BSCBO- 102

B. Sc. I YEAR

Phycology and Bryology

DEPARTMENT OF BOTANY
SCHOOL OF SCIENCES
UTTARAKHAND OPEN UNIVERSITY

BSCBO-102

PHYCOLOGY AND BRYOLOGY

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CONTENTS

BLOCK-1- ALGAE: GENERAL ACCOUNT

UNIT –1 – GENERAL CHARACTERS AND LIFE CYCLES OF ALGAE

1.1 OBJECTIVES

After going through this unit you will able to know

- General characteristics of algae
- Various type of reproduction of algae
- Life cycle patterns and alternation of generation in algae

1.2 INTRODUCTION

Before knowing about the details of algae, have you ever wondered where one could find algae? What is the cell structure of algae? Whether they have prokaryotic or eukaryotic structure? Are they good for environment? Can they be used as food? These are some obvious questions that come in our mind when someone talks about algae. During rainy season most of us have experienced the slippery green structure on the shady and moist places, which is actually responsible for many accidents. All these structures about which we are talking about are in fact the living organisms which we are going to study in the following paragraphs. These organisms are commonly known as ‘algae’- a Latin word which literally means sea weeds. Phycologists however, use the term algae in common manner for all the classes of algae. They are thalloid **autotrophic organism** which can synthesize their own food by the process of photosynthesis in the presence of chlorophyll and sun light. The study of algae is known as **Phycology.** Various Indian and international phycologists have worked on algae. Amongst them R.N.Singh, M.O.P. Iyengar, H.D.Kumar, M.S.Randhawa (all are Indians), F.E. Fritsch and G.M Smith are known for their valuable contributions**. M.O.P. Iyengar** is known as “father of Phycology” **in India** and **F.E. Fritsch is known as “father of Phycology”.**

1.3 GENERAL CHARACTERSTICS OF ALGAE

Algae are chlorophyll bearing autotrophic organisms having a **thalloid plant** body i.e., the plant body is not differentiated into root, leaf and stem. The thallus is **non vascular** therefore have no element for the transport of fluids. Algae have simple reproductive structure, sex organ are unicellular and if multicellular all the cells are fertile. Sex organs also lack a sterile jacket of cells around the reproductive cell and no embryo is formed after the fertilization.
They occur in a variety of habitat but mostly they are aquatic. They show distinct alteration of generation.

1.3.1 Occurrence and distribution (Algal habitat)

The algae are predominantly aquatic and are found in both fresh and marine water. Some are terrestrial and can grow under the soil surface damp and shaded sides. So, on the basis of habitat they may be classified in the following type.

A. Aquatic algae
B. Terrestrial algae
C. Algae of unusual habitats

A. Aquatic algae – Majority of algae are aquatic and found either in fresh water or in salty or marine water. The aquatic algae are either free floating or attached to the substratum with the help of holdfast.

1) **Fresh water algae-** These forms occur in fresh water of ponds, pools, lakes, streams, river etc. these fresh water forms may be present in slow running water e.g., *Cladophora, Oedogonium, Chara* or in stagnant or still water e.g., *Hydrodictyon, Chlamydomanas.*
2) **Marine water algae-**These algae occur in saline water of sea. Most of the members of class Phaeophyceae and Rhodophyceae are found in marine water. Marine algae are generally macroscopic having large thalli and commonly known as “sea weeds”. Examples of marine forms are *Ectocarpus, Sargassum, Fucus, Laminaria.*
3) **Planktonic algae-** Floating forms of algae are generally referred as planktonic forms. These forms may be uniformly distributed in water or may be discontinuous and patchy in pitches both horizontally and vertically. The examples of fresh water planktonic algae are *Chlorella, Hydrodictyon, Chlamydomonas, Volvox,* while *Cyclotella, Hemidiscus, Fragillaria, Trichodesmium, Ocillatoria* are the example of marine water planktonic form. The abundant growth of planktonic algae imparts color and odor to the water. Such a phenomenon is called water- bloom or algal bloom. Formation of algal blooms fairly depends upon the factors like temperature, longer days and nutrient availability.

B. Terrestrial algae- Many algal genera are found on or beneath the moist soil surface and are called terrestrial algae. The algal forms also occur on the surface of soil e.g., few species of ***Vaucheria, Botrydium, Fristchilla*** while some algae having subterranean habit e.g., few species of ***Nostoc, Anabaena*** and ***Euglena*** and these are known as Cryptophytes.

1) **Aerophytes**: Such algal forms are adapted for aerial mode of life and occur on the tree trunks, moist walls, flower pots, rocks, fencing wires and get their water and carbon dioxide requirement directly from atmosphere are called Aerophytes.

2) **Cryophytes**: Algae growing on the mountain peaks covered with snow are called cryophytic algae. These algae impart attractive colours to the mountains. ***Haematococcus nivalis*** gives red colour to the arctic and alpine regions while ***Chlamyodomanas yellowstonesis*** gives yellow green colour to the snow of the mountains of European countries particularly in Arctic region.

3) **Thermophytes**: The algal genera occurring in hot springs at quite high temperature. There are some algae which are known to tolerate the temperature upto $85^{\mathbf{0}}$ C. ***Oscillatoria brevis,*** and ***Haplosiphon lignosum*** are example of thermophytes which survive upto temperature of 70^0C at which plant life is not possible. Majority of thermal algae belong to Myxophyceae.
4) **Lithophytes**: The algae growing attached to stone and rocky surface are called lithophytes. Usually the members of Cyanophyceae grow on moist rock, wet wall and other rocky surface e.g. *Nostoc*, *Rivularia.*

C. Algae of unusual form

1) **Epiphytes**- Such algal form which grow on the other plants are called epiphytic algae. These algae do not obtain food from plants on which they grow, rather require support only. *Coleochaete* in association with *Chara* and *Nitella* while *Chaetophora* on leaves of *Vallisnaria* and *Nelumbo, Oedogonium* on *Hydrilla* are seen frequently growing in natures as epiphytes.
2) **Halophytes**: Certain algae inhabit in water with high percentage of salts are called halophytes. They include *Chlamydomonas chrenbergii*, *Dunaliella* and *Stephanoptera.*
3) **Symbionts**: A large number of algae live in association with dissimilar organisms for their mutual advantage and are called symbiotic algae. The common examples of such association are the presence of *Nostoc* in *Anthoceros*, *Anabaena* in the coralloid root of *Cycas, Anabaena azollae in Azolla.* Lichen is one of the best examples of symbiosis where the association lies in between algae and fungi.
4) **Epizoic**: Many algae grow on the shells of Mollusces, turtles and fins of fishes and are called epizoic algae. e.g., *Cladophora* is found on snails and shells of bivalves while *Protoderma* and *Basicladia* grow on the back of turtle.
5) **Endozoic**: Algae which are found inside the body of aquatic animal is called endozoic algae. *Zoochlorellae* occur in the coelom (body cavity) of hydra and several other invertebrates. *Zooxanthella* lives in intimate association with coral community.
6) **Parasitic algae**: Few algae depend on other plants for obtaining food; these are termed as parasitic algae. The common intercellular parasitic algae is *Cephaleuros* which grow on the leaves of the tea plant (*Thea sinesnsis*) and cause the red rust disease of tea.

1.3.2 Organisation of thallus

Algal thalli range from unicellular microscopic structure to large sea weeds (macro algae) such as giant kelp which is more than one hundred feet in length. The thallus organization among algae shows a wide range of variation. One extreme is represented by a simple motile unicell (*Chlamydomonas*) or non motile unicell (*Chlorella*), while in some; cells are grouped into aggregations called colonies. (*Volvox*, *Pediastrum*). These colonies are again may be motile or non motile (*Hydrodictyon*). If a colony has a definite shape it is known as **coenobium** (*Volvox*). The filamentous habit is most elementary type of thallus and are multicellular. These filaments may be unbranched. e.g., *Ulothrix* or simple branched e.g., *Cladophora* or a highly complex e.g., *Ectocarpus, polysiphonia, Sargassum, Laminaria*. It is noteworthy that no single type of thallus is restricted to any particular division and there exists a striking parallelism among different division of algae. Detail of thallus organization you will study in unit 3.

There are two types of cell structures present in algae-

A. Prokaryotic cell
B. Eukaryotic cell

1.3.3 Prokaryotic cell

The prokaryotic cell organization is found only in class Cyanophyceae (Mixophyceae). The characteristic feature of prokaryotic algae is the presence of primitive or incipient nucleus, in this type of nucleus nuclear membrane and histones (the basic protein) are absent. The DNA consists of fibrils which may extend throughout the cell or concentrated in the central part. The chlorophyll pigment is found in the photosynthetic lamellae or thylakoids which may arrange in parallel layer in the periphery of the cytoplasm or form a network extending throughout the cell cytoplasm. The chloroplast, mitochondria, Golgi body and endoplasmic reticulum (the membrane bound organelle) are absent. The simple cells of blue green algae which lack a nuclear membrane, mitochondria, plastids and do not divide by mitosis are called prokaryotic. The cell wall is made up of mucopeptide, a specific strengthening component not found in cell walls of other algae (Fig. 1.1).

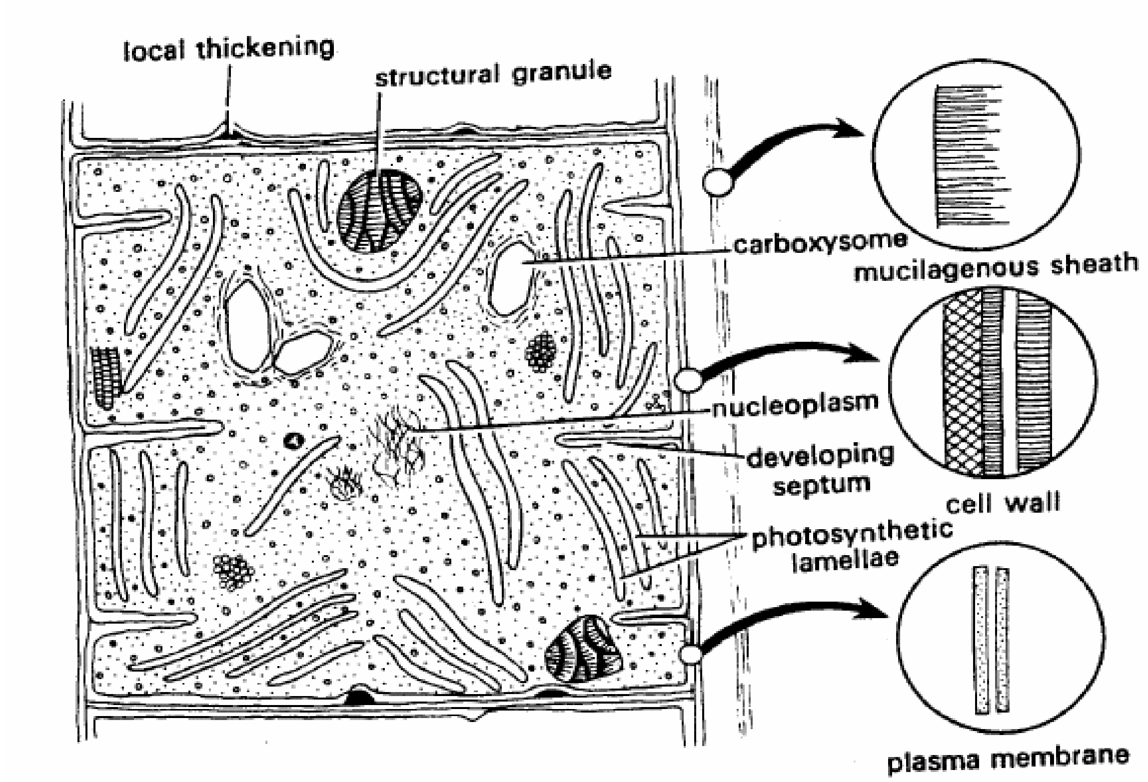

Fig 1.1: A detailed structure of Prokaryotic cell (Cyanophycean cell)

1.3.4 Eukaryotic cell

The eukaryoti**c** cell is characterized b**y** the presence of well organized nucleus and membrane bounded organelles like plastids, mitochondria and Golgi bodies (Fig 1.2).

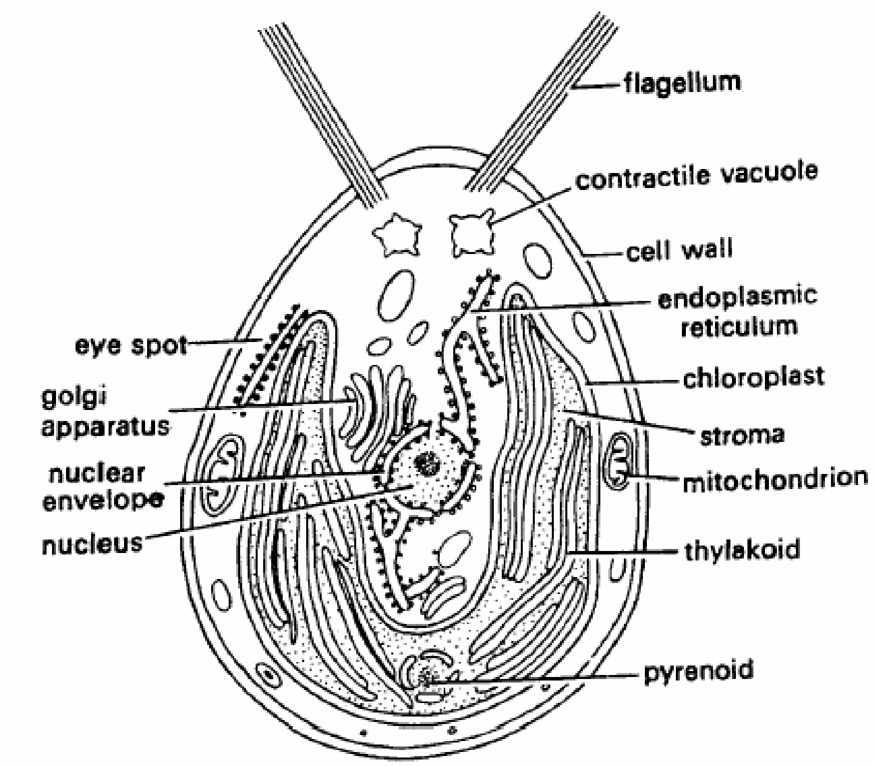

Fig 1.2: A Typical Eukaryotic Cell of Algae

1.3.5 Nucleus

The nucleus is having a well developed nuclear membrane which separates it from cytoplasm and it divides by mitosis. Algal cell may be uninucleated or multinucleated (**coenocytic).** Each nucleus contains one or more dark stained nucleoli or endosomes. There are four different types of nuclear structure found in algae are: a single nucleolus per nucleus, two or more distinct nucleoli per nucleus, a complex nuclear mass and a linear association of large number of small nucleoli.

1.3.6 Golgi bodies

Golgi bodies are composed of 2-20 flat vesicles. These are arranged in stacks (Dictysomes). The Golgi bodies are associated with the synthesis of cell metabolites and have also been shown to contribute to the plasma membrane as in higher plants.

1.3.7 Mitochondria

The respiratory enzymes are located in mitochondria so act as respiratory center of the cells. Mitochondria are also a site of enzyme action in protein synthesis and amino acid conversion. Mitochondria are also known as power house of the cell.

1.3.8 Endoplasmic reticulum

The cytoplasm of the algal cell is traversed by a system of interconnecting tubules called endoplasmic reticulum. The surface of endoplasmic reticulum has ribosomes, the sites of protein synthesis in the cell.

1.3.9 Eye spot

The motile vegetative and reproductive cells of algae have a pigmented spot called eye spot. The eye spot is considered to be light sensitive organelle which directs the movement of swimming cell (Fig 1.3).

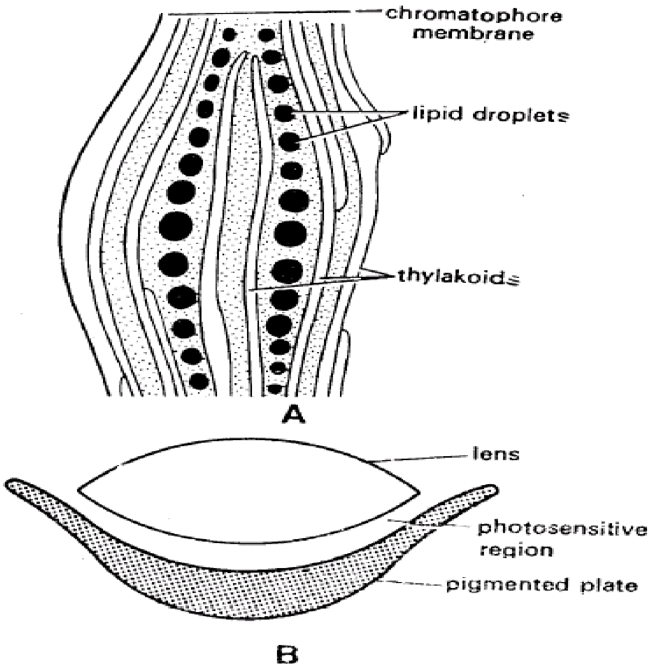

Fig 1.3: Eye spot in algae A- *Chlamydomonas* with thylakoids & B - *Volvox*

On the basis of their position and structure, there are five types of eye spots:

- **Type A-** Eye spot is located in the chloroplast and it has no association with flagella.
- **Type B**- Eye spot is located in the chloroplast and associated with a swollen flagellum.
- **Type C**- Eye spot is an independent clusters of osmophilic granules and are situated at anterior side of cell.
- **Type D**-Eye spot having osmophilic granular structure with membranous lamella. It is present near flagellar bases.
- **Type E**-Eye spot having a lens, retinoid and pigmented cup.

1.3.10 Vacuoles

The vacuole is bounded by a distinct membrane called tonoplast. There are two types of vacuoles:

- **Simple or contractile vacuoles-** These vacuoles show periodic contraction and throughout waste product out of cell and it has a secretary function.
- **Complex vacuoles**- A complex vacuole consists of a tube like cytopharynx, a large reservoir, and a group of vacuoles of different sizes.

Vacuoles act as the main osmoregulatory organ in the cell and help in regulating the absorption of water and solutes.

1.3.11 Pyrenoid

Pyrenoids are additional cell organelles present within or on the surface of chloroplast or chromatophore. They are **proteinaceous bodies** made up of densely packed proteinaceous fibrils and are the site of accumulation and synthesis of starch. In some algae the pyrenoids are transient structure, found only in certain stages. There may be single pyrenoid as in ***Chlamydomonas*** **or more than one as** ***in Oedogonium and Spirogyra.*** **Pyrenoids are invariably absent in class cyanophyceae.**

1.3.12 Flagella

Flagella are (singular Flagellum) the thread like structure concerned with cell movement and found in almost all the classes of algae except Rhodophyceae and Cyanophyceae. Each flagellum consists of 2 central fibrils surrounded by 9 peripheral double fibrils (9+2 arrangements) (Fig.1.4). A cell having flagella is also known as motile cell.

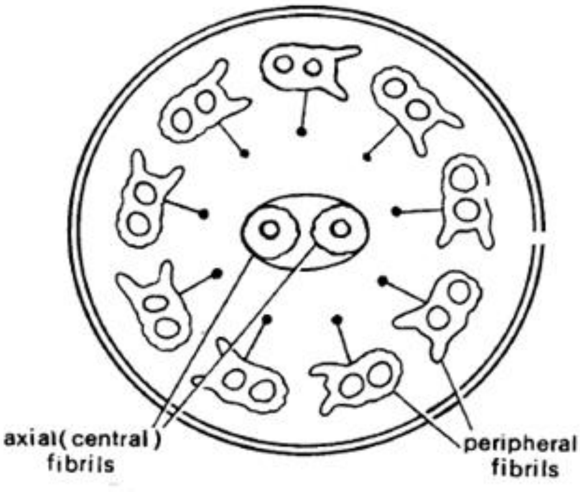

Fig.1.4: T.S of Flagella showing 9+2 arrangements of fibrils

There are mainly two types of flagella found in algae

A. **Whiplash or acronematic flagella-**Flagella having a smooth surface (Fig 1.5 A & B).

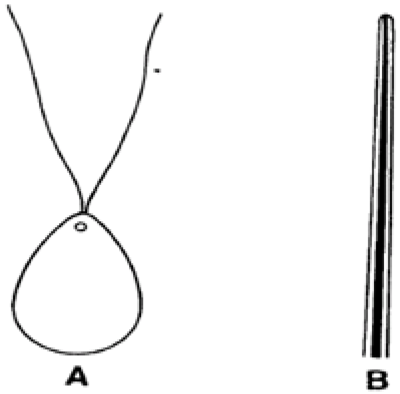

Fig.1.5: (A & B) Whiplash or acronematic flagella

B. Tinsel flagella or pleuromematic flagella-Here the surface of flagella is covered with fine hair like appendages called **mastigonemes.** On the basis of arrangement of mastigonemes tinsel flagella may be (i) **pantonematic** having two opposite rows of mastigonemes (Fig 6 D) (ii) **pantocronematic** is having a terminal fibril (Fig 6 C) and (iii) **stichonematic** flagellum in this mastigonemes develop only on one side of flagellum (Fig.1.6 D).

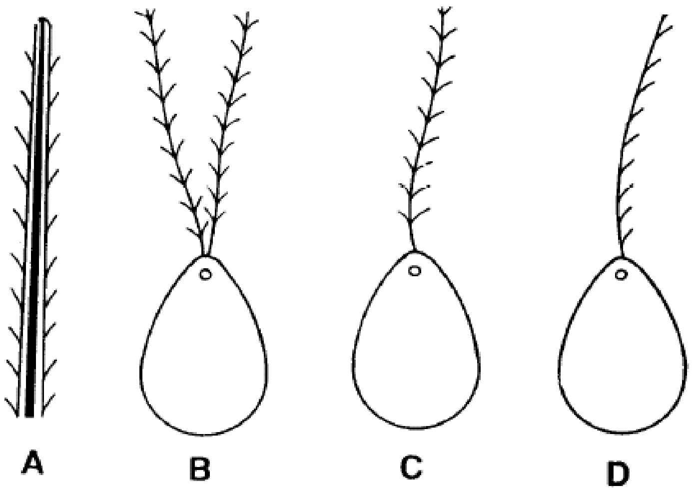

Fig.1.6: A- Pleuronematic (Tinsel), B – Pantonematic Flagella, C – Pantocronematic Flagella & D- Stichonematic Flagella

If the flagella of a cell are similar it is known as **isoknot** and when dissimilar, it is called **heteroknot.**

The size, number and arrangement of flagella are characteristic of specific class of algae or genera.

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

1.3.13 Reserve food material

As we know that the algae are the autotrophic organisms which are capable of synthesizing their food by the process of photosynthesis. The food synthesized during photosynthesis is stored in different forms in various classes of algae which is known as **stored food or reserve food material** which depends on the nature of pigmentation present in that particular class. Reserve food in green algae is starch, in Cyanophyceae it is cyanophycean starch, in Rhodophyceae it is floridean starch, while in Phaeophyceae it is mannitol and laminarian starch.

1.3.14 Pigmentation in algae

The colour of thallus in algae is due to presence of pigments. Each pigment has its own characteristics colour. Each algal division has its own particular combination of pigments and a characteristic colour. In all there are four different kind of pigments found in the Algae. These are chlorophylls, xanthophylls, carotenes and phycobilins. Usually the algal pigments are located in plastids. Different forms of plastids are present in algae. They may be cup shaped, in the form of parietal plate, lens- shaped, disc or network like or as an axial band, or star shaped (stellate) or oval shaped, a lobed disc or in the form of a parietal ring. The Cyanophyta lacks plastids and the pigments are located in the lamellae.

1-The chlorophylls

There are five known chlorophylls, namely, chlorophyll-a-b-c-d and –e. Of these chlorophyll a occurs in all classes of algae and the chemical formula of chlorophyll a is $C_{55} H_{72}O_5N_4Mg$. Chlorophyll a and b are found in Chlorophyta, Euglenophyta and Charophyta. Chlorophyll-c occurs in Bacillariophyta, Pyrrophyta and Phaeophyta. Chlorophyll-d occurs only in red algae, while Chlorophyll-e is found in Xanthophyta. The plastids containing both chlorophyll a and b are called the Chloroplasts and those which lack Chlorophyll b and have carotenoids in excess over the chlorophyll are usually called chromatophores. Chlorophylls are fat soluble but insoluble in water. They absorb blue and red rays and are important photosynthetic pigments.

2-The carotenoids (Carotenes + Xanthophylls)

It is a group of yellow, orange, red and brown pigments. About 60 different carotenoids have been reported in plants. They are placed under two categories, the orange yellow **carotenes** and yellow or brown **xanthophylls** or carotenols. The carotenoids are protective pigments functioning as screens to light. They absorb blue and green light waves.

(a) Carotenes – The Carotenes are linear unsaturated hydrocarbons represented by a chemical formula $C_{40}H_{56}$. There are five carotenes so far known, namely Carotenes-a- B,-e,- Y and lycopene. Carotenes are fats soluble pigments. They are insoluble in aqueous solution but are soluble in lipid solvents such as ethyl alcohol, chloroform and carbon disulphide and absorb blue and green light waves.

(b) Xanthophylls- They are yellow or brown pigments represented by the molecular formula $C_{40}H_{56}O_2$. They are closely related to the carotenes but contain oxygen in addition to carbon and hydrogen. Both xanthophylls are insoluble in water but are soluble in chloroform. Common xanthophylls are Zeaxanthin, Astaxanthin, lycopene, Diatoxanthin, Oscilloxanthin, Fucoxanthin etc.
Fucoxanthin is characteristic pigment of the Phaeophyta imparting distinctive brown or olive coloration to the thalli.

3-The Phycobilins
It is another group of pigments comprising the tetrapyrrolic compounds joined to the globulin proteins. So far seven phycobilin pigments both blue and red have been enlisted. They are pycoerythrin r,- c,- x,- b- and phycocyanin-r and -c-. Phycobilin are water soluble pigment found in red and blue green algae. Of the seven phycobilins, r-phycoerythrin and r-phycocyanin are common, the former absorb blue, green and sometime yellow rays whereas the latter absorb green.

Chlorophyll-a is of prime importance in photosynthesis. The accessory pigments function only indirectly. The wavelength of light which are not absorbed by chlorophyll are absorbed by Phycocyanin and Phycoerythrin. The light energy trapped by the latter two pigments is then transferred to chlorophyll–a which utilize it in photosynthesis.

1.4 REPRODUCTION IN ALGAE

Before going to the life cycle pattern among the algae it is necessary to know about the process of reproduction in algae especially the process of sexual reproduction. Algae reproduce by following three types: Vegetative, asexual and sexual.

1.4.1 Vegetative reproduction

Vegetative reproduction occurs generally under favourable conditions. Any portion of the thallus plant body gets detached from parent and develops into new individual without any apparent change in genetic constitution. It occurs through:
1. Cell division – It is the simplest method of propagation and usually common in unicellular forms of algae e.g., ***Microcystis, chlorococcus***. In this process **algal cell divides mitotically** to form two daughter cells, each eventually grows into an independent organism.
2. Fragmentation- This process is common in filamentous forms where the thallus breaks into small fragments e.g., ***Spirogyra, Ulothrix***. The process of fragmentation may be due to mechanical pressure, accidental or due to the formation of separation disc.
3. Budding – In this bud like structures are formed due to prolification of vesicle which later on get separated from the parent plant by the formation of the septum and develop into a new plant. e.g., ***Protosiphon***
4. Hormogonia – It is a specialized method of vegetative propagation characteristic of blue green algae. The trichomes (filaments) of many filamentous genera regularly multiply by

breaking of their trichome into short fragments called hormogonia. The formation of hormogone occurs either due to the formation of heterocyst or by formation of separation disc e.g., ***Oscillatoria, Nostoc*** (Fig.1.7).

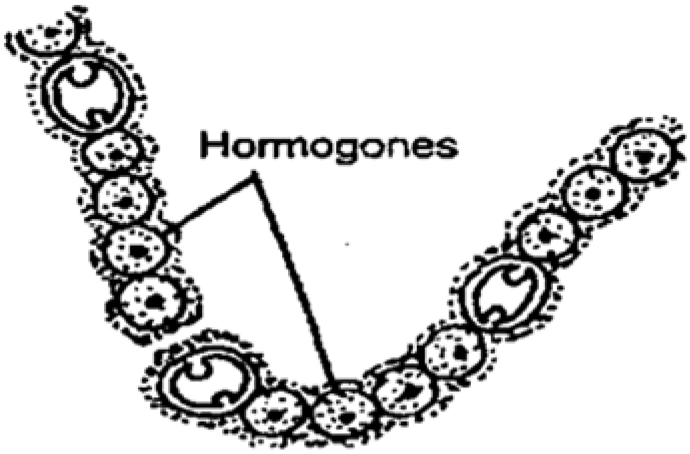

Fig.1.7: Hormogones

5. Tuber-Due to storage of food material some tuber like structures are formed on the rhizoids and lower nodes of *C**har***a .When detached from the parent plant, they produce independent plant

6. Amylum star- Some nodal cells on the lower node of the plant proliferate and develop special star shaped starch filled bodies. These are known as amylum stars (e.g. ***Chara)*** and are capable of forming a new plant (Fig.1.8).

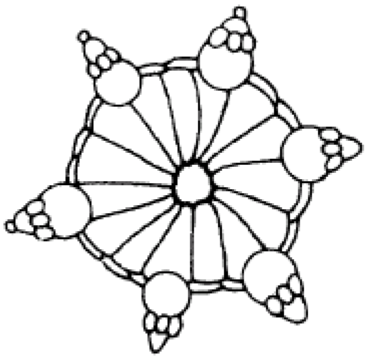

Fig.1.8: Amylum star

7. Protonema – Secondary protonema develops either from the rhizoidal node of primary protonema or from the basal node of primary rhizoid. Secondary protonema develops into new plant just like primary protonema ***(Chara)*** (Fig.1.9)**.**

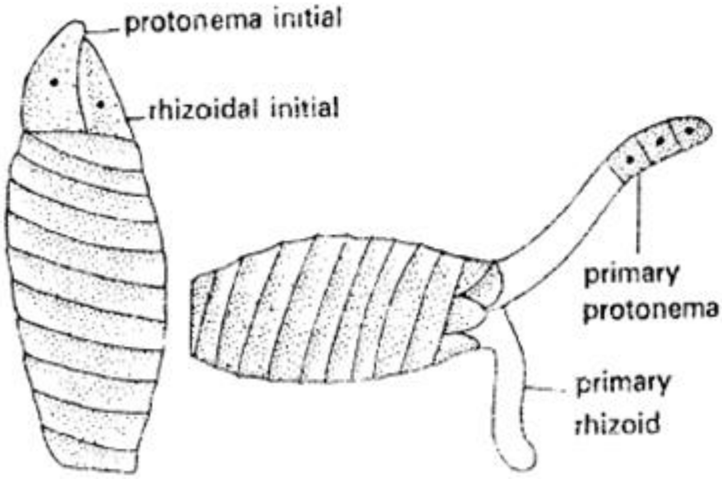

Fig.1.9: Protonema

8. Adventitious branches –In some genera adventitious branches develop from the nodal cell or storage part of thallus and on detachment from parent plant they are capable of forming new plant e.g. ***Chara and Fucus***.

1.4.2 Asexual reproduction

Generally the asexual reproduction also occurs in **favourable conditions.** In prokaryotic algae (Cynophyceae), the sexual reproduction is absent and asexual reproduction is the only means of reproduction. It is **uniparental** in which male and female two parents are not required and mode of cell division is always mitotic. Asexual reproduction is the process where the protoplast is released from the cell to form spore which develop into the new individual. The cell which produces the spores is called sporangium. Ordinary vegetative cell (e.g. ***Chlamydomonas***) or any specially modified cell can become sporangium. Spores present inside sporangia may be motile or non motile. Motile spores are called zoospores. So, on the basis of structure, spores are of following type:

1. **Zoospore-** Zoospores are **motile,** naked structures with two, four or many **flagella.** These flagella are usually inserted anteriorly, but are lateral in some brown algae. They are produced in zoosporangium. These zoospores are formed both in unicellular as well as filamentous algae e.g., ***Chlamydomonas, Ulothrix, Oedogonium, Ectocarpus*** etc (Fig 1.10 A & B). The zoospore of Xanthophyceae is known as **synzoospore** which is **multinucleated structure having numerous pairs of flagella**. These motile spores are altogether absent in class Cyanophyceae and Rhodophyceae.

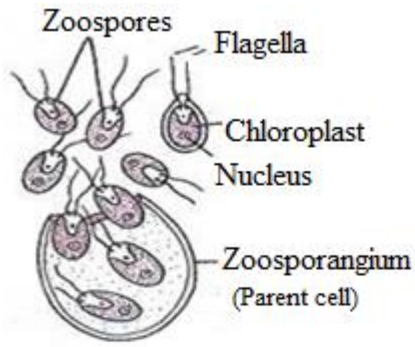

Fig 1.10 A: Zoospores **Fig 1.10 B: Synzoospores**

2. **Aplanospore**- These are **non-motile spore**s, commonly found in terrestrial algae and in some aquatic algae. Each cell may form a single aplanospore or its protoplast may divide to form many aplanospores e.g., ***Ulothrix, Vaucheria*** etc (Fig.1.11).

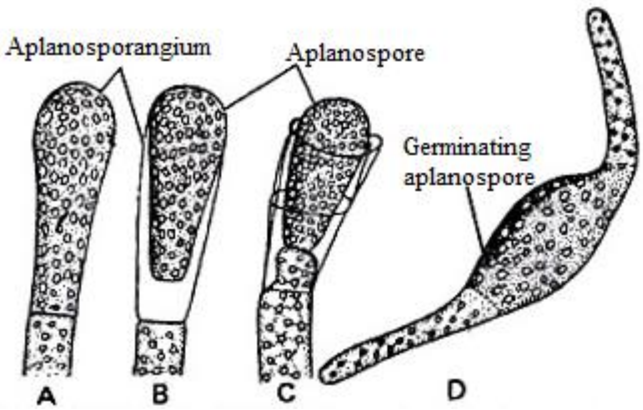

Fig. 1.11 Aplanospore formation, liberation and germination

3. **Hypnospore**- Aplanospore of some algae secretes thick walls to overcome prolonged period of desiccation. Such **thick walled aplanospores** are called hypnospore. Under favourable conditions, hypnospore germinate and grow into new individuals or their protoplast may form zoospores. The hypnospores of *Chlamydomonas nivalis are* red in colour due to deposition of pigment, haematochrome, in their cell walls e.g., *Chlamydomonas, Sphaerella* etc (Fig.1.12).

Fig.1.12: Hypnospores

4. **Tetraspores**- Diploid plants (sporophytic stage) of some algae form aplanospores which are four in number and hence is called tetraspores. e.g., *Polysiphonia* (Fig.1.13).

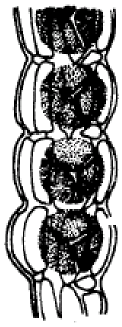

Fig 1.13: Tetraspores

5. **Autospore**- The aplanospores when they are morphologically **similar to the parent ce**ll, except in size are called autospores e.g., (***Chlorella)*** **(**Fig.1.14**).**

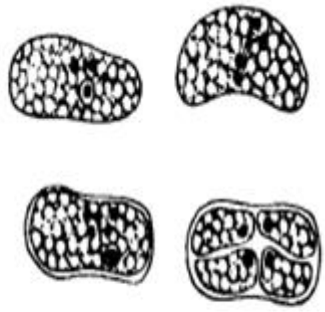

Fig.1.14: Autospore

6. **Akinete-** In some algae vegetative cell develops into **thick walled spore** like structure with the abundant food reserves. These are called akinetes. They are the **resting cells** preferably meant for perennation rather than multiplication. Akinetes always have additional wall layer. They are resistant to **unfavourable environmental conditions (*Nostoc*, *Pithophora*)** (Fig.1.15).

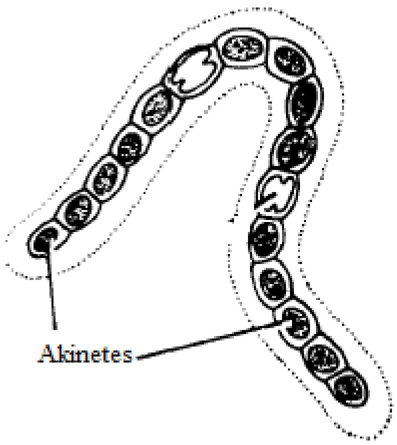

Fig.1.15: Akinete

7. **Carpospores**- In certain member of Rhodophyceae these are produced by division of zygote while within the carposporangium, e.g., ***Batrachospermum***, ***Porphyra*** etc.

8. **Exospores**- The exospores are formed externally. The protoplast of the cell comes out through terminal pore and successively cut spherical spore e.g., ***Chamaesiphon*** (Fig.1.16)**.**

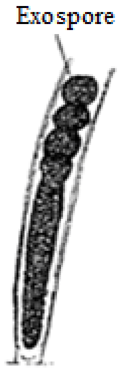

Fig1.16: Exospores

9. **Endospore**- Endospores are non motile and produced inside the sporangium by division of protoplasts. These are formed in certain member of Cyanophyceae such as ***Dermocarpa*** (Fig 1.17).

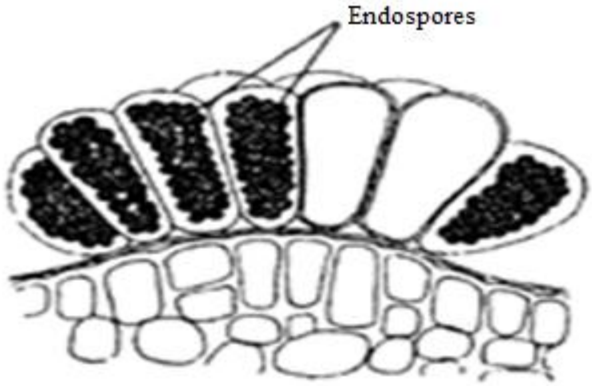

Fig 1.17: Endospores

1.4.3 Sexual Reproduction

Usually the sexual reproduction occurs during **unfavorable** conditions. **Sexual reproduction leads to creation of new combination of genes in the offspring**. It involves the fusion of two specialized reproductive cells called **gametes**. The fusing gametes may be from same parent (monoecious) or from two different parents (dioecious). The process of fusion of gamete is called fertilization and the product of fusion of gamete is called **zygote** (a diploid structure). Sexual reproduction involves three phases:

(1) **Plasmogamy** i.e. fusion of cytoplasm **(2) Karyogamy** i.e. fusion of nuclei of two different gametes / cells and **(3) Meiosi**s i.e. meiotic division in zygote (a product of karyogamy) to produce haploid cells.

On the basis of the structure and physiological behaviour of sex organ and their complexity the following types of sexual reproduction is reported in algae:

1. **Isogamy**: The simplest type of sexual reproduction in algae is isogamy (Fig.1.18). Iso means similar, gamy means fusion i.e. the fusion of two morphological similar gametes .Gamete is usually naked and always haploid. Gametes may be motile or nonmotile. However, in some species of *Chlamydomonas*, the mature adult may directly function as gamete (**hologamy).**

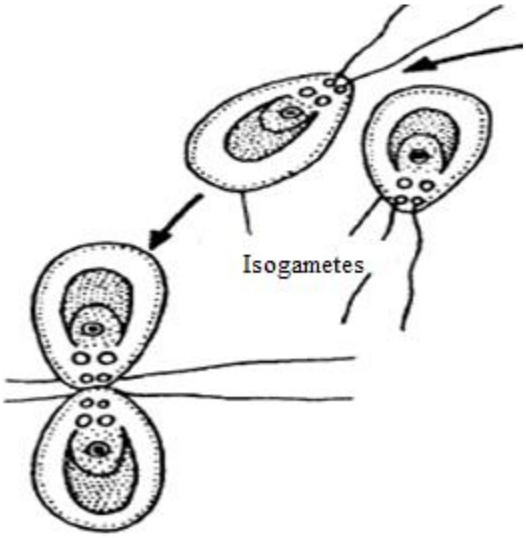

Fig 1.18 : Isogamy

2. Heterogamy: In this process the **fusion occurs between morphologically as well as physiologically different gametes**. (Hetero= different, gamy= fusion) Heterogamy is of two types (Fig 1.19).

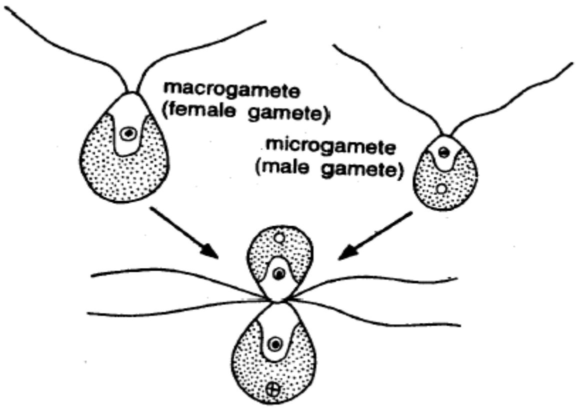

Fig 1.19: Heterogamy /Anisogamy

(a) Anisogamy

(i) Anisogamy is fusion of dissimilar gametes where male is more active and smaller in size (microgamete) while female is less active and bigger in size (macrogamete) e.g., *Chlamydomonas braunii*

(ii) Physiological anisogamy:- Sometimes the fusing gametes are morphologically similar but physiologically different, they show physiological variation with one plus (+) and other minus (-) strain.

(b) **Oogamy** is the **most advance** stage of sexual reproduction in which male gamete develops within male gametangium / antheridium, the **male gametes are active and smaller** in size, while the female gamete or egg is formed within **oogonium which is large and nonmotile**. Male gamete (antherozoid) fuses with the egg to form zygote e.g., *Chara*, *Vaucheria* (Fig 1.20).

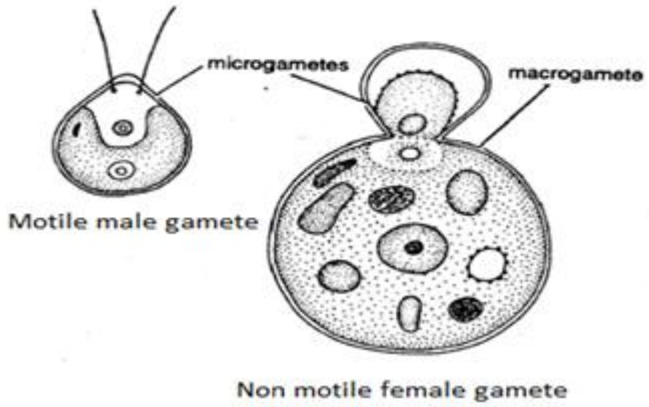

Fig 1.20: Oogamy

1.5 LIFE CYCLE

Most of the algae found in nature are haploid (n) but diatoms are diploid (2n). The **haploid generation** is commonly **gametophytic** generation is mainly known as gamete producing phase while **diploid** g**eneration (2n) or sporophytic** generation is mainly spore producing phase. Presence of both the phases is the integral part of life cycle. Now on the basis of whether **haploid** phase is dominant or **diploid phase** we name them haplontic or diplontic type of life cycle respectively. **So the sequences of events through which an organism passes from zygote to the zygote of next generation is called life cycle pattern.** However there are no regular and fixed alternation of generations are found in higher plants. Blue green algae and certain Chlorophyceae (e.g. *Protococcus*) are the exception where sexual reproduction is completely absent and they reproduce asexually only. So there is no alternation of generation.

In algae there are following type of life cycle are present which we will study in detail:

1.5.1-Haplontic type

This is the simplest and **most primitive** type of life cycle. The other patterns of life cycle have originated from this type. In most of member of Chlorophyceae haplontic type of life cycle is present.

The main plant body is thalloid and may be unicellular, multicellular or colonial. It bears gametes in the gametangium and is thus called gametophyte (n).

In haplontic life cycle the major portion of life cycle is haploid while the diploid (2n) phase is only represented by zygote which is formed by the fusion of gametes. The zygote immediately divides meiotically or reduction division into 4 haploid zoospore or meiospore which develop into individual plant. Example of haplontic type of life cycle is ***Chlamydomonas*** (a unicellular alga) and most multicellular algae like ***Oedogonium, Spirogyra, Chara*** etc (Fig 1.21).

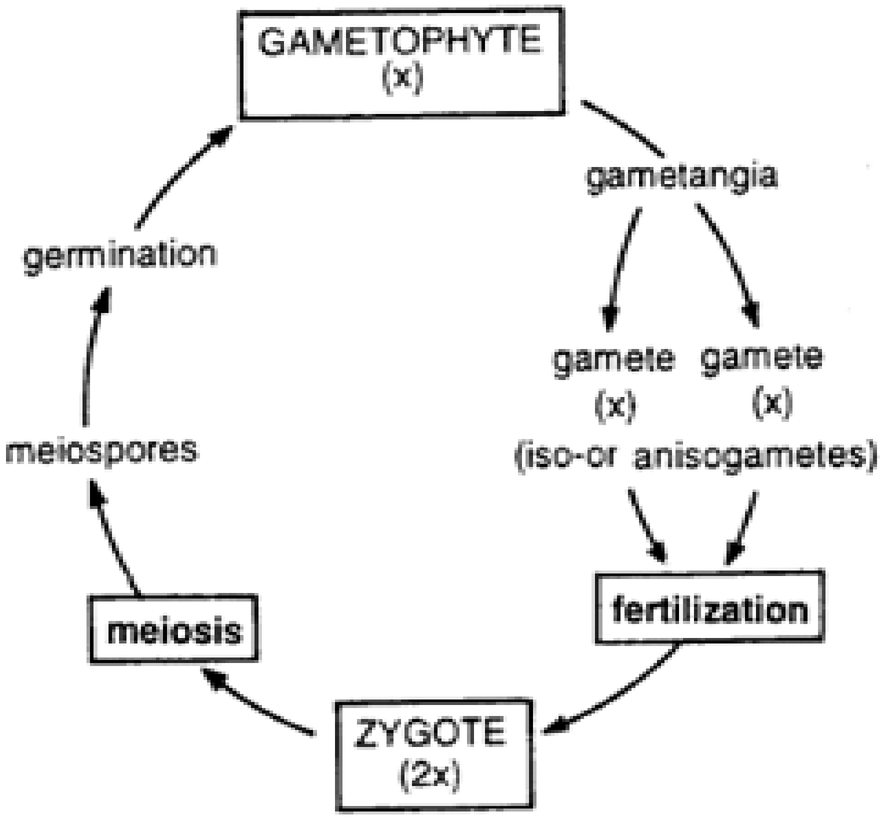

Fig 1.21: Haplontic type

1.5.2 Diplontic type

As the name indicate in diplontic type of life cycle the dominant phase of life cycle is diploid or 2n or sporophyte. We can also say that this type of life cycle is reverse of haplontic type. Here the somatic phase or main plant body is diploid (2n)

It bears sex organ (2n) which after reduction division produces gametes. Thus meiosis or reduction division occurs at the time of differentiation of gametes in the sex organ. Therefore, it is called as **gametogenic meiosis**. In these organisms the haploid condition is limited to the gametes only. The zygote after mitotic division develops into the sporophyte. The adult or main plant is sporophytic (2n). The sporophytic plant in the life cycle alternate with a few haploid cells, the gametes. Such a life cycle is called diplontic. The characteristic of this life cycle is the presence of gametogenic meiosis (Fig 1.22).

