What type of reproduction is seen in *Volvox* under favourable conditions ?
17. In Plakea stage, what is the term used for the aperture at the exterior end when plakes curve further and form a hollow sphere ?
18. What is the number of contractile vacuoles and pyrenoids in spermatozoid ?
19. After fertilization, what changes occur in ovum as regards to food reserve ?
20. What is the structure known as when exospore and mesospore rupture and endospore encloses the protoplast ?
21. What type of sexual reproduction in present in *Hydrodictyon* ?
22. What type of chloroplast is present in the cell of *Hydrodictyon* ?
23. Name the spores formed during asexual reproduction in *Hydrodictyon* ?
24. How many pyrenoids are present in each cell of *Hydrodictyon* ?
25. An intersection of a mesh in Hydrodictyon is formed by how many cells ?

26. Give an example of a common India species of *Oedogonium.*
27. How does growth occur in *Oedogonium* ?
28. What are the 2 ways in which *Oedogonium* reproduces vegetatively ?
29. Mention the conditions required for sexual reproduction to occur in *Oedogonium.*
30. Given an example of macrandrous monoecious species in *Oedogonium.*
31. Explain in short idioandrosporous filament with example.
32. Give an example of species which lacks suffultory cell in *Oedogonium.*
33. Give the names of 2-types of nannandrous species in *Oedogonium.*
34. Which cells are concerned with cell division in *Oedogonium ?*
35. Give an example of a species with terminal oogonia is *Oedogonium.*
36. What compounds given onion like odour to *Chara* species ?
37. Which character gives the name stonewort to *C. flaccida ?*
38. Give function of rhizoids in reproduction.
39. Give 2 examples of unistipulate species of *Chara.*
40. Give 2 examples of corticate species of *Chara.*
41. Mention a species which shows formation of amylum stars.
42. Give 2 examples of dioecious species of *Chara.*
43. Why is *Chara* known as aquatic horse-tail ?
44. Mention position of sex organs in *Chara* if both develop at same node.
45. How many antherozoids are formed form each cell of antherdial filament ?

Multiple Choice Questions :

1. The opening in young sphere of *Volvox* colony during asexual reproduction is called:
   (a) Synzoospore (b) Carpospore
   (c) Catiole (d) Phialopore
2. The normal orientation of *Volvox colony* during asexual reproduction is achived by :
   (a) Inversion (b) Conversion
   (c) Convulsion (d) Transition
3. The sexual reproduction in *Volvox* is :
   (a) Isogamous (b) Anisogamous
   (c) Oogamous (d) Hologamous
4. The zoospores and antherozoids in *Volvox* are :
   (a) Multiflagellated (b) Biflagellated
   (c)Non-flagellated (d) Stephanokontic
5. Neuromotor apparatus is found is
   (a) *Nostoc* (b) *Chlamydomonas*
   (c) Sargassum (d) *Oedogonium*
6. The plants of *Hydrodictyon* are found in :
   (a) Fresh water pond (b) Marine water
   (c) Estuaries (d) Hot water springs
7. The cell wall of *Hydrodictyon* encloses
   (a) Four cells (b) Ten cells
   (c) Fifty cells (d) Few hundred to several thousand cells
8. The cell wall of *Hydrodictyon* encloses
   (a) Spiral Chlroplast (b) Reticulate chloroplasts
   (c) Cup shaped chloroplast (d) Girdle shaped chloroplast
9. The sexual reproduction in *Hydrodictyon* corresponds to :
   (a) Isogamy (b) Oogamy
   (c) Anisogamy (d) Hologamy
10. The zygospore of *Hydrodictyon* given rise to a
    (a) Aplanospore (b) Hypnospore
    (c) Akinete (d) Zoospore

11. The charophytes are commonly called as :
    (a) stone worts (b) bladder worts
    (c) liver worts (d) aquatic horse tails
12. In *Chara* the male reproductive structure is called as :
    (a) nucule (b) globule
    (c) amylum star (d) primary protonema
13. The female reproductive structure in *Chara* is :
    (a) nucule (b) globule
    (c) carpogonium (d) protonema
14. In *Chara* amylum stars and bulbils are :
    (a) vegetative reproductive structures
    (b) asexual reproductive structures like zoospores
    (c) sexual reproductive structure
    (d) the parts of main thallus
15. The *Chara* thallus is
    (a) diploid (b) triploid
    (c) haploid (d) either diploid on haploid

ANSWERS

Objective Type Questions :

1. Whiplash 2. Controls movement and protoplasmic sensatio
3. Paradesmos 4. *C. reticulata* 5. Store phosphates
6. Haematochrome 7. Calyptogametes 8. *C. intermedia*
9. Chlamydomonadinase 10. *C. yellowstonensis* 11. *V. globator*
12. *Voureus and V. globator* 13. Haematochrome 14. Oogamous
15. Chlorophyeae 16. Asexual 17. Phialopore
18. Two, one 19. Starch transforms into oil
20. Meiospore 21. Isogamous 22. Reticulate
23. Zoospores 24. Many 25. Three
26. Elegans 27. By division of intercalary cells
28. Fragmentation and akinete formation
29. Water should be alkaline and deficient in nitrogen, sufficient light and CO
30. *O. fragile*
31. When androsporangia develop on separate filament other than female filar *e.g., O. confertum*
32. *O. americanum* 33. Gynandrosporous and idioandrosporous
34. Cap cells 35. *O. palaiense.* 36. Sulphurated
37. Lime crust 38. Produce bulbils and secondary protonema
39. *C. nuda* and *C. branuii* 40. *C. aspera* and *C. vulgaris*
41. *C. stelligra* 42. *C.aspera* and *C. inferma*
43. Because it resembles tail of sea horse
44. The nucule is always above the globule
45. one.

Multiple Choice Questions :

1. (d) 2. (a) 3. (c) 4. (b) 5. (b) 6. (a) 7. (d) 8. (b) 9. (a) 1
11. (a) 12. (b) 13. (a) 14. (a) 15. (c)

8

XANTHOPHYTA

STRUCTURE

- Introduction
- Occurrence
- *Reproduction*
- Important Questions
- Answers

• INTRODUCTION

Division Xanthophyta include more than 600 species. Members of this group are heterogenous photosynthetic, which primarily live in fresh water but few are marine. It includes only are order Vacheriales (Heterosiphonales) current classification scheme now place traditional Xanthophyte taxa into three classes : Tribophyceae (Xanthophyceae), Eustigmatophyaeae and Raphidophyceae (*van den Hoek et.al* 1995 and *ott* and *oldham* 2003).

Class Xanthophyceal or tribophyceae exibits folowing features.

(i) Cell are unicelled, coccoid or filamentous flagellar are two apical

(ii) Primary pigments are chlorophyll 'a', C_1, C_2

(iii) Colour of thalus is of yellow-green or green.

(iv) Major accessory pigments are β-caratene, vaucheria xanthin, heteroxanthin, diaxanthin, and diadionoxanthin.

(v) Chloroplast is discoid and without pyrenoid.

(vi) Main storage product is crysolaminorin.

(vii) Cell wall is made of cellulose.

(viii) Total genera about 100 and species are about 600.

(ix) Important member are *Vacheria, Botridium, Characiospsis* and *Trisponema.*

• OCCURRENCE

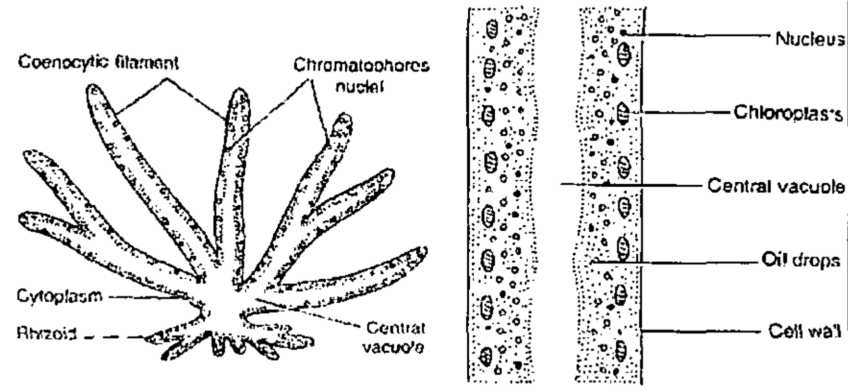
Vaucheria is represented by 54 sepcies of which about 19 species are found in India. *Vaucheria* is found mostly in fresh water but about six species are marine and some are terrestrial found on moist soil. The terrestrial species like *V. sessilis* and *V. terrestris* form green mats on moist soil in shady places in green houses. *V. amphibia* is amphibous. *V. jonesii* was reported by **Prescott** (1938) in winter ice in U.S.A. The common Indian species of *Vaucheria* are *V. amphibia, V. geminata, V. polysperma, V. sessilis* and *V. uncinata etc.*

Thallus

The thallus is made of long, cylindrical well branched filaments. The filament is aseptate, coenocytic structure. The thallus is attached to substratum by means of branched rhizoids or branched holdfast called the haptera. The thallus of *V. mayyanadensis* is differentiated in subterranean branched rhizoidal system and an erect aerial system. Some species like *V. debaryana* show calcium carbonate incrustations. The branching may be lateral or dichotomous. The filaments are non-septate, the protoplasm with many nuclei is continuous along the entire length of thallus thus the coenocytic *Vaucheria* thallus makes **siphonaceous** structure (Fig. 1 B). The septa formation occurs only during reproduction or in **Gongrosira** condition for sealing of an injury.

The thallus structure is differentiated into cell wall and protoplasm. The cell wall made of two layers, the outer layer is **pectic** and the inner layer is **cellulosic**.

Inner to the cell wall there is thick layer of protoplasm. A very large **central vacuole** filled with cell sap runs from one end of the filament to another forming continuous canal or siphon. In peripheral part of protoplasm are present a large number of small oval or disc shaped chloroplasts which lack pyrenoids (Fig. 1 B).



(a) (b)

Fig. 1. (A, B). *Vaucheria* structure. (A) Entire thallus, (B) A part of thallus

The chromatophores in *Vaucheria* contain pigments, chlorophyll a, chlorophyll C_2, carotenoids and an unknown xanthophyll. The pigments in *Vaucheria* are like those of Xanthophyceae as chlorophyll b the characteristic pigment of Chlorophyceae absent. The cytoplasm also contains other membrane bound cell organelle such mitochondria, small vesicles and food is stored in form of oil. The growth of filament apical, the filament increases in length by apical growth of all the branches.

Nature of Thallus

The thallus of *Vaucheria* is branched, non-septate and multinucleate structure which appears like single large cell but *Vaucheria* cannot be considered as single cell. As in multicellular forms mitotic divisions take place increasing the number of nuclei. The apical growth takes place. Hence the aseptate coenocytic structure of *Vaucheria* should be considered as **acellular coenocyte**.

• REPRODUCTION

Reproduction in *Vaucheria* takes place by vegetative, asexual and sexual methods.

(i) Vegetative Reproduction

The vegetative reproduction takes place by fragmentation. The thallus can break into small fragments due to mechanical injury or insect bites etc. A septum develops the place of breaking to seal the injury. The broken fragment develops thick wall and later on develops into *Vaucheria* thallus.

(ii) Asexual Reproduction

The asexual reproduction takes place by formation of **zoospores, aplanospores** and **akinetes**.

(a) By Zoospores. The zoospores formation is the most common method reproduction in aquatic species. In terrestrial species it takes place when the plants are flooded. Zoospore formation takes place in favourable seasons or can be induced aquatic species are transferred from light to darkness or from running water to still water. Zoospores are formed singly within elongated club shaped zoosporangium (F

2A, B). The development of zoosporangium begins with a club shaped swelling at the tip of a side branch. A large number of nuclei and chloroplasts along with the cytoplasm move into it. Then each separated protoplast secretes thin membrane and zoosporangium gets separated by a cross wall. Inside zoosporangium the vacuole decreases, the contents of sporangium become very dense and round off. The entire protoplasm of the zoosporanigum contracts to form oval zoospore. Opposite to each nucleus two flagella are produced making zoospore a multiflagellate structure. A terminal aperture develops in zoosporangium by gelatinization of wall. The zoospore is liberated through aperture in morning hours (Fig. 2 C, D).

Each zoospore is large yellow green, oval structure. It has a central vacuole which has cell sap and may be traversed by cytoplasmic strands. The protoplasm outer to vacuole has many nuclei towards the walls and chromatophores towards vacuoles. **Fritsch** (1948) regarded this kind of zoospore as **compound zoospore** or **synzoospore** as a number of biflagellate zoospores have failed to separate from one another. According to **Greenwood**, **Manton** and **Clarke** (1957) the flagella of a pair are heterokontic and whiplash type. The shorter flagellum of each pair is directed towards the anterior end of the zoospore.

According to **Greenwood *et. al*** (1957), there is large anterior vacuole and small ones in the posterior region of the zoospores. Mitochondria are present in the peripheral layer of cytoplasm. Fat bodies and plastids are present in the cytoplasm. Chlorophyll has also been reported from the zoospores.

The zoospores swim in water for 5–15 minutes and germinate without undergoing any significant period of rest. The zoospores get attached to the substratum, withdraw flagella and secrete thin walls (Fig. 2 E, F). The two tube like outgrowths develop in opposite directions. One of the two outgrowths elongates, branches to form colourless lobed holdfast and the other outgrowth forms yellow-green tubular coenocytic filament (Fig. 2 G, H).

(b) By Aplanospores. non-motile Aplanospores are commonly observed in species. *V. geminata*, *V. uncinata* and in marine species *V. pitoboloides*. The aplanospores are generally formed by terrestrial species. The aplanospores are formed under unfavourable in special structures called **aplanosporangia** (Fig. 3 A–C). The

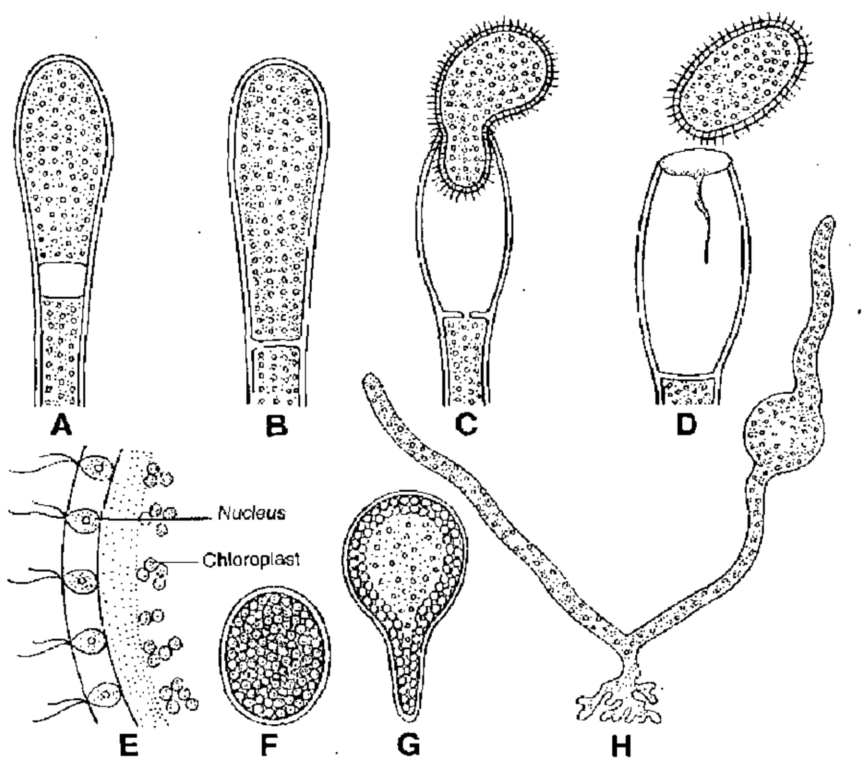


Fig. 2. (A–H). ***Vaucheria.*** **Asexual reproduction.**

aplanospores are produced singly in cells at the terminal end of the short lateral terminal branch. The protoplasm of aplanosporangium gets metamorphosed into sing multinucleate aplanospore which is thin walled. In *V. germinata* aplanospores are ov and are liberated from apical pore formed by gelatinization. In *V. uncina* aplanospores are spherical and are liberated by rupture of the sporangial wall. Th aplanospores soon after liberation germinate into new thallus (Fig. 3D).

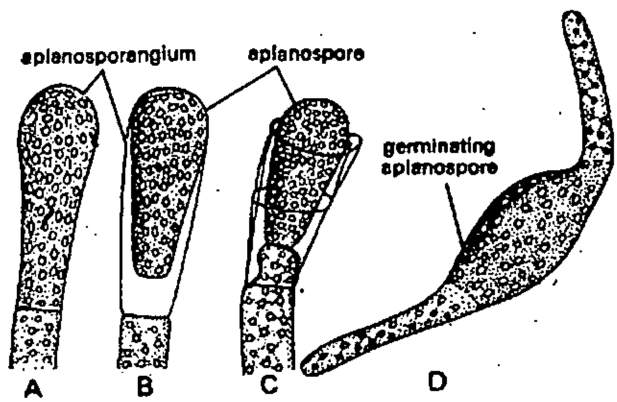


Fig. 3. (A–D). ***Vaucheria*. Aplanopore formation, liberation and germination**

(c) By Akinetes. Akinetes are thick walled structures formed during unfavourable conditions like drought, and low temperature. The akinetes have been commonly observed in *V. geminata, V. megaspora* and *V. uncinata*. The akinetes are formed on the terminal part of lateral branches where protoplasm migrates to the tips followed by cross-wall formation (Fig. 4). These multinucleate, thick walled segments are called **akinetes or hypnospores**.

The akinetes by successive divisions may form numerous thin walled bodies called **cysts**. When many akinetes remain attached to the parent thallus, the thallus gives the appearance of another alga ***Gongrosira***. Hence this stage of *Vaucheria* is called ***Gongrosira*** stage. During favourable conditions the akinetes and cysts develop into new thalli.

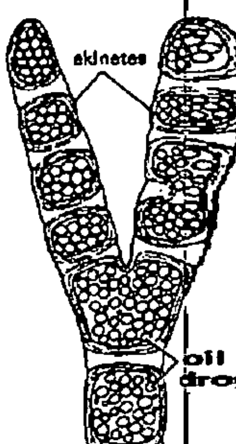


Fig. 4. ***Vaucheria*. Akinetes**

(iii) Sexual Reproduction

In *Vaucheria* sexual reproduction is of advanced **oogamous** type. The male and female sex organs are **antheridia** and **oogonia**, respectivel Majority of the freshwater sepcies are **monoecious** or **homothallic** while som species like *V. dichotoma, V. litorea* and *V. mayyanadensis* are **dioecious** c **heterothallic**. There are different types of arrangement of antheridia and oogonia i homothallic species. The position, structure and shape of antheridia are of taxonom importance in *Vaucheria*. The common patterns of arrangement of sex organs are a follows :

(a) Antheridia and oogonia develop close to each other on the filament at interva (Fig. 5 A–C).

(b) The antheridia and oogonia are borne on special side branches with a termina antheridium and a number of lateral oogonia (Fig. 5D).

(c) Antheridia and oogonia are borne on adjacent branches (Fig. 5E).

In *V. geminata* and *V. terrestris* the sex organs are produced at the ends of the latera branches with a terminal antheridium and a group of oogonia (Fig. 5D). The sex organ are unilateral or bilateral.

Structure and development of antheridium. The mature antheridia may b cylindrical, tubular, straight or strongly curved. The antheridium is separated fro main filament by a septum. The antheridia can be sessile (without stalk) arisin

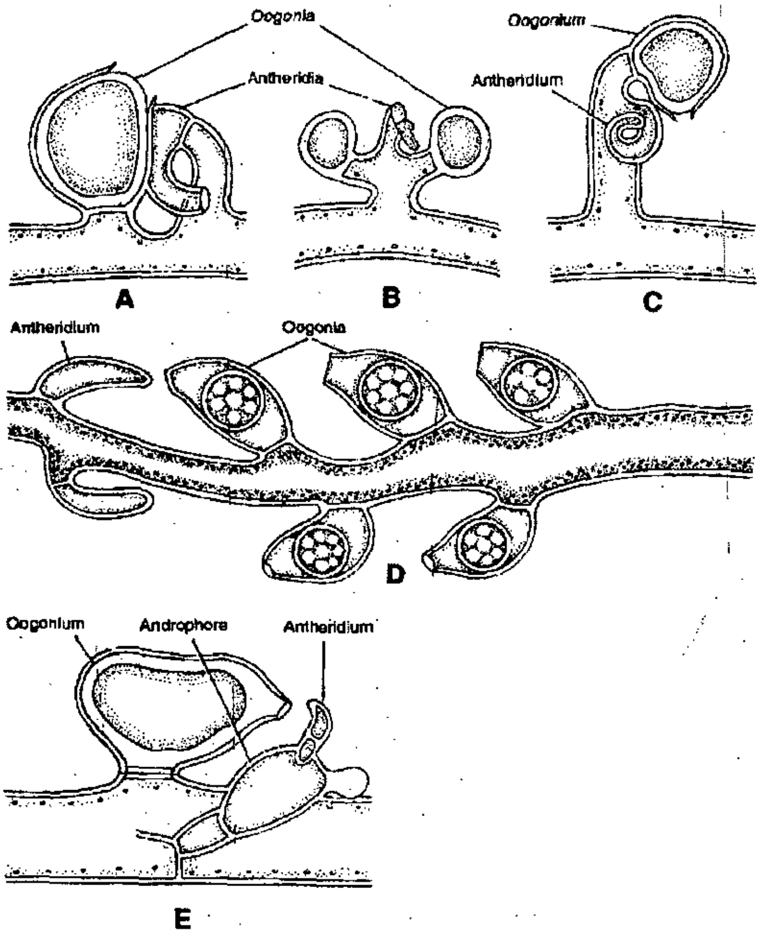


Fig. 5. (A–E). *Vaucheria*. Arrangement of antheridia and oogonia.

directly from main branch *e.g.*, *V. aversa*. The antheridia may be placed high on the branch, the antheridia are situated on androphore *V. synandra*. The young antheridium is usually green in colour. It contains cytoplasm, nuclei and chloroplasts. The mature antheridia are yellow and contain many spindle shaped antherozoids. The antherozoids are liberated through a terminal pore *e.g.*, *V. aversa* or through many pores *e.g.*, *V. debaryana*.

The antherozoids are liberated from the tip of antheridium through apical pore shortly before day break (Fig. 6A–I).

Structure and Development of Oogonium

The oogonium development starts with accumulation of colourless multinucleate mass of cytoplasm near the base of antheridial branch. This accumulated cytoplasm has been termed as **"wanderplasm."** The wanderplasm enters into the outgrowth or bulging of the main filament. This outgrowth is called as **oogonial initial**. Large amount of cytoplasm and nuclei enter into oogonia, making it a large globular structure called as **oogonium** (Fig. 6 B–E). As the oogonium matures, it gets separated from main branch by the development of septum at its base. The mature oogonium is uninucleate structure. The nucleus of oogonium with protoplasm develops into a single egg. There are three hypothesis regarding the fate of extra nuclei of oogonium of *Vaucheria* :

(a) According to **Oltmanns** (1895) accept a single nucleus which forms female nucleus, all other nuclei migrate back into the filament. This was supported by **Heidinger** (1908) and **Couch** (1932).

(b) According to **Davis** (1904), the single nucleus forms the egg and all other nuclei degenerate.

(c) According to **Brehens** (1890) all nuclei fuse to form a single nucleus.

The mature oogonia are globose, obovoid, hemispherical or pyriform in shape. T oogonia may be sessile or stalked structure. The entire protoplasm with single nucle makes a central spherical mass called as **oosphere** or **ovum**. In mature oogoniu distinct vertical or oblique **beak** develops in apical part. Opposite to beak develop colourless receptive spot. A pore develops just opposite to receptive spot (Fig. 6 F).

Fertilization

The oogonium secretes a gelatinous drop through a pore near the beak. A la number of liberated antherozoids stick to the drop. Many antherozoids push into t oogonium. Only one antherozoid enters into the oogonium. After its entry t membrane develops at the pore to stop the further entry of antherozoids. The m nucleus increases in size and fuses with the egg nucleus to make diploid zygote. T zygote secretes a thick 3–7 layered wall and is now called as **oospore** (Fig. 6 G—I). T chromatophores degenerate and lie in the centre of the cell.

Germination of oospore. The oospore undergoes a period of rest befo germination. During favourable season the oogonial wall disintegrates and the oospo is liberated. The oospore germinates directly into new filaments. Although the exa stage at which the reduction division takes place in *Vaucheria* is not clear, it is believ that reduction division occurs in first nuclear division in the germinating oospore. T oospore germinates to make haploid thallus of *Vaucheria*.

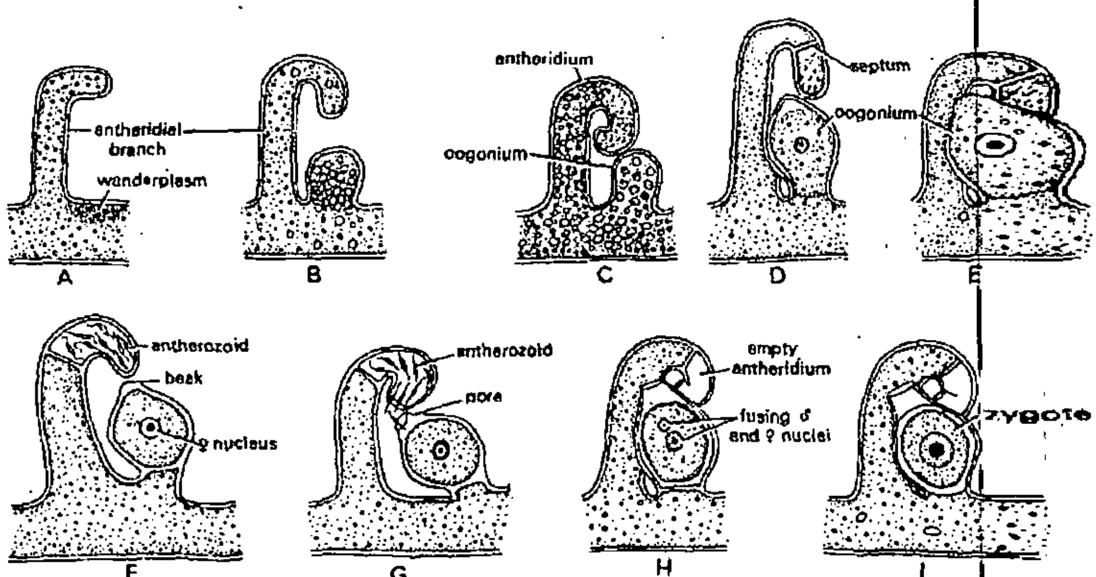


Fig. 6. (A–I). *Vaucheria*. Sexual reproduction in *V. sessilis*.

Life Cycle of *Vaucheria*

According to **Williams, Hanatsche** and **Gross** the life cycle of *Vaucheria* haplontic, the oospore being the only diploid structure in life cycle (Figs. 7). *Vaucher* thallus is haploid, it is aseptate, branched, tubular and coenocytic structure. Vegetati reprodcution takes place by **fragmentation**. Asexual reproduction takes place b **zoospore** in aquatic species and by **aplanospores** in terrestrial species. The zoospo is large multiflagellate structure and is supposed to be compound zoospore synzoospore.

The sexual reproduction is **advanced oogomous** type, the male and female se organs are **antheridia** and **oogonia**. Most of the species are homothallic, some a heterothallic. After fertilization, a diploid **zygote** is formed which converts in **oospore** and undergoes a period of rest. The reduction division takes place in oospo during germination resulting in an haploid thallus is developed.

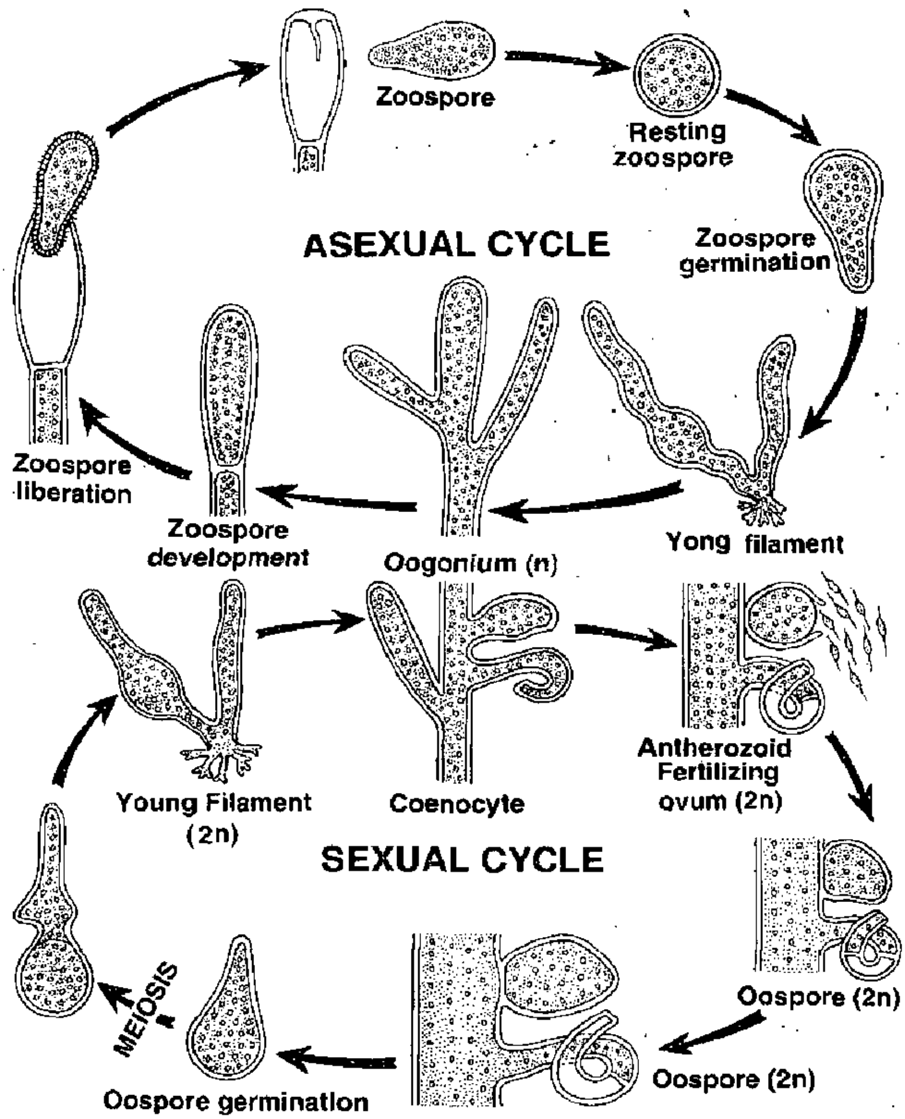


Fig. 7. ***Vaucheria*. Diagrammatic life cycle.**

Systematic Position and Affinities of *Vaucheria*

The position of *Vaucheria* in algae has always been debatable. **Fritsch** (1935) placed it in the order **Siphonales** of the class **Chlorophyceae**, it was also supported by **Iyengar** (1951).

Chadefaud transferred it to **Xanthophyceae** and **Smith** (1959) placed it in order **Heterosiphonales** of the class **Xanthophyceae**. This view was supported by **Chapman** (1962), **Taylor, Prescott** (1969) and **Morris** (1968).

A. Affinities of *Vaucheria* with Xanthophyceae

(i) Siphonaceous, acellular thallus.

(ii) Predominance of carotenoids over chlorophylls. Absence of chlorophyll *b* from *Vaucheria* which is a characteristic pigment of Chlorophyceae.

(iii) Chloroplasts without pyrenoids.

(iv) Reserve food material is oil, instead of starch.

(v) In *Vaucheria* antherozoids flagellation is heterokontic. There are two lateral, unequal flagella. The anterior flagellum is **tinsel type** and the posterior as **whiplash** type.

B. Affinities of *Vaucheria* with Chlorophyceae

(i) Multinucleate, aseptate, coenocytic thallus.

(ii) Sexual reproduction being advanced oogamous type.

C. Affinities of *Vaucheria* with Oomycetes (Fungi)

(i) The development of the sex organs in *Vaucheria* show striking resmeblance to some members of **Oomycetes.**

(ii) Coenocytic nature of thallus is like that of **Saprolegniaceae.**

These features along with heterokontic flagella in antherozoids suggest that lower fungi could have been derived from *Vaucheria* like ancestors.

• IMPORTANT QUESTIONS

Long Answer Type Questions :

1. Give an illustrated account of the structure and like history of *Vaucheria.*
2. Describe in brief the structure and reproduction of *Vaucheria.*

Short Answer Type Questions :

1. Discuss in brief the systematic position of *Vaucheria.* Discuss in short.
2. Write in short about asexual reproduction by hypnospores in *Vaucheria.*
3. Give the 3 hypothesis in short regarding uninucleate condition of oogonium of *Vaucheria.*
4. Draw graphically, life cycle of *Vaucheria.*
5. Mention 5 affinities of *Vaucheria* with members of Xanthophyceae.
6. Describe the structure of a mature zoospore of *Vaucheria.*
7. How can *Vaucheria* be called an acellular coenocyte ?
8. What is *Gorgrosira* stage ?

Objective Type Questions :

1. Name a common Indian species of *Vaucheria.*
2. Name two Indian amphibious species.
3. What is holdfast technically termed as ? Is it branched or unbranched ?
4. Mention 3 ways in which asexual reproduction occurs in *Vaucheria.*
5. Give two examples in which asexual reproduction commonly occurs by aplanospores.
6. Which stage is termed as *Gongrosira* stage ?
7. Give 2 examples of dioecious (heterothallic) species of *Vaucheria.*
8. Who coined the term Wanderplasm in 1932 ?
9. To which order does *Vaucheria* belong ?
10. Give one affinity of *Vaucheria* with green algae.

Multiple Choice Questions :

1. In Vaucheria the thallus is :
   (a) Branched, septate and multinucleate
   (b) Unbranched. septate and multinucleate
   (c) Branched, nonseptate and multinucleate
   (d) Branched, nonseptate and uninucleate.
2. In *Vaucheria* thallus, the septum formation :
   (a) Throughout the vegetative phase
   (b) Only during sex organ formation
   (c) During fragmentation
   (d) Both at the time of fragmentation and repróductive organs formation.

3. In *Vaucheria*, the multiflagellate zoospore is :
   (a) A compound zoospore
   (b) Sexually abnormal zoospore
   (c) Sexually produced structure
   (d) None of these
4. The *Gongrosira* stage in *Vaucheria* occurs during
   (a) Antheridia formation
   (b) Oogonia formation
   (c) Akinete formation
   (d) Gametes formation
5. The protoplasm accunulation during oogonium development is called :
   (a) Wanderplasm
   (b) Periplasm
   (c) Cytoplasm
   (d) Nucleoplasm.

ANSWERS

Objective Type Questions :

1. *V. geminata* **2.** *V. amphibia* and *V. sessilis*
3. Hapteron, branched **4.** By zoospores, aplanospores and hypnospores
5. *V. hamata* and *V. uncinata*
6. In asexual reproduction formation of akinetes
7. *V. litorea* and *V. dichotoma* **8. Couch**
9. Heterosiphonales **10.** Oogamous sexual reproduction.

Objective Type Questions :

1. (c) 2. (d) 3. (a) 4. (c) 5. (a)

9

RHODOPHYTA

STRUCTURE

- Introduction
- Polysiphonia
- Systematic Position
- Important Questions
- Answers

• INTRODUCTION

CLASS : RHODOPHYCEAE

The algae of class **Rhodophyceae** are commonly called **red algae** due to their red colour. Rhodophyceae is represented by about 831 genera and 5250 species. The distinguishing characters of class Rhodophyceae are as follows :

(i) All members of Rhodophyceae except twenty fresh water species are marine and about two hundred species inhabit land waters. The fresh water species either grow in fast flowing water (*e.g.*, *Batrachospermum*, *Lamanea*) or grow in stagnant water with sufficient aeration (*e.g.*, *Asterocystis*, *Compsopogon*).

(ii) Algae of Rhodophyceae are most abundant in the lower intertidal and sublittoral zones at a depth of 60 meter or more. A few are adapted to a considerable exposure living at or above the high tide level. Some are terrestrial (*Porphyridium*). Apart from some being epiphytes, several species are distinctly parasites (*Ceratocolax*, *Calleocolax*, *Pterocladiophila*). Some algae have deposit of calcareous substances in their wall.

(iii) Most of the members of Rhodophyceae are red, soft and slimy, the thallus ranges from unicellular to complex multiaxial forms.

(iv) The thallus is unicellular in *Porphyridium*, filamentous in *Goniotrichum*, palmelloid in *Asterocytis* or parenchymatous in *Porphyrà*, *Gelidium*, *Gracillaria*. Thallus in *Batrachospermum* has uniaxial structure and in *Polysiphonia* it is multiaxial.

(v) The cell wall is differentiated into an outer pectic layer and inner cellulosic layer. The mucilaginous matter of the outer pectic layer consists of agars and carrageenans. Cells are generally uninucleate and in some genera they may be multinucleate (*e.g.*, *Griffithsia*).

(vi) The main pigments are chlorophyll a and b, α and β carotene, xanthophylls and biliproteins. The pigments **r-phycoerythrin** and **r-phycocyanin** are responsible for red colour of the thallus.

(vii) The food is stored in the form of **floridean starch**. There is complete absence of all motile stages either in asexual or sexual phase of life cycle.

(viii) The reproduction takes place by asexual and sexual methods.

(ix) The asexual reproduction takes place by **monospores, neutral spores, carporpores** or by **tetraspores**.

(x) The non-motile male gametes are called **spermatia** which are produced in **spermatangia**.

(xi) The female reproductive organ called **procarp** consists of **carpogonium** and **trichogyne**. The carpogonium is swollen basal part containing female nucleus and the trichogyne is narrow gelatinous receptive part.

(xii) During post fertilization the carpogonium transforms into **carposporophyte**. In carposporophyte, carposporangia are formed. In carposporangia, carpospores are produced. The carpospores on germination produce gametophytic thallus or alternate diploid thallus.

(xiii) Higher forms (*e.g.*, *Polysiphonia*) produce **tetraspores** and **tetrasporophyte.**

ORDER : CERAMIALES

The order ceramiales is represented by about 160 genera and 900 sepcies. The algae of this group are mostly marine. The thalli are complex multiaxial or polysiphonous.

The order Ceramiales is divided into four families :

Family 1. Ceramiaceae *e.g.*, *Ceramium*
Family 2. Delesseriaceae *e.g.*, *Delesseria*
Family 3. Rhodomelaceae *e.g.*, *Polysiphonia*
Family 4. Dasyaceae *e.g.*, *Dasya*

FAMILY : RHODOMELACEAE

The algae of family Rhodomelaceae are polysiphonous. The thallus consists of central siphon and pericentral siphons. The cells of central siphon are uninucleate. The male and female reproductive structures develop on special reproductive branches called as trichoblasts. After fertilization carposporophytes and tetrasporophytes are formed. The life cycles are diplobiontic.

POLYSIPHONIA

• SYSTEMATIC POSITION

Class	:	**Rhodophyceae**
Sub-class	:	**Florideae**
Order	:	**Ceramiales**
Family	:	**Rhodomelaceae**
Genus	:	***Polysiphonia***

OCCURRENCE

Polysiphonia is a large genus with about 200 species. The genus is represented in India by about 16 species found is southern and western coasts of India. Some common Indian species are *P. ferulacea*, *P. urceolata* and *P. variegata*. Most of the species are **lithophytes** *i.e.*, found growing on rocks. Some species are **epiphytic**, found growing on other plants and algae *e.g.*, *P. ferulacea* grows on *Gelidium pusillum*. *P. variegata* grows on the roots of mangroves. Some species are semiparasitic *e.g.*, *P. fastigiata* is semiparasiite on *Ascophyllum nodosum* and *Fucus*.

THALLUS STRUCTURE

The thallus is filamentous, red or purple red in colour. The thallus is multiaxial and all cells are connected by pit connections hence, the name given is *Polysiphonia*. Due to continuous branching and rebranching the thallus has feathery appearance (Fig. 1A). The thalli may reach the length of about 30 cm.