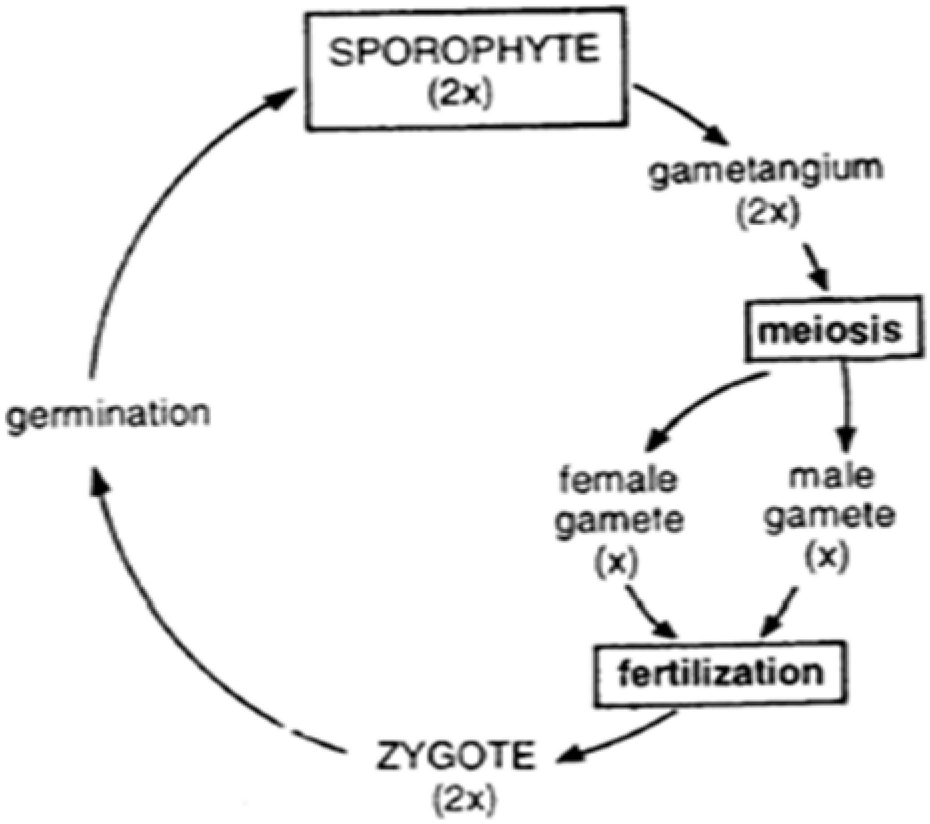

Fig 1.22: Diplontic type

Immediately after gametic union sporophytic phase or diploid phase is re-established. This type of life cycle occurs in many diatoms **(Bacillariophyceae)** and other examples are ***Fucus, Sargassam*** (Brown algae) etc.

According to Drew (1955) the haplontic and diplontic life cycle can be considered as **monomorphic or monogenic type- as the only one vegetative type of individual is dominant** as haploid or diploid in their life cycles.

1.5.3 Diplohaplontic life cycle

As you have studied in previous life cycles i.e. haplontic and diplontic, in both the case only one vegetative phase either gametophytic or sporophytic is present in the life cycle but in case of diplohaplontic life cycle there is **alternation of two distinct vegetative individuals having not only different chromosome number but different function as well.** One of these individual is haploid or gametophyte which is concern with sexual reproduction. The other is diploid or sporophyte which after meiosis produces meiospore. This type of life cycle which consist of the alternation of two vegetative individuals the gametophyte and the sporophyte with sporogenic meiosis is called diplohaplontic life cycle. It is also called diphasic life cycle.

Diplohaplontic life cycle is also of two types-

(a) Isomorphic diplohaplontic life cycle

Isomorphic type: In this type of life cycle there is an alternation of two generation which are exyernally similar but one is haploid (gametophyte) producing gametes and the other diploid (sporophyte) producing Zoospores. The zygote germinates directly into 2n plant without undergoing reduction division or meiosis and form a sporophytic plant which is morphologically similar to gametophytic plant. Meiosis occurs in the sporongia present on 2n plant. In case of Cladophorales and Ulvalves it occurs in zoosporangia while in case of *Ectocarpus* it is unilocular or unicellular sporangia. This type of meiosis is also known as sporogenic meiosis as it occurs in zoosporangia. The haploid zoospores thus formed grow into new haploid plant. Sex organ (gametangia) develops on the haploid plant and these give rise to haploid gametes. The haploid gametes fuse to form diploid zygote (e.g ***Ulva, Cladophora, Ectocarpus, Dictyota*** etc) (Fig1.23).

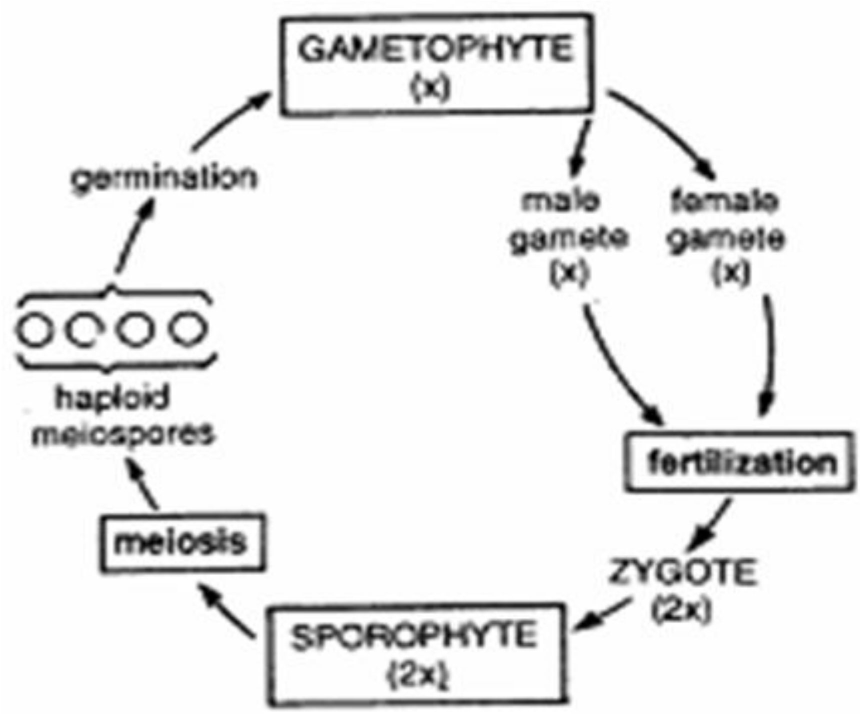

Fig.1.23: Isomorphic Type

(b) Heteromorphic diplohaplontic life cycle

As the name indicates in this life cycle **both sporophyte (2n) and gametophyte (n) plants are morphologically distinct** and they alternate to each other. Mostly the sporophytic plant is large in comparision of gametophytic plant. In ***Laminaria*** the sporophyte is several metres long which bears diploid sporangia .This **macroscopic diploid plants** bears zoosporangia which after sporogenic meiosis produces haploid meiospores. These spores germinate into **minute gametophyte or haploid plant** which produces gametes. These gametes after fusion develop in to zygote which directly develops into diploid sporophytic plant (2n) (Fig 1.24).

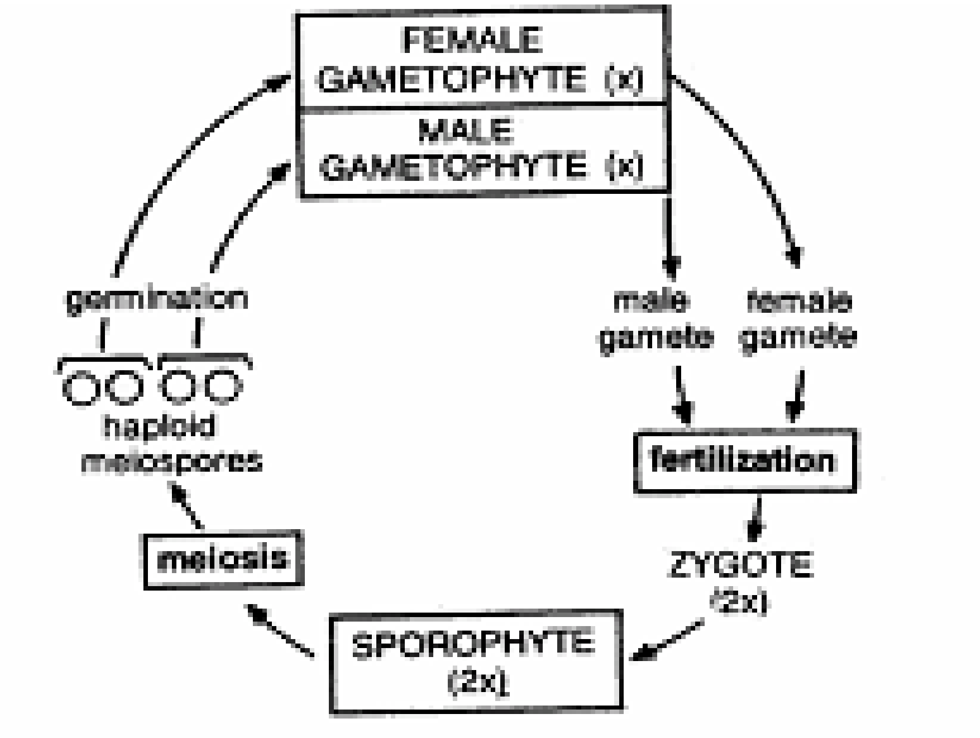

Fig. 1.24: Heteromorphic Type

1.5.4 Triphasic life cycle

Triphasic life cycle is a **succession of three generations**. This life cycle is again of two types.

(a) **Haplobiontic Life Cycle:** The best examples of this life cycle is the members of Rhodophyceae (***Batarachospermum and Nemalion)***where two well developed haploid phases are present in the life cycle therefore it is called haplobiontic triphasic. The diploid phase is represented by zygote only. The plant body of *Batarachospermum* is gametophyte which bears sex organs (spematangium and carpogonia). Male gamete(spermatium) and female gamete (egg) are formed in these sex organs which after fusion formed diploid zygote while the basal portion of carpogonium gives rise to a haploid filament (gonimoblast filament)The uppermost cell of these filaments function as carposporangium(n) which bear haploid carpospores. The gonimoblast filament, carposporangia and carpospores covered by sterile filments together represent carposporophyte generation (n). On liberation carpospores germinate into heterotrichous chantransia stage. From chantrantia stage eventually arise the normal gametophytic plant. There is thus alternation of three successive dissimilsr, somatic haploid generation (**carposporophyte, chantrantia stage and parent gametophyte)** with a diploid phase of short duration (Fig 1.25).

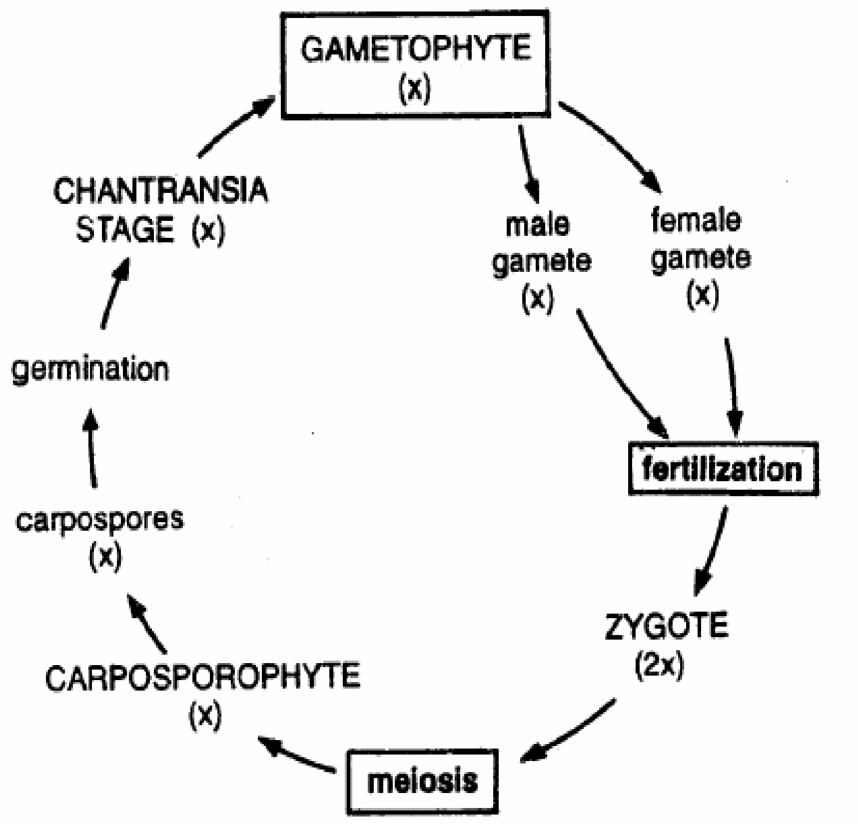

Fig 1.25: Triphasic Haplobiontic Type

(b)Diplobiontic or Diplobiontic triphasic life: During diplobiontic life cycle there are two distinct diploid phases i.e. carposporophyte and tetrasporophyte alternate with haploid gametophytic phase and the best example is ***Polysiphonia*** of Rhodophyceae.The male and female gametes are present on the their respective sex organs. These sex organs develop on male and female gametophytic plant respectively. The product of fusion of male and female gamete is zygote. The zygote divides mitotically and form small diploid carposporophyte which remain attached to the gametophytic plant .The carposporophyte than produce carposporangia having a single diploid carpospores. On liberation diploid carpospores germinate to form a free living diploid tetrasporophyte. The adult tetrasporophyte bears tetrasporangia (2n). Now meiosis occures in tetrasporangia and four haploid tetraspore are formed. The tetraspore, on germination produces a free living gametophytic plant (Fig 1.26). It is believed that the diplobiontic life cycle has evolved from the haplobiontic by sudden mutation (Fritch, 1942b).

In general, we can conclude sexually producing algae complete their life cycle by passing through two distinct phases (i**) gametophytic phase** (n) concerned with the production of gametes and (ii) **sporophytic phase** (2n) concerned with the production of spores. These two phases **alternate each other in a regular sequence, and is known as alternation of generation.**

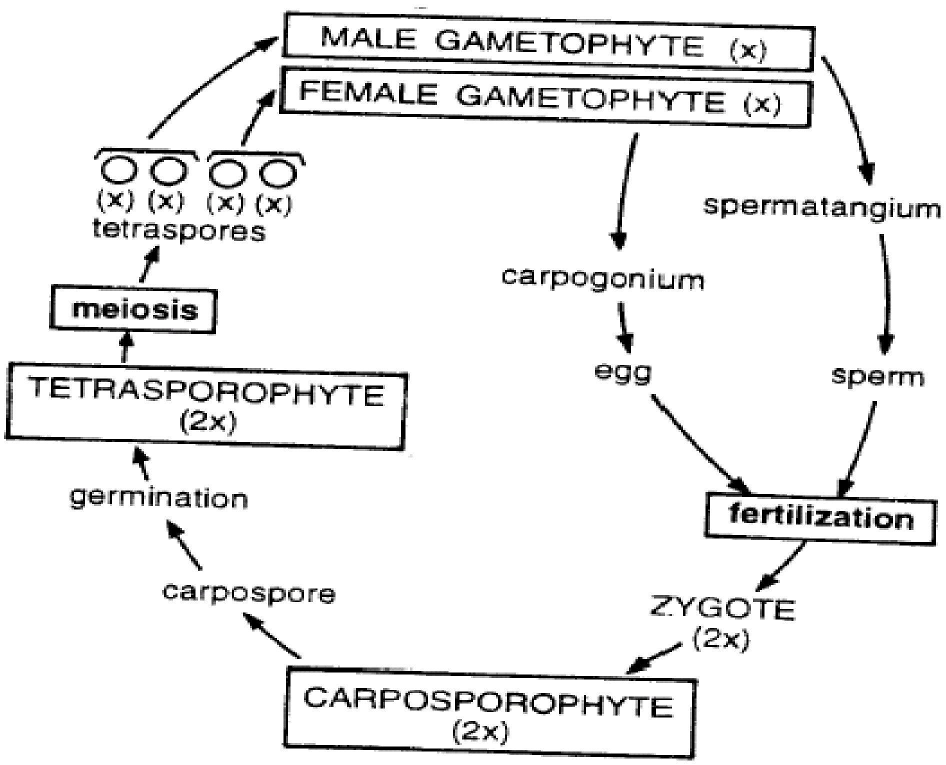

Fig 1.26: Triphasic Diplobiontic Type

1.6 SUMMARY

Algae are the first chlorophyll bearing thalloid organisms which can synthesize their own food by the process of photosynthesis. They exhibit a great diversity in their thallus organization ranging from unicellular to parenchymatous. Flagella are present in all the classes of algae except Cyanophyceae and Rhodophyceae. Algae are cosmopolitan in nature and present almost every place where life is possible but predominantly they are aquatic.

The plant body of algae is thalloid having no differentiation into root, leaf and stems. Sex organs are unicellular and if multicellular each cell is fertile.

The cell structure of algal thalli are basically of two kinds prokaryotic and eukaryotic. The prokaryotic cell having incipient nucleus is present only in the class Cyanophyceae while all the other classes of algae exhibit eukaryotic cell structure having a well developed nucleus and all the membrane bounded cell organelle present in the cell.

The primary classification of algae is based on the habit and habitat, presence and ratio of chlorophyll and other photosynthetic pigments, chemical nature of reserve food material, presence or absence of flagella.

The propagation of algae takes place by vegetative, asexual and sexual methods. Vegetative reproduction occurs by the means of cell division, Hormogonia and adventious braches etc. Asexual reproduction takes place with the help of Zoospore, Aplanospore, Hypnospore, Tetraspore, Autospore, Akinetes etc. These are produced in sporangia.

Sexual reproduction involves the fusion of two gametes which come from same or different parents/ gametangia. The sexual reproduction may be isogamous, anisogamous or oogamous type.

Members of the sexually reproducing algae exhibit various life cycle pattern. They are haplontic, diplontic, diplohaplontic (isomorphic or heteromorphic) or haplobiontic/diplobiontic with triphasic life cycle.

1.7 GLOSSORY

Zoosore: Asexually produced motile spore
Aplanospore: Asexually produced non motile spore.
Heterogamy: In sexual reproduction when the two fusing gametes are morphologically different
Oogamy: Fusion of motile sperm with non motile passive egg
Thallus: Plant body that is not differentiated into root leaf and stem
Hypnospore: Thick walled spore, meant for perennation
Phycology: Study of algae
Autotrophic: Plant that can make their own food by the process of photosynthesis
Haplontic life cycle: when the main plant body and the major portion of life cycle is haploid and the zygote represents only diploid stage.
Diplontic life cycle: The plant body is diploid (sporophyte) and the major portion of life cycle is diploid .The gametes represents only haploid stage.
Isomorphic life cycle: There is a alternation of two generation which are externally similar but functionally different. One is gametophyte producing gametes while other is sporophyte producing zoospore.

1.8 SELF ASSESSMENT QUESTIONS

1.8.1 One word Answer:

1. Name the class of algae where sexual reproduction is absent.
2. Give one example of algae having haplontic life cycle.
3. Which organelle is associated with storage of starch?
4. Name the causal organism of red rust of tea.
5. What are the characteristic pigments of class Chlorophyceae?

6. What is the characteristic pigment of class Phaeophyceae?
7. What are phytoplanktons?
8. What we call an association of two dissimilar organisms for mutual benefit.

1.8.1- Answers: 1. Cyanophyceae 2. *Chlamydomonas,* 3. Pyrenoid, 4. *Cephaleuroce,* 5.Chlorophyll a and b, 6. Fucoxanthin, 7. Aquatic and floating algae, 8. Symbionts

1.8.2 True and False

1. The red and brown algae do not contain chlorophyll-b.
2. Motile reproductive bodies are completely absent in Rhodophyceae.
3. The spermatium is motile body.
4. Hypnospores are thick walled aplanospore.
5. Zoospore is non motile spore.
6. *Polysiphonia* is example of triphasic life cycle.
7. A colony having a definite shape is called coenobium.
8. M.O.P Iyenger is known as " Father of Phycology in India".

1.8.2 Answers: 1. False, 2. True, 3. False, 4. True, 5. False, 6. True, 7. True, 8. True

1.8.3 Fill in the blanks-

1. …………… are the proteinaceous body found in chromatophore.
2. …………… is known as father of phycology.
3. The plant body of algae is ………………..
4. ………………… is a photoreceptive organ.
5. Study of algae is known as…………………
6. Sexual reproduction is absent in the members of class…………
7. All the classes except …………. include unicellular form.
8. Chlorophyll a and Chlorophyll b is present in class…………..only.

1.8.3 Answers: 1.Pyrenoids, 2.F.E.Fritch, 3.Thalloid, 4.Eye spot, 5.Phycology, 6.Cyanophyceae, 7.Phaeophyceae, 8.Chlorophyceae

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1.11 TERMINAL QUESTIONS

1.11.1 Long answer type questions:

1. What are algae? Give the characteristic features of algae.
2. Describe the various pigments present in algae.
3. Give an illustrated account of various types of life cycle found in algae.
4. Describe the various modes of vegetative reproduction in algae.
5. Describe the various modes of asexual reproduction in algae.
6. Describe the basic types of cell organelle in algae.
7. Differentiate between isomorphic and heteromorphic types of life cycle.
8. Differentiate between prokaryotic and eukaryotic cell.
9. Give an account of asexual reproduction in algae studied by you.

1.11.2 Short answer type questions:

1. Algal habitat
2. Flagella in algae
3. Structure of prokaryotic cell
4. Triphasic life cycle in algae
5. Haplontic life cycle
6. Diplontic life cycle
7. Eye spot in algal cell
8. Types of chloroplast found in algae

UNIT-2- IMPORTANT CLASSIFICATIONS

2.1- OBJECTIVES

After reading this section you will know -

1. What are different algal classifications
2. Classification given by F.E. Fritsch.
3. Algal Classification given by Smith
4. Algal Classification given by R.E. Lee

2.2- INTRODUCTION

Algae possess diverse characters in their pigments, nature of reserve food, nature of cilia/ flagella etc. According to these morphological and physiological differences many classifications have been proposed by phycologists.

Chlorophyll is present in all groups of algae but in some groups pigments other than chlorophyll are dominant and mask the green colour of chlorophyll. On the basis of their colour following four groups were recognized.

(i) Cyanophyceae (blue-green algae) dominant pigment – c- phycocyanin.

(ii) Chlorophyceae (green algae) dominant pigment - chlorophyll a and b.

(iii) Phaeophyceae (brown algae) dominant pigment - (fucoxanthin) Xanthophyllus.

(iv) Rhodophyceae (red algae) dominant pigment - (r-phycocrythrin) Phycobilin.

In the last few decades new informations have been reported on the structure, reproduction and physiological processes of algae which has been used to develop more natural systems of classification.

Although phycologists do not agree on the details of algal classification, However algae are generally classified on the basis of the following characteristics:

1. Nature and properties of pigments.
2. Chemistry of reserve food products or assimilatory products of photosynthesis.
3. Type, number, insertion (point of attachment) and morphology of flagella.
4. Chemistry of cells and thalli.
5. Morphological characteristics of cells and thalli.
6. Life history pattern, reproductive structures and methods of reproduction.

2.3 IMPORTNAT CLASSIFICATIONS

2.3.1 Classification proposed by F.E. Fritsch

The first most comprehensive and authorative classification of algae was given by F.E Fritsch (1935,1948) in his book, **The Structure and Reproduction of the Algae**. His classification was based on the following criteria:

(i) Pigmentation

(ii) Types of flagella
(iii) Assimilatory products
(iv) Thallus structure and
(v) Methods of reproduction.

F.E. Fritsch divided algae into the following 11 classes.

1. **Myxophyceae (Cyanophyceae)**. Plants simple, no definite nucleus, absence of chromatophores and motile cells; reproduction by fission; pigment c-phycocyanin in addition to chlorophyll; commonly blue-green; products of photosynthesis sugar and glycogen; sexual reproduction absent, e.g. *Nostoc, Anabaena, Rivularia, etc.*
2. **Euglenophyceae**. (Flagellates). Plants unicellular, combining characters of plants and animals. Fresh- water or salt water, mostly solitary and free-swimming, but some forms in gelatinous colonies and some are attached. Plants motile, green, with one or two cilia, definite nucleus, contractile vacuole, chloroplasts and prominent eye spot; reproduction by fission only, e.g. *Euglena, Heteronema*, etc.
3. **Chlorophyceae**. Plants variable in structure with definite nucleus, chloroplasts and motile reproductive cells bearing variable number of flagella; commonly green due to *chlorophyll*; products of assimilation starche and sugar; sexual reproduction ranges from isogamy to anisogamy and oogamy, e.g. *Volvox, Ulothrix, Spirogyra, Vaucheria, etc.*
4. **Chloromonadineae**. Plants bright - green with excess of chlorophyll; products of assimilation fats; chloroplasts many, discoid; reproduction by longitudinal division of individuals. Not much is known about the representatives of this class as yet.
5. **Xanthophyceae (Heterokontae**). Chloroplasts yellow-green owing to an excess of xanthophyll; oil replaces starch; flagella two, of unequal lengths; sexual reproduction rare, but isogamous; cell wall of two equal or unequal halves, overlapping each other, e.g. *Botrydium*, *Tribonema*, etc.
6. **Chrysophyceae**. Plants primitive; chloroplasts brown or orange due to the presence of accessory pigments such as phycochrysin; cell wall may or may not be present; fat and leucosin (protein like substance) are usual forms of food storage; cysts silicified; motile cells with one, two, rarely three equal flagella, rarely unequal; sexual reproduction rare but isogamous when present, e.g. *Chromulina, Chrysamoeba*, etc.
7. **Bacillariophyceae** (Diatoms). Cell wall partly silicified and partly pectose, symmetrical halves ornamented with delicate markings; chromatophores yellow or golden-brown, one set of forms radially symmetrical, the other bilaterally symmetrical; sexual reproduction isogamous or anisogamous, e.g. *Pinnularia, Navicula, Melosira*, etc.
8. **Cryptophyceae**. Each cell with two large parietal chloroplasts with diverse colours though frequently of a brown shade; starch as product of photosynthesis; motile cells

with two unequal flagella; mostly flagellate forms; sexual reproduction isogamous in one species only; cysts common and endogenous, e.g. *Cryptomonas, Chilomonas,* etc.

9. **Dinophyceae** (Peridineae). Most members are unicellular and motile with a tendency towards filamentous habit: cell wall sculptured; chromatophores discoid, dark-yellow or brown in colour; starche and fat are products of photosynthesis ; motile cells with a longitudinal and transverse furrow, biflagellate; sexual reproduction rare, but isogamous when present, e.g. *Heterocapsa, Ceratium, Peridinium*, etc.

10. **Phaeophyceae**. Mostly marine; colour brown due to the presence of a brown pigment- *fucoxanthin*; products of photosynthesis alcohol, fat, polysaccharide and sugar; plants filamentous or highly organized into large sea weeds with internal and external differentiation; reproductive cells biflagellate, the flagella attached to one side, one directed forward and the other backward, produced in uni or plurilocular sporangia; sexual reproduction iso/aniso/or oogamous, e.g. *Ectocarpus, Fucus, Dictyota, Laminaria, etc.*

11. **Rhodophyceae.** Mostly marine, few are fresh-water, coloured red or violet, due to the presence of r- *phycoerythrin* and r-*phycocyanin;* food reserve is floridean starch; reproductive cells non-flagellate; plants filamentous or highly organized showing complex differentiation, though not as in phaeophyceae; protoplasmic connections present between cells of all forms except proto-florideae; sexual reproduction oogamous; male cells or spermatia carried by water currents to the trichogyne of the female cell ; cystocarps produce carpospores which germinate to produce tetrasporic diploid plants ; alternation of generations common, e.g. *Nemalion, Batrachospermum, Polysiphonia,* etc.

    Nematophyceae, a fossil group with two genera has also been suggested by Fritsch. True affinities of this class are still doubtful; internal morphology similar to higher Chlorophyceae, while spore tetrads are similar to Rhodophyceae.

2.3.1.1 Characters of different classes of algae given by F.E. Fritsch

1**. Class: Chlorophyceae** (Green Algae)

Occurrence: Most forms are fresh water and a few are marine.

Pigments: Chief pigments are chlorophyll a and b and carotenoids (yellow pigments)

Reserve food: Starch

Structure: Unicellular motile to heterotrichous filaments. Cell wall consists of cellulose. Pyrenoids are commonly surrounded by starch sheath. Motile cells have equal flagella.

Reproduction: Sexual reproduction ranges from isogamous to advanced oogamous type.

Example: *Chlamydomonas, Volvox, Chlorella, Scenedesmus, Pediastrum.*

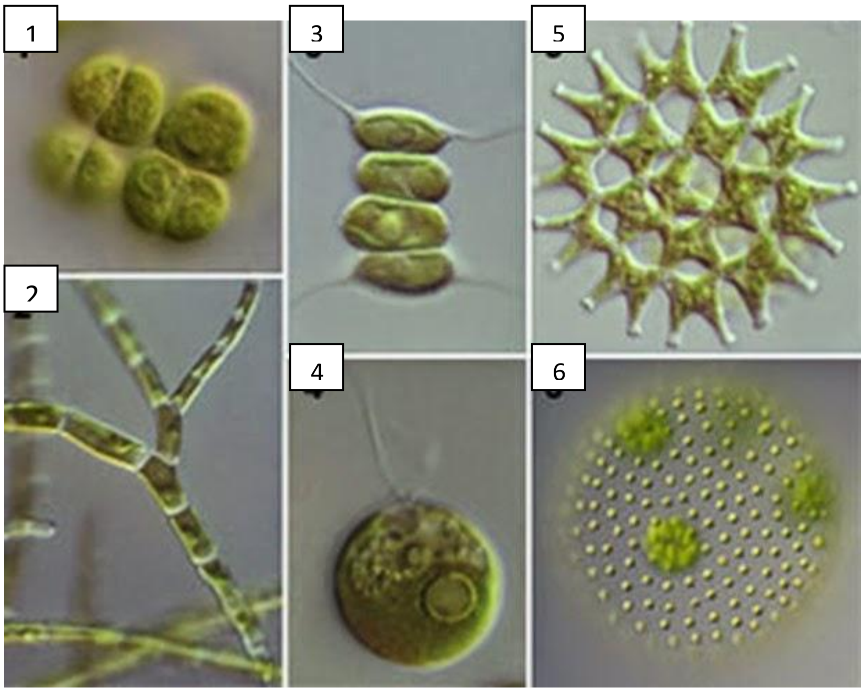

Fig. 2.1 a. Desmotetra b. Stigeoclonium c. Desmodesmus d. Chlamydomonas e. Pediastrum and f. Volvox

2. **Class: Xanthophyceae** (Yellow green algae)

Occurrence: Most forms are fresh water but a few are marine.

Pigments: Yellow xanthophyll is found abundantly.

Reserve food: oil

Structure: Unicellular motile to simple filamentous forms. Cell wall rich in pectic compounds and composed of two equal pieces overlapping at their edges. Motile cells have two very unequal flagella. Pyrenoids absent.

Reproduction: Sexual reproduction is rare and always isogamous, if present

Example: Vaucheria

3. **Class: Chrysophyceae**

Occurrence: Most forms occur in cold fresh water but few are marine.

Pigments: Chromatophores are brown or orange coloured. Phycochrysin serves as chief accessory pigments.

Reserve food: Fat and leucosin.

Structure: Plants are unicellular motile to branched filamentous forms. Flagella are unequal attached at front end. Cells commonly contain one or two parietal chrmatophores.

Reproduction: Sexual reproduction seldom occurs but is of isogamous type when present.

4. **Class: Bacillariophyceae** (Diatoms)

Occurrence: In all kind of fresh water, sea, soil and terrestrial habitats.

Pigments: Chromatophores are yellow or golden brown. Nature of accessory pigments is not very definite.

Reserve food: Fat and volutin.

Structure: All the members are unicellular or colonial. Cell wall is partly composed of silica and partly of pectic substances. It consists of two halves and each has two or more pieces. Cell wall is richly ornamented.

Reproduction: Forms are diploid. Sexual reproduction is special type, occurs by fusion of

protoplasts of the ordinary individuals.

Example: *Pinnularia*

5. **Class: Cryptophyceae**

Occurrence: Both in marine and fresh water

Pigments: Chromatophores show diverse pigmentation. It may be some shades of brown. Chromatophores are usually parietal.

Reserve food: Solid carbohydrates or in some cases starch.

Structure: Represented by motile cells and most advanced forms are coccoid, flagella are slightly unequal.

Reproduction: Isogamous in the reported cases.

Example: *Chroomonas*

6. **Class: Dinophyceae**

Occurrence: Plants occur widely as sea water planktons. A few may be fresh water forms.

Reserve food: Starch and oil

Pigments: Chromaophores are dark yellow, brown , etc., and contain a number of special pigments.

Structure: plants are unicellular motile to branched filaments.

Reproduction: Sexual reproduction is of isogamous type. it is rare and not very definite.

Example*: Dinoflagellate , Ceratium*

7. **Class: Chloromonadineae**

Occurrence: All plants are fresh water forms.

Pigments: Chromatophores are bright green in colour and contain an excess of chlorophyll.

Reserve food: Oil

Structure: The plants are motile, flagellate with two almost equal flagella.

8. **Class: Euglenineae**

Occurrence: Only fresh water forms are known

Pigments: Chromatophores are pure green. Each cell has several chromatophores.

Reserve food: Polysaccharide and Paramylon

Structure: Motile flagellates, flagella may be one or two arising from the base of canal like invagination at the front end. Complex vacuolar system and a large prominent nucleus.

Reproduction: Sexual reproduction is not substantially known. It is isogamous type.

Example: *Euglena*

9. **Class: Phaeophyceae** (Brown algae)

Occurrence**:** Mostly marine

Pigments**:** chl a, c, carotenes, xanthophylls, chl b absent.

Reserve food**:** Mannitol as well as laminarin and fats.

Structure**:** The plants may be simple filamentous to bulky parenchymatous forms. Several plants attain giant size, external and internal differentiation.

Reproduction**:** Sexual reproduction ranges isogamous to oogamous. Motile gametes have two laterally attached flagella. Varied types of alternation of generation.

Example: *Ectocarpus, Sargassum*

10. Class: Rhodophyceae (Red algae)

Occurrence**:** Few forms are fresh water and others are marine.

Pigments**:** Chromatophores are red blue containing pigments like red r-phycoerythrin and blue r-phycocyanin, Chl a, d, and carotenes.

Reserve food: Floridean starch

Structure**:** Simple filamentous forms, attaining considerable complexity of structure. Motile structures are not known.

Reproduction**:** Sexual reproduction is advanced oogamous type. The male organ produces non motile gametes and the female organ has a long receptive neck. After sexual reproduction special spores (carpospores) are produced

Example: *Batrachospermum, Polysiphonia*

11**. Class: Myxophyceae** (Cyanophyceae or Blue green algae)

Occurrence**:** Found in sea and fresh water, as well as moist places

Pigments: Chlorophyll, carotenes, xanthophylls, and c-phycocyain and c-phycoerythrin. The ratio of last two pigments exhibits colour variation, commonly blue green.

Reserve food**:** Sugars and Glycogen

Structure**:** Simple type from cell to filamentous and some of the filamentous forms show false or true branching, very rudimentary nucleus, no proper chromatophores, the photosynthetic pigments being diffused throughout the peripheral position. No motile stages.

Reproduction**:** There is no sexual reproduction.

Example: *Oscillatoria, Nostoc*

2.3.2 Classification of algae given by Smith

Classification by Smith

The classification of algae proposed by Smith (1933, 1951, 1955) is based on the physiological characteristics of vegetative cells and the morphology of motile reproductive cells. He divided algae into seven divisions and then related classes were included in each division. The classes which show close affinity have been placed under the same division. For example, Xanthophyceae, Chrysophyceae and Bacillariophyceae show certain resemblances in the structure and composition of the cell wall, flagellation and nature of food reserves and despite differences in their pigment there is enough ground for placing them together in the same division Chrysophyta. The seven divisions of algae recognized by Smith are as follows:

Division 1. Chlorophyta

Class 1. Chlorophyceae (grass-green)

Class 2. Charophyceae

Division 2 Englenophyta

Class 1 Englenophyceae

Division 3 Pyrrophyta

Class 1 Desmophyceae (dinophysids)

Class 2 Dinophyceae (dimoflagelloids)

Division 4 Chrysophyta

Class 1 Chrysophyceae (golden brown)

Class 2 Xanthophyceae (yellow green)

Class 3 Bacillariophyceae (diatoms)

Division 5 Phaeophyta (brown algae)

Class 1 Isogenerateae

Class 2 Heterogenerateae

Class 3 Cyclosporeae

Division 6 Cyanophyta (Blue Green algae)

Class 1 Myxophyceae

Division 7 Rhodophyta (Red Algae)

Class 1 Rhodophyceae

Algae of uncertain Systematic position

Chloromonadaceae

Cryptophyceae

2.3.3 Classification of algae proposed by R.E. Lee

Classification by R.E Lee

According to Lee there are 4 distinct groups within the algae.

Group 1 – It contains the only prokaryotic algae, the Cyanophyta or blue-green algae. It forms a natural group by virtue of being the only prokaryotic algae.

Prokaryotic algae have an outer plasma membrane enclosing protoplasm containing photosynthetic thylakoids, 70S ribosomes and DNA fibrils not enclosed within a separate membrane. Chlorophyll a is the main photosynthetic pigment and oxygen is evolved during photosynthesis.

Group 2 – It contains 1) Glaucophyta 2) Rhodophyta and 2) Chlorophyta. These form a natural group of algae in that they have plastids surrounded by two membranes. The evolutionary event that led to the chloroplast occurred as follows. The uptake of a cyanobacterium by a protozoan into a food vesicle. This resulted in the establishment of an endosymbiosis between the cyanobacterium and the protozoan. Through evolution, the endosymbiotic cyanobacterium evolved into a chloroplast surrounded by two membranes of the chloroplast envelope.

Group 3 -The Euglenophyta and Dinophyta are natural groupings in that this is the only algal group to have one membrane of chloroplast endoplasmic reticulum. Chloroplast endoplasmic reticulum resulted when a chloroplast from a eukaryotic alga was taken up to as a food vesicle by a phagocytotic euglenoid or dinoflagellate. Initially a chloroplast was taken up by a phagocytotic protozoan into a food vesicle. An endosymbiosis resulted, with the food vesicle membrane eventually evolving a single membrane of chloroplast endoplasmic reticulum surrounding the chloroplast.

Group 4- Algae with two membranes of chloroplast endoplasmic reticulum (chloroplast ER) has the inner membrane of chloroplast ER surrounding the chloroplast envelope. The other membrane of chloroplast ER is continuous with the outer membrane of the nuclear envelope and has ribosomes on the outer surface.

2.4- SUMMARY

F.E. Fritsch classified the whole of the algae into eleven classes on the basis of types of pigments, nature of reserve food material, mode of reproduction etc. They are Chlorophyceae, Xanthophyceae, Chrysophyceae, Bacillariophyceae, Cryptophyceae, Dinophyceae, Chloromonodineae, Euglinineae, Phaeophyceae, Rhodophyceae and Myxophyceae (Cyanophyceae). The classification is published in his book titled **"The Structure and Reproduction of Algae".**

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

According to Lee there are 4 distinct groups within the algae.

2.5 GLOSSARY

Acronematic: Flagella with smooth surface and ending in a thin hair.
Akinete: Non motile resting spore.
Amyloplast: A colorless plastid
Anisogamy: Fusion of two dissimilar gametes.
Anisokont: Cell with flagella of dissimilar length
Aplanospore: Non motile spore.
Autospores: Aplanospore similar in shape to the parent cell
Axoneme: The shaft of the flagellum**.**
Coenobium: Colony consisting of a definite number of cells arranged in a definite manner.
Coenocyte: Multinucleate cell.
Cyanelle: Endosymbiotic cyanobacterium
Cyanome: Host cell containing cyanelle
Endophytic: Plant living within another plant.
Endosymbiosis: Term that describes an organism living inside a host in a mutually beneficial relationship- symbiosis
Endozoic: Living within the tissues of animal but not parasitic.
Epizoic: Growing attached to the outer surface of animals.
Eye spot or Stigma: Pigmented area inside the algal cell composed of lipid droplets associated with phototaxis.
Gametangium: Gamete bearing organ.
Heterokont: The presence of unequal flagella.

Heteromorphic alternation of generation: Alternation of morphologically dissimilar generations

Heterothallic (Dioecious): Producing male and female gametangia on different thalli

Heterotrichous: Thallus differentiated into prostate and erect systems.

Holophytic or autotrohic: Needing only light and inorganic substances for growth

Holozoic or phagocytosis: Absorbing food particles whole into food vesicles for digestion

Homothallic (Monoecious): Producing both male and female gametangia on the same thallus (Self compatible)

Isokont: Cell with flagella of the same length

Isomorphic alternation of generation: Alternation of morphologically similar generations

Mastigoneme: Hair like appendage on flagella**.**

Oogamy: Fusion of motile/non motile male gamete with large non motile female gamete.

Palmelloid: Palmella like habit.

Pantonematic: Flagellum with surface covered with hairs.

Phycobilisome: Particles containing phycobiliproteins

Pseudoparenchymatous: Collection of cells, filaments forming tissue that resembles parenchyma.

Rhizopodia: False feet for locomotion or attachment.

Siphonaceous: Tubular thallus in algae lacking septa or cross walls.

Stephanokont: Cell with a ring of flagella at one end

Thallus: Plant body in which root, stem and leaves cannot be differentiated.

Zoospore: Motile flagellated asexual cell.

2.6 SELF ASSESSMENT QUESTIONS

2.6.1 Long answer type questions:

(i) Give Classification given by F.E. Fritsch
(ii) Explain Classification given by Smith
(iii) Give Classification proposed by R.E. Lee

2.6.2 Short answer type questions:

(i) Name of the book in which Fritsch has given the algal Classification.
(ii) Mention the criteria on which algal classification proposed by Smith is based.

2.6.3 Multiple choice type questions:

(i) All algae possess
(a) Nuclei (b)Chloroplasts
(c) Both a and b (d)None of these

(ii) Kelps are algae found in
(a) Chlorophyta (b) Chrysophyta
(c) Phaeophyta (d) Pyrrophyta

(iii) Frustules made of silica are characteristic of
(a) Euglenoids (b)Diatoms
(c) Desmids (d)Seaweeds

(iv) Which of the following best describe the algae known as diatoms?
(a) Cells have intricate shells of silicon dioxide with two halves
(b) Diatoms Cells have intricate shells of silicon dioxide with two halves
(c) Cells are encased in rigid walls composed of cellulose coated with silicon
(d) Cells have flagella and a light-detecting eye spot

(v) Chrysolaminarin is an energy storage material characteristic of
(a) Chlorophyta (b)Chrysophyta
(c) Phaeophyta (d)Rhodophyta

(vi) The ____________________ is the vegetative body of algae
(a) Mycelium (b) Plasmodium
(c) Pseudoplasmodium (d)Thallus

(vii) *Chlamydomonas* and *Volvox* are similar because
(a) They both are motile (b) They are members of the Chlorophyta
(c) Both (a) and (b) (d) None of these

(viii) Starch is an energy material characteristic of
(a) Chlorophyta (b) Chrysophyta
(c) Phaeophyta (d) Rhodophyta

2.6.3 Answers of Multiple choice questions-

(i)	c	(v)	b
(ii)	c	(vi)	d
(iii)	b	(vii)	c
(iv)	b	(viii)	a

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- B.R. Vashishta, A.K.Singha, V.P. Singh (2013), Botany for Degree Students (Part-1) Algae, S. Chand & Company Ltd. New Delhi

2.8 SUGGESTED READINGS

- Textbook of Algae by H.D. Kumar.
- Structure and Reproduction in Algae by F.E. Fritsch
- The records of Botanical survey of India by K. Biswas
- Cyanophyta by T.V. Desikachary
- Charophyta by B. P. Pal, V.S. Sundaralingam & G.S. Venkataraman
- Algae : Forms & function by G.S. Venkataraman, S.K. Goyal, B.K. Kaushi & P. Roy choudhary

2.9 TERMINAL QUESTIONS

1. Who coined the term algae?
2. What is the study of algae called?
3. Give four most important characteristic features of algae.
4. Give one example each of unicellular, colonial, filamentous and parenchymatous type of algae.
5. Differentiate between
   a) Algae and fungi
   b) Isogamy and Oogamy
   c) Acronematic and pantonematic
   d) Aplanospore and zoospore
6. Write short notes on:
   a) Eye spot b) Pyrenoid c) Phycobiliproteins
7. Discuss briefly the different types of storage products found in various algal groups.
8. Discuss in brief, the classification given by R.E. Lee.
9. What are the main criteria for the classification of algae.
10. How are blue green algae distinguished from the other algae.
11. What is the name of the book written by Fritsch?
12. How would you justify the inclusion of the cyanophyta & Charophyta among algae.
13. What are the reserve food materials found in the cells of Rhodophyceae.
14. How many classes were recognized in algae by G.M Smith.
15. What are the common pigments present in algae. State the importance of these pigments in the classification of algae.

16. Give Systematic position of the following algae on the basis of G.M Smith classification.
    1) *Nostoc* *2) Chara*
    3) Ectocarpus *4) Polysiphonia.*
17. What are the different types of chloroplasts found in Chlorophyceae.
18. Discuss the three types of sexual reproductions found in algae.
19. Discuss the four major groups of algae based on nature of the plastids and its evolutionary origin according to Lee's classification.

UNIT- 3- RANGE OF VEGETATIVE STRUCTURE IN ALGAE

3.1- OBJECTIVES

After reading this unit you will be able to:-

- Know about thalloid plants.
- Know the thallus organization in algae.
- Understand the thallus structure of different forms of algae.

3.2- INTRODUCTION

As we know algae are chlorophyll containing autotrophic thalloid plants. They occur in a variety of habitats, but majority of them are aquatic. Algae are placed in the division thallophyta. The plant body is generally called thallus. Thallus is a plant body which is not differentiated into root, stem and leaves. The vegetative structure of algae shows a wide variety and it ranges from unicellular to complex multicellular thalli. The size of algal thalli ranges from one micron to several meters. Multicelluar forms have been derived by repeated division of unicellular forms. Filamentous algal thallus developed by repeated transverse division of cells without separation of daughter cells. The daughter cells remain attached with parental cell. A colonial type of thallus organization is formed by the aggregation of the products of cell division within a mucilaginous mass. The siphonaceous types of thallus organization developed by repeated nuclear divisions but without cross wall (septa) formation except during formation of reproductive structure. Siphonaceous forms looks as a tube-like multinucleate structure or a coenocyte. Parenchyma is a tissue composed of thin walled closely associated cells which has arisen by the repeated division of a parent cell. Generally parenchymatous thalli developed by the division of cells of a filament in two or more planes. Some algal thalli are pseudoparenchymatous means false parenchymatous plant body. This structure is secondary in development; close association of cells is a result of interweaving of filaments. Thus there are great variations among the vegetative structure of algal thalli which are as follows (Fig. 3.1).

1. Unicellual forms
2. Colonial forms
3. Filamentous form
4. Siphonaceous form
5. Pseudoparenchymatous form
6. Parenchymatous form

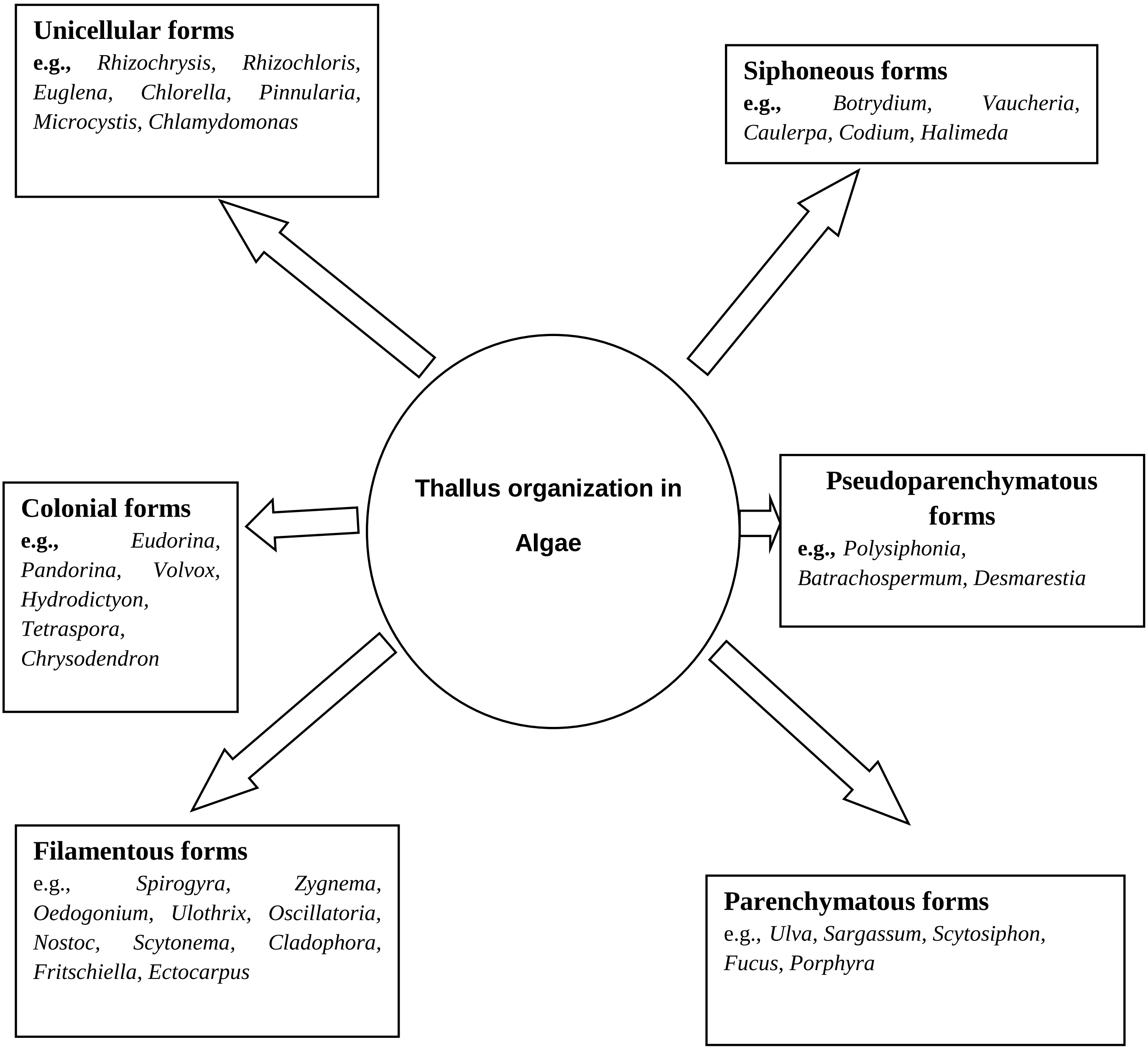

Fig. 3.1 Different types of thallus organization in Algae

1. Unicellular Forms

Unicellular forms are quite common in all the groups of algae except Charophyceae and Phaeophyceae. Unicellular forms function as a complete unit without any cellular differentiation. The unicellular types may be amoeboid, motile or non-motile. Unicellular types can be divided into following sub-groups-

(a) Unicellular rhizopodial form
(b) Unicellular motile form

(c) Unicellular filamentous form
(d) Unicellular non-motile

(a) Unicellular rhizopodial forms- The important features of these algae are as follows:-

(i) These are also called amoeboid forms.
(ii) These algae lack flagella.
(iii) The movement in these algae takes place by cytoplasmic projections.
(iv) The rigid cell wall is absent in these algae.
(v) Examples- *Chrysamoeba, Rhizochrysis* (Fig. 3.2) etc.

(b) Unicellular Motile Forms- Following are the important features of these algae are as-

(i) Flagella are present in all the groups of algae except Cyanophyceae, Phaeophyceae, Rhodophyceae and Bacillariophyceae.
(ii) Flagella are the important character in algae.
(iii) The number of flagella is varying from species to species. For example in Chlorophyceae have two Flagella while in Euglenophyceae there is only one Flagellum, inserted at the anterior end of the thallus.
(iv) The size and nature of flagella is also varying from species to species, e.g., in Dinophyceae and Xanthophyceae there are two unequal flagella.
(v) Examples- *Chlamydomonas, Euglena* (Fig. 3.2) etc.

(c) Unicellular filamentous forms - These are mostly spiral or coiled structure. Examples- *Spirulina, Pinnularia* (Fig. 3.2)

(d) Unicellular non-motile forms- The important features of these algae are as follows:-

(i) Lack of flagella and eye spot.
(ii) These types of algae are called coccoid type it includes forms of diverse shape and size.
(iii) Examples- *Chlorella* (Fig. 3.2).

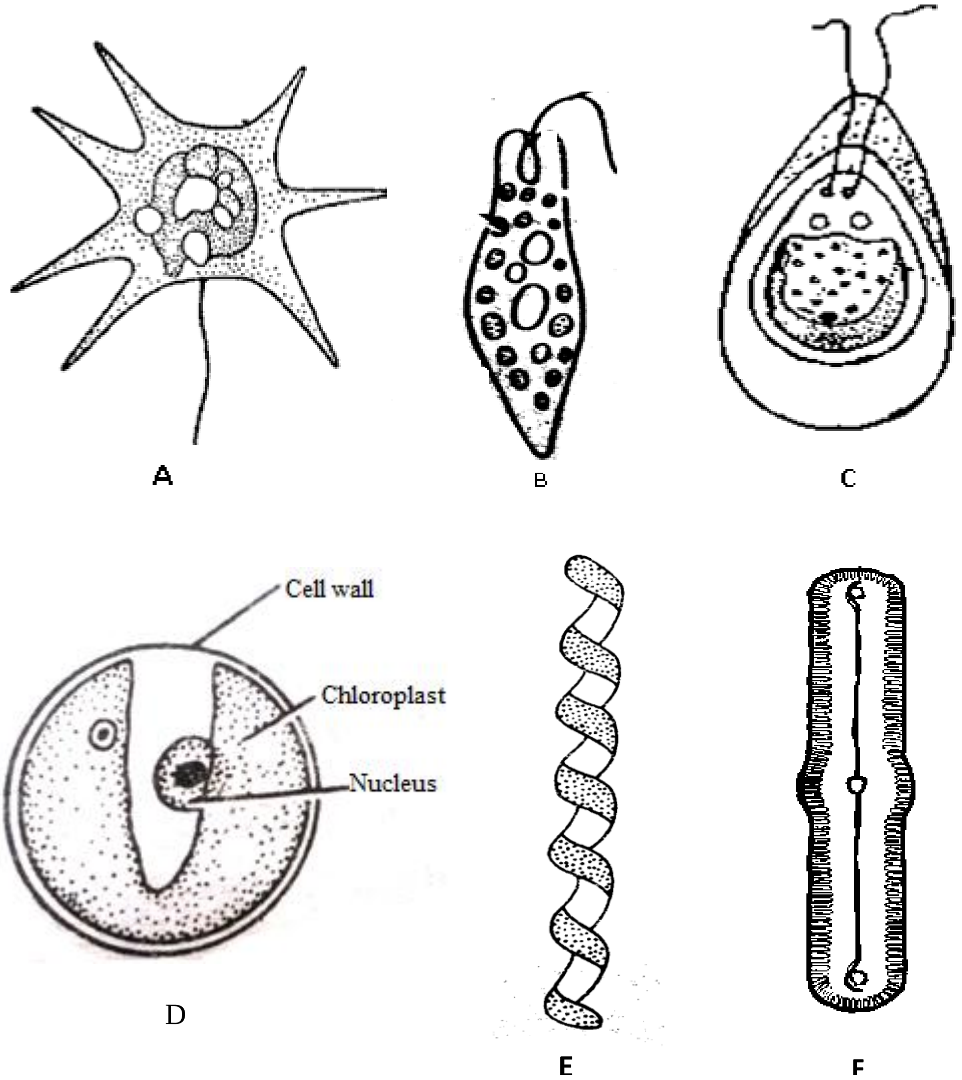

Fig.3.2. Unicellular thallus organization in algae, A. Chrysamoeba, B. Euglena, C. Chlamydomonas, D. Chlorella, E. Spirulina and F. Pinnularia

2. **Colonial Forms**

A colony is a group of separate cells generally similar in structure and function but aggregated in a mucilaginous matrix. The members of some algal colony are connected with each other by cytoplasmic connections so that they cannot break into small pieces or segments (e.g. *Volvox*). On the basis of morphology there are following four types of colonial organizations present in algae-

(a) Coenobial Colony

(b) Palmelloid Colony

(c) Dendroid Colony

(d) Rhizopodial Colony

(a) Coenobial Colony

A coenobium colony has a definite number of cells arranged in a particular manner which is determined at the juvenile stage and does not increase during its subsequent growth even though the cell enlarges. Coenobia may be motile or non-motile. In motile from flagella are present e.g., *Volvox* and in non-motile, flagella are absent e.g. *Hydrodictyon* (Fig. 3.3).

(b) Palmelloid Colony

In palmelloid colony the number of cells, their shape and size is not definite. The cells remain irregularly aggregated within a common mucilagenous mass, but they function independently. Palmelloid stage may be temporary phase (e.g. *Chlamydomonas*) or it may be a permanent feature (e.g. *Tetraspora*) (Fig. 3.3).

(c) Dendroid Colony

In Dendroid colonies, the cells are united together in a branching manner by a mucilagenous thread. The colony looks like a tree in habit, also called microscopic tree. In this colony the number, shape and size of the cells are also indefinite. Examples- *Chrysodendron* (Fig. 3.3).

(d) Rhizopodial Colony

In a rhizopodial colony the cells are united through rhizopodia. Example- *Chrysidiastrum*.

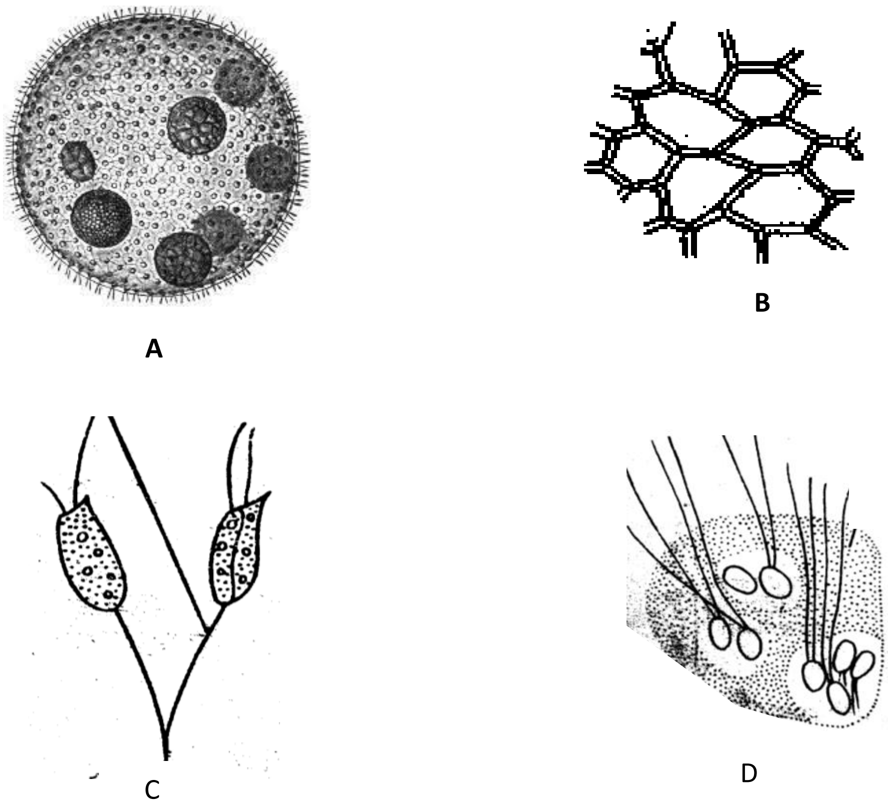

Fig.3.3. Colonial type of thallus organization in algae:
A. *Volvox*, B. *Hydrodictyon*, C. *Chrysodendron*, D. *Tetraspora*

3. **Filamentous Forms**

As we know a filament is developed by repeated transverse division of cells. The filaments may be branched or unbranched. Unbranched filaments are present in few groups of algae. The filament may be attached to the substratum (e.g. *Zygnema, Oedogonium*), free floating (e.g. *Spirogyra*) or form colony (e.g. *Nostoc, Oscillatoria*) (Fig. 3.4). Branched Filaments is of two kinds- false and true. In false branching which occurs in the scytonemataceae, the trichome generally fragments due to the degeneration of an intercalary cell after which one or both of its ends adjacent to the dead cell grow out of the parent sheath, giving the resemblance of branching (e.g. *Scytonema*). True branching results from repeated transverse divisions of the lateral outgrowths produced by a few or many scattered cells of the main filament. The true branched thalli are of two types-

(i) Simple Branched Filaments

(ii) Heterotrichous Filaments

Simple branched filaments remain attached to the substratum by a basal cell. In such filament branches may arise from any cell except the basal cell. Example- *Cladophora.* The heterotrichous habit is the most highly evolved type of filament, and differentiated into prostrate and erect systems. This most highly evolved type of plant body showing a good amount of division of labour, is characteristic of some groups like Chaetophorales, in many Pheophyceae, Rhodophyceae, in some Chrysophyceae and Dinophyceae. This type of Algal thallus is made up of two distinct parts- (i) a basal or prostrate creeping system and (ii) an erect or upright system. The prostrate system is attached to the substratum, grows apically and gives rise to numerous photosynthetic and rhizoidal filaments. In *Fritschiella* the rhizoid filaments sometime penetrate the substratum. The erect system, develop from the prostrate system and is composed of one or more and usually branched photosynthetic filaments. Examples- *Draparnaldiopsis*, *Ectocarpus, Sphacelaria, Chaetopeltis* etc.

4. Siphonaceous Form

A Siphonaceous thallus is multinucleate and lacks septation (Septa) except during the formation of reproductive organs. The simple organization is in the form of a small unbranched vesicle. It contains a central vacuole with chloroplasts and nuclei in the peripheral cytoplasm (Fig. 3.5).

Examples- *Vaucheria, Botrydium, Caulerpa, Protosiphon* etc.

5. Pseudoparenchymatous form

The term ‘pseudo’ means false, the plant body gives the appearance of paranchymatous construction. The pseudoparenchymatous thallus is a secondary development; close association of cells is a result of interweaving of filaments. Secondary filamentous structure develops in many genera. Pseudoparenchymatous thallus may be develop as (i) Uniaxial and (ii) Multiaxial forms; In Uniaxial from, the thallus developes by the branching of only one filament (e.g. *Batrachospermum*) while in multiaxial forms, branches of more than one filaments are involved (e.g. *Polysiphonia*) (Fig. 3.6).

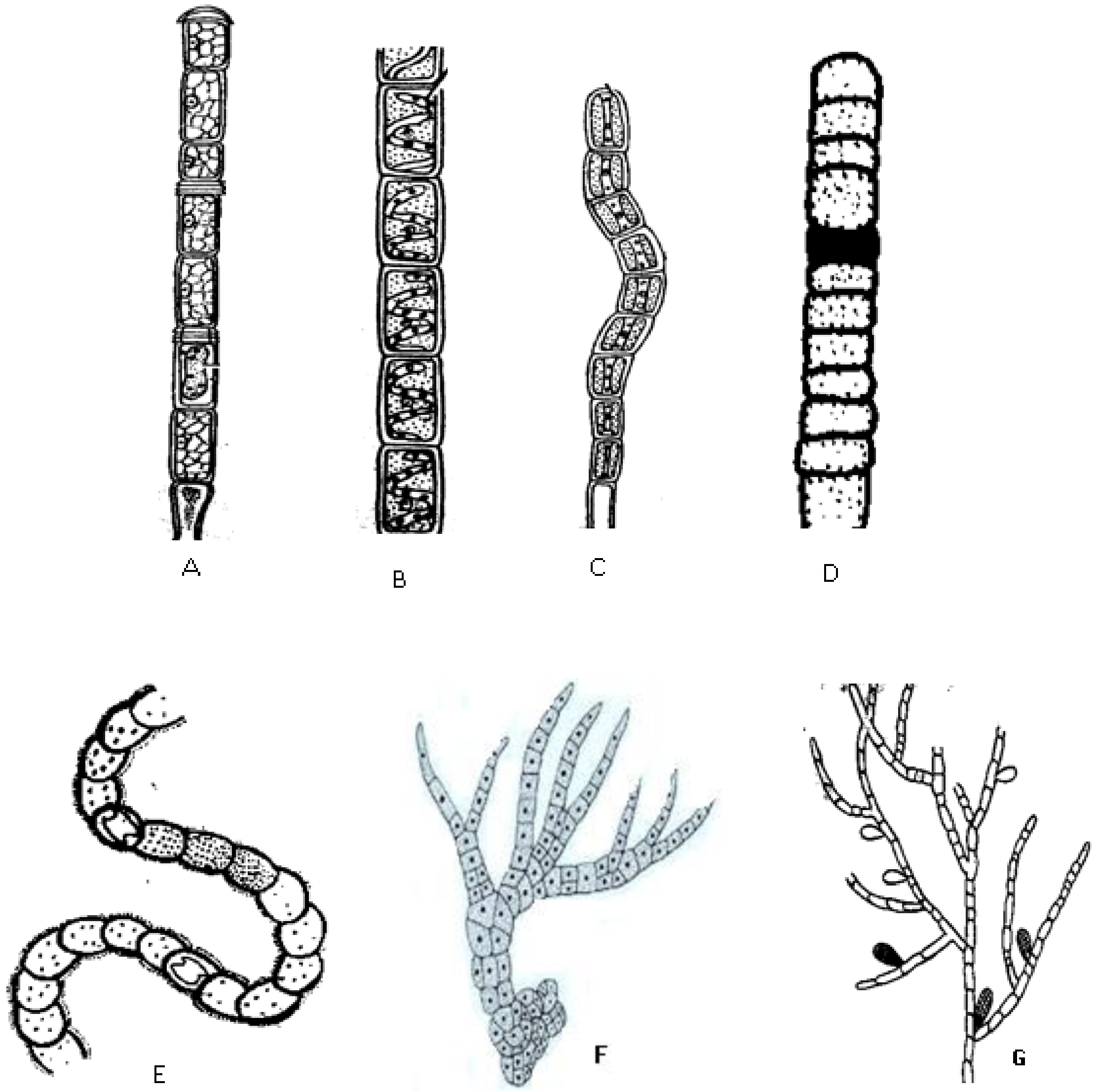

Fig.3.4. Filamentous thallus organization: A. ***Oedogonium,*** **B.** ***Spirogyra*** **C.** ***Ulothrix,*** **D.** ***Oscillatoria,*** **E.** ***Nostoc,*** **F.** ***Fritschiella*** **G.** ***Ectocarpus***

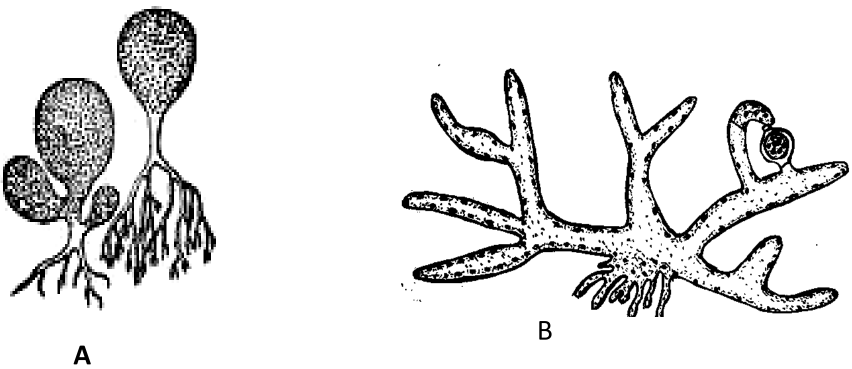

Fig.3.5. Siphonaceous type of thallus organization. A. ***Botrydium,*** **B.** ***Vaucheria***

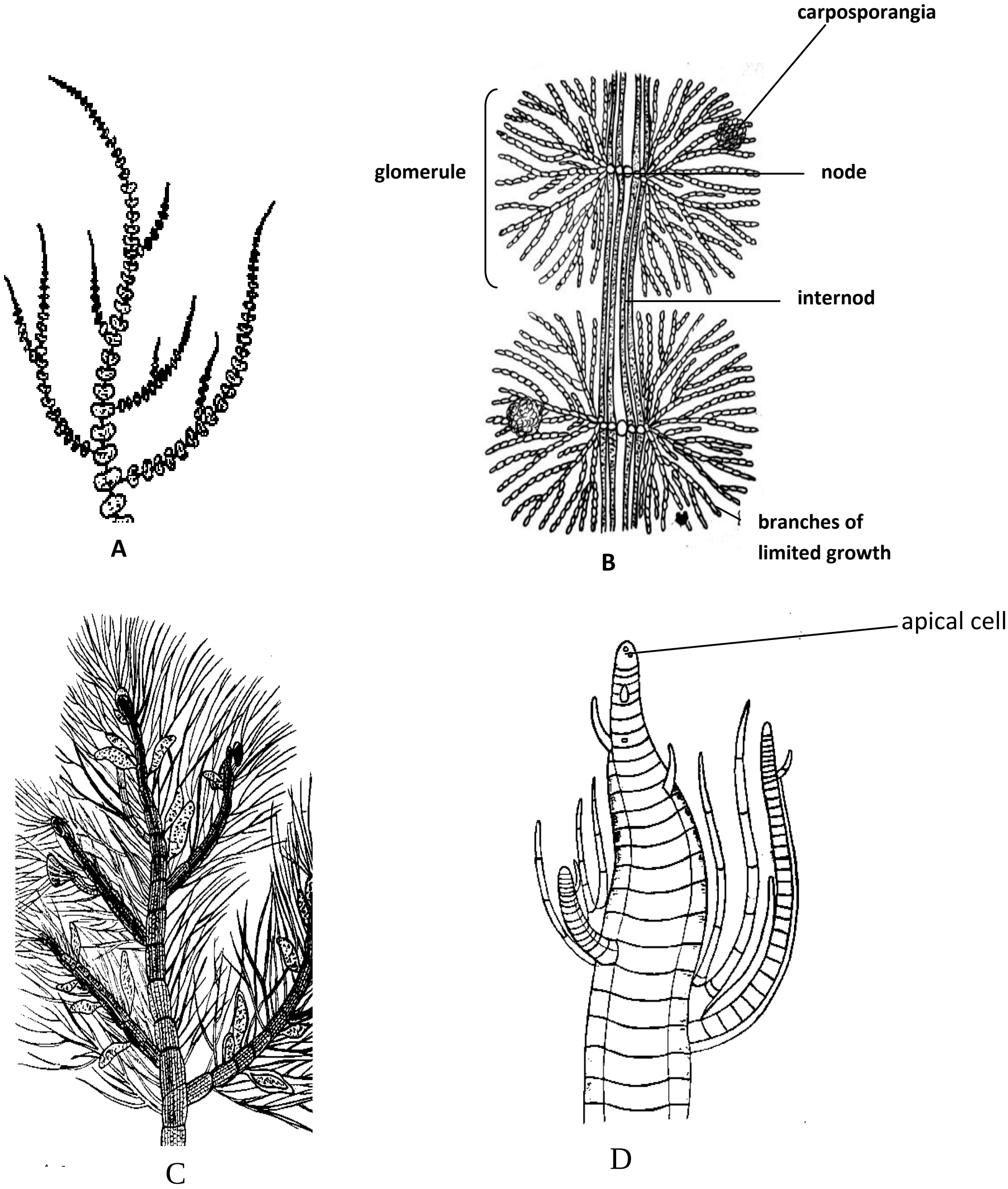

Fig. 3.6 Pseudoparenchymatous type of thallus organization. A & B. *Batrachospermum* part of thallus and magnified view C&D. *Polysiphonia* Part of thallus and thallus apex

6- Parenchymatous Forms

Parenchyma is a simple permanent tissue composed of thin walled closely associated cells which has arisen by the cell division of a common parent cell. Parenchymatous thallus organization also is a modification of the filamentous habit, with cell division in more than one plane. The parenchymatus thalli may be leaf like or foliose, tubular or highly developed structure. Flat, foliose or tubular thalli is develop by the division of the cells in two or three planes (e.g. *Ulva*, *Porphyra*). The example of tubular thallus is *Scytosiphon*, and of the complex thallus is *Sargassum*. *Sargassum* thallus is diploid and sporophytic and differentiated into holdfast and the main axis. The holdfast helps in attachment of thallus to substratum. The internal structure is also made up of parenchymatous tissue (Fig. 3.7).

Examples- *Ulva, Porphyra, Scytosiphon, Sargassum, Fucus, Dictyota, Laminaria* etc.

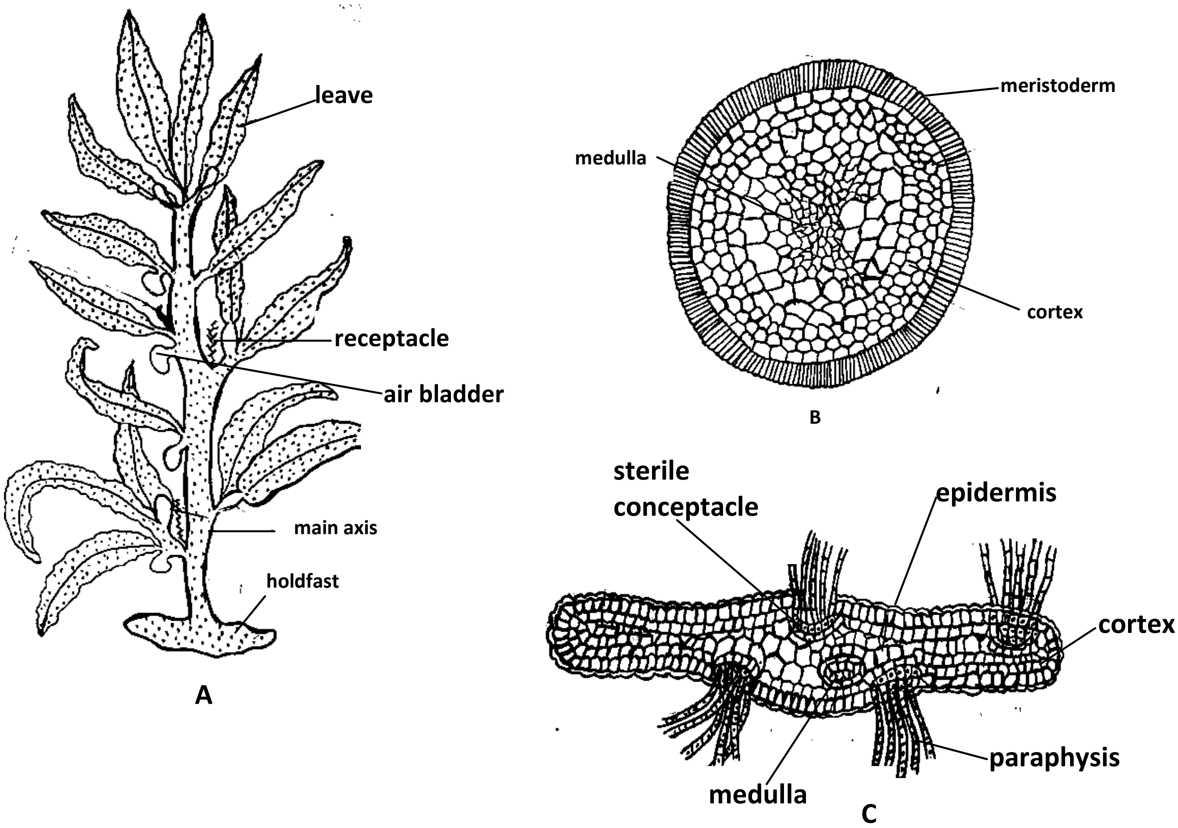

Fig.3.7. Parenchymatous type of thallus organization, A. Sargassum thallus, B. T.S. of main axis C. vertical section of leaf

3.3- ORGANIZATION OF THALLUS

3.3.1- *Chlamydomonas*

Chlamydomonas is a motile unicellular green alga. The thallus is represented by a single cell. The cell is biflagellate (two flagella) spherical, ellipsoidal or pear shaped; about 30 μm in length and 20 μm in diameter. The pyriform or pear shaped thalli are common; they have narrow anterior end and a broad posterior end (Fig. 3.8 A). In some species *of Chlamydomonas* the posterior end is pointed (e.g. *Chlamydomonas caudata*). Two, rarely more, contractile vacuoles are found near the base of each flagellum, and a prominent cup shaped chloroplast is present in each cell. Cellulose is the main structural component of the cell wall. In some species the cellulose wall is surrounded by a gelatinous sheath. Most of the species of *Chlamydomonas* have a massive cup-shaped parietal chloroplast. Besides cup-shaped chloroplast following types of chloroplast are also present in different species of *Chlamydomonas*-

'H' shaped chloroplast	-	*Chlamydomonas biciliata*
discoid chloroplast	-	*Chlamydomonas alpina*
reticulate chloroplast	-	*Chlamydomonas reticulacta*
ridged chloroplast	-	*Chlamydomonas stenii*
axile chloroplast	-	*Chlamydomonas eradians*

Pyrenoid a proteinaceous body is present in chloroplast. Pyrenoids are concerned to with the synthesis and storage of starch. The thallus contains single large, dark nucleus lying inside the cavity of the cup shaped chloroplast. The flagella are present in the anterior end of the cell. Flagella are equal in length and whiplash or acronematic type. The flagella are mostly longer to the thallus but in some species it may be shorter or equal to the thallus. Each flagellum originates from a basal granule or blepharoplast and comes out through a fine canal in cell wall. The main function of the vacuole is excretion or osmoregulation. A pigmented spot known as eye-spot or stigma is located at the anterior part of the cell. The shape and position of the eye spot varies in different species. The eye spot has a colourless biconvex photosensitive lens and a curved pigmented plate. It is photoreceptive organ and functions as a primitive eye. (Fig 3.8 B)

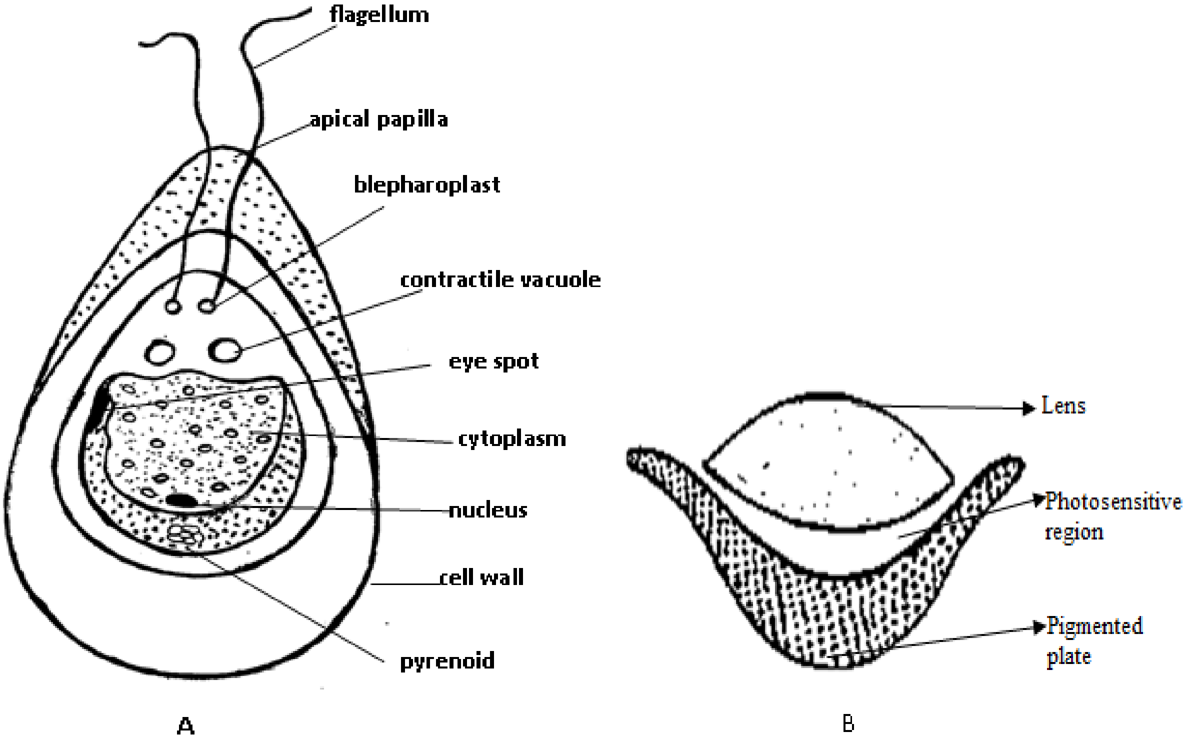

Fig 3.8 Thallus organization of Chlamydomonas A. Cell structure, B. Structure of eye spot

3.3.2- *Volvox*

Volvox is a colonial green alga. The habit of thallus is called coenobium. The colonies are oval or spherical in shape having 500-60000 cells in each coenobium. The cells are biflagellate and are arranged in a single layer within the periphery of the gelatinous colonial envelop (Fig 3.9 A). The movement is brought about by the joint action of the flagella of individual cells. The cells are connected to each other by cytoplasmic strands. The cells of anterior end possess bigger eye spots than the cell of posterior end. The cells of posterior end become reproductive at maturity. The cells of *volvox* colony are *Chlamydomonas* type. The cells of colony are usually pyriform with narrow anterior end and broad posterior end. Two flagella of equal length are present in each cell and are whiplash type. The protoplasm of cell is enclosed within plasma membrane. Each cell contains one nucleus, a cup shaped chloroplast, pyrenoid, an eye spot and two contractile vacuoles. The eye spot is towards the external face of the cell. It has a colourless biconvex photosensitive lens and a curved pigmented plate (Fig 3.9 B). Most cells of a colony are vegetative only a few are reproductive. The flagella are absent in reproductive cells. Each cell of the colony is independent for various functions.

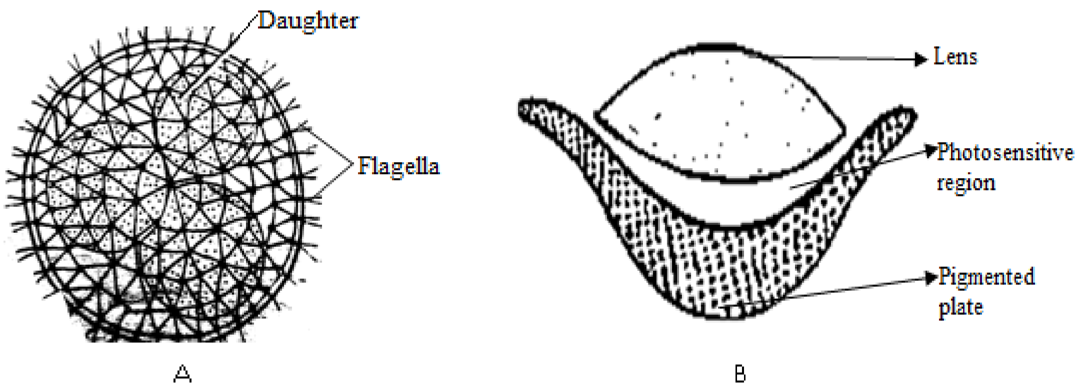

Fig. 3.9: *Volvox* A. a colony, B. An eye spot

3.3.3- *Oedogonium*

Oedogonium is the filamentous and multicellular fresh water green alga. The filaments are nbranched and consist of cylindrical cells except the basal cell which is modified into a holdfast. The basal cell, which acts as holdfast is devoid of chloroplast. The terminal cells of the filaments are generally rounded, elongated or acuminate and the intercalary cell shows an apical basal polarity. A characteristics feature of this alga is the presence of distinct transverse bands at the distal ends of some cells. The band formed at the time of cell division is called apical cap, and the cell with apical cap is known as cap cell (Fig. 3.10).

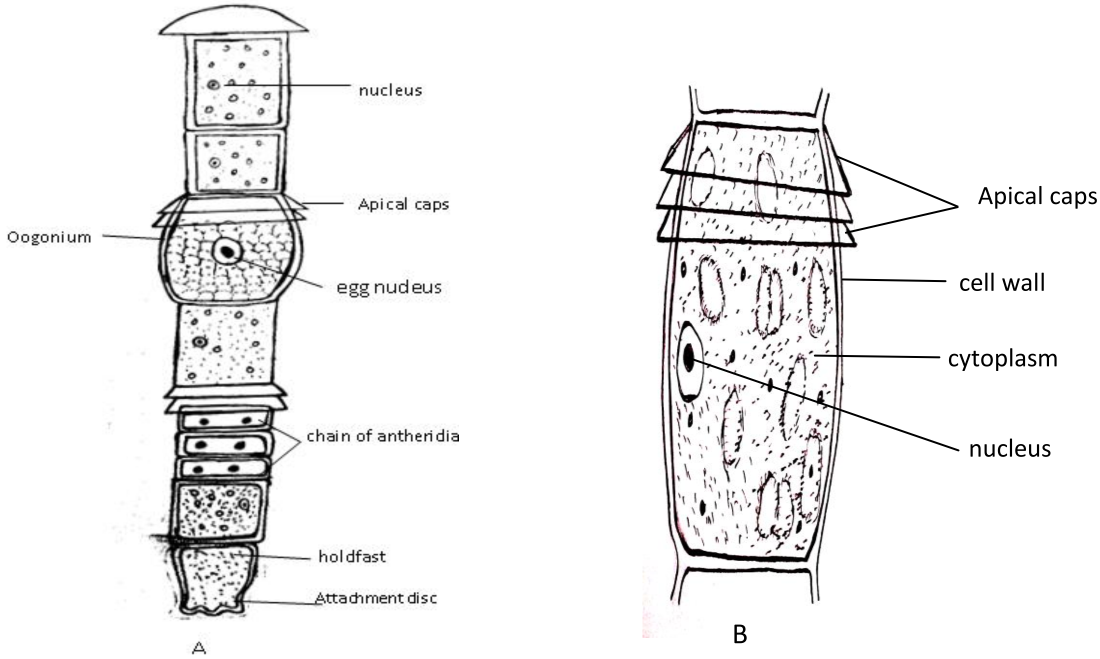

Fig.3.10. *Oedogonium*, A. a filament B. cell structure

3.3.4- *Chara*

Chara is a multicellular, highly advanced and macroscopic alga. Mostly *Chara* is 6-10 inches tall and differentiated into main axis and rhizoids. The main axis and banches of *Chara* are differentiated into nodes and internodes. Each node bears a whorl of several branches and consists of a pair of central cells surrounded by a peripheral group of cells. The internode is composed of a single elongated cell surrounded by elongated narrow cells forming cortex. Two types of branches i.e. branches of limited growth and branches of unlimited growth arise from node. 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 branches are also known as branchlets or branches of first order or primary laterals or leaves. The branches of unlimited growth arise from the axils of the branches of limited growth hence these are also called axillary branches or long laterals. The basal node of the branches of limited growth develops short, oval, pointed single cell outgrowths called stipulodes. Reproductive organs of *Chara* are highly advanced and complex amongst algae. The sex organs are borne on the branches of limited growth (primary laterals). The male sex organ is called globule or antheridium and the female sex organ is called nucule or oogonium. Development of globule and nucule is almost simultaneous, but in some species globule mature before nucule. The growth of main axis takes place by a dome- shaped apical cell. (Fig. 3.11).

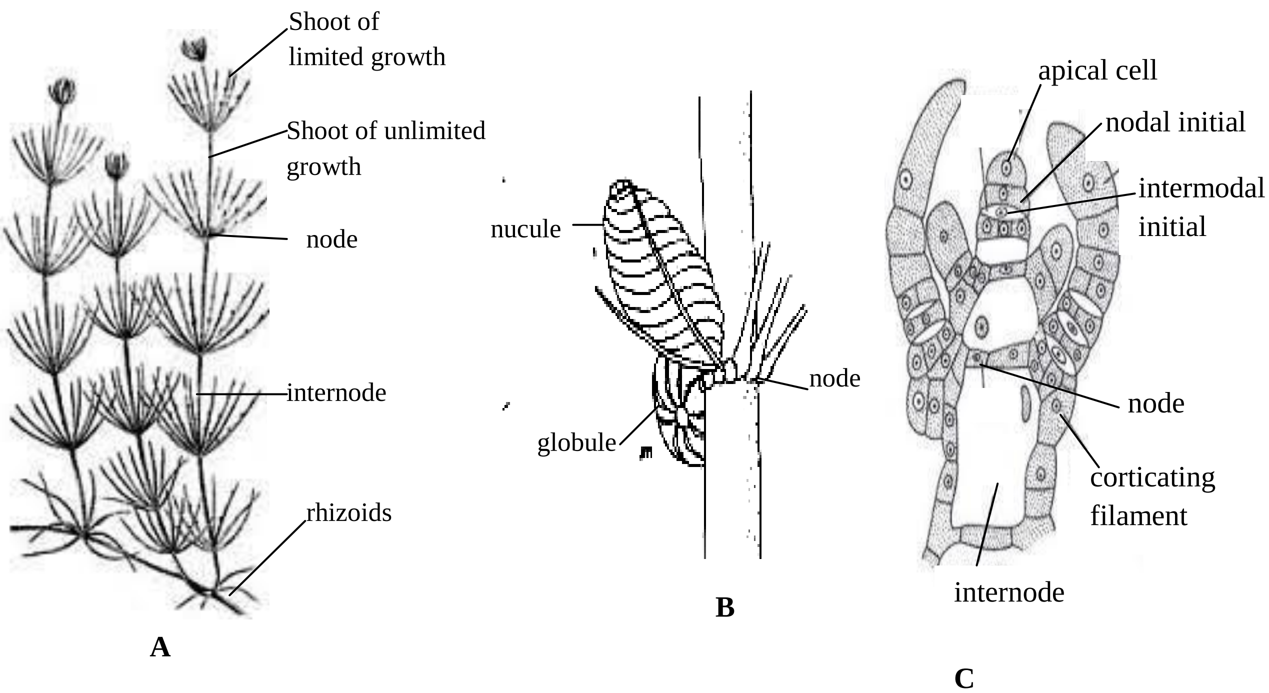

Fig. 3.11, *Chara*, A. Thallus, B. well developed reproductive organ, C. V.S. of apical part

3.3.5- *Vaucheria*

The thallus of *Vaucheria* is sparingly branched, coenocytic and siphonaceous type. The thallus is made up of long, cylindrical well branched filaments. The filament is aseptate, multinucleate (coenocytic) structure. The thallus is attached to substratum by means of branched rhizoids. The thallus contains an outer cellulosic cell wall, a central vacuole which runs continuously from one end of the thallus to the other. The filaments are non-septate, the protoplasm is continuous along the entire length of thallus making it a siphanaceous structure. The male sex organ is called antheridium and female sex organ is called oogonium (Fig. 3.12). The septa formation occurs only in sex organs. The cell wall is made up of two layers, the outer layer is pectic and the inner layer is cellulosic. The growth of filament is apical; the filament increases in length by apical growth of all the branches.

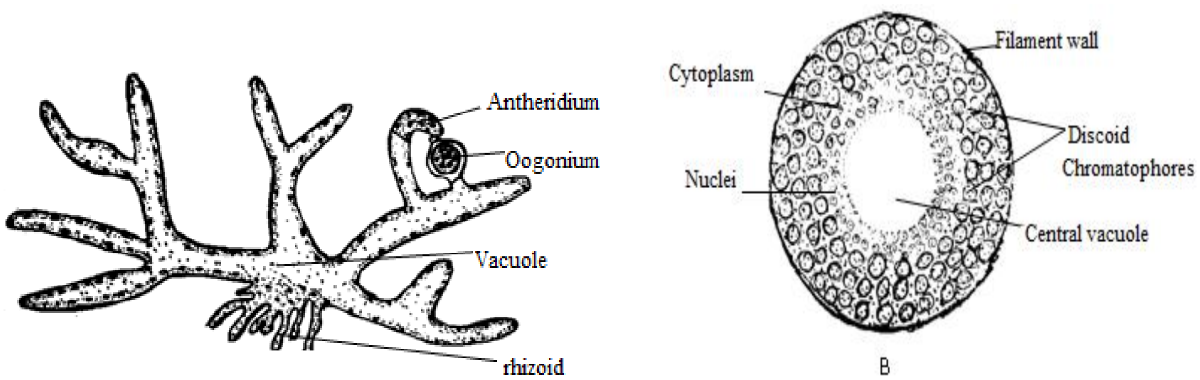

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Fig. 3.12: *Vaucheria,* A. Thallus structure B. T.S. of vegetative filament

3.3.6- *Polysiphonia*

Polysiphonia is a marine red alga. The thallus of *Polysiphonia* is heterotrichous type. The thallus is multiaxial or polysiphonous. The plant body is differentiated into a basal prostrate and an erect aerial system (heterotrichous). The prostrate system creeps over the substratum. The prostrate system helps in anchoring the plant to the substratum with the help of unicellar elongaed rhizoids. However, in some species (e.g. *P. elongate* and *P. violacea*) multiaxial prostrate system is absent. The erect aerial system arises from the prostrate system. It is made up of central axial cells (siphon), surrounded by pericentrd cells (siphon) of variable number (multiaxial). Cells are connected to each other by cytoplasmic connection. The thallus is dichotomously or laterally branched with two kinds of branches. The branches of unlimited growth, which are made up of central and pericentral siphons; and the branches of limited growth, known as trichoblasts. The thallus grows by means of an apical cell which by repeated divisions forms a row of axial cells. A branch of unlimited growth may sometimes arise in the axial of a trichoblast in which case its basal cell serves as the branch initial (Fig. 3.13).

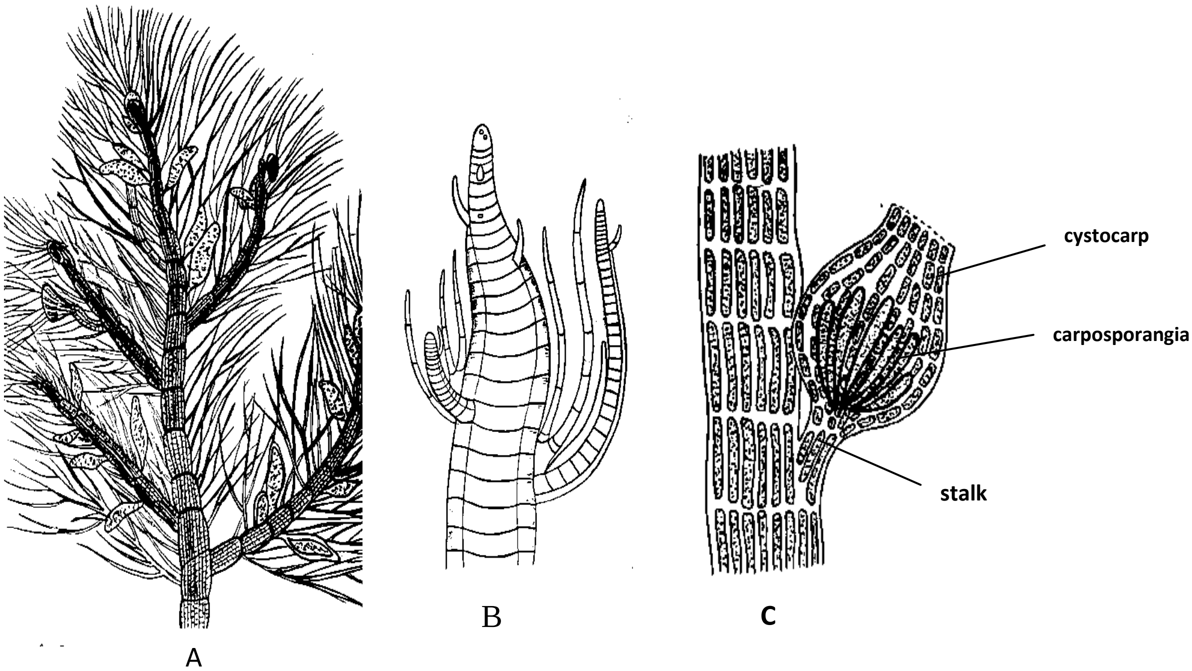

Fig. 3.13. *Polysiphonia,* A. thallus, B. thallus apex, C. Cystocarp

3.4 – SUMMARY

In this unit we have discussed the simple thalloid plants of the sub-division Algae. Algae range in size from minute unicellular plants (less than 1micron in diameter in some plankton) to very large highly differentiated multicelluar forms. They are autotrophic in nature i.e., they synthesize their own food. Algae are of universal occurrence and they are found in variety of habitats, such as freshwater, sea water, on snow, on rocks and on/or within the plant and animal bodies. The algal thallus shows different forms. Their forms may be

unicellular, colonial, filamentous, siphoneous and parenchymatous. Unicelllar forms are quite common in all the classes of algae except Charophyceae and Phaeophyceae. Unicellular forms function as complete unit without any cellular differentiation. The Unicellular types may be amoeboid, motile or non-motile. A colony is a group of separate cells generally similar in structure and function and aggregated in a mucilaginous matrix. The members of algal colony are connected with each other by cytoplasmic connections so that they cannot break into small pieces or segments. Filamentous thallus may be branched or unbranched. Unbranched filaments are present in a few groups of algae. The filaments may be attached to the substratum (e.g. *Zygnema, Oedogonium*), free floating (e.g. *Spirogyra*) or form colony (e.g. *Nostoc, Oscillatoria*).. A 'tube- like multinucleate structure (coenocytes) is the characteristic feature of Siphonaceous type of thallus. A Siphonaceous thallus lacks septation (Septa) except during the formation of reproductive organs. The simple organization is in the form of a small unbranched vesicle. It contains a central vacuole with chloroplasts and nuclei in the peripheral cytoplasm. The pseudoparenchymatous thallus is a secondary development; close association of cells is a result of interweaving of filaments. Parenchymatous thallus organization also is a modification of the filamentous habit, with cell division in more than one plane. The parenchymatus thalli may be leaf like or foliose, tubular or highly developed structure.