The thallus is heterotrichous and is differentiated into a **basal prostrate system** and **erect aerial system**. The **prostrate system** (Fig. 1B) creeps over the substratum. Its functions are attachment of the thallus to the substratum and perennation. In many species of *Polysiphonia e.g.*, in *P. nigrescens*, the prostrate system is well developed and multiaxial in structure. In some species *e.g.*, *in P. elongata* and *P. violacea* the multiaxial prostrate system is absent. The plants remain attached to the substratum by :

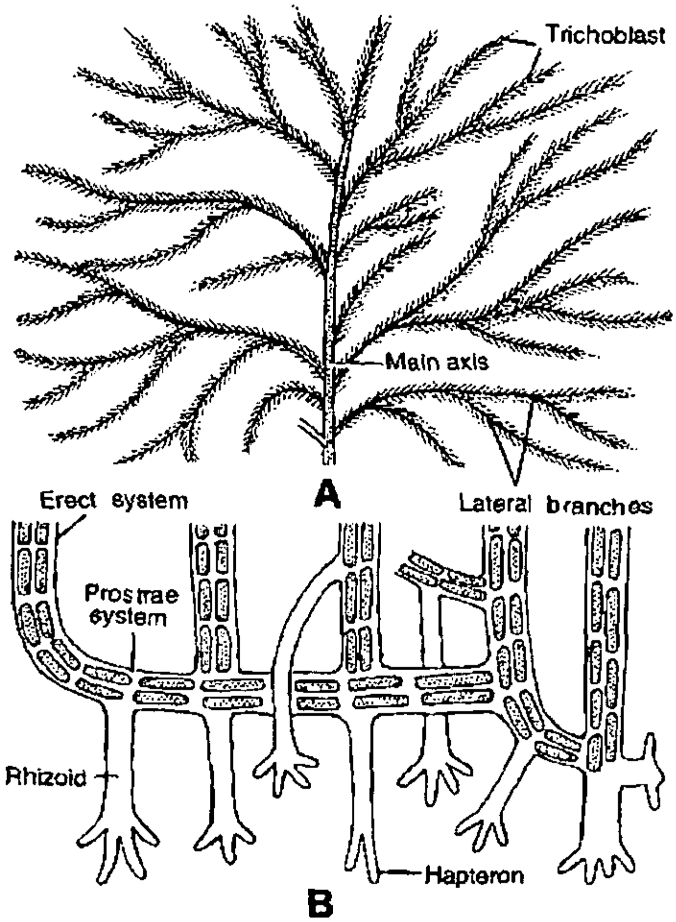


Fig. 1 (A, B). *Polysiphonia*. External features.
(A) Habit, (B) Prostrate and erect system

(a) unicellular richly branched rhizoids arising from multiaxial prostrate system.

(b) rhizoids arising from the erect system, forming, an attachment disc or **hapteron**.

(c) by the unicellular rhizoids arising in groups from the prostrate system *e.g.*, *P. fastgata*.

The **erect aerial system** arises from the prostrate system. It is made of multiaxial branched filaments.

These are made of a central large filament or **central siphon** of cylindrical cells. The central siphon is surrounded by a number of **pericentral cells** or **pericentral siphons** (Fig. 2 A, B). The length of central and pericentral siphons is equal hence, the filaments appear to be divided in **nodes** and **internodes** like.

Each pericentral siphon remains connected with central siphons through **pit connections.** The successive central siphon cells and all peripheral cells are also connected to each other through pit connections. Hence the complete thallus makes a **polysiphonaceous** structure (Fig. 2 C).

Branching : The thallus of *Polysiphonia* bears two types of branches (a) Short branches (b) Long branches. The branches are lateral and monopodial. The branching starts from the cell lying 2–5 cells below the apical cell.

(A) Short branches or trichoblasts. The short branches or trichoblasts are branches of limited growth. These are uniaxial in structure and lack pericentral siphons. The cells are connected to each other by pit connections. These branches arise on main axis and on long branches in **spiral** manner. These branches are deciduous, perennial species shed these branches before winter and retained as **scar cell** by the pericentral siphon.

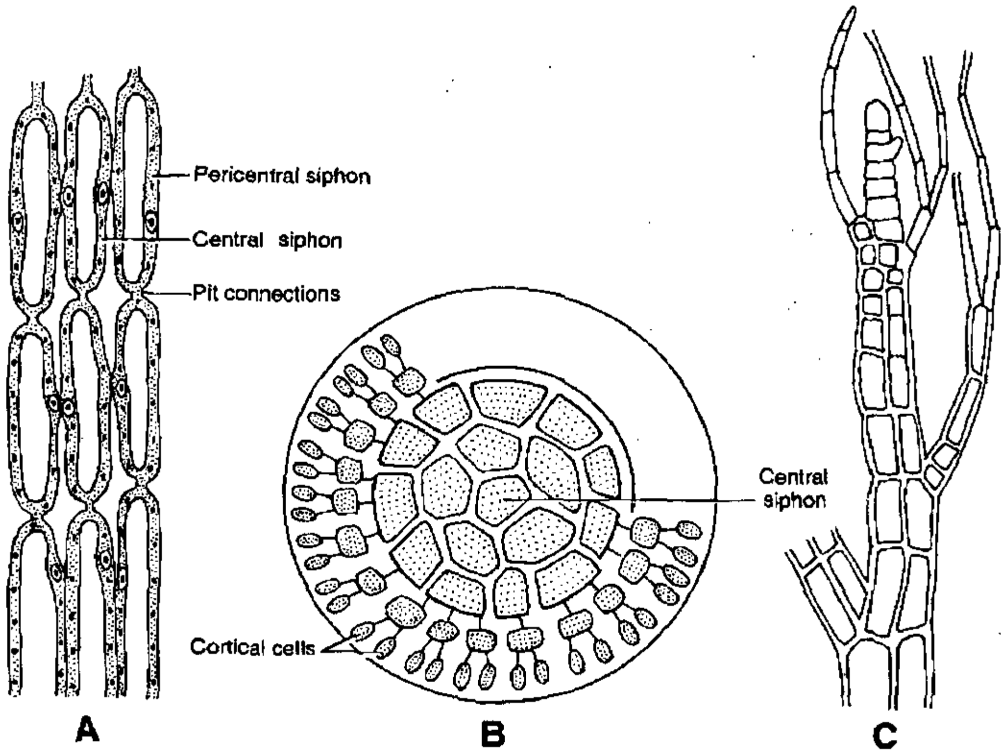


Fig. 2 (A–C). *Polysiphonia.* Thallus structure. (A) Part of aerial branch, (B) T.S. of aerial axis, (C) Vertical section of main axis.

Development of trichoblast :

The **trichoblast initial** is differentiated from a cell 2–5 cells below the apical cell (Fig. 3 A, B). It starts as a small cell and divides repeatedly to form dichotomously branched, uniseriate multicellular hair like trichoblast (Fig. 4 C, D). The trichoblast may bear male and female reproductive structures or remain sterile.

(B) Long lateral branches. The long lateral branches are branches of unlimited growth are polysiphonous at the base and monosiphonous in terminal parts. These branches develop from the basal cells of short branches. In species like *P. violacea* they develop as outgrowth from trichoblast initial. They develop along with trichoblast and after few divisions the trichoblasts are pushed aside so they appear to arise from trichoblast dichotomously. The outgrowth functions as the apical cell of the long branch which after repeated division forms the central siphon. The central siphon later on develops pericentral siphons. In species like *P. elongata* the long branches arise directly from the main axis. The outgrowth develops from a cell 2–5 cells below the apical cell. The outgrowth forms central siphon and later pericentral siphon in normal way.

Cortication

The cortical cells arise from outer pericentral cells by pericentral division. The central cells divide anticlinally and surround the pericentral cells. The cortical cells are parenchymatous in nature and form several layers. The cortical cells may be present in lower part of thallus *e.g.*, *P. mollis* or through out the thallus *e.g.*, *P. crassiuscula*.

Cell Structure

The cells of central and pericentral siphons are cylindrical and elongated. The cell wall is differentiated into outer **pectic** and inner **cellulosic** layer. The cell contains a large central vacuole. The cytoplasm is present between the cell wall and the central vaucole. The cell contains a number of red discoid **chromatophores** which lack pyrenoids. The chromatophores contain pigments chlorophyll a, chlorophyll d,

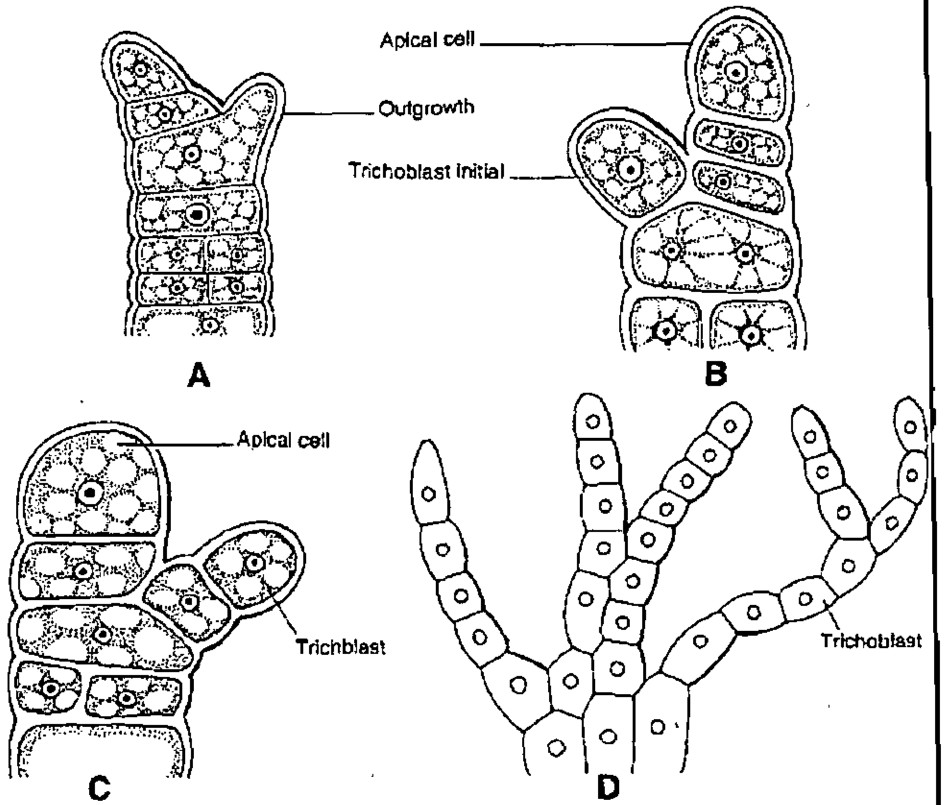


Fig. 3 (A–D). ***Polysiphonia*****. Development of trichoblast.**

α carotene, β carotene, r-phycoerythrin and r-phycocyanin. The chromatophores are parietal in position (Fig. 2A). The cytoplasm contains granules of **floridean starch** as food reserve.

Growth

The growth takes place by the dome shaped apical cell located on the tip of central siphon. The apical cell cuts many cells on lower side by transverse divisions which form the central siphon. Some of the lower cells divide vertically to form pericentral cells.

Reproduction

Polysiphonia is mainly heterothallic. In the life cycle of *Polysiphonia* three kinds of thalli are found. These are :

(a) The **gametophytic** thalli which are **haploid** free living and dioecious. The male sex organs **spermatangia** are formed on **male gametophytic plant** and the female sex organs **carpogonia** are formed on **female gametophytic** plant.

(b) The **carposporophytes** are diploid, depend upon the female gametophyte. They develop after fertilization from zygote and later bear carposporangia. The carposporangia form diploid carpospores.

(c) The **tetrasporophytic** plant which is formed by germination of diploid carpospores is diploid and independent. Then plant bears tetrasporangia which form four haploid tetraspores which again give rise to male and female gametophytic plants.

In life cycle of *Polysiphonia* both asexual and sexual reproduction takes place. The life cycle is example of **triphasic alternation of generation**.

Sexual Reproducton

Sexual reproduction is **oogamous** type and plants are dioecious *i.e.*, male and female sex organs are produced on different male and female gametophytic plants.

α

Male Gametophyte

The male sex organs, **spermatangia** or **antheridia** develop on fertile trichoblasts present on tips of male gametophytic plant. The male trichoblast when only 2–3 celled, divides dichotomously. In most of the species one branch remains sterile and the other bears spermatangia, in some species both branches become fertile. The sterile branch may divide again to form fertile trichoblasts. The cells of fertile uniaxial trichoblast except the 2–3 divide periclinally to form pericentral cells. The pericentral cells form **spermatangial mother cells** on outerside (Fig. 4B). Each spermatangial mother cell cuts off 2–4 sporangia on outer side. The complete structure makes cone shaped cluster of spermatangia (Fig. 4 A).

The uninucleate protoplast of spermatagnium forms a male gamete or **spermatium.** The spermatium is non-motile and is released through an apical pore in the spermatangium (Fig. 4 C).

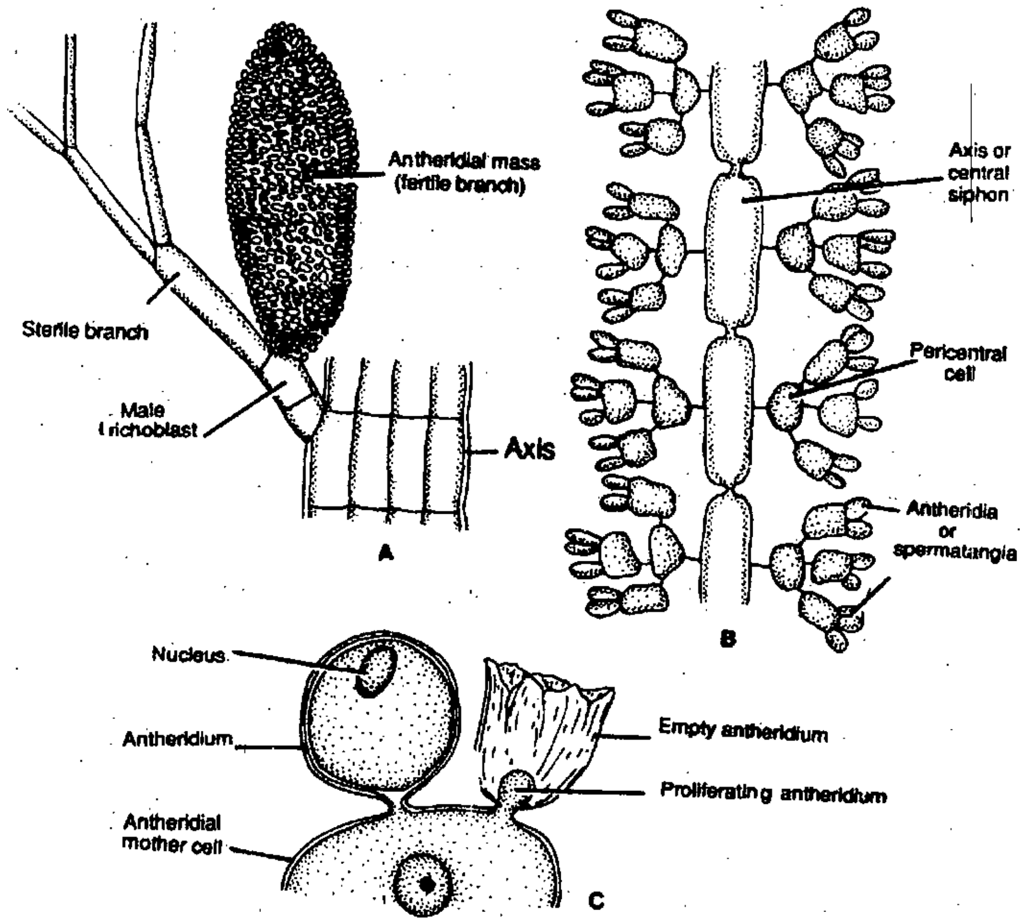


Fig. 4 (A–C). ***Polysiphonia.*** **Development of spermatangium.**

Female Gametophyte

The female sex organ of *Polysiphonia* is called as **carpogonium.** (Fig. 5 F). The carpogonium develops on trichoblast on female gametophytic plant. The trichoblast initial arises from a cell, 2–4 cells behind the apical cell. It develops into 5–7 celled female trichoblast. The three lower cells form 5 pericentral cells of which there is one adaxial, two lateral and two abaxial cells (Fig. 5 C–E). These cells surround the central cell. The adaxial cell called **supporting cell**, forms a basal sterile filament initial, a lateral sterile filament initial and a curved four celled **carpogonial branch.**

The basal swollen flask shaped cell of the carpogonial branch functions as **carpogonium** or egg cell and the upper tubular elongated part is called **trichogyne** (Fig. 5 C). The sterile sheath around carpogonium is called **pericarp** (Fig. 5 F).

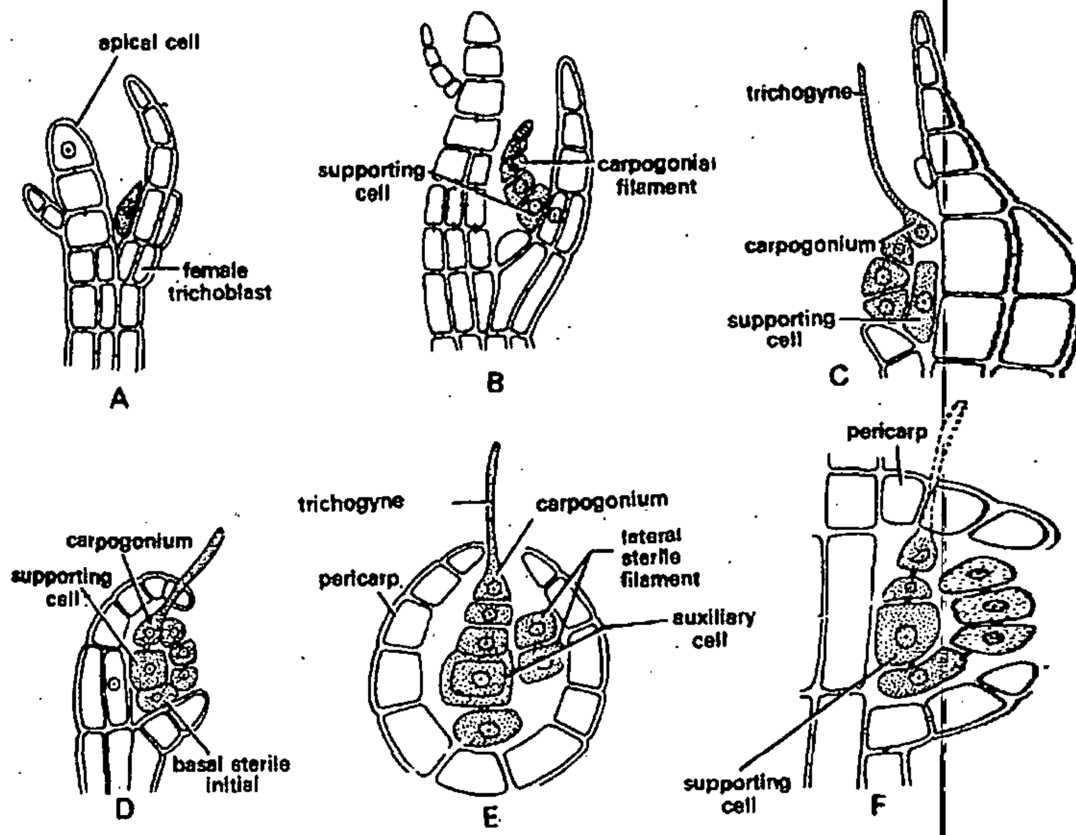


Fig. 5. (A–F). ***Polysiphonia.*** **Development of female gametophyte.**

Fertilization. The spermatia are carried to the trichogyne of carpogonium throu water currrents. The spermatium adheres to the trichogyne by the mucilage around The walls between spermatium and the trichogyne dissolve. The male protopla enters carpogonium through trichogyne. After fertilization of male and female nucle diploid zygote cell is formed.

Post fertilization changes. After fertilization the basal sterile initial divides *form basal sterile filaments* which *are* 2–4 celled. The lateral *sterile initials* divide make lateral sterile filaments which are 4–10 celled. The sterile filaments are nutritive nature. The supporting cell divides transversely to form an **auxillary c** between itself and the carpogonium. A tubular protoplasmic connection is establish between auxillary cell and carpogonium (Fig. 6A, B).

The diploid zygote nucleus divides mitotically and forms two diploid nuclei of wh one nucleus remains in the carpogonium and the other nucleus migrates into auxillary cell. The auxillary cell which contains one haploid nucleus receives t diploid nucleus. The haploid nucleus of the auxillary cell degenerates and it th contains diploid nucleus only.

The trichogyne at this time degenerates, the carpogonium, auxillary cell a supporting cell fuse and form irregular shaped **placental cell.** The diploid nucleu. the auxillary cells divides mitotically forming many diploid nuclei in the placental ce

A number of gonimoblast initials arise from the placental cell and each ini receives a diploid nucleus from placental cell. Each gonimobalst initial forms a celled **gonimoblast filament** or **gonimalobe.** The lower cell of gonimoblast filam can also give rise to new gonimoblast filaments. All the gonimoblast filaments mak called the carposporophyte (Fig. 6 B–D).

Carposporophyte. This is diploid sporophytic phase in life cycle of *Polysipho* and it is dependent upon the gametophytic haploid phase. The **carposporophyte cystocarp** or **gonimocarp** is made of many gonimoblast filaments attached on

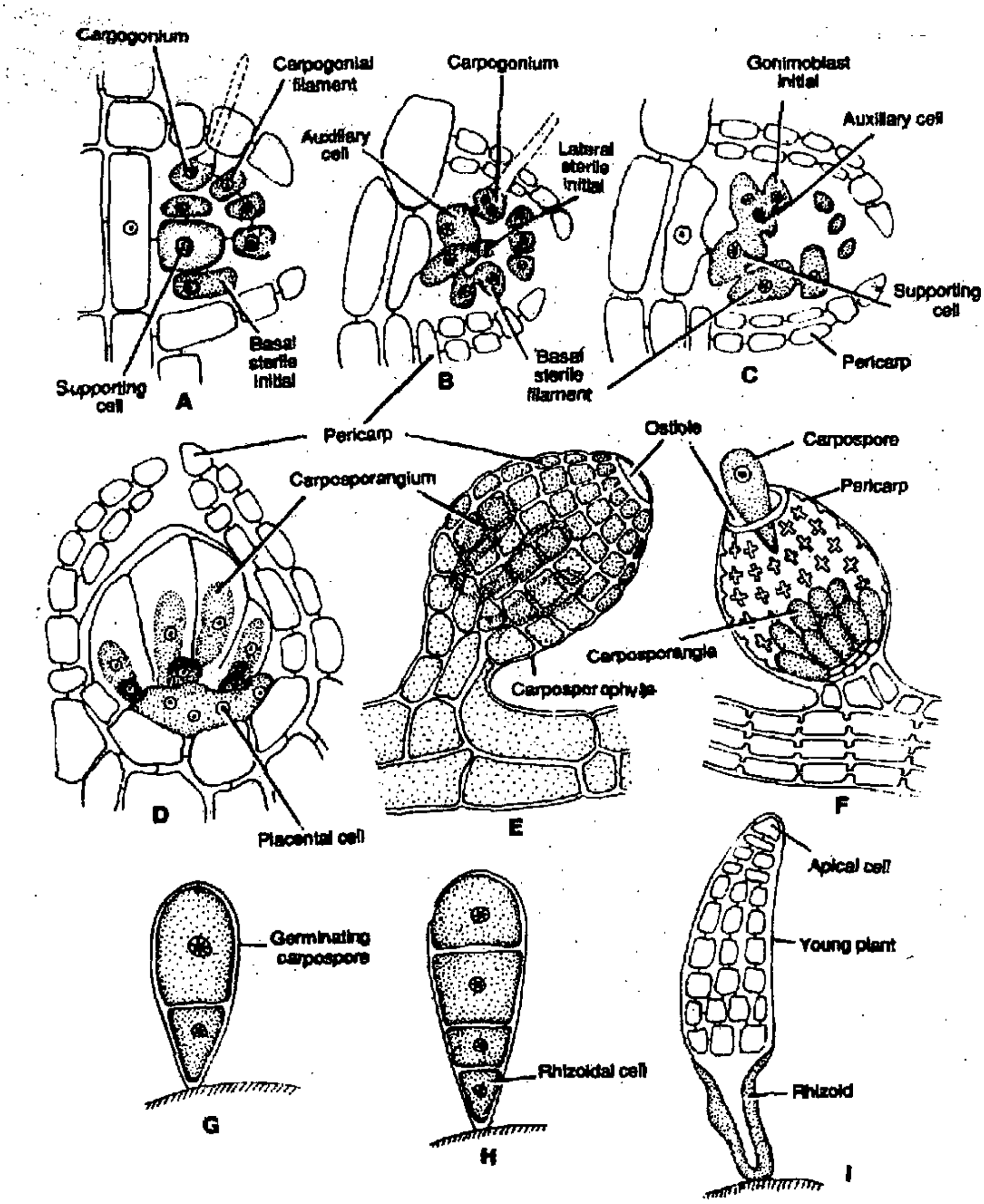


Fig. 6. (A–I). ***Polysiphonia.*** **Post fertilization changes**

placental cell which remain covered by sterile **pericarp.** (Fig. 6 B–D). It is urn shaped structure. The terminal cell of the gonimoblast filament develops into a **carposporangium** which forms a single diploid **carpospore.** The diploid carpospores are liberated through the **ostiole** of carposporophyte (Fig. 6E-F). The carpospores are carried away by water and germinate on suitable substratum.

The carpospore develops a wall around itself and then divides by mitotic division to make a small lower cell and the larger apical cell. The two celled filament divides to make four celled filament. The germination of diploid carpospore results in the formation of diploid **tetrasporophytic plant** (Fig. 6G–I).

Tetrasporophyte. The tetrasporophytes are free living diploid plants in the life cycle of *Polysiphonia*. Morphologically these plants are similar to haploid gametophytic plants but they do not bear male or female sex organs like gametophytic plants. Some pericentral cells of tetrasporophytic plant function as **tetrasporangial initials**. These are smaller than other pericentral cells and only one in each tier. The tetrasporangial initial divides by vertical division to make an outer **cover cell** (Fig. 7 A–C) and the inner **sporangial mother cell**. The cover cell divides further to make two or more cover cells. The sporangial mother cell divides by transverse division to make a lov stalk cell and the upper **sporangial cell**. The sporangial cell enlarges and mal **tetrasporangium.** The branches bearing tetrasporangia become twisted and swoll and are called **stichidia.**

The diploid nucleus of tetrasporangium divides meiotically forming four hapl nuclei followed by the division of protoplast. The four uninucleate segments devel into four haploid **tetraspores** or **meiospores** which are arranged tetrahedrally.

The tetraspores on maturity are liberated by splitting of sporangial w accompanied by lifting of the cover cell. Two of the four tetraspores germinate to ma haploid male gametophytic plants and the two make haploid female gametophy plants (Fig. 7 D–I). Hence the asexual reproduction in *Polysiphonia* take place means of haploid tetraspores which are formed on tetrasporophytic plant.

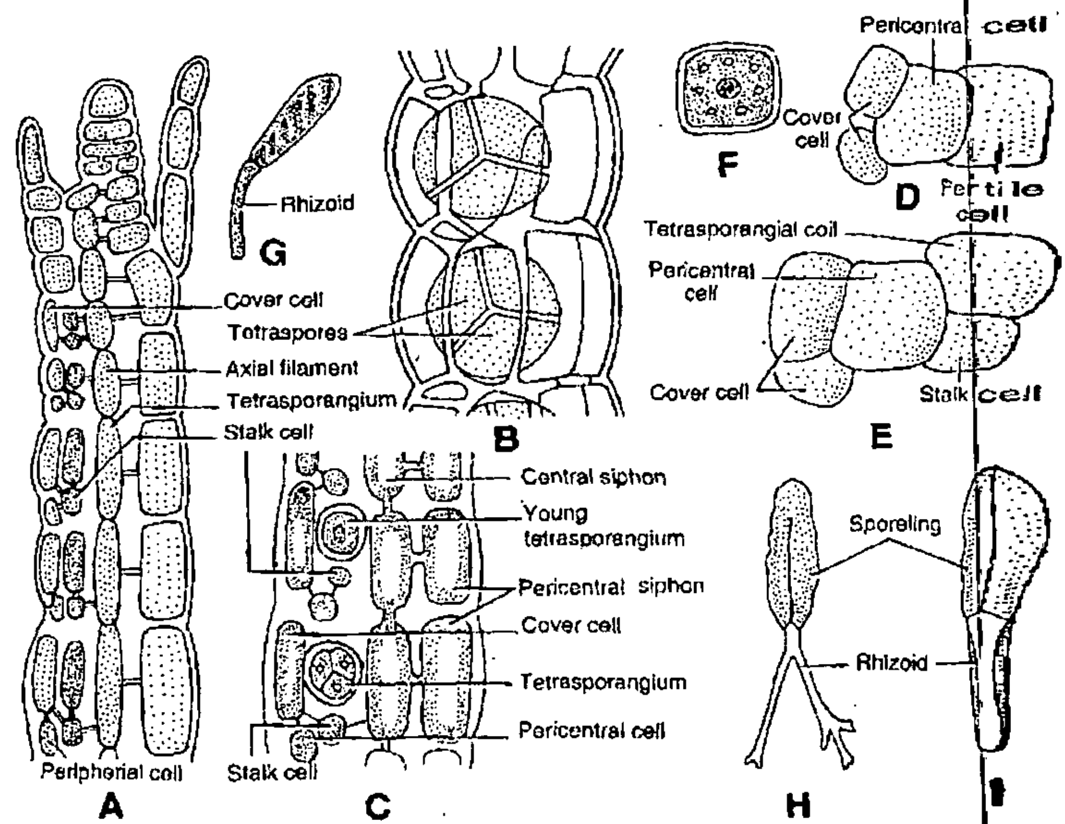


Fig. 7 (A–I). *Polysiphonia* Tetrasporophyte. (A, C). A part of stichidium showing development of tetrasporangia. (B) A part of stichidium with tetrasporangia. (D, E). Development of tetrasporangium from pericentral cell. (F) A tetraspore, (G–I). Development of new gametophytic thallus.

Alternation of Generation

The life cycle of *Polysiphonia* exhibits **triphasic alternation of generation.** In the life cycle three distinct phases occur. These are :

1. Gametophytic phase.
2. Carposporophyte phase.
3. Tetrasporophyte phase.

Polysiphonia is dioecious plant. The male gametophytic plants and the female gametophytic plants are distinct.

The haploid **male gametophytic plant** bears sex organs **spermatangia** which produce haploid **spermatia.** The haploid female gametophytic plant bears sex organs

carpogonium. The fertilization takes place *in situ* and diploid zygote nucleus is formed. The zygote develops in second phase of life cycle, the **carposporophyte** is dependent upon female gametophytic plant. The carporophyte is urn shaped structure and forms diploid **carpospores** in **carposporangia.** The carpospores germinate to make diploid **tetrasporophytic plants.** The tetrasporophytic plant bear tetrasporangia. The diploid tetrasporangial nucleus divides meiotically to form four haploid **tetraspores** which again make gametophytic male and female plants. In life cycle of *Polysiphonia* two diploid phases carposprophyte and tetrasporophyte alternate with one haploid gametophytic phase. The life cycle of *Polysiphonia* can be called as **triphasic diplobiontic with isomorphic** alternation of generation (Figs. 8).

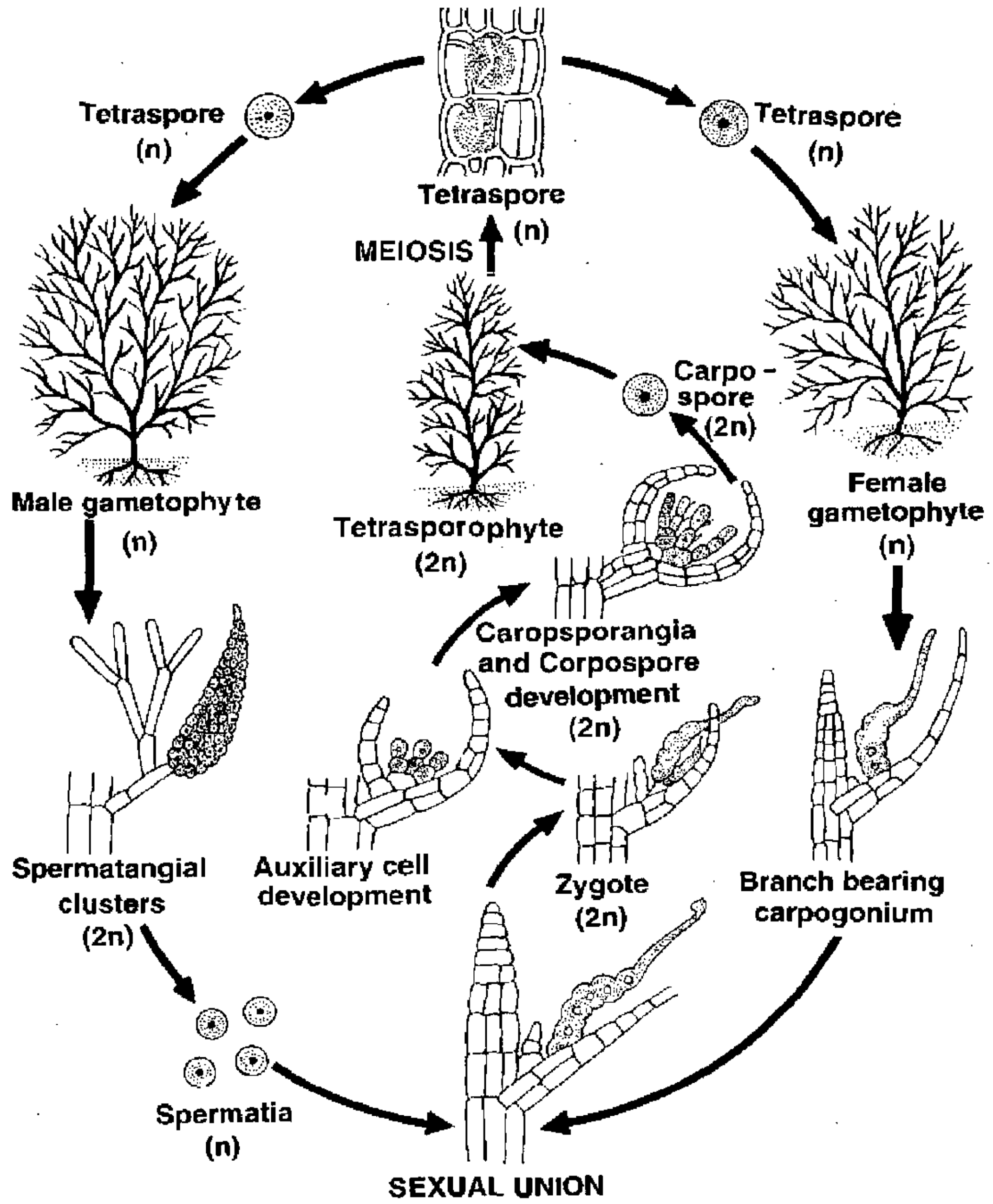


Fig. 8. ***Polysiphonia*****. Diagrammatic life cycle.**

• IMPORTANT QUESTIONS

Long Answer Type Questions :

1. Give an account of sexual reproduction in *Polysiphonia.*
2. Give an account of the life cycle of *Polysiphonia* and the type of alternatio generation it exhibits.
3. With the help of labelled diagrams only explain the structure and life histor *Polysiphonia.*

Short Answer Type Questions :

1. Write a note on the trichoblasts in *Polysiphonia* ?
2. Draw a labelled diagram showing a mature carpogonium.
3. Write a short note on tetrasporophyte.
4. Give graphically life cycle of *Polysiphonia.*
5. Draw labelled diagram of a mature cystocarp.
6. Sketch a simple diagram of a part of stichidium with tetrasporangia and lab giving a proper caption along with diagram of a tetraspore.

Objective Type Questions :

1. Give one example each of an epiphytic and a semi-parasitic species.
2. Given 2 examples of *Polysiphonia* which lack prostrate system.
3. How is pericentral siphon connected to central siphon ?
4. What type of branching is found in *Polysiphonia* ?
5. In which form do some species possess bromine ?
6. What are the different ways of vegetative reproduction found in *Polysiphonia* ?
7. How many pericentral cells are produced by lower 3 cells of female trichoblast
8. After degeneration of one, which nucleus is left in the auxillary cell.
9. How can life cycle of *Polysiphonia* be called triphasic ?
10. Give the sub-class and order of *Polysiphonia.*

Multiple Choice Questions

1. In red algae food is stored mainly in the form of :
   (a) Oil
   (b) Sugar
   (c) Protein and oil
   (d) Floridean starch
2. In *Polysophonia,* carposporophyte is :
   (a) Haploid
   (b) Diploid
   (c) Triploid
   (d) Not fixed
3. In *Polysophonia* carpogonium represents :
   (a) Female reproductive organ
   (b) Male reproductive organ
   (c) Post fertilization stage
   (d) None of these.

UNIT–III

BRYOPHYTES

10

GENERAL CHARACTERS OF BRYOPHYT

STRUCTURE

• INTRODUCTION

Bryophyta (Gr. *Bryon* = mass; *phyton* = plant), a division of **kingdom Plan** comprises of mosses[2], Hornworts and Liverworts[3]. They are groups of green pl which occupy a position between the thallophytes (Algae) and the vascular cryptog (Pteridophytes). **Bryophytes produce embryos but lack seeds and vasc tissues.** They are the most simple and primitive group of **Embryophyta**[4]. They said to be the **first land plants** or non-vascular land plants (**Atracheata**). Presen swimming antherozoids is an evidence of their aquatic ancestory[5].

1. **Whittaker** (1969) divided the organisms into five kingdoms on the basis of three criteria—complexi cell structure, organism's body and the mode of obtaining nutrition. The five kingdoms are : Monera, Prot Plantae, (plants), Fungi and Animalia (animals).

2. The word moss at times is applied to plants that have no relevance to Bryophytes *e.g.*,

(a) Reindeer moss	—	Lichen (*Cladonia rangifera*)
(b) Iceland moss	—	Lichen (*Cetraria iclandica*)
(c) Oak moss	—	Lichen (*Evernia prusostri*)
(d) Wolf moss	—	Lichen (*Letharia vulpina*)
(e) Irish moss or sea moss or Carrageen moss	—	Algae (*Chondrus crispus*)
(f) Club moss	—	Pteridophyte (*Lycopodium spp.*)
(g) Spike moss	—	Pteridophyte (*Selaginella spp.*)
(h) Bird's nest moss	—	Pteridophyte (*Selaginella rupestris*)
(i) Spanish moss	—	Angiosperm (*Tillandisai usncoides*)

3. Some of the thalloid Bryophytes resemble liver. An ancient belief was that these plants have cura significance of liver diseases. So the name **liverwort** has been given to thalloid forms. However, the v liverwort, is misnomer because there is no evidence that these liverworts are of medicinal value. Moreo many of liverworts are leafy.

4. **Engler** (1886) opined that all the plants above the level of thallophytes *i.e.*, algae, fungi and lic should be grouped under the sub-kingdom **Embryophytes**. The Embryophyta include all those plant which multicellular embryo develops from the zygote while the zygote is still attached to the parent pla

5. Bryophytes need water for dehiscence of antheridia, liberation of antherozoids, transfer of antheroz from antheridia to archegonia, opening of archegonial neck, secretion of mucilage substance and movement of antherozoids into the archegonial neck for fertilization.

• DISTRIBUTION

Bryophytes are represented by 960 genera and 24,000 species. They are cosmopolitan in distribution and are found growing both in the temperate and tropical regions of the world at an altitude of 4000–8000 feet. In India, Bryophytes are quite abundant in both Nilgiri hills and Himalayas; Kullu, Manali, Shimla, Darjeeling, Dalhousie and Garhwal are some of the hilly regions which also have a luxuriant growth of Bryophytes. Eastern Himalayas have the richest in bryophytic flora. A few species of *Riccia*, *Marchantia* and *Funaria* occur in the plains of U.P., M.P., Rajasthan, Gujarat and South India. In hills they grow during the summer or rainy season. **Winter is the rest period.** In the **plains the rest period is summer**, whereas active growth takes place during the winter and the rainy season. Some Bryophytes have also been recorded from different geological eras *e.g.*, *Muscites yallourensis* (Coenozoic era), *Intia vermicularies*, *Marchantia* spp. (Palaeozoic era) etc.

• HABITAT

Bryophytes grow densely in moist and shady places and form thick carpets or mats on damp soils, rocks, bark of trees especially during rainy season. Majority of the species are terrestrial but a few species grow in fresh water (aquatic) *e.g.*, *Riccia fluitans*, *Ricciocarpos natans*, *Riella* etc. Bryophytes are not found in sea but some mosses are found growing in the crevices of rocks and are being regularly bathed by sea water *e.g.*, *Grimmia maritima*. Some Bryophytes also grow in diverse habitats *e.g.*, *Sphagnum*–grows in bogs, *Dendroceros*–epiphytic, *Radula protensa*, *Crossomitrium*–epiphyllous, *Polytrichum juniperinum*–xerophytic, *Tortula muralis*–on old walls, *Tortula desertorum* in deserts, *Porella platyphylla*–on dry rocks, *Buxbaumia aphylla* (moss), *Cryptothallus mirabilis* (liverwort) are saprophytic.

• GENERAL CHARACTERS

1. Plant body is gametophytic, independent, dominant, autotrophic, either thalloid (*i.e.*, thallus like, not differentiated into root, stem and leaves) or folise (Fig 1), containing a rootless leafy shoot.