3.5- GLOSSARY

Anterior	-	In or towards front portion of thallus
Antheridium	-	Male gametangium
Blepharoplast	-	Granule lying at base of flagellum; gives rise to one flagellum
Coccoid	-	Pertaining to habit; non-motile spherical unicells
Coenobium	-	Colony consisting of definite number of cells arranged in specific manner.
Coenocytic	-	Multinucleate aseptate structure.
Colonial	-	Habit showing number of cells held together within a mucilaginous envelope.
Colony	-	Group of similar cells which have developed together from single, original parent plant or cell. Each cell is potentially capable of carrying out life activities independent of others in the colony.
Contractile vacuoles.	-	Organelles of osmoregulation; also thought to play role in excretion of waste material.
Corticated	-	Outer layer of small cells covering the central part and

produced directly by apical cell.

Eyespot - Red-coloured photo receptive spot (stigma) generally believed to have visual function

False branching. - Branching resulting from degeneration of cell in loop or from growth of free ends of trichome through filament sheath, as in some blue-green algae.

Flagella - Fine, thread-like structures and by the activity of which algal cells move.

Gas vacuoles - Gas-filled cavities in cells of certain blue-green algae which disappear when subjected to pressure. These are also known as pseudovacuoles

Globule - Male reproductive organ of order Charales having jacket of sterile cells around fertile cells; analogous to antheridium.

Heterotrichous - Thallus differentiated into prostrate and erect system of branching filaments.

Holdfast - Single cell or group of cells that acts as organ of attachment.

Heterocyst - A specialized cell found in certain blue-green algae.

Intercalary - Growth pattern in which newly formed cells are produced between two existing cells of filament.

Internode - Space between two joints (nodes); in a filament.

Motile - Capable of independent movement by means of flagella or some other device

Multiaxial - Formation of main axis of thallus by group of filaments

Multiseriate - Having more than one row of cells

Node - Point or area of axis where branching or leafing occurs. In filament, it is location of septum

Nucule - Female reproductive organ of Charales

Palmella stage - Temporarily non-motile sedentary stage in life history of certain motile algae; cells remain passive and embedded in gelatinous matrix

Palmelloid - Palmella-like habit

Pseudoparenchymatous - Collection of cells, filaments or hyphae forming tissue that resembles parenchyma

Rhizopodia - Unicellular organisms capable of forming pseudopodia or false feet for locomotion or anchorage

Rhizopodial - Type of habit in which unicellular organisms form pseudopodia as locomotory organs

Siphoneous - Tubular thallus in algae lacking septa or cross walls

		during vegetative phase of growth
Substratum	-	Surfaces or object upon or within which organism is growing
Thalloid/Thallus	-	Plant body that is not differentiated into roots, stem, and leaves
True branching	-	Branched by lateral division of cell in main filament
Uniseriate	-	Arranged in single row or series

3.6- SELF ASSESSMENT QUESTIONS

3.6.1-Long answer type question:

Q.1- What is a thalloid plant? Give an account of range of thallus organization in algae.

3.6.2-Short answer type questions:

Q 1. Write short notes on colonial forms.

Q 2. Write short notes on parenchymatous forms.

Q 3. Define heterotrichous type of thallus.

Q 4. Describe thallus of *Chlamydomonas*.

Q 5. Define filamentous type of thallus.

Q 6. Write comments on reproductive organs of *Chara*.

3.6.3-Fill in the blanks:

Q 1. The flagella in *Chlamydomonas* are…………………….type.
Q 2. Pyrenoids are concerned to be associated with the …………………………
Q 3. The……… …………………………. habit is the most highly evolved type of filament, and differentiated into prostrate and erect systems.
Q 4. The ………………………….. thalus organization developed repeated nuclear divisions without cross wall (septa) formation.
Q 5. A colony has a definite number of cells arranged in a particular manner is called ………………………..colony.
Q 6. The…………….. colony looks like a tree in habit, also called microscopic tree.
Q 7. *Sargassum* is an example of …………………………….……type of thallus.
Q 8. *Batrachospermum* is the best example of …………………………type of thallus.
Q 9. Cap cells are present in ..………………………………….
Q 10. The thallus of ..…………… is sparingly branched, coenocytic and siphonaceous type.
Q 11. The thallus of *Polysiphonia* is …………………………. type.
Q 12. In *Chara* the ………… sex organ is called globule.

3.6.4-True and false

Q 1. Algae are placed in the division thallophyta. (T/F)

Q 2. *Chlamydomonas* is a multicellular quadriflagellate alga. (T/F)

Q 3. Unicelllar forms are quite common in all the groups of algae except Charophyceae and Phaeophyceae. (T/F)

Q 4. *Spirulina*,is a multicelluar colonial algae. (T/F)

Q 5. *Chrysamoeba* and *Rhizochrysis* are the examples of Unicellular rhizopodial algae. (T/F)

Q 6. The heterotrichous habit does not differentiate into prostrate and erect systems. (T/F)

Q 7. In the *Botrydium* the thallus is multinucleate and lacks septation (septa). (T/F)

Q 8. The functions of contractile vacuoles are excretion or osmoregulation. (T/F)

Q 9. *Volvox* colony is called palmelloid colony. (T/F)

Q 10. In the coenobium colony, each cells of colony are independent for its various functions. (T/F)

Q 11. In *Chara*, female sex organ is called nucule. (T/F)

Q 12. In *Polysiphonia* the erect system of filaments anchoring the plant to the substratum with the help of unicellar elongaed rhizoids. (T/F)

Answer Keys:

3.6.3-FILL IN THE BLANKS:

1.whiplash or acronematic type	4. siphonaceous type	7. Parenchymatous thallus	*10. Vauncheria*
2. synthesis and storage of starch	5. A coenobium colony	8. Pseudoparenchymatous thallus	11. Heterotrichous
3. heterotrichous habit	6. Dendroid Colony	9. *Oedogonium*	12. male sex organ

3.6.4-TRUE FALSE

1. T	4. F	7. T	10. T
2. F	5. T	8. T	11. T
3. T	6. F	9. F	12. T

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3.9- TERMINAL QUESTIONS

Q 1. Give an account of range of thallus organization in algae with the help of suitable examples.

Q 2. In C*hara* the sex organs are highly advanced. Explain it with the help of suitable diagrams.

Q 3. How the filamentous type of thallus developed? Describe it in detail.

UNIT-4- ECOLOGICAL AND ECONOMIC IMPORTANCE OF ALGAE

4.1 OBJECTIVES

After going through this unit you will be able to know

- How algae is ecologically important for living beings.
- Economic importance of algae
- Harmful effects of algae

4.2 INTRODUCTION

Since from ancient times, algal species are intimately connected with human beings as direct source of food, medicine, etc. Algae are a very large and diverse group of oxygenic phototrophic organisms. Previous chapters gave you the knowledge of structure, habit, habitat and reproduction of Algae. Now in this chapter we will study the economic and ecological importance of algae and its negative effects. Products made from algae are the natural solution to the energy, food, economic and climate challenges facing our earth today.

Most of the algae are eukaryotic which means they have a true nucleus. They are oxygenic phototrophs, meaning they use sunlight as their energy source for growth and produce oxygen as a byproduct. In general algae can be referred to as plant-like organisms but what distinguishes algae from plants is that algae do not have true roots, stems, leaves and vascular tissue and have simple reproductive structures. There are about 30,000 species of algae. Algae are the fastest- growing plants in the world. Almost everywhere on our planet e.g., in marine water, fresh water, on the rocks, snow, in the soil and plants. They vary from unicellular forms such as *chlorella* and diatoms to complex multicellular forms, such as the giant kelps, a large brown alga that may grow upto 50 meters in length. Products made from algae are the natural solution to the energy, food requirement and climate challenges facing our world today. Algae have the power to put fuels in our vehicles, recycle CO_2, and provide nutrition for human beings and animals.

4.3 ECOLOGICAL IMPORTANCE

Algae are very important ecologically because they are the bases of the aquatic food chain. Algae are a vital food source for marine organisms. Phytoplankton, usually unicellular algae, are consumed by small, grazing animals called zooplankton, most of which are crustaceans that drift near the surface of the sea. The zooplanktons are in turn fed upon by larger zooplanktons and small fishes. Larger fishes eat the smaller ones. At the top of the open water food web may be fish eating birds, whales, seals, very large fish such as tuna, sharks, bluefine and human being.

Algae are macroscopic too and some of these algae are very huge and provide shelter for fishes and other aquatic animals.

Algae in sewage disposal: Sewage disposal is an aerobic process and requires oxygen which is released by algae. Algae like *Chlorella, Euglena, Chlamydomonas, Scendesmus, Spirullina,* etc are grown in sewage oxidation ponds or tanks along with suitable bacteria (algal-bacterial-systems). They provide surplus oxygen for aerobic decomposition. Algae take up nitrates and phosphates from the shallow tanks of effluents for its metabolism liberating oxygen in photosynthesis. It helps the aerobic bacteria to decompose raw sewage, thus purifying these wastes.

Role of Algae in Pollution Control: The photosynthesis done by algae is very important to the biosphere because it reduces the amount of carbon dioxide and increase the amount of oxygen in the atmosphere. Microalgae are capable of fixing CO_2 in the atmosphere, thus facilitating the reduction of increasing atmospheric CO_2 levels. About 50% of total CO_2 fixation on earth is carried out by algae through photosynthesis. Algae bioreactors are used by some power plants to reduce CO_2 emissions. The CO_2 can be pumped into a shallow pond or tank on which the algae feed. Carbon dioxide and water are the basic requirements for alga growth and this in turn will release oxygen as a by-product.

Algae as a pollution indicator: One can identify the level of pollution in water by observing the composition and growth pattern of the algal flora in a water body. According to Kolkwitz and Marsson (1909), there are three zones in a polluted river, each zone having its characteristic alga flora.

1-**Mesosaprobic Zone**: Algae like *Oscilltoria, Phormidium, Ulothrix* etc present in this zone, organic waste is less and little quantity of O_2 is available.

2-**Polysaprobic zone:** *Euglena* and *Oscillatoria* hardly grow in this zone. There is high content of decomposable organic matter, but oxygen is deficient.

3-**Oligosaprobic zone:** Algae like *Calothrix, Cladophora, Meridian,* and *Batrachospermum* grow where there is little or no decomposable organic matter and water is rich in O_2.

Diatoms are highly sensitive to pH and different species of diatoms are found at different pH values of water body. The excessive growth of some algae like *Stigeoclonium, Cladophora* etc in a water body indicates pollution due to heavy metals because these type of algae accumulate and absorb many heavy metals from the water. According to Patrick (1956) diatoms are the best suited to be the algal indicators of water pollution.

Water Blooms (Algal Blooms): Excessive growth of algae which forms thick floating mats on water surface is called water blooms or algal blooms. Only Planktonic algae form blooms. Alga blooms severely affect the aquatic ecosystems in which they occur. Luxuriant growth of some marine algae causes red tides that turn the surrounding sea a deep red colour. Water blooms cause oxygen depletion in water reservoirs thus causing death of many fishes by suffocation. Water blooms may be temporary or may be permanent in some lakes as the Sambhar Lake in Rajasthan has a permanent bloom of *Anabenopsis.*

4.4 ECONOMIC IMPORTANCE

Some most useful aspects of algae are mentioned below:

1-Algae as a Food for Man: From ancient times large numbers of green, brown and red algae are used as source of food by human beings. They are rich in carbohydrates, proteins, vitamins and minerals. People of coastal countries like China and Japan are using sea weeds and certain other algae as a source of food. Many kind of seaweed are edible and rich in vitamins and iodine. In many countries like Thailand, Malaya, China, Japan, Burma and Indonesia, the seaweeds are consumed on large scale. *Porphyra* has 25-30% protein, vitamin B and C, minerals like iodine. *Porphyra* is considered to be a tasteful dish in England. In Japan a soup is prepared from boiling plants of *Porphyra.* A Japanese delicacy kombu is eaten in Japan which is prepared from the stipes of *Laminaria.* *Ulva* in Europe is called sea lettuce and it is used as food. In Scotland *Ulva lactuca* was used in preparation of salad and soups. The *Chlorella* is high in protein and lipid contents, therefore used as substitute food by Astronauts and Cosmonauts in space. In India a few species of *Oedogonium* and *Spirogyra* are used as food in South India. Iodine is manufactured from Laminaria. Algae are also used to decorate cakes, pastries, sandwiches in Japan. *Rhodymenia* which is popularly known as dillis in Ireland, Dulse in Scottland, and Sol in Iceland is in great demand as a food.

2-Algae as Fodder: Algae are nutritious, high in protein and a low cost food option for animals. Kelps (Brown algae) are used as fodder for cattle and chopped for sheep and chickens in Great Britain, France etc. *Rhodymenia* is used for cattle food in Norway and France. The diets of dairy cows and pigs can be supplemented with algal food. In China *Sargassum* is used as fodder. Adding algae to the diet of cows resulted in a natural breakdown of unsaturated fatty acids and a higher concentration of these beneficial compounds in milk and meat. The milk yielding capacity and number of eggs of the poultry increased by using kelp.

Fodder for aquatic animals: Algae form the base of the aquatic food chains that produce the food resources that fish are adapted to consume. According to Chacko (1970), "*Oscillatoria* is the most favoured blue-green alga consumed by 56 species of fishes. Others in order of preference are *Spirulina, Anabaena, Microcystis, Lyngbya and Merismopedia*". Certain types of algae are used in aquarium, fisheries etc. Snails, Tadpoles of frog and crabs etc also feed on algae. Micro algae are a natural component of the diet of many larval fishes. Diatoms form a permanent food of many aquatic animals along with some fishes.

3-Algae as Medicine: Algae have been used for centuries, as a remedy to prevent or cure various diseases. Researchers found that algae are beneficial for human health. A few algae yield antibiotis. Antibiotic chlorellin is obtained from green alga *Chlorella,* which inhibit the growth of certain bacteria. Chlorellin is effective against a number of Pathogenic bacteria. An antibiotic is obtained from a diatom *Nitzschia palea* which is effective against *Escherichia coli* due to high iodine contents. Many seaweeds are used in manufacture of various goiter medicines because of the high percentage of iodine content in them. Seaweeds have beneficial effect on thyroid glands, gall bladders, kidneys, uterus and pancreas. Kelpeck is prepared from kelps which is useful in the treatment of Goiter and other glandular troubles. An effective and important algal product is Agar-Agar which is used in the manufacture of ointments and tablets. Certain species of *Polysiphonia* produce anti bacterial substances which are effective against both gram-positive and gram-negative bacteria. Sea weed consumers are immune to hay fever. *Chara* and *Nitella* are used as mosquito repellents. *Chara* is useful in the destruction of mosquito larvae. In Japan *Spirogyra* is used in the manufacture of lens paper.

4-Algae in Nitrogen Fixation: It has been observed that species of blue -green algae are able to fix atmospheric nitrogen in the soil. Species of *Anabena, Nostoc, Calothrix, Scytonema, Aulosira, Stigonema, Tolypothrix, Gleotrichia* etc are the common nitrogen fixing blue green algae. It has been found that about 60 species belongs to blue green algae are capable of nitrogen fixation. Increase in amount of nitrogen makes the soil fertile. Blue green algae are used for nitrogen fixation in rice fields. Many countries like Japan, China, Philippines, Thailand and India have practiced the use of blue green in rice cultivation.

5-Algae in reclamation of Soil: The blue-green algae can also be used in the reclamation of barren alkaline soils. It has been observed that some blue-green algae form a thick stratum on the surface of the saline usar soils during the rainy season. These algae can be of used in the reclamation of the ‘usar’ lands. During the rainy season various species of *Scytonema, Nostoc, Anabaena, Aulosira* etc grow in plenty. Gradually they decrease the alkalinity of soil and increase the nitrogen, phosphorus and organic content in the soil thus converts it into a fertile land after sometime.

Binding of Soil Particles: Algae play an important role as binding agent on the surface of the soil. The sea weeds have the properties of soil binding. The concentrated extract of seaweeds are sold as liquid fertilizer and added to lands.

6-Algae as Fertilizers: Since ancient times, most of the coastal countries of the world used the sea weeds as fertilizers. Sea weeds are rich in Potassium chloride (KCl), Phosphorous, calcium, some trace elements and growth substances. *Oscillatoria, Spirulina, Scytonema* etc are used in rice fields. To overcome calcium deficiency *Chara* is used in the fields. *Fucus* is used as common manure in Ireland in the cultivation of tuber crops. Scientists have been successful in preparing a liquid fertilizer from a brown seaweed *Sargassum* which contains micronutrients required for plants. The large brown and red algae are used as organic fertilizers due to the presence of potassium. Green algae also increase the soil fertility.

7-Algae in Industry: Algae yield certain chemical products which are extensively used in various industries. The four major products derived commercially from algae are- Diatomite, agar, carrageenin and alginates.

Diatomite: Diatomite is a soft, powdery, highly porous, friable light coloured sedimentary rock formed by the accumulation of the amorphous silica remains of dead diatoms in marine sediments. The fossil remains consist of a pair of symmetrical shells or frustules. Diatomite, also known as diatomaceous earth, has various applications. It is used in the preparation of Dynamite in ancient time. Alfred Nobel used the properties of diatomaceous earth in the manufacture of dynamite as an absorbent for nitroglycerin. Due to its highly absorbent and fire proof properties it is used in filters in brewing industries, sugar refineries etc. In paints, diatomite alters glass and sheen and in plastic it works as an antiblocking agent. It is used as insulator in furnaces and pipes. Diatomite has been used in toothpaste, metal polishes and in some facial scrubs. Due to its abrasive and physico-sorptive properties it is used as an insecticide.

Kelps are a rich source of soda, iodine, potash and aliginic acid. Japan produces about 100 tons of iodine per year from kelps. Potash and soda from seaweeds are used in the manufacture of alum, soap, glassware etc. In Japan, Funori is a type of glue obtained from red alga *Gleopeltis furcata*. It is used for sizing paper and cloth. It is also used as an adhesive.

Agar-agar: Agar-agar is dried, non-nitrogenous, jelly like substance extracted from different species of red algae. Japan produces the largest quantity of agar and exports it to other countries. Agar-Agar is used as a culture medium in laboratories for culturing microorganisms because of its ability to afford good range of temperature for culturing. Its melting point is between 90 and 100^0 F. At lower temperature it changes into a solid. Agar is employed as thickening material in the preparation of ice-cream, jellies, deserts, melted milk, candies, pasteries, sauces, soups etc. It is also used for making moulds for artificial leg, artificial silk and leather. Agar is used as a lubricant for photographic films. In the medicine, agar is used as a laxative.

Alginates: Alginates or alginic acid was discovered in sea weeds and isolated from *Laminaria*. Alginates are the salts of alginic acid present in the cell wall of Phaeophyceae. It is insoluble in water and hard when dry but can absorb water 200-300 times its weight. They are usually extracted from the middle lamella and primary walls of the brown and red algae. Alginates are used in the preparation of flame-proof fabrics, water proofing concrete, production of non-inflammable wrapping film, in surgical dressing, ice-creams etc. Sodium alginate is used in sizing material for water proof articles dyes etc.

Carragenin: Carragenin, usually extracted from cell wall of red algae like *Chondrus crispus* and *Gigartina*. It is a polysaccharide esterfied with sulphate. Carragenin is extracted by boiling algae with 100 parts of water. When Carragenin dissolves in water, it is mixed with active charcoal and filtered. At last the gel obtained is carragenin. It is used as emulsifier in pharmaceutical industry. Carragenin is also used as a remedy for cough. It is used in stabilizing and gelling foods, leather industry, brewing industries and textile manufacture.
Algae as fertilizers: Blue-green algae treated as bio-fertilizers from ancient time. A bio-fertilizer is a substance which contains microorganisms which restore the soils natural nutrient cycle and build soil organic matter. Cynophyaceae (Blue-green algae) act as bio-fertilizers. They have the capacity to accumulate mineral such as sulphur, calcium, potassium, zinc, magnesium, copper, iodine, boron, lead, nickel, antimony, arsenic, manganese, cobalt, molybdenum. Sea weeds are used as fertilizers in many countries due to the presence of Potassium chloride. The red algae and larger brown algae are rich in potassium. They are also used as organic fertilizers. Concentrated extract of sea weeds is sold as liquid fertilizers.

Algae as a source of biofuel: Alga fuel or alga biofuel may provide an alternative to fossil fuel. Algae based biofuels is a new energy source. Algal biofuels use algae as a source of natural oils. The oils can be extracted from the harvest and then refined into biodiesel, gasoline, diesel or even jet fuels. Algal based biofuels is non-toxic, biodegradable and contains no sulphur. It can reduce CO_2 emissions. Scientists are exploring more possibilities of using algae to make gasoline, diesel and other fuels.

Negative effects of algae:

Besides many useful uses of algae there are certain types of algae which create different types of problems. Some of the harmful effects of algae are:

1. Some blue green algae like *Anabaena*, *Microcyctis*, etc have been reported poisonous. They cause death of aquatic animals and fish by suffocation. Harmful effects as weakness, loss of weight, abortion etc have seen who consume such contaminated water.
2. **Paralytic shell-fish poisoning:** Dinoflagellates like secrete toxins called Saxitoxin which is fatal to large number of marine fishes and invertebrates, as well as humans who eat shellfish containing the toxins. Consumption of Dinoflagellates has been reported to cause paralytic shell fish poisoning (PSP) and neurotoxic shell fish poisoning (NSP).

3. **Fouling of Ships:** The luxuriant growth of large marine algae may slowdown the smooth movement of boats and ships. *Sargassum* causes hindrance for the smooth sailing of ships. The submerged metallic parts of ships carrode by algae.

4. **Blocking of Photosynthesis:** The epiphytic algae growing on plants and trees can block photosynthesis process and damage the plants. *Cephaleuros virescens*, grows as parasite on tea leaf causing red rust of tea. It is a great economic loss to Assam and Darjeeling tea.

5. **Contamination of water supply:** The excessive growth of plankton algae in reservoirs and ponds make them unfit for water supply by their over abundant growth. Excessive growths of many species of blue-green and green algae choke the pipelines, water tanks etc and make the quality of water poor, unpleasant in smell, colouration of water, fishy in taste and unfit for drinking.

4.5-SUMMARY

Algae are extremely important species on this earth. These are very important form economic and ecological point of view. Algae are economically very significant as it provides food, medicine, fodder for animals. Algae also have many commercial and industrial uses, in addition to their ecological roles as oxygen producers and as the food base for aquatic animals. Another potential use is in the production of bio-fuels. Algae are indicators of ecosystem pollution. Besides so many uses of algae certain types of algae can be harmful in some aspects. Algae as *Anabaena*, *Microcyctis* etc. are poisonous, while some algae form the water blooms.

4.6-GLOSSARY

Zooplankton: Microscopic animals that are suspended in the water reservoirs
Algin: the soluble sodium salt of alginic acid
Alginate: the salt form of alginic acid
Diatomaceous Earth: Siliceous deposits made up of the sedimentary buildup of diatom frustules
Alginic acid: A viscous gum that is abundant in the cell walls of brown algae
Agar-Agar: Gelatinous product of certain sea weeds, it is used as a base for bacterial culture media and as a food additive
Diatom: A unicellular alga encased in siliceous shell or frustules a member of the class Bacillariophyceae
Green Alga: A member of the Chlorophyaceae.
Algal bloom: high concentrations or densities of algae.
Dinoflagellate: A single-celled organism found in fresh and marine waters.
Laminaria is a genus of 31 species of brown algae commonly called “Kelp”.
Chryophyceae: unicellular golden brown algae that inhabit fresh and salt water environments.

4.7-SELF ASSESSMENT QUESTION

4.7.1 Objective Type Questions:

1- “Red tides are produced by massive blooms of:

(a) Red algae (b) Brown algae
(c) Dinoflagellates (d) None

2- Agar- agar is extracted from:
(a) Brown algae (b) Blue-green algae
(c) Red algae (d) Green algae

3- Iodine is obtained from:
(a) *Laminaria* (b) *Oedogonium*
(c) *Ulothrix* (d) *Ectocarpus*

4- Ability to fix atmospheric nitrogen is found in:
(a) Marine red algae (b) *Chlorella*
(c) Blue-green algae (d) None

5- Paralytic shellfish poisoning can be caused by the toxins produced by:
(a) Yellow green algae (b) *Euglena* species
(c) Dinoflagellates (d) All of these

6- Kelpeck is effective in:
(a) Kidney problem (b) Goiter and other glandular troubles
(c) Hay fever (d) Typhoid

7- Which of the following is a parasitic algae:
(a) *Cladophora* (b) *Sargassum*
(c) *Cephaleuros* (d) *Oedogonium*

4.7.1 Answers: 1-(c), 2- (c), 3- (a), 4- (c), 5-(c), 6- (b), 7- (c)

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4.10-TERMINAL QUESTIONS

1- Discuss in detail the economic importance of Algae.
2- Describe the role of algae as a medicine.
3- What are the negative effects of Algae.
4- What is the role of Algae in Nitrogen fixation?
5- Write the ecological importance of Algae.

BLOCK- 2- ALGAE: MAJOR GROUPS

UNIT- 5- OCCURRENCE, STRUCTURE OF THALLUS AND MODE OF REPRODUCTION IN CYANOPHYTA AND BACILLARIOPHYTA

5.1 OBJECTIVES

After reading this unit you will be able to:-

- Know about general characteristic features of division Cyanophyta or blue green algae.
- Understand the thallus organization and mode of reproduction in blue green algae like *Oscillatoria, Nostoc*
- Understand the general account of diatoms and how these differ from other algae.

5.2 INTRODUCTION

As we know algae are green in colour due to the presence of chlorophyll but some algae are bluish green in colour. These blue algae are placed in the division Cyanophyta. The members of division Cyanophyta (Myxophyta) are commonly known as Blue green algae. There are about 160 genera and 1500 species in this division. In India there are about 98 genera and 833 species. c-Phycocyanin is the major pigment in these algae. Beside c- Phycocyanin they also contain chlorophyll a, β- carotene and c-phycoerythrin. The members of this group show typical prokaryotic nature. The nucleus is of primitive type which lacks nuclear membrane and nucleolus. Flagella are altogether absent in the members of this division. Blue green algae have also been named as Cyanobacteria. There are many similarities between bacteria and blue green algae. Mostly the members of this division are fresh water in habitat. A few species are found in marine habitat. Some species like *Nostoc* and *Oscillatoria* grow in terrestrial habitats. Some members are growing as endophytes inside roots of *Cycas*, leaves of *Azolla* and thalli of *Anthoceros*.

Bacillariophyta, a group of microscopic algae have some unique features which differentiate it from other division of algae. These are beautiful golden brown algae. This is a large group of algae, consisting of over 10,000 species belonging to 200 genera. The members are popularly known as diatoms. Fine geometrical expressions and intricate sculpturing in the cell wall make these organisms one of the most beautiful microscopic objects. They occur in almost every aquatic habitat as free-living photosynthetic autotrophs, or photosynthetic symbionts. Diatoms are also found in terrestrial habitats and form a substantial proportion of the soil flora. In tropical rain forests, they grow in association with blue-green algae on leaves of trees. In India the group is represented by 569 species distributed over 92 genera.

5.3- CYANOPHYTA

Following are some important characteristics features of blue green algae.

- The division is also known as myxophyta
- The members of this division are commonly called blue green algae.
- c-phycocyanin, chlorophyll a and c- phyoerythrin are principal pigments of this division. Due to these pigments these look bluish green.
- Pigments are embedded within lamellae called thylakoids.
- The thallus organization is very simple. These are unicellular (e.g. *Chroococcus*), colonial (e.g. *Gloeocapsa*), chain of cells called trichomes (e.g. *Oscillatoria, Scytonema)* or unbranched filamentous form (e.g. *Nostoc, Anabaena*).
- Cell wall is made up of mucopeptides as in case of bacterial cell wall.
- The cell structure is prokaryotic in nature. It lack membrane bound organelles and the nucleus is of incipient poorly developed type.
- The cell organelles like chloroplast, mitochondria, endoplasmic reticulum are altogether absent.
- Flagella are also absent.
- Some members of this division show gliding or jerky movement (*Oscillatoria*).
- Reserve food material is cyanophycean starch.
- In some members of this division a special type of cell known as heterocyst is present.
- Heterocysts are found in the members of Nostocales (except Oscillatoriaceae) and Stigonematales.
- Heterocysts are somewhat enlarged vegetative cells. These may be terminal or intercalary.
- Heterocysts considered as nitrogen fixing in blue green algae.
- Reproduction takes place by vegetative and asexual means.
- The sexual reproduction is completely absent.

5.3.1- *Oscillatoria*

5.3.1.1- Occurrence

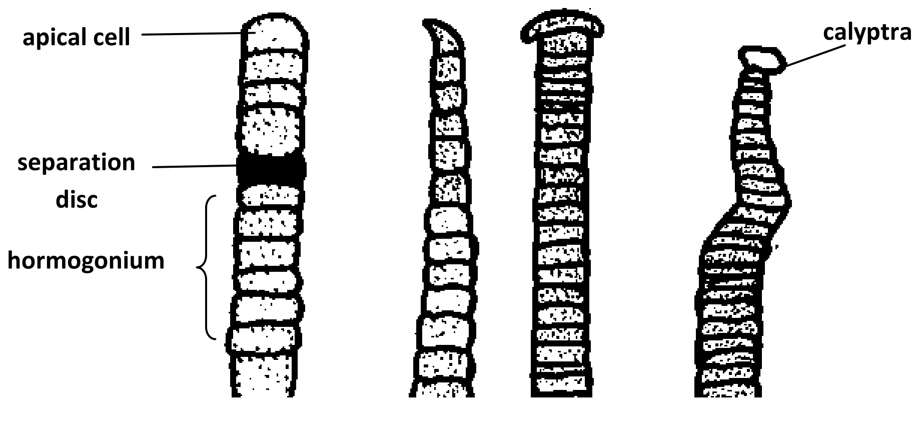
This is a fresh water blue green alga, represented by 76 species. Commonly found in fresh and polluted water of ponds, pools, drains, streams and also in damp soils and rocks. These form bluish scums on water surface or at pond-bottom. *O. princeps* grows in sea water and sub-aerial habitats. *O. brevis* can bear a temperature of -16^{0}C while *O. terebriformis* occurs in hot water springs (thermal algae). Some species are saprophytic and found in the digestive and respiratory tracts of the animals.

5.3.1.2- Structure of thallus

It is an unbranched, long, flat thread like filamentous made up of numerous cells filamentous alga. Filaments also called trichome. Each trichome is made up of many cells, arranged in uniseriate manner. Filaments may be either attached or free floating and rarely occur singly. In majority of the species they form compact tangled mass or spongy sheets. The filaments may be interwoven or arranged in parallel rows. The trichome is slightly different at the anterior end and usually smooth but sometimes constricted at the cross walls. The cells are broader than long in their length and show prokaryotic organization. In some species a thickened membrane is present in the apical cell known as calyptra (Fig. 5.1).

All cells in the trichomes are similar in structure. Reserve food material is in the form of cyanophycean starch, lipid, globules and cyanophycin. Planktonic species of *Oscillatroia* possess gas vacuoles or pseudovacuoles which are devoid of any membrane. It is made of a number of 'hexagonal' structures called 'gas vesicles'. *Oscillatoria* exhibits intercalary growth. All the cells of trichome are capable of division. Plasmodesmata connect the two adjacent cells.

The name *Oscillatoria* (oscillare, to swing) is given to this alga due to the peculiar movement shown by the trichome. It is called 'oscillatory movement'. These are the jerky, pendulum like movements of the apical region of the trichome. Two types of movements are commonly found i.e. gliding or creeping movement and Oscillatory movement (Fig. 5.2). Gliding movement takes place within mucilaginous sheath and there is no change in the shape of the organism. This movement is always along the longitudinal axis. In the oscillatory movement the trichomes move left and right of the axis.



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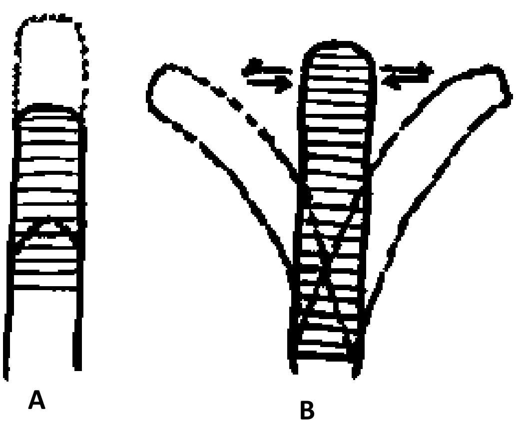

Fig. 5.2 Oscillatoria Movement, A. Gliding movement, B. Oscillatory movement

5.3.1.3- Mode of reproduction

Reproduction takes palace only by vegetative methods. There are following two modes of vegetative reproduction:-

1. By fragmentation
2. By Hormogonia

1. **By fragmentation**

In fragmentation, the trichomes break into small pieces due to injury. This injury may be due to biting of some insects or any mechanical injury. Each of these fragments is capable of developing into a new thallus.

2. **By Hormogonia**

Hormogonia or hormogones are short segments of trichome which consist of few cells. These are formed due to formation of separation discs. These discs are mucilaginous, pad like and biconcave in shape. These are formed by death of one or more cells of the filament. These mucilage filed dead cells are also called necridia. These hormogonia are capable of movement, and by repeated cell division they develop into new trichomes.

5.3.2- *Nostoc*

5.3.2.1- Occurrence

Nostoc occurs in freshwater as well as in terrestrial habitats. Macroscopic colonies are formed by fresh water species on the surface of water which vary from few millimeters to few centimeters. Each colony is bounded externally by a common membrane. Some species of this genus occur in terrestrial habitat in alpine region for example *N. commune*. Some species of this genus are endophytic in nature i.e. they occur in symbiotic association within other plants like *N. punctiforme* is found in the coralloid roots of *Cycas*. Besides *Cycas* this is also reported in the cavity of some bryophyte (*Anthoceros)* thallus. Some species of *Nostoc* help in increasing fertility of the soil in rice field because they are capable to fix atmospheric nitrogen.

In India there are some important species of this genus reported by several workers i.e. *N. calcicola, N. endophyllum, N. ellipsoporum, N. muscorum and N. punctiforme*.

5.3.2.2- Structure of thallus

Nostoc thallus is uniseriate and trichome or filament like. Each trichome is surrounded by a gelatinous mucilaginous sheath. Usually many trichomes aggregate together, and their gelatinous envelopes dissolve to form colonies of various shapes and sizes. Some times it looks like a ball called a *Nostoc* ball which contain numerous filaments (Fig.5, A). The important feature of this alga is the presence of specialized cell, heterocyst (Fig. 5.3, B & C). These heterocysts are somewhat enlarged vegetative cells. These may be terminal or intercalary. The intercallary heterocysts have two polar nodules and the terminal ones have only one (basal) polar nodule. The cell wall is made up of mucopolymeric substance.

5.3.2.3- Mode of reproduction

Only vegetative reproduction is reported in this genus. Sexual reproduction is completely absent. The vegetative propagation takes place by the following methods.

1. By fragmentation
2. By Hormogonia
3. By akinetes
4. By heterocysts
5. By endospores

1. By fragmentation

This is one of the common methods of vegetative reproduction in this genus. Sometime the colony may break into small fragments due to mechanical, physiological or other factors. After fragmentation each fragment has the capability to develop into a new colony.

2. By hormogonia

The *Nostoc* filaments break into small segments due to the degeneration of intercalary vegetative cells or because of the presence of intercalary heterocysts. The multicellular cell structures developed after breaking are called hormogonia. Generally hormogonia come out of the gelatinous mass of the colony, grow rapidly and form new colonies (Fig. 5.3).

3. By akinetes

Akinetes develop during unfavourable conditions. Under unfavourable conditions, some cells of the trichome are transformed into thick wall cells or resting spores called akinetes. These akinetes develop new colonies when conditions become favorable (Fig 5.3). During favourable conditions, the protoplasm becomes active and breaks the thick outer wall and forms a new trichome or filament (Fig. 5.4).

4. By heterocysts

Heterocysts also participate in vegetative reproduction in some species of *Nostoc* (e.g. *N. commune*). The protoplasm of heterocyst become active and germinates to form a new trichome. The thick wall of the heterocyst ruptures and develops into a new filaments or trichome (fig 5.5).

5. By endospore

In some species of *Nostoc* the protoplasm of the heterocyst divides successively to form endospores (e.g. *N. commune, N. microscopicum*). Enospores are thin walled. Disintegration of the heterocyst wall results in their liberation, and the rounded spores later germinate to form new trichomes.

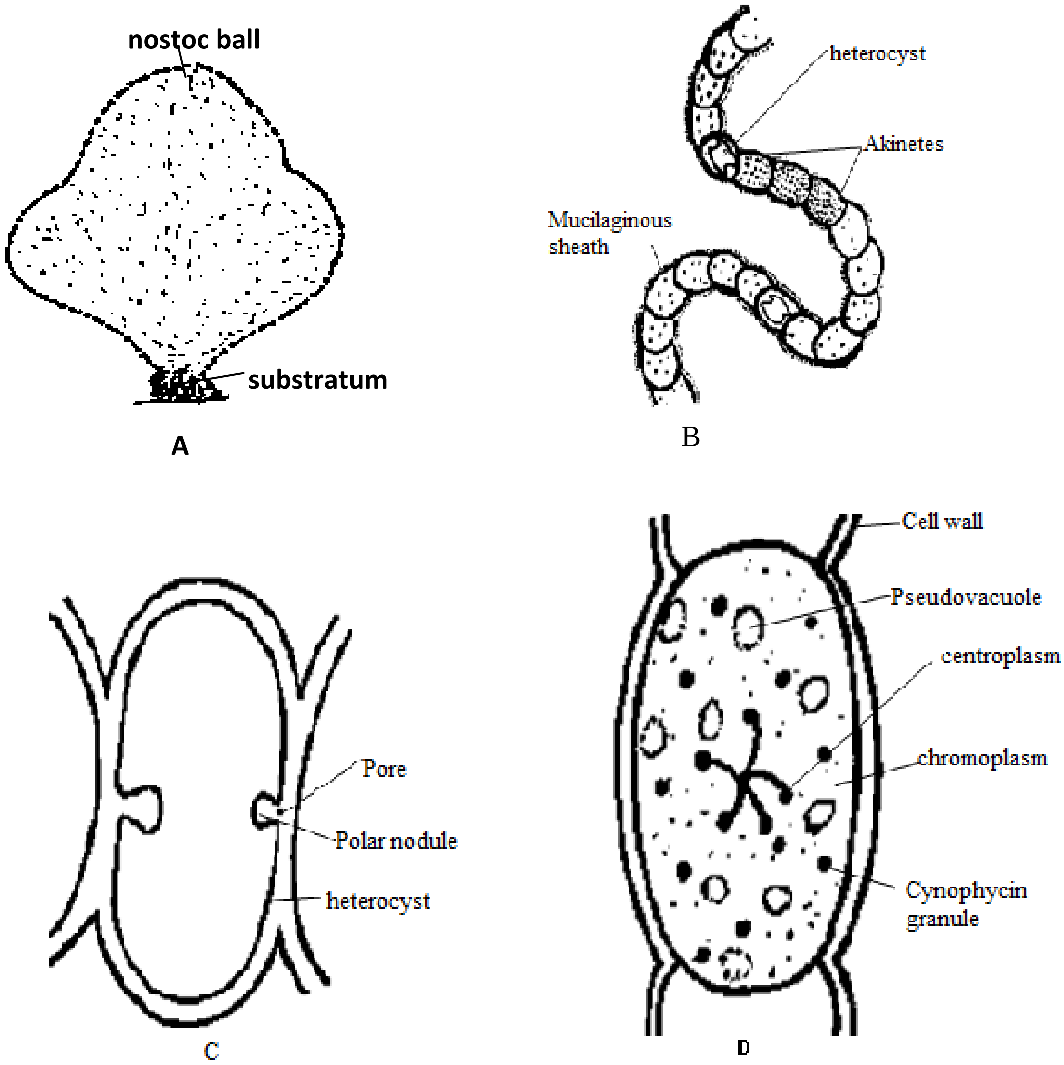

Fig. 5.3. *Nostoc* . A. Colony, B. Filament, C&D. Heterocyst

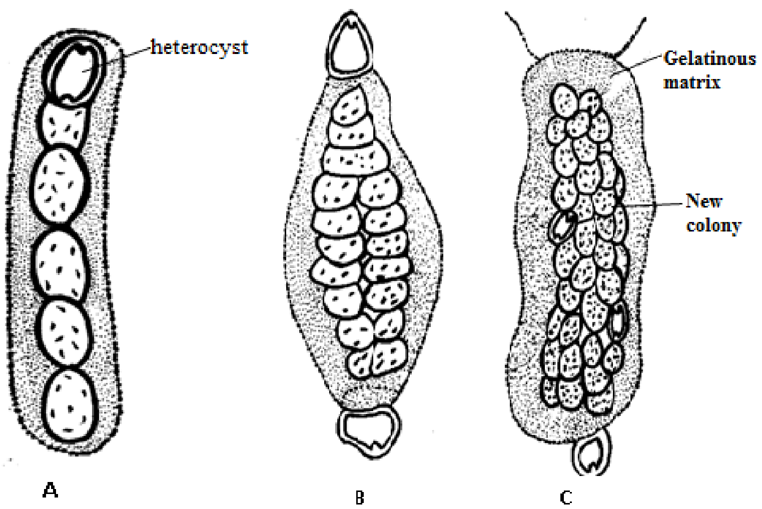

Fig. 5.4. *Nostoc*, Reproduction by hormogonia

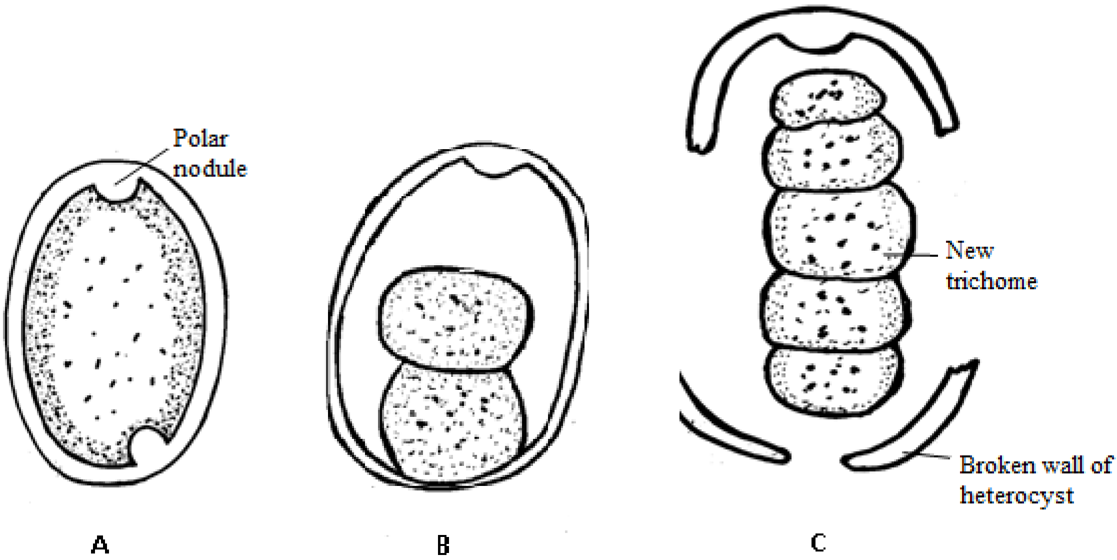

Fig. 5.5: ***Nostoc*, Reproduction by heterocyst**

5.4- GENERAL ACCOUNT OF BACILLARIOPHYTA

This is a large group of algae, consisting of over 10,000 species belonging to 200 genera. The members are popularly called diatoms, comprising a homogenous assemblage of unicellular and colonial forms. In India, the group is represented by 569 species distributed over 92 genera. *Pinnularia graciloides*, *Niedium gracile*, *Cymbella affinis*, *Eunotia pectinalis*, and *Cosinodiscus radiatus* are some common Indian species of diatoms. Diatoms are differing from other algae in possessing highly sculptured and symmetrically ornamented cell wall. This unique feature makes these organism one of the most beautiful microscopic objects. Followings are some unique features of diatoms which differentiate them from other division of algae:-

a. Vegetative cells are diploid in nature.
b. The presence of chlorophyll-a and –c, together.
c. Cell wall is silicified which consists of two highly perforated overlapping pieces.
d. The stored food material is oil and chrysolaminarin but not starch.

Followings are some important features of division Bacillariophyta:-

1. Diatoms are cosmopolitan in distribution. These form a major component of planktonic vegetation. Mostly they are fresh water in habitat.
2. Some species grow epiphytically on other freshwater algae such as *Cladophora* and *Oedogonium.*
3. Benthic diatoms occur on rocks, sand or mud, or be epiphytic, epizoic or endozoic (e.g. *Licmophora*) (Fig. 5.6).
4. Diatoms are also found in terrestrial habitats and form a substantial proportion of the soil flora. In tropical rain forests, they grow in association with blue-green algae on leaves of trees.

5. Diatoms are mostly unicellular but some colonial species form filaments, loose chains or mucilagenous colonies.
6. Unicellular diatoms are divided into two orders, the pinnate diatoms (Pennales) and the centric diatoms (Centrales).
7. The cell shows isobilateral symmetry (e.g. *Pinnularia*) or radial symmetry (e.g. *Cyclotella*) (Fig. 5.7).
8. Colonial diatoms are organized into uniseriate filaments, as in some species of *Melosira.*
9. Cell wall is silicified, it shows characteristics secondary structures, which are called frustule.
10. Motile diatoms are characterized by the presence of raphe.
11. The cell wall (frustule) of the diatoms consists of two overlapping halves. The upper half is larger, called epitheca and lower smaller half is called hypotheca.
12. The cells are microscopic and are variable in shape. They may be triangular (e.g. *Triceratium*), boat shaped (e.g. *Gyrosigma, Cymbella*), rod shaped (e.g. *Bacillaria*), oval (e.g. *Cocconeis placenula*) or spherical (e.g., *Coscinodiscus excentricus*).
13. Bacillariophyta are commonly called golden brown algae. These looks golden brown because of their characteristics pigments which include carotenoids, fucoxanthin, diatomin, besides chlorophyll-a and chlorophyll-c.
14. The stored food material is oil and chrysolaminarin but not starch.
15. Reproduction takes place by cell division and auxospore formation.
16. Motile cells (antherozoids) have one pantonematic flagellum.
17. The cell shows gliding movements.
18. The zygote formed as a result of gametic union develops into a special type of spore, called auxospore.
19. Life cycle of the diatom is predominantly diploid, predominant, without a well marked alternation of generation.