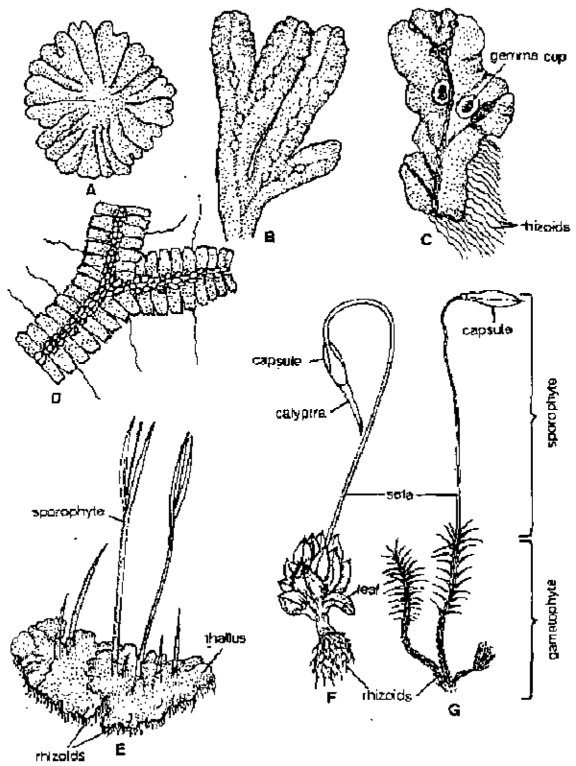


Fig. 1. (A–G). Bryophytes. External features. (A) *Riccia* (Rosette habit), (B) *Riccia* (thallus), (C) *Marchantia*. (D) *Porella*, (E) *Anthoceros*, (F) *Funaria*, (G) *Polytrichum*.

2. Plant body is very small and ranges from a few mm. to many cm. *Zoopsis* is the smallest bryophyte (5 mm.) while the tallest bryophyte is *Dawsonia* (50–70 cms.).

3. Leaves and stems found in vascular plants are absent, **Koch** (1956) termed these 'leaf' and 'stem' like structures as 'axis' and 'phylloid' respectively.

4. Roots are absent. Functions of the roots are performed by rhizoids. Cells are also capable to absorb moisture directly from the ground or atmosphere. Therefore Bryophytes can also survive on the moist soils.

5. Rhizoids may be unicellular, unbranched (*e.g.*, *Riccia*, *Marchantia*, *Anthoceros*) or multicellular and branched (*e.g.*, *Sphagnum*, *Funaria*).

6. In members of order Marchantiales (*e.g.*, *Riccia*, *Marchantia*) **scales** are present. These are violet coloured, multicellular and single cell thick. They protect the growing point and help to retain the moisture.

7. Vascular tissue (xylem and phloem) is completely absent. Water and food material is transferred from cell to cell. However, in some Bryophytes (*e.g.*, mosses) a few cells in groups of 2–3 are present for conduction of water and food (photoassimilate). These cells are known as **hydroid** (collectively hydrom) and **leptoids** respectively. Cuticle and stomata are absent.

• ADAPTATIONS OF BRYOPHYTES TO LAND HABIT

Bryophytes are **first land plants**. Evidences support that **Bryophytes are evolved from Algae.** During the process of origin they developed to certain adaptations to land habit. These are :

1. Development of compact plant body covered with epidermis.
2. Development of organs for attachment and absorption of water *e.g.*, rhizoids.
3. Absorpion of carbon dioxide from atmosphere for photosynthesis *e.g.*, airpores.
4. Protection of reproductive cells from drying and mechanical injury *i.e.*, jacketed sex organs.
5. Retention of zygote within the archegonium.
6. Production of large number of thick walled spores.
7. Dissemination of spores by wind.
8. Presence of primitive vascular system in the form of conducting strand.

• BRYOPHYTES : AMPHIBIANS OF PLANT KINGDOM

Bryophytes are also known as amphibians of **plant kingdom** because **water is needed to complete the life cycle.** In animal kingdom class Amphibia (Gr. *Amphi* = two or both ; *bios* = life) includes those vertebrates which are amphibians in nature *i.e.* they can live on land as well as in water. Similarly, majority of the bryophytes are terrestrial but they are incompletely adapted to the land conditions. They are unable to grow during dry season and require sufficient amount of water for their vegetative growth. Water is absolutely essential for the maturity of sex organs and fertilization. Without water they are unable to complete thier life cycle. On account of their complete dependence on external water for completing their life cycle, Bryophytes along with Pteridophytes are regared as **amphibians of plant kingdom.**

• ALTERNATION OF GENERATION IN BRYOPHYTES

Bryophytes show a distinct and sharply defined **heteromorphic** alternation of generation. In the life cycle of these plants, there exist two distinct phases. One is **haploid** (X) or **gametophytic phase** (produces gametes). It is the **dominant and independent** phase of the life cycle. It produces the male and female sex organs *i.e.* **antheridia** and **archegonia** respectively. Haploid gametes *i.e.*, antherozoids and eggs are produced inside the sex organs. Antherozoids are produced in antheridia and eggs are produced in archegonia. The gametes fuse to form a diploid (2x) zygote. The zygote is the starting point of the next phase of the life cycle.

On germination the zygote forms the second diploid adult of the life cycle called **sporophyte** or **sporogonium**. Sporogonium produces **spore mother cells** in the capsule region, which undergo meiosis and form the haploid spores called **meiospores**. The **zygote, embryo, sporogonium** and **spore mother cells** together constitute the **sporophytic generation**. This generation is dependent completely or partially on the gametophytic generation for its nutrition. Each meiospore germinates and produces a gametophytic plant which again bears the sex organs. In this way the life cycle goes on.

Because the two generations (gametophytic and sporophytic) appear alternately in the life cycles, Bryophytes show alternation of generation. Since the generations differ completely in their morphology *i.e.*, gametophyte is either thalloid or foliose, and the sporophyte usually consists of **foot, seta** and **capsule**, it is called **heteromorphic alternation of generation**.

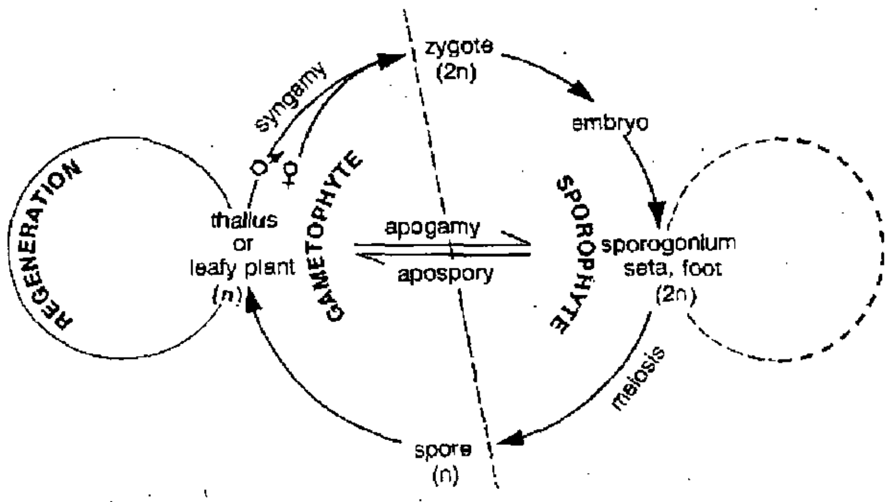


Fig. 2. Life cycle or heteromorphic alternation of generation in Bryophytes (diagrammatic representation)

• APOGAMY AND APOSPORY

Bryophytes are endowed with a remarkable regeneration capacity. Parts of the plant or any living cell of the thallus are capable of regenerating the entire plant. The sporophytic cells regenerate to form a protonema on which appear gametophytes. This **regeneration of diploid gametophyte from a sporophyte without the formation of spores** is called **apospory**. Conversely a gametophyte may form a mass of cells which may regenerate a sporophyte. This **regeneration of a diploid sporophyte from a gametophyte, without the formation of gametes** is called **apogamy**. Aposory and apogamy are rarely found in life cycle of Bryophytes.

• RHIZOIDS AND SCALES IN BRYOPHYTES

Rhizoids

In Bryophytes roots are absent and the functions of the root *i.e.*, anchorage and absorption is performed by the filamentous structures known as **rhizoids**. Rhizoids may be unicellular, unbranched (Fig. 3B–D) in thallose forms of Hepaticopsida and Anthocerotopsida (*e..g, Riccia, Marchantia, Anthoceros*) or multicellular and branched in foliose forms of Bryopsida (Fig. 3 E) (*e.g., Funaria, Polytrichum*) Multicellular rhizoids possess oblique cross walls. Unicellular rhizoids are of two types **smooth-walled** and **tuberculated** (Fig. 3 B–D). The members of order Marchantiales (*e.g., Riccia, Marchantia*) possess both types of rhizoids while Anthocerotales (*e.g., Anthoceros*) possess only smooth walled rhizoids.

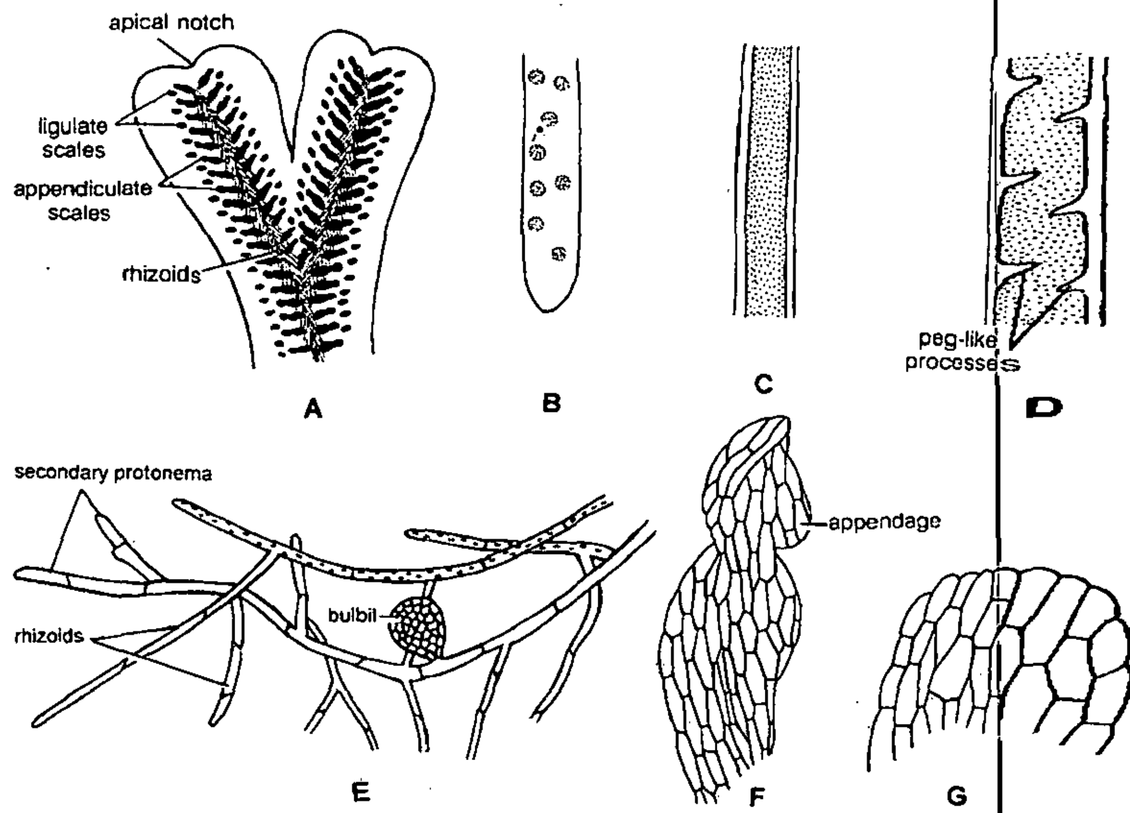


Fig. 3. (A–G) *Marchantia*. Scales and rhizoids. (A) *Marchantia* thallus : Ventral surface showing rhizoids and scales, (B) Tuberculated rhizoid (surface view), (C) Smooth walled rhizoid (surface view), (D) Tuberculate rhizoid (internal view), (E) Multicellular rhizoids, (F) Appendiculate scale, (G) Ligulate scale.

In thalloid forms rhizoids are borne on the ventral surface (Fig. 3 A) along the mi rib, however, in foliose forms rhizoids arise from the base of the 'stem'. In aquat Bryophytes (*e.g.*, *Riccia fluitans, Ricciocarpus natans*) rhizoids are absent.

Scales

Scales are present only in the members of order Marchantiales and absent in a Bryophytes. The scales are multicellular, violet coloured and single cell thick. They ar violet in colour due to the presence of the pigment **anthocyanin.** Scales develop on th ventral surface of the thallus (Fig. 3A). They may be arranged in one row (*e.g.*, youn thallus of *Riccia*) or in two rows on each side of the mid rib (*e.g., Targionia*) or in two four rows on each side of the mid rib (*e.g., Marchantia*) or irregularly distributed ove the entire ventral surface (*e.g., Corsinia*). In *Riccia* the scales are **ligulate** (Fig. 3C while in *Marchantia* the scales are of two types-**ligulate** and **appendiculate** .(divide by a narrow constriction into two parts—body and appendage, Fig. 3F).

Scales protect the growing point by covering their delicate cells and secreting slim to keep them moist. The scales are absent in some aquatic members of order Marchantiales e.g., *Riccia fluitans.*

• ARCHESPORIUM

The archesporium is the first cell generation of the **sporogenous tissue.** It divide and redivides to form a mass of cells. It is a solid tissue and also called sporogenou tissue. The cells of the last cell generation of soild tissue separate from each other an are known as **spore mother cells.** The origin, position and fate of archesporium varie in different members of Bryophytes. It is as follows:

Classes and orders	Origin	Position	Fate
Class I. Hepaticopsida			
Order. Marchantiales			
Riccia	Endothecium	Fills the cavity of the capsule.	Spore mother cells and in some species few nurse cells.
Marchantia	Endothecium	Fills the cavity of the capsule.	Spore mother cells, elater mother cells and in few species apical cap (*e.g., M. chenopoda*).
Order. Mertzgeriales			
Pellia	Endothecium	Fills the cavity of the capsule.	Spore mother cells, elaters and basal elaterophore.
Order. Jungermanniales			
Porella	Endothecium	Fills the cavity of the capsule.	Spore mother cells and elaters.
Class II. Anthocerotopsida			
Order. Anthocerotales			
Anthoceros	Inner layer of amphithecium	Arches over the columella.	Spore mother cells and pseudoelaters.
Class III. Bryopsida			
Order. Sphagnales			
Sphagnum	Inner layer of amphithecium	Dome shaped, lies in the upper parts of the capsule and archs over the columella.	Spore mother cells.
Order. Funariales			
Funaria	Outer layer of the endothecium	Barrel shaped and surrounds the columella.	Spore mother cells.
Order. Polytrichales			
Polytrichum	Outer layer of the endothecium	Surrounds the columella.	Spore mother cells.

• ECONOMIC IMPORTANCE OF BRYOPHYTES

The Bryophytes are not considered to be of much economical value because except a few Bryophytes none of these are of direct use to man. However, they play an important role in the economy of the nature. We can study their economic importance under the following heads :

1. Ecological importance. Bryophytes are of great ecological importance due to following reasons :

(a) Pioneer of the land plants. Bryophytes are pioneer of the land plants because they are the first plants to grow and colonize the barren rocks and lands.

(b) Soil erosion. Bryophytes prevent soil erosion. They usually grow densely and hence act as soil binders. Mosses grow in dense strands forming mat or carpet like structure. They prevent soil erosion by:

(i) bearing the impact of falling rain drops,

(ii) holding much of the falling water and reducing the amount of run off water.

(c) Formation of soil. Mosses and lichens are slow but efficient soil formers. The acid secreted by the lichens and progressive death and decay of mosses help in the formation of soil.

(d) Bog succession. Peat mosses change the banks of lakes or shallow bodies o water into soild soil which supports vegetation *e.g.*, *Sphagnum*.

(e) Rock builders. Some mosses in association with some green algae (*e.g.*, *Char* grow in water of streams and lakes which contain large amount of calcium bicarbonat These mosses bring about decomposition of bicarbonic ions by abstracting free carbo dioxide. The insoluble calcium carbonate precipitates and on exposure harden forming calcareous (lime) rock like deposits.

2. Formation of peat. Peat is a brown or dark colour substance formed by th gradual compression and carbonisation of the partially decomposed pieces of dea vegetative matter in the bogs. *Sphagnum* is an aquatic moss. While growing in water secretes certain acids in the water body. This acid makes conditions unfavourable fo the growth of decomposing organisms like bacteria and fungi. Absence of oxygen an decomposing microorganisms slows down the decaying process of dead material and large amount of dead material is added year by year. It is called **peat** (that is wh *Sphagnum* is called **peat moss**). Various uses of peat are :

(a) Used as fuel in Ireland, Scotland and Northern Europe.

(b) In production of various products like ethyl alcohol, ammonium sulphate, pea tar, ammonia, paraffin, dye, tannin materials etc.

(c) In horticulture to imporve the soil texture.

(d) In surgical dressings.

3. In medicines. Some Bryophytes are used medicinally in various diseases fo *e.g.*,

(a) Pulmonary tuberculosis and affliction of liver—*Marchantia* spp.

(b) Antitumour properties—Extracts of *Marchantia polymorpha*, *M. stellat* *Polytrichum commune* etc.

(c) Acute heamorrhage and diseases of eye—Decoction of *Sphagnum*.

(d) Stone of kidney and gall bladder—*Polytrichum commune*.

(e) Antiseptic properties and healing of wounds—*Sphagnum* leaves and extracts o some Bryophytes for *e.g.*, *Conocephalum conicum*, *Dumortiera*, *Sphagnum protoricens* *S. strictum* show antiseptic properties.

4. As packing material. Dried mosses and Bryophytes have great ability to hol water. Due to this ability the Bryophytes are used as packing material for shipment o cut flowers, vegetables, perishable fruits, bulbs, tubers etc.

5. As bedding stock. Because of great ability of holding and absorbing water, i nurseries beds are covered with thalli of Bryophytes.

6. As food. Some Bryophytes *e.g.*, mosses are used as food by chicks, birds an Alaskan reindeer etc.

7. In experimental botany. The liverworts and mosses play an important role a research tools in various fields of Botany such as genetics. For the first time in liverwort, *Sphaerocarpos*, the mechanism of sex determination in plants wa discovered.

• IMPORTANT QUESTIONS

Long Answer Type Questions :

1. What are Bryophytes ? Write their distinguishing features.
2. Mention the chief characteristics of Bryophytes. In what way do they resemble wit or differ from Pteridophytes ?
3. Discuss the origin and affinities of Bryophytes.
4. Define Alternation of Generation. Point out the difference between Alternation o Generation met within the algae and the Bryophytes.
5. Write an eassay on general characters of Bryophytes.

Short Answer Type Questions :

1. Why the Bryophytes are called amphibians of plant kingdom ?
2. Rhizoids in Bryophytes.
3. Scales in Bryophytes.
4. Apogamy.
5. Apospory.
6. Alternation of generation in Bryophytes.
7. Economic importance of Bryophytes.
8. Affinities of Bryophytes.
9. General characters of sporophyte of Bryophytes.
10. Distribution of Bryophytes.
11. Habitat of Bryophytes.
12. Reproduction in Bryophytes.
13. Archesporium.
14. Ecological significance of Bryophytes.

Objective Type Questions :

1. In which of the group you will place a plant which produces spores but lacks seeds and vascular tissues ?
2. Who is known as 'Father of Indian Bryology' in India ?
3. Which are the first land inhabiting plants ?
4. Name the process in which sporophyte is directly formed from gametophyte without fertilization.
5. Which generation is more dominant in the life cycle of Bryophytes.
6. Name any epiphyllous Bryophyte.
7. Name any xerophytic Bryophyte.
8. Name the largest Bryophyte.
9. Name the smallest Bryophyte.
10. Write the name of any free floating aquatic Bryophyte.

Multiple Choice Questions :

1. Which among the following is least likely to occur along the sea coasts :
   (a) Green algae (b) Red algae
   (c) Brown algae (d) Mosses
2. Development of diploid gametophyte directly from the sporophyte without the formation of spores is knows as
   (a) Apospory (b) Apogamy
   (c) Parthenogenesis (d) Amphimixis
3. Bryophytes differ from Pteridophytes in :
   (a) Swimming antherozoid (b) An independent gametophyte
   (c) Archegonia (d) Lack of vascular tissue,
4. Who is known as the 'Father of Indian Bryology' :
   (a) Ram udar (b) Parihar
   (c) Shiv Ram Kashyap (d) D.C. Bhardwaj
5. Bryophytes have important role in ecological succession in :
   (a) Hydrosere (b) Xerosere
   (c) Halosere (d) None of these.
6. Bryophytes usually grow densely over the soil surface and hence check the :
   (a) Soil conservation (b) Soil erosion
   (c) Both (a) and (b) (d) None of these,

7. Elaters exhibit :
   (a) Hydrochasy (b) Xerochasy
   (c) Chemotropism (d) Seismotropism.
8. The only positive evidence to aquatic ancestory of Bryophytes is :
   (a) Their green colour (b) Thread like protonema
   (c) Ciliated sperms (d) Some forms are still aquatic.

ANSWERS

Objective Type Questions :

1. *P. urceolata* and *P. fastigiata* **2.** *P. violacea* and *P. elongata*
3. Through pit connections **4.** Monopodial
5. As brominated phenols **6.** Only by fragmentation
7. Five **8.** One diploid nucleus
9. Because it exhibits 3 phases viz. gametophytic, carposporophytic and tetrasporophytic
10. Florideae and Ceramiales.

Multiple Choice Questions

1. (d) 2. (a) 3. (d) 4. (c) 5. (b) 6. (b) 7. (a) 8. (c)

11

CLASSIFICATION OF BRYOPHYTES

STRUCTURE

The term **Bryophyta** was first introduced by **Braun** (1864), however, he included algae, fungi, lichens and mosses in this group. Later, algae, fungi and lichens were placed in a separate division **Thallophyta** and liverworts, mosses in division **Bryophyta**. The rank of division Bryophyta to this well defined group of plants was first given by **Schimper** (1879). **Eichler** (1883) was the first to divide Bryophyta into two groups :

Group I. Hepaticae

Group II. Musci.

Engler (1892) recognised **Hepaticae** and **Musci** as two classes and divided each class into the following three orders :

• DIVISION. BRYOPHYTA

Class I. Hepaticae divided into three orders :

Order 1. Marchantiales

Order 2. Jungermanniales

Order 3. Anthocerotales

Class II. Musci divided into three orders :

Order 1. Sphagnales

Order 2. Andreaeales

Order 3. Bryales.

Due to isolated characters of *Anthoceros* and related genera, **Howe** (1899) raised the order **Anthocerotales** to the rank of a class and divided division Bryophyta into three classes :

Class I. Hepaticae

Class II. Anthocerotes

Class III. Musci.

This system of classification was followed by **Smith** (1938, 1955), **Takhtajan** (1953), **Wardlaw** (1955) and **Schutser** (1958) but preferred to call class **Anthocerotes** as **Anthocerotae**.

International code of Botanical Nomenclature (ICBN) suggested in 1956 tha suffix–**opsida** should be used for the classes and such usage had already been prop by **Rothmaler** (1951) for the classes of Bryophytes. He changed the class names

Class I. Hapaticae as Hepaticopsida.

Class II. Anthocerotae as Anthoceropsida

Class III. Musci as Bryopsida.

Proskauer (1957) suggested that the class name **Antheoceropsida** shoul changed to **Anthocerotopsida**. **Parihar** (1965) and **Holmes** (1986) foll **Proskauer's** system of classification and divided Bryophyta into three classes :

Clase I. Hepaticopsida

Class II. Anthocerotopsida

Class III. Bryopsida.

• CLASS I. HEPATICOPSIDA (LIVERWORTS)

General Characters

1. This class includes about 280 genera and 9500 species.
2. The name of this class is derived from a latin word **Hepatica** which means li Hence, the members of this class are commonly known as **liverworts.**
3. Plant body is gametophytic and the gametophyte is either thalloid or foliose
4. Thalloid forms are prostrate, lobed, dorsiventral and dichotomously branche
5. In foliose forms, 'leaves' are entire, lobed or divided and without 'midrib'. 'Lea are arranged in two to three rows on the axis.
6. Rhizoids are unicellular and branched.
7. Photosynthetic cells contain many **chloroplasts.**
8. **Pyrenoids** are absent.
9. Sex organs are borne dorsally or apically, superficial or embedded gametophytic tissues.
10. Members may be **monoecious** or **dioecious.**
11. Sporophyte is either simple and represented by **capsule** only (*e.g.*, *Riccia* may be differentiated into **foot, seta** and **capsule** (*e.g., Marchantia*).
12. **Archesporium** is endothecial in origin.
13. Sporogenous tissue either forms only spores (*e.g., Riccia*) or is differentiated sterile **elater mother cells** and fertile **spore mother cells.**
14. **Columella** is absent in the capsule.
15. Elaters are unicellular, hygroscopic with spiral thickenings.
16. Capsule wall is one to several layers thick and without stomata.
17. Dehiscence of the capsule is irregular or in definite number of valves.
18. Spores on germination form the gametophytic plant body.
19. Plants show **heteromorphic alternation of generation.**

Campbell (1936) divided the class **Hepaticopsida** into four orders :

Order 1. Marchantiales (*e.g., Riccia, Marchantia*).

Order 2. Sphaerocarpales (*e.g., Sphaerocarpos*).

Order 3. Jungermanniales (*e.g., Pellia*).

Order 4. Calobryales (*e.g., Calobryum*).

Schuster (1953, 1958) divided the class Hepaticae into two sub-classes :

Sub-class 1. Jungermanniae. It includes four orders :

Order 1. Calobryales (*e.g.*, *Calobryum*)

Order 2. Takakiales (*e.g.*, *Takakia*)

Order 3. Jungermanniales (*e.g.*, *Pellia*)

Order 4. Metzgeriales (*e.g.*, *Metzgeria*)

Sub-class 2. Marchantiae. It includes three orders :

Order 5. Sphaerocarpales (*e.g.*, *Sphaerocarpos*)

Order 6. Monocleales (*e.g.*, *Monoclea*)

Order 7. Marchantiales (*e.g.*, *Marchantia*).

• CLASS II. ANTHOCEROTOPSIDA (HORNWORTS)

General Characters

1. This class is represented by about 6 genera and 300 species.
2. Plant body is flat, dorsiventral, thalloid, gametophytic and variously lobed.
3. **Smooth walled** rhizoids are present.
4. **Tuberculated** rhizoids and **scales** are absent.
5. Internally the thallus is not differentiated into zones.
6. All cells are alike.
7. **Air chambers** or **air pores** are absent.
8. Each cell has a single **chloroplast** and each chloroplast contains a single **pyrenoid**.
9. Mucilage cavities open on the ventral surface by slime pores.
10. Sex organs are embedded in the thallus.
11. Antheridia develop either singly or in groups in closed cavities called **antheridial chambers**.
12. The sporophyte is differentiated into **foot,** an **intermediate zone** or **meristematic zone** and **capsule.**
13. Due to the presence of the meristematic zone, the sporophyte shows **indeterminate growth** *i.e.*, it continues to grow indefinitely.
14. Archesporium is **amphithecial** in origin.
15. Sporogenous tissue forms the fertile spores and sterile elaters. Elaters do not have spiral thickenings and are known as **pseudoelaters.**
16. Capsule wall is four to six layered thick and epidermis has the stomata.
17. Capsule matures from apex to base and usually dehisce by two valves.

The class Anthocerotopsida has only a single order **Anthocerotales. Muller** (1940), **Proskauer** and **Reimers** (1954) divided the order Anthocerotales in two families :

Family 1. Anthocerotaceae (*e.g.*, *Anthoceros*)

Family 2. Notothylaceae (*e.g.*, *Notothylas*).

• CLASS III. BRYOPSIDA (MOSSES)

General Characters

1. It is the largest class in Bryophyta and includes about 700 genera and 14,000 species.
2. The main plant body is gametophytic and can be differentiated into two stages–**juvenile stage** and **leafy stage** or **gametophore.**
3. Juvenile stage is represented by green, filamentous branched structures called **protonema**. It develops from the germination of the spore.

4. Gametophores are erect leafy branches which develop on the protonema.

5. Gametophores can be branched or unbranched and can be differentiated i three parts–rhizoids, 'stem' and 'leaves'.

6. Branches arise below the 'leaves'.

7. 'Leaves' are with midrib, unlobed and arranged spirally in three to eight rows the axis or 'stem'.

8. Rhizoids are multicellular, filamentous, branched with oblique septa.

9. The axis is differentiated into central conducting strand enclosed by cortex.

10. Sex organs borne apically in the groups on main 'stem' or a branch.

11. The sporophyte is green in early stages and can be differentiated into **foot, s** and **capsule.**

12. The seta is usually elongated and rigid.

13. Columella is usually present and endothecial in origin.

14. Archesporium (spore forming tissue) is dfferentiated only in spores.

15. Elaters are absent.

16. Dehiscence of capsule takes place by separation of **lid** or **operculum**.

17. Peristome helps in the dispersal of spores.

18. Spores on germination produce the **protonema**.

Bower (1935), **Wettstein** (1933–1935), **Campbell** (1940) divided the cl Bryopsida into three orders :

Order 1. Sphagnales

Order 2. Andreaeales

Order 3. Bryales.

Dixon (1932) gave the above orders the rank of sub-class and divided the Bryops into three sub-classes:

Class. Bryopsida (Musci)

Sub-class I. Sphagnales

Sub-class II. Andreaeales

Sub-class III. Bryales.

Smith (1938, 1955) divided the class Bryopsida into three sub-classes :

Sub-class 1. Sphagnobrya

Sub-class 2. Andreaeobrya

Sub-class 3. Eubrya.

Reimers (1954) divided the class Bryopsida into 5 sub-classes and he us suffix-**idea** for the sub-class :

Sub-class 1. Sphagnidae–1 order. Sphagnales–1 family.

Sub-class 2. Andreaeidae–1 order. Andreaeales–1 family.

Sub-class 3. Bryidae–12 orders

Sub-class 4. Buxbaumiidae–1 order. Buxbaumilaes–2 families.

Sub-class 5. Polytrichidae–2 orders. Polytrichales and Dawsoniales–2 families.

Parihar (1955) divided the class Bryopsida into 3 sub-classes :

Sub-class 1. Sphagnidae

Sub-class 2. Andreaeidae

Sub-class 3. Bryidae.

• CRITERIA USED FOR THE CLASSIFICATION OF BRYOPHYTES

Various characters are used for the classification of Bryophytes. Some important characters are:

(i) External and internal structure of the thallus.
(ii) Types of rhizoids.
(iii) Types of scales.
(iv) Position of sex organs.
(v) Structure and nature of sporophyte.
(vi) Degree of sterilisaion in the sporophyte.

• COMPARISON BETWEEN THE LIVERWORTS AND MOSSES

It may be studied under two heads resemblances and differences and as follows :

(a) Resemblance

1. Main plant body is gametophytic. It is long lived and independent as compared to sporophyte.
2. Early development of archegonium is similar.
3. In sporogonium, meristematic tissue is absent.
4. Antherozoids are biflagellate and flagella also of whiplash type.
5. Calyptra is present.
6. Both show heteromorphic type of alternation and generation.

(b) Difference

Liverworts	Mosses
1. Plant body is dorsiventral, thalloid or foliose.	1. Radial and always leafy.
2. Rhizoids are unicellular and unbranched.	2. Rhizoids are multicellular and branched.
3. 'Leaf' when present lacks midrib.	3. 'Leaf' has a midrib.
4. Central conducting strand is absent.	4. Central conducting strand is present.
5. Seta is soft and without internal differentiation.	5. Seta is long, tough with hypodermis and central strand.
6. Capsule is simple.	6. Capsule is highly organised.
7. There is no air space within capsule.	7. One or two air spaces are present in the capsule.
8. Annulus is absent.	8. Annulus is present.
9. Elaters are absent.	9. Elaters are present.
10. Columella is absent.	10. Columella is present.
11. Capsule lacks stomata on the capsule wall.	11. Capsule has stomata on the capsule wall.
12. Spores develop from entire endothecium.	12. Spores develop from outermost layer of the endothecium.
13. Spores on germination produce gametophytic plants.	13. Spores on germination produce protonema (juvenile stage).

• COMPARATIVE ACCOUNT OF THREE CLASSES (HEPATICOPSIDA, ANTHOCEROTOPSIDA AND BRYOPSIDA) OF BRYOPHYTES

Class. Hepaticopsida	Class. Anthocerotopdsida	Class. Bryopsida
1. Represented by about 280 genera and 9500 species.	1. Represented by 6 genera and 300 species.	1. Represented by about 700 genera and 14,000 species.
2. Plants are commonly called as **liverworts.**	2. Plants are commonly called as **hornworts.**	2. Plants are commonly called as **mosses.**

3. Gametophytic plant body is either thalloid or foliose forms.	3. Gametophytic plant body is thalloid.	3. Gametophytic plant bo is having two stag juvenile stage and lea gametophore.
4. Rhizoids are unicellular and unbranched.	4. Rhizoids are unicellular and unbranched.	4. Rhizoids are multicellu and branched.
5. Scales are present.	5. Scales are absent..	5. Scales are absent.
6. Internally tissue is homogenous.	6. Internally tissue is homogenous.	6. Internally differentiat into epidermis, cortex a conducting strand.
7. Sex organs or either stalked or embedded in the thallus.	7. Sex organs are embedded in the thallus.	7. Sex organs borne apica in the groups on ma stem or branches.
8. Sporophyte is represented either by capsule or foot, seta and capsule.	8. Sporophyte is represented by foot, meristematic zone and capsule.	8. Sporophyte represented by foot, se and capsule.
9. Growth of sporophyte is limited.	9. Growth is unlimited.	9. Growth is limited.
10. Columella is absent.	10. Columella is present.	10. Columella is present.
11. Sporogenous tissue is endothecial in origin.	11. Sporogenous tissue is amphithecial in origin.	11. Sporogenous tissue endothecial in origin a surrounds the columell
12. Elaters present and have spiral thickenings.	12. Elaters are without spiral thickenings and are called pseudoelaters.	12. Elaters are absent.
13. Capsule wall one to several layered thick.	13. Capsule wall 4–6 layered thick.	13. Capsule wall multilayered.
14. Stomata absent on capsule wall.	14. Stomata present.	14. Stomata present.
15. Dehiscence of capsule is irregular or in definite valves.	15. Capsule usually dehisce in two valves.	15. Dehiscence of capsu takes place by separati of lid or operculum.

• DIFFERENCES IN BETWEEN FAMILY RICCIACEAE AND MARCHANTIACEAE

Ricciaceae	Marchantiaceae
1. This family includes about 3 genera and 140 species.	1. Includes about 23 genera and 250 specie
2. Rhomboidal areas (areolae) are absent.	2. Dorsal surface is marked by rhomboi areas (areolae).
3. Upper epidermis is discontinuous and consists pear shaped hyaline cells.	3. Upper epidermis is continuous and ce contain few chloroplasts.
4. Air pores are simple.	4. Air pores are barrel shaped.
5. Thallus lack photosynthetic chambers. Air canals are present.	5. Thallus is chambered. Air canals a absent.
6. Photosynthetic filaments are unbranched.	6. Photosynthetic filaments are branched.
7. Sex organs embedded in the thallus.	7. Sex organs are raised on gametophores
8. Sporophyte with capsule only.	8. Sporophyte with foot, seta and capsule.
9. Elaters are absent.	9. Elaters are present.
10. Spores are dispersed by the decay of the capsule wall and surrounding sterile tissues.	10. Capsule dehisces either by separation o lid or by valves. It results in the dispersal sproes.
11. *e.g.*, *Riccia*, *Oxymitra* etc.	11. *e.g.*, *Marchantia*, *Plagiochasma* etc.

Prof. Shiv Ram Kashyap

Prof. Shiv Ram Kashyap, the founder of the school of Bryology in India, published monograph **Liverworts of the Western Himalayas and the Punjab Plains** in two volumes in 1929 and 1932. For his work on Bryophytes, he is called as **father of Indian Bryology**.

IMPORTANT QUESTIONS

Long Answer Type Questions :

1. Give briefly the classification of Bryophytes.
2. List the salient features of different classes of Bryophytes.
3. Give an account of the various systems of classification of Bryophytes.

Short Answer Type Questions :

1. General characters of class Hepaticopsida.
2. Comparison between the characters of liverworts and mosses.
3. Comparison between the characters of class Hepaticopsida, Anthocerotopsida and Bryopsida.
4. Various criteria used for the classification of Bryophytes.
5. General characters of class Anthocerotopsida.

Objective Type Questions :

1. Who was the first to introduce the term Bryophyta ?
2. Who first of all gave the rank of a division to Bryophytes ?
3. According to **Proskauer's** system of classification Bryophyta was divided into how many classes ?
4. Who raised the order Anthocerotales to the rank of a class ?
5 Who suggested that the class name Anthoceropsida should be changed to Anthocerotopsida ?
6. Name the largest class in Bryophytes.
7. How many orders included in class Hepaticae by **Engler** in 1892 ?

Multiple Choice Questions :

1. Some Bryophytes like Riccia, Marchantia are commonly called liverworts because they
   (a) Cause diease of liver (b) Multiply in liver
   (c) Have flat lobed or forked thalli (d) All of the above
2. The term Bryophyta was introduced by :
   (a) Fritisch (b) Braun
   (c) Linnaeous (d) Bower.
3. The thallus of liverworts is :
   (a) Dichotomously branched (b) Branched
   (c) Foliose (d) Leafy.
4. Liverworts differ from mosses in having :
   (a) Scales (b) Multicellular rhizoids
   (c) Peristomial teeth (d) None of these
5. Scales are violet coloured multicellular structures to conserve water and protect growing apices. These characteristics of:
   (a) All Bryophytes (b) Mosses only
   (c) Liverworts only (d) Hornworts only.

ANSWERS

Objective Type Questions :

1. **Braun** (1864) 2. **Schimper** (1879)
3. Three class-Hepaticopsida, Anthocerotopsida and Bryopsida
4. **Howe** (1899) 5. **Proskauer** (1957) 6. Bryopsida
7. Three orders-Marchantiales, Jungermanniales and Anthocerotales.

Multiple Choice Questions :

1. (c) 2. (b) 3. (a) 4. (a) 5. (c)

12

REPRODUCTION AND AFFINITIES OF BRYOPHYTES

STRUCTURE

• REPRODUCTION

Bryophytes reproduce by **vegetative** and **sexual** methods.

• VEGETATIVE REPRODUCTION

Bryophytes posses a characteristic feature and that is their tendency towards extensive vegetative reproduction. The vegetative reproduction takes place in favourable season for vegetative growth. Majority of the Bryophytes propagate vegetatively and it is brought about in many ways. Some important methods of vegetative reproduction are as follows :

1. By death and decay of the older portion of the thallus or fragmentation.
2. By gemmae (fig. 1B).
3. By adventitious branches (fig. 1O).
4. By tubers (fig. 1D).
5. By persistent apices.
6. By innovation.
7. By bulbils (fig. 1 P).
8. By secondary protonema.
9. By primary protonema.
10. By Regeneration.
11. By apospory.
12. By separation of shoot tips.
13. By rhizoidal tips.
14. By separation of whole shoots.
15. By cladia.

1. By death and decay of the older portion of thallus or by fragmentation. In Bryophytes the growing point is situated at the tip of the thallus. The basal, posterior or older portion of the thallus starts rotting or disintegrating due to ageing or drought. When this process of disintegration or decay reaches upto the place of dichotomy, the lobes of the thallus get separated. These detached lobes or fragments develop into independent plants by apical growth. This is the most common method of vegetative reproduction in *Riccia*, *Marchantia*, *Anthoceros* and some mosses like *Sphagnum* (Fig. 1 A-C).