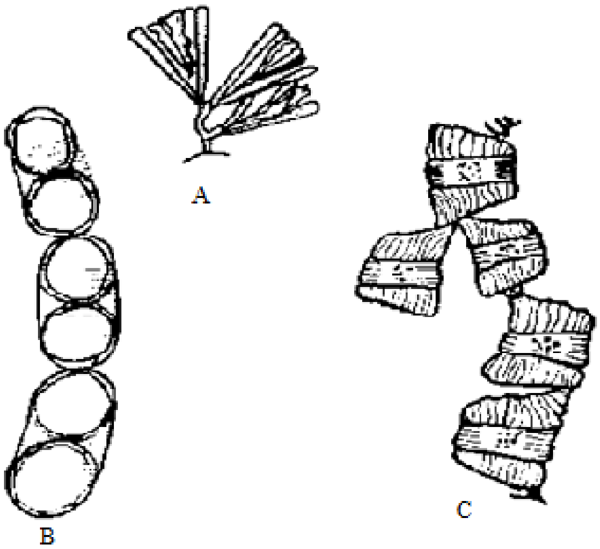

Fig. 5.6. Common benthic diatoms, A. Licmophora, B. Melosira, C. Isthmia

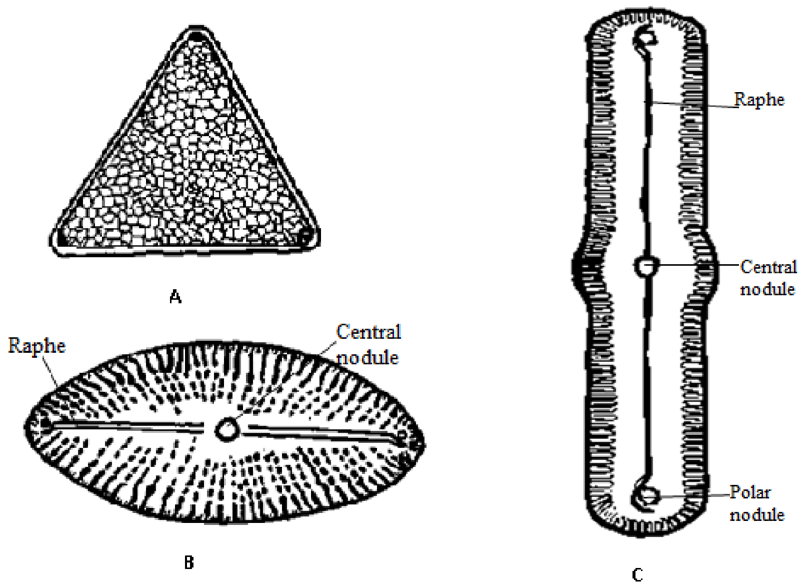

Fig. 5.7, Diatoms, A. Triceratium, B. Navicula, C. Pinnularia

5.5- SUMMARY

In this unit we have discussed the characteristic features of division Cyanophyta and Bacillariophyta. The members of division Cyanophyta are commonly known as blue green algae. c-phycocyanin, chlorophyll a and c- phyoerythrin are principal pigments of this division. Due to these pigments these look bluish green. Pigments are embedded within thylakoids. These are unicellular, colonial, chain of cells- trichomes or unbranched filamentous form. Cell wall is made up of mucopeptides. The cell structure is prokaryotic in nature. The cell organelles like chloroplast, mitochondria, endoplasmic reticulum are altogether absent. Flagella are altogether absent. Some members of this division show gliding or jerky movement. Reserve food material is cyanophycean starch. In some members terminal or intercalary heterocyst are present. These heterocysts are found in the members of Nostocales (except Oscillatoriaceae) and Stigonematales. Heterocysts considered as nitrogen fixing in blue green algae. Reproduction takes place by vegetative and asexual means. The sexual reproduction is completely absent.

Oscillatoria is unbranched filamentous blue green alga. It is commonly found in fresh and polluted water of ponds, pools, drains, streams and also in damp soils and rocks. The name *Oscillatoria* is given to this alga due to the peculiar oscillatory movement shown by the trichome. Reproduction takes place by fragmentation and hormogonia. *Nostoc* is another important member of division Cyanophyta. The thallus of *Nostoc* is uniseriate and filament like. Usually many trichomes aggregate together, and their gelatinous envelopes dissolve to form colonies of various shapes and sizes. Some time it is look like a ball called a *Nostoc* ball which contain numerous filaments. The important feature of this alga is presence of specialized cell, heterocyst. Heterocysts considered as a site of nitrogen fixation in blue green algae. Only vegetative reproduction is reported in this genus.

We also learned that the members of Bacillariophyta (golden brown algae) are popularly called diatoms; these comprise a homogenous assemblage of unicellular and colonial forms. These look golden brown because of their characteristics pigments which include carotenoids, fucoxanthin, diatomin, besides chlorophyll-a and chlorophyll-c. Diatoms are differing from other algae in possessing highly sculptured and symmetrically ornamented cell wall. Diatoms are entirely unique among the other division of algae because of (i) The diploid nature of vegetative cells (ii) the presence of chlorophyll-a and –c, (iii) cell wall is silicified which consists of two highly perforated overlapping pieces and (iv) the storage food material is oil and chrysolaminarin. Reproduction takes place by cell division and auxospore formation.

5.6- GLOSSARY

Anterior	-	In or towards front
Antheridium	-	Male gametangium
Akinete	-	Vegetative cell that becomes converted into thick walled non-motile resting spore; wall of cell becomes wall of spore.
Auxospore	-	Cell that enlarges greatly to offset diminution by vegetative cell division; in most cases, a zygote.
Carotenoids	-	General name for pigments of carotene and xanthophyll type; yellow, orange, or red pigments composed of eight linearly joined isoprenoid units, wide-spread among all organisms.
Chloroplast	-	Double membrane-bounded semiautonomous organelle of cytoplasm of eucaryotes and characterized by internal chlorophyll containing lamellar structure (thylakoids) embedded in protein-rich stroma.
Coccoid	-	Pertaining to habit; nonmotile unicells
Colonial	-	Number of cells held together within envelope.
Colony	-	Loose organization of similar cells which have developed together from single, original parent plant or cell. Each cell is potentially capable of life activities independent of others in the colony.
Cyanophycin granules	-	Proteinacesous food reserve occurring in granular form in cells of blue-green algae.
Endospore	-	Internally formed thin-walled spores of Cyanophyta, analogous to aplanospores.
Exospores	-	Spores produced externally or outwardly as in Cyanophyta; analogous to aplanospores.

Flagella	-	Fine, thread-like structures helps in movement.
Heterocyst	-	A specialized cell found in certain blue-green algae.
Filamentous	-	Thread-like photosynthetic plants.
Intercalary	-	Growth pattern in which newly formed cells are produced between two existing cells, e.g. of filament.
Motile	-	Capable of independent movement by means of flagella or some other device
Pantonematic	-	Flagellum in which surface is covered with hair-like appendages.
Substratum	-	Surfaces or object upon or within which organism is growing
Thalloid	-	Like plant or alga that is not differentiated into roots, stem, and leaves
Thallus	-	Relatively undifferentiated plant body that is not divided into roots, stem, and leaves
Trichome	-	Row of cells without inveting sheath (as in Cyanophyta); any sterile filamentous branch arising from thallus (as in algal divisions other than Cyanophyta).
Thylakoid	-	Structural unit of lamellar system forming double membrane disc.; photosynthetic lamella
Uniseriate	-	Arranged in single row or series
Vegetative	-	Formation of plant body lacking reproductive structures or organs.

5.7- SELF ASSESSMENT QUESTIONS

5.7.1 Long answer type questions:-

Q 1. Describe the general characteristic features of blue green algae.
Q 2. Describe the occurrence and thallus organization of *Oscillatoria.*
Q 3. Describe the mode of reproduction in *Nostoc.*
Q 4. Give an account of characteristics features of diatoms with the help of suitable diagram.

5.7.2 Short answer type of questions:-

Q 1. Write a short note on movement in *Oscillatoria*.
Q 2. Write a short note on thallus structure in *Nostoc.*
Q 3. Write a short note on Heterocyst.
Q 4. Mention the unique features of diatoms which differentiate them from other divisions of algae.
Q 5. What are Hormogonia.
Q 6. Write a short note on Akinetes.

5.7.3 Fill in the blanks.

Q 1. The members of division Cyanophyta are commonly known…………..….algae.
Q 2. The members of division………………….are popularly known as diatoms.
Q 3. The cell structure of Cyanophyta is………………………….
Q 4. Blue-green algae *Nostoc* is an unbranched ………………………alga.
Q 5. In the ………………… movement the trichomes move left and right of the axis.
Q 6. Generally akinetes are developed during …………………………. conditions.
Q 7. Hormogonia formation is the mode of ………………………reproduction.
Q 8. The reserve food material in the members of cyanophyta is………………….
Q 9. The function of Heterocysts is……………………………… in blue green algae.
Q 10. *Pinnularia graciloides* is the member of division…………………………….
Q 11. Cell wall of diatom is called…………………………….
Q 12. In the members of diatoms, the storage food material is ………………………..

5.7.4 True and false

Q 1.The members of division Cyanophyta (Myxophyta) are commonly known as Blue green algae.
Q 2. The members of Bacillariophyta are popularly known as diatoms.
Q 3. Flagella are present in the members of blue green algae.
Q 4. *O. terebriformis* occurs in hot water springs.
Q 5. Generally Akinetes develope during favourable conditions.
Q 6. The filaments of *Oscillatoria* are uniseriate and unbranched.
Q 7. *Oscillatoria* reproduce vegetatively by fragmentation and hormogonia.
Q 8. Unicellular diatoms are divided into two orders, the pinnate diatoms (Pennales) and the centric diatoms (Centrales).
Q 9. Bacillariophyta are commonly called red algae.
Q 10. In the members of diatoms the storage food material is starch.
Q 11. Heterocysts is concerned with nitrogen fixation in blue green algae.
Q 12. In *Nostoc* reproduction takes place by auxospore formation.

ANSWERS:

5.7.3 Fill in the blanks.

1. Blue green algae	4. Filaments	7. Vegetative	10. Bacillariophyta
2. Bacillariophyta	5. Oscillatory	8. Cyanophycean starch	11. Frustules
3. Prokaryotic	6. Unfavourable	9. Nitrogen fixing	12. Chrysolaminarin

5.7.4 True and false

1.	T	4.	T	7.	T	10.	F
2.	T	5.	F	8.	T	11.	T

3. F 6. T 9. F 12. F

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5.10- TERMINAL QUESTIONS

1. Describe the thallus organization and reproduction of *Oscilltoria* in detail.
2. Describe the thallus organization and reproduction of *Nostoc.*
3. Describe the general characteristic features of diatoms in detail.

UNIT- 6- OCCURRENCE, STRUCTURE OF THALLUS AND MODE OF REPRODUCTION IN CHLOROPHYTA AND XANTHOPHYTA

6.1- OBJECTIVES

After reading this unit you will be able to:-

- Know the general characteristics features of division Chlorophyta.
- Know the general characteristics features of division Xanthophyta.
- Understand the thallus organization and mode of reproduction of *Chlamydomonas, Volvox* and *Oedogonium.*
- Understand the thallus organization and mode of reproduction of *Vaucheria.*

6.2- INTRODUCTION

In this unit we will discuss about the thallus organization and mode of reproduction of some important genera belonging to division Chlorophyta and Xanthophyta. The division Chlorophyta is commonly known as green algae. This is a large division of algae and is represented by about 429 genera and 6500 sepcies. The members of Chlorophyta are mainly fresh water algae (about 90 per cent species are fresh water and 10 per cent marine). The freshwater species are commonly found in ponds, pools, lakes, ditches, water tanks, rivers and canals. There are some species of this division which are marine and found in the sea. Some species of this division are found in both types of habitat i.e. fresh water and marine e.g. Chaetophorales and Cladophorales. Many members are epiphytic in nature. Many species of *Cladophora* and *Characium* are epizoic algae. Some green algae like *Trebouxia, Chlorella* form symbiotic associationship with animals like *Zoochlorella* and *Hydra*. Some green algae form symbiotic association with fungi to form lichens. *Cephaleuros* is parasitic algae on leaves of tea, coffee, piper and magnolia plants. *Cephaleuros* causes red rust of tea. *Chlamydomonas nivalis* causes red snow and *Clamydomanas yellowstonensis* causes green snow. Some *Chlamydomonas* species are thermophilic.

The members of another division Xanthophyta are commonly yellow green in colour. This division includes 375 species and 75 genera. Mostly these are fresh water algae. The thallus organization exhibits morphological diversity. Mostly the members of this division are motile, coccoid, filamentous and Siphoneous forms. The order Heterosiphonales also called Vaucheriales includes the coenocytic siphoneous forms.

6.3- CHLOROPHYTA

Important features of Chlorophyta

1. The division Chlorophyta is commonly known as green algae.
2. The cells are eukaryotic and contain mitochondria, Golgi bodies, plastids, endoplasmic reticulum and ribosome.

3. The cell wall is made of two layers, the inner layer mainly consisting of cellulose and the outer layer consisting of pectic substances.
4. The chloroplasts are well organized, the main pigments are chlorophyll -a and –b and the other pigments are carotenes and xanthophylls.
5. 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. *Zygnema,* spiral e.g. *Spirogyra*, discoid e.g., *Chara*.
6. The reserve food is in form of starch and its formation is associated with pyrenoids.
7. The motile reproductive structures i.e. zoospores and gametes have 2 or 4 flagella that are apical or subapical, and equal in size and acronematic (whiplash) type.
8. The sexual reproduction is isogamous, anisogamous or oogamous type.

6.3.1- *Chlamydomonas*

6.3.1.1- Occurrence

Chlamydomonas is a large genus and is found almost in all places. It is represented by about 400 species. This is simple, unicellular, motile fresh water alga. Mainly found in fresh water which is 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 a planktonic alga and makes surface of water appear green. Some species of *Chlamydomonas* are terrestrial, growing on moist soil surface, in rice fields and on banks of rivers and lakes. Palmella sages of genus make scum on soil surfaces. Some species are found in salty brackish water. *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.

6.3.1.2- Structure of thallus

Chlamydomonas is a motile unicellular green alga. The thallus is represented by a single cell. The cell is biflagellate (with two flagella) spherical, ellipsoidal or pear shaped, about 30 μm in length and 20 μm in diameter. The pyriform or pear shaped thalli are common, they have narrow anterior end a broad posterior end (Fig. 6.1). In some species *of Chlamydomonas* the posterior end is pointed (e.g. *Chlamydomonas caudata*). Two, rarely more, contractile vacuoles are found near the bases of the flagella, and a prominent cup shaped chloroplast is present in each cell. Cellulose is the main structural component of the cell wall. In some species the cellulose wall is surrounded by a gelatinous sheath. Besides cup-shaped chloroplast following types of chloroplast are also present in some species of *Chlamydomonas*-

'H' shaped chloroplast	-	*Chlamydomonas biciliata*
discoid chloroplast	-	*Chlamydomonas alpina*
reticulate chloroplast	-	*Chlamydomonas reticulacta*
ridged chloroplast	-	*Chlamydomonas stenii*

axile chloroplast - *Chlamydomenas eradians*

Pyrenoids are proteinaceous bodies present in chloroplast. Pyrenoids are concerned with the synthesis and storage of starch. The thallus contains single large, dark nucleus lying inside the cavity of the cup shaped chloroplast. The flagella are present at the anterior end of the cell. Flagella are equal in length and whiplash or acronematic type. The flagella are mostly longer than the thallus but in some species it may be shorter or equal than the thallus. Each flagellum originates from a basal granule or blepharoplast and comes out through a fine canal in cell wall. Two contractile vacuoles are present at the base of flagella. The main functions of these vacuoles are excretion or osmoregulation. A pigmented spot known as eye-spot or stigma located in the anterior part of the cell. The shape and position of the eye spot varies in different species. The eye spot has a colourless biconvex photosensitive lens and a curved pigmented plate. It is photoreceptive organ and functions as a primitive eye.

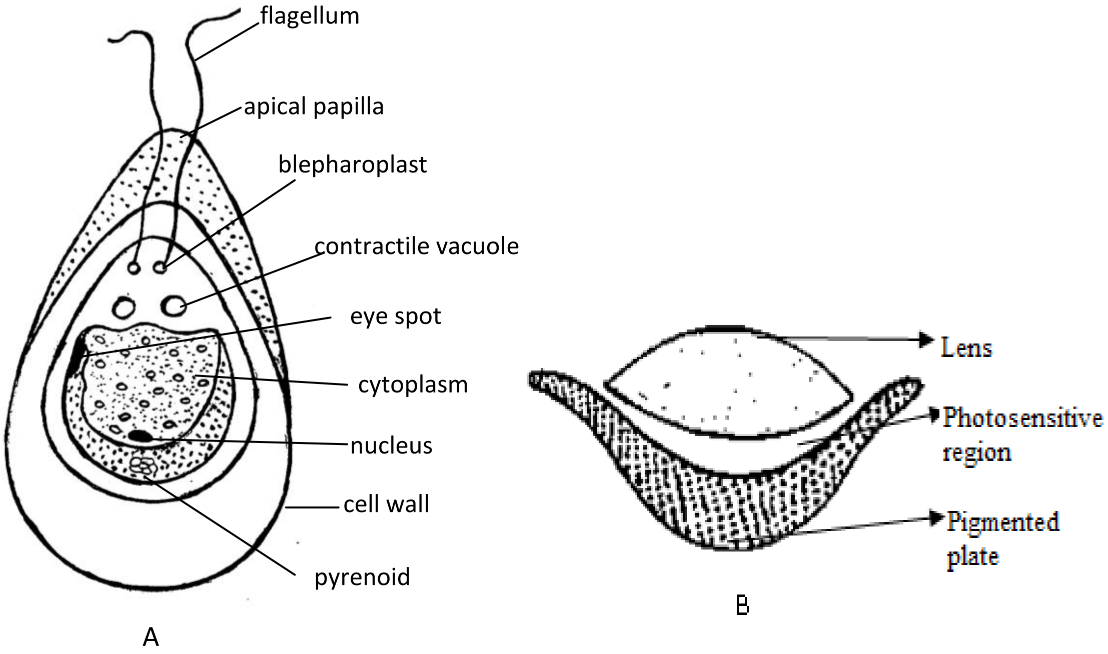


Fig. 6.1. Thallus organization of Chlamydomonas, A. Cell structure, B. Structure of eye spot

6.3.1.3- Mode of reproduction

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

Reproduction in *Chlamydomonas*

Asexual reproduction

- **By zoospores**
- **By aplanospores**
- **Palmella stage**

Sexual reproduction

- **Isogamous**

  e.g. *C. debaryanum, C. longistima, C. reinhardii*

- **Anisogamous**

  e.g. *C. braunii, C. suboogama*

- **Oogamous**

  e.g. *C. coccifera, C. ooganum*

1. Asexual Reproduction

Asexual reproduction takes place by following types of spores:

A. By zoospores
B. By aplanospores
C. Palmella stage

A. By zoospores

Zoospore development is the common feature of *Chlamydomonas*. These zoospores develop during favourable conditions. In the zoospore formation the protoplast contracts and gets detached from the cell wall. The parent cell loses flagella. The contractile vacuoles and the neuromotor appearatus disappear. The protoplasm divides longitudinally by simple mitotic division forming two daughter protoplasts. The second longitudinal division of protoplasm takes place at right angle to the first, thus making four daughter chloroplasts. Each daughter cell develops cell wall, flagella and transforms into zoospore. The zoospores are liberated from the parent cell or zoosporangium by gelatinization or rupture of the parent cell wall. The zoospores are identical to the parent cell in structure but smaller in size. The zoospores simply enlarge to become mature *Chlamydomonas* (Fig 6.2).

B. By aplanospores

The aplanospores are formed under unfavourable conditions. During unfavourable conditions the parent cell loses flagella. The protoplast divides into daughter protoplasts. The protoplast rounds off and secretes a thin wall outside but does not develop flagella. These non-motile structures are called aplanospores. Under favourable conditions aplanospores may germinate either directly or divide to produce zoospores. e.g. *C. nivalis.*

C. Palmella Stage

The palmella stage also formed under unfavorable conditions as shortage of water, excess of salts etc. The protoplast of parent cell divides to make many daughter protoplasts but they do not form zoospores. The parent cell wall gelatinizes to make mucilaginous sheath around daughter protoplasts. The daughter protoplasts also develop gelatinous wall around themselves without developing flagella. These protoplast segments are called palmellospores. The division and redivision of the protoplast ultimately forms amorphous colony with indefinite number of spores and it is called palmella stage .When favorable conditions return, the gelatinous wall dissolves, palmella spores develop flagella, and these spores are released to make new thalli. This stage is a non-motile and temporary phase (Fig 6.2).

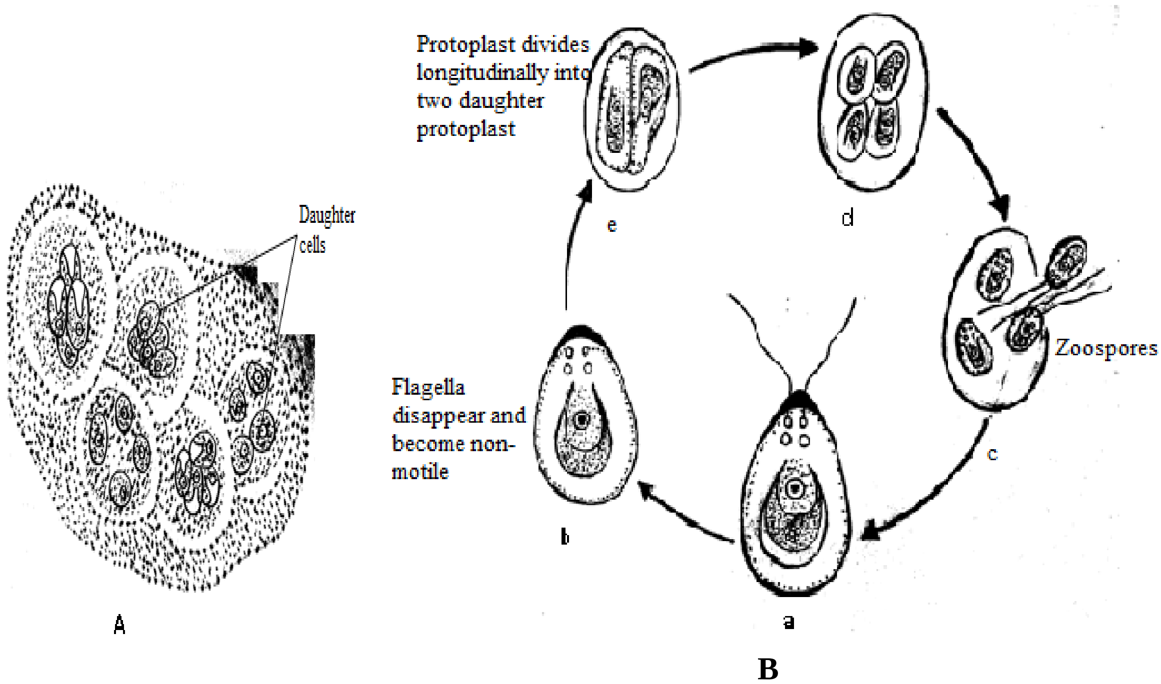


Fig. 6.2. Asexual reproduction, A. Palmella stage, B. formation of zoospores

1. Sexual reproduction

The sexual reproduction in *Chlamydomonas* takes place by following methods:-

A. Isogamous
B. Anisogamous
C. Oogamous

A. 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, takes place. These gametes are morphologically similar but physiologically dissimilar. The two gametes come close to each other by their anterior ends and later fusion proceeds to lateral sides. The fusion product is quadriflagellate and binucleate structure with two pyrenoids and two eye spots. The quadriflagellate zygote remains motile for several hours to few days (Fig. 6.3). The two nuclei ultimately fuse forming zygote.

B. Anisogamy

In anisogamous reproduction the fusing gametes are unequal in size. The male gamete is smaller called microgamete and female gamete is larger and called macrogamete. The macrogametes are formed in female gametangium in which the protoplast divides to make 2 to 4 gametes only. The microgametes are formed in male gametangium where the protoplast divides to make 8-16 gametes. 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 (Fig. 6.4).

C. Oogamy

The oogamous sexual reproduction takes place in few species of this genus like *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. The microgametes are formed by four divisions of protoplast as in case of anisogamous reproduction. The microgamete reaches the female gamete and unites by anterior ends followed by the fusion and diploid zygote is formed (Fig. 6.5).

Zygote and its development

The zygote is a diploid spore. The zygote survives for a long period of unfavourable conditions and germinates on approach of favorable conditions (Fig. 6.6). Zygote divides by reduction division developing four daughter protoplasts. Each protoplast converts into biflagellate zoospore which then grows into a mature thallus.

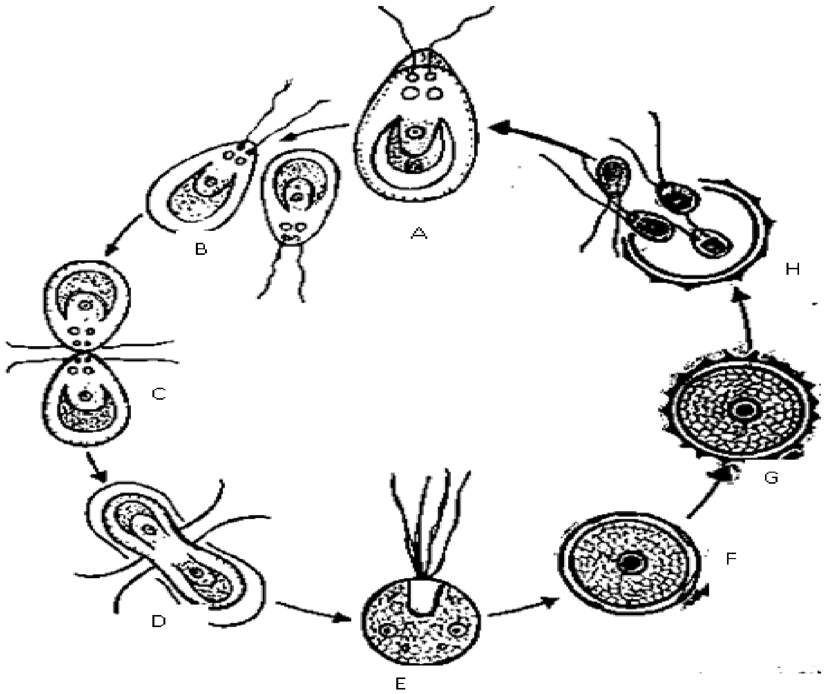


Fig.6.3. Chlamydomonas: Isogamous sexual reproduction. A. vegetative cell, B. Isogametes, C-E Fusion of gametes, F-G. Zygote, H. Germination of zygote.

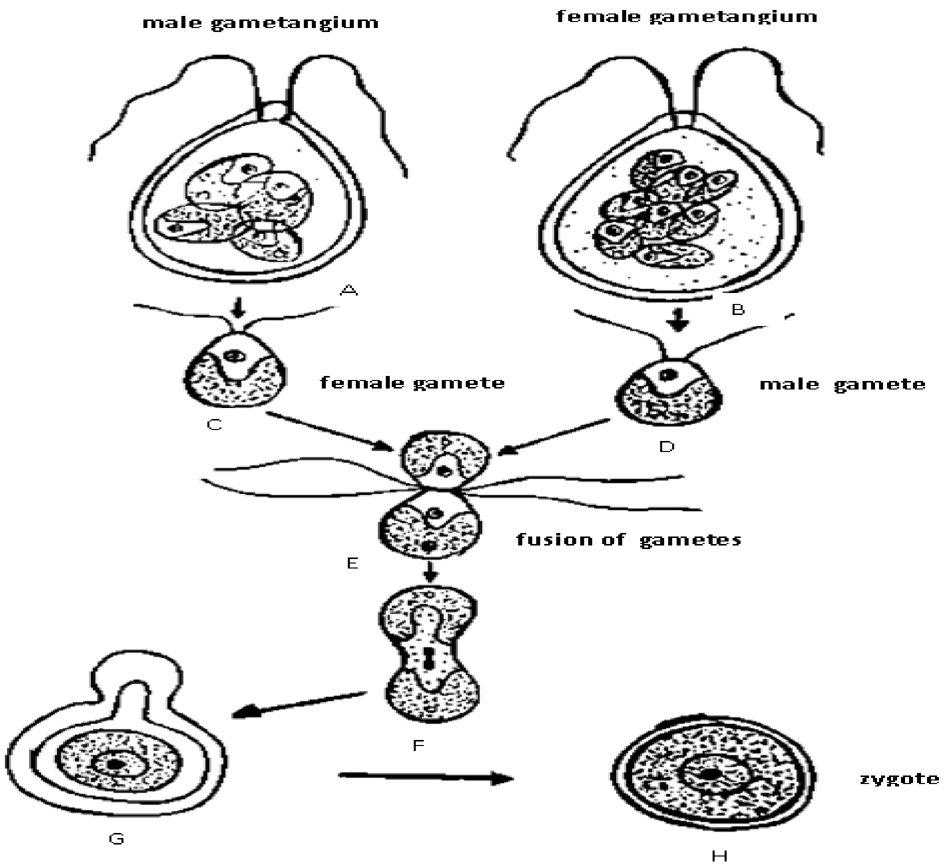


Fig.6.4 Chlamydomonas: Anisogamous type of sexual reproduction

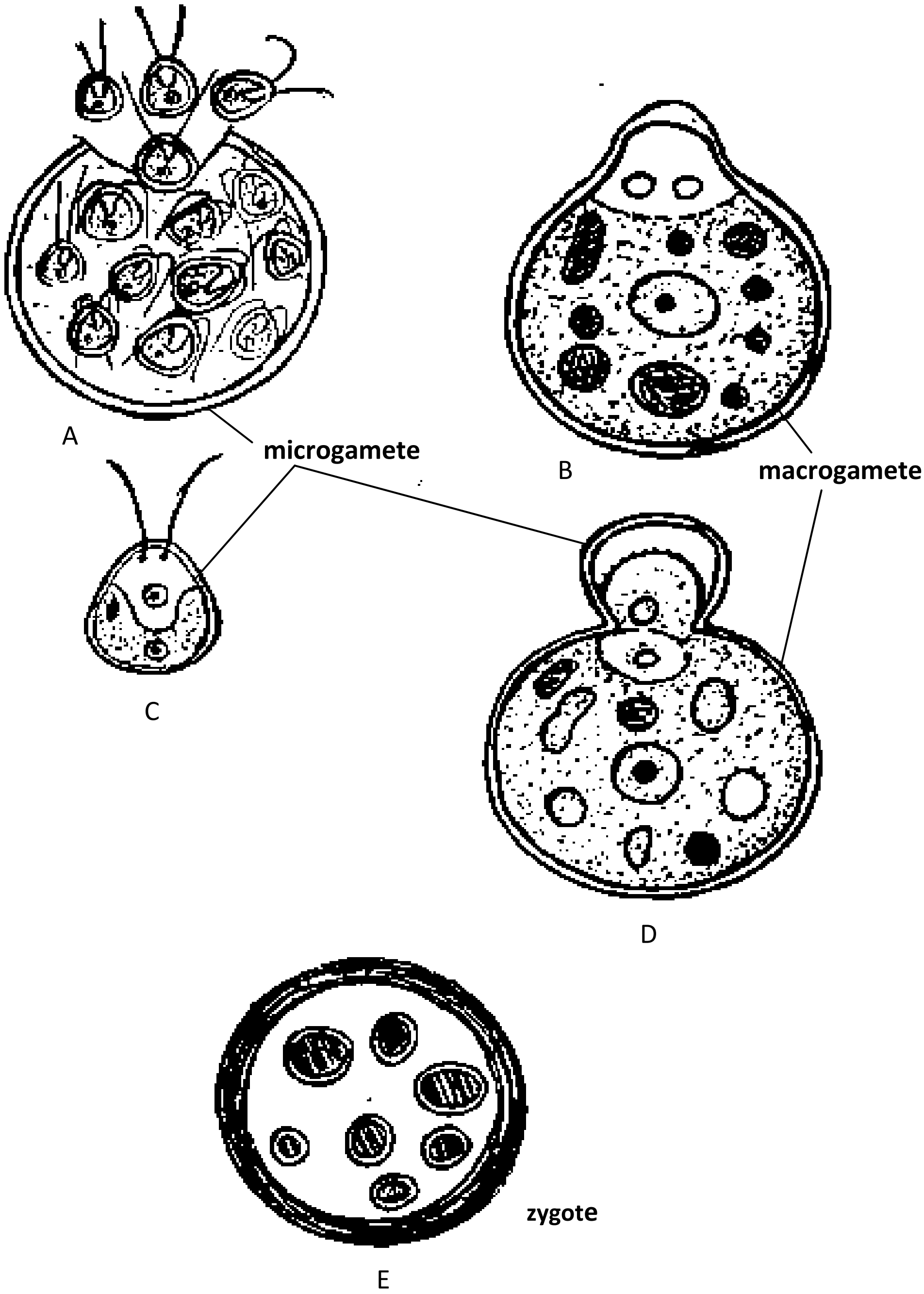


Fig. 6.5 Chlamydomonas: Oogamous sexual reproduction

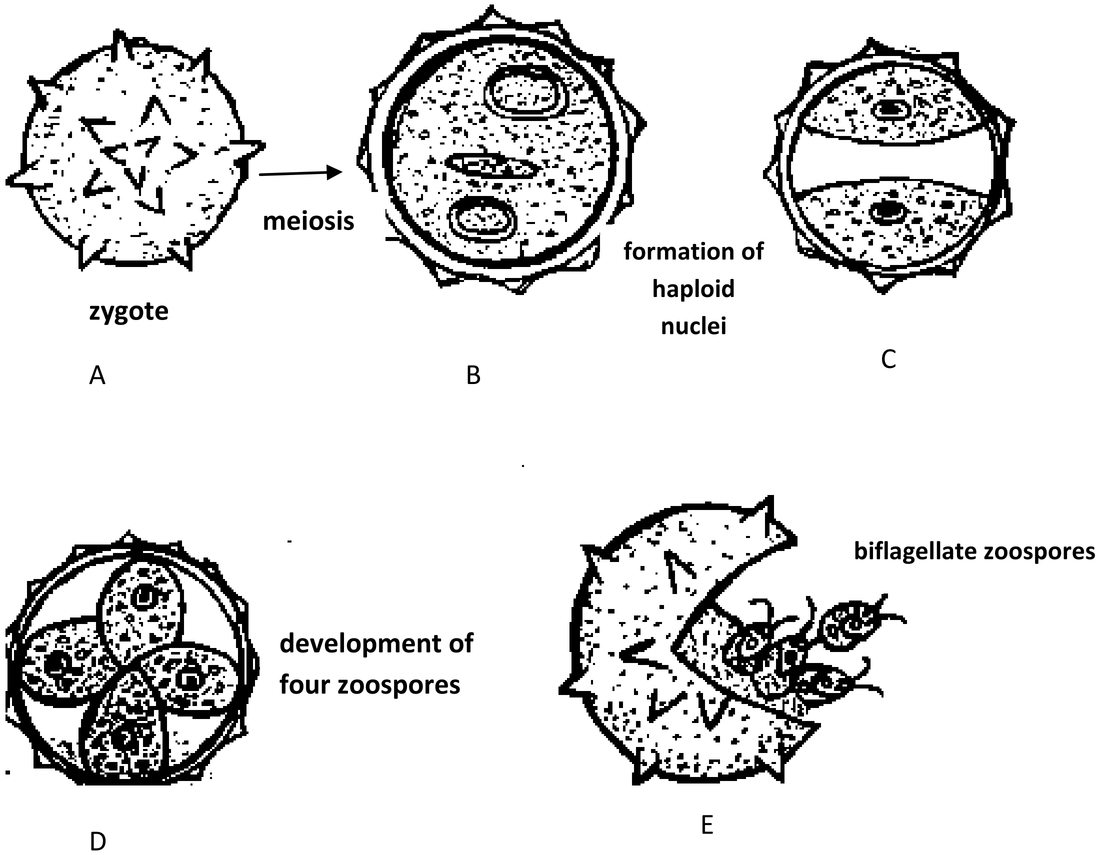


Fig. 6.6 Chlamydomonas: Germination of zygote

6.3.2- *Volvox*

6.3.2.1- Occurrence

Volvox is a free floating fresh water green colonial alga. It has about 20 species which grows as planktons on surface of water bodies like temporary and permanent ponds, and water tanks. During rainy season due to its fast growth the surface of water bodies become green. The *Volvox* colonies appear as green rolling balls on surface of water. Some important species in India are *V. globator, V. aureus, V. prolificus, V. africanus and V. rousselettii.*

6.3.2.2- Structure of thallus

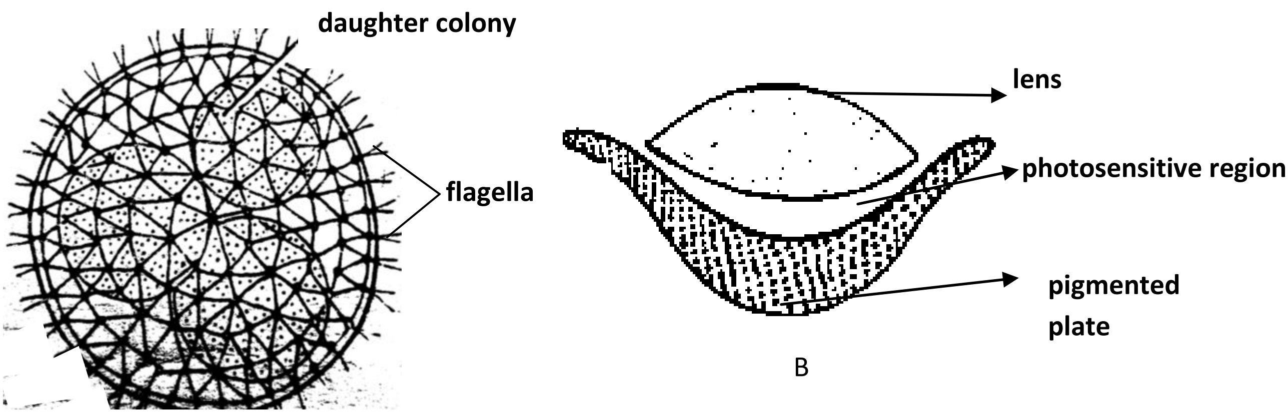
Volvox is a motile colonial alga with definite shape and number of cells and called coenobium. The colonies are oval or spherical in shape having 500-60000 cells in each colony (Fig. 6.7). The cells are biflagellate and are arranged in a single layer within the periphery of the gelatinous colonial envelop. The movement is brought about by the joint action of the flagella of individual cells. All the cells are connected to each other by cytoplasmic strands. The cells of anterior end possess bigger eye spots than those of the cells of posterior end. The cells of the posterior ends take part in reproduction at maturity.

The cells of *Volvox* colony are similar to *Chlamydomonas*. The cells of colony are usually pyriform with narrow anterior end and broad posterior end. Two flagella are present in each cell which is equal in size and whiplash type. The protoplasm of cell is enclosed within plasma membrane. Each cell contains one nucleus, a cup shaped chloroplast, pyrenoids, an eye spot and two contractile vacuoles. The eye spot is towards the external face of the cell. It has a colourless biconvex photosensitive lens and a curved pigmented plate. Most cells of a colony are vegetative only a few are reproductive. The flagella are absent in reproductive cells. Each cell of colony is independent for various functions (Fig. 6.7).

6.3.2.3- Mode of reproduction

In *Volvox* 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. Reproduction is of following types-

I. Asexual reproduction
II. Sexual reproduction



A **Fig. 6.7. Volvox A. a colony, B. An eye spot**

I. Asexual Reproduction

The asexual reproduction takes place under favourable conditions during spring and early summer. Followings are some important steps (Fig. 6.8) of asexual reproduction in this genus:-

1. In the asexual reproduction some cells of the posterior end of the colony become reproductive. These cells called gonidia or parthenogonidia.
2. Gonidia are larger than the vegetative cells. Flagella and eye spots are absent in gonidia. Pyrenoids increase in number.
3. These gonidia are pushed towards interior of the colony. The protoplast of the gonidium divides and forms daughter colonies.
4. The first division of gonidium is longitudinal to the plane of coenobium and this forms two cells.
5. The second division is also longitudinal and at right angle to the first, forming 4. 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 it is called plakea stage.

6. Each of these 8 cells divides by longitudinal division forming 16 cells arranged in the form of a hollo sphere.
7. The sphere is open on exterior side as a small aperture called phialopore.
8. The cells at this stage continue to divide till the number of cells reaches the characteristic of that species.
9. The cells at this stage are naked and in close contact with each other. The pointed anterior end of cells is directed towards inside.
10. The next step is called inversion of colony. As cells become opposite in direction, their anterior pointed end has to face the periphery of colony.
11. The inversion of colony starts with formation of a constriction opposite to phialopore. The cells of posterior end along with constriction are pushed inside the sphere, till the whole structure comes out of the phialopore.
12. After inversion, the cells develop cell wall, flagella and eye spot. The cells become seperated due to development of gelatinous sheath around each cell. This newly developed colony is called daughter colony.
13. The daughter colonies initially remain attached to gelatinized wall of parent colony and later become free in gelatinous matrix of parent colony.

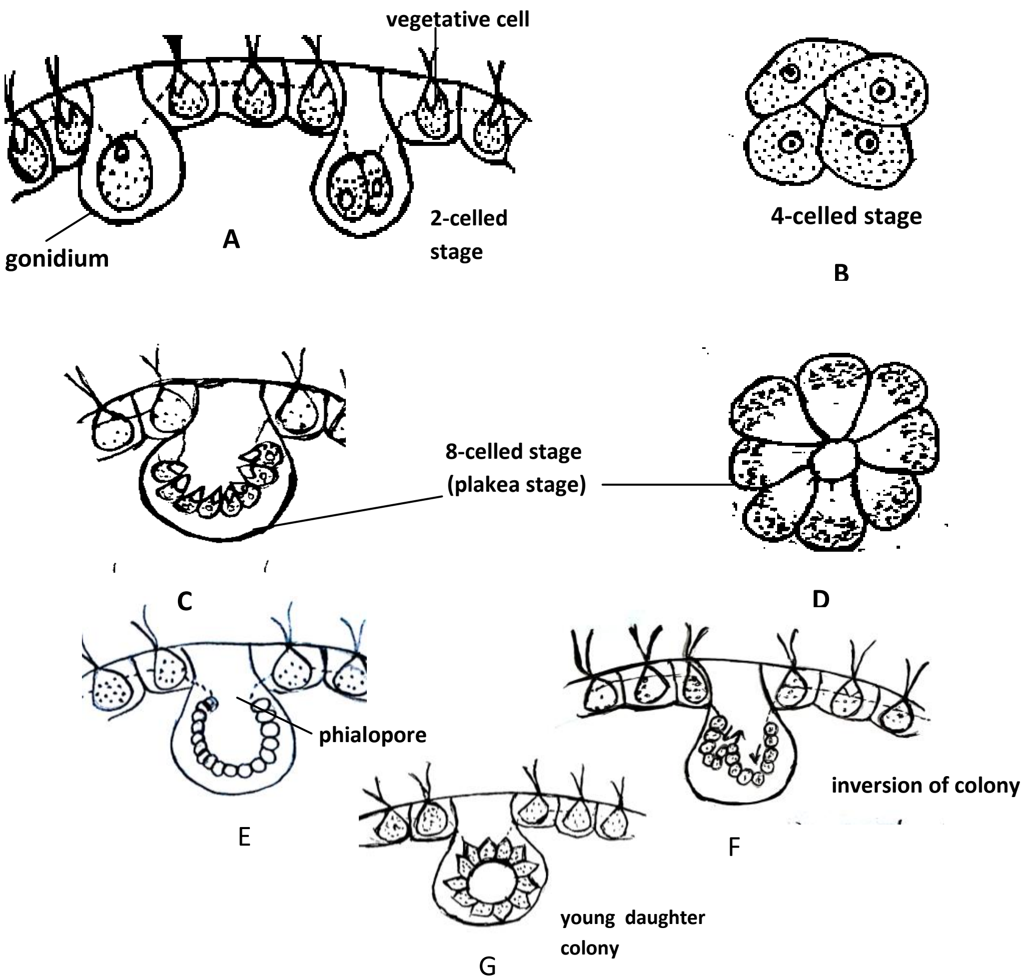


Fig. 6.8. Volvox. Asexual reproduction: development of daughter colony

II. Sexual Reproduction

Oogamous type of sexual reproduction takes place in this genus. The species of *Volvox* are either monoecious (e.g., *V. globator)* or dioecious (e.g. *V. aureus.* Monoecious species are usually protandrous i.e. antheridia mature before oogonia. Usually a colony involved in sexual reproduction does not have asexual daughter colonies. There are followings developmental stages (Fig. 6.9&10) of sexual reproduction in *Volvox:-*

1. Reproductive cells mostly differentiate in the posterior part of colony. These cells enlarge, lose flagella and are called gameteangia.
2. The male reproductive cells are called antheridia or androgonidia and female reproductive cells are called oogonia or gynogonidia.
3. In the posterior ends of the colony the development of antheridium starts with formation of antheridial initial or androgonidial cell.
4. The initial cells enlarge, lose flagella, protoplasm becomes dense and nucleus becomes larger. This cell undergoes simple divisions several times developing many daughter cells.

5. Each cell develops into a naked, biflagellate and fusiform male reproductive cell called antherozoid.
6. 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.
7. The antherozoids are released individually or sometimes in groups (Fig. 6.9).
8. The oogonium is larger than other cells of the colony.
9. The mature oosphere or ovum is round or flask shaped structure.
10. The egg is uninucleate struture, the beak of flask shape oogonium functions as receptive spot (Fig. 6.10).
11. After liberation from antheridium, the antherozoids swim freely on surface of water.
12. Due to chemotactic response the antherozoids reach the oogonia. Some antherozoids enter each oogonium. Only one antherozoid enters inside the oogonium through receptive spot.
13. 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.
14. The diploid zygote secretes a thick wall. It may remain dormant for some time. The dormant zygote germinates on approach of favourable climatic conditions, by undergoing reduction division. Three out of four daughter cells degenerate and only one survives. The surviving cell becomes zoospore. This zoospore divides mitotically again and again developing into a colony.

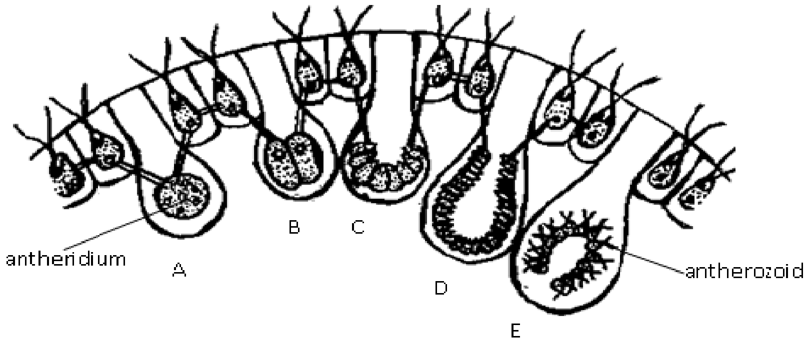


Fig. 6.9. ***Volvox:*** **Development of antherozoids**

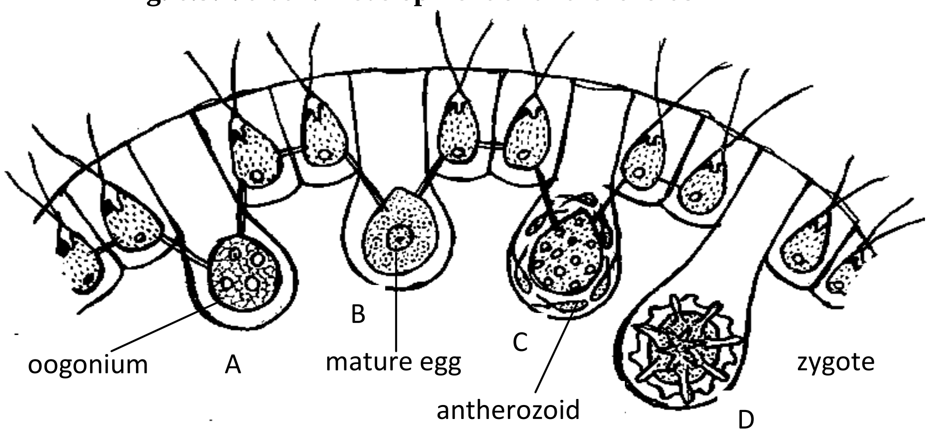


Fig. 6.10 Volvox, A-B Development of oogonium, C. Fertilization, D. Zygote

6.3.3- *Oedogonium*

6.3.3.1. Occurrence

This is a freshwater unbranched filamentous alga usually present in permanent water bodies like lakes, tanks and ponds. Some species are terrestrial (e.g. *O.terrestris, O. randhawe*) and found in moist soil. There are about 200 species reported in India.

6.3.3.2. Structure of thallus

Oedogonium is the filamentous and multicellular alga. The filaments of *Oedogonium* are unbranched and consist of cylindrical cells except in the basal cell which is modified into a holdfast. The basal cell, which acts as holdfast is devoid of chloroplast. The terminal cells of the filaments are generally rounded, elongated or acuminate. A characteristics feature of this alga is the presence of distinct transverse bands at the distal ends of some cells. The band formed at the time of cell division is called apical cap, and the cell with apical cap is known as cap cell (Fig. 6.11).

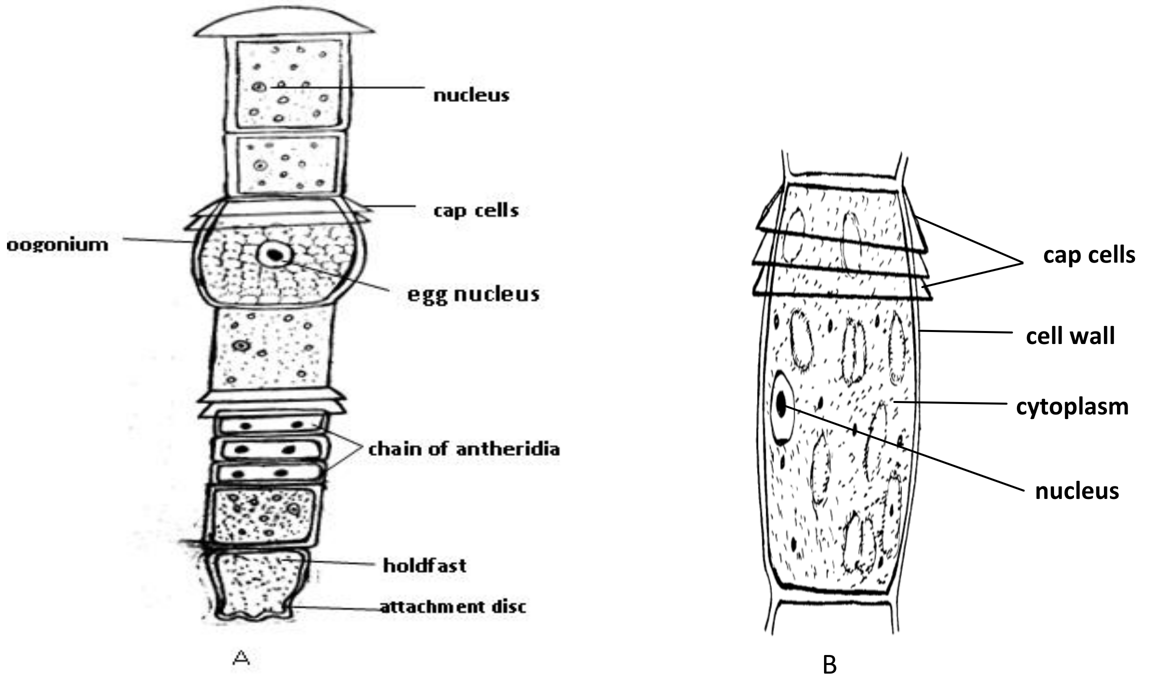


Fig. 6.11 Oedogonium, A. A filament, B. Cell structure

6.3.3.3. Mode of reproduction

Reproduction takes place by following three methods-

I. Vegetative reproduction
II. Asexual reproduction
III. Sexual reproduction

I. Vegetative reproduction

The vegetative multiplication takes place by following means-

1. Fragmentation
2. Akinetes

1. Fragmentation: Like many other algae, small fragments of *Oedogonium* filament have the capacity to grow independently and develop into a new thallus. The fragmentation of thallus may be due to the mechanical pressure or dissolution of transverse walls.

2. Akinetes: Akinetes are formed during unfavorable conditions. Cells become thick walled reddish or brownish structures at the advent of unfavorable conditions and formed in small chains. These akinetes germinate under favourable conditions and each akinete forms new filaments.

II. Asexual reproduction

The asexual reproduction takes place by means of zoospores. The zoospores are multiflagellate formed singly in the intercalary cap cell. Usually the newly formed cap cell functions as the zoosporangium. After maturation, the wall of the zoosporangium splits near the apical region and liberates the zoospore. The mature zoospores are ovoid, spherical or pyriform. These are uninucleate and contain a chloroplast. After liberation these zoospores swims and then settles on substratum with its anterior end downwards. The apical cell divides repeatedly to form a new filament.

III. Sexual reproduction

An advanced oogamous type of sexual reproduction reported in this genus. It takes place with the help of male and female gametes. The male gametes (antherozoids) are produced in antheridia and the female gametes (eggs) are produced in oogonia. The genus *Oedogonium* exhibits sexual dimorphism as both gametes differ morphologically and physiologically. There are followings some important developmental steps (fig. 6.12) of sexual reproduction in this genus-

1. On the basis of distribution of sex organs the genus is divided into two types of species i.e. Macrandrous species and Nannandrous species.
2. In macrandrous species the antheridia are born on the filaments of normal size. In some species antheridia and oogonia develop on same filament are called macrandrous monocious. Examples– *O. nodulosum* and *O. fragile.*
3. In some macrandrous species the antheridia and oogonia born on different filaments, known as macrandrous dioecious species. Examples- *O. crassum* and *O. aquaticum.*
4. In the nannandrous species, filamentous bearing antheridia and oogonia show morphologically distinction. The male filaments are much smaller than the female filaments are called dwarf male or nannandrium. The dwarf males develop from androspores, formed in the androsporangia.
5. The antherozoids are unicellular, uninucleate and multiflagellate structures.
6. The development of oogonia is similar in both macrandrous and nannandrous species.
7. During fertilization mostly a single antherozoid enters into the oogonium through the opening present on the oogonial wall. Fertilization takes place and diploid zygote is formed.

8. Mostly zygote undergoes a period of rest. The germination of zygotes takes place under favorable conditions. Zygote divides undergoing reduction division forming four daughter cells which converts into zoospores**.**

9. Zoospores are liberated after the rupture of the zygote wall.

10. These zoospores germinate and develop new haploid filaments.

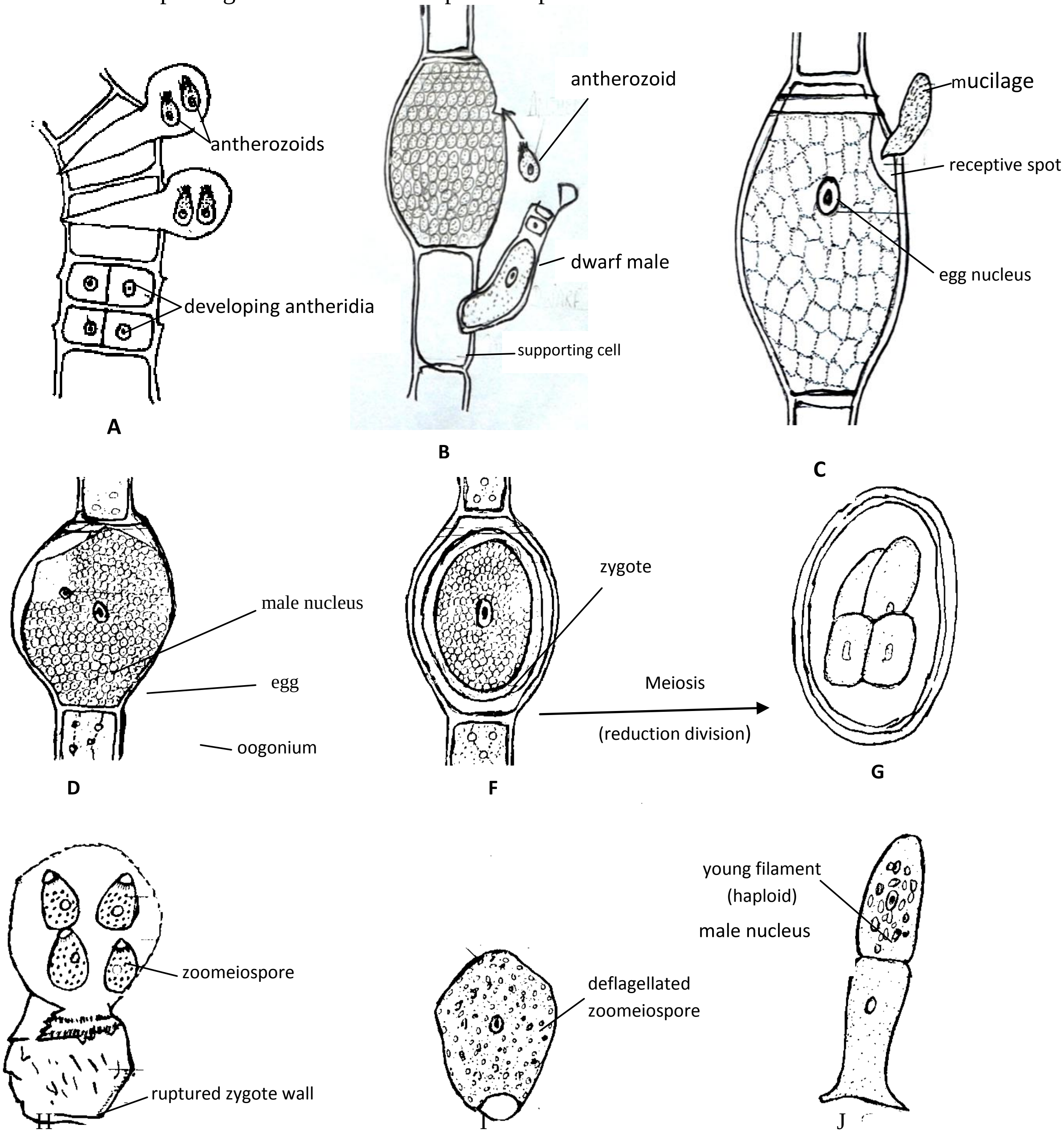


Fig 6.12 Oedogonium: Different stages of sexual reproduction. A. a developed antheridium, B. liberation of antherozoid, C. an oogonium, D-J Fertilization and germination of zygote.

6.4 *XANTHOPHYTA*

Important features of Xanthophyta

1. The members of this division are called yellow green algae.
2. The plastids are yellow green and contain chlorophyll a chlorophyll-e and β-carotene.
3. The amount of carotenoids is usually large.
4. The chromatophores are discoid and many in each cell.
5. Reserve food materials are oil, fat and leucosin or chrysolaminarin.
6. The cell wall is silicified in a few species.
7. The motile forms have two unequal flagella. These flagella are inserted at the anterior end. The tinsel flagellum is longer and whiplash flagellum is shorter.
8. Sexual reproduction is rare but in *Vaucheria* it is oogamous.
9. Mostly the members of this division are fresh water forms but a few species are subaerial and terrestrial
10. The order vaucheriales includes the Coenocytic siphoneous forms. e. g. *Vaucheria*
11. The order Vaucheriales or Heterosiphonales comprises of two families, Botrydiaceae and Vaucheriacea.

6.4.1- *Vaucheria*

6.4.1.1- Occurrence

Vaucheria is represented by 54 species of which about 19 species occur in India. Mostly the species are fresh water in habitat but few species are marine (e.g., *V. poloboloides*) and some are terrestrial (e.g., *V. sessilis, V. hamata* and *V. terrestris*). The terrestrial species are found as green mats on moist soil at shady places. *V. amphibia* is reported as amphibious species. The common Indian species of *Vaucheria* are *V. amphibia, V. geminata, V. polysperma, V. sessilis and V. uncinata* etc.

6.4.1.2- Structure of thallus

The thallus is sparingly branched, coenocytic and siphonaceous type. The thallus is made up of long, cylindrical well branched filaments (Fig. 6.13). The filament is aseptate, coenocytic structure. The thallus is attached to substratum by means of branched rhizoids. The thallus contains an outer cellulosic cell wall, a central vacuole which runs continuously from one end of the thallus to the other. The filaments are non-septate, the protoplasm with many nuclei is continuous, along the entire length of thallus making the thallus (coenocytic) making the thallus a siphonaceous structure. The male reproductive sex organ is antheridium and female is oogonium (Fig. 6.13). Septa or cross wall formation occurs at the time of reproduction. The cell wall is made up of two layers, the outer layer is pectic and the inner layer is cellulosic. The growth of filament is apical; the filament increases in length by apical growth of all the branches. The reserve food material in *Vaucheria* is oil instead of starch.

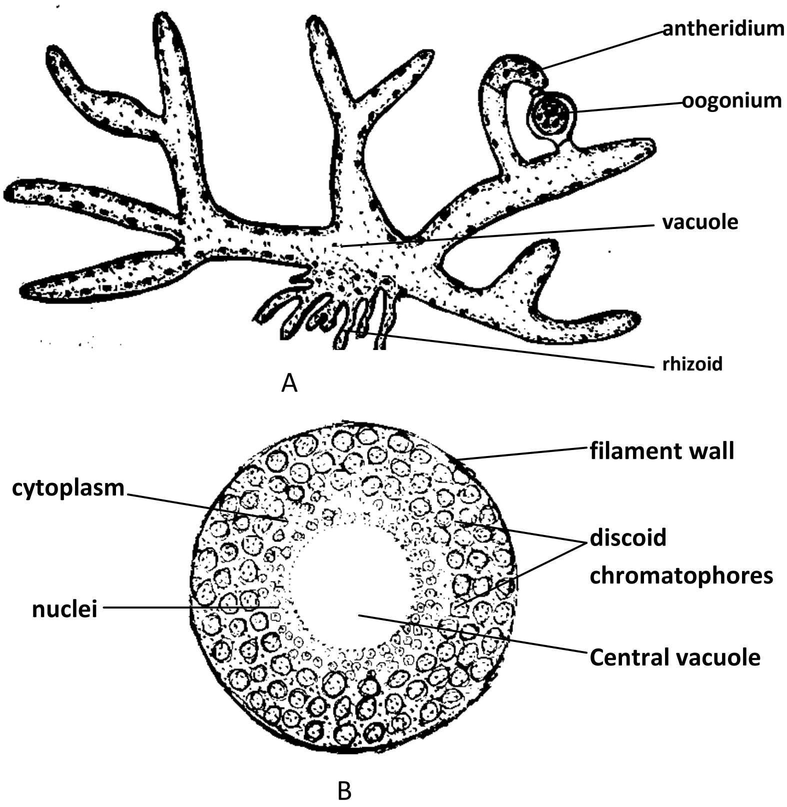


Fig. 6.13. Vaucheria A. Thallus structure B. T.S. of vegetative filament

6.4.1.3- Mode of reproduction

There are following three modes of reproduction in *Vaucheria*-

I. Vegetative reproduction
II. Asexual reproduction
III. Sexual reproduction

I. Vegetative reproduction

Vegetative reproduction takes place by fragmentation. The thallus may be braek into small segments due to the mechanical injury. The broken fragment develops thick wall and later on develops into new thallus.

II. Asexual reproduction

Asexual reproduction takes place by following types of spores-

1. Zoospores
2. Aplanospores
3. Akinetes

1- Zoospores: Asexual reproduction by means of zoospores is quite common in aquatic species of *Vaucheria.* These zoospores formed under favorable conditions within elongated club shaped zoosporangium. The culb shaped zoosrangium is cut off by a septum at the base. The sporangial protoplast shrinks slightly and a pair of flagella, which are of unequal length, develops opposite each nucleus. This multinucleate and multiflagellate sporangial mass behave as zoospores. These spores are entirely different from those of other green algae due to their multiflagellate nature. After liberation, these zoospores come to rest. Flagella disappear and secrete a thin mucilaginous mass around itself. Under favourable condition these spores germinate and develop new thalli (Fig.6.14).

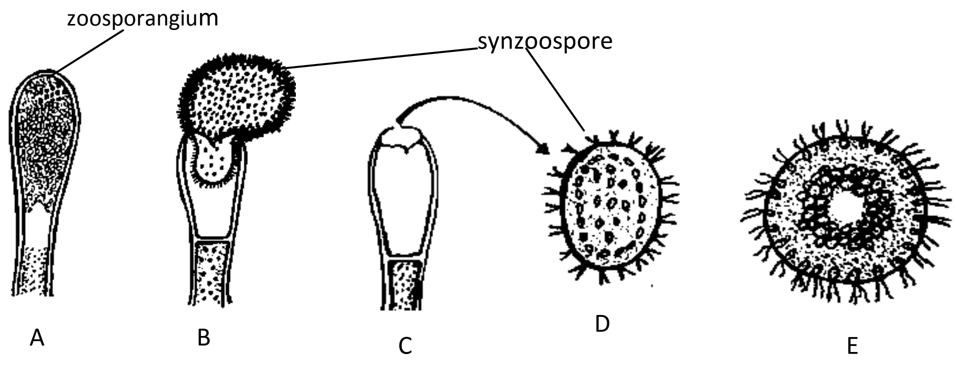


Fig. 6.14. Vaucheria, Asexual reproduction: Development of Zoospore A-Zoosporangium, B-C. Liberation of zoospore, D- Synzoospore, E- T.S. of synzoospore

2- **Aplanospores**: These spores are generally formed in terrestrial species. Aplanospores develop singly within aplanosporangium at the terminal end. The aplanospores are non-motile in nature. In *Vaucheria uncinata* alpanospores are spherical in shape and liberate by rupture of the sporangial wall. These aplanospores after liberation germinate into new thalli (Fig. 6.15 A).

3- **Akinetes**: Akinetes are thick walled multinucleate segments also called cysts or hypnospores. These akinetes develop when conditions are not favorable. When many akinetes remain attached to the parent thallus, the thallus gives the appearance of another alga *Gongrosira.* Hence this stage of *Vaucheria* is also called *Gongrosira* stage. These spores under favourable conditions develop into new thalli (Fig.6.15, B).

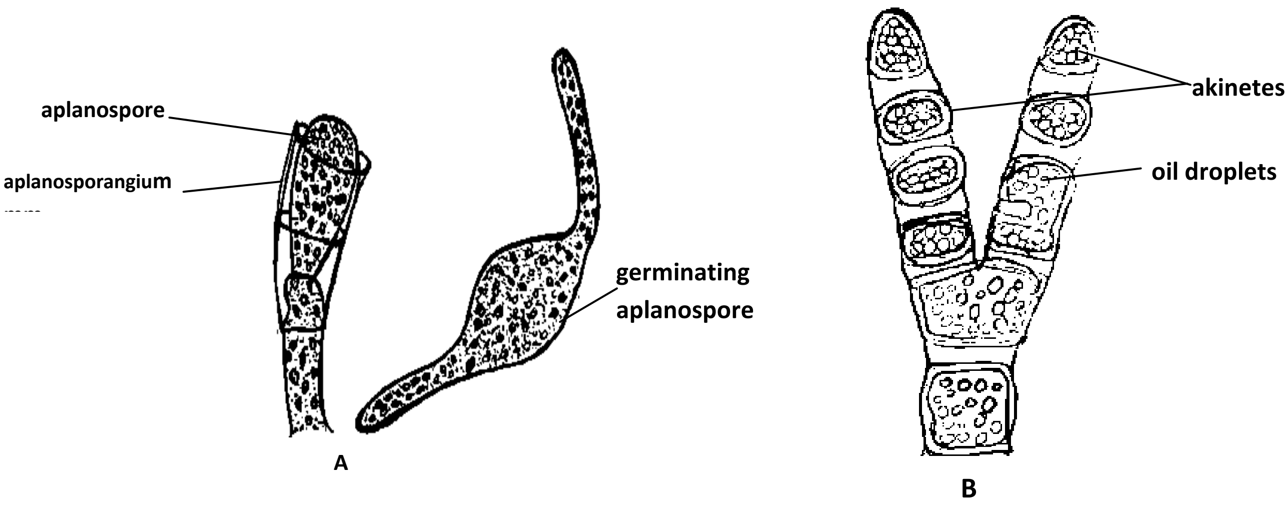


Fig.6.15. Vaucheria, Asexual reproduction: A. aplanospore, B Akinetes

III. Sexual reproduction

Sexual reproduction in *Vaucheria* is advanced and oogamous type. The male and female sex organs are called antheridia and oogonia, respectively. Mostly all the species are homothallic or monoecious, but few are heterothallic or dioecious (e.g. *V. dichotoma, V. litorea).* In homothallic species antheridia and oogonia are borne adjacent to one another on a common lateral branch (Fig. 6.16). Followings are some important developmental stages (Fig. 6.17) of sexual reproduction:-

1. The mature antheridium may be cylindrical, tubular, straight or curved. The antheridium may be sessile (without stalk) arising directly from main branch.
2. The young antheridium is usually green in colour. It contains cytoplasm, nuclei and chloroplasts.
3. The anthrozoids do not have chloroplast and eyespot. The biflagellate antherozoids are liberated through an aperture at the anterior end of the antheridium.
4. The mature oogonim is spherical or sub-spherical with an apical beak. It is uninucleate structure. The nucleus of oogonium with protoplasm develops into a single egg.
5. The oogonium secretes a gelatinous material through a pore near the beak. A large number of liberated antherozoids stick this gelatinous material and only one antherozoid enters into the oogonium.
6. The nucleus of the antherozoid increases in size and fuse with the egg nucleus to make zygote (Fig. 6.17), in the process of fertilization.
7. The zygote secretes a thick layer around itself. Initially the zygote green in colour but turns red due to degeneration of chlorophyll. It is dormant for a few months before germination.
8. After germination the zygote develops new coenocytic thallus (Fig 6.17).

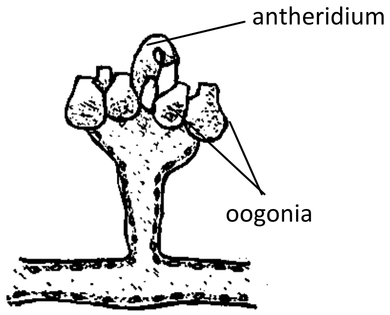
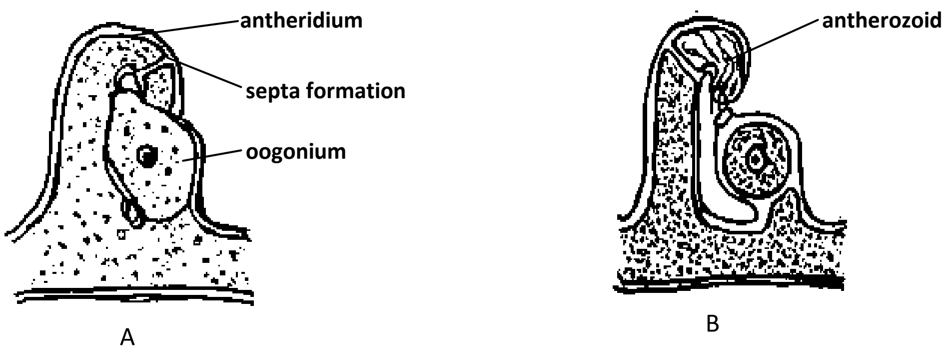


Fig. 6.16 Vaucheria: Reproductive organs. Mature antheridium surrounded by many oogonia



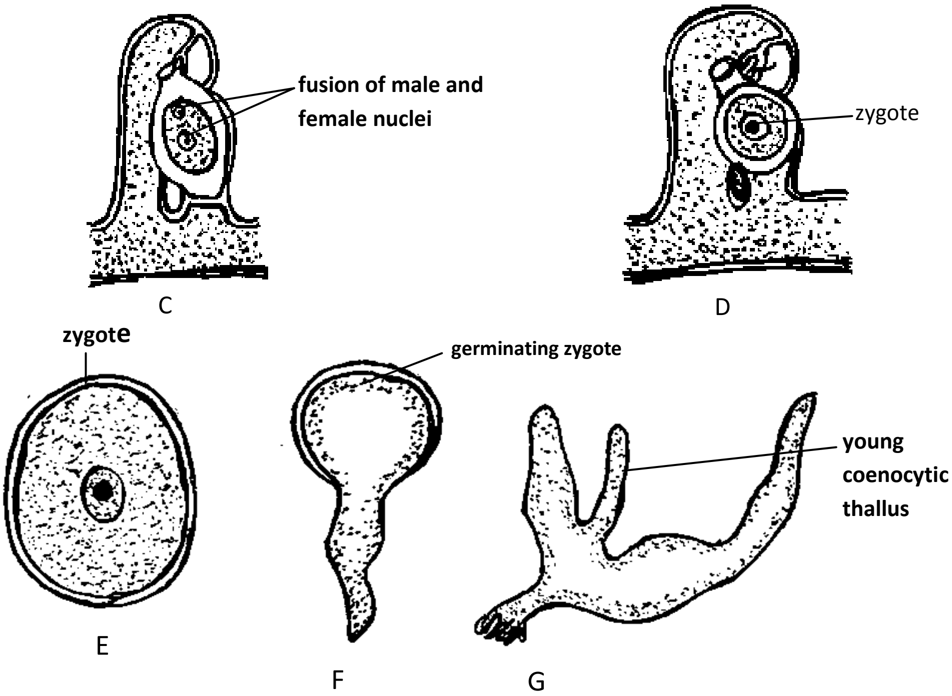


Fig.6.17. Vaucheria, Sexual reproduction and germination of zygote

6.5- SUMMARY

In this unit we have discussed general characteristics features of Chlorophyta and Xanthophyta. The division Chlorophyta is commonly known as green algae. This is a large division of algae and is represented by about 429 genera and 6500 sepcies. The members of Chlorophyta are mainly fresh water (about 90 percent species are fresh water and 10 percent marine). The fresh water species are commonly found in ponds, pools, lakes, ditches, water tanks, rivers and c A ome species of this division are marine and found in the Sea. Some species of this division are fresh water as well as marine. Many green algae grow as epiphytic or epizoic algae. Some grow in symbiotic association with animals like *Zoochlorella* and *Hydra*. Some green algae form symbiotic association with fungi to form lichens. *Cephaleuros* is a parasitic alga Some *Chlamydomonas* species are thermophilic. Reproduction takes place by vegetative, asexual and sexual methods.

The members of division Xanthophyta are yellow green in colour. Mostly these are found in fresh water. The thallus organization exhibits morphological diversity. Mostly the members of this division are motile and coccoid forms, filamentous and Siphoneous forms. The order Heterosiphonales also called Vaucheriales which includes the coenocytic siphoneous form. *Vaucheria* is an important genus of this division.

6.6- GLOSSARY

Blepharoplast	-	Granule lying at base of flagellum; gives rise to one flagellum
Coccoid	-	Non-motile unicells
Coenobium	-	Colony consisting of definite number of cells arranged in specific manner.
Coenocytic	-	Multinucleate aseptate structure.
Colonial	-	Habit showing number of cells held together within envelope.
Colony	-	Loose organization of similar cells and parent plant each cell is potentially capable of life activities independent of others in the colony.
Contractile vacuoles.	-	Organelles of osmoregulation; also thought to play role in excretion of waste material.
Eyespot	-	Red-coloured spot (stigma) generally believed to have visual function
Flagella	-	Fine, thread-like structures by activity of which algal cells move.
Gas vacuoles	-	Gas-filed cavities in cells of certain planktonic blue-green algae which disappear when subjected to pressure. Also known as pseudovacuoles
Holdfast	-	Single cell or group of cells that act as an organ of attachment.
Motile	-	Capable of movement by means of flagella or some other devices
Palmella stage	-	Temporarily non-motile sedentary stage in life history of certain motile algae.
Plakea Stage	-	Curved plate-like, eight-celled stage in development of coenobium.
Palmelloid	-	Palmella-like habit
Siphoneous	-	Tubular thallus in alga lacking septa or cross walls during vegetative phase of growth
Substratum	-	Surfaces or object upon which organism is growing

6.7- SELF ASSESSMENT QUESTIONS

6.7.1-Long answer type questions:-

Q 1. Describe the habitat and thallus organization of *Chlamydomonas* in detail.

Q 2. Write an account of reproduction in *Chlamydomonas.*

Q 3. Describe the habitat and mode of reproduction in *Volvox.*

Q 4. Give an account of habitat, thallus organization and sexual reproduction in *Oedogonium.*

Q 5. Describe the habitat and thallus organization of *Vaucheria.*

6.7.2-Short answer type of questions:-

Q 1. Write a short note on characteristics features of division Chlorophyta.

Q 2. Write a short note on eye spot of *Chlamydomonas*

Q 3. Write a short note on palmella stage of *Chlamydomonas.*

Q 4. Write comments on *Volvox* colony.

Q 5. Write a short note on plakea stage of *Volvox.*

Q 6. Write a short note on thallus structure of *Oedogonium.*

Q 7. Write a short note on vegetative reproduction found in *Oedogonium.*

Q 8. Enumerate the characteristics features of division Xanthophyta.

Q 9. What is synzoospore.

Q 10. Describe Aplanospores of *Vaucheria*& their function.

.

6.7.3-Fill in the blanks

Q 1. The members of division Chlorophyta are commonly known…………...algae.

Q 2. In *Chlamydomonas* the reserve food is in the form of ………………..

Q 3. The flagella are present at the …………………end of the *Chlamydomonas* cell.

Q 4. Zoospores developed during ………………..conditions in *Chlamydomonas.*

Q 5. In isogamous reproduction the fusion of gametes are …………….in size, shape and structure

Q 6. *Volvox* is free floating fresh water green …………………. alga.

Q 7. In *Volvox* reproductive cells mostly developed in the …………… part of colony.

Q 8. The genus *Oedogonium* exhibits sexual …………………… as both gametes are differ morphologically and physiologically.

Q 9. In *Vaucheria* the thallus is attached to substratum by means of ………………..

Q 10. Akinetes are thick walled multinucleate segments also called ………………….

Q 11. Sexual reproduction in *Vaucheria* is an …………………… type

Q12. Aplanospores are generally formed by …………………….species

6.7.4-True and false

Q 1. The members of Chlorophyta are mainly fresh water algae. (T/F)

Q 2. The members of division Xanthophyta are commonly called yellow green algae (T/F)

Q 3. *Cephaleuros* causes red rust of tea. (T/F)

Q 4. The reserve food is in form of manitol in the division of Chlorophyta. (T/F)

Q 5. This palmella stage is a motile and temporary phase. (T/F)

Q 6. In *Volvox* the reproductive cells are called gonidia or parthenogonidia. (T/F)

Q 7. Sexual reproduction in *Vaucheria* is advanced and oogamous type. (T/F)

Q 8. In *Vaucheria* the aplanospores are motile in nature. (T/F)

ANSWERS:

6.7.3-Fill in the blanks

1. Green algae	4. Favorable	7. Posterior	10. cysts or hypnospores
2. Starch	5.Equal	8. Dimorphism	11. Oogamous
3. Anterior	6. Colonial	9. branched rhizoids	12. terrestrial

6.7.4-True and false

1. T	3. T	5. F	7. T
2. T	4 .F	6. T	8. F

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6.10- TERMINAL QUESTIONS

1. Give an account of habitat thallus organization and sexual reproduction of green alga that you have studied.
2. Discuss the reproduction of *Volvox.*
3. Compare the mode of sexual reproduction in macrandrous and noannandrous species of *Oedogonium.*
4. Describe the thallus organization and mode of reproduction of *Vaucheria.*

UNIT- 7- OCCURRENCE, STRUCTURE OF THALLUS AND MODE OF REPRODUCTION IN PHAEOPHYTA

7.1 OBJECTIVES

After reading this unit you will be able to:-

- Know the general characteristics features of division Phaeophyta.
- Understand the habitat, thallus organization and mode of reproduction of *Ectocarpus*
- Understand the habitat, thallus organization and mode of reproduction of *Sargassum*

7.2- INTRODUCTION

The members belonging to Phaeophyta are commonly called "brown algae". There are about 250 genera and 1500 species included in this division. Most of the members of this division are marine in habitat. Mostly brown algae are lithophytes growing in rocky sea coastal region of oceans. They are prominently found in colder regions of Arctic and Antarctic oceans. In India brown algae are commonly found on western and southern coasts. Members of Ectocarpales, Dictyotales and species of *Sargassum* grow in warm waters. In the tropics they are most abundant in the Sargasso Sea of the Atlantic. There are few fresh water species also. Smith (1935) divided this division into three divisions i.e. Isogeneratae, Heterogeneratae and Cyclosporeae. Members of isogenerate are characterized by alternation of two isomorphic generations. The members of heterogeneratae show alternation of heteromorphic generations. There is no alternation of free-living multicelluar generations in the cyclosporeae.

7.3- PHAEOPHYTA

The important characteristic features of this division are as follows-

1. Thallus organization ranges from simple to complex parenchymatous structure. They include Heterotrichous forms (e.g., *Ectocarpus*), Uniaxial pseudoparenchymatous forms, Mutiaxial forms and Parenchymatous forms.
2. The thallus is differentiated into holdfast, stipe and blade.
3. These algae are attached to rock with the help of discoid or branched holdfast.
4. Cell structure is eukaryotic type.
5. The cell wall is made of two or more layers. The inner layer is made up of cellulose and the outer mucilaginous layer is of pectin containing alginic and fucinic acid.
6. The cell contains a single large nucleus.
7. The chromatophores are usually pariental and the number varies from one to many.
8. The characteristic brown colour is due to the dominance of carotenoid pigment-fucoxanthin. The other pigments are chlorophyll a, chlorophyll c, and xanthophylls.
9. Single, stalked or projected pyrenoid like body is present in cells.
10. The cytoplasm contains a number of small colourless vacuoles known as fucosan vesicles which appear in cells as metabolic by-product.

11. The characteristic food reserve is Laminarin, which is long term storage product. However the accumulation product of photosynthesis is mannitol, a sugar alcohol is also a reserve food material.
12. The flagellated structures have two unequal flagella. At the anterior end pantonematic flagellum is present whereas at the posterior end acronematic flagellum is present.
13. In the male gamete an eye spot is present which is attached to chromatophores.
14. Reproduction takes place by vegetative, asexual and sexual methods.
15. Vegetative reproduction is mostly by fragmentation or by propagules. The fragments or propagules grow into new thalli when detached from parent thallus.
16. Asexual reproduction takes place by zoospores except the members of Dictyotales and Fucales.
17. Sexual reproduction is be isogamous, anisogamous and oogamous types.
18. In most brown algae fertilization is external. The gametes fuse outside the gametangium in water.
19. There is no meiosis or reduction division during the germination of zygote.
20. After germination of zygote, a diploid thallus is formed.
21. The life cycle of brown algae may be isomorphic, heteromorphic, or diplontic.

7.3.1- *Ectocarpus*

7.3.1.1- Occurrence

Ectocarpus is worldwide in distribution particularly in colder regions of sea water of temperate and polar regions. In India alga is commonly found on the western coastal regions, growing epiphytically on sea plants or attached to rock. There are about 13 species reported from India. *Ectocarpus indicus, E. coniferus, E. geminifructus* and *E. dermonematus* are some common Indian species.

7.3.1.2- Structure of thallus

The thallus is typically heterotrichous and differentiated into (a) creeping or prostrate rhizoidal system and (b) an erect branched system. In some species one of the two systems may be reduced. In epiphytic forms the prostrate system is well developed than the erect system. In many species the thallus is sparingly to profusely branched, the cells are uniseriate and joined end to end in a row (Fig 7.1). In some species, the older portion of the main branch is corticated by a layer of descending rhizoidal branches. In many species the terminal portion of a branch may end in a colourless hair with a basal meristem. The erect part of thallus is usually irregularly branched. The filaments are made up of uninucleate rectangular cells. Cell wall is made up of two layers, an outer gelatinous layer and an inner cellulose layer. The outer gelatinous layer is made up of algin and fucoiden. Chlorophyll-*a*, chlorophyll-*c*, carotene (fucoxanthin) and xanthophylls are major algal pigments of this genus. The chromatophores contain large amount of xanthophylls in addition to chlorophyll. Fucosan vesicles or granules are present in large number along with pyrenoid like bodies in the cell. The reserve food material is in the form of laminarin and mannitol. Thallus grows by the apical growth in prostrate part and intercalary growth in erect part.

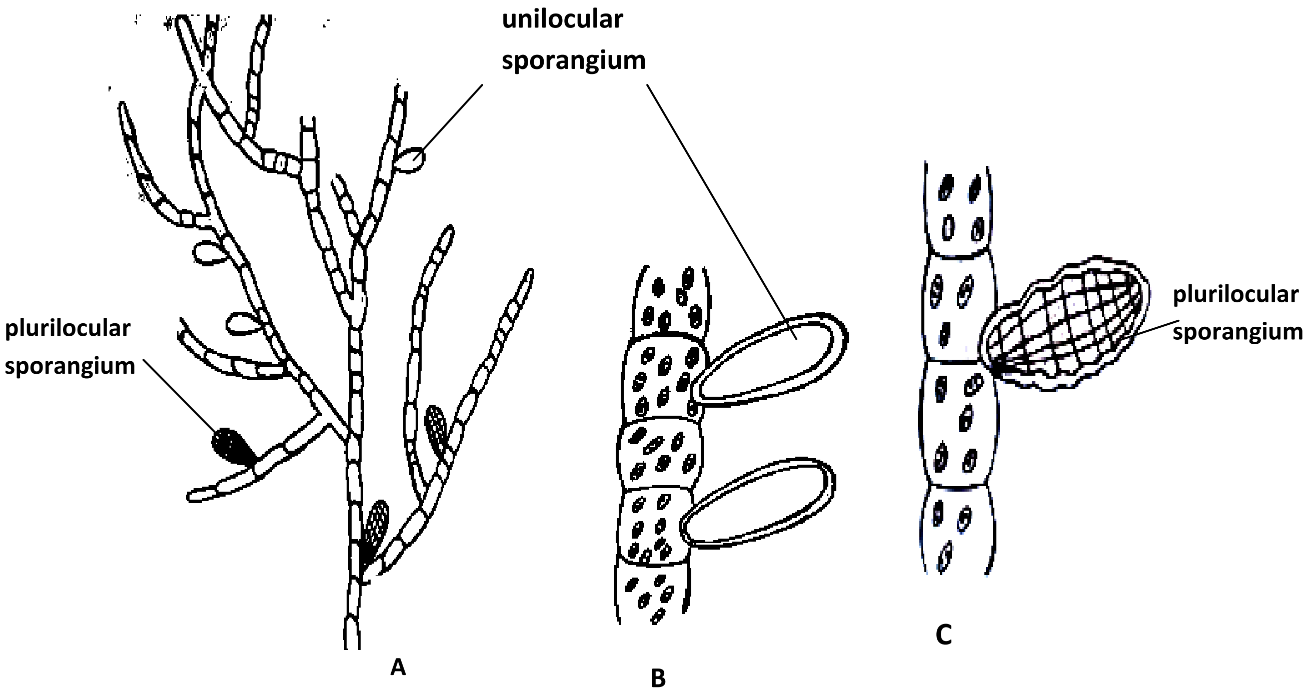

Fig. 7.1, Ectocarpus; A- Thallus organization, B- Unilocular sporangium and C- Plurilocular sporangium

7.3.1.3- Mode of reproduction

Reproduction is of following type-

1. Asexual reproduction
2. Sexual reproduction

1- Asexual Reproduction

The asexual reproduction takes place with the help of zoospores. These zoospores are biflagellate in nature and develop in sporangia. The sporophytic (diploid) plant produces two types of sporangia: (i) unilocular zoosporangia, and (ii) plurilocular or neutral zoosporangia. Both types of zoosporangia borne on the same plant or on different plants. The unilocular sporangia form haploid zoospores and the plurilocular sporangia develop diploid zoospores. Unilocular sporangia develop singly at the tips of small branchlets (Fig. 7.1). The terminal cell of the branchlet enlarges in size and functions as sporangial initial. Subsequently, it undergoes a series of divisions, first being meiotic followed by mitotic divisions, producing several hundred small cubical cells. Each cubical cell is haploid and forms a biflagellate zoospore. These zoospores liberated through a terminal or lateral pore (Fig. 7.2). After liberation these zoospores are settled on solid substratum with their anterior end and grow into a haploid or gametophytic thallus.

Plurilocular sporangium has many locules and protoplast of each locule develop into a diploid zoospore, diploid zoospore on liberation settles down and develop into a diploid or sporophytic thallus which again bears uni & plurilocular sporangia.

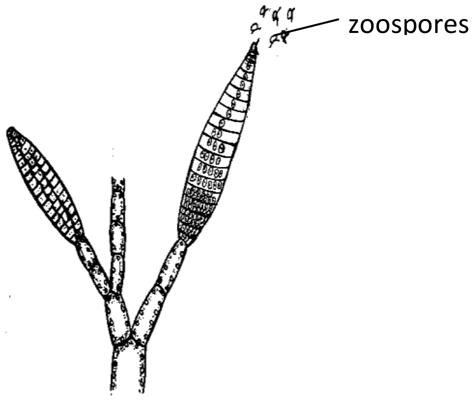

Fig. 7.2 Ectocarpus: Liberation of zoospores

2- Sexual Reproduction

Sexual reproduction may be isogamous, anisogamous or oogamous, but most of the species of *Ectocarpus* are anisogamous. The ansiogamy may be physiological or morphological. The gametes develop in gametophytic thallus which develop plurilocular gametangia that are similar to plurilocular sporangia. The zoogametes produced singly from each locule and equal in size and are morphologically identical to the zoospores. In which shows morphological ansiogamy, two types of gametangia are produced. The megagametangium with larger locules and larger gametes, and the microgametangium with smaller locules and smaller gametes. Mostly male gametes are active and motile and female gametes are passive and sluggish. A large number of male gametes cluster around female gamete to make clump formation (Fig. 7.3). One male gamete fuses with the female and form zygospore or zygote. The zygote germinates directly into new diploid thallus. During germination of zygote no meiosis occurs. The new developed diploid thallus bears both unilocular and plurilocular sporangia.

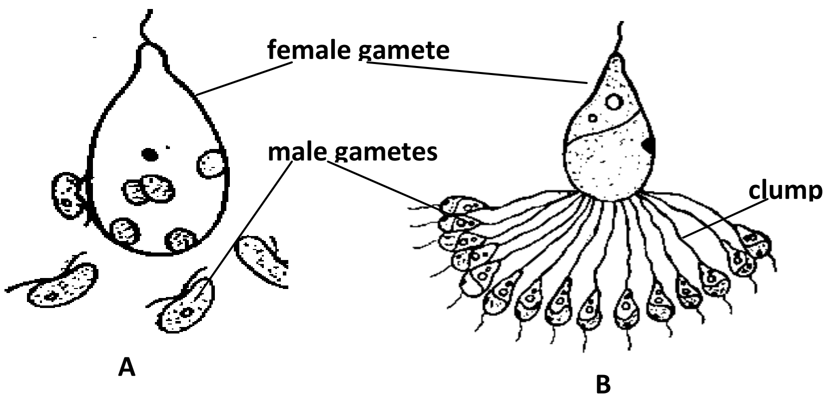

Fig. 7.3 Ectocarpus; Sexual reproduction

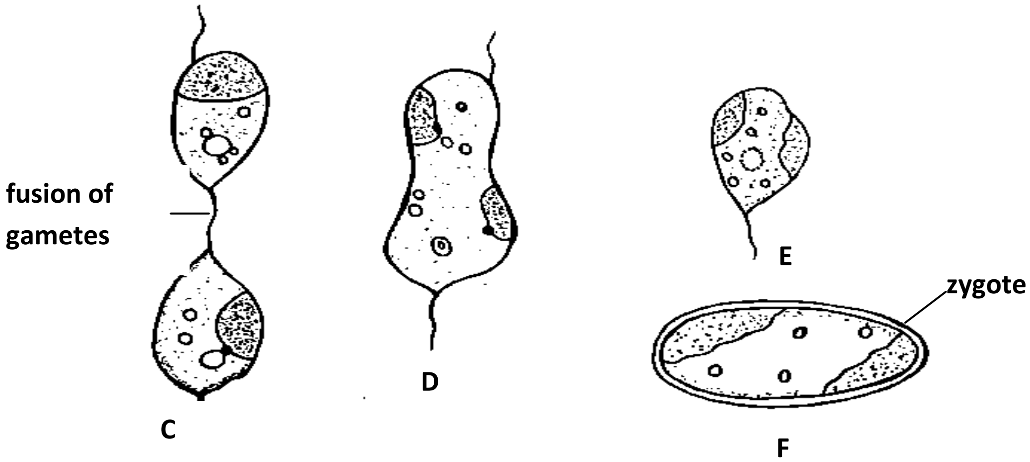

Fig. 7.3 Ectocarpus; Sexual reproduction

7.3.2- *Sargassum*

7.3.2.1- Occurrence

This genus is represented by about 150 species, widely distributed in warmer regions of tropical and sub-tropical seas of the southern hemisphere. The Atlantic Ocean of the African continent called Sargasso Sea because of huge and abundant presence of this species. In India the genus is represented by 16 species which occur along the western and southern coastal areas. Some common Indian species of this genus are: *S. tenerrium, S. carpophyllum, S. duplicatum, S. plagiophyllum* and *S. wightii*.

7.3.2.2- Structure of thallus

The thalli are highly advanced parenchymatous structure and show bilateral or radial organization. The thallus is sporophytic (diploid) and differentiated into holdfast and the main axis. The holdfast helps in attachment of thallus to substratum. In some species the holdfast is stolon like and in some species holdfast is absent in case of free floating species.
The main axis, also called stipe or stem is erect, elongated or flat upto 30 cm in length. However, the length of thallus varies from species to species. The main axis bears large number of primary laterals of unlimited growth. The main axis as well as the primary laterals bear flat leaf-like branches, known as secondary laterals or leaves. These leaf like structures are flat and simple with blade, veins and petiole like structure. The mid-rib is present in the leaf except in *S. enerve*. Air bladders are also present which help in floating of plants by increasing buoyancy. In some species air bladders terminate into leaf like structure. Receptacles arise from branches which bear reproductive organ in special flask-shaped structure, known as conceptacles (Fig. 7.4 A).

Anatomically the main axis is differentiated into three distinct parts as meristoderm, cortex and medulla (Fig. 7.4, B). The outermost layer functions as epidermis and meristematic in nature. The cortex part is made up of narrow, elongated parenchymatous tissue. The cortex region contains reserve food material and acts as storage region of main axis. The central part medulla functions in induction to transport water and metabolites to different parts of the thallus. Internally the leaf is also differentiated into three distinct regions as meristoderm, cortex and medulla (Fig 7.4, C). The outermost is epidermis followed by cortex present between meristoderm and medulla. The function of medulla is conduction. Many unbranched filaments arise from the wall of conceptacles, called paraphyses. The thallus grows by a quadrangular apical cell.