2. By Gemmae. Gemmae are green, multicellular reproductive bodies of various shapes. These are produced in gemma cups, on the surface of the leaves, on stem apex or even inside the cells. They get detached from the parent plant and after falling on a

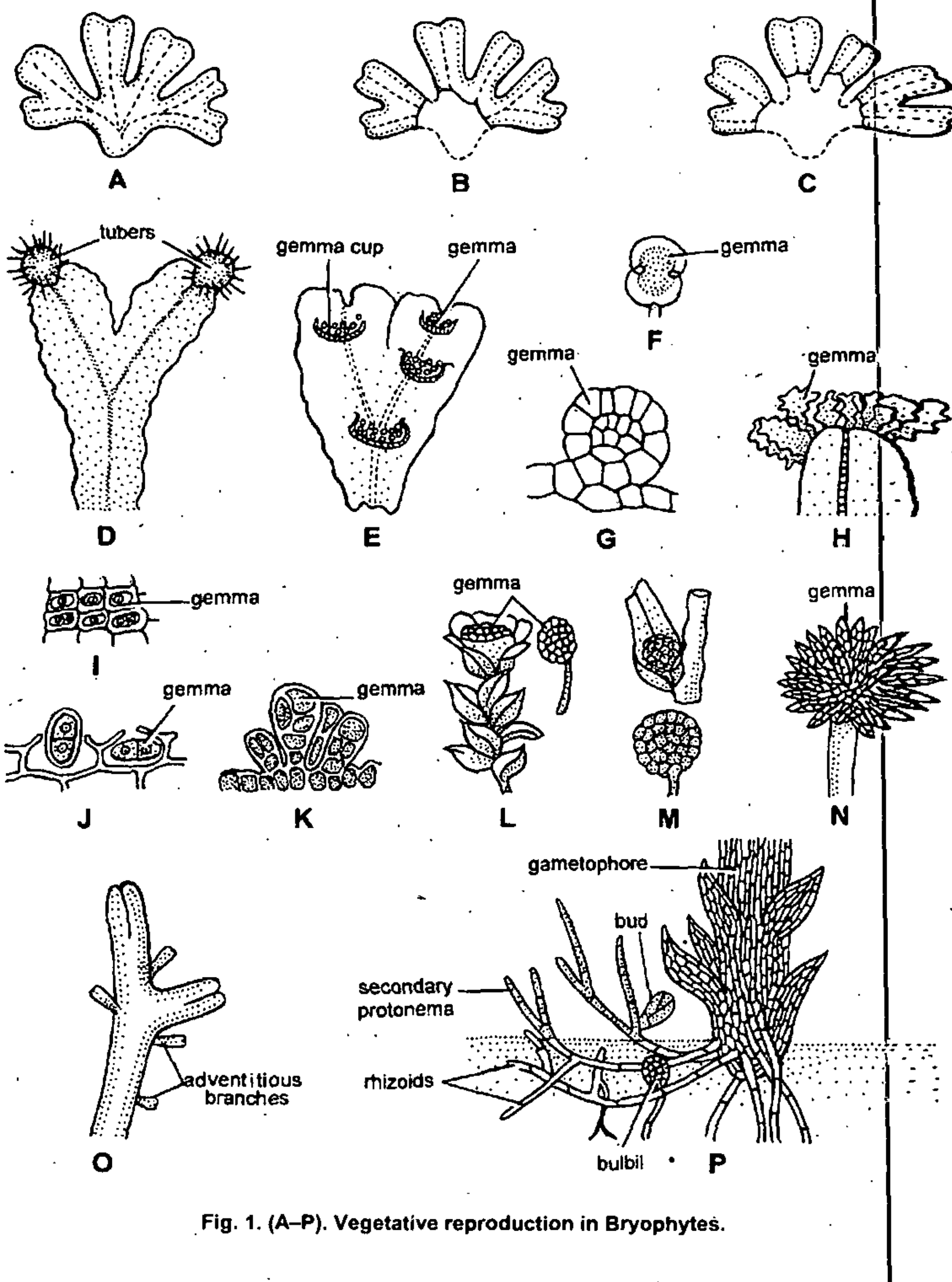


Fig. 1. (A–P). Vegetative reproduction in Bryophytes.

suitable substratum gemmae give rise to a new individual directly (*e.g., Marchantia*) or indirectly (*e.g., Mosses*). Some common forms of gemmae produced in different Bryophytes are :

Class I. Hepaticopsida

(A) Multicellular, discoid, gemmae :

(i) Produced in gemma cup on dorsal surface *e.g., Marchantia, Lunularia* (Fig. 1 E, F).

(ii) Produced on leaves *e.g., Radula* (Fig. 1 G).

(iii) Produced on erect gemmiferous branches *e.g., Metzgeria uncigera* (Fig. 1 H).

(B) One to four celled gemmae :

(i) One to three celled gemmae on stem apex *e.g., Lophozia heterocolpa.*

(ii) One to three celled gemmae on leaves *e.g.,*: *Marsupella emarginata, Lophozia barbata.*

(iii) Two celled gemmae produced within any external cell of the thallus *e.g., Riccardia multifida* (Fig. 1 I, J).

(iv) Three to four celled gemmae produced in the axils of the leaves *e.g., Treubia.*

(C) Subspherical gemmae. Produced in abundance in flask shaped gemma receptacle *e.g., Blasia.*

(D) Star shaped gemmae. Produced on the dorsal surface of the thallus *e.g., Blasia.*

Class II. Anthocerotopsida

Multicellular gemmae produced along the margins of the dorsal surface of the thallus *e.g., Anthoceros.*

Class III. Bryopsida

(A) Articulated gemmae. Produced on the leaves *e.g., Ulota phyllantha, Orthotrichum lyelli* etc. (Fig. 1 K).

(B) Multicellular gemmae :

(i) Stalked, green, lenticular gemmae produced at the tip of shoot *e.g., Tetraphis pellucida* (Fig. 1 L).

(ii) Globular, produced at the base of the stem *e.g., Bryum rubens, B. erythrocarpum* (Fig. 1M).

(iii) Fusiform, produced at the ends of distinct leafless terminal stalk *e.g., Aulacomnium androgynum* (Fig. 1 N).

(iv) Produced on the rhizoids of leafy shoots *e.g., Tortula stanfordensis, Ditrichum cylindricum, Bryum erythrocarpum* etc.

3. By adventitious branches. The adventitious branches develop from the ventral surface of the thallus *e.g., Riccia fluitans, Anthoceros*. On being detached from the parent plant these branches develop into new thalli. In *Marchantia, Dumortiera* these branches develop from archegoniophore while in *Pellia* these branches arise from the dorsal surface or margins of the thallus (Fig. 1 O).

4. By tubers. Tubers are formed in those species which are exposed to dessication (drying effect of the air). Towards the end of the growing season, the subterranean branches get swollen at their tips to from the underground tubers. On the periphery of a tuber are two to three layers of water proof corky, hyaline cells develop. These layers surrounds the inner cells which contain starch, oil globules and albuminous layers. During the unfavourable conditions the thallus dies out but the dormant tubers remain unaffected. On the return of the favourable conditions each tuber germinates to from a new plant *e.g.*, *Riccia, Anthoceros, Conocephalum, Conicum, Fossombronia* etc. Thus tubers also serves as organ of perennation (Fig. 1 D).

5. By persistent apices. Due to prolonged dry or summer or towards the end of growing season the whole thallus in some Bryophytes (*e.g.*, *Riccia, Anthoceros, Cyathodium*) dries and get destroyed except the growing point. Later, it grows deep into the soil and becomes thick. Under favourable conditions it develops into a new thallus.

6. By innovation. In *Sphagnum* one of the branches in the apical cluster instead of forming drooping branches or divergent branches, develop more vigourously than the others and continues the growth upwards. This long upright branch has all the characteristics of main axis. It is called **innovation**. Due to progressive death and decay of the parent plant these innovation become separated from the parent plant and establish themselves as parent plants.

7. By bulbils. These are small resting buds develop on rhizoids. Bulbils are devoid of chlorophyll but full of starch. On germination bulbils produce a protonema which bears leafy gametophores (Fig. 1 P).

8. By secondary protonema. The protonema formed by other methods than from the germination of spores is called **secondary protonema.** It may develop from any living cells of the leafy gametophore *i.e.*, from leaf, stem, rhizome, injured portion of the leafy gametophore, antheridium, paraphysis or archegonium. From this arise the leafy gametophores or lateral buds in the same manner as in primary protonema *e.g.*, *Funaria, Sphagnum* (Fig. 1 P).

9. By primary protonema. Primary protonema is the filament like stage produced by the developing spores of the mosses. It produces the leafy gametophores. It breaks into short filament of cells by the death of cells at intervals. Each detached fragment grows into a new protonema which bears a crown of leafy gametophores *e.g.*, *Funaria*.

10. By regeneration. The liverworts possess an amazing power of regeneration. Part of the plant or any living cell of the thallus (*e.g.*, rhizoid, scales) are capable of regenerating the entire plant for *e.g.*, *Riccia, Marchantia* etc.

11. By apospory. The production of diploid gametophyte from the unspecialized sporophyte without meiosis is known as apospory *e.g.*, *Anthoceros*. In *Funaria* green protonemal filaments may arise from the unspecialised cells of the various parts of sporogonium. These protonemal filaments bear lateral buds which develop into leafy gametophores.

12. By separation of shoot tips. It occurs in *Campylopus piriformis*. The separated shoot tips develop into new plant.

13. By rhizoidal tips. The apical part of the young rhizoids divide and redivide to form a gemma like mass of cells *e.g.*, *Riccia glauca*. These cells contain chloroplast and are capable to develop into new thallus. (**Fellner**, 1975; **Campbell**, 1915).

14. By Separation of whole shoots. A number of catkin like deciduous branches develop over the entire surface of the gametophytic plant. On separation these branches develop into new plant *e.g.*, *Pohlia nutans*.

15. By Cladia. These are the small or broad detachable branches which help in vegetative reproduction. These are of two types :

(i) Leaf cladia. Arising from the individual cell of the leaf *e.g.*, *Plagiochila, Bazzania, Frullania fragilifolia* etc.

(ii) Stem cladia. These cladia arise from the stem and occupy the same position as sexual branches *e.g.*, *Bryopteris*.

• METHODS OF PERENNATION

Perennation is the survival from season to season, generally with a period of reduced activity between each season. The chief methods of perennation are :

1. By persistant apices.

2. By tubers.

3. By bulbils.

The spore and gemmae can also perennate and in some instances even the protonema does. The perennial mosses perennate as gametophytes.

• SEXUAL REPRODUCTION

1. Sexual reproduction is highly **oogamous**.

2. Male and female sex organs are known as **antheridia** (Sing. antheridium) and **archegonia** (Sing. archegonium), respectively.

3. Sex organs are **jacketed** and multilayered.

4. Antheridium is stalked, pear shaped or oblong and has an outer one cell thick jacket which encloses a mass of fertile cells called **androcytes**. Each androcyte metamorphoses into biflagellate antherozoid.

5. Archegonium is stalked, flask shaped structure. It has a basal swollen portion called **venter** and an elongated **neck**. The neck is filled with many **neck canal cells** whereas venter has a large egg cell and a small venter canal cell.

6. Antherozoids are attracted towards the neck of the archegonium chemotactically by certain substances (like sugars, malic acid, proteins, inorganic salts of potassium etc.) present in the mucilaginous substance formed by the degeneration of neck canal cells and venter canal cell.

7. Water is essential for fertilization.

8. The fertilized egg or **zygote** is the beginning of the sporophytic phase. It is retained within the venter of the archegonium.

• SPOROPHYTE

1. Without resting period, the zygote undergoes repeated divisions to form a multicellular structure called the **embryo.**

2. The first division of the zygote is always transverse and the outer cell develops into embryo. Such an embryogeny is called **exoscopic.**

3. Embryo develops into a **sporophyte** or **sporogonium**.

4. The sporophyte is usually differentiated into **foot, seta** and **capsule.** In certain cases it is represented only by capsule (*e.g.*, *Riccia*) or by foot and capsule (*e.g.*, *Corsinia*).

5. Sporophyte is attached to parent gametophytic plant body throughout its life. It partially or completely depends on it for nutrition.

6. Foot is basal, bulbous structure. It is embedded in the tissue of parent gametophyte. Its main function is to absorb the food material from the parent gametophyte.

7. Seta is present between the foot and capsule. It elongates and pushes the capsule through protective layers. It also conducts the food to the capsule absorbed by foot.

8. Capsule is the terminal part of the sporogonium and its function is to produce spores.

9. All Bryophytes are **homosporous** *i.e.*, all spores are similar in shape, size and structure.

10. Capsule produces sporogenous tissue which develops entirely into spore moher cells (*e.g.*, *Riccia*) or differentiated into **spore mother cells** and **elater mother cells** (*e.g.*, *Marchantia, Anthoceros*).

11. Spore mother cells divide diagonally to produce asexually four haploid spores which are arranged in **tetrahedral tetrads.**

12. Elater mother cells develop into elaters (*e.g., Marchantia*) or pseudoelaters (*e.g., Anthoceros*) which are hygroscopic in nature. Elaters are present in liverworts and absent in mosses.

13. Venter wall enlarges with the developing sporogonium and forms a protective multicellular layer called **calyptra** (gametophytic tissue enclosing the sporophyte).

• YOUNG GAMETOPHYTE

1. The **meiospore** (spore formed after meiosis) is the first cell of the gametophytic phase.

2. Each spore is unicellular, haploid and germinates into young gametophytic plant (*e.g., Riccia* or *Marchantia*) or first germinates into a filamentous protonema on which buds are produced to give rise to a young gametophytic plant. (*e.g., Funaria*).

• AFFINITIES OF BRYOPHYTES

From evolutionary point of view Bryophytes occupy an intermediate position between the **Algae** and the **Pteridophytes**. They show affinities with both Algae and Pteridophytes.

Resemblance of Bryophytes with Algae

1. Plant body simple, thalloid and gametophytic.

2. Autotrophic.

3. Gametophytic phase is dominant.

4. Roots are absent.

5. Cell wall is made up of cellulose.

6. Pigments (chlorophyll a, chlorophyll b, α and β carotene, Lutin, Violaxanthes and Xeoxanthin) are similar in chloroplast.

7. Vascular tissue is absent.

8. Antherozoids are motile (biflagellated).

9. Flagella are whiplash type.

10. Water is essential for fertilization.

11. A filamentous protonema is produced by Bryophytes (juvenile stage in mosses) which resembles with the filamentous green algae.

12. In order Anthocerotales of Bryophytes, plastids are with pyrenoids which is characteristic of Chlorophyceae (Green algae).

Difference of Bryophytes with Algae

S. No.	Algae	Bryophytes
1.	Mostly aquatic.	Mostly aquatic and prefer to grow on moist and shady places.
2.	Thallus may be unicellular, multicellular or pseudo-parenchymatous.	Thallus is made up of parenchymatous cells except protonema which is filamentous.
3.	No tissue differentiation in the plant body.	Cells in the different parts have specific functions.
4.	Stomata or pores are absent.	Present.
5.	Rhizoids are absent (except in some heterotrichous forms).	Present.

6.	All the cells of the plant body are capable of division.	Divisions are restricted at certain places only.
7.	Asexual reproduction (zoospores, aplanospores, akinetes) are present.	Absent.
8.	Sex organs are unicellular (some times a group of cells) and without jacket of vegetative sterile cells.	Sex organs are multicellular and enclosed by a jacket of vegetative sterile cells.
9.	Sexual reproduction may be isogamous, anisogamous or oogamous.	Sexual repoduction is oogamous.
10.	Zygote is liberated from the parent plant	Zygote is retained by the parent plant.
11.	After liberation zygote passes into the resting period.	Zygote does not go into any resting period.
12.	Zygote does not form embryo but produces haploid spores.	Zygote forms embryo.
13.	Sporophytic phase is represented by zygote and it is independent.	Sporophytic phase is well developed and dependent upon the gametophyte..
14.	Algae show homologous or isomorphic type of alternation of generation.	Bryophytes show heterologous or heteromorphic type of alternation of generation.

Resemblance of Bryophytes with Pteridophytes

1. Plants are terrestrial.

2. Primitive simple leafless and rootless sporophytes of Pteridophytes (members of order Psilophytales) can be compared with the sporophytes of Bryophytes.

3. Sexual reproduction is oogamous.

4. Androcytes are enclosed by sterile jacket layer.

5. Antherozoids are flagellated.

6. Water is essential for fertilization.

7. Permanent retention of zygote within the archegonium.

8. Zygote forms the embryo.

9. Moss capsule is similar to terminal sporangium and columella of Psilophytales.

10. Both Bryophytes and Pteridophytes are characterised by heteromorphic alternation of generation.

Difference between Bryophytes and Pteridophytes

S. No.	Bryophytes	Pteridophytes
1.	Plant body is gametophytic, thalloid or foliose.	Plant body is sporophytic and can be differentiated into root, stem and leaves.
2.	Gametophytic phase is dominant phase of life cycle.	Sporophytic phase is the dominant phase of life cycle.
3.	Vascular tissue is absent.	Vascular tissue is well developed.
4.	Sporophyte is completely dependent on gametophyte.	Sporophyte is independent.
5.	Sporophyte is not capable of independent growth.	Sporophyte is capable of independent growth.

• ORIGIN OF BRYOPHYTES

Nothing definite is known about the origin of Bryophytes because of the very little fossil record. There are two views regarding the origin of Bryophytes. These are :

(1) Algal hypothesis of the origin of Bryophytes.

(2) Pteridophytean hypothesis of the origin of Bryophytes.

Algal Hypothesis of Origin

There is no fossil evidence of origin of Bryophytes from algae but Bryophytes resemble with algae in characters like–amphibious nature, presence of flagellated antherozoids and necessity of water for fertilization. This hypothesis was supported by **Lignier** (1903), **Bower** (1908), **Fritsch** (1945) and **Smith** (1955) etc.

According to **Fritsch** (1945) and **Smith** (1955) Bryophytes have been originated from the heterotrichous green algae belonging to the order Chaetophorales for *e.g.*, *Fritschiella*, *Coleochaete* and *Draparnaldiopsis*.

Pteridophytean Hypothesis of Origin

According to this hypothesis Bryophytes are **descendent of Pteridophytes.** They are evolved from Pteridophytes by **progressive simplification** or **reduction.** This hypothesis is based on certain characters like–presence of type of stomata on the sporogonium of *Anthoceros* and apophysis of mosses similar to the vascular land plants, similarly in the sporophytes of some Bryophytes (*e.g.*, *Anthoceros*, *Sphagnum*, *Andreaea*) with some members of Psilophytales of Pteridophytes (*e.g.*, *Rhynia*, *Hormophyton* etc.)

This hypothesis was supported by **Scot** (1911), **Kashyap** (1919), **Kidston** and **Lang** (1917-21), **Haskell** (1914) **Christensen** (1954), **Proskaner** (1961), **Mehra** (1968) etc.

• IMPORTANT QUESTIONS

Long Answer Type Questions :

1. Write an essay on methods of vegetative reproduction in Bryophytes.
2. Describe the sexual reproduction in Bryophytes.
3. What do you understand by regeneration in Bryophytes? Explain its various methods with examples.
4. Discuss the origin and affinities of Byrophytes.

Short Answer Type Questions :

1. Gemmae, tubers and cladia.
2. Vegetative reproduction in Bryophytes.
3. Sexual reproduction in Byrophytes
4. Affinites of Bryophytes.

Objective Type Questions :

1. Name the structure which is a cell, or group of cells and it serves for vegetative reproduction.
2. Name the gemmae like structures which develop on rhizoids inside the substratum and serve for vegetative reproduction.
3. Name that method of vegetative reproduction in which one of the branch grows more vigourously and when detached from the parent plant establish itself as an independent individual.

4. What that method of vegetative reproduction is called in which diploid gametophyte is formed from the unspecialised sporophyte without meiosis.
5. In the Bryophytes, there is a regeneration of diploid gametophyte from a sporophyte, without he formation of spores. What it is called ?

Multiple Choice Questions :

1. Development of diploid gametophyte directly from the sporophyte without the formation of spores is known as
   (a) Apospory (b) Apogamy
   (c) Parthenogeriesis (d) Amphimixis.
2. Gemmae are the vegetative reproductive bodies in :
   (a) Algae (b) Liverworts
   (b) Mosses (d) Gymnosperms.
3. Bryophytes reproduce by :
   (a) Vegeative, asexual and sexual methods
   (b) Sexual and asexual methods
   (c) Vegetative and asexual methods
   (d) Vegetative and sexual methods.
4. The number of thalli formed by a gemma of Marchantia upon successful germination:
   (a) One (b) Two
   (c) Three (d) Four
5. The chemotactic substances excreted from the archegonium of Bryophytes at the time of fertilization is possibly some :
   (a) Fats (b) Sugars
   (c) Acids (d) Esters.
6. The Venter wall enlarge with the developing embryo to form the protective envelope, called as :
   (a) Perigynium (b) Perichaetium
   (c) Involucre (d) Calyptra.
7. Inside jacket of antheridium biflagellated antherozoids develop from a mass of ;
   (a) Androgonial cells (b) Venter cells
   (c) Venter canal cell (d) Neck canal cell.
8. Venter is a part of :
   (a) Antheridium (b) Archegonium
   (c) Sporangium (d) Sporogonium.
9. Bryophytes differ from Pteridophytes in :
   (a) Swimming antherozoid (b) An independent gametophyte
   (c) Archegonia (d) Lack of vascular tissue.
10. Elaters exhibit :
    (a) Hydrochasy (b) Xerochasy
    (c) Chemotropism (d) Seismotropism.
11. Movement of antherozoids towards archegonial neck is :
    (a) Chemotropism (b) Hydrotropism
    (c) Chemotactic (d) Phototaxis.

12. Bryophytes depend on water because :
    (a) Archegonium has to remain filled with water for fertilization
    (b) Water is essential for fertilization
    (c) Water is essential for their vegetative reproduction
    (d) The sperm can easily reach upto egg in the antheridium.

ANSWERS

Objective Type Questions :

1. Gemmae 2. Bulbils 3. Innovation 4. Apospor
5. Apospory

Multiple Choice Questions :

1. (a) 2. (b) 3. (d) 4. (b) 5. (b) 6. (d) 7. (a) 8. (b) 9. (d)
10. (a) 11. (c) 12. (b)

UNIT–IV

BRYOPHYTES

13

GAMETOPHYTIC AND SPOROPHYTIC ORGANISATION OF HEPATICOPSIDA (*Riccia, Marchantia*)

STRUCTURE

• INTRODUCTION

Class Hepaticopsida or Hepaticeae

The class hepaticopsida or hepaticeae includes about 280 genera and 9500 species. Hepaticeae is the latin word meaning liver and the members of hepaticopsida therefore propularly called as **Liverworts.**

The salient features of the class hepatiopsida are as follows :

1. The vegetative plant body or gametophyte is usually dorsiventral and is either a thallus (thallose) or a leafy axis (foliose).

2. The gametophyte is internally either simple or made up of many tissues, but the photosynthetic cells always contains numerous chloroplasts without pyrenoids.

3. The sex organs are usually formed directly from the dorsal superficial cells of the thallus, except when terminal in position.

4. The sporogonium has little or no chlorophyllous tissue and lacks stoma.

5. The sporogonium may be simple (as in *Riccia*) or may be differentiated into foot, seta and capsule (as in *Marchantia*).

6. The capsule lacks a sterile region, the columella.

7. There is a distinct alternation of generation.

8. The class hepathicae consists of four order *viz*—Spherocarpales, Marchantiales, Jungermanniales and Calobryales according to the latest classification.

• ORDER : MARCHANTIALES

(i) This order is represented by approximately 35 genera and 420 species.

(ii) Thallus is branched, dorsiventral and dichotomously branched.

(iii) Rhizoids are smooth-walled and tuberculated. Scales are present.

(iv) Internally the thallus is differentiated into **upper photosynthetic zone** and **lower storage zone**.

(v) Sex organs are embedded in the thallus or develop in chamber gametophores.

(vi) Archegonial neck is of six vertical rows of cells.

(vii) Capsule wall is single layered (unistratose).

• FAMILY : RICCIACEAE

(i) The family includes 3 genera and about 140 species.

(ii) The members are the simplest members of order Marchantiales.

(iii) Plant body is a gametophytic thallus, small, green, flat, fleshy, rosette and dichotomously branched.

(v) Photosynthetic regions consist of photosyntheic cells arranged in vertical rc

(vi) Air canals are present in two vertical rows of chlorophyllous cells.

(vii) Sex organs occur singly in open cavities embedded on the dorsal surfac thallus.

(viii) The sporophyte is represented only by capsule. Foot and seta is absent.

(ix) Archesporium produces only spores. Elaters are absent.

(xi) Spores are liberated by death and decay of the vegetative tissue of the thallu

Riccia

• SYSTEMATIC POSITION :

Division	:	**Bryophyta**
Class	:	**Hepaticopsida**
Order	:	**Marchantiales**
Family	:	**Ricciaceae**
Genus	:	***Riccia***

• DISTRIBUTION AND HABITAT

Riccia, the most widely distributed genus of family Ricciaceae, is represente about 200 species (**Reimer**, 1954). The name *Riccia* was given in honour of **P. F. R** a Florentine politician. Widely distributed in both tropical and temperate regions o world, this genus is represented in India by about 33 species (**Puri**, 1973). Howe **Srivastava** (1964) recorded 29 species from different parts of India.

All species are terrestrial and prefer to grow on moist and shady places except *Ri fluitans*, which is an aquatic species. Some of the common terrestrial Indian species

R. gangetica, *R. discolor*, (*R. himalayensis*), *R. glauca*, *R. crystalline*, *R. frosti hirsuta and R. melanospora*. *Riccia gangetica*, *R. kashyapii* and *R. pandei* are endc species *i.e.*, confined to Indian territory only.

• GAMETOPHYTIC PHASE

The plant body of *Riccia* is gametophytic and gametophytes are fleshy, prostrate dichotomously branched. Repeated dichotomy results into a typically rosette appearance (Figs. 1, 3). In *Riccia cruciata* only two dichotomy result in a cruciate f (Fig. 4). Each branch of the thallus is linear, wedge-shaped or obcordate. Thallus is mm long and 1.2 mm broad in all the terrestrial species. However, in *R. fluitans* 30-50 mm long and 1-2 mm broad.

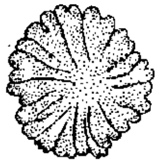


Fig. 1 *Riccia*. Rosette habit

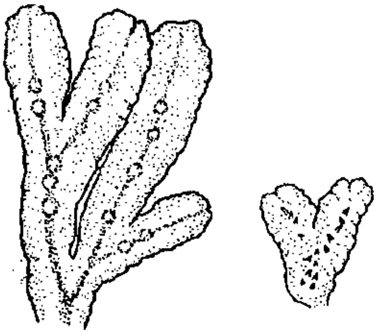


Fig. 2, 3. *Riccia*. Robust

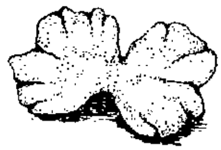


Fig. 4. *Riccia*. Cruciate thallus

Dorsal surface

The dorsal surface is light green or dark green body, each branch having a thick midrib with a conspicuous median longitudinal groove forming an apical notch. Growing point is situated in the apical notch. The main function of the mid-dorsal groove is to retain water required for fertilization. Some hairy epidermal outgrowths are also seen in *Riccia melanospora*, though rarely (Fig. 5).

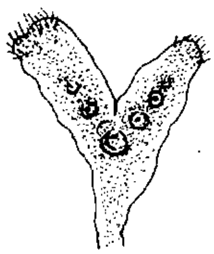


Fig. 5. *Riccia* Thallus of *R.*

Ventral surface

The ventral surface of thallus bears many scales and rhizoids. **Scales** are violet coloured, multicellular and one celled thick structures (Fig. 6). The colour of the scale is due to dissolution of the pigment in the cell sap. In the apical region they project forward and overlap the growing point to provide it protection and moist environment by capillary conduction of water.

Fig. 6. *Riccia*. Scale

In hygrophilous species (species which need a large supply of moisture for their growth) the scales are ephemeral (*i.e.*, short lived) but in xerophilous species the scales are leafy and persistent. In *Riccia crystallina* the scales are inconspicuous and absent.

Rhizoids are unicellular and unbranched. They develop as prolongations of the lower epidermal cells. They are of two types (i) smooth-walled rhizoids and (ii) tuberculate rhizoids (Fig. 7). The main function of rhizoids is to anchor the thallus on the substratum and to absorb water and mineral nutrients from the soil.

In *Riccia fluitans*, the only aquatic species, thallus is long, narrow, ribbon-like and dichotomously branched. Rhizoids and scales are absent (Fig. 8). This species can also grow on soil. In terrestrial species thallus bears many rhizoids and small, colourless or violet scales near the apex (Fig. 9).

Fig. 7. *Riccia*. Smooth walled and tuberculated rhizoids

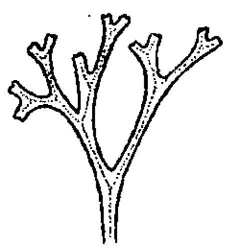


Fig. 8.

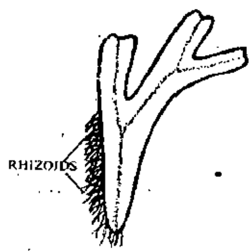


Fig. 9.

• ANATOMY OF THE GAMETOPHYTE

A vertical cross section of the thallus shows two distinct zones, *viz*., upp photosynthetic zone and lower storage zone (Fig. 10A, B).

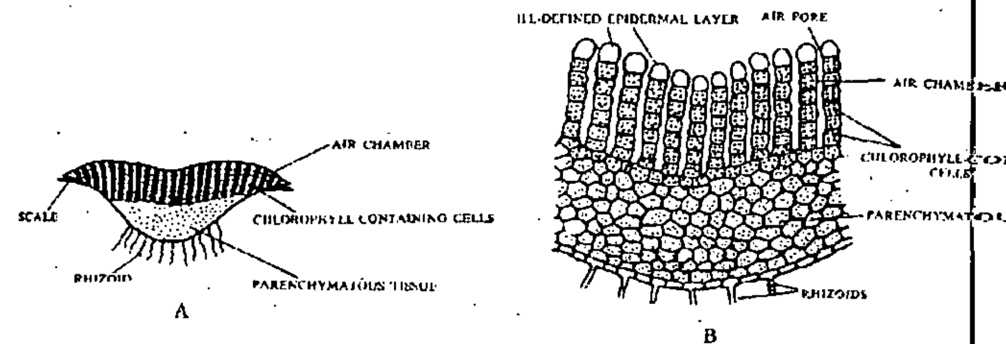


Fig. 10. (A, B) *Riccia*. (A) Tranverse section of thallus (diagrammatic); (B) A part cellular

Upper photosynthetic zone

It is green, dorsal on upper region of the thallus. It is made of somewhat verti rows of unbranched photosynthetic filaments. All the cells of the photosynthe filament except the thick **epidermis.**

Photosynthetic filaments are separated from each other by narrow longitudi vertical canals called **air chambers**. Each air chamber is bounded by four epiderm cells (*e.g., Riccia glauca,* or eight epidermal cells (*e.g., R. vesiculosa*). Air chambers h in the gaseous exchange.

In aquatic form of *Riccia fluitans* epidermis is continuous and air chambers almost completely closed. However, in the terrestrial form of this species each chamber opens on the upper surface by a small opening.

Lower Storage Zone

This zone represents the ventral tissue of the thallus and lies below t photosynthetic zone. It consists of compactly arranged parenchymatous cells. The cells are devoid of chlorophyll and contain starch as reserve food material.

• REPRODUCTION

Riccia reproduces by vegetative and sexual methods.

Vegetative reproduction

Vegetative reproduction in *Riccia* is quite common and takes place by the follow methods :

1. **Death and decay of the older portion of the thallus :** The thallus in *Riccia* dichotomously branched and the growing point is situated in its apical notch. The ba or the posterior part of the thallus starts rotting or disintegrating due to ageing drought. When this process of disintegration or decay reaches upto the place dichotomy, the lobes of the thallus get separated and develop into independent pla by apical growth. It is the most common method of vegetative reproduction in *Riccia*.

2. **By adventitious branches :** The adventitious branches develop from t ventral surface of the thallus in species like *Riccia fluitans*. On being detained, the branches develop into new thalli.

3. **By persistent apices :** Due to prolonged dry summer or towards the end growing season the whole thallus in some species (*e.g., Riccia discolor*) dries and g destroyed except the growing point. Later, it grows deep into the soil and becomes thi Under favourable conditions it develops into a new thallus. It is more a method perennation rather than multiplication.

4. **By tubers** : Towards the end of the growing season the apices of the thallus lobes get thickened and form the perennating **tubers.** These are capable to pass on the unfavourable conditions. On resumption of favourable conditions tubers produce new thalli. Tubers are common in *Riccia discolor, R. billardieri, R. perennis* and *R. vesicata* (Fig. 11).

5. **By rhizoids** : The apical part of the young rhizoids divides and redivides to form a gemma like mass of cells in some species (*e.g., Riccia glauca*). These cells contain chloroplast and are capable of developing into new thallus.

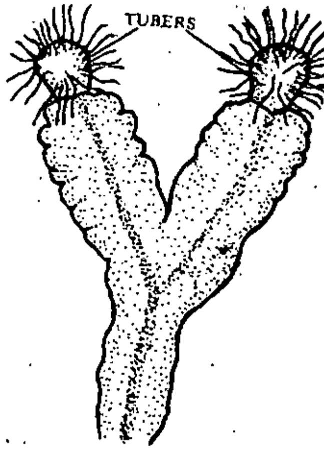


Fig. 11. *Riccia.* Thallus showing apical tubers.

Sexual reproduction

Sexual reproduction in *Riccia* is **oogamous.** Male reproductive bodies are known as **antheridia** and female as **archegonia**. Some species of *Riccia* like *R. crystallina, R. gangetica, R. billardieri* and *R. glaul* are *monoecious* or *homothallic* (*i.e.,* both anheridia and archegonia develop on the same thallus) while other species like *R. curtisii, R. perssonii, R. bischoffii, R. frostii, R. discolor* are dioecious or heterothallic (*i.e.,* antheridia and archegonial develop on different thalli). Antheridia and archegonia remain enclosed with in the antheridial and archegonial chambers and develop on the dorsal surface of the thallus (Fig. 2, 3). They develop in **acropetal succession** (*i.e.,* mature sex organs are present at the posterior end, the young ones towards the apex of the thallus). In monoecious species alternate groups of antheridia and archegonia develop at a sufficient distance from the growing point.

• ANTHERIDIUM

Development

The development of antheridium starts on dorsal surface from a superficial *antheridial initial. The antheridial initial enlarges in size,* becomes papillate and divides first by a transverse division to form an upper outer cell and a lower basal cell (Fig. 12 A, B). Basal cell remains embedded in the tissue of thallus, undergoes only a little further development and forms the embedded portion of the antheridial stalk. Outer cell divides by transverse divisions to form a filament of 4 cells. Upper two cells of the 4 celled filament are known as **primary antheridial cells** and lower two cells are known as **primary stalk cells** (Fig. 12 C-E). Primary stalk cells form the stalk of the antheridium. Primary antheridial cells divide by two successive vertical divisions at right angle to each other to form two tiers of four cells each (Fig. 12 F, G). A periclinal division is laid down in both the tiers of four cells and there is the formation of eight outer **sterile jacket initials** and 8 inner **primary androgonial cells** (Fig. 12 H, I). Jacket initials divide by several anticlinal divisions to form a single layer of an theridial jacket. Primary androgonial cells divide be several repeated transverse and vertical divisions resulting in the formation of large number of small cubical androgonial cells that develop into androcyte mother cells (Fig. 12 K-M).

Spermatogenesis

The process of metamorphosis of androcyte mother cells into antherozoids is called **spermatogenesis**. It completes within a few minutes. Each androcyte mother cell *divides by a diagonal mitotic division to form two triangular cells called* **androcytes.** Each **androcyte** has a prominent nucleus and a small extra-nuclear granule called **blepharoplast.** It lies near the periphery of the protoplast. The androcyte soon looses its triangular shape and becomes somewhat round or oval. Its blepharoplast elongates into a cord and occupies about two-thirds of its part. Simultaneously the nucleus also becomes crescent shaped, homogeneous and ultimately comes in contact with the blepharoplast. Two large flagella develop from the conspiciously thickened end of the the pharoplart. Each androcyte thus metamorphosis into an antherozoid.

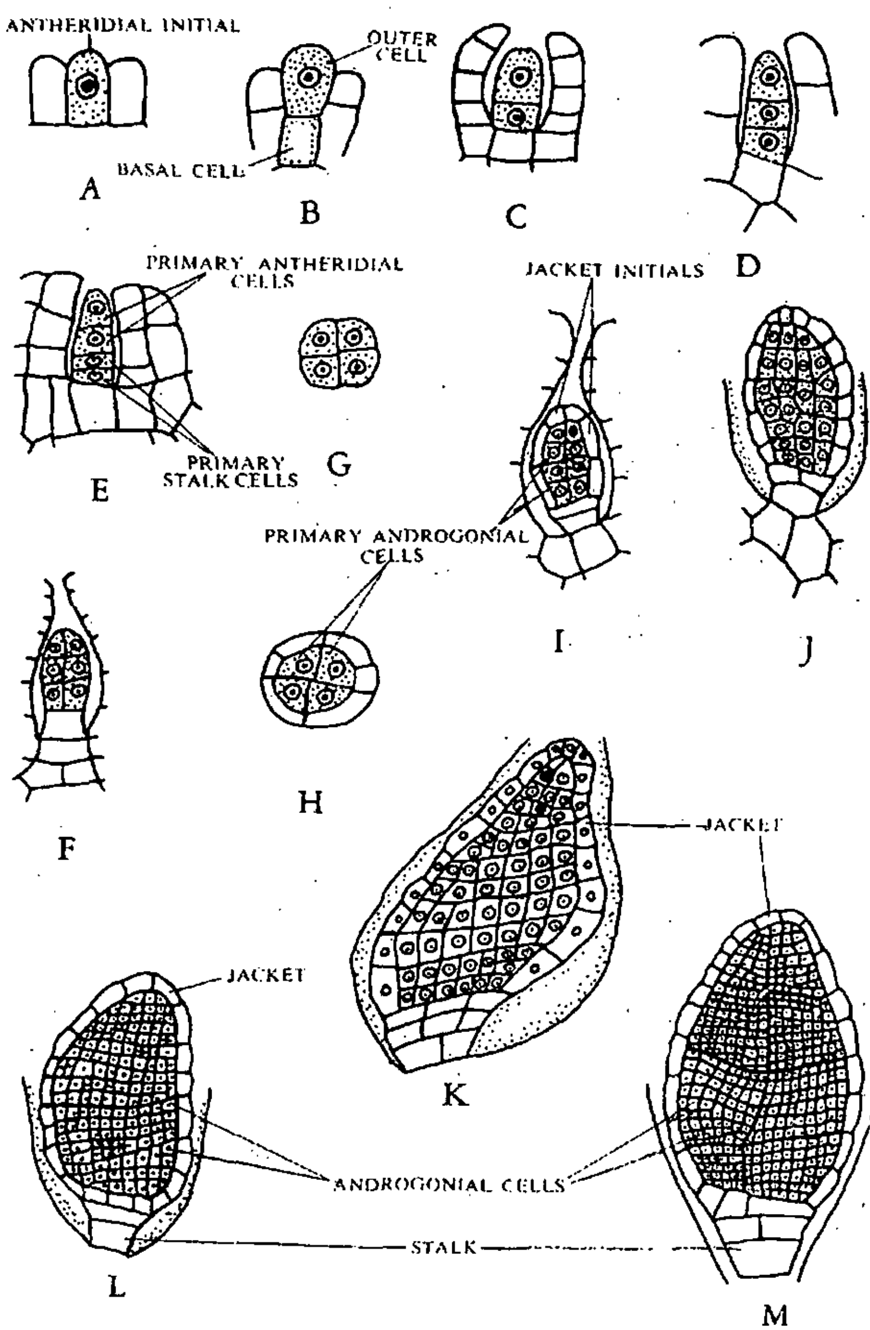


Fig. 12 (A–M) *Riccia*. Development of antheridium.

Mature antherozoid

A mature antherozoid is unicellular, uninucleate, biflagellate and coiled structu Both flagella resemble morphologically but differ in function. One flagellum serves propulsion and the other for rotation and for changes in direction (Fig. 12 H).

Dehiscence

Water helps in the dehiscence of the anheridium. Antheridial chamber, in which antheridium lies, communicates with the dorsal surface of the thallus by termin opening. The cell walls form the semifluid content of the antheridium during t metamorphosis. Mature antherozoids remain free in the semifluid substance in t antheridial cavity. As water enters in their antheridial chamber, the sterile apical ce of the antheridial jacket enlarge by absorbing water, become softened and ultimate break open. The mature antherozoids along with semifluid mass, come out of t antheridium to the antheridial chamber liberated.

• ARCHEGONIUM

Development

The development of the archegonium starts on the dorsal surface of the thallus from a single superficial cell, which acts as an archegonial initial (Fig. 13 A). This initial enlarges, becomes papillate and first divides transversely into a **basal cell** and an **outer cell** (Fig. 13 B). There is no further division in the basal cell and it forms the embedded portion of the archegonium. **The entire archegonium develops from the outer cell.** This outer cell divides by three successive intersecting walls or periclinal vertical walls resulting in the formation of three peripheral initials and a fourth median cell, the **primary axial cell** (Fig. 13 C-E).