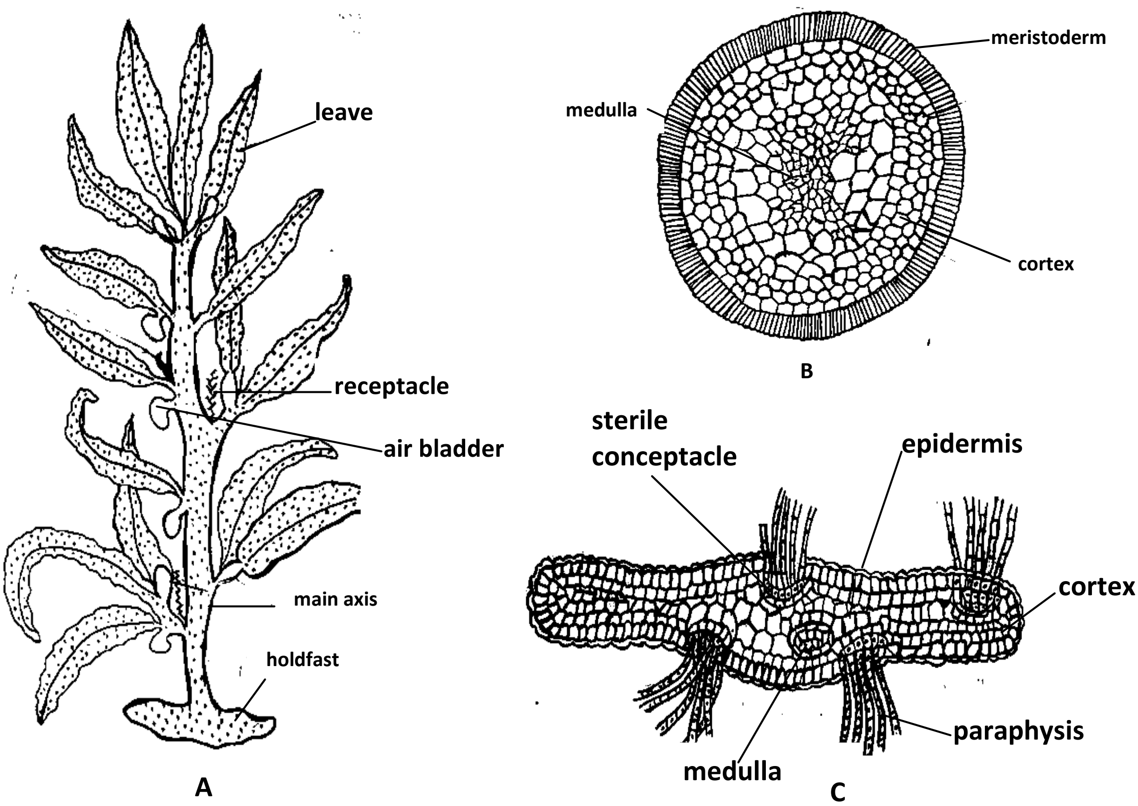

Fig. 7.4 *Sargassum*: A- Thallus, B- Transverse section (T.S.) of main axis, C- Vertical section (V.S.) of leaf.

7.3.2.3- Mode of reproduction

The reproduction takes place vegetative and sexual reproduction. Asexual reproduction is completely absent.

Vegetative reproduction

Sargassum multiplies by fragmentation of thallus. Due to injury, death and decay occur in older part of the, thallus which breaks into small segments. These segments grow into new thallus.

Sexual reproduction

Sexual reproduction is oogamous type. The reproductive organs develop in special flask-shaped cavities, known as conceptacles. The male sex organ is called antheridium and the female oogonium. The male and female sex organs develop in separate conceptacles. The important developmental stages of *Sargassum* sexual reproduction are as followings-

1. The conceptacle develops from a single cell called initial cell (Fig. 7.5). The initial cell divides by transverse division into two cells. The lower cell is called basal cell and the upper cell is called tongue cell. The tongue cell elongates and divides transversely to form a small filament which soon disappears.
2. The fertile layer of the conceptacle develops from the basal cell. The sex organs develop from the cells of this layer.
3. Antheridium develops from the fertile layer of the conceptacle. The antheridial initial cell divides into two, lower stalk cell and an upper antheridial cell (Fig. 7.6). Upper cell develops into antheridium.
4. The mature antheridium is an oval structure surrounded by a two layered wall. The outer wall is called the exochite and inner wall layer, the endochite. (Fig. 7.6,D, E). The antheridium attached to the base of the conceptacle with the help of a stalk cell. Antheridium produces 64 pear shaped biflagellate antherozoids (Fig. 7.6, E)
5. After maturation these antheridia are detached from the stalk and come out of the conceptacle through the ostiole (Fig. 7.6, F).
6. Any cell of the fertile layer of the female conceptacle can function as oogonial initial (Fig 7.7, A). The oogonial initial divides by a transverse division to make very small lower stalk cell and the large, upper oogonial cell (Fig. 7.7 C). Oogonia are almost sessile.
7. The oogonial cell gradually become spherical having dense cytoplasm. The diploid nucleus of the oogonial cell undergoes a meiotic division (reduction division) followed by two simple divisions and eight haploid nuclei are formed. Out of these, only one nucleus function as the egg nucleus and remaining degenerate (Fig. 7.7 E-H).
8. The mature oogonia are discharged from the conceptacle but remain attached to the conceptacle wall by means of a long gelatinous stalk (Fig 7.7 I and J).
9. A large number of antherozoids surround the oogonium and attach to oogonial wall with the help of anterior flagellum. Only one antherozoid penetrates the oogonial wall (Fig. 7.8, A).
10. The male and female nuclei fuse together and form a diploid zygote (Fig. 7.8, B).
11. After fertilization zygote germinates immediately. The zygote first divides by transverse division to make a lower and an upper cell. The lower cell develops rhizoids, whereas the upper cell develops a new diploid thallus after anticlinal and periclinal divisions (Fig. 7.8, C-G).
12. The life cycle of S*argassum* is diplontic type and there is no alternation of morphological generations.

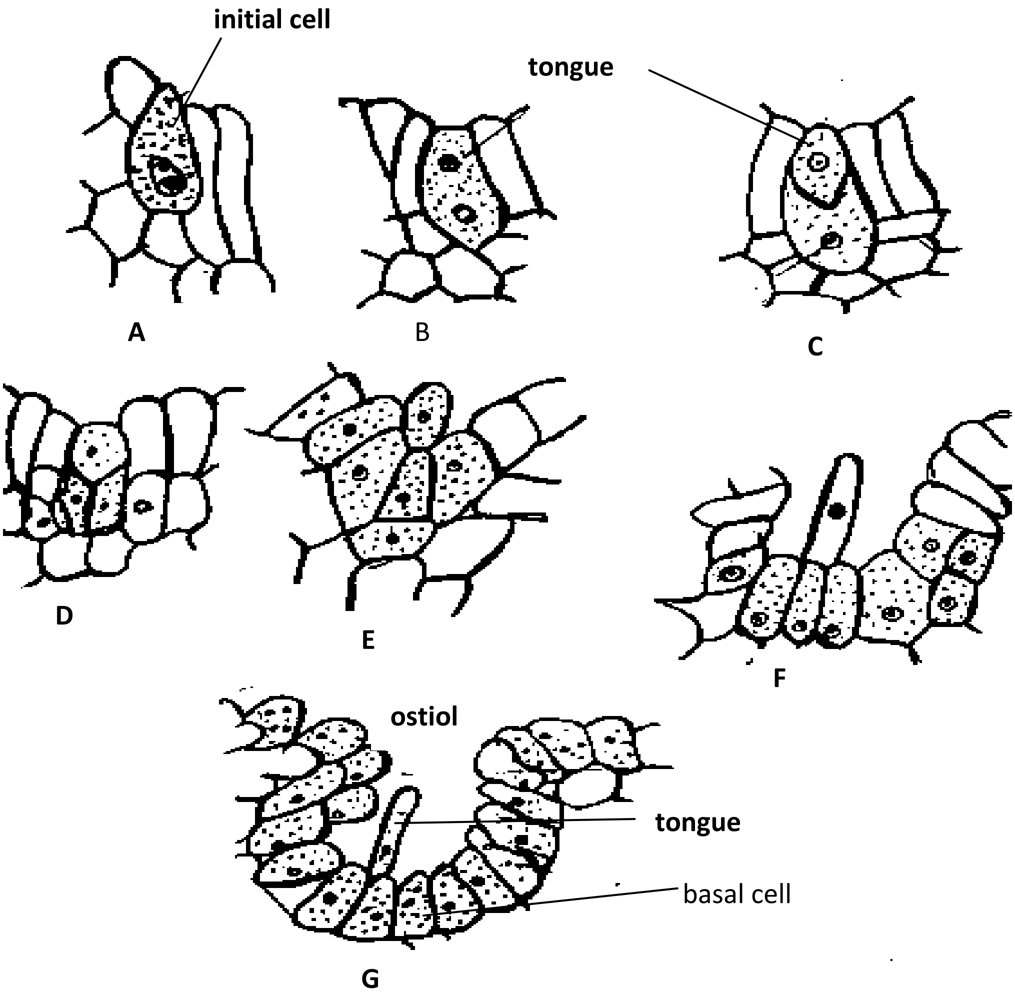

Fig. 7.5 *Sargassum:* Development of conceptacle

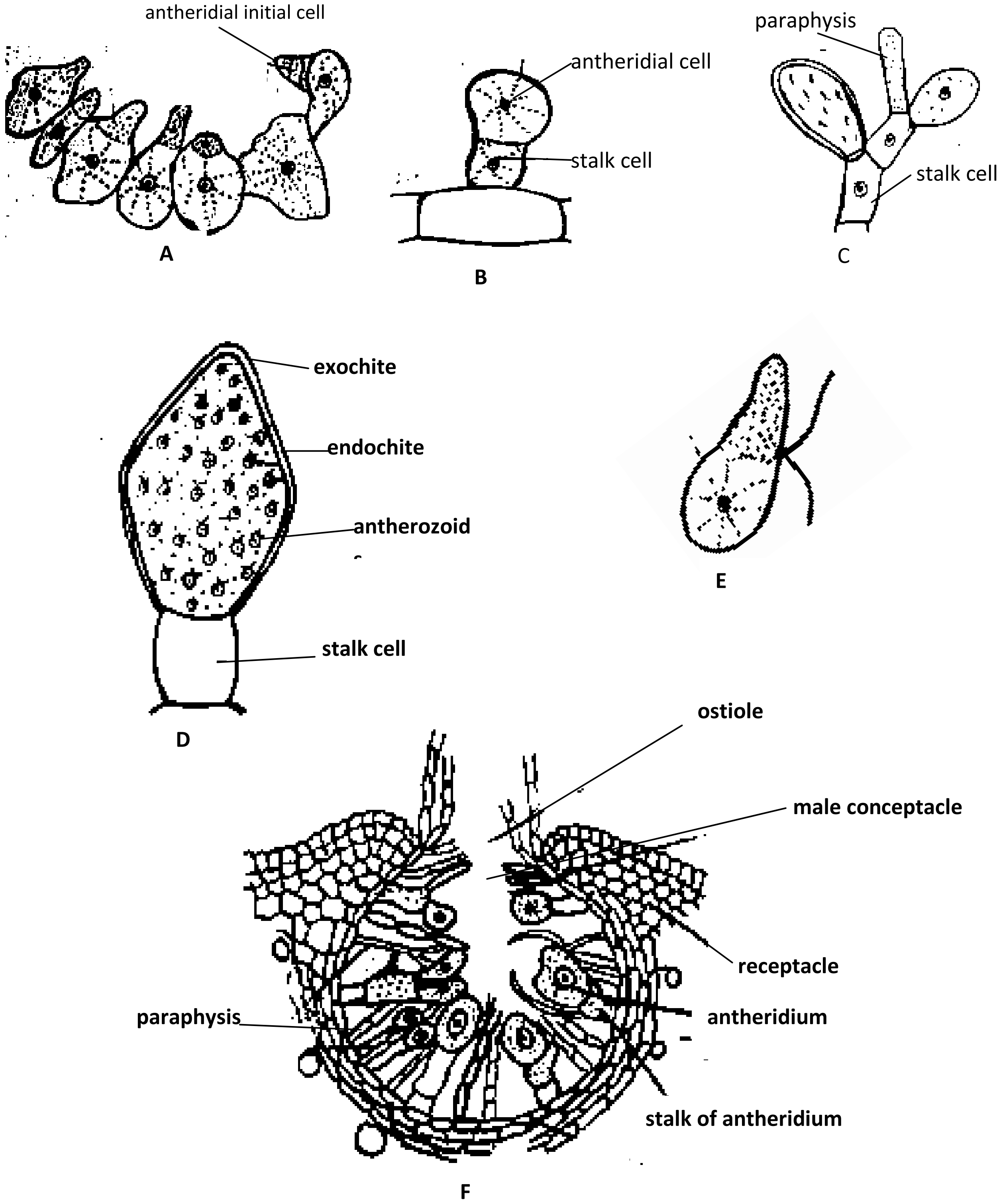

Fig. 7.6, *Sargassum:* Development of antheridium; A-C. Initial stages of antheridial development, D- Mature antheridium, E- Antherozoid (a male gamete), F- Vertical section of a male conceptacle

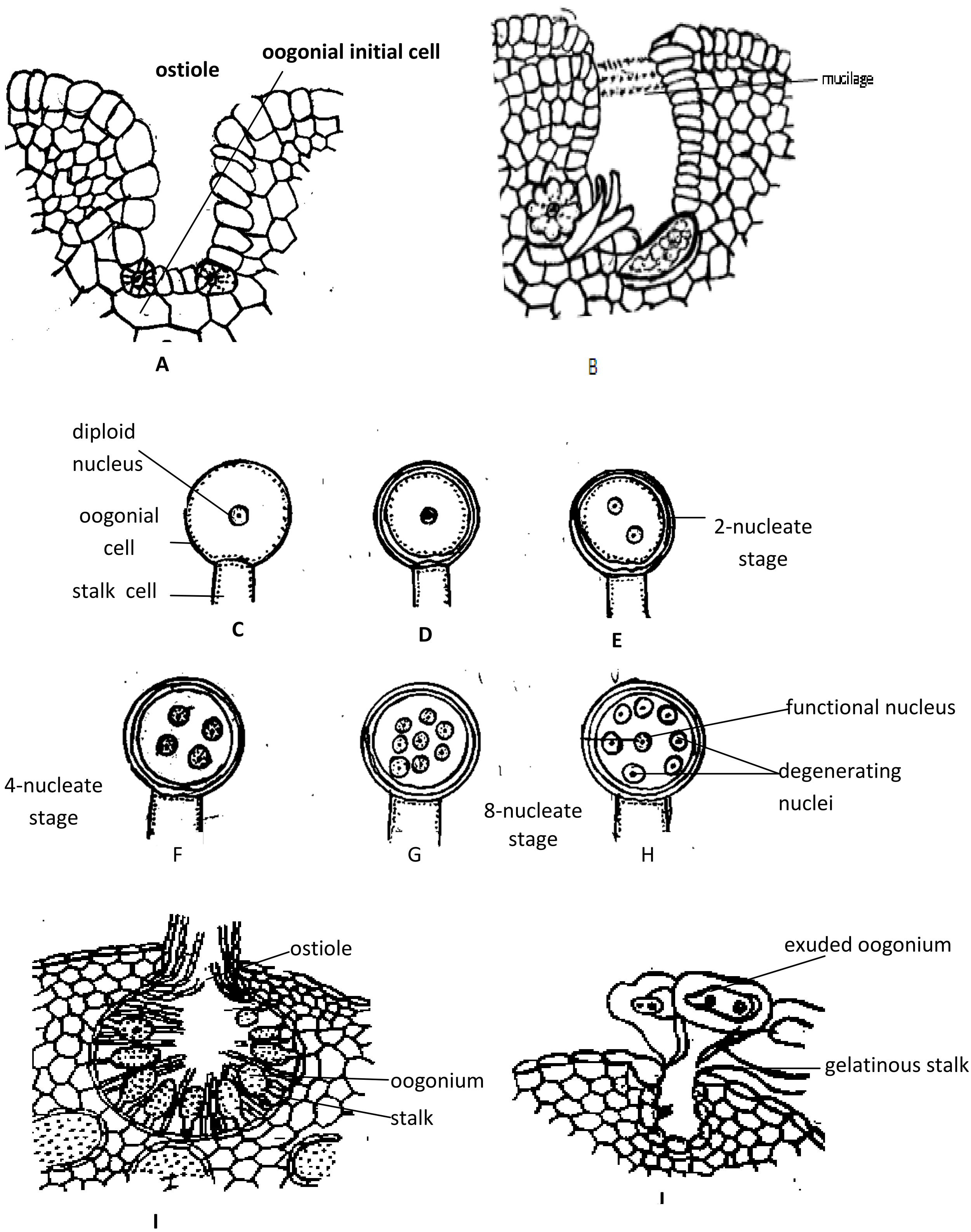

Fig. 7.7 ***Sargassum*****; different developmental stages of an oogonium (female sex organ)**

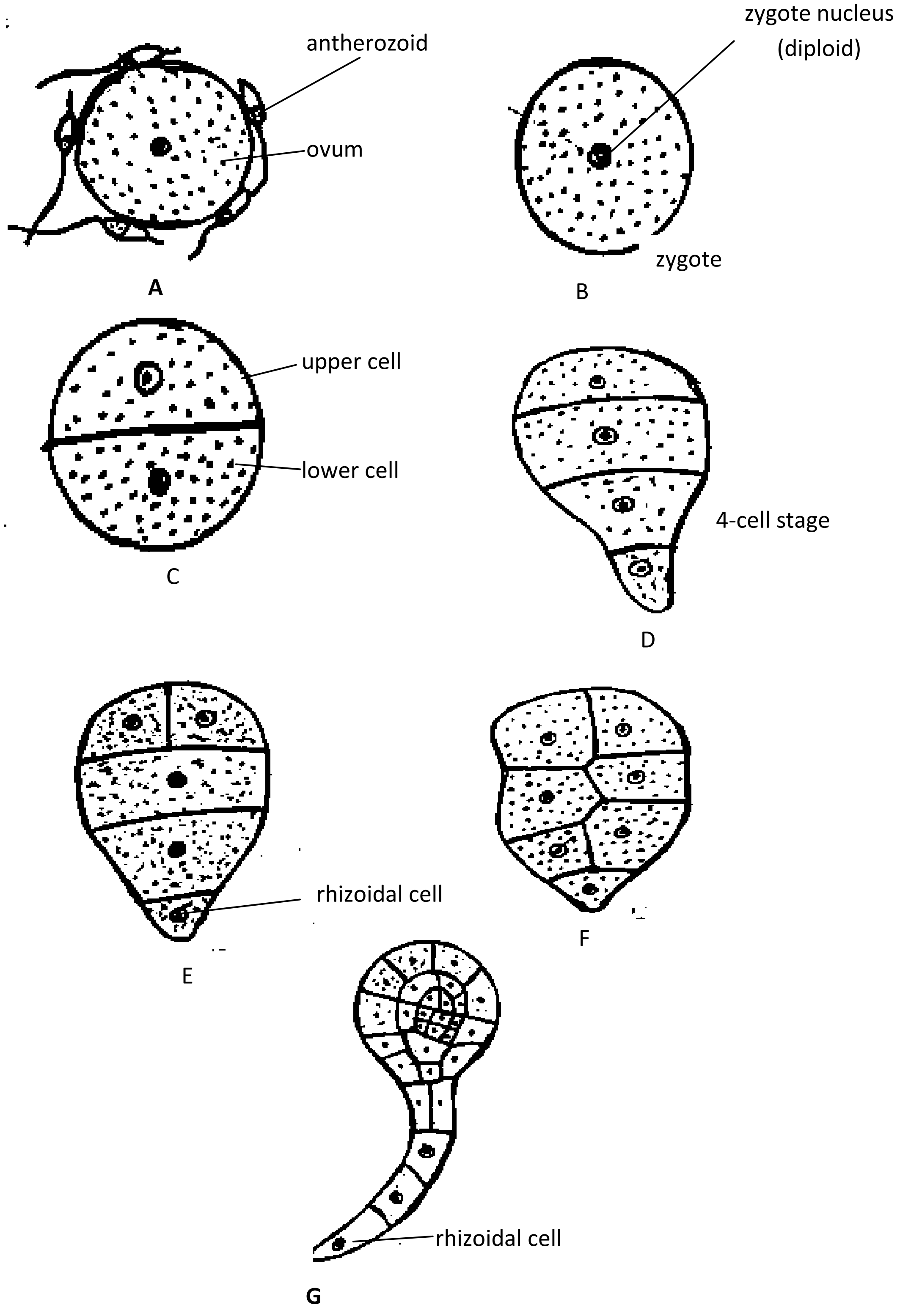

Fig.7.8. ***Sargassum*****; fertilization and germination of zygote**

7.4- SUMMARY

In this unit we have discussed about brown algae. Mostly brown algae are lithophytes growing in rocky sea coastal region of oceans. They are prominently found in colder regions of Arctic and Antarctic oceans. In India brown algae are commonly found on western and southern coasts. Species of *Sargassum* grow in warm waters. In the tropics they are most abundant in the Sargasso Sea of the Atlantic. Mostly all the members of this division are marine in habitat. Few fresh water species of this division are also reported. The thallus organization of these algae is highly advanced. These look like an angiospemic plant through truly not angiosperms as they lack complex tissue organization. The plant body is made up of parenchymatous type of tissue and differentiated into main axis, leaves and rhizoids. Thallus organization includes Heterotrichous forms, Uniaxial pseudoparenchymatous structure, Mutiaxial forms and Parenchymatous forms. The brown colour of these algae is due to the accessory carotenoid pigment fucoxanthin. Other pigments are chlorophyll a, chlorophyll c, and xanthophylls.

Ectocarpus, an important genus of the division is found in colder regions of sea water. In India the alga commonly found on the western coastal region. There are about 13 species reported from India. The thallus is typically heterotrichous and differentiated into (a) creeping or prostrates rhizoidal system and (b) an erect branched system. Reproduction takes place by asexual and sexual means. The asexual reproduction takes place with the help of zoospores which develops in sporangia. The sporophytic (diploid) plant produces two types of sporangia: (i) unilocular zoosporangia, and (ii) plurilocular or neutral zoosporangia. Both types of zoosporangia borne either on the same plant or on different plants. Sexual reproduction may be isogamous, anisogamous or oogamous, but in most of the species of *Ectocarpus* it is anisogamous type. After fertilization, the zygote germinates directly into new diploid thallus without undergoing any reduction division (meiosis).

Sargassum, the another member is widely distributed in warmer regions of tropical and sub-tropical seas of the southern hemisphere. In India there about 16 species of this genus which occurs along the western and southern coastal areas. The thallus of *Sargassum* is highly advanced and made up of parenchymatous type of tissue. The thallus is diploid, and differentiated into main axis and holdfast. The internal structure of the main axis and leaf is advanced and differentiated into meristoderm, cortex and medulla. So such advanced tissue differentiation is a unique feature of this alga. The reproduction takes place vegetative and sexual means. Asexual reproduction is completely absent in *Sargassum*. Vegetative reproduction takes place by fragmentation. Sexual reproduction is an oogamous type. The sex organs developed in special flask-shaped cavities, known as conceptacles. The male and female sex organs develop in separate conceptacles. After fertilization zygote germinates immediately, undergoing mitotic (simple) division producing diploid plant. There is no morphological alternation of generations.

7.5- GLOSSARY

Algin	-	One or more polysaccharides in intercellular spaces of tissues of larger Phaeophyceae.
Alginate	-	General term for salts of alginic acid, especially Na salts.
Antheridium	-	Male gametangium
Anisogamy	-	Fusion between two morphologically dissimilar gametes.
Antherozoids	-	Sperms; male gametes.
Anticlinal.	-	Cell division which occurs in direction perpendicular to circumference of surface.
Carotenoids	-	General name for pigments of carotene and xanthophyll type.
Chloroplast	-	Double membrane-bounded semiautonomous organelle of cytoplasm of eucaryotes and characterized by internal chlorophyll containing lamellar structure (thylakoids) embedded in protein-rich stroma.
Heteromorphic	-	Morphologically dissimilar thalli
Heterotrichous	-	Thallus differentiated into prostrate and erect system of branching filaments
Holdfast	-	Single or group of cells that acts as organ of attachment
Filamentous	-	Thread-like photosynthetic plants.
Intercalary	-	A cell between two cells a filament.
Isogamy	-	Fusion between morphologically similar gametes.
Pantonematic	-	Flagellum in which surface is covered with hair-like appendages.
Oogamy	-	Fusion of motile sperm with large passive non-motile egg
Parenchymatous	-	Tissue composed of thin-walled, living cells
Substratum	-	Surfaces or object upon or within which organism grows
Thallus	-	The plant body that is not differentiated into root, stem, and leaf.
Uniseriate	-	Arranged in single row or series

7.6- SELF ASSESSMENT QUESTIONS

7.6.1-Long answer type questions:-

1. Write a general account of division Pheaophyata with the help of suitable examples.
2. Describe the occurrence and thallus organization of *Ectocarpus.*
3. Describe the mode of reproduction in *Ectocarpus.*
4. Describe the occurrence and thallus organization of *Sargassum* in detail.
5. Describe the mode of reproduction in *Sargassum.*

7.6.2-Short answer type of questions:-

1. Write a short note on thallus structure of *Ectocarpus*.
2. Write a short note on zoospore development in *Ectocarpus.*
3. Draw labeled diagrams of internal structure of *Sargassum* main axis and leaf.
4. Write comments on development of conceptacle in *Sargassum.*
5. Write a short note on clump formation.
6. Describe development of antheridium of *Sargassum.*
7. Discuss germination of zygote of *Sargassum.*

7.6.3-Fill in the blanks:

1. The members of division Phaeophyta are commonly known as………..…. algae.
2. Mostly all the members of division Phaeophyta are …………… in habitat.
3. Brown algae are attached to rock with the help of discoid or branched ………
4. The characteristic brown colour of brown algae is due to the accessory carotenoid pigment ………
5. In *Ectocarpus* the asexual reproduction takes place with the help of ………
6. The internal structure of *Sargassum* leaf differentiated into three distinct regions as meristoderm, cortex and ………………
7. The vegetative reproduction of *Sargassum* takes place by ………of thallus
8. In *Ectocarpus,* antheridia are detached from the stalk and come out of the conceptacle through the ………………
9. Members of isogenerate are characterized by alternation of two …………generations.
10. Life cycle of *Sargassum* is ……………. type.

7.6.4-True and False (T/F):

1. The members of division Pheophyta are commonly known as Red algae.
2. The air bladders are present in the thallus of *Sargassum*.
3. *Ectocarpus indicus* ,is an Indian species.
4 In most brown algae fertilization is external, the gametes fuse outside the gametangium in water.
5. In brown algae meiosis division occur during the germination of zygote.
6. In *Sargassum,* air bladder helps in floating of thallus by increasing buoyancy.
7. Asexual reproduction is present in *Sargassum*. (T/F)
8. During fertilization of *Sargassum*, only one antherozoid penetrates the oogonial wall

ANSWERS

7.6.3-Fill in the blanks

1. brown 3. holdfast 5. zoospores 7. fragmentation 9. isomorphic

2. marine 4. fucoxanthin 6. medulla 8. ostiole 10. diplontic

7.6.4-True and false (T/F):

1. F	3. T	5. F	7. F
2. T	4. T	6. T	8. T

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7.9- TERMINAL QUESTIONS

1. Write a general account of important characters of division Pheophyta .
2. Describe the thallus structure and reproduction in *Ectocarpus.*
3. Describe the external and internal thallus organization of *Sargassum* with the help of suitable diagram.
4. Describe the development of male and female sex organs of *Sargassum* with the help of suitable diagram.

UNIT– 8- OCCURRENCE, STRUCTURE OF THALLUS AND MODE OF REPRODUCTION IN RHODOPHYTA

8.1- OBJECTIVES

After reading this unit you will be able to:-

- Know the general characteristic features of division Rhodophyta
- Understand the occurrence, thallus organization and mode of reproduction of *Polysiphonia.*
- Understand the thallus organization and mode of reproduction of *Batracospermum*

8.2- INTRODUCTION

Rhodophyta is a large group of algae represented by about 831 genera and 5,250 species. The members of this division are commonly called red algae. Most of these algae are marine in habitat with uniaxial or multiaxial thalli except few fresh water species. The fresh water species are found either in fast flowing streams (e.g., *Batrachospermum*) or grow in stagnant water (e.g., *Compsopogon*). Generally the larger and fleshy forms of the algae are found in the cool temperate regions while small and filamentous forms occur in the tropical seas. One important feature regarding the members of Rhodophyta is their ability to live at greater depths in the ocean than members of other algal groups. Thallus organization ranges from unicellular to multicelluar complex structure. The best example of unicellular red algae is *Porphyridium*, found in terrestrial habitats. The red algae also exhibit a high degree of epiphytism and parasitism with considerable specificity. Some species are epiphytic growing on other red algae. Generally the cell wall is made up of two layers, the outer layer is pectic and inner cellulosic in nature.

8.3- RHODOPHYTA

The important characteristic features of division Rhodophyta are as follows:-

1. Mostly red algae are beautiful, soft and slimy.
2. Thallus organization ranges from simple unicellular to complex multiaxial forms.
3. The thallus organization is more advanced and complex in the members of sub-class Florideae which is divided into two types i.e. Uniaxial thallus and multiaxial thallus.
4. The uniaxial thallus is characterized by the presence of a single central or axial filament which is usually corticated by many well branched laterals. Example- *Batrachospermum.*
5. The multiaxial thallus is a mass of central or main filaments and each central filament gives out lateral branches. Examples- *Polysiphonia,* and *Helminthocladia*.
6. The cell wall is made up of two layers of which outer layer is pectic and inner layer is cellulosic.
7. The mucilaginous material of the outer pectic layer mainly consists of agars and carrageenans.
8. Cells are generally uninucleate and in some genera they may be multinucleate.

9. The cell is eukaryotic in nature contains organelles like endoplasmic reticulum, mitochondria and dictyosomes.
10. The photosynthesis pigments present in the chromatophore include chlorophyll *a* and *d*, xanthophylls and carotenes (biliproteins) such as *r*-phycoerythrin and *r*-phycocyanin.
11. The pigments *r*-phycoerythrin and *r*-phycocyanin are responsible for red colour of the thallus.
12. *β*-Phycoerythrin is present in the primitive red alga, *Porphyridium.*
13. The reserve food material is stored in the form of floridean starch.
14. There is complete absence of motile stage either in asexual or sexual phase of life cycle.
15. The reproduction takes place mainly by asexual and sexual methods.
16. Asexual reproduction takes place by aplanospores (monospores, neutral spores, carpospores and tetraspores).
17. The sexual reproduction is of oogamous type.
18. The non-motile male gametes are called spermatia which are produced in spermatangia.
19. The female reproductive organ is called procarp which consists of carpogonium and trichogyne.
20. In the sub-class Florideae the fertilization is followed by the production of specialized filaments, called gonimoblasts.
21. Fritsch (1935) classified this division into two major sub-classes, Bangioideae and Florideae.
22. Sub-class Bangioideae includes primitive's forms of Rhodophyta. They lack pit connection and apical growth.
23. Sub-class Florideae have uni-or multiaxial thalli which show apical growth. The reproductive organs are more developed and complex. The zygote on germination forms gonimoblast filaments and the terminal cell of these filaments develops into a carposporangium. Example- *Polysiphonia*.

8.3.1- *Polysiphonia*

8.3.1.1- Occurrence

Polysiphonia is a marine genus comprising about 150-200 species. In India there are 16 species found on the Southern and Western coasts. Most of the species of this genus are lithophytic (growing on rocks). However, some species are epiphytic growing on other algae. The plants grow in dense tufts.

8.3.1.2- Structure of thallus

The thallus of *Polysiphonia* is heterotrichous type. The thallus is multiaxial or polysiphonous. The main axis and its branches have central axial cell (siphon) surrounded by pericentral cells (siphon) of variable number. The cells are connected to each other through cytoplasmic connections and each cell is uninucleate with many disc shaped plastids. The plant body is differentiated into a basal prostrate and an erect aerial system. The prostrate system creeps over the substratum. The prostrate system of filaments is anchored the thallus to the substratum with the help of unicellular elongated rhizoids. However, in some species (e.g. *P. elongate and P. violacea*) multiaxial prostrate system is absent. The erect aerial system arises from the prostrate system. It is made up of multiaxial branched filaments. The thallus is dichotomously or laterally branched with two kinds of branches. The branches of unlimited growth are made up of central and pericentral siphons; and the branches of limited growth, known as trichoblasts. The thallus grows by means of an apical cell which by repeated divisions forms a row of axial cells. A branch of unlimited growth may sometimes arise in the axis of a trichoblast in which case its basal cell serves as the branch initial.

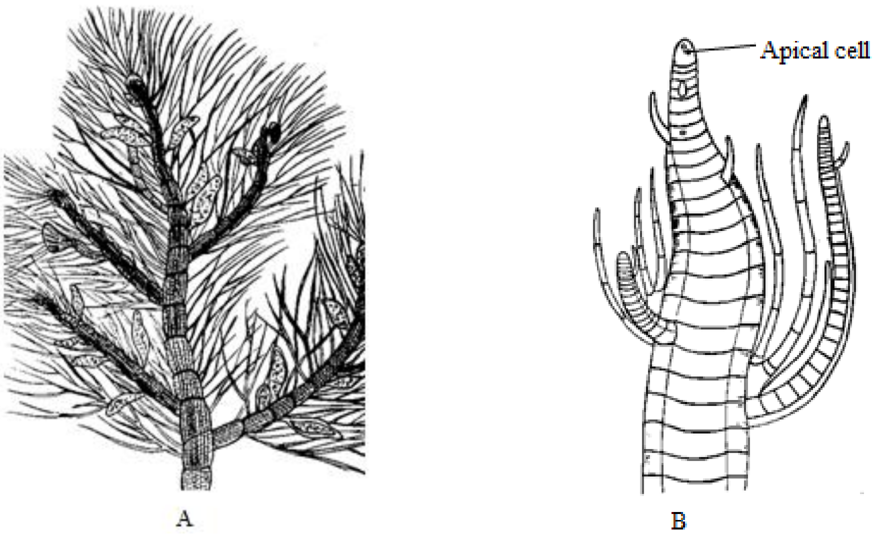

Fig 8.1 *Polysiphonia;* A: Thallus organization, B: A portion of aerial axis

Polysiphonia is mainly heterothallic and following three types of thalli are found:

1. The gametophytic thalli which are haploid, free living and dioecious. The male and female sex organs develop on different thalli. The male sex organs spermatangia are formed on male plant and the female sex organs carpogonia develop on female plant (Fig 8.2, A&B).
2. The carposporophyte develops by mitotic division of zygote and diploid in nature. It is dependent upon the female gametophyte and bears carpospores.
3. The asexual thallus or tetrasporophyte develops from diploid carpospores and bear tetrasporangia. Tetraspores are haploid in nature which again give rise to male and female gametophytic plants.

8.3.1.3- Mode of reproduction

In the life cycle of *Polysiphonia* the reproduction takes place both asexual and sexual means. Followings are some important points of reproduction in *Polysiphonia*-

1. The asexual reproduction takes place by means of tetraspores. These tetraspores are formed in tetrasporangia and haploid in nature (Fig. 8.2, C&D).

2. After liberation, out of the four tetraspores in a sporangium, two develop male gametophytes and two female gametophytes.
3. The sexual reproduction is oogamous type. Male and female reproductive organs develop on different thalli.
4. The male sex organs are called spermatangia or antheridia. The spermatangia develop on fertile trichoblasts present at the tip of the male gametophyte. Spermatangia are short stalked, spherical or oval structure. Each spermatangium produces a single male gamete or spermatium.
5. The spermatium is liberated through a narrow slit present at the tip of the spermatangium.
6. The female sex organ is called carpogonium. Carpogonia also develop formed on the trichoblast present on the female gametophyte. A flask shaped carpogonium develops at the tip of carpogonial filament. Carpogonium has a swollen base and a narrow elongated part known as trichogyne.
7. During fertilization the spermatia are carried to the trichogyne of carpogonium by water current. The spermatium adheres to the trichogyne by the mucilage around it. The male protoplasm enters carpogonium through trichogyne and fuses with the egg nucleus. After fertilization, a diploid zygote is formed.
8. After fertilization the supporting cells of carpogonia filament cuts off an auxillary cell from its apex and a tubular connection is established between auxillary cell and carpogonium.
9. The diploid zygote nucleus divides mitotically into two daughter nuclei, one of which remains within the carpogonium and the other passes into the auxillary cell through the tubular connection. The haploid nucleus of the auxillary cell degenerates and contains diploid nucleus only.
10. The diploid nucleus of the auxillary cell divides mitotically and gonimoblast filaments develop from auxillary cell.
11. The apical cell of each gonimoblast filament develops into a carposporangium. The protoplasm of carposporangium develops a single diploid carpospore.
12. The sterile cells close to the carpogonium grow out to form sterile filament forming a protective layer.
13. The gonimoblast filaments along with carposporangia get enclosed within a sheath and form a large urn-shaped body, called cystocarp or carposporophte (Fig 8.2, E).
14. The carpospores (diploid) are liberated through the ostiole of carposporophyte.
15. The carpospores germinates and form a diploid asexual thallus called tetrasporophyte.
16. The tetrasporophytes are free living diploid plants in the life cycle which are morphologically similar to haploid gametophytic plants.
17. Tetrasporangia develop in the central cells (central siphon) of the axis.
18. The diploid nucleus of tetrasporangium divides meiotically forming four haploid nuclei. The four uninucleate segments then develop into four haploid tetraspores. These tetraspores are arranged tetrahedrally and also called meiospores (Fig. 8.2 D).

19. After liberation these tetraspores develop haploid gametophytic thalli, two develop male and two develop female plants.
20. *Polysiphonia* thus exhibits the triphasic alternation of generation. In the life cycle of this genus two diploid phases (tetrasporophyte and carposporophyte) alternate with one haploid (gametophytic) phase.

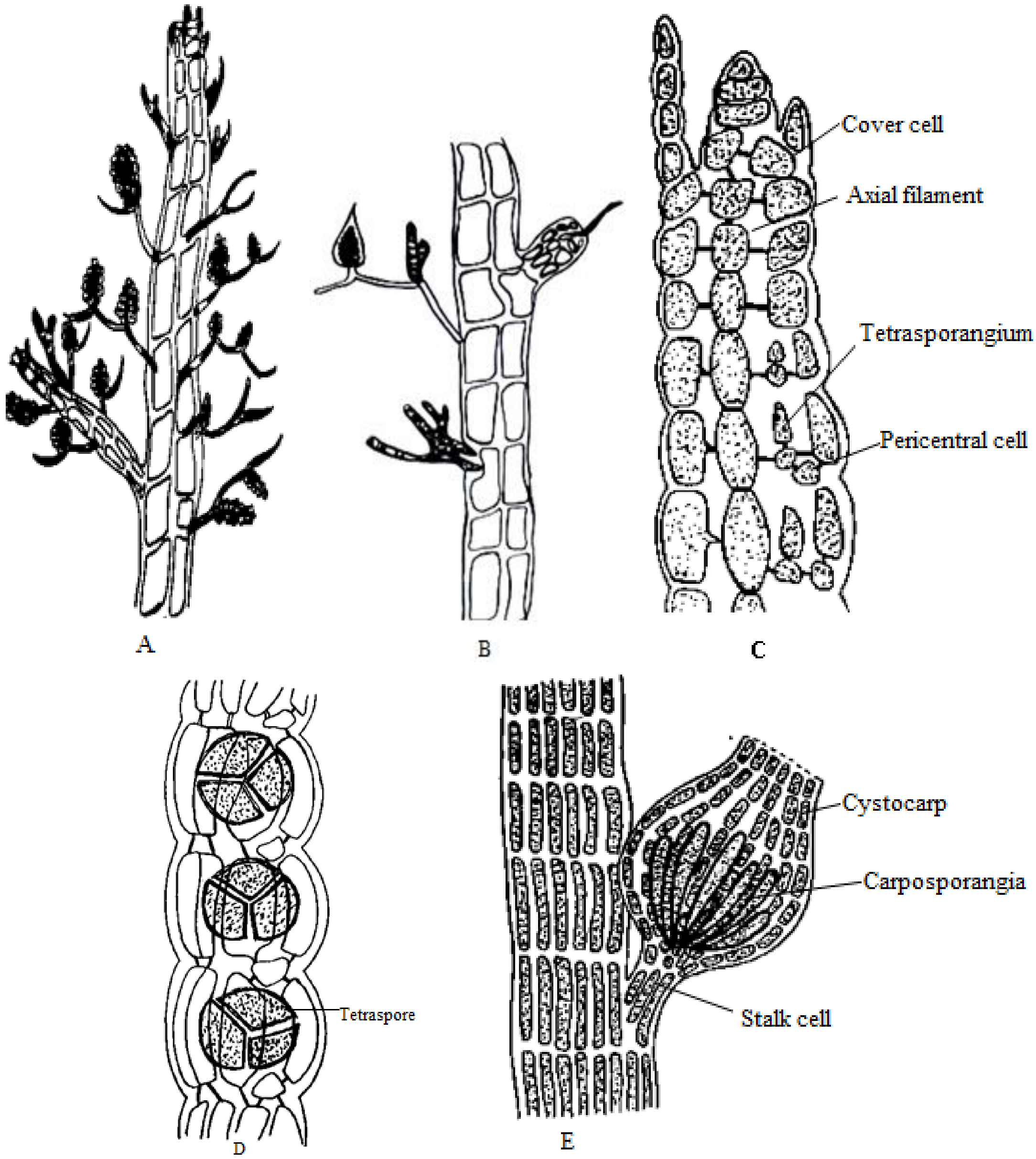

Fig. 8.2 ***Polysiphonia;*** **A. male gametophyte, B. female gametophyte, C. section through apex of tetrasporophyte. D. tetraspores, E. mature carposporophyte (cystocarp)**

8.3.2- *Batracospermum*

8.3.2.1- Occurrence

This is a freshwater red alga. It grows in slow moving water of streams, lakes and ponds in the tropical and temperate regions. Usually thallus grows in deep and shady ponds and lakes.

Commonly alga is found in well aerated waters. The thallus is blue-green, olive-green, violet and reddish in colour. However, the colour varies as a result of the differences in light intensity. The species which grow in deep water are reddish or violet in colour whereas the species growing in shallow water are olive-green in colour.

8.3.2.2- Structure of thallus

The thallus is profusely branched filamentous and gelatinous structure. The thallus is haploid (gametophytic). Thallus organization is differentiated into a prostrate and an erect system. The prostate system anchors the thallus to the substratum. Many species are attached by rhizoids. The primary main axis of thallus is made up of a uniseriate row of large cells and differentiated into nodes and internodes (Fig. 8.3,). Two types of lateral branch's develop from the nodal regions of the thallus i.e. branches of limited growth and branches of unlimited growth. The branches of limited growth arise in whorls just below the septa of the axial filament. The basal cells of the lateral branches grow into narrow threads. These threads grow downwards forming an envelope around the main axis concealing it and giving corticated appearance. The whorl of branches of limited growth present at a node is known as glomerule. The branches of unlimited growth develop from the nodal cells of the main axis. The main pigments are chlorophyll *a*, chlorophyll *d*, and dominant pigments are *r*-phycoerythrin and *r*-phycocyanin. Cell structure is eukaryotic type. Floridean starch is the reserve food. The cells of the axial filament are interconnected through pit connection. Thallus grows by means of hemispherical apical cell. The apical cell, by repeated divisions, gives rise to a series of cells towards the posterior ends.

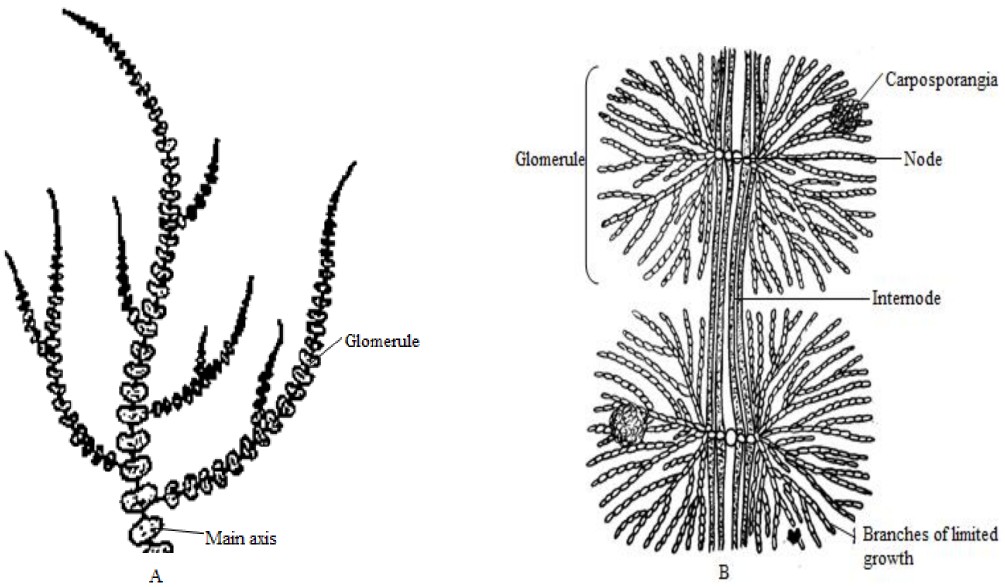

Fig. 8.3, *Batrachospermum*; A. Thallus organization. B An enlarge view of glomerule

8.3.2.3- Mode of reproduction

In *Batrachospermum,* reproduction takes place by asexual and sexual means (fig. 8.4)-

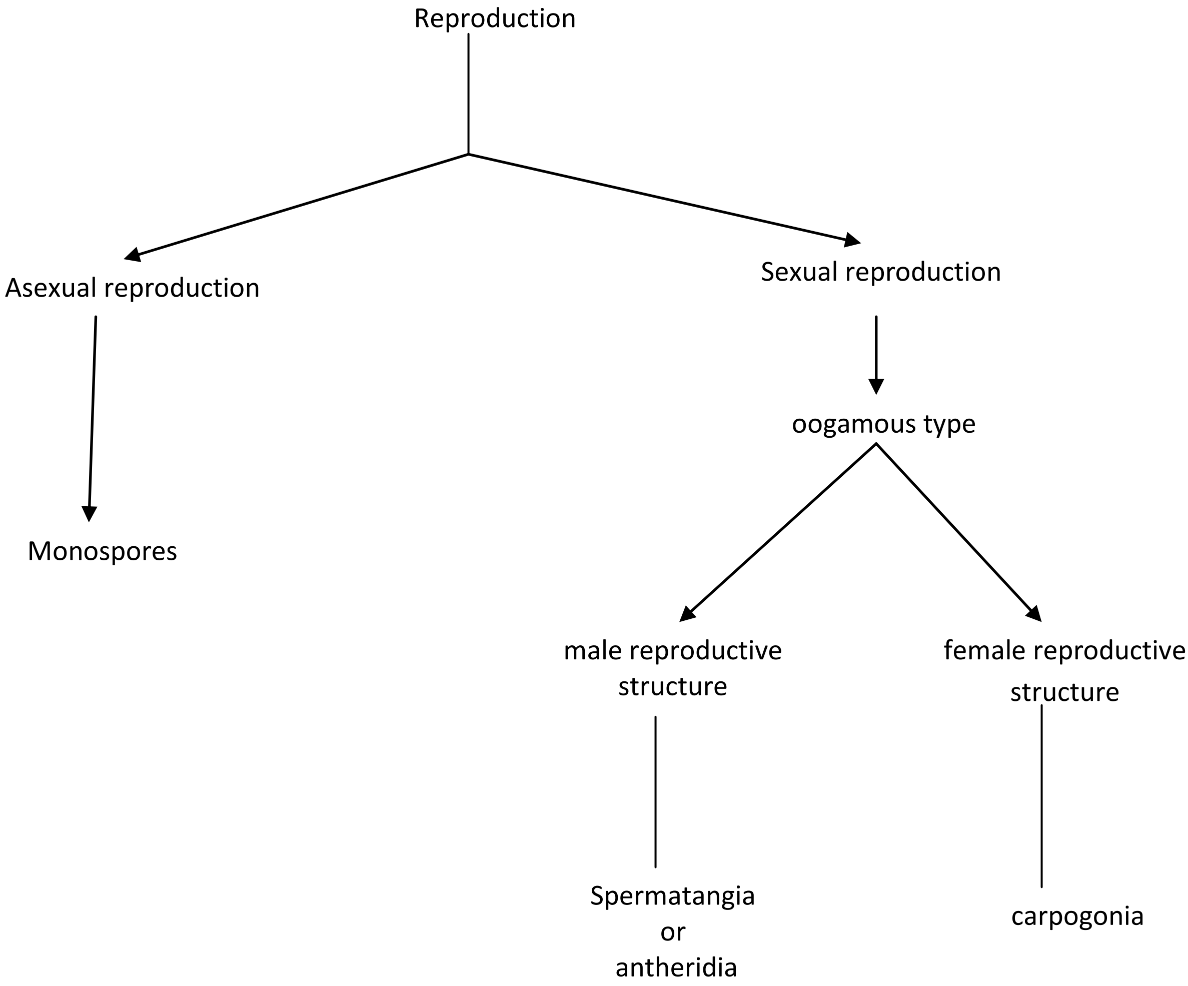

Fig. 8.4, *Batrachospermum*; types of reproduction

Asexual reproduction

Followings are some important points of asexual reproduction-

1. Asexual reproduction takes place by means of monospores formed singly in the monosporangia (Fig. 8.6, B).
2. Monospores are uninucleate, haploid and non-motile.
3. Monospores develop in the erect portion of heterotrichous filaments of 'Chantransia' stage which is produced during post fertilization stage of the sexual reproduction.
4. The monospore gives rise to haploid gametophyte of *Batrachospermum.*

Sexual reproduction

Followings are some important points of sexual reproduction-

1. The sexual reproduction in this genus is highly advanced oogamous type. Thallus may be monoecious or dioecious.
2. The male reproductive organ is called spermatangium or antheridium (Fig 8.5, A).
3. The spermatangia are unicellular, uninucleate, spherical or globose and colourless structure.
4. Spermatngia develop at the distal ends of the branches of limited growth.
5. Each spermatangium bears a single spermatium.
6. The female reproductive organ is called carpogonium.
7. The carpogonium is a flask shaped structure, differentiated into a basal swollen egg cell and a narrow neck called trichogyne (Fig 8.5, B).
8. The carpogonia develops on special lateral branches, known as carpogonial branches.
9. The spermatia liberated from the spermatangium reach to the trichogyne of the carpogonium with the help of water currents.
10. The male and female nuclei fuse together and form a diploid zygote. Trichogyne part disappears gradually.
11. The zygote undergoes meiotic division; resulting into four haploid nuclei. These nuclei divide repeatedly forming many daughter nuclei. At this stage, many outgrowths arise from the basal swollen part of the carpogonium. These outgrowths with haploid nuclei are called gonimoblast initials.
12. Repeated transverse divisions of gonimobast initials give rise to a number of small, unbranched or branched gonimoblast filaments (Fig 8.5, C).
13. The terminal cell of gonimoblast filaments function as carposporangium. Each carposporangium develop a single carpospores. Numerous sterile threads develop from cells below carpogoninm, forming an ecvelop around gonimoblast filaments.
14. Collectively the carposporangia, carpospores and gonimoblast filaments along with sterile filaments is known as cystocarp or carposporophyte.
15. After liberation, carpospores form a protonema like structure which eventually develop into a heterotrichous structure, called chantransia stage or juvenile stage (Fig. 8.6, A).
16. The life cycle of this genus is called triphasic haplobiontic. The diploid phase (zygote) is short-lived.