Each of the three peripheral initials divides by an anticlinal vertical division forming two cells. In this way the primary axial cell gets surrounded by six cells (Fig. 13 J, M). These cells are called **jacket initials**. Six jacket initials divide transversely into upper **neck initials** tier and lower **venter initial tier** (Fig. 13 G). Neck initials tier divides by repeated transverse divisions to form a tube-like neck. Neck of the archegonium consists of **six vertical rows** and each row consists six to

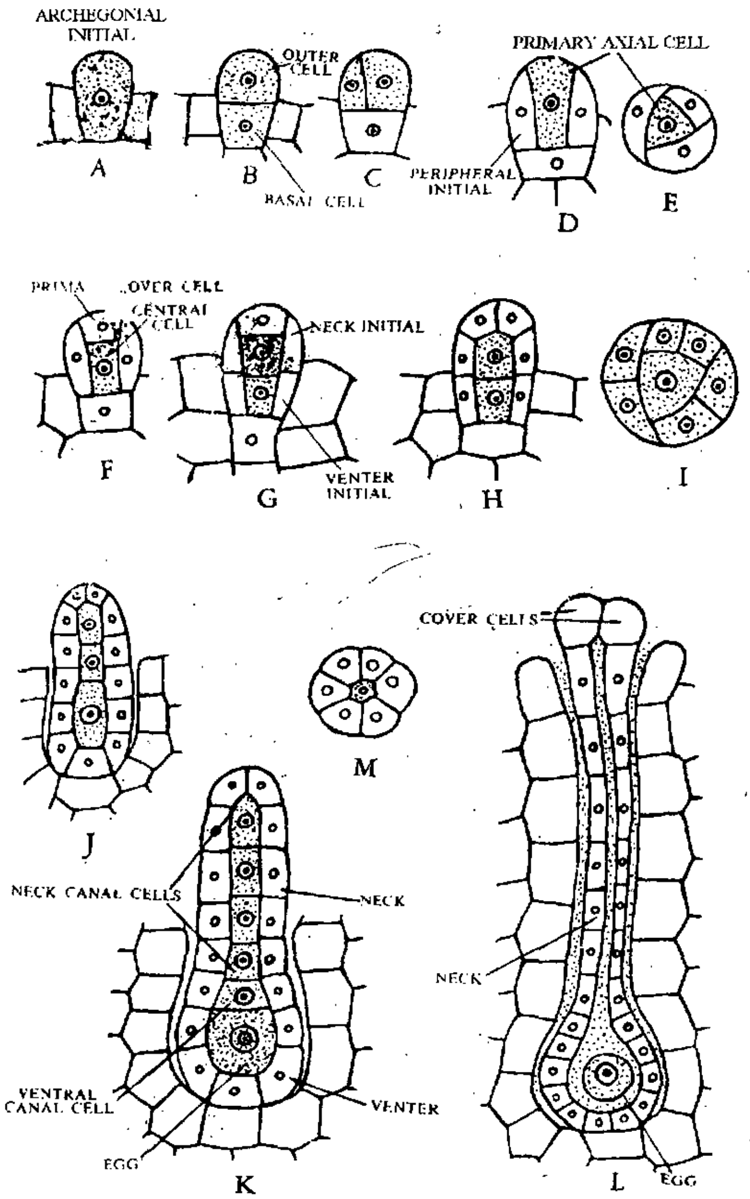


Fig. 13. ***Riccia.*** **Development of archegonium.**

nine cells. Venter initial tier also divides by repeated transverse divisions to form a single layer of swollen venter.

Simultaneously the primary axial small cell divides transversely and unequally to form small **upper primary cover cell** and **large lower central cell** (Fig. 13 F). The central cell divides into an upper primary **neck canal cell** and a **lower venter cell.** Primary neck canal cell divides by a series of transverse divisions to form four neck canal cells. Primary venter cell divides only once and forms a small **venter canal cell** and a large **egg** (Fig. 13 J, K).

The primary cover cell divides by two vertical divisions at right angle to one another forming four **cover cells** which form the mouth of the archegonium.

Mature archegonium

A mature archegonium is a flask shaped structure. It remains attached to the thallus by a short stalk. It consists of upper elongated slender **neck** and basal globular portion called **venter.** The neck consists of six vertical rows enclosing four neck canal cells. The venter consists of a single layered jacket. Twelve to twenty cells in perimeter enclose a small venter canal cell and large egg. Four cover cells are present at the top of the neck (Fig. 13 L).

Fertilization

Water is essential for fertilization. It enters the antheridial chamber. Apical cells of the antheridial wall get swollen by absorbing water. These cells become softened and finally breakdown to release mass of antherozoids. These antherozoids come up to dorsal surface of the thallus from the antheridial chamber where they swim in the thin film of water and reach the mouth of the neck of the archegonium.

In the mature archegonium the venter canal cell and neck canal cells disintegrate and form a mucilaginous mass by absorbing water, and comes out of the archegonial mouth by pushing the cover cells apart. This mucilaginous mass consists of chemical substances attracts many antherozoids and they reach upto egg. One of the antherozoids penetrates the egg and fertilization is effected (Fig. 18A-C). The fusion of the nuclei of male and female gamete results in the formation of diploid **zygote or oospore.** Fertilization ends the gametophytic phase.

SPOROPHYTIC PHASE

After fertilization the diploid zygote or oospore enlarges until it completely fills the cavity of the venter of the archegonium. A wall is then secreted around the oospore. The act of fertilization also stimulates the division of the wall of the venter. It divides anticlinally and periclinally to form a two-layered calyptra along the developing sporophyte.

• DEVELOPMENT OF SPOROPHYTE

The zygote divides first by a transverse division to form two almost equal sized cells (Fig. 14 D). The second division is at right angle to the first and results in the formation of four cells. This represents **quadrant stage** (Fig. 14 E). The next division is also vertical but it is at right angle to the first. An 8-called stage thus results. It is called octant stage (Fig. 14 D). The cells of the octant divide in all possible planes to form a spherical mass of 20-40 cells (Fig. 14 E-H). The cells of the peripheral region divide by a periclinal division to form an outer layer of **amphithecium** and the central mass of cells called **endothecium.** The cells of the amphithecium divide only by anticlinal division to form a single-layered sterile jacket or capsule wall. The endothellium forms the archesporium. Its cells divide and redivide to form a mass of sporogenous cells (sporocytes, Fig. 14 I–L).

According to **Pagan** (1932), some of the spore mother cells in *Riccia crystallina* fail to produce spores and form abortive nutritive cells called *nurse cells.* He considered these cells as the fore-runnes of elaters found in higher forms of Marchantiales.

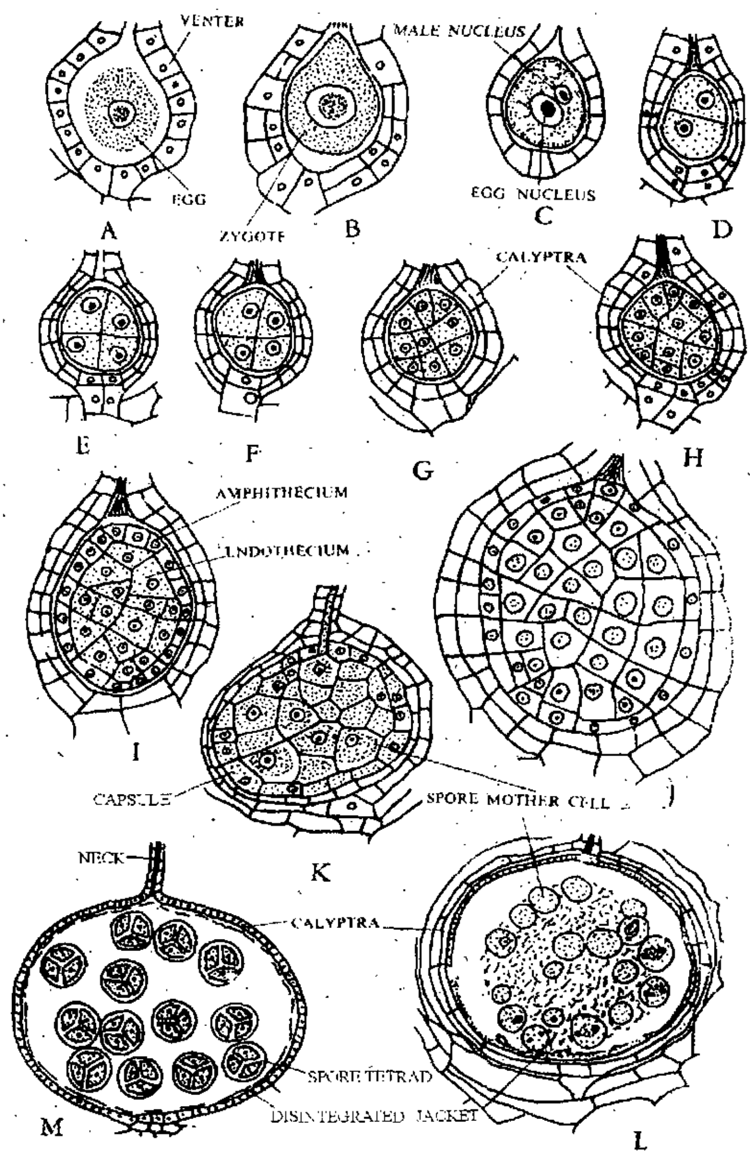


Fig. 14. *Riccia*. Development of sporogonium.

Sporogenesis

At the time of meiosis, the spore mother cells lie free within the cavity of sporogonium (Fig. 15). Spore mother cells undergo meiosis. Nucleus of each spore mother cell divides by two successive divisions to form 4 haploid nuclei. The four nuclei migrate to the periphery of the spore mother cell and lie at equal distance from each other. Simultaneously cell walls are formed around each haploid nucleus, thus delimiting four haploid spores.

The spores are tetrahedrally arranged. However, in *Riccia personii* four spores are isobilaterally arranged (**Khan**, 1953). The haploid number of chromosomes is 8 in species like *Riccia arvensis, R. campbelliana, R. donnelleii, R. sorocarpa* and *R. trichocarpe.* However, in species like *R. austini* and *R. californica* it is 9 (**Siler,** 1934). In India a in polyploid species *Riccia gangetica* Udar and Chopra (1957) reported 24 (*n*) and 48 (2*n)* chromosomes number.

Mature sporogonium

A mature sporogonium is represented only by spherical spore sac or capsule. It lacks foot and seta. It has a single-layered capsule wall which encloses spores. There are no elaters. A bilayered calyptra forms a protective covering around the capsule. The capsule wall and inner layer of calyptra break down before the spore mother cells divide

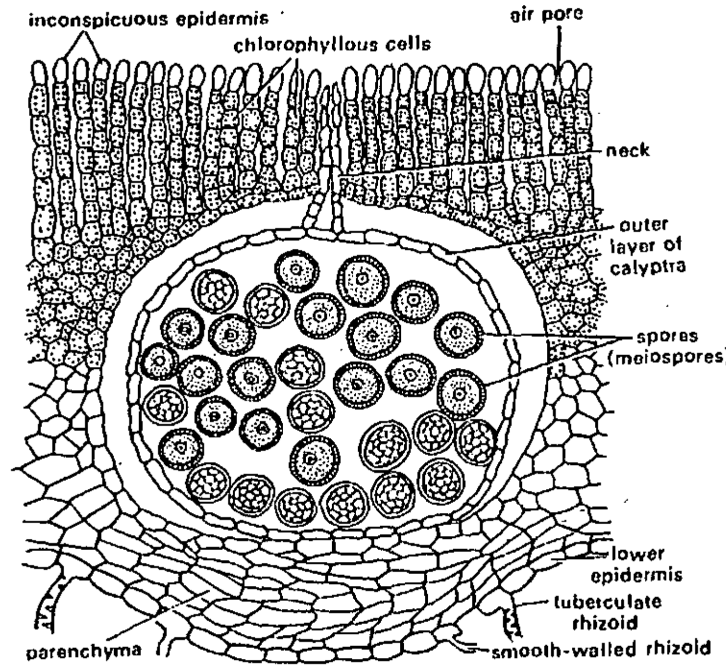


Fig. 15. ***Riccia.*** **Transverse section of thallus passing through mater sporogonium.**

to form the spores. After meiosis the mass of spores lies free in the outer layer of calyptra and mature sporogonium has no diploid structure. The newly formed young gametophyte remains enclosed with in the old gametophyte.

Dispersal of spores

Spores are not immediately dispersed in *Riccia.* There is no special method of dispersal, Spores remain inside the thallus for one year or so and dispense after the death and decay of the calyptra and surrounding tissue.

The spore

Spores are very small (0.05–0.12 mm in diameter). They are haploid uninucleate and pyramidal in shape (Fig. 16). Each spore remains surrounded by three layers *i.e.,* an outermost ornamented cutinised layer called **exosporium**, the middle layer called **mesosporium** (differentiated into 3 concentric zones) and the innermost layer called the **endosporium**. The endosporium is made up of cellulose and pectose (**Beer,** 1906).

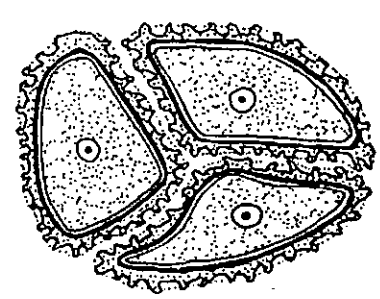


Fig. 16. ***Riccia.*** **Spore Tetrad**

Germination of spores and formation of young gametophyte

Light, low temperature and water is essential for spore germination. According to **Campbell** (1918) the exosporium and mesosporium rupture at the triradiate mark and the endosporium comes out in the form of a tubular outgrowth called the germinal (Fig. 17 A–C). Germival tube is filled with cytoplasm which contain albumin granules chloroplasts and oil granules. The germ tube elongates rapidly to form a club-shaped structure because the content of the cytoplasm move to the distal end. At the end it divides by a transverse division to form a small cell (Fig. 17 D). It again divides by a transverse division which is parallel to first division. Both these cells divide by two vertical divisions at right angle to one another and form two tiers of four cells each. This represents **octant stage** (Fig. 17 E). The distal tier of four cells of the octant stage functions as an apical cell with 2 **cutting faces**. It cuts a number of cells on its left and right side to form the multicellular thallus (Fig. 17 G, H).

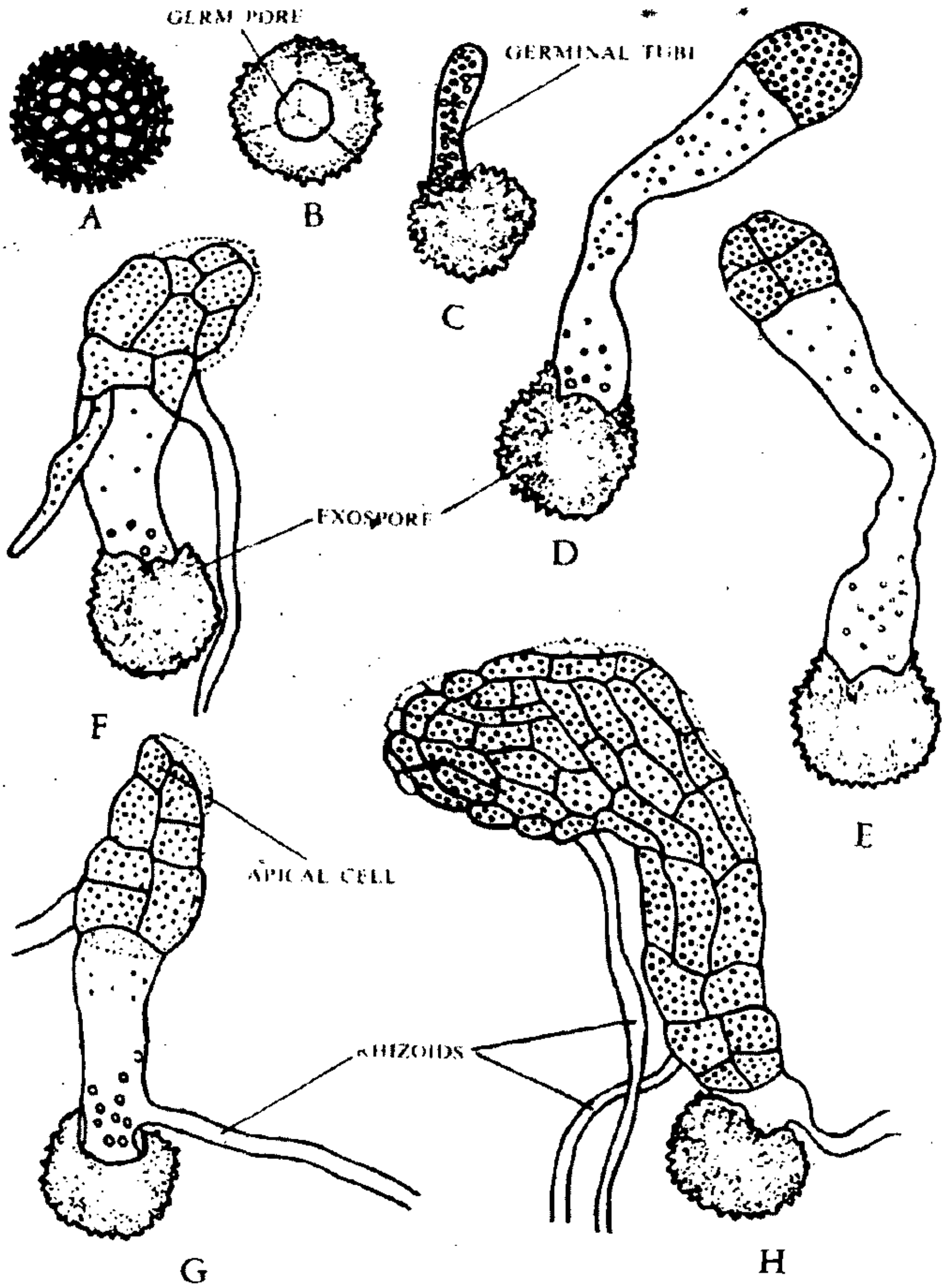


Fig. 17. ***Riccia*****. Germination of spore and formation of young gametophyte.**

Along with these divisions the first rhizoid develops at the base of the germ tube. Many rhizoids develop later on from the multicellular thallus and fix it on the soil (Fig. 18 A, H). Formation of rhizoids is affected by light intensity (**Chopra** and **Sood**, 1973). Rhizoids develop in the light of medium intensity (2000 Lux). In *Riccia crustissi* two spores of a tetrad develop into male thalli and two spores develop into female thalli (**Mc Allister**, 1928).

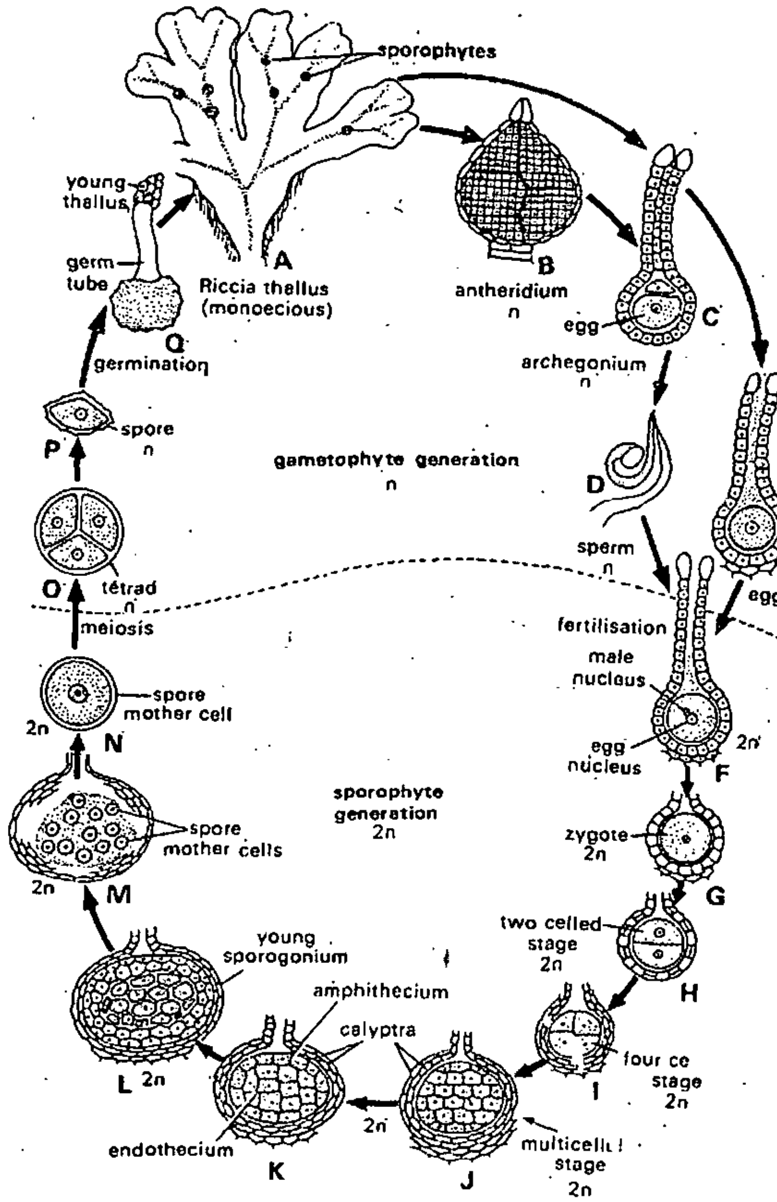


Fig. 18. *Riccia.* Diagrammatic life cycle.

• FAMILY : MARCHANTIACEAE

(i) The family Marchantiaceae includes about 23 genera and 250 species.

(ii) Dorsal surface is marked by rhomboidal areas (areolae).

(iii) Air pores are barrel shaped.

(iv) Photosynthetic zone is divided into many chambers.

(v) Each chamber has several simple or branched photosynthetic filaments.

(vi) Sex organs are raised on erect and stalked receptacles cal **gametophores.**

(vii) Receptacle bearing antheridia and archegonia are called **antheridiopho** and **archegoniophores** respectively.

(viii) Sporophyte is differentiated into **foot, seta** and **capsule.**

(ix) **Elaters** are present in capsules.

(x) Capsule dehisces either by separation of lid or by valves.

Marchantia (Common Liverwort)

• SYSTEMATIC POSITION :

Division	:	**Bryophyta**
Class	:	**Hepaticopsida**
Order	:	**Marchantiales**
Family	:	**Marchantiaceae**
Genus	:	***Marchantia***

• DISTRIBUTION AND HABITAT :

Marchantia, the most important genus of family Marchantiaceae is represented by about 65 species. The name *Marchantia* was given in honour of **Nicolas Marchant**. All species are terrestrial and cosmopolitan in distribution. The species prefer to grow in moist and shady places like wet open woodlands, banks of streams, wood rocks or on shaded stub rocks. These grow best after the forest fire in the burnt soil. It is perhaps because of nitrification of soil due to fire (**Richard**, 1958).

In India, *Marchantia* is represented by about 11 species (**Chopra**, 1943). **Udar** (1970) reported only 6 species from different parts of the country. These species are commonly found growing in the Himalayan region at an altitude of 4000–8000 feet. Eastern Himalayan region particularly supports the growth of these species. Some species are also found growing in plains of Haryana, Punjab, Uttar Pradesh and hilly regions of South India. Some of the common Indian species are *M. palmata*, *M. polymorpha*, *M. simlana* etc. *M. polymorpha* is most widely distributed species. *M. polymorpha* var *aquatic* grows submerged in swampy meadows.

The thalli with gemma cups are found throughout the year whereas the thalli with sex organs occur abundantly during February to March in Himalayas and October to November in hills of South India.

GAMETOPHYTIC PHASE

• EXTERNAL FEATURES OF GAMETOPHYTE

The plant body is gametophytic, thalloid, flat, prostrate, plagiotropic, 2–10 cm. long and dichotomously branched (Fig. 1 A).

Dorsal surface. Dorsal surface is dark green. It has a conspicuous midrib and a number of polygonal areas called **areolae.** The midrib is marked on the dorsal surface by a shallow groove and on the ventral surface by a low ridge. Each polygonal area representes the underlying **air chamber**. The midrib ends in a depression at the apical region forming a growing point (Fig. 1 B).

Dorsal surface also bears the vegetative and sexual reproductive structures. The vegetative reproductive structures are **gemma cup** and develop along the midrib. These are crescent shaped with spiny or fimbriate margins and are about one eighth of a inch in diameter (Fig. 1 A, B). Sexual reproductive structures are borne on special stalked structures called **gametophores** or **gametangiophores.** The gametophores bearing archegonia are called **archegoniophores** and that bearing antheridia are called **antheridiophores** (Fig. 1 A, B).

Ventral surface. The ventral surface of the thallus bears scales and rhizoids along the midrib. Scales are violet coloured, multicellular, one cell thick and arranged in 2–4 rows (Fig. 1 C). Scales are of two types : **(i) simple** or **ligulate** and **(ii) appendiculate**. Appendiculate (Fig. 1 C, D) scales form the inner row of the scales close with midrib. Ligulate scales form the outer or marginal row and are smaller than the appendiculate scales (Fig. 1 C, E).

Rhizoids are unicellular, branched and develop as prolongation of the lower epidermal cells. They are of two types : **(i) smooth-walled rhizoids, (ii) tuberculate rhizoids.** In smooth–walled rhizoids both the inner and outer wall layers are fully

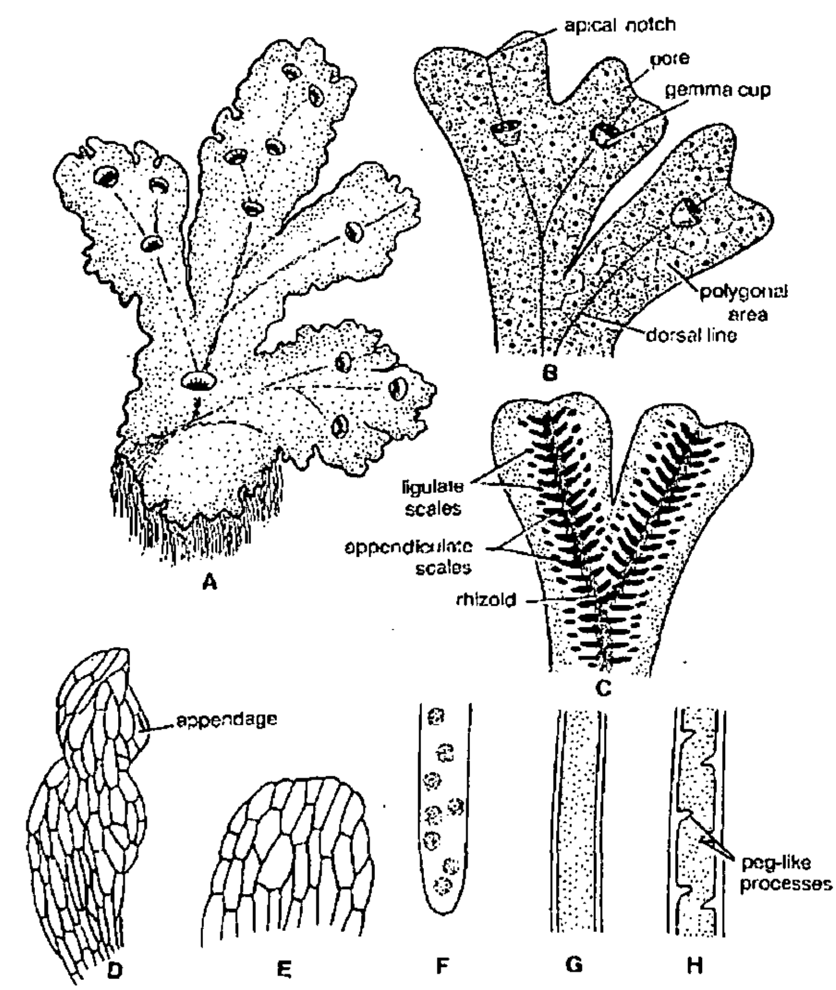


Fig. 1. (A–H). ***Marchantia.*** **Thallus structure (A) Vegetative thallus, (B) Dorsal surface, (C) Ventral surface, (D) Appendiculate scale, (E) Ligulate scale, (F) Tuberculated rhizoid (surface view), (G) Smooth–walled rhizoid, (H) Tuberculated rhizoid showing internal view**

stretched while in tuberculate rhizoids appear like circular dots in surface vie (Fig. 1 F). The inner wall layer modifies into peg like ingrowth which projects into t cell lumen (Fig. 1 H). The main functions of the rhizoids are to anchor the thallus on t substratum and to absorb water and mineral nutrients from the soil.

• ANATOMY OF THE GAMETOPHYTE

A vertical cross section of the thallus can be differentiated into two zones, *vi.* **upper photosynthetic zone** and **lower storage zone** (Fig. 2 A, B, C, D).

Upper Photosynthetic zone. The outermost layer is upper epidermis. Its cells a thin walled square, compactly arranged and contain few chloroplasts. Its continuity broken by the presence of many barrel shaped air pores. Each pore is surrounded l four to eight superimposed tiers of concentric rings. (Fig. 2 B) with three to four cells each tier. Air pores are compound in nature. The lower tier consists of four cells whi project in the pore and the opening of the pore looks star like in the surface view. Th walls of the air pore lie half below and half above the upper epidermis.

Just below the upper epidermis photosynthetic chambers are present in a horizont layer. Each air pore opens inside the air chamber and helps in exchange of gases durin photosynthesis. These air chambers develop schizogenously (localized separation cells to form a cavity) and are separated from each other by single layered partitio walls. The partition walls are two to four cells which contain chloroplast.

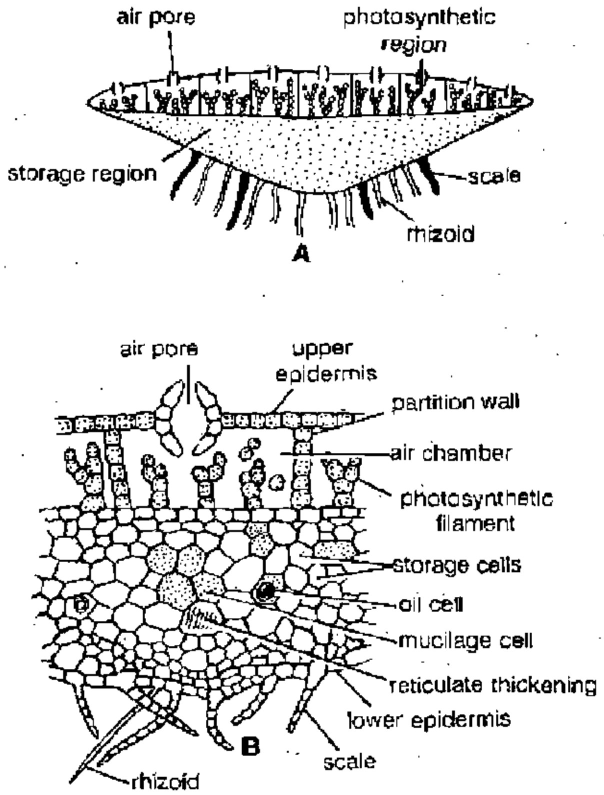


Fig. 2. (A-E). *Marchantia*. Internal structure of the thallus. (A) Vertical Transverse Section (V.T.S.) of thallus (diagrammatic), (B) V.T.S. of thallus (a part cellular), (C) Air pore as seen in the ventral view, (D). Air pore as seen in the dorsal view.

Storage zone. It lies below the air chambers. It is more thickened in the centre and gradually tapers towards the margins. It consists of several layers of compactly arranged, thin walled parenchymatous isodiametric cells. Intercellular spaces are absent. The cells of this zone conain starch. Some cells contain a single large oil body or filled with mucilage. Some cells of the middle layer of lower epidermis extend to form both types of scales and rhizoids (Fig. 2 B).

• REPRODUCTION

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

Vegetative reproduction

In *Marchantia* it is quite common and takes place by the following methods :

1. By Gemmae. Gemmae are produced in the **gemma cups** which are found on the dorsal surface of the thallus (Fig. 3 A). Gemma cups are crescent shaped, 3 m.m. in diameter with smooth, spiny or fimbriate margins (Fig. 3 B). The gemma cup differentiated into two regions : **upper photosynthetic region** and **inner storage region** (Fig. 3 D). The structure of both the zones is similar to that of the thallus. Mature gemmae are found to be attached at the base of the gemma cup by a single celled stalk. Intermingled with gemmae are many mucilage hairs. Each gemma is autotrophic, multicellular, bilaterally symmetrical, thick in the centre and thin at the apex. It consists parenchymatous cells, oil cells and rhizoidal cells. It is notched on two sides in which lies the growing point (Fig. 3 C). All cells of the gemma contain chloroplast except rhizoidal cells and oil cells.

Dissemination of Gemmae. Mucilage hairs secrete mucilage on absorption of water. It swells up and presses the gemmae to get detached from the stalk in the gemma cup. They may also be detached from the stalk due to the pressure exerted by the growth of the young gemmae. The gemmae are dispersed over long distances by water currents.

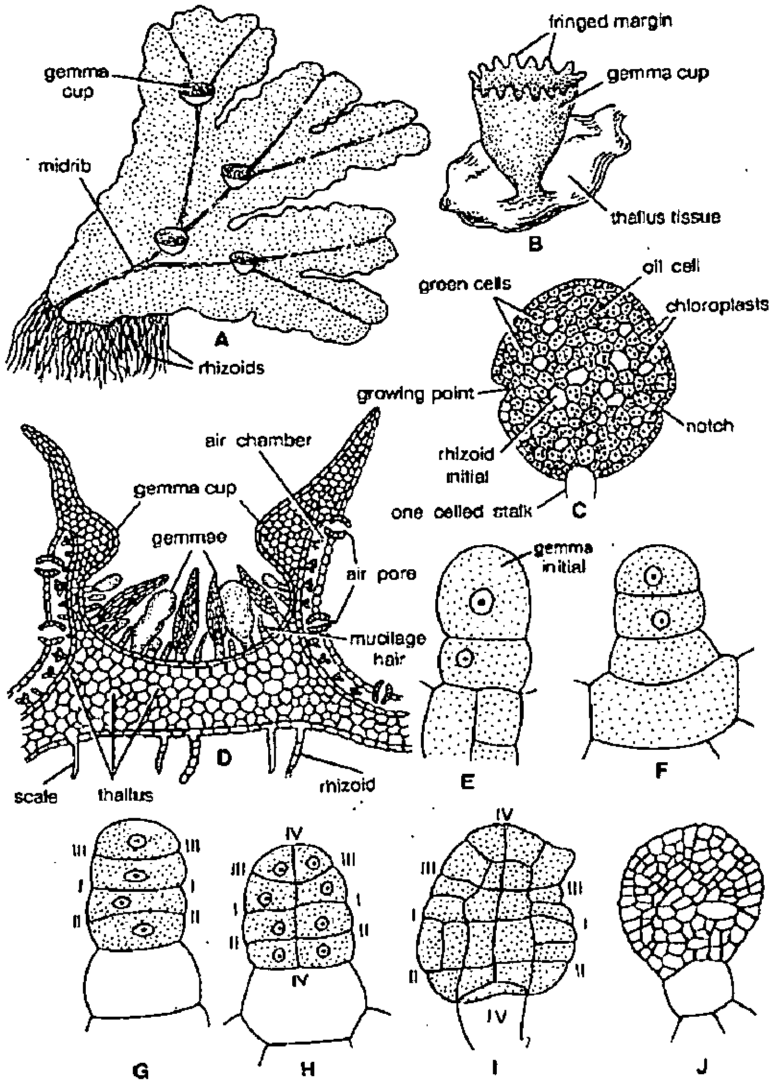


Fig. 3. (A-J). ***Marchantia.*** **Gemma cup. (A) Thallus showing gemma cup on the dorsal surface, (B) A gemma cup, (C) Gemma, (D) Gemma cup in a vertical section, (E-J). Different stages in the development of Gemma.**

Germination of Gemmae. After falling on a suitable substratum gemmae germinate. The surface which comes in contact with the soil becomes ventral surface. The rhizoidal cells develop into rhizoids. Meanwhile, the growing points in the two lateral notches form thalli in opposite directions. Thus, **from a single gemmae two thalli are formed.** Gemmae which develop on the male thalli form male plants and those on the female thalli form the female plant.

Development of Gemma. The gemma develops from a single **superficial cell** which develops on the floor of a gemma cup. It is papillate and called **gemma initial** (Fig. 3 E). It divides by a transverse division to form lower **stalk cell** and upper cell (Fig. 3 F). The lower cell forms the single celled stalk. The upper cell further divides by transverse division to form two cells. Both cells undergo by similar divisions to form four cells (Fig. 3 G). These cells divide by vertical and horizonal division to form a like structure with two marginal notches. It is called gemma (Fig. 3 H–J).

2. Death and decay of the older portion of the thallus or fragmentation. The thallus is dichotomously branched. The basal part of the thallus rots and disintegrates due to ageing. When this process reaches upto the place of dichotomy, the lobes of the thallus get separated. The detached lobes or fragments develop into independent thalli by apical growth (Fig. 4 A–C).

3. By adventitious branches. The adventitious branches develop from any part of the thallus or the ventral surface of the thallus or rarely from the stalk and disc of the archegoniophore in species like *M. palmata* (**Kashyap**, 1919). On being detached, these branches develop into new thalli (Fig. 4 D).

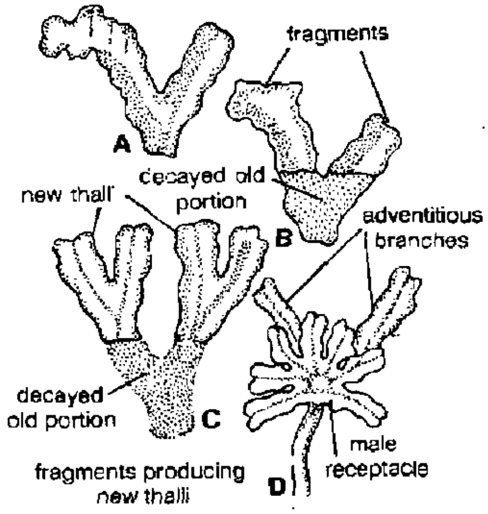


Fig. 4. (A-D). *Marchantia.* Vegetative reproduction. (A-C). Fragmentation, (D) Adventitious branches arising between the lobes from the lower surface of the male disc.

Sexual reproduction

Sexual reproduction in *Marchantia* is **oogamous**. All species are **dioecious**. Male reproductive bodies are known as **antheridia** and female as **archegonia**. Antheridia and archegonia are produced on special, erect modified lateral branches of thallus called **antheridiophore** and **archegoniophore** (carpocephalum) respectivly (Fig. 5 A, B). Furher growth of the thallus is checked because growing point of the thallus is utilised in the formation of these branches. In some thalli of *M. palmata* and *M. polymorpha* abnormal receptacle bearing both anheridia and archegonia have also been reported. Such bisexual receptacles are called as **androgynous receptacles.**

Internal structure of Antheridiophore or Archegoniophore. Its transverse section shows that it can be differentiated ino two sides: ventral side and dorsal side. Ventral side has two longitudinal furrows with scales and rhizoids. These grooves, run longitudinally through the entire length of the stalk. Dorsal side shows an internal differentiation of air chambers. (Fig. 5 C).

Antheridiophore. It consists of 1–3 centimetre long stalk and a lobed disc at the apex (Fig. 5 A). The disc is usually eight lobed but in *M. geminata* it is four lobed. The lobed disc is a result of repeated dichotomies.

L.S. through disc of Antheridiophore. The disc consists of air chambers alternating with antheridial cavities. Air chambers are more

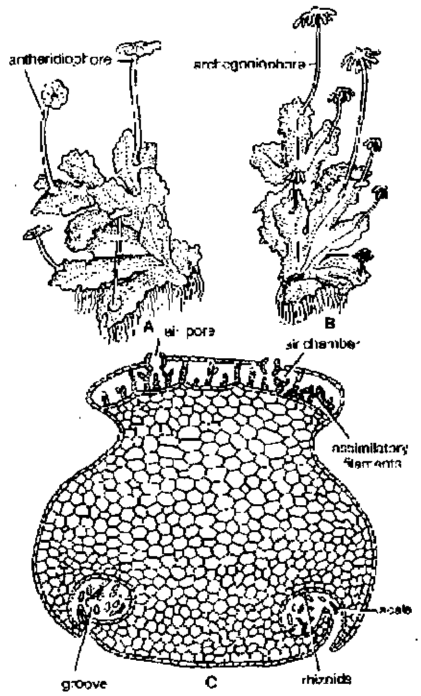


Fig. 5. (A-C). *Marchantia.* Gametophores. (A) Thallus bearing antheridiophores, (B) Female thallus bearing archegoniophores, (C) Transverse section of gametophore.

or less triangular and open on upper surface by n pore called **ostiole.** Antheridia a in acropetal succession *i.e.*, the older near the centre and youngest at the mar (Fig. 6 A).

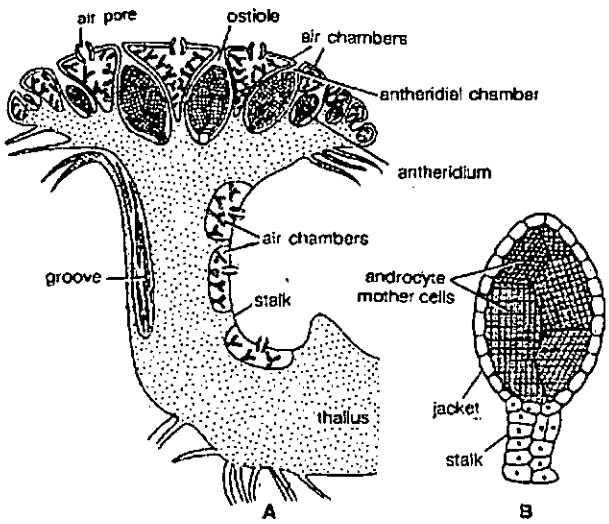


Fig. 6. (A-B). ***Marchantia*** **Antheridia. (A) Vertical or longitudinal section passing throu disc of antheridiophore, (B) a mature antheridium antheridium.**

Development of antheridium. The development of the antheridium starts single superficial cell which is situated on the dorsal surface of the disç, 2–3 cells bel the growing point. This cell is called **antheridial initial** (Fig. 7 A). The antheri initial increases in size and divides by a transverse division to form an outer upper and a lower basal cell (Fig. 7 B). Basal cell remain embedded in the tissue of the tha undergoes a little further development and forms the embedded portion of antheridial stalk. Outer cell divides to form a filament of four cells. Upper two cel the four celled filament are known as **primary antheridial cells** and lower two c are known as **primary stalk cells** (Fig. 7 C). A periclinal division is laid down in t the tiers of four cells and there is formation of eight outer sterile **jacket initials** eight inner **primary androgonial cells** (Fig. 7 E). Jacket initials divide by sev anticlinal divisions to form a single layer of sterile **antheridial jacket.** Prim androgonial cells divide by several repeated transverse and vertical divisions resul in the formation of large number of small **androgonial cells** (Fig. 7 F). The generation of the androgonial cells is known as **androcyte mother cells** (Fig. 7

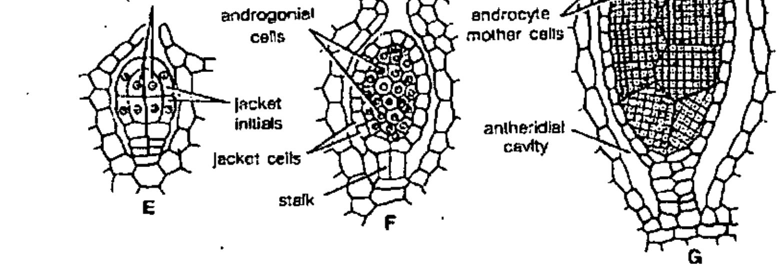


Fig. 7. (A-H). ***Marchantia.*** **Development of antheridium (A-F). Successive stages in the development of antheridium, (G). A mature antheridium.**

Each androcyte mother cells divides by a diagonal mitotic division to form two triangular cells called **androcytes**, which **antheozoid** (Fig. 8 A–G).

Spermatogenesis. The process of metamorphosis of androcyte mother cells into antherozoids is called **spermatogenesis**. It is completed in two phases :

(1) Development of blepharoplast.

(2) Elongation of androcyte nucleus.

1. Development of blepharoplast. In the young triangular androcyte (Fig. 8 D) blepharoplast appears as a dense granule in one of the acute angles. It elongates to some extent and puts its whole body in close contact with the inner contour of androcyte. From the elongated blepharoplast emerge the flagella.

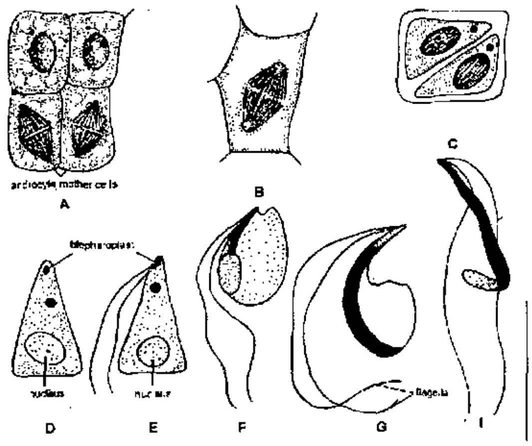


Fig. 8. (A-H). ***Marchantia.*** **Spermatogenesis. (A-C) Formation of androcytes, (D-G). Stages in Spermatogenesis, (H). A single antherozoid.**

2 Elongation of androcyte nucleus. With the elongation of blepharoplast, the nucleus also elongates (Fig. 8 E–H).

Archegoniophore or carpocephalum.

It arises at the apical notch and consists of a stalk and terminal disc. It is slightly longer than the antheridiophore. It may be five to seven cm. long. The young apex of the archegoniophore divides by three successive dichotomies to form eight lobed rosette like disc. Each lobe of the disc contain a growing point. The archegonia begin to develop *in each lobe in acropetal sucession.*

Development. The development of the archegonium starts on the dorsal surface from a single superficial cell called **archegonial initial** enlarges and divides by transverse division to form a **basal cell** or **primary stalk cell** and an **outer cell** or **primary archegonial cell** (Fig. 9 A, B). The primary stalk cell undergoes irregular divisions and forms the stalk of the archegonium. The primary archegonial cell divides by three successive intercalary walls or periclinal vertical walls resulting in the formation of three **peripheral initials** and a fourth median cells, the **primary axial cell** (Fig. 9 C, D).

Each of the three peripheral initials divides by an anticlinal vertical division forming two cells (Fig. 9 G, H) In this way primary axial cell gets surrounded by six cells. These are called **jacket initials** (Fig. 9 H, I). Six jacket initials divide transversely into upper **neck initials** and lower **venter initials** (Fig. 9 F). Neck initial tier divides by repeated transverse divisions to form a tube like **neck.** Neck of the archegonium consists of six vertical rows. (Fig. 9 I). Each row consists six to nine cells. Venter initials tier also divides by rapid transverse divisions to form a single wall layer of swollen venter (Fig 9 K).

Simultaneously, the primary axial cell divides transversely and unequally to form upper small **primary cover cell** and **lower large central cell** (Fig. 9 E). The central cell divides into **primary neck canal cell** and a lower **venter cell.** Primary neck

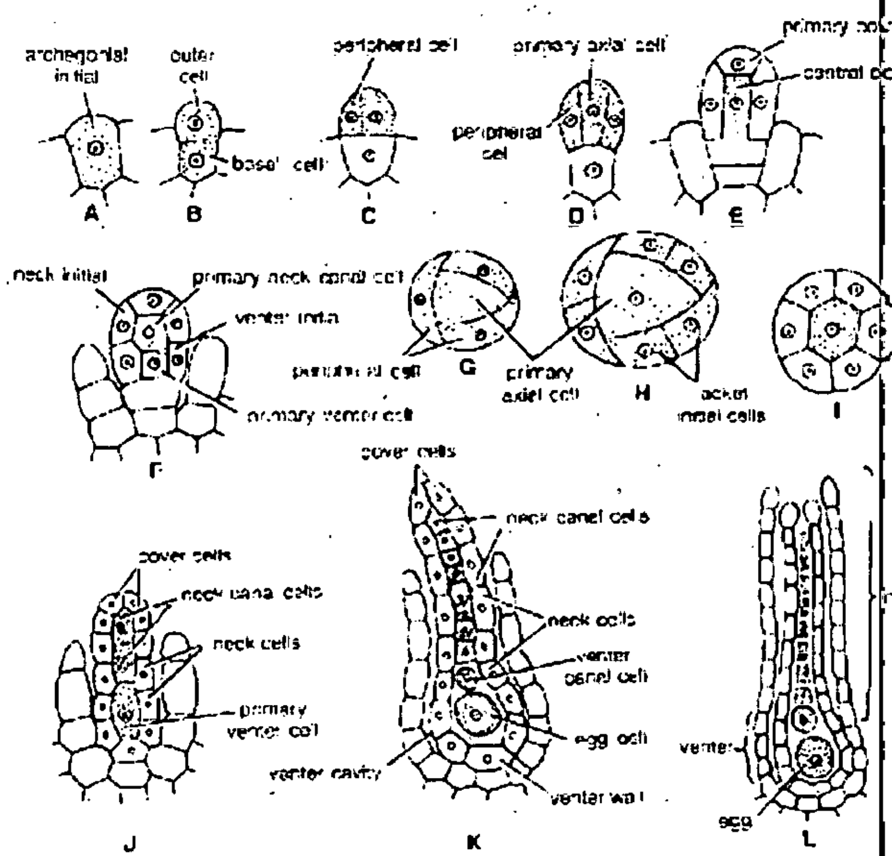


Fig. 9. (A-L) *Marchantia*. Development of archegonium. (A-K) successive stages in the development of archegonium. (L) A mature archegonium.

canal cells divides by a series of transverse divisions to form a row of about eight t walled **neck canal cells** (Fig. 9 J, K). Primary venter cell divides only once and forr small upper **venter canal cell** and a lower large **egg** or **ovum** (Fig. 9 K).

The primary cover cell divide by two vertical divisions at right angle to one anot to form four **cover cells** which form the mouth of the archegonium.

Mature archegonium. A mautre archegonium is a flask shaped structure remains attached to the archegonial disc by a short **stalk.** It consists upper elong slender **neck** and basal globular portion called **venter.** The neck consists of six vert rows enclosing eight neck canal cells and large egg. Four cover cells are present at top of the neck. (Fig. 9 L).

Fertilization. *Marchantia* is **dioecious**. Fertilization takes place when male female thalli grow near each other. Water is essential for fertilization. The neck of archegonium is directed upwards on the dorsal surface of the disc of archegoniophore (Fig. 9 A). In the mature archegonium the venter canal cell and r canal cells disintegrate and form a mucilaginous mass. It absorbs water, swells up comes out of the archegonial mouth by pushing the cover cells apart. This mucilagir mass consists of chemical substances.

The antherozoids are splashed by rain drops. They may fall on the nearby fem receptacle or swim female receptacle. Many antherozoids enter the archegonial necl chemotactic response and reach upto egg. This mechanism of fertilization is ca **splash cup mechanism**. One of the antherozoids penetrates the egg and fertiliza is effected. The fusion of both male and female nuclei results in the formation of dip **zygote** or **oospore.** Fertilization ends the gametophytic phase.

SPOROPHYTIC PHASE

Post fertilization changes

After fertilization the following changes occur simultaneously :

1. Stalk of the archegoniophore elongates.

2. Remarkable over–growth takes place in the central part of the disc. As a result of this growth the marginal region of the disc bearing archegonia is pushed downward and inward. The archegonia are now hanging towards the lower side with their neck pointing downwards (Fig. 10 B–D).

3. Wall of the venter divides to form two to three layered **calyptra.**

4. A ring of cells at the base of venter divides and redivides to form a one cell thick collar around archegonium called **perigynium (Pseudoperianth).**

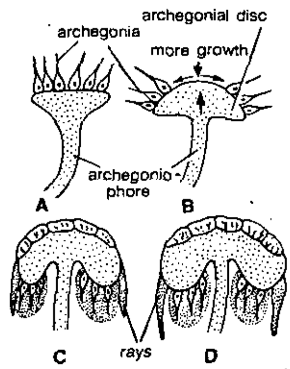


Fig. 10. (A-D). *Marchantia.* (A) Position of the archegonia before fertilization, (B-D). Inversion of the archegonia after fertilization.

5. A one celled thick, fringed sheath develops on both sides of the archegonial row. It is called **perichaetium** or **involucre.** Thus, the developing sporophyte is surrounded by three protective layers of gametophytic origin *i.e.*, **calyptra, perigynium** and **perichaetium** (Fig. 11). The *main function* of these layers is to provide protection, against drought, to young sporophyte.

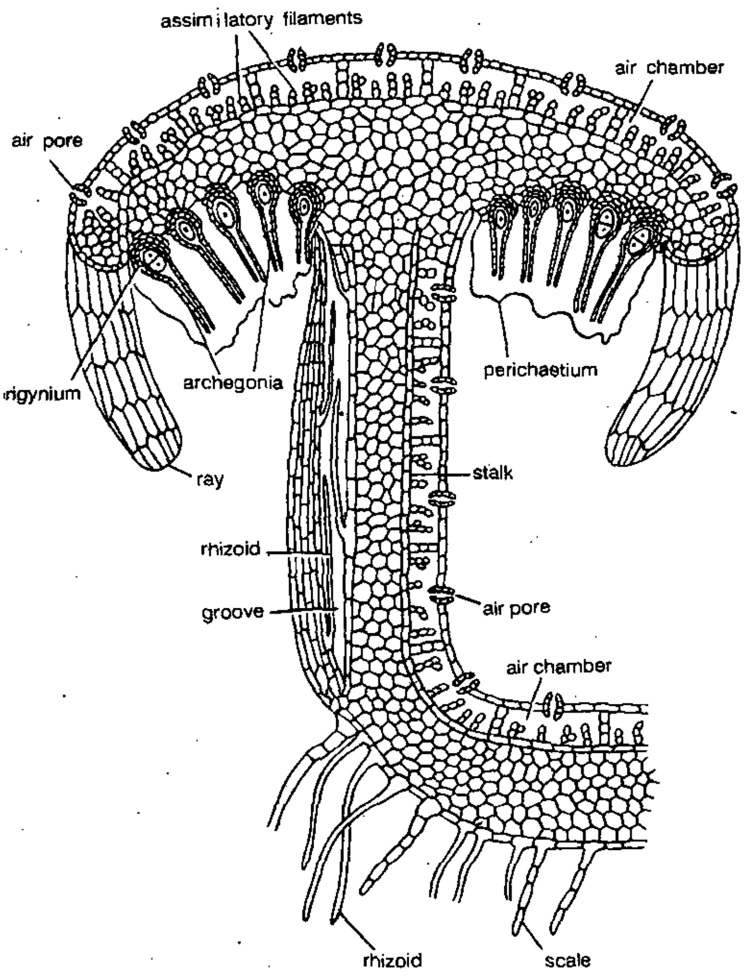


Fig. 11. *Marchantia.* Vertical longitudinal section (V.L.S.) of archegoniophore showing protective layers and rays. (After fertilization)

6. Between the groups of archegonia, long, cylindrical processes develop from periphery of disc. These are called **rays**. They radiate outward, curve downwards give the disc a stellate form. In *M. polymorpha* these are nine in number.

7. Zygote develops into **sporogonium.**

Development of sporogonium. After fertilization the diploid zygote or oosp enlarges and it completely fills the cavity of the archegonium. It first divides transverse division (at right angle to the archegonium axis) to form an outer epib **cell** and inner **hypobasal cell** (Fig. 12 A, B).

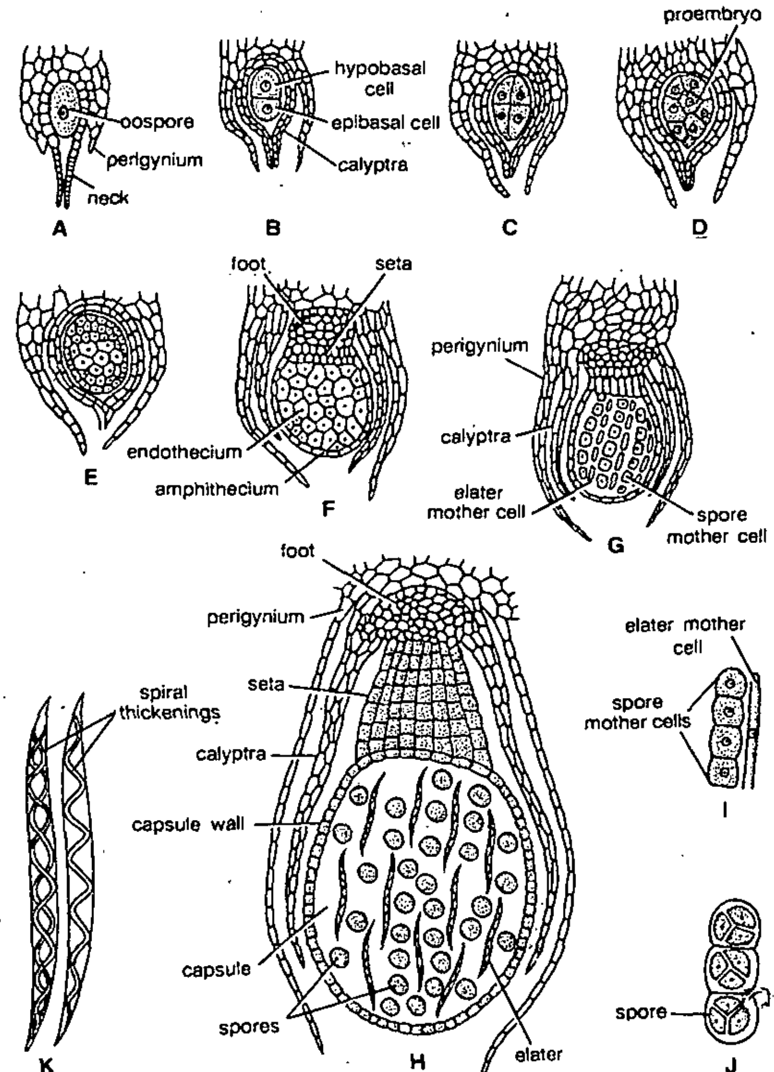


Fig. 12. (A-J). ***Marchantia*. Development of sporophyte. (A-J). Successive stages in the development of sporoginium, (H). L.S. of mature sporogonium, (J) Spores tetrad, (K) Two elaters.**

The second division is at right angle to the first and results in the formation of f cells. This represents the **quadrant stage** (Fig. 12 C). The epibasal cell forms **capsule** and hypobasal cells form the **foot** and **seta**. Since the capsule is develop from the epibasal cell and forms the apex of the sporogonium, the type of embryogen known as **exoscopic**. The next division is also vertical and it results in formation eight celled stage or **octant stage.** Now the divisions are irregular and globular emb is formed (Fig. 12 D). The lower cells divide to form a massive and bulbous foot. The c of the seta divide in one plane to form vertical rows of cells. In upper region of caps (when the young sporogonium is about a dozen or more cells in circumferen periclinal division occurs and it differentiates it into outer single layer

amphithecium and multilayered **endothecium** (Fig. 12 E, F) The cells of the endothecium divide only by anticlinal divisions to form a single layered sterile jacket or **capsule wall.** The endothecium forms the **archesporium.** Its cells divide and redivide to form a mass of **sporogenous cells** (sporocytes). Half of the sporogenous cells become narrow and elongate to form the **elater mother cells.** (Fig. 12 G, I). In *M. polymorpha* sporogenous cells divide by five successive divisions to form thirty two spore mother cells while in *M. domingensis* sporogenous cells divide only by three to four divisions to form eight or sixteen spore mother cells. The elater mother cells elongate considerably to form long, slender **diploid** cells called **elaters.** Elaters are pointed at both the ends and have two spiral bands or thickenings on the surface of the wall. These are hygroscopic in nature and help in dispersal of spores (Fig. 12 K). The spore mother cell is diploid and divides meiotically to form four haploid spores which remain arranged tetrahedrally for quite sometime (Fig. 12 J). The spores later become free and remain enclosed by the capsule wall along elaters. (Fig. 12 H).

The quadrant type of development of sporogonium is quite common in many species of *Marchantia* (*e.g.*, *M. polymorpha*) but in a few species zygote divides by two transverse divisions to form the 3-celled filamentous embryo. In it the hypobasal cell forms the foot, the middle seta and the epibasal cell develops into capsule. However, it is the rare type of embryo development in *M. chenopoda.*

Mature sporogonium

A mature sporogonium can be differentiated into three parts, *viz.*, the foot, seta and capsule.

Foot. It is bulbous and multicellular. It is composed of parenchymatous cells. It acts as anchoring and absorbing organ. It absorbs the food from the adjoining gametophytic cells for the developing sporophyte.

Seta. It connects the foot and the capsule. At maturity, due to many transverse divisions it elongates and pushes the capsule through three protective layers *viz.*, calyptra, perigynium and perichaetium.

Capsule. It is oval in shape and has a single layered wall which encloses spores and elaters. It has been estimated that as many as 3,00,000 spores may be produced in single sporogonium and there are 128 spores in relation to one elater.

Dispersal of spores

As the sporogonium matures, seta elongates rapidly and pushes the capsule in the air through the protective layers. The ripe capsule wall dehisces from apex to middle by four to six irregular **teeth** or **valves** exposing the spores and elaters.

The elaters are hygroscopic in nature. In dry weather they lose water and become twisted. When the atmosphere is wet, they become untwisted and cause the jerking action. Due to this the spore mass loosens and spores are carried out by air currents.

Structure of spore

Spores are very small (0·012 to 0·30 mm in diameter). They are haploid, uninucleate, globose and surrounded by only two wall layers. The outer well layer is thick, smooth or reticulate and is known as **exospore** or **exine**. The inner wall layer is thin and is calleds **endospore** or **intine**. In *M. torsana* and *M. caneiloba* they are tetrahedrally arranged.

Germination of spores and development of Gametophyte

Under favourable conditions, the spores germinate immediately. In first year the spore viability is approximately 100%. Before germination it divides by transverse division to form two unequal cells (Fig. 13 A, B). The lower cell is small in size. It is relatively poor in cell contents, achlorophyllous and extend to form **germ-rhizoid** (Fig. 13 C). The large cell is chlorophyllous and undergoes divisions to form a six to eight cell **germ-filament** or **protonema** (Fig. 13 D). At this stage the contents of the cells migrate at the apex. The apex is cut off from the rest of the sporeling by a division. It behaves as apical cell. It is wedgeshaped with two cutting faces. The apical cell cuts off five to seven cells alternately to the left and right. These cells by repeated division form a platelike structure (Fig. 13 F). According to **O' Hanlon's** (1976) a marginal ro of cells appears in the apical region in this plate. By the activity of these marginal cells the expansion of the plate takes place into thallus, a characteristic of *Marchantia*.

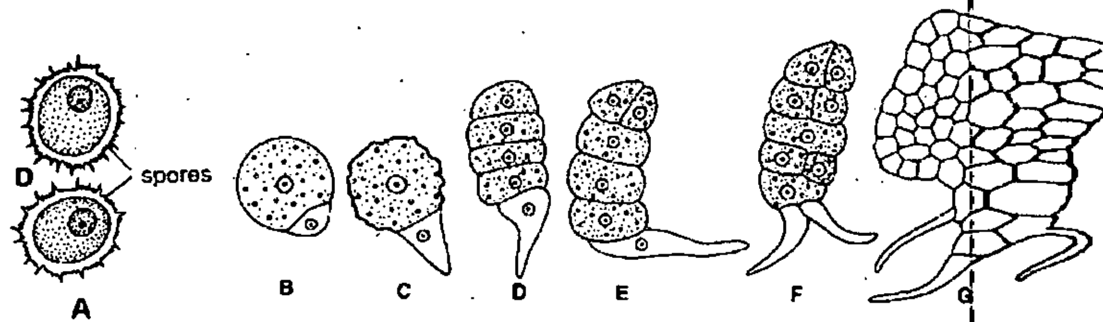


Fig. 13. (A-G). *Marchantia*. Successive stages in the germination of spore and development of sporophyte.

Marchantia is **dioecious**, 50% of the spores develop into male thalli and 50% develop into female thalli (Fig. 14).

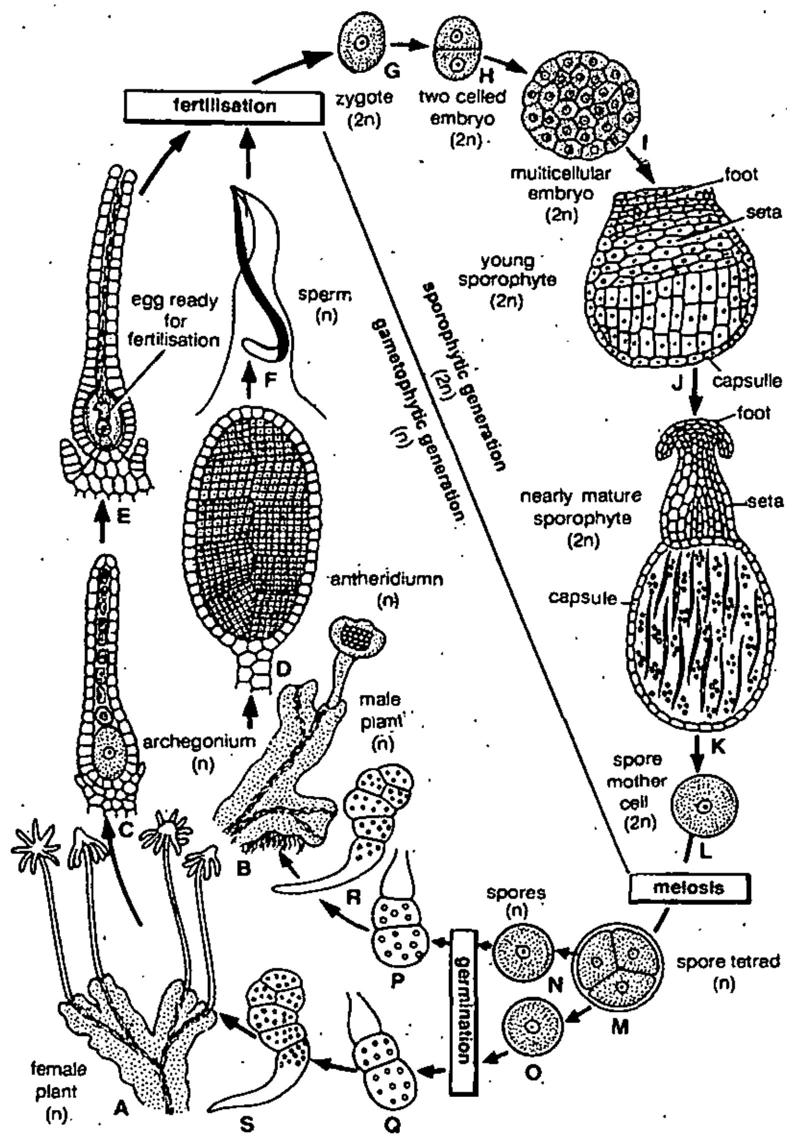


Fig. 14. *Marchantia*. Diagrammatic representation of the sexual life cycle.

Alternation of Generation. The life cycle of *Marchantia* shows regular alternation of two morphologically distinct phases. One of the generations is **Haplophase** and the other is **diplophase.**

Haplophase or gametophytic phase. In *Marchantia* this phase is dominant and produces the sex organs. Sex organs produce gametes to form a diploid zygote.

Diploid phase or sporophytic phase. Zygote develops into sporophyte. In *Marchantia* sporophyte is represented by foot, seta and capsule. The sporophyte produces the spores in the capsule. The spores on germination produce the gametophyte.

• IMPORTANT QUESTIONS

Long Answer type Questions :

1. Describe briefly the life cycle of *Riccia* with the help of suitable diagrams.
2. Explain the life cycle of *Riccia* with the help of annonated diagrams only.
3. Describe the structure and development of sporophyte of *Riccia*.
4. Describe briefly the life cycle of *Marchantia* with the help of suitable diagrams.
5. Explain the life cycle of *Marchantia* with the help of annonated diagrams only.
6. Describe position, structure and development of sex organs in *Marchantia.*
7. Desrible the strucutre and development of sporophyte in *Marchania.*
8. With the help of suitable diagrams describe the structure of the antheridiophore and archegoniophore of *Marchandia.*

Short Answer Type Questions :

1. Vegetative reproduction in *Riccia.*
2. Scales and rhizoids in *Riccia.*
3. Transverse section of thallus of *Riccia.*
4 Transverse section of thallus passing through sporophyte
5. Antheridium and archegonium of *Riccia.*
6. Scales in *Marchantia.*
7. Elaters.
8. Vegetative reproduction in *Marchantia.*
9. Rhizoids in *Marchantia.*
10. Structure of thallus in *Marchantia.*

Objective Type Questions :

1. Name the aquatic species of *Riccia.*
2. How many types of rhizoids are present in *Riccia* ?
3. Internally the thallus of *Riccia* is differentiated into how many regions ?
4. Name any dioecious species of *Riccia.*
5. How many antheridia are present in the antheridial chamber of *Riccia* ?
6. Arrange the following cells in the archegonium of Bryophytes from base to apex : Neck canal cells, Cover cells, Venter canal cell and Egg cell.
7. How many thalli of *Marchantia* are formed when seven gemmae germinate ?
8. How many flagella are present in the antherozoid of *Marchantia.*
9. How many rows of neck cells are present in the neck of the archegonium of *Marchantia* ?
10. Name the structure on which the sex organs develop in *Marchantia.*
11. Name any dioecious species of *Marchantia.*
12. Name the curtain which forms a protective covering around the group of archegonia in *Marchantia.*
13. Calyptra develops from which part of the archegonium ?

Multiple Choice Questions :

1. Antiseptic properties are shown by the moss :
   (a) Funaria (b) Pogonatum
   (c) Polytrichum (d) Sphagnum
2. Protonema is a stage in the life cycle of :
   (a) Riccia (b) Marchantia
   (c) Anthoceros (d) Sphagnum
3. In Sphagnum reduction division takes place in :
   (a) Capsule (b) Archegonium
   (c) Antheridium (d) At the tip of rhizoids
4. The leaves of Sphagnum prossess :
   (a) Distinct mid-rib (b) No mid-rib
   (c) distinct mid-rib venation (d) none of the above
5. The operculum is separated from rest of the capsule by a circular groove of thin walled cells, known as :
   (a) Medulla (b) Axial cylinder
   (c) Hadrome (d) Annulus.
6. The common name of Funaria by which it is generally known as :
   (a) Pond moss (b) Peat moss
   (c) Bog moss (d) Green moss
7. The plants of *Funaria* grow :
   (a) Solitary (c) In pairs
   (c) In aggregates (d) As saprophytes
8. In *Funaria* the leaves are arranged on the stem :
   (a) Oppositely (b) Spirally
   (c) Whorled (d) Opposite decussate
9. Antheridia are mixed with paraphyses. Each paraphysis is :
   (a) Multicellular and uniseriate (b) Multicellular and multiseriate
   (c) Unicellular and branched (d) Multicellular and branched.
10. In *Funaria*, the jacket of the archegonium in venter region is :
    (a) Single layered (b) Double layered
    (c) Three layered (d) Multilayered.
11. In *Funaria* stomata having pores bounded by :
    (a) Two kidney shaped guard cells
    (b) Two dumb-bell shaped guard cells
    (c) A single ring like (annular) guard cell
    (d) A single dumb-bell shaped guard cell.
12. In *Funuria* air space is traversed by delicate filaments of elongated parenchymatous cells called as
    (a) Annulus (b) Rim
    (c) Peristome (d) Trabeculae
13. In the centre of the theca sterile part is known as
    (a) Trabeculae (b) Columella
    (c) Annulus (d) Operculum
14. In *Funaria* sporophyte, following is absent :
    (a) Foot (b) Seta
    (c) Capsule (d) Elaters.
15. The epidermal cells of the axis or stem of *Funaria* contain :
    (a) Cuticle and stomata but devoid of chloroplasts
    (b) Stomata and chloroplast but devoid of cuticle
    (c) Chlotoplasts but devoid of cuticle and stomata
    (d) Stomata.

16. The common name of Pogonatum by which it is generally known is :
    (a) Peat moss (b) Bog moss
    (b) Bog moss (d) Green moss

ANSWERS

Objective Type Questions :

1. *Riccia fluitans* 2. Two types : smooth walled and tubereulated
3. Two regions : upper photosynthetic region and lower stroage region
4. *Riccia crystallina* 5. Only one
6. Egg cell, Venter canal cell, Neck canal cells, Cover cells
7. Fourteen 8. Two 9. Six 10. Gametophore
11. *M. polymorpha* 12. Perichaetium 13. Wall of venter

Multiple Choice Questions :

1. (d) 2. (d) 3. (a) 4. (c) 5. (d) 6. (d) 7. (c) 8. (b) 9. (a) 10. (b) 11. (c) 12. (d) 13. (b)
14. (d) 15. (c) 16. (c)

14

GAMETOPHYTIC AND SPOROPHYTI ORGANISATION OF ANTHOCEROPSID (Anthocero

STRUCTURE

• FAMILY. ANTHOCEROTACEAE*

(i) Capsule is cylindrical and erect.

(ii) Epidermis is the outermost layer of the capsule wall.

(iii) Pseudoelaters are present.

(iv) Archesporium is amphithecial in origin.

(v) Columella présent *e.g., Antheoceros.*

Anthoceros (Horn-Wort)

• SYSTEMATIC POSITION :

Division	:	Bryophyt
Class	:	Anthocerotopsid
Order	:	Anthocerotale
Family	:	Anthocerotacea
Genus	:	*Anthocero*

• DISTRIBUTION AND HABITAT

Anthoceros is represented by about 200 species. All species are terrestrial an cosmopolitan in distribution. The species grow in very moist and shady places lik slopes, rocks or sides of the ditches. Some species are found growing on decaying woo (**Cavers**, 1911). Unlike other bryophytes *Anthoceros* is usually not well adapted t resist dry conditions.

In India *Anthoceros* is represented by about 25 species. Out of these three species o *Anthoceros viz., A. himalayensis, A. erectus* and *A. chambensis* are commonly foun

*Order Anthocerotales has the same characteristics as the class.

growing in the Western Himalayan region at an altitude of 5000–8000 feet (**Kashyap**, 1915). These species are also found growing in Mussoorie, Kulu, Manali, Kumaon, Chamba valley, Punjab, Madras and in plains of South India. **Mehra** and **Handoo** (1953) reported *A. himalayensis* and *A. erectus* from Simla, Nainital and Dalhousie. Some other species of *Anthoceros* and their places of occurrence are—*A. dixitii*, *A. sahyadrensis* (Poona and neighbouring hills), *A. crispulus* (Lucknow), *A. assamicus* (Assam), *A. shvianandani* (Kerala) etc. The species of *Anthoceros* may be perennial (*A. himalayensis*) or annual (*A. erectus*).

GAMETOPHYTIC PHASE

• EXTERNAL FEATURES

The gametophytic plant body is thalloid, dorsiventral, prostrate, dark green in colour with a tendency towards dichotomous branching. Such branching results into an orbicular or semiorbicular rosette like appearance of the thallus. The thallus is bilobed (*A. himalayensis*, Fig. 1 A) or pinnately branched (*A. hallii*) or spongy with large number of sub-spherical spongy bodies like a gemma (*A. gemmulosus*, Fig. 1 C) or

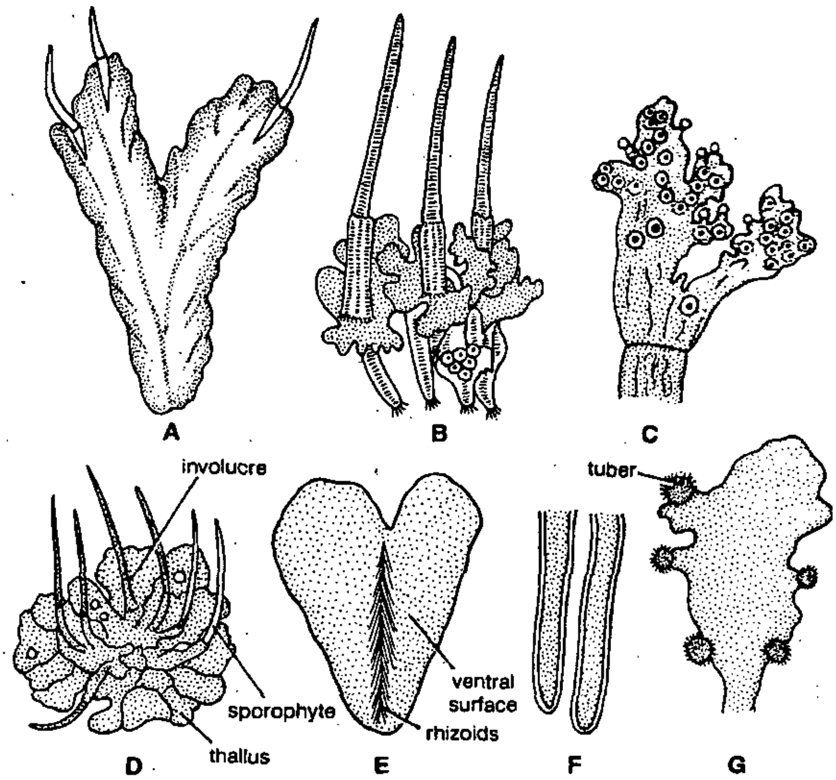


Fig. 1. (A-F). *Anthoceros.* External features (A) *A. himalayensis*, (B) *A. erectus*, (C) *A. gemmulosus*, (D) *A. crispulus* (dorsal surface), (E) Ventral surface, (F) Smooth–walled rhizoids, (G) Thallus with tubers.

raised on a thick vertical stalk like structure. (*A. erectus*, Fig. 1 B)

Dorsal Surface. The dorsal surface of the thallus may be smooth (*A. laevis*) or velvety because of the presence of several lobed lamellae (*A. crispulus*) or rough with spines and ridges (*A. fusiformis*). It is shining, thick in the middle and without a distinct mid rib (Fig. 1 D).

Ventral Surface. The ventral surface bears many unicellular, smooth–walled rhizoids (Fig. 1 E, F). Their main function is to anchor the thallus on the substratum and to absorb water and mineral nutrients from the soil. Tuberculated rhizoids, scales or mucilaginous hairs are absent. Many small, opaque, rounded, thickened dark bluish green spots can be seen on the ventral surface. These are the **mucilage cavities** filled with *Nostoc* colonies.

In the month of September and October the mature thalli have erect, elongated ar cylindrical sporogonia. These are horn like and arise in clusters. Each sporogoniu is surrounded by a sheath like structure on its base. It is called **involucre** (Fig. 1 D)

• INTERNAL STRUCTURE

The vertical transverse section (V. T. S.) of the thallus shows a very simp structure. It lacks any zonation (Fig. 2 A, B). It is uniformly composed of thin walle parenchymatous cells. The thickness of the middle region varies in different species. is 6–8 cells thick in *A. laevis*, 8–10 cells thick in *A. punctatus* and 30–40 cells thick in *crispulus*. The outer most layer is **upper epidermis.** The epidermal cells ar regularly arranged, smaller in size and have large lens shaped chloroplasts. In *A. hall* the epidermal layer is not distinguishable.

Each cell of the thallus contains a single large discoid or oval shaped **chloroplas** Each chloroplast encloses a single, large, conspicuous body called **pyrenoid,** characteristic feature of class Anthocerotopsida (Fig. 2 C, D). 25–300 disc to spindl shaped bodies aggregate to form pyrenoid. The number of chloroplasts per cell als varies in different species. In *A. personi* each cell has two chloroplasts and in *A. hall* the number may be even four. The nucleus lies in the close vicinity of the chloroplas near the pyrenoid (Fig. 2 D). Sometimes the chloroplast encircles the nucleus in (Fig. 2 E).

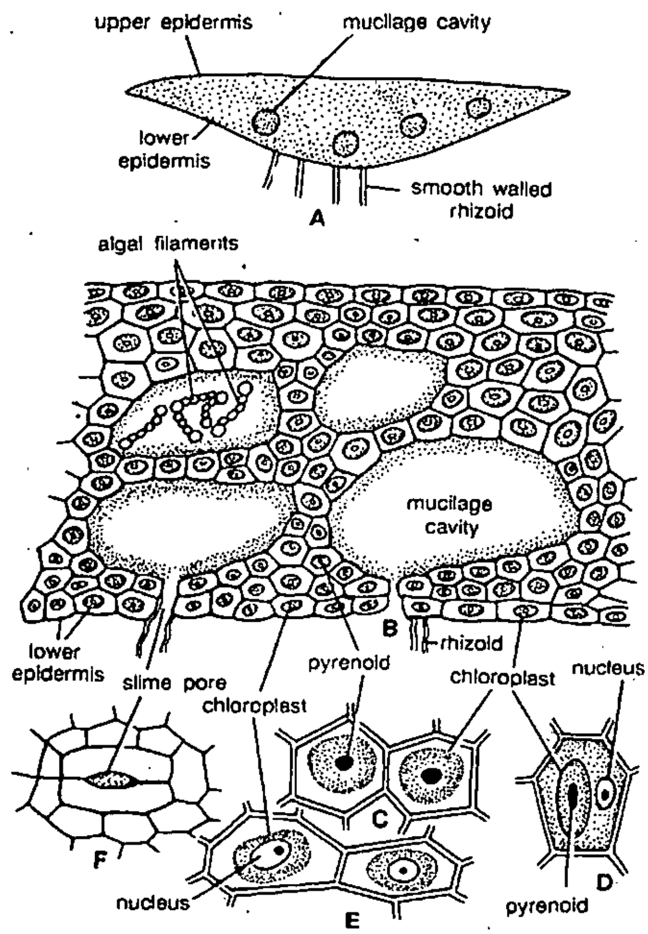


Fig. 2. (A-F). ***Antheceros.*** **Internal structure of the thallus. (A) Vertical transverse section (V.T.S.) of thallus (diagrammatic), (B) V.T.S. of thallus (a part cellular), (C) Cells showing chloroplast and pyrenoid, (D) cells showing chloroplast, pyrenoid and nucleus, (E) Parenchymatous cells with chloroplast and nucleus, (F) Surface view of slime pore.**

The air chambers and airpores are absent in *Anthoceros*. However, in a few species intercellular cavities are present on the lower surface, filled with mucilage and are alled **mucilage cavities.** These cavities open on the ventral surface through stoma ike slits or pores called **slime pores** (Fig. 2 B). Each slime pore has non-functional two guard cells with thin walls (Fig. 2 F). The pore remains completely open. The slime pores represent the vestigial remanents of a previously existing aerating system. With the maturity of the thallus the mucilage in the cavities dries out. It results in the formation of air filled cavities. The blue green algae *Nostoc* invades these air cavities through slime pores and form a colony in these cavities. The presence of *Nostoc* colonies n the thallus of *Anthoceros* is beneficial for the growth of gametophyte is not definitely known. **Pierce** (1906) assumed that the thalli without *Nostoc* grow better than the ones containing the endophytic algae. However, according to **Rodgers** and **Stewart** (1977) it is a symbiotic association. The thallus supplies carbohydrates to the *Nostoc* and the latter, in turn, adds to nitrate nutrients by fixing atmospheric nitrogen.

Some cells of the lower epidermis extend to form the smooth–walled rhizoids (Fig. 2 B).

REPRODUCTION

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

Vegetative Reproduction

It takes place by the following methods :

1. By death and decay of the older portion of the thallus or fragmentation. The older portion of the thallus starts rotting or disintegrates due to ageing or drought. As it reaches upto the place of dichotomy, the lobes of the thallus get separated. Thus, detached lobes develop into independent plants by apical growth. This method is not so common in *Anthoceros* as in liverworts.

2. By Gemmae. In some species of *Anthoceros* like *A. glandulosus*, *A. propaguliferus*, *A. formosae* many multicellular stalked structures develop along the margins of the dorsal surface of the thallus. These structures are called **gemmae.** When detached from the parent thallus, each gemma develops into new plant.

3. By tubers. Under unfavourable conditions or prolonged drought, the marginal tissue of the thallus get thickened and forms the perennating tubers. (Fig. 1 G). Their position varies in different species. They may develop behind the growing points (*A. laevis*) or along the margins of the thallus (*A. hallii*, *A. pearsoni*). In *A. himalayensis* the tubers are stalked and develop along the margins on the ventral surface of the thallus.

The tubers enclose the tissue containing oil globules, starch grains and aleurone granules. They are capable to pass on the unfavourable conditions. On resumption of favourable conditions tubers produce new thalli.

4. By apospory. In *Anthoceros*, unspecialised cells of the many parts of the sporogonium (for *e.g.*, intercalary meristematic zone, subepidermal and sporogenous region of the capsule) form the gametophytic thallus. This phenomenon is called **apospory (Schwarzenbach**, 1926, **Lang,** 1901). The thalli are diploid but normal in appearance *e.g.*, *A. laevis*.

5. By persistant growing apices. Due to prolonged dry summer or towards the end of the growing season, the whole thallus in some species of *Anthoceros* (*A. pearsoni*, *A. fusiformis*) dries and gets destroyed except the growing point. Later it grows deep into the soil and becomes thick under unfavourable conditions. It develops into new thallus.

Sexual reproduction

Sexual reproduction is **oogamous.** Male reproductive bodies are known as **antheridia** and female as **archegonia.** Some species of *Anthoceros* like *A. longii*, *A. gollani*, *A. fusiformis*, *A. punctatus*, *A. crispulus* and *A. himalayensis* are **monoecious** while some species like *A. erectus*, *A. chambensis*, *A. hallii*, *A. pearsoni* and *A. laevis* are **dioecious.** The monoecious species are **protandrous** *i.e.*, antheridia mature before archegonia.

Antheridium

Structure. A mature antheridium of *Anthoceras* has a stalk and club or pouc body. The stalk attaches the antheridium to the base of the antheridial chamber. may be slender and composed of four rows of cells (*e.g.*, *A. punctatus*, *A. erectus*, Fig or more massive (*e.g.*, *A. laevis* Fig. 3 J). A single or a group of two to four or antheridia are present in the same antheridial chamber (Fig. 3 H). A single lay sterile jacket encloses the mass of androcytes which metamorphosis into antheroz In some species for *e.g.*, *A. punctatus* and *A. erectus* jacket layer is formed of four ti reactangular cells (Fig 3 I). In *A. laevis* and *A. himalayensis* jacket is composed of n relatively smaller and less regularly arranged cells (Fig. 3 J). The cells of the u most tier are triangular with a narrow end towards the apex (Fig. 3 I) and con plastids. At maturity these plastids change their colour from green to red to br orange. Young antheridia are, therefore, green and mature one turn bright orang reddish.

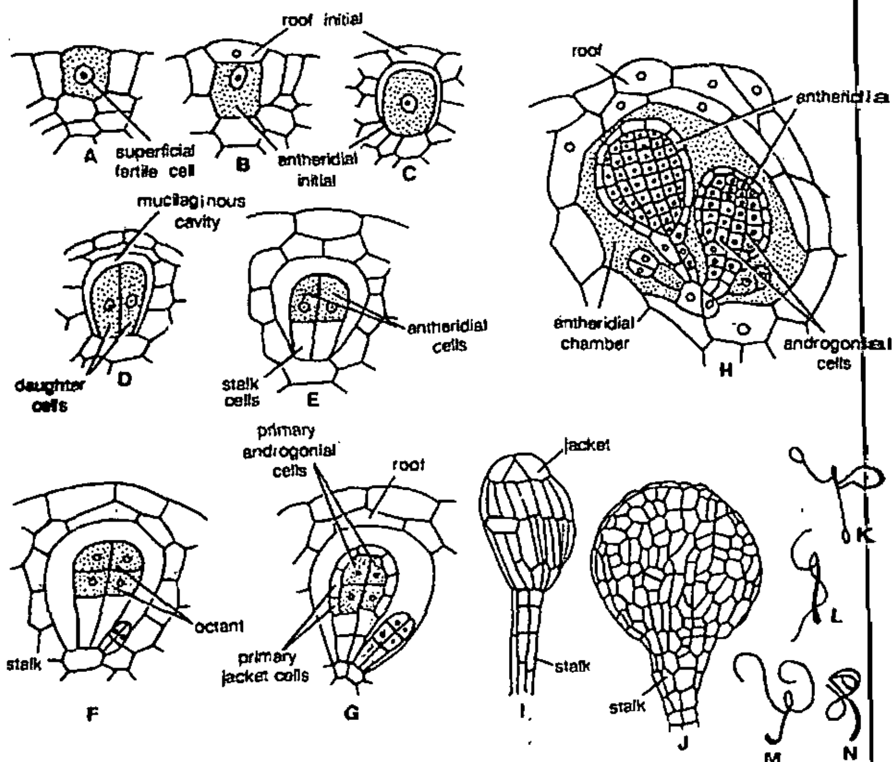


Fig. 3. (A-N) *Anthoceros*. (A-H) Successive stages in the development of antheridium, (I) Mature antheridium of *A.punctatus* (J) Mature antheridium of *A. laevis*, (K, L) Antherozoids of *A. laevis*, (M, N) Antherozids of *A. punctatus*.

The Antherozoid. A mature antherozoid is unicellular, uninucleate, biflagellat and has a linear body. The flagella are of almost the same length as the bo (Fig. 3 K, L).

Development. The development of the antheridium starts from a superficial dors cell with a periclinal division into an outer **roof initial** and inner **antheridial initi** (Fig. 3 A, B). Unlike the class Hepaticopsida (*e.g.*, *Marchantia*), the antheridiu develops from the inner cell. Therefore, the antheridium is **endogenous** in orig Soon after the division a mucilaginous filled space develop between the antherid initial and roof initial. (Fig. 3 C). The roof initial divides by periclinal divisions follow by many anticlinal divisions to form **two layered** roof of the antheridial chamber. T antheridial initial either directly develops into a single antheridium (*e.g.*, *A. pearsor* or it may divide vertically into two, four or sometimes more daughter cells (*e.g.*, *erectus*). Each of the daughter cells functions as antheridial initial. The antheridi initial divides by two vertical divisions at right angle to each other to form four ce (Fig. 3 D). All the four cells divide by transverse division to form eight cells, arranged two tiers of four cells each (Fig. 3 E). The cells of the lower tier are called **stalk cells.** These cells form multicellular stalk of the antheridium. The four cells of the upper tier form the body of the antheridium. These cells divide by transverse division (Fig. 3 F). To form the eight outer **primary jacket cells** and eight inner **primary androgonial cells** (Fig. 3 G). Primary androgonial cells divide by several repeated transverse and vertical division resulting in the formation of large number of small cubical **androgonial cells.** The last generation of androgonial cells is known as **androcyte mother cells.** Each androcyte mother cell divides by a diagonal mitotic division to form the two triangular cells called **androcytes.** The protoplast of each androcyte metamorphosis into biflagellated **antherozoid.** A single antheridial chamber consists varying number of antheridia in different stages of development (Fig. 3 H).

Dehiscence of Antheridium. Water helps in the dehiscence of the antheridium. As the antheridia mature, the roof of the antheridial chamber breaks down irregulary, exposing the antheridia in a cup like chamber. The antheridia absorb water and the uppermost tier of triangular cells fall apart releasing a mass of antherozoids. After dehiscence the antheridium loses turgour and collapses. It is followed by another antheridia to converge towards the opening in the roof and in this way a continuous stream of antherozoids is possible. It explains the formation of large number of sporophytes in Hornworts.

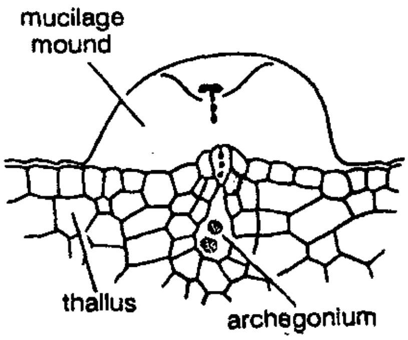


Fig. 4. ***Anthoceros.*** **Mature archegonium with mucilage mound.**

Archegonium. Archegonia develop in the flesh of the thallus on dorsal surface. The place of an archegonium on a thallus can be identified by the presence of a mucilage mound (Fig. 4).

Structure. A mature archegonium consists of two to four cover cells, an axial row of four to six neck canal cells, a venter canal cell and an egg. (Fig. 5 G, H).

Development. The development of the archegonium starts on the dorsal surface of the thallus from a single superficial cell which acts as an **archegonial initial** (Fig. 5 A). It can be differentiated from other cells by its dense protoplasm. The archegonial initial may divide by transverse division to form an upper **primary archegonial cell** and lower **primary stalk cell** (*e.g., A. crispulus, A. gemmulosus*) or it may directly functions as **primary archegonial cell** (*e.g.,A. erectus*). The primary archegonial cell divides by three successive periodical vertical walls to form **jacket initials** and a fourth median cell, the **primary axial cell** (Fig. 5 B, C). Jacket initials divide by transverse divisions to form into two tiers of three cells each. The cells of the upper tier divide by anticlinal division to form six cells. These cells divide transversely to form a jacket of six rows of sterile neck cells. The three cells of the lower tier divide by transverse and vertical divisions to form venter wall. Since the archegonium is embedded in the thallus, it is difficult to trace the development of the cells and to distinguish them from the vegetative cells (Fig. 5).

The primary axial cells divide by a transverse division to form an **outer cell** and **inner (central) cell** (Fig. 5 D). The outer cell divides by a transverse division to form terminal **cover initial** and inner **primary neck canal cell** (Fig. 5 E). The inner cell directly functions as **primary venter cell** and divide only once to form upper small **venter canal cell** and a lower large **egg.** Primary neck canal cell divides by series of transverse divisions to form four to six neck canal cells. Cover initial divides by one to two vertical divisions to form two to four rosette like cover cells at the tip of the neck (Fig. 5 G, H).

Fertilization. Water is essential for fertilization. In the mature archegonium, the venter canal cell, neck canal cells disintegrate and form a mucilaginous mass. It absorbs water, swells up and comes out of the archegonial neck by pushing the cover cells apart. This mucilaginous mass becomes continuous with the mucilage mound and in this way an open passage down to egg is formed. The mucilaginous mass consists of

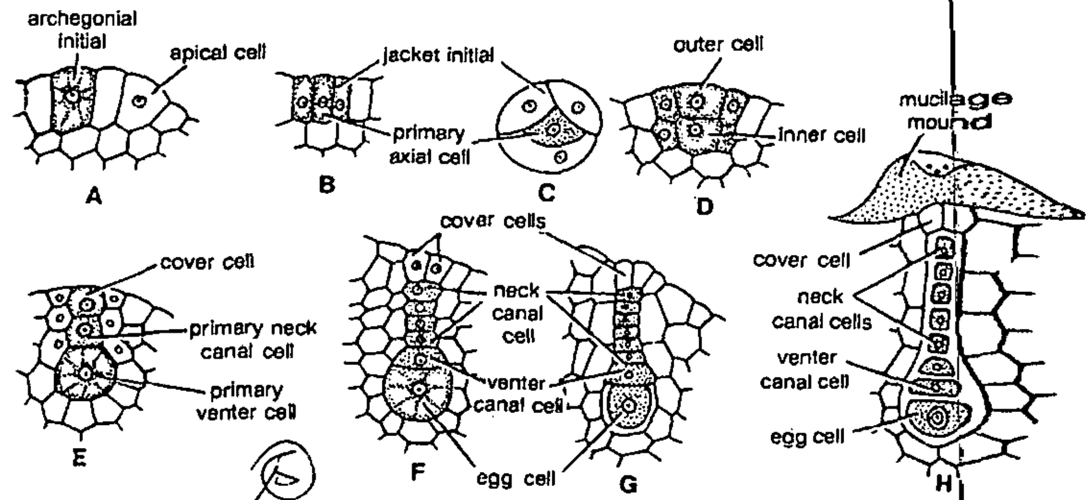


Fig. 5. (A-H). ***Anthoceros*. Development of archegonium. (A-H). Successive stages in the development of archegonium.**

chemical substances. Many antherozoids caught in the mucilage enter in th archegonial neck because of the chemotactic response, reach upto the egg, an fertilization is effected. Prior to fertilization, egg enlarges and fills the cavity of th venter. Fusion of both male and female nuclei results in the formation of diploi **zygote** or **oospore**. Fertilization ends the gametophytic phase.

SPOROPHYTIC PHASE

After fertilization the diploid zygote or oospore still enlarges in size and fills th cavity of the venter of the archegonium. It secretes an outer cellulose wall.

Development of sporophyte. The first division of the zygote (Fig. 6 A, B) i vertical. In other Bryophytes the first division of the zygote is transverse. This is th important difference in the development of sporophyte of Hornworts and rest of th Bryophytes. The second division is transverse (Fig. 6 C) and is so oriented that th upper two cells are usually longer than the lower two (quadrant stage). All the four cell divide by vertical walls to produce eight cells (octant stage). The eight cells ar arranged in two tiers of four cells each.

Further development of the sporophyte varies in different species. In majority of the species like *A. fusiformis, A. pearsoni* and *A. himalayensis* upper tier of four cells divide by transverse division to form three tiers of four cells each (Fig. 6 D). The lowermost tier forms the **foot**, the middle tier forms the **meristematic zone** or **intermediate zone** and uppermost tier develops into the **capsule.**

The four cells of the lower tier divide by irregular divisions to form broad, bulbous foot, made up of parenchymatous cells. In some species (*e.g, A. punctatus*) the superficial cells of the foot form a palisade layer of cells while in some species (*e.g., A. laevis, A. himalayensis*) the superficial layer grows into haustoria like projections. The uppermost tier of four cells which forms the capsule divide by one to two transverse divisions to form two to three tiers of cells. It is followed by periclinal division to form an outer layer of amphithecium and the central mass of cells called **endothecium** (Fig. 6 F). The entire endothecium develops into the sterile **columella.** In young sporophyte it is made of four cells but in mature sporophyte it is made of **sixteen vertical rows** (Fig. 6 D, E) of cells (4 × 4). The amphithecium divides by a periclinal division to differentiate into an outer sterile layer of **jacket initials** and inner **fertile layer** (Fig. 7 A). The cells of the jacket initials divide by anticlinal and periclinal divisions to form **four to six layered capsule wall**. The outermost layer of the capsule wall is called **epidermis** (Fig. 8 A). It is characterised by the presence of stomata (Fig. 6 F). The cells of the inner layers of capsule wall have chloroplast.

In young sporophyte the archesporium over archs the columella (Fig. 6 G). The archesporium may single layered in thickness throughout in its further development

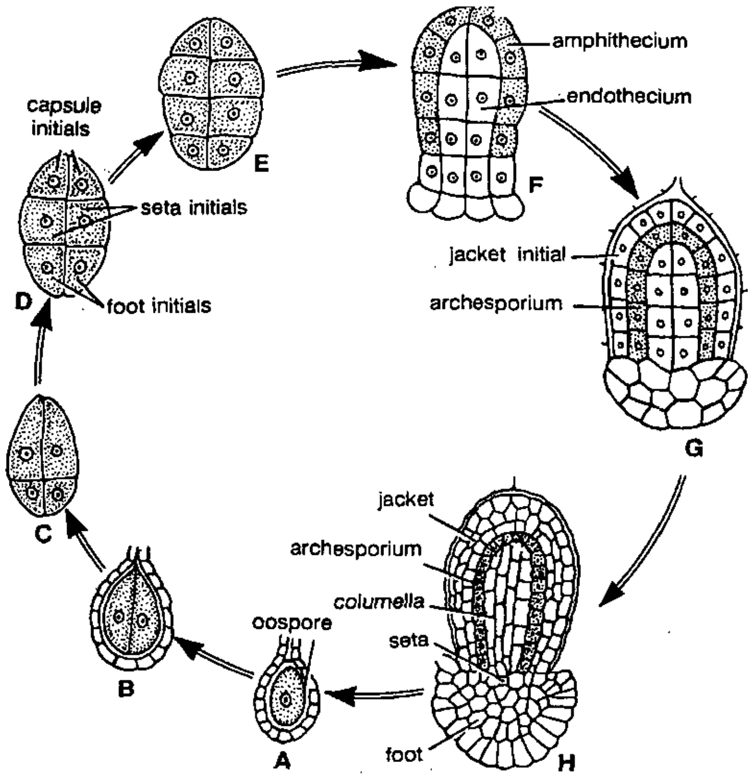


Fig. 6. (A-H). *Anthoceros*. Successive stages in the development of sporophyte.

(*e.g.*, *A. erectus*) or become two layered (*e.g.*, *A. pearsoni*) or two to four layered (*e.g.*, *A. hallii*). On maturity the archesporium gives rise to two types of cells: **spore mother cells** and **elater mother cells**. These cells are arranged in alternate manner one above the another (Fig. 7 A). Spore mother cells are spherical or oval with dense cytoplasm and large nuclei. These cells divide by meiotic divisions to form **spore tetrads** (Fig. 7 A). Elater mother cells are elliptical with small nuclei. These cells divide mitotically to form four celled elaters. The four cells of the elaters may remain attached to each other or may break into 1-celled, 2-celled or 3-celled units. The broken units are called **pseudoelaters**. (The elaters are without thickening bands and therefore, called pseudoelaters, Fig. 7 A). By the activity of the meristematic zone various tissues of the capsule are continuously produced so that it becomes elongated.

The young sporophyte of the *Anthoceros* is surrounded by a fleshy covering or sheath. It is called **involucre** (Fig. 7 A). It is developed partly from the tissue of the archegonium and partly from the tissue of the gametophytic thallus. In young stages the sporophyte is completely surrounded by involucre.

Structure of mature sporogonium

The mature sporophyte consist a bulbous **foot** and a smooth, slender, erect, cylindrical, structure called **capsule.** Capsule varies in length from two to fifteen centimeter in different species. The sporogonium appears like a 'bristle' or 'horn', hence, the species are called 'hornworts' (Fig. 1 A, 7 A).

Internal structure. A mature sporogonium can be differentiated into three parts *viz.*, the **foot, seta** and the **capsule.**

Foot. It is bulbous, multicellular and made up of a mass of parenchymatous cells. It acts as an haustorium and absorbs food and water from the adjoining gametophytic cells for the developing sporophyte (Fig. 7 A).

Meristematic Zone or Intermediate Zone or Intercalary Zone. Seta is represented by meristematic zone. This is present at the base of the capsule and consists meristematic cells. These cells constantly add new cells to the capsule at its base. The presence of meristem at the base enables the capsule to grow for a long period and form spores. It is a unique feature of *Anthoceros* and is not found in any ot bryophyte. We are able to see different stages of development from base upwards in sporogonium of *Anthoceros* (Fig. 7 A).

Capsule. Its internal structure can be differentiated into following parts :

Columella. It is central sterile part, extending nearly to its tip. It is endothecial

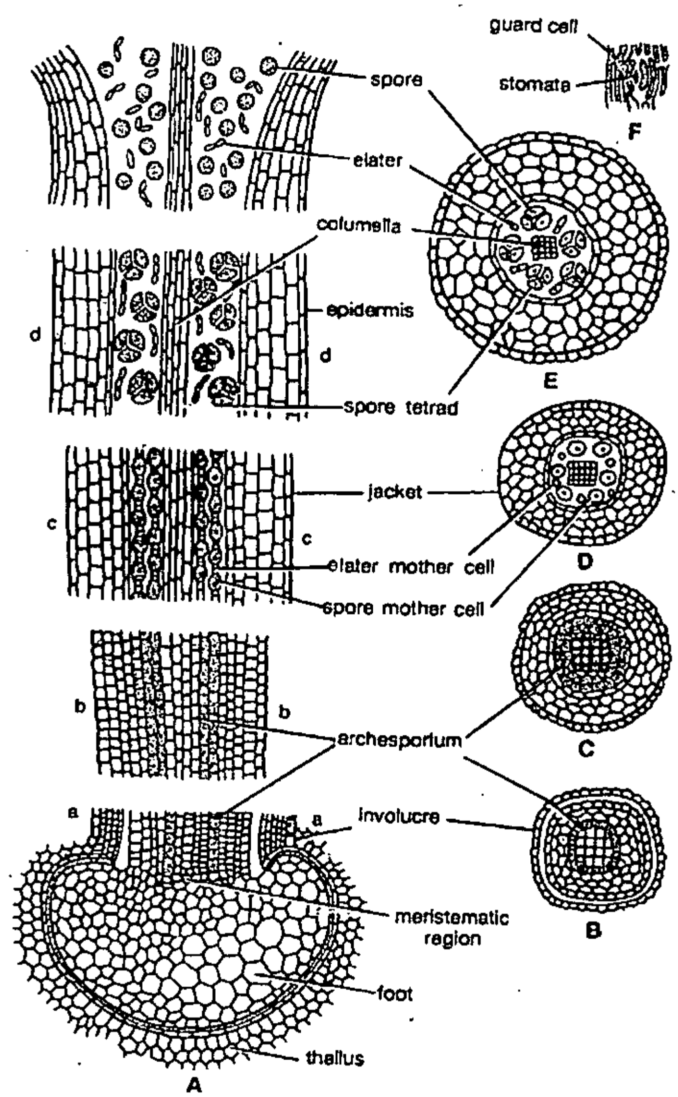


Fig. 7. (A-F). ***Anthoceros*. Internal structure of the sporogonium (A) Longitudinal Section (L.S.) through the mature sporogonium. (B) Cross section of the sporogonium at a–a level (C) cross section of the sporogonium at b–b level, (D) cross section of the sporogonium a c–c level, (E) Cross section of the sporogonium at d–d level, (F) Structure of stomata from the epidermis of sporogonium wall.**

origin. In young sporophyte it consists of four vertical rows of cells but in matu sporophyte it is made up of 16 vertical rows of cells (4 × 4). In a transverse section thes cells appear as a solid square (Fig. 7 D, E). It provides mechanical support, functions a water conducting tissue and also helps in dispersal of spores.

Archesporium. It is present between the capsule wall and the columella. It extenc from base to the top of the capsule. It originates from the inner layer of amphithecium In young sporophyte it over arches the columella (a feature in contrast to liverworts).

In a few species of *Anthoceros* for *e.g.*, *A. crenatifrons*, *A. hawaiensis* and *A. erectu* the archesporium may remain one cell in thickness throughout its furthe development. However, in *A. pearsoni* and *A. himalayensis* it may become two layere

;hick a little above the base. In *A. hallii* it may even become two to four cells in ,hickness (Fig. 7 A, a-a). In upper part of the capsule it is differentiated into sporogenous tissue which produce spores and pseudoelaters. Pseudoelaters may be unicellular or multicellular, branched or unbranched and may consiss more or less elongated cells (Fig. 8 A–D). The spiral thickenings are absent (characteristic of *Anthoceros*) but in *A. physocladus* the cells have long and thick walls with extremely reduced lumen (**Pande**, 1960). In some species of *Anthoceros* their secondary walls possess helical thickenings (**Proskauer**, 1960).

Capsule wall. It consists of four to six layers of cells, of which the outermost layer is epidermis (Fig. 8 A, d-d). The cells of the epidermis are vertically elongated and have deposit of cutin on their walls. The continuity of epidermis is broken by the presence of stomata. The stomata are oriented vertically with the axis of the sporogonium and are widely separated from each other. Each stoma consists a pore surrounded by two guard cells (Fig. 7 F). The cells of the inner layers have intercellular spaces and contain chloroplast. Thus, the sporogonium is partially self sufficient to synthesize its own organic food but partially it depends on the gametophyte for the supply of water and mineral nutrients.

Dehiscence of the capsule. Capsule dehisces basipetally *i.e.*, from apex to base. As the capsule matures, its tip becomes brownish or black. Vertical lines of dehiscence appear in the jacket layer (Fig. 8 E). The dehiscence of the capsule is usually by two longitudinal lines, occasionly it is by single line (Fig. 8 F) or rarely by four lines. The capsule wall dries and shrinks at maturity. Consequently narrow slits appear in the capsule wall all along the shallow grooves (line of dehiscence), which gradually widen and extend, towards the base. (In *A. crispulus* capsule splits first along one line of dehiscence and it is followed by splitting along other line of dehiscence). It results in the formation of two valves of the capsule wall (Fig. 8 G). Still attached at the tip and exposing the columella is the mass of spores and pseudoelaters. The two valves thus separated, diverge and twist hygroscopically. The pseudoelaters also dry out, twist and helps to loosen the spores. Thus, the twisting of the valves and the movement of the pseudoelaters in the exposed spore mass helps in the shedding of the spores. Air currents also helps in the dispersal of spores.

Structure of spore. The spores are haploid, uninucleate, semicircular with a conspicuous triradiate mark (Fig. 9 A). Each spore remains surrounded by two wall layers. The outermost layer is thick ornamented and is known as **exospore.** It varies in colour from dark brown to black (*e.g.*, *A. punctatus*) or yellowish (*e.g.*, *A. laevis*). The inner layer is thin and is known as **endospore.** Wall layers enclose colourless plastids, oil globules and food material.

Germination of spore and formation of young gametophyte. Under favourable conditions the spores germinate immediately in *A. erectus* and *A. punctatus* (**Mehra** and **Kachroo**, 1962). However, in *A. fusiformis* the spores undergo a resting period of few weeks or months before germination (**Campbell**, 1928). At the time of germination spore absorbs water and swells up. Exospore ruptures at the triradiate mark and endospore comes out in the form of a tube. It is called **germ tube** (Fig. 9 B). Contents migrate into the germinal tube where the colourless plastids turn green. Two successive transverse walls are laid down at the tip of the germinal tube resulting in the formation of three celled filament (Fig. 9 C, D). The upper cell divides by a vertical division (Fig. 9 E) followed by similar vertical division in the lower cell (quadrant stage Fig. 9 F). These four cells again divide by a vertical division at right angle to first to form eight cells (octant stage). This octant stage is known as **sporeling**. The distal tier of four cells function as apical cells and form the new gametophyte. First rhizoid develops as an elongation of any cell of the young thallus (Fig. 10 G, H). As the growth proceeds, the mucilage slits appear on the lower surface and these slits are infected by *Nostoc*.

Alternation of Generation. The life cycle of *Anthoceros* show regular alternation of two morphologically distinct phases. One of these generations is **haplophase** and the other is **diplophase.**

Haplophase or gametophytic phase. In *Anthoceros* this phase is dominan produces the sex organs. Sex organs produce gametes to form a diploid zygote.

Diploid phase of sporophytic phase. Zygote develops into sporophyt *Anthoceros* sporophyte is represented by foot, meristematic zone and capsule sporophyte produces the spores in the capsule. The spores on germination produc gametophyte.

So, in *Anthoceros*, two morphologically distinct phases (haplophase and diplop constitute the life cycle. The life cycle of this type which is characterised by altern of generation and sporogenic meiosis is known as **heteromorphic diplohaplontic**. (Fig. 10, 11).

• AFFINITIES OF *Anthoceros* OR PRIMITIVE AND ADVANCED CHARACTERS OF *Anthoceros*

The thallus of *Anthoceros* shows both primitive and advanced charac *Anthoceros* on one hand forms a connecting link with the Chlorophyceae (green al liverworts, mosses and on the other hand it is linked with primitive Pteridophyte

Primitive Characters

1. Resemblances with Chlorophyceae (green algae) :

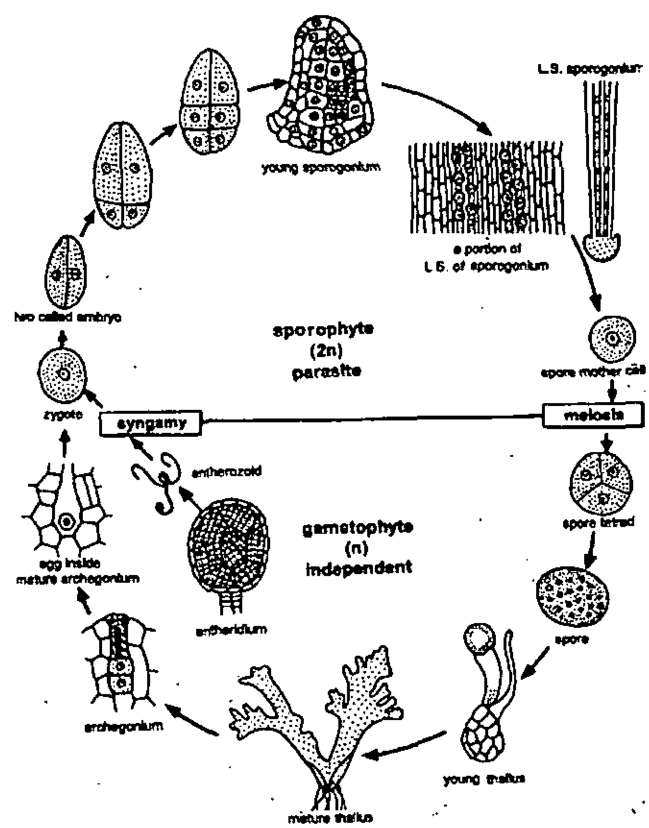


Fig. 9. (A–H). *Anthoceros*. Successive stages in the germination of spore and formation of gametophyte.

(a) Simple, green, gametophytic thalloid plant body.

(b) Presence of less number of chloroplasts per cell.

(c) Definite shape of the chloroplast.

(d) Presence of pyrenoid.

(e) Structure and function of pyrenoid is similar to that of green algae (form sta grains at periphery).

2. Resemblances with liverworts :

(a) Simple, green, gametophytic plant body, without any differentiation of tissues like *Pellia*.

(b) Similar apical growth.

(c) Biflagellated antherozoids.

(d) Periclinal division separates amphithecium and endothecium.

(e) Archesporium is differentiated into spore mother cells and elater mother cells.

Advanced Characters :

1. Resemblances with mosses :

(a) Presence of highly differentiated and ventillated system in the capsule wall.

(b) Presence of columella (endothecial in origin).

(c) Presence of reduced archesporium.

(d) Archesporium archs over the columella like *Sphagnum*.

2. Resemblance with Pteridophytes :

(a) Gametophytic plant body resembles with fern prothallus.

(b) Sunken sex organs.

(c) Structure of archegonium is similar.

(d) Semiparasitic sporophyte of *Anthoceros* resembles with primitive fossil vascular plants of order Psilophytales.

• IMPORTANT QUESTIONS

Long Answer Type Questions :

1. Describe briefly the life cycle of *Anthoceros* with the help of suitable diagrams.
2. Describe position, structure and development of sex organs in *Anthoceros*.
3. With the help of labelled diagrams explain the structure and development of sporophyte of *Anthoceros*.
4. Explain the structure of the *Anthoceros* sporogonium. In what features it differs from sporogonium of other Bryophytes studied by you.
5. Give an account of the life history of *Anthoceros* and mention about its phylogenetic importance.
6. Give a comparative account of the sporophyte of *Marchantia* and *Anthoceros*.

Short Answer Type Questions :

1. Structure of gametophyte of *Anthoceros*.
2. Structure of mature sporophyte of *Anthoceros*.
3. Vegeative reproduction in *Anthoceros*.
4. Pseudoelater.
5. Compare the structure of the gametophytes of *Marchantia* and *Anthoceros*.
6. Archegonium of *Anthoceros*.
7. Internal structure of thallus of *Anthoceros*.
8. Transverse section (T.S.) of thallus of *Anthoceros*.
9. Meristematic zone.
10. Importance of the study of *Anthoceros*.
11. Development of antheridium in *Anthoceros*.
12. Morphology of *Anthoceros* plant.
13. Mucilaginous cavities.
14. Mechanism of dispersal of spores in *Anthoceros*.

Objective Type Questions :

1. Name the sterile part present in the centre of the mature sporophyte of *Anthoceros*.
2. Name the species where the archesporium is single layered throughout in sporophyte of *Anthoceros*.
3. Name any dioecious species of *Anthoceros*.
4. Give the name of any perennial species of *Anthoceros*.
5. Sporophyte of which Bryophyte (included in your syllabus) contains columella ?
6. Mention the shape of antheridia in *Anthoceros*.
7. How many vertical rows of cells are found in stalk of *Anthoceros* ?
8. How many layered wall is present in the capsule of *Anthoceros* ?

ANSWERS

Objective Type Questions :

1. Columella
2. *A. crenatifrons, A. erectus, A. hawaiensis*
3. *A. laevis*
4. *A. himalayensis*
5. *Anthoceros, Funaria*
6. Club or Pouch shaped
7. Four
8. Four to six

15

GAMETOTOPHYTIC AND SPOROPHYTIC ORGANISATION OF BRYOPSIDA (*Funaria*)

STRUCTURE

Funaria (JOIN-TOOTHED-MOSS)

• SYSTEMATIC POSITION :

Division	:	**Bryophyta**
Class	:	**Bryopsida**
Sub-class	:	**Bryidae**
Order	:	**Funariales**
Family	:	**Funariaceae**
Genus	:	***Funaria***

• HABIT AND HABITAT

Funaria is represented by more than 117 species which are cosmopolitan in distribution. In India it is represented by about 18 species. *Funaria* grows in close tufts on moist and shady walls, soils banks and some times even on tree trunks. *Funaria hygrometrica* is the most common species.

GAMETOPHYTIC PHASE

• EXTERNAL FEATURES

Plant body is gametophytic and consists of two different stages namely (i) **Juvenile stage** represented by primary protonema and (ii) **The leafy gametophore** which represents the adult form. The adult gametophyte (gametophore) is differentiated into **rhizoids, axis** or **'stem'** and **'leaves'** (Fig. 1 A). Rhizoids arise from the base of the axis. They are slender, branched, multicellular and have oblique septa. Axis is 1—3 cm. high, upright, slender and branched. Each branch is **extra axillary** *i.e.*, arise below a leaf. Leaves are sessile, oblong-ovate with entire margin, pointed apex and are arranged spirally on the branches and 'stem'. Each 'leaf' is traversed by a single mid (Fig. 1B). 'Leaves' are borne in 1/3 phyllotaxy which becomes 3/8 at maturity.

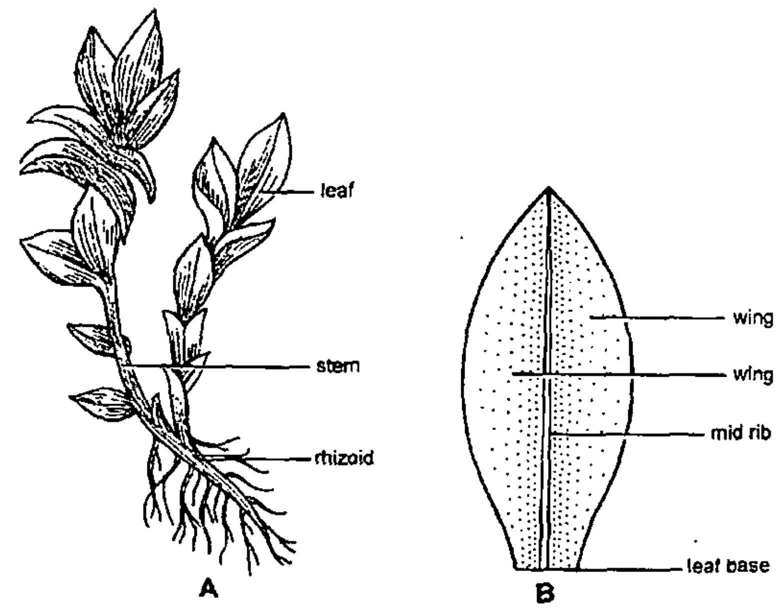


Fig. 1. (A, B). *Funaria*. (A) A plant, (B) Outline sketch of a leaf.

• INTERNAL STRUCTURE

1. Axis or 'stem'

The transverse section (T. S.) of axis can be differentiated into three distin regions :

(i) Epidermis

(ii) Cortex

(iii) Central conducting strand or central cylinder.

(i) Epidermis. It is the outer most single layered protective covering consisting small tangentially elongated chlorophyll bearing cells. Cuticle and stomata are absen (Fig. 2).

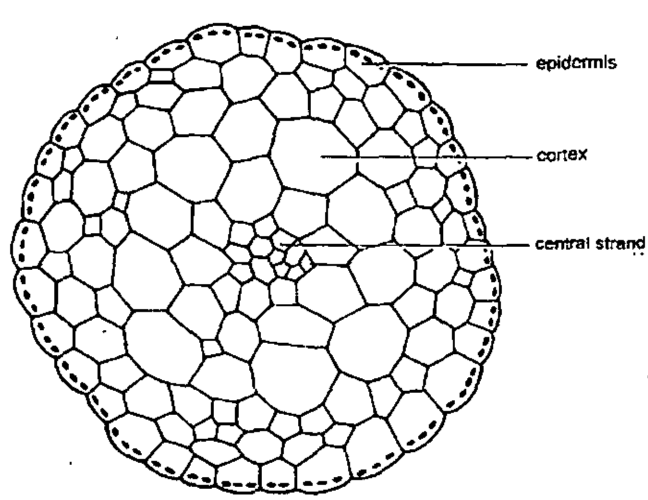


Fig. 2. *Funaria*. Transverse section (T.S.) of axis.

(ii) Cortex. It is present between the epidermis and conducting tissue. It is mad up to parenchymatous cells. Younger part of the cortex contain chloroplasts but in th older part they are lacking. At maturity few outer layers of cortex become thick walled and are reddish brown in colour but those of the inner layers become thin walled.

(iii) Central conducting strand. It is made up of long, narrow thin walled dead cells which lack protoplasm. These cells are now commonly called as **hydroids**. Conducting strand besides providing a certain amount of mechanical support, functions in the upward conduction of water and solutes.

2. 'Leaf'

Transverse section (T. S.) of 'leaf' shows a well defined midrib with two lateral wings. Except the midrib region, the 'leaf' is composed of single layer of *parenchymatous polygonal cells. The cells contain many large and prominent* chloroplasts (Fig. 3). The central part of the mid rib has narrow conducting strand of thick walled cells which help in conduction.

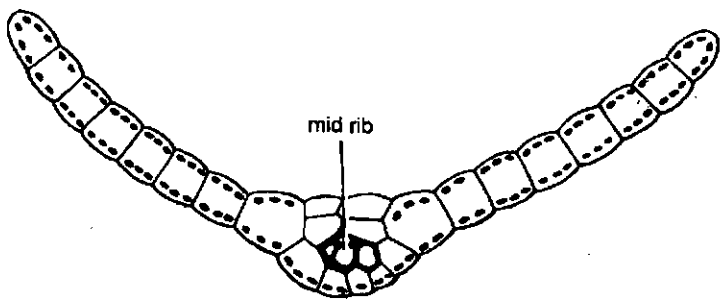


Fig. 3. ***Funaria.*** **Transverse section (T.S.) of 'leaf'**

• REPRODUCTION

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

Vegetative Reproduction

It takes place by the following methods :

1. By multiplication of primary protonema. In *Funaria*, spores on germination form a branched, filamentous, multicellular structure. It s called **primary protonema**. In it certain colourless **separation cells** are formed by intercalary divisions. These cells die out and break up the protonema into single cell or many celled *fragments. These fragments grow into new protonema* which bear buds. Each bud develops into a leafy gametophore.

2. By secondary protonema. When protonema is developed by other than the germination of spore, it is called **secondary protonema**. It may be developed from any detached living part of the gametophyte such as 'stem', 'leaves', antheridium, archegonium paraphysis, sterile cells of capsule, seta or when the rhizoids are exposed to sun light in moist atmosphere (Fig. 10 G).

3. By Gemmae. During unfavourable conditions, the terminal cells of the protonemal branches divide by transverse, longitudinal divisions and form green multicellular bodies of 10–30 cells. These are called **gemmae**. At maturity gemmae become slightly reddish brown in colour. On the return of favourable conditions gemmae germinate and form new plants.

4. By Bulbils. When such gemmae like structures are produced on rhizoids inside the substratum, these are called **bulbils**. These are devoid of chloroplasts but capable of developing into leafy individuals under favourable conditions.

5. Apospory. Development of gametophyte from sporophyte without the formation of spores is known as **apospory**. Any vegetative cell of the sporophyte may form green protonemal filaments which bear lateral buds. These buds later develop into leafy gametophores. The gametophores thus formed are **diploid.** Sexual reproduction in *such gametophores results in the formation of tetraploid (4n) zygote.*

• SEXUAL REPRODUCTION

Sexual reproduction is **oogamous.** Male reproductive structure is known **antheridium** and female as **archegonium.** *Funaria* is **monoecious** (having m and female sex organs on the same thallus) and **autoicous** (antheridia and archegon develop on separate branches of the same thallus). Sex organs are borne on lea gametophores in **terminal clusters**. The main shoot of the leafy gametophore bea antheridia and act as male branch. Female branch grows higher than the male bran *Funaria* is **protandrous** (antheridia mature before the archegonia). It ensures t cross fertilization.

Structure of an Antheridium

The antheridium is club shaped. It can be differentiated into two parts (a) sho multicellular stalk and (b) body of antheridium (Fig. 4K). Body of antheridium h sterile, **single layered jacket** of polyhedral flattened cells. When young the cells of t jacket contain chloroplasts which turn orange or reddish brown at maturity. Jack encloses a large number of **androcytes** (antherozoid mother cells). At maturity t distal end of the antheridium bears one or two thick walled, colourless cells call **operculum**. The opercular cells become mucilaginous, absorb water and swell, brea

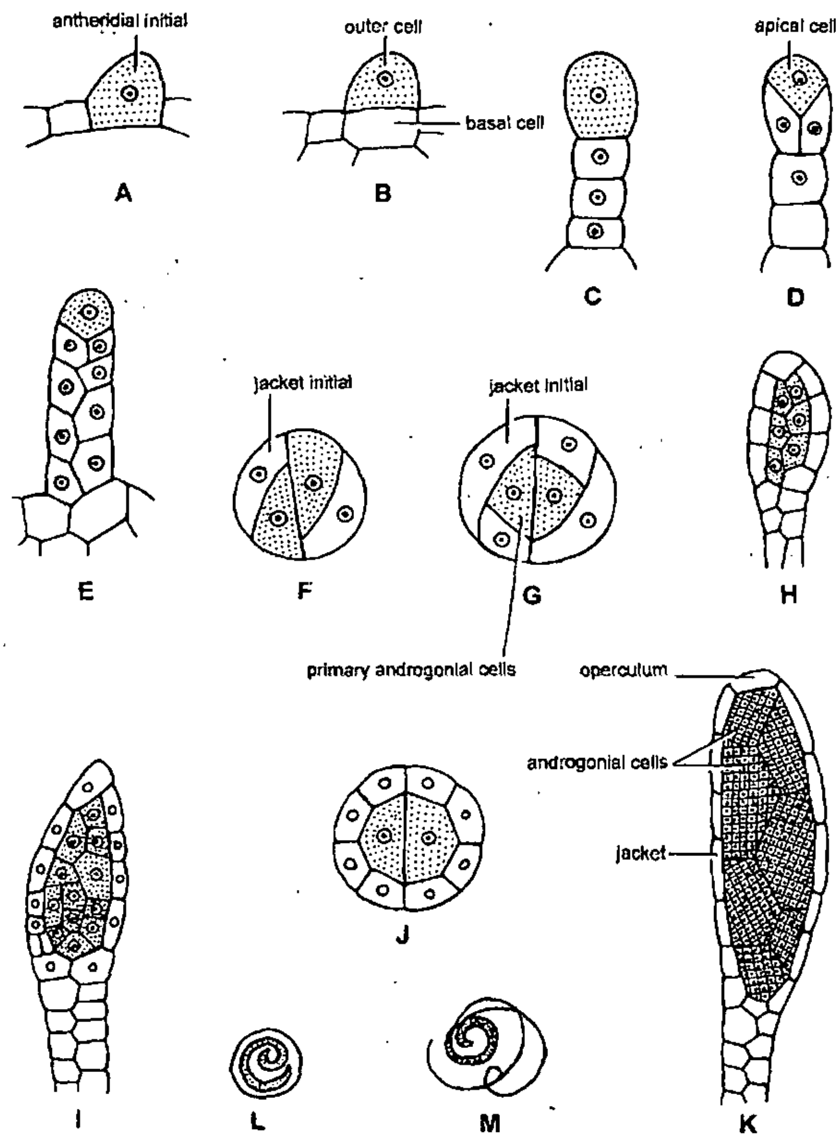


Fig. 4. (A–K). *Funaria*. Development of antheridium. (A–J). Successive stages in the development of antheridium, (K) A mature antheridium, (L) Antherozoid inside the wall of anodrocyte, (M) Free antherozoid.

connections with the neighbouring cells and form a narrow pore. Androcytes ooze out in the form of a viscous fluid through this pore.

Development of Antheridium

Antheridium develops from a single superficial slightly projected cell. It is called **antheridial initial.** It develops at the apex of the male branch. It divides by a transverse division to form a **basal cell** and an **outer cell** (Fig. 4 A, B). The basal cell form the embedded portion of the stalk. The outer cell forms the entire antheridium and is known as **antheridial mother cell.** It divides by transverse divisions to form a short filament of 2–3 cells (Fig. 4 C).

The lower cells form the lower part of the stalk of the antheridium. The terminal cell of the filament divides by two vertical intersecting walls, thus an apical cell with two cutting faces is differentiated (Fig. 4D). The apical cell cuts segments in two rows in regular alternate sequence. In this way 5–7 segments cut off (Fig. 4E). Simultaneously when the apical cell is dividing, the third or fourth segments below the apical cell, starts dividing from base, upwards by diagonal vertical walls. The first wall divide the segment into two cells of unequal size. Small cell is called **jacket initial** (Fig. 4 F). Larger cell further divides periclinally into an inner large **primary androgonial cell** (Fig. 4 G) and outer **jacket initial.** In a transverse section (T. S.) primary androgonial cell appears as a triangular cell (Fig. 4G). Such type of divisions take place in all the upper segments except the apical cell which develops into **operculum.**

All the jacket initials divide only by anticlinal divisions to form a single layered wall of antheridium (Fig. 4 H–J). Primary androgonial cells divide and redivide to form the androcyte mother cells. The cells of the last cell generation are called **androcyte mother cells.** Each androcyte mother cell divides further and form two **androcytes.** Each androcyte produces a single biflagellate sperm or **antherozoid** or **spermatozoid**. Each antherozoid is elongated, spirally coiled, biflagellated structure (Fig. 4L, M).

Structure of an Archegonium

A mature archegonium is flask shaped structure. It remains attached to the female branch by a massive stalk. It consists upper elongated slender **neck** and basal globular portion called **venter** (Fig. 7B). The neck is slightly tubular, twisted, single layered and consists of six vertical rows of **neck cells**, which enclose an axial row of ten or more **neck canal cells.** The venter wall is two layered and encloses **venter canal cell** and **egg cell**. Venter canal cell is situated just below the neck canal cells.

Development of Archegonium

Archegonium develops from a single superficial cell called the **archegonial initial** (Fig. 5 A). It differentiates at the apex of the female branch. Archegonial initial divides by transverse division to form the **basal cell** or **stalk cell** and a **terminal cell**. The basal cell divides and redivides to form the stalk of the archegonium. The termial cell functions as **archegonial mother cell** (Fig. 5 B). It divides by three intersecting walls forming three **peripheral cells** enclosing a tetrahedral **axial cell** (Fig. 5 C, D). The peripheral cells divide anticlinally to form a single layered wall of venter which later becomes two layered.

The axial cell divides, transversely to form an outer **primary cover cell** and inner **central cell** (Fig. 5F). The outer primary cover cell functions as aplical cell with four cutting faces (three lateral and one basal). It cuts off three lateral segments and one basal segment. Each lateral segment divides by a vertical wall so that the six rows of cells form the neck of the archegonium (Fig. 5 G, H). Each basal cell adds to neck canal cell. The inner central cell divides by transverse division into an outer **primary neck canal cell** and an inner **primary venter cell** (Fig. 5H). Primary neck canal cell undergoes transverse divisions to form a row of neck canal cells. Thus in *Funaria* the neck canal cells have double origin (lower and middle neck canal cells in the neck canal are derived from the primary neck canal cell while those in the upper portion of neck are derived from the primary cover cell). The primary venter cell divides by transverse division to form the **venter canal cell** and **egg cell** (Fig. 5 I, J).

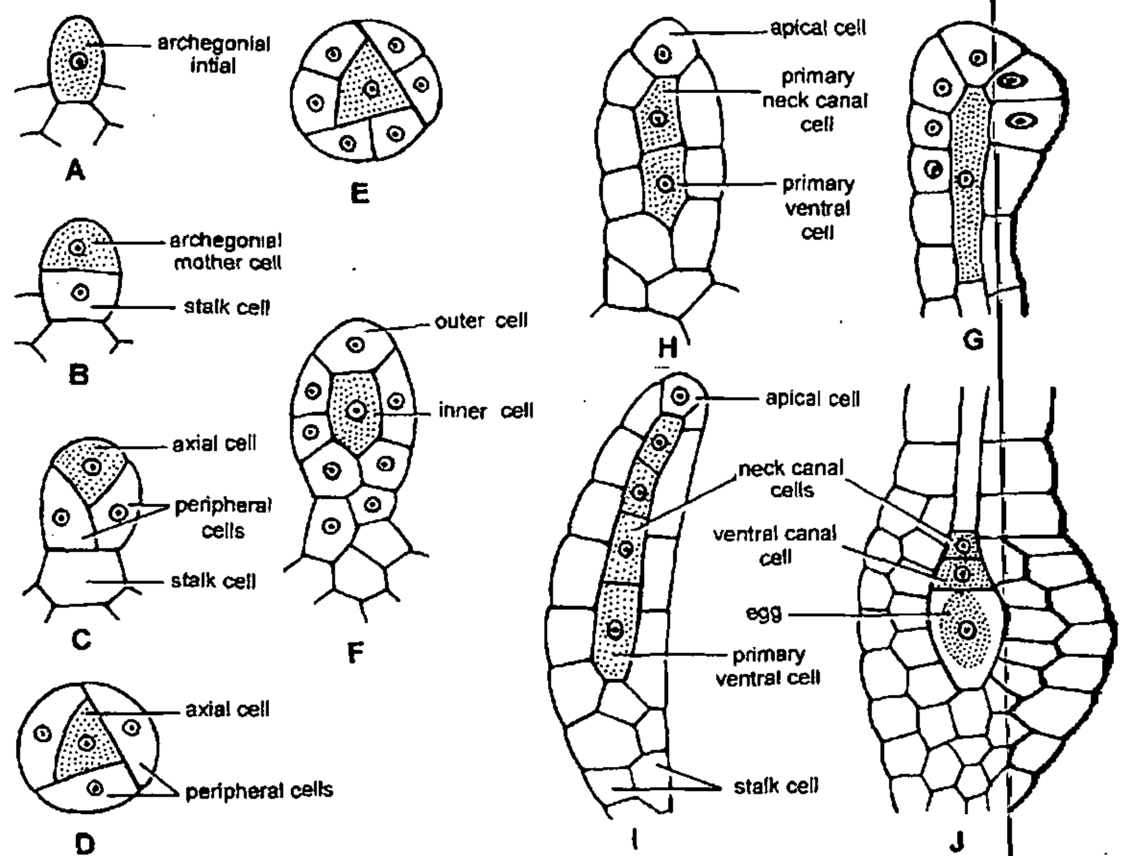


Fig. 5. (A–J) *Funaria*. Successive stages in the development of archegonium.

Fertilization

Water is essential for fertilization. The opercular cells of the antheridium rupture and releases mass of antherozoids. When archegonium reaches at maturity, the neck canal cells and venter canal cell disintegrate to form a mucilaginous mass. It absorbs water, swells up and comes out of the archegonial mouth by pushing the cover cells apart. This mucilaginous mass consists chemical substances (mainly sugars). The cover cells of the neck separate widely from each other and form a passage leading to the egg. Rosette like perigonial leaves serve as **splash cup** from which rain drops disperse antheroziods to some distance (rain drops falling on the archegonial cluster situated at lower level). Many antherozoids enter the archegonial neck because of chemical response but only one of them fuses with the egg to form the **zygote**. Fertilization ends the gametophytic phase (fig. 6).

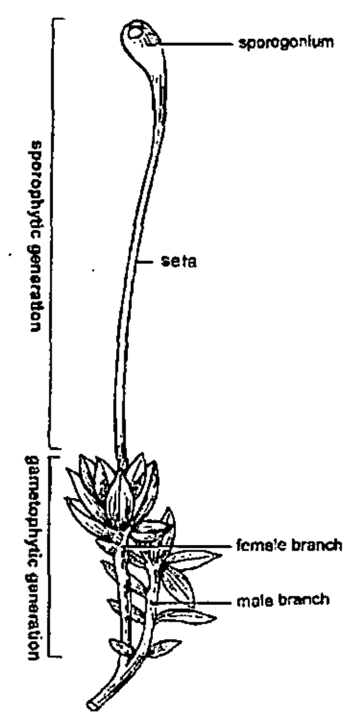


Fig. 6. *Funaria*. A gametophytic plant with sporophyte.

SPOROPHYTIC PHASE

Zygote is the first cell of the sporophytic phase. Development of sporophyte takes place within the venter of the archegonium.

Structure of Sporophyte

The sporophyte is **semi-parasitic** in nature. the mature sporophyte can be differentiated into three distinct parts—**foot, seta** and **capsule**.

Foot. It is the basal portion of the sporogonium. It is small dagger like conical structure embedded in the apex of female branch. It functions as anchoring and absorbing organ.

Seta. It is long, slender, stalk like hygroscopic structure. It bears the capsule at its tip. It raises the capsule above the apex of leafy gametophore. Its internal structure is more or less similar to axis. The epidermis is followed by thick walled cortex which surrounds the axial cylinder. It is mechanical in function and also conducts the water and nutrients to the developing capsule.

Capsule. It is the terminal part of the sporophyte and is developed at the apex of the seta. It is green in colour when young but on maturity it becomes bright orange coloured. It is covered by a cap like structure called calyptra. (gametophytic tissue develops from the upper part of the archegonium).

Internal structure of the capsule

Longitudinal Section (L.S.) of the capsule shows that it can be differentiated into three distinct regions–**apophysis, theca** and **operculum** (Fig. 7A).

Apophysis. It is the basal sterile part of the capsule. It is bounded by the single layered epidermis which is interrupted by stomata. The sotmata have **single ring like guard cells.** Below the epidermis is **spongy parenchyma.** The central part of the apophysis is made up of elongated thin walled cells forming a conducting strand. It is called neck of the capsule. It is the photosynthetic region and connects seta with capsule.

Theca. It is the middle, slightly bent spore bearing region of the capsule. It lies between the apophysis and operculum. Longitudinal section (L. S.) passing through the theca shows the following regions :

(i) Epidermis. It is the outer most layer. It is single layered with or without stomata.

(ii) Hypodermis. It is present below the epidermis. It consists two to three layers of compactly arranged colourless cells.

(iii) Spongy parenchyma. It consists two to three layers of loosely arranged chlorophyllous cells. It is present inner to hypodermis. These cells are capable to manufacture their own food but dependent on gametophyte for water and mineral nutrients. Therefore, the sporophyte of *Funaria* is **partially dependent on gametophyte.**

(iv) Air spaces. These are present just below the spongy parenchyma and outside the spore sacs. Air spaces are traversed by green cells (chlorenchymatous cells) called **trabeculae** (elongated parenchymatous cells).

(v) Spore sac. These are present below the air spaces on either side of the columella. It is 'U' shaped and broken at the base. (It separates its both arms).

It has an outer wall (3–4 cells thick) and an inner wall (single cell in thickness). Between the outer wall and inner wall is the cavity of the spore sac. When young, the cavity of the spore sac is filled with many spore mother cells. At maturity the spore mother cells divide by meiotic divisions and form many haploid spores.

(vi) Columella. It is the central part of the theca region. It is made up of compactly arranged colourless parenchymatous cells. It is wide above and narrow below,

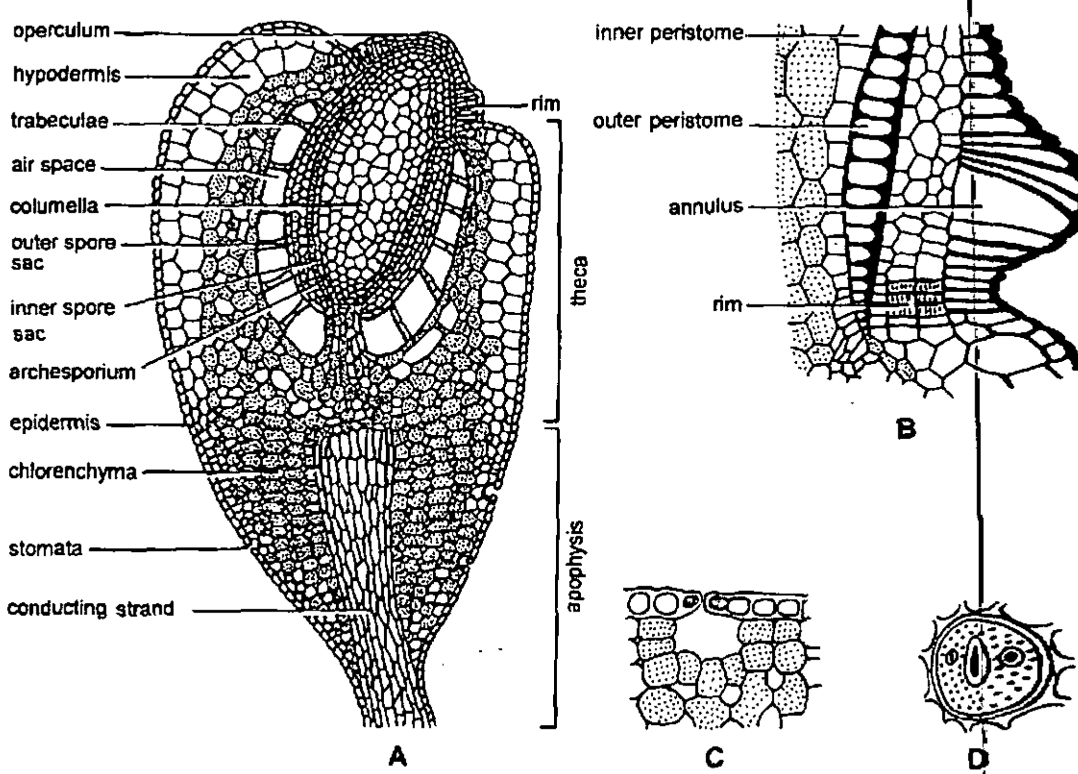


Fig. 7. (A–D) *Funeral.* Internal structure of the capsule. (A) Longitudinal Section (L.S.) of entire capsule, (B) L.S. through annulus region, (C) Structure of stomata in L.S. (D) Stomata in surface view.

connecting the central strand of apophysis. It helps in conduction of water and mineral nutrients.

Operculum. It is the upper dome shaped region of the capsule consists four to five layers of cells. The outermost layer is thick walled and called **epidermis**. Operculum is differentiated from theca by a well marked constriction. A **diaphragm** or (rim). It is composed of two to three layers of radially elongated pitted cells. Immediately above the rim is **annulus** which consits of 5–6 superimposed layers of cells. Its upper cells are thick but two lowermost layers of cells are thin. Annulus separates the theca from the operculum. Below the operculum lies the **peristome** (Fig. 7 B). It is attached below to the edge of the diaphragm. The peristome consists of two rings of radially arranged peristomial teeth. In each ring there are **sixteen teeth**. The teeth are not cellular but they are simply the strips of the cuticle. The teeth of the outer ring are conspicuous, red with thick transverse bands while the teeth of the inner ring are small, delicate, colourless and without transverse bands. Inner to peristome teeth lies a mass of thin walled parenchymatous cells. (Fig. 7B).

• DEVELOPMENT OF SPOROPHYTE

Soon after fertilization, the zygote secretes a wall around it and enlarges in size. It divides by a transverse wall forming an upper **epibasal cell** and lower **hypobasal cell** (Fig. 8 A, B). Epibasal cell divides by two intersecting oblique walls. It differentiates an apical cells with two cutting faces in the epibasal cell (Fig. 8C). Similarly, the hypobasal cell differentiates an apical cell (Fig. 8 D). The entire sporophyte is differentiated by the activity of these two apical cells. So, the development of embryo sporophyte is **bi-apical**. Epibasal apical cell develops into **capsule** and **upper portion of the seta** while the hypobasal apical cell develops into **foot** and **remaining part of the seta**. Both apical cells cut out alternate segments and form the elongated filamentous structure of **young sporogonium** (Fig. 8 E, F).

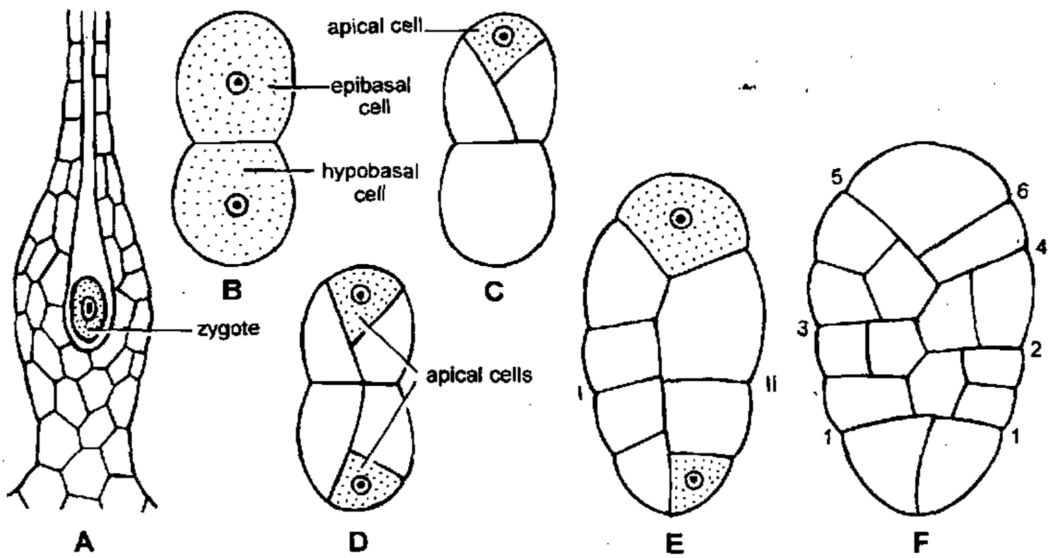


Fig. 8. *Funeria*. Early stages in the development of sporophyte.

Development of Capsule

A cross section through the upper portion of the young sporogonium shows a two identical segments which divide by a vertical division at right angle to the previous one to form a quadrant (4 cellled stage). Each cell of the quadrant divides by anticlinal wall in such a way that a smaller almost triangular cell and a larger more or less rectangular cell is formed. Each rectangular cell now divides by a periclinal division. It results in formation of a group of four central cells surrounded by 8 peripheral cells. The central tissue is known as **endothecium** and the peripheral cells from the **amphithecium** . From these two group of cells the further development takes place. There is formation of different rings by anticlinal and periclinal divisions.

The amphithecium divides by periclinal division to form two concentric layers. The inner layer of 8 cells is called **first ring**. The cells of the outer layer divide by anticlinal divisions to form 16 cells. This is followed by the periclinal division in this layer. The inner part of this layers is called the **second ring**. Again the outer layer of these two layers divide anticlinally to form 32 cells. This layer divides periclinally to form two layers of 32 cells. The inner layer is called third ring. Similarly by periclinal divisions fourth and fifth ring of 32 cells are formed.

The four cells of the endothecium also divides similarly to amphithecium. The first division is curved and anticlinal. The second division is periclinal. It results in the formation of a central group of 4 endothecial cells, surrounded by 8 peripheral endothecial cells. Further development of the tissues in the capsule region takes place by these amphithecial rings and endothecial cells. It can be studied under the following three headings.

(i) **Development of fertile (theca) region** (middle portion of young capsule) :

(ii) ***Development of apophysis region of the capsule :***

(iii) **Development of operculum or apical region of the capsule :**

The fertile region in capsule comprises archesporium lined by outer and inner spore sac. Archesporium is endothecial in origin. Its cells may undergo sub-divisions to form two cell layers thick **spore mother cells** which by meiosis form tetrad of spores. Elaters are absent.

Dehiscence of the Capsule

Funaria is a **stegocarpous** moss (dehisce along a pre determined line) Dehisce of the capsule is achieved by 'breaking off' of annulus. As the capsule mature becomes inverted due to epinasty. The thin walled cells of the annulus break away, operculum is thrown off and the peristome teeth are exposed (Fig. 10). The o peristomial teeth (exostome) are **hygroscopic**. The inner peristomial t (endostome) do not show any hygroscopic movements but act as a sieve allowing on few spores to disperse at a time. The lengthening and shortening of the o peristomial teeth help in the dispersal of spores. In high humidity the exostome abs water, increase in length and curve inwards. In dry weather, the exostome teeth water, bend outwards with jerky movements. It allows the dispersal of spores from capsule in instalments. At maturity the seta also shows jerky movements. Twisting swinging of seta in dry weather further aids in the dispersal of spores.

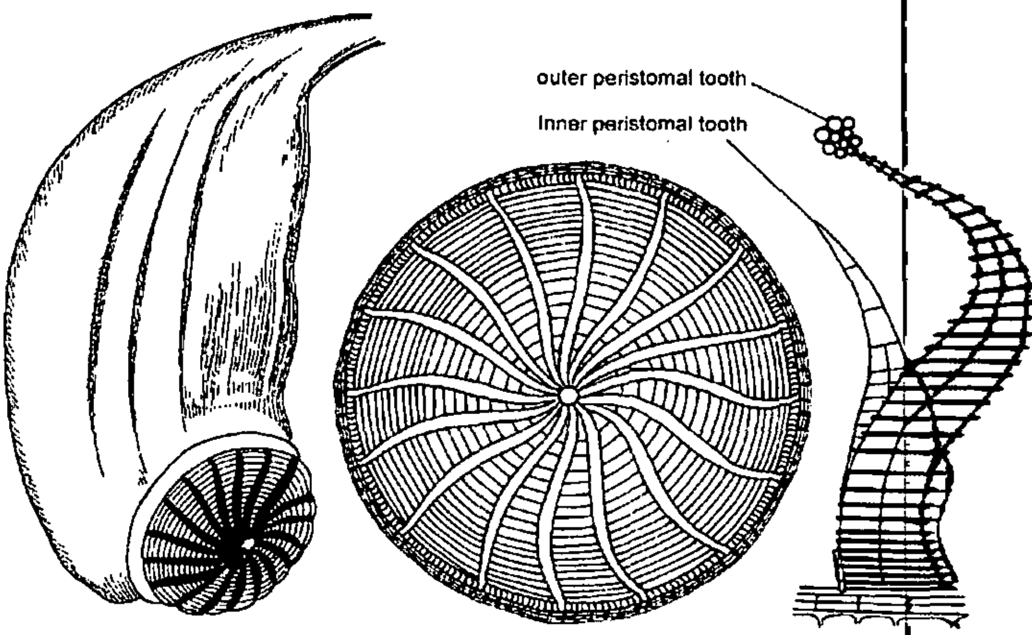


Fig. 9. (A–I). *Funaria*. Dehiscence of capsule. (A) Capsule with peristome, (B) Top view peristome, (C) An outer and an inner peristomial teeth.

Structure and germination of spore

Spore is the first cell of the gametophytic phase. Each spore is spherical, 12—20 μ diameter and surrounded by two wall layers (Fig. 10 A). The outer wall is thick, smoo brown and known as **exosporium**, while the inner wall is thin, hyaline and cal **endosporium.** Spore wall encloses single nucleus, chloroplasts and many oil globu Under favourable conditions (sufficient moisture) spores germinate. Exosporí ruptures and endosporium comes out in the form of one or two germ tul (Fig. 10B, C). Each germ tube is multicellular, green with oblique septa. The germ t grows in length, divides by septa to form green algal filament like structure cal **primary protonema** (Fig. 10 D, E).

Primary protonema

It is the juvevile (young) stage of the gametophyte formed by the germination spore. It forms two different types of branches. Most of the branches grow horizonta on the moist surface of the soil and are known as **chloronemal** branches (posit phototrophic, thick and rich in chloroplast) while some branches grow down in the and are called **rhizoidal branches** (non green, thin and possess oblique sep (Fig. 10F). These branches can develop chlorophyll if expose to light. Rhizoi branches function as anchoring and absorbing organs while chloronemal branc

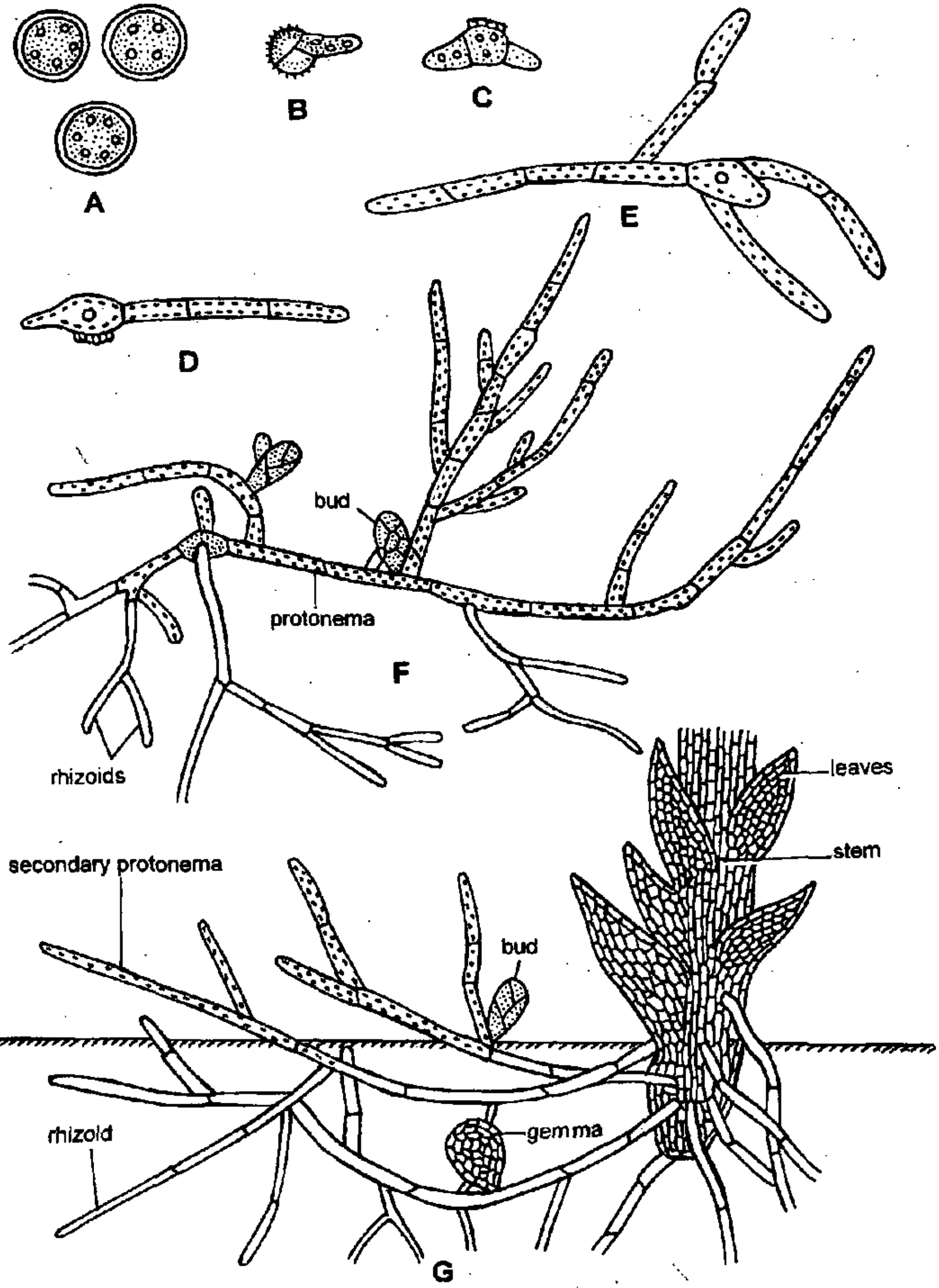


Fig. 10. (A, B). *Funaria.* (A–G) (a) spores, (B–F) Stages in the germination of spores and formation of primary protonema, (G) Secondary protonema.

develop minute green buds behind the cross walls which develop into leafy gametophores. From one primary protonema many moss plants develop, so the moss is **gregarious** in habit. Primary protonema is short lived.

According to **Sirnoval** (1947) development of protonema under laboratory conditions can be differentiated into two stages—**chloronemal stage** and **caulonemal stage**. Chloronemal stage is characterised by irregular branching, right angle colourless cross walls, and many evenly distributed discoid chloroplast. It is positive phototropic but never produce buds. Nearly after 20 days chloronemal stage matures into caulonemal stage. This stage is characterised by regular branching, brown cell walls, oblique cross walls and fewer chloroplasts. It is negative phototropic and produce buds which later develop into leafy gametophores. Rhizoids arise from base of a bud (Fig. 11).

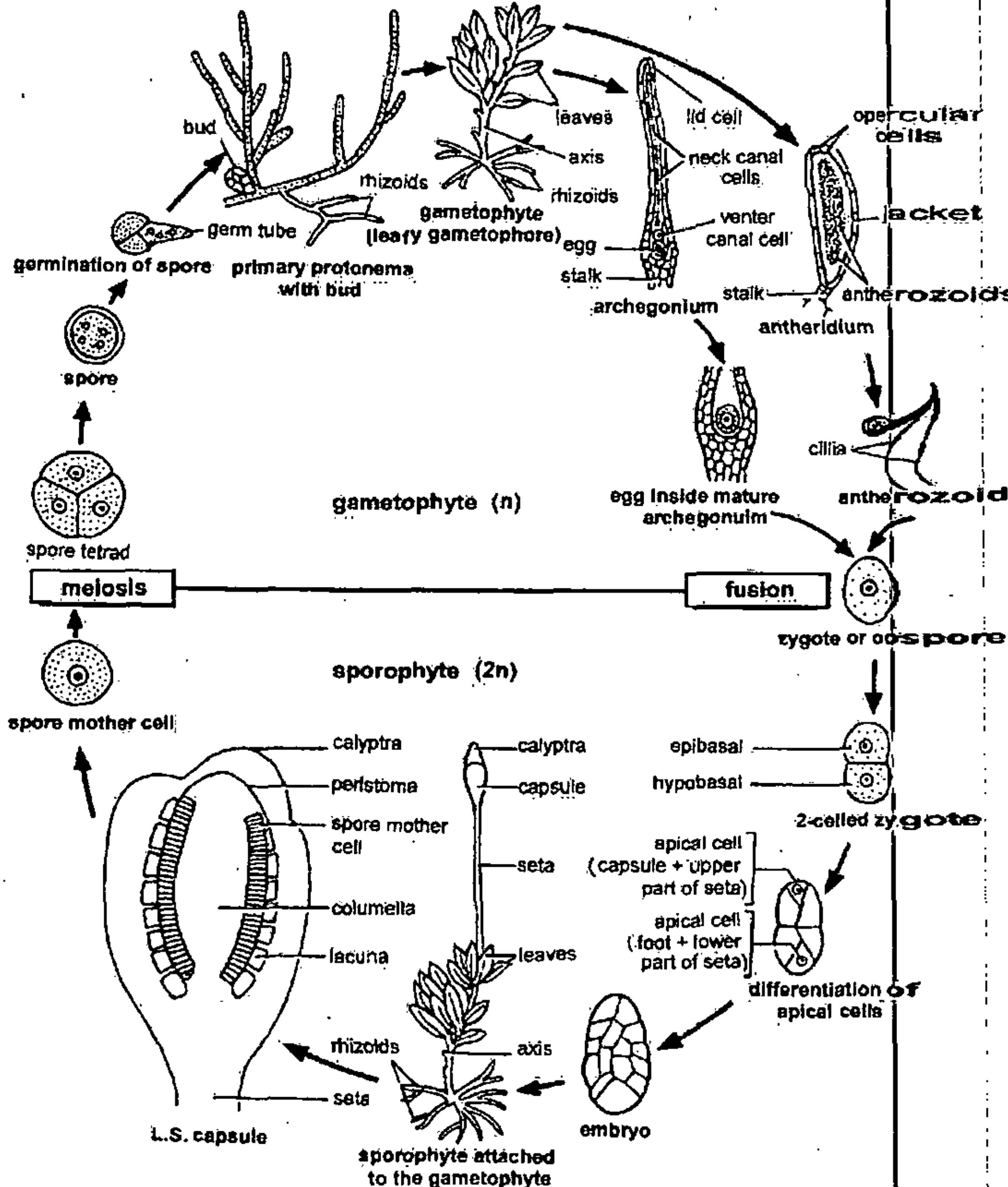


Fig. 11. (A–G). *Funaria*. Diagrammatic life cycle.

• IMPORTANT QUESTIONS

Long Answer Type Questions :

1. Descrive the significant steps in the life cycle of *Funaria.*
2. Give an illustrated account of the phenomenon of alternation of generation *Funaria.*
3. Describe the structure and development of sex organs in *Funaria.*
4. Describe the internal and external structure of the capsule of *Funaria.*
5. Describe the development of sporophyte in *Funaria.*
6. Draw a neat and well labelled diagrams to depict the life cycle of *Funaria.* description is required.

Short Answer Type Questions :

1. Transverse section (T.S.) of axis of *Funaria.*
2. Leafy gametophore.
3. Juvenile stage.
4. Transverse section (T.S.) of 'leaf' of *Funaria.*
5. Vertical section (V.S.) of male branch of *Funaria.*
6. Protonema of Moss.
7. Rhizoids of *Funaria.*
8. Peristomial teeth of Moss.
9. Archegonium of Moss.
10. Spore of *Funaria.*
11. Dispersal of spores in *Funaria.*
12. Vegetative reproduction in *Funaria.*
13. Fertilization in *Funaria.*
14. Antheridium of *Funaria.*
15. Paraphyses.
16. Operculum.

Objective Type Questions :

1. Name the most common species of *Funaria.*
2. How many neck canal cells are present in the neck of the archegonium of *Funaria* ?
3. Name the algal filament like structure produced by germination of spores in *Funaria.*
4. Name the term used for *Funaria* bearing antheridia and archegonia on different branches of the same thallus.
5. Name the first cell generation of sporogenous tissue in *Funaria.*
6. Name the central tissue found in the capsule of *Funaria.*
7. In *Funaria*, what is the term used for the ring of hygroscopic teeth like structure encircling the mouth of capsule for the dispersal of spores ?
8. Which phase in the life cycle of *Funaria* needs a greater amount of moisture ?
9. Name the branches which develop from primary protonema.
10. Name that part of the capsule which separates operculum from theca.

Multiple Choice Questions :

1. In *Anthoceros*, the rhizoids are :
   (a) Smooth walled only (b) Tuberculated only
   (c) Multicellular and septate (d) Absent
2. In *Anthoceros* the scales are :
   (a) Absent (b) Appendiculate
   (c) Ligulate (d) Discoid.
3. In *Anthoceros* the meristematic tissue is present :
   (a) At the apex of the sporogonium (b) Just below the foot
   (c) Just below the capsule (d) None of these.
4. Stomata are present on capsule wall of :
   (a) *Marchantia* (b) *Anthoceros*
   (c) *Porella* (d) *Riccia*
5. In Anthoceros spore producing layer originates from ;
   (a) Endothecium (b) Amphithecium
   (c) Columella (d) Foot
6. Endophytic algae present in the thallus of *Anithoceros* is :
   (a) *Volvox* (b) *Vaucheria*
   (c) *Chlamydomonas* (d) *Nostoc*

7. The abnormal sporophyte of *Anthoceros* show its phylogenetic corr-elation with the sporophyte of
   (a) Mosses (b) Ferns
   (c) Fossil Gymnosperms (d) *Rhynia.*
8. The thalli of *Anthoceros* are :
   (a) Unbranched (b) Rarerly branched
   (c) Dichotomously branched (d) Variously lobed.

ANSWERS

Objective Type Questions :

1. *Funaria hygrometrica*
2. Ten or more
3. Primary protonema
4. Autoicous
5. Archesporium
6. Columella
7. Peristome
8. Gametophytic phase
9. Chloronemal and rhizoidal
10. Rim or diaphragm.

Multiple Choice Questions :

1. (a) 2. (a) 3. (c) 4. (b) 5. (b) 6. (d) 7. (d) 8. (d)

B.Sc. ZBC-103

सर्वे भवन्तु सुखिनः सर्वे सन्तु निरामयाः ।
सर्वे भद्राणि पश्यन्तु मा कश्चिद् दुःख भाग्भवेत् ॥

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