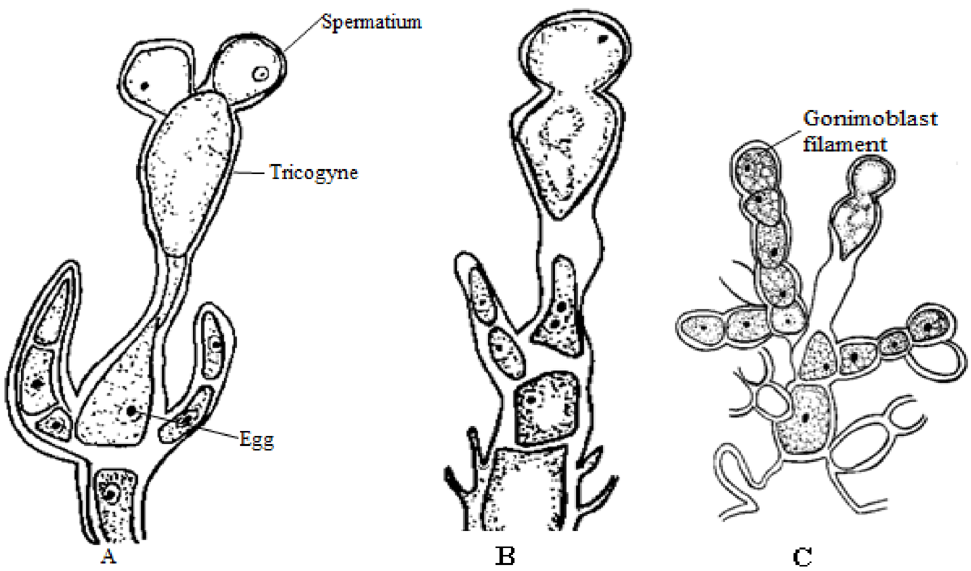

Fig. 8.5, *Batrachospermum*; Different stages of fertilization

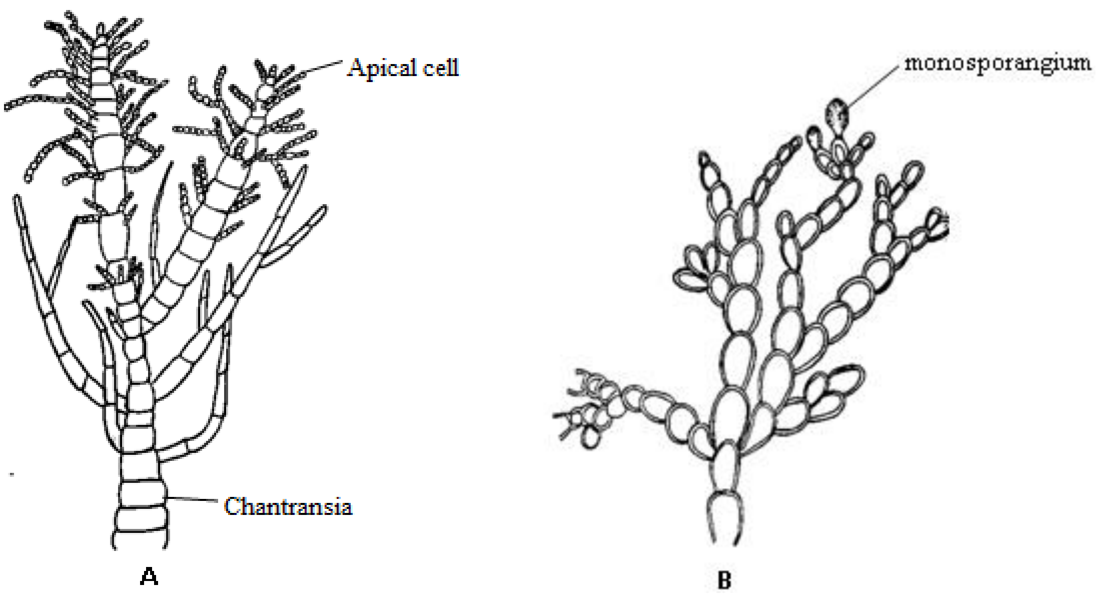

Fig. 8.6: *Batrachospermum;* A. Juvenile stage (Chantransia stage), B. Monosporangium

8.4- SUMMARY

In this unit we have learned about the division Rhodophyta. This is a large group of algae. The members of this division are commonly called red algae. Mostly these are marine in habitat except few species which are fresh water in habitat. Generally the cell wall is made up of two layers, the outer cell wall is pectic and inner cellulosic. The members of this division are eukaryotic in nature. The photosynthetic pigments present in the chromatophore include chlorophyll *a* and *d*, carotenes, xanthophylls and biliproteins such as *r*-phycoerythrin and *r*-phycocyanin. The red colour of these algae is due to the dominant pigments *r*-phycoerythrin and *r*-phycocyanin. The reserve food material is stored in the form of floridean starch. One important point is the absence of motile stage. The reproduction takes place mainly by asexual and sexual methods. Asexual reproduction takes place by aplanospores (monospores, neutral spores, carpospores and tetraspores). The sexual reproduction is highly advanced and oogamous type. In this unit we learned about *Batrachospermum* (fresh water alga) and *Polysiphonia* (marine alga).

Batrachospermum is a freshwater genus of division Rhodophyta**.** The thallus is profusely branched filamentous and haploid. The thallus organization also advanced like *Polysiphonia*. It is differentiated into a prostrate and an erect system. Main axis of thallus is made up of a uniseriate row of large cells and differentiated into nodes and internodes. This is also a unique feature of this alga. Reproduction takes place by asexual and sexual means. Asexual reproduction takes place by means of monospores formed singly in the monosporangia. Sexual reproduction is advanced oogamous type. The life cycle consists of two gametophytic phases (*Batrachospermum* and chantransia stage) alternating with one short lived sporophytic (zygote) phase. The life cycle of this genus is triphasic & called haplobiontic. The diploid phase (zygote) is short-lived.

Polysiphonia is an important marine genus of this division. The thallus organization is also advanced type. The thallus is multiaxial or polysiphonous. The plant body is differentiated into a basal prostrate and an erect aerial system. The prostrate system creeps over the substratum. The prostrate system is anchored to the substratum with the help of unicellular elongated rhizoids. The reproduction takes place both by asexual and sexual means. The asexual reproduction takes place by means of tetraspores. The sexual reproduction is advanced, oogamous type. Male and female reproductive organs develop on different male and female gametophytic thalli. This genus exhibits the triphasic alternation of generation. In the life cycle two diploid phases (tetrasporophyte and carposporophyte) alternate with one haploid (gametophytic) phase.

8.5- GLOSSARY

Antheridium	-	Male gametangium
Corticated	-	Outer layer of small cells covering main axis.
Carpogonium	-	Female reproductive part of red algae.
Carpospore	-	Spore produced within carposporangium of red algae.
Heterotrichous	-	Thallus differentiated into prostrate and erect system of branching filaments.
Internode	-	Space between two joints or points of attachment.
Meiospore	-	Spores formed after meiosis.
Multiseriate	-	Having more than one row of cells
Node	-	Point or area of axis where branching or leafing occurs.
Spermatium	-	Non-flagellated naked male gamete of red algae.
Substratum	-	Surfaces or object upon or within which organism is

growing

Uniseriate - Arranged in single row or series

8.6- SELF ASSESSMENT QUESTIONS

8.6.1-Short answer type of questions:-

1. Write a short note tetrasporophyte.
2. Write a short note on cystocarp.
3. Describe thallus structure of *Batrachospermum..*
4. Write comment on the thallus structure of *Polysiphonia*.
5. Write short notes on Chantransia stage.
6. Write short notes on monosporangium.

8.6.2- Fill in the blanks:

1. The members of division Rhodophyta are commonly known…………..…. algae.
2. In Rhodophyta, the tip of the carpogonium is prolonged into a structure called…………
3. The female reproductive structure in *Polysiphonia* is called……………………..
4. Chantransia stage is a juvenile stage in the life history of …………………………
5. In *Polysiphonia,* the tetraspores are produced after…………… cell division.
6. The pigments ………………are responsible for red colour of the thallus.
7. In the Rhodophyta the reserve food material is stored in the form of ………starch
8. There is a complete absence of ……………. in the life cycle of Rhodophyta.
9. In Rhodophyta, the sexual reproduction is mostly ……………..type
10. The carposporophyte depends upon the …………………gametophyte.

8.6.3-True and false

1. *Batrachospermum* is a fresh water alga (T/F)
2. The thallus of *Polysiphonia* is heterotrichous type. (T/F)
3. In *Polysiphonia* the branches of unlimited growth is known as trichoblasts (T/**F**)

4 Tetraspores are diploid in nature (T/F)

5. Thallus of *Batrachospermum* is multiaxial (**T**/F)
6. The carposporangium, bears a single haploid carpospores (T/F)
7. The juvenile stage of *Batrachospermum* is known as 'Chantransia stage' (T/F)
8. Monospores are multinucleate and motile in nature (T/F)
9. Tetraspores are also called meiospores which are arranged tetrahedrally (T/F)
10. The life cycle of *Batrachospermum* is called triphasic diplobiontic (T/F).
11. Thallus of *Polysiphonia* is uniaxial (T/F).
12. In *Batrachospermum*, the branches of unlimited growth developed from the internodal cells of the main axis (T/F).

Answer Keys:

8.6.2-Fill in the blanks

1. red	3. carpogonium	5. meiotic	7. floridean	9. oogamous
2. trichogyne	4. *Batrachospermum*	6. *r*-phycoerythrin and *r*-phycocyanin	8. motile	10. female

8.6.3-True and false

1. T	4. F	7. T	10. F
2. T	5. F	8. F	11. F
3. F	6. T	9. T	12. F

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8.9- TERMINAL QUESTIONS

1. *Polysiphonia* is a heterothallic genus. Discuss it with the help of suitable diagram.
2. Describe the mode of reproduction in *Batrachospermum* with the help of suitable diagrams.

3. Write a general account of division Rhodophyta with the help of suitable examples.
4. Give an account of the thallus organization and reproduction of *Polysiphonia*.
5. Describe the occurrence, thallus organization and mode of reproduction in *Batrachospermum.*

BLOCK – 3- BRYOPHYTES

UNIT-9 HABIT, DISTRIBUTION, CLASSIFICATION AND ECONOMIC AND ECOLOGICAL IMPORTANCE

9.1 OBJECTIVES

After reading this unit-

- To know about the bryophytes.
- To study the nature (habit) of these plants.
- To know about their disttibution in world with particular reference to India.
- To study the classification of bryophytes.
- To know whether the bryophytes are economically important or not.
- How are the bryophytes useful ecologically?

9.2 INTRODUCTION

What Are Bryophytes?

The bryophyes are simple and primitive members of the plant kingdom. They are small (largest *Dawsonia*, may reach a height of 40 to 70 cm), inconspicuous green plants. They usually grow in tufts and cushions and contribute green colour to the mountains, forests and moors in rainy season. They are the simplest, truly land-inhabiting plants and restricted to moist and shady places. They are regarded as incompletely adapted to land conditions, because almost all of them still require water for the act of fertilization. Most of them also require sufficient moisture for vigorous growth. Because of the requirement of water to complete their life cycle, they are called “Amphibians” of plant kingdom.

9.3 HABIT

The plant body of bryophyte is broadly divided into two types. It may be a simple thallus (thallose) or a leafy shoot (foliose). Sometimes partly thallose or partly foliose forms are also found.

Thallose Forms: The gametophyte is a thallus. The thalloid forms are not differentiated into stem and leaves. The thallus is usually flat, green, prostrate, dorsi-ventral and dichotomously branched (Fig.9.1). It has a distinct midrib (*Riccia* and *Marchantia*) or midrib may be absent (*Anthoceros*). Thallus is generally fixed on the soil by means of rhizoids and in many cases possesses scales on the ventral surface.

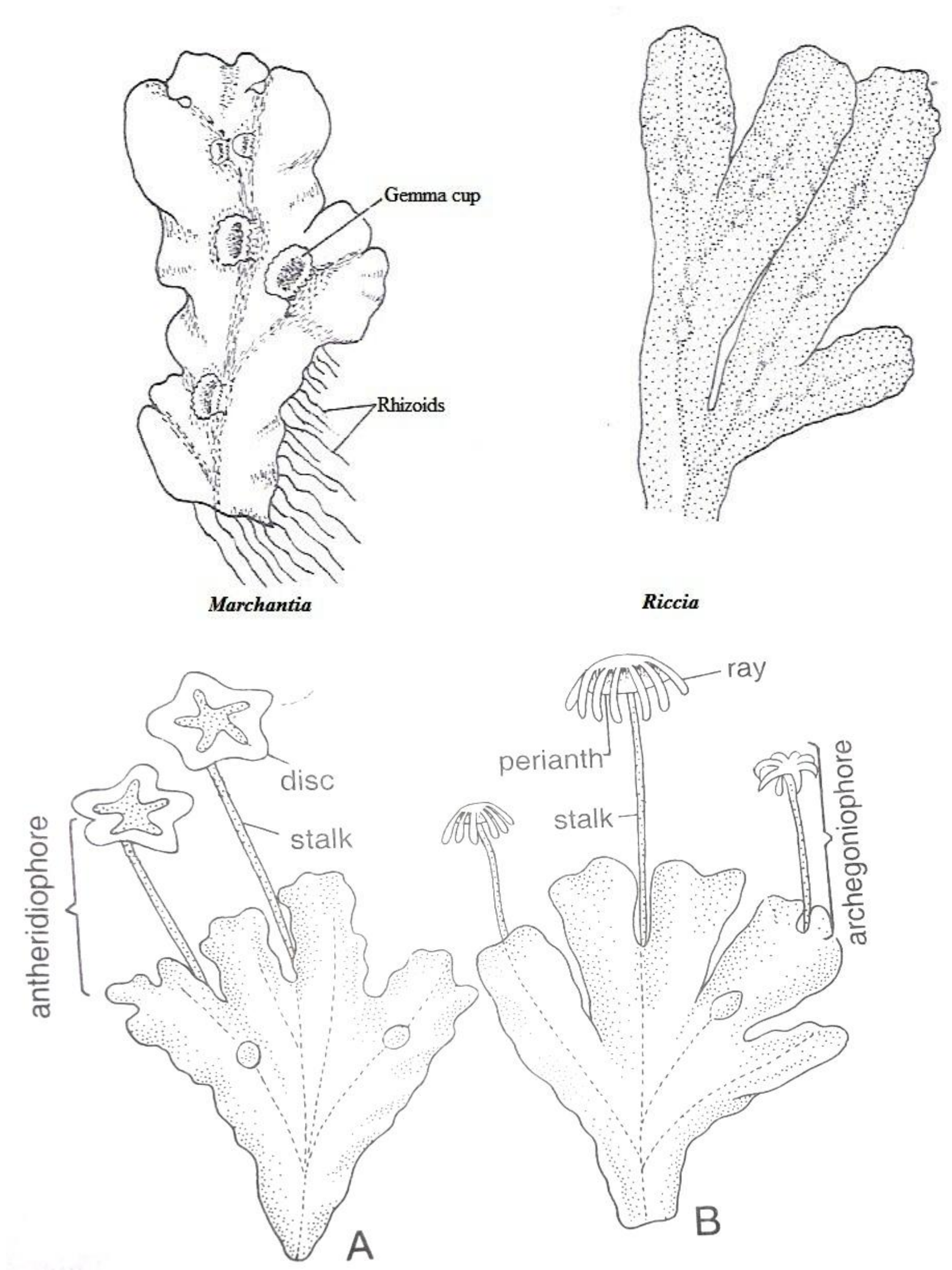

Fig. 9.1 Thalloid forms

Leafy Forms: The gametophyte of leafy liverworts has more or less prostrate leafy axis and have three rows of leaves; two rows of dorsal leaves which are placed laterally, one on each side of the stem and a third ventral row of smaller leaves, which are present on the underside of the stem (*Porella*). The leaves are always without a midrib (Fig 9.2 A). The rhizoids are not septate. The protonema is small and short- lived.

In mosses, gametophytic plant body is a leafy shoot consisting of main axis (stem), phylloids (leaves) and rhizoids (Fig.9.2 B, C). The leaves are small, simple sessile and are spirally arranged on the stem in three vertical rows. The leaves generally possess a midrib of variable size. Branching is lateral (*Funaria* and *Polytrichum)* and pinnate type. Rhizoids are branched and transversely septate. Protonema a juvenile stage in mosses is well developed, filamentous and branched. Sometimes thalloid protonema is also found.

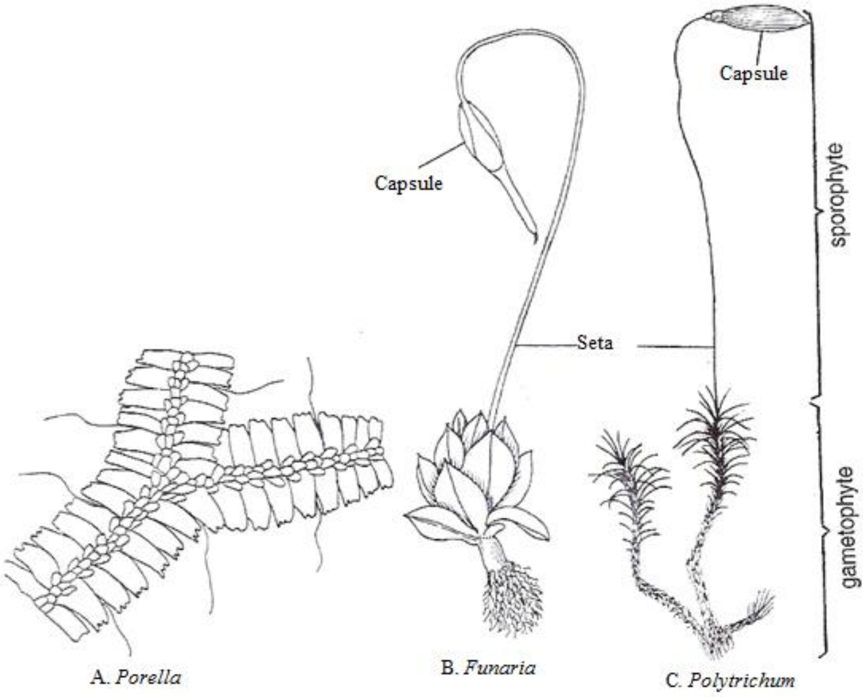

Fig. 9.2 Leafy forms

9.4 DISTRIBUTION

Bryophytes tend to show wider distributions than flowering plants. Many families are found throughout the world. Several genera, like *Polytrichum, Grimmia, Bryum* and *Brachythecium* among mosses; *Plagiochila*, *Lophpcolea*, *Radula* and *Frullania* among liverworts are worldwide in distribution. Some of the species are known as international weed species as they are cosmopolitan in distribution, for example, *Funaria hygrometrica, Tortula muralis* etc.

Herzog (1926) indicated certain patterns of distribution that was repeated again and again. Therefore, groups of families and genera that showed **circumboreal, Mediterranean, Pan tropical, bipolar** and other kinds of distribution can be observed. Endemism, among bryophytes is of two main kinds. First, there are forms which are evolved recently and lacked the time to achieve wider distribution. Second, those ancient species which vanished from their stations elsewhere; and now they have become restricted to a single country. Some of them evolved far back in time but because of geographical barriers remained **endemic.**

In Indian context, Pande (1958) and Kachroo (1969) divided the Indian subcontinent into six bryo-geographical units each one with distinctive vegetation (See Map).

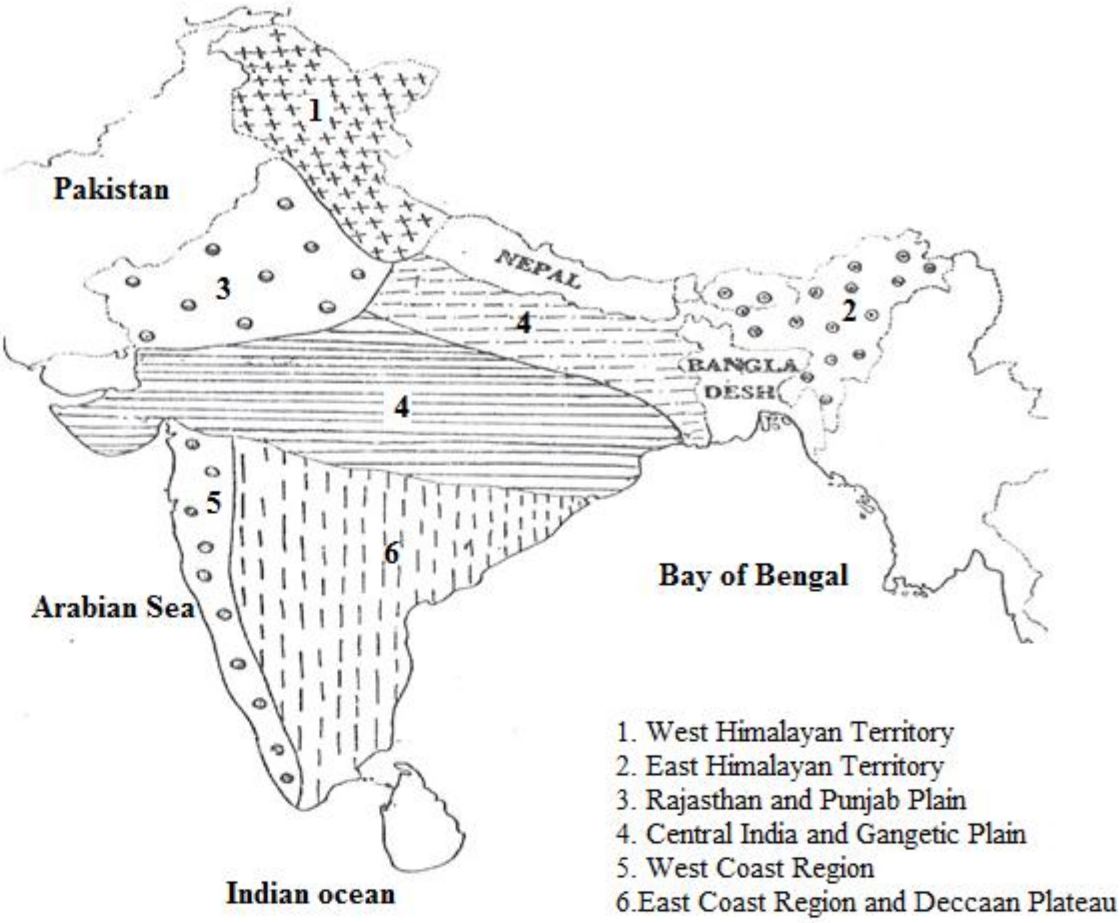

Fig. 9.3 Map of India showing Bryogeographical units

I. The Western Himalayan Territory: It extends from the western boundary of Nepal to Kashmir. In this area rain fall is less. The most luxuriant vegetation occurs between altitudes 6000-8000 ft. The vegetation is characterized by some endemic genera and arctic species such as *Sauteria alpina* and *S. spongiosa*. Some temperate or cosmopolitan elements common to Europe are also represented. An interesting plant is the genus *Delavayella* with restricted distribution in Almora, and Darjeeling.

II. Eastern Himalayan Territory: It comprises the eastern part of mountains of Indian Territory that separates the India proper from Burma and China and includes a vast area of Assam: The rain fall in this area is fairly heavy. Some plants confined entirely to this territory in India and with restricted distribution in other parts of the world, present interesting distribution patterns. *Conocephalum supradecompositum* is known from subtropical regions of Japan,the province of Shensi in China and from Darjeeling, *Monoselenium tenerum* is known from China, Japan and Assam; *Jackielia* Schiffn. has its 5 species distributed in Japan, Java, Ceylon, Sumatra, Singapore, Tahiti and Caroline Islands and among these *J. javanica* var. *carvifolia* Schiffn. is known from Darjeeling; *Schiffneria* St., represented by a species in Japan (*S. viridis* St.), another in Batjan (*S. hyalina* St.) is also represented in Indian flora by *S. levieri* Schiffn. from Darjeeling and *Megaceros stahlii* is distributed only in Java and Darjeeling.

III. The Punjab and the west Rajasthan plains: This area with very low and inconsistent precipitation is not well-suited for hepatic growth. Only some xeromorphic forms such as species of *Asterella, Plagiochasma, Riccia* and *Targionia* grow in favourable habitats.

IV. Central India and the Gangetic plain: In this part of the country, although the rain fall is not very heavy (average 70-80 inches) the hepatic vegetation is comparatively more luxuriant. About 40 species are known, of which 26 are common to the western Himalayas, 18 to the eastern Himalayas and 24 to South India. The area is a meeting ground for the hepatics of northern and southern parts of India. Some of the interesting plants known from this zone are *Anthoceros crispulus, Riccia curtisii* and *Riella affinis*.

V. The west Coast region: This region lies between the crests of the Western Ghats and the Arabian Sea. Places such as Augumbe, Kunduremukh and Dodabetta, with heavy rainfall, support luxuriant hepatic vegetation and particularly Augumbe (rainfall ca. 35inches) abounds in a number of epiphyllous liverworts. Several of these, viz., *Cololejeunea, Diplasiolejeunea, Leptocolea, Microlejeumea, Rectolejeunea,* etc. strongly resemble their African allies and also to that of Mouflong forest in Assam and Sikkim Himalayas. *Leptocolea* has an interesting distribution pattern. *L. himalayensis*, described from the western Himalayas has been reported from South Africa and probably also occurs in South India and the eastern Himalayas and *L. marginata* and *L. ocellata* known from America and Japan occur also in South India (Chopra, 1938).

VI. The East Coast region and Deccan plateau: This zone consists of the Eastern Ghats, the Nilgiris and the Deccan plateau. It has about 31 species of liverworts common to Indo-Malayan countries including Java, Formosa, Sumatra, Philippines, Luzon, Borneo, Siam, Caroline Islands, Nicobar, etc. The Deccan plateau has no distinctive flora and shows plants common to the western and Eastern Ghats and is a meeting ground for the vegetation of these two areas.

9.4.1 General Characters of Bryophytes

The term Bryophyta was introduced by Braun (1864), wherein he included Algae, Fungi, Lichens and Mosses. Schimper (1879) formed the division Bryophyta. The meaning of this word is moss like plants (Gr. Bryon = Moss; Phyton = plant).

Bryophytes as Amphibians of Plant Kingdom

The bryophytes occupy the position intermediate between the green Thallophyta (Algae) and the vascular cryptogams (Pteridophyta). The plants that grow in water are called aquatics and others are terrestrial. In Aquatics you must have studied algae. In land plants you will study the seed bearing plants (spermatophytes).

Between the land and water, a transitional zone is present, where plants can grow on both the habitats (water and land). These plants are known as bryophytes and they have successfully adapted to land as well as water. But, these may be regarded as incompletely adapted to land conditions, because all of them require water for the act of fertilization. Most of them require sufficient moisture for vigorous vegetative growth and they are unable to grow actively during dry periods. On account of their complete dependence on external water for completing their life cycle, the bryophytes are known as the amphibians of the plant kingdom.

9.4.2 Salient Features in the Life Cycle of Bryophytes

The gametophyte is the conspicuous and dominant phase of the life cycle as compared with the sporophytic generation. The gametophyte is small, highly developed with tissue differentitation and is an independent plant.

1. The gametophyte plant body is rootless either a simple flattened thallus or a definite rootless leafy shoot (leafy form; Fig. 9.1 and 9.2).
2. The thalloid plant body is not differentiated into root, stem and leaves. It grows prostrate on the ground and is attached by branched or unbranched unicellular or multi cellular hair like structure, the rhizoids (Fig. 9.4). In leafy forms that is, in mosses the plant body is erect. It consists of central axis which bears leaf like expansions.
3. Like the thallophytes, the dominant phase of the life cycle of bryophytes is the gametophyte. It is independent and related to sexual reproduction.
4. In general, Bryophytes does not possess vascular tissues (xylem and phloem) in their sporophytes and gametophytes, which is present in fern and other higher plants, and therefore also called as Atracheata by Tippo (1942).

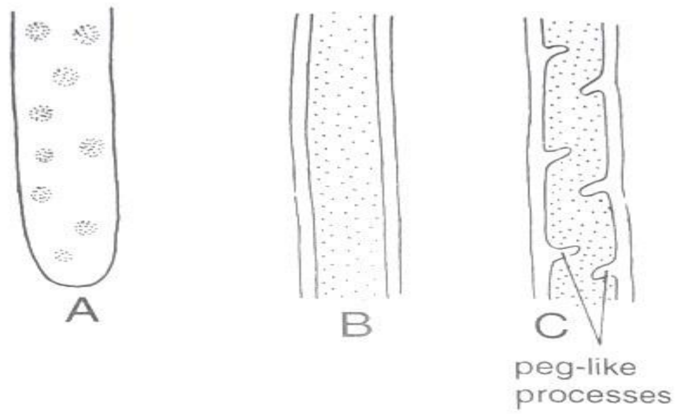

Fig.9.4 Rhizoids; A. Tuberculate rhizoid in surface view, B&C Smooth walled rhizoid and tuberculate rhizoid as under microscope

9.4.3 Reproduction

9.4.3.1 Vegetative reproduction:

Bryophytes have ability to reproduce by vegetative means. It takes place by various methods such as, by death and decay of the older parts of the plants, by growing apices, by adventitious branches, by fragmentation, by tubers, by gemmae (Fig.9.5), by bulbils, by primary protonema and by secondary protonema.

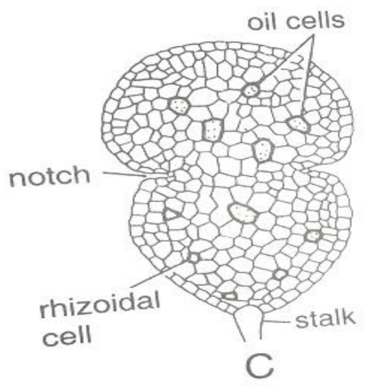

Fig. 9.5 Gemmae

9.4.3.2 Sexual reproduction

In bryophytes sex is determined either by morphologically distinct sex chromosomes *(Sphaerocarpos donellii*) or by environmental factors.

Sexual reproduction is oogamous type. The sex organs are jacketed and multicellular. **Archegonium:** Female sex organ is called archegonium which is first reported in bryophytes (Fig. 9.6A).

Antheridium: The male sex organ is called antheridium. It is stalked globose or somewhat elliptical structure. It has an outer sterile one cell thick jacket, which surrounds the fertile mass of androcytes. The androcytes metamorphoses into motile biflagellate antherozoids (Fig. 9.6 B & C).

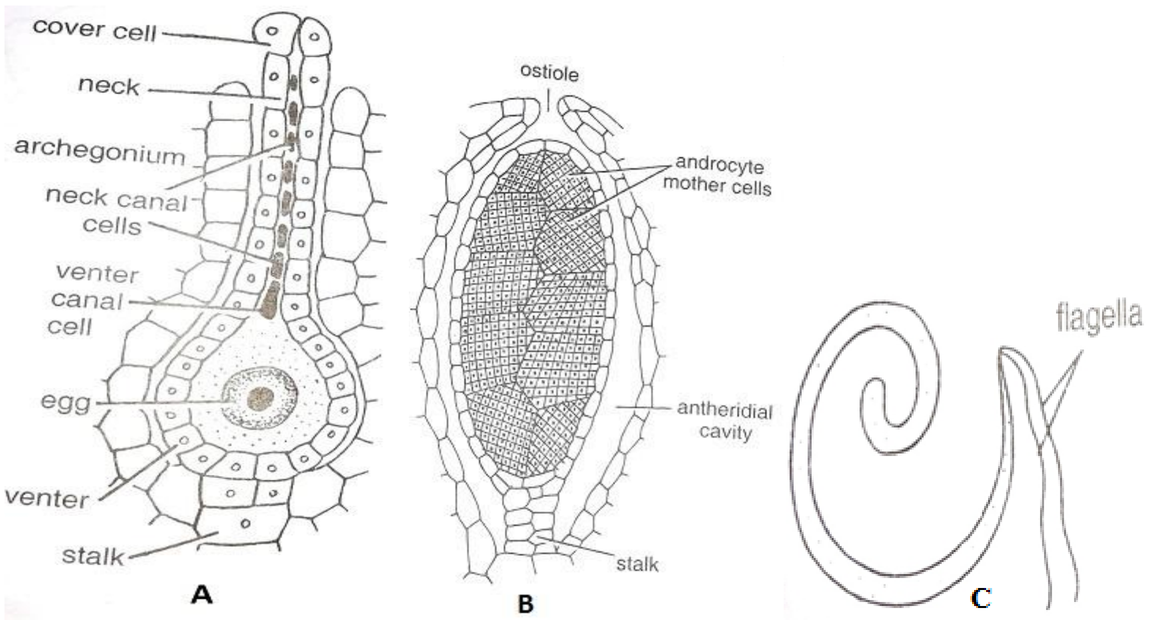

Fig. 9.6 Archegonium (A), Antheridium (B) and antherozoid (C)

9.4.3.3 Fertilization

It takes place in the presence of water (Fig.9.7).

The fertilized egg (zygote) remained within the venter of the archegonium.

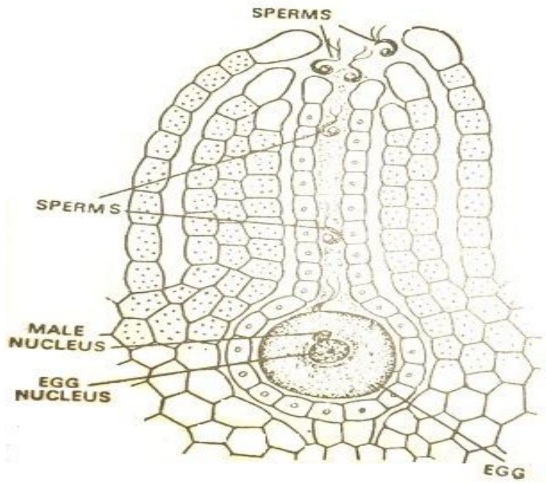

Fig.9.7 Diagram illustrating fertilization

Sporophyte

Zygote: The zygote does not pass the resting period but immediately undergoes simple (miotitic) division (Fig. 9.8).

Embryo: It undergoes the repeated division to form an undifferentiated, multicellular structure called embryo.

Sporogonium: The embryo by further cell divisions and differentiation forms the sporophyte. It consists of a foot, a seta and a capsule (Fig. 9.9).

The sporophyte is attached to the parent gametophyte throughout its life and is dependent on it partially or wholly for nutrition.

The sporogonium is concerned with asexual reproduction. It produces non motile haploid meiospores which disseminate by wind.

All meiospores are morphologically same hence, bryophytes are homosporous.

The unicellular haploid spores after falling on suitable substratum germinate and give rise to gametophytic plant either directly as in *Riccia* and *Marchantia* or indirectly to produce a juvenile filamentous or thalloid protonema as in mosses.

The life cycle of bryophytes is diplo-haplontic type, where diploid (Sporophytic) phase is followed by haploid (Gametophytic) phase.

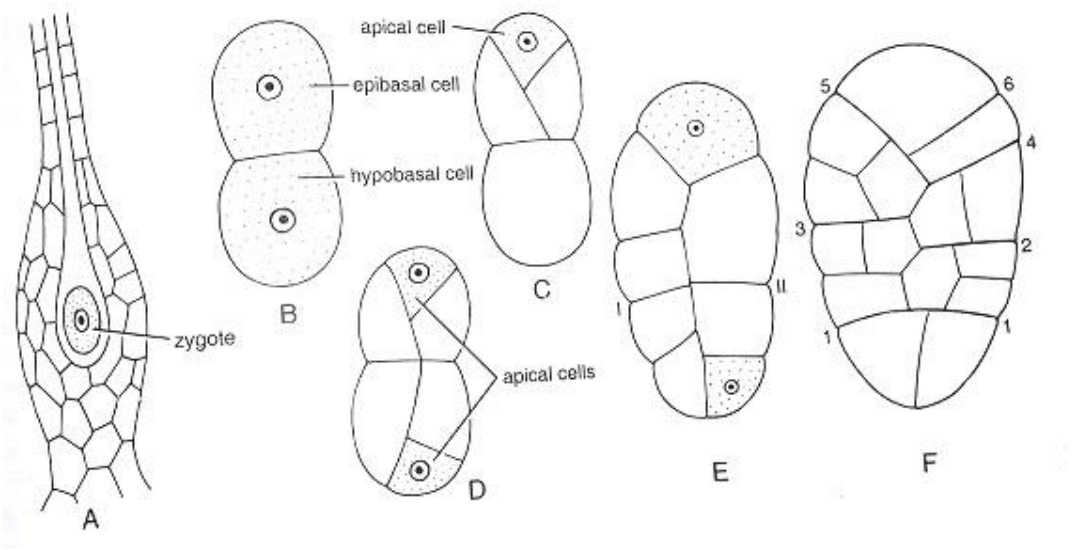

Fig. 9.8 Stages of zygote development (A-F)

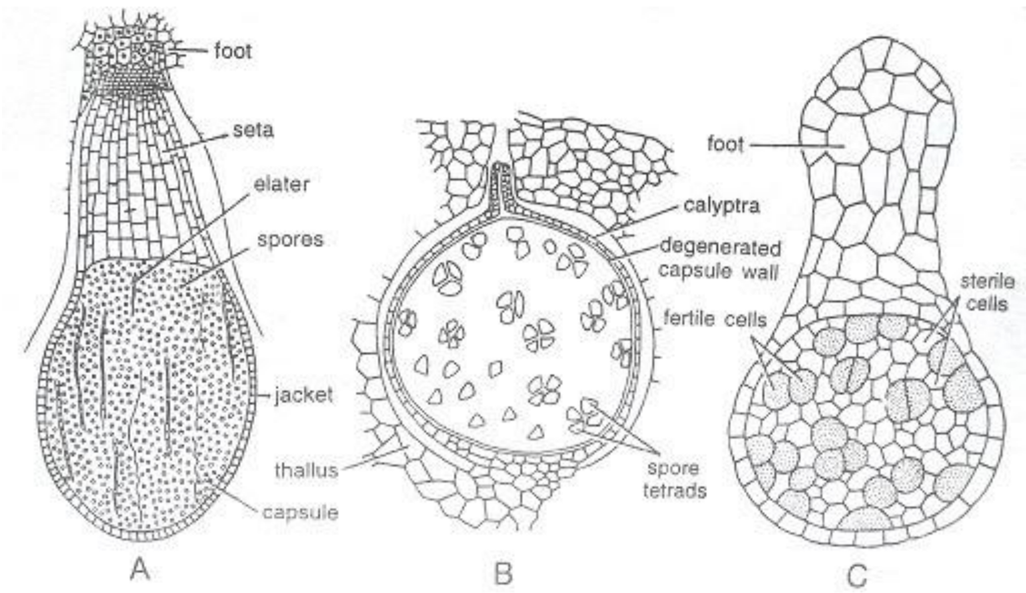

Fig.9.9 Sporophytes: A. Marchantia B. Riccia C. Corsinia

9.4.3.4 Alternation of Generations

The alternating individuals in the life cycle are morphologically distinct. This kind of alternation of generation is called heterologous or heteromorphic. The difference in two generations is due to the different modes of life. The gametophyte is independent, while the sporophyte is partially or wholly dependent on the gametophyte (Fig. 9.10).

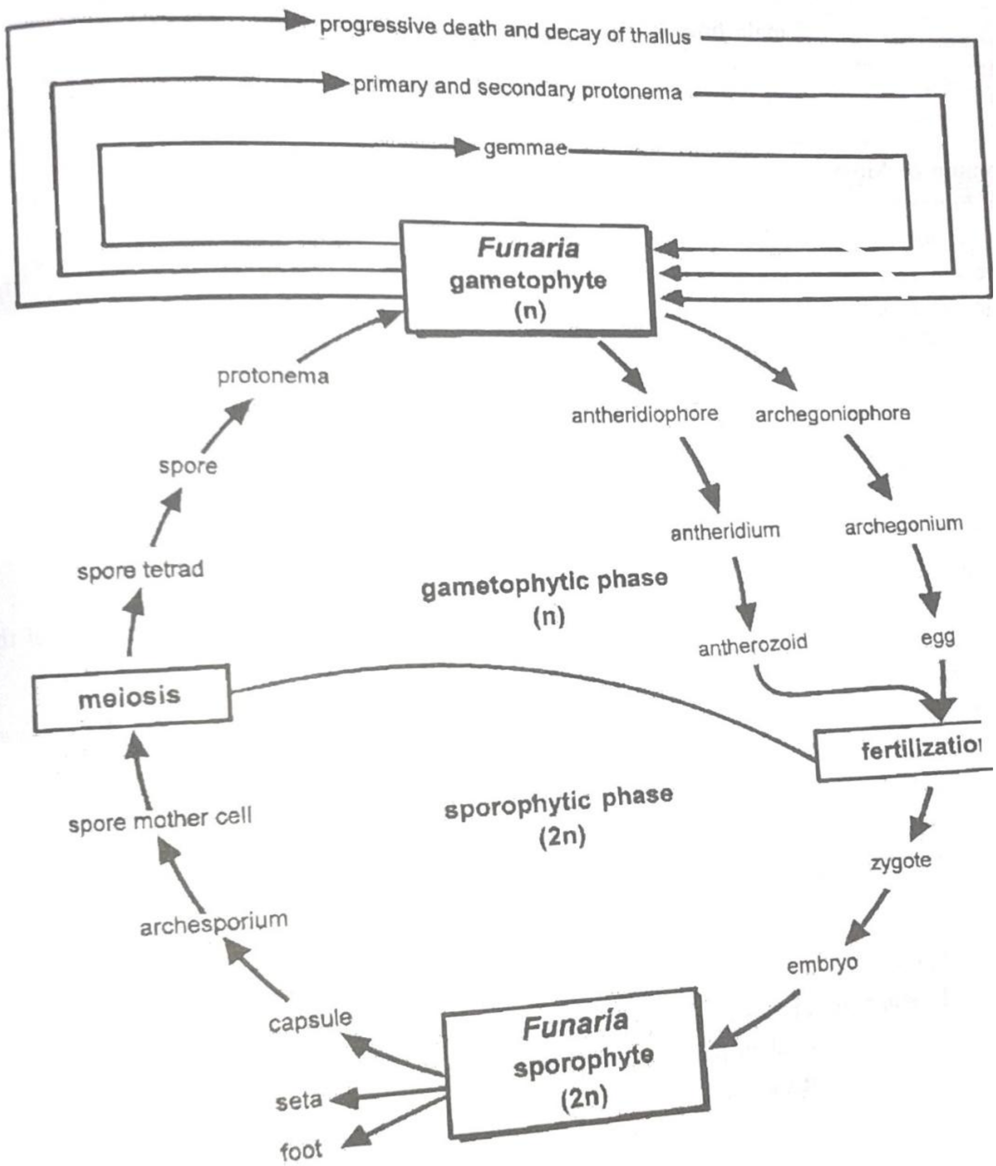

Fig. 9.10 Alternation of generation in bryophytes

Similarities between the Bryophyta and Algae

1. Presence of thalloid plant body is a feature of both Bryophyta and Algae.
2. In both groups, the dominant phase of the life cycle is gametophyte.
3. In both groups, plants are autotrophic in nature.
4. In both groups, chloroplast contains chlorophyll a, chlorophyll b, alpha and beta carotene, lutein, violaxanthin and xeoxanthin.
5. In Chlorophyceae (green algae) and Anthocerotales plastids with pyrenoids are present.
6. In both groups starch is the reserved food material
7. In both groups, vascular tissue is absent and Cellulose is the chief constituent of cell wall.
8. In both groups, motile and flagellate antherozoids with whiplash type of flagella are present.

9. A filamentous protonema, formed in the juvenile stage of mosses, resembles with algal filaments in structure.

Differences between the Bryophyta and Algae

1. Bryophytes are generally terrestrial growing on shady and moist habitats, whereas most of the algae are aquatic.
2. In bryophytes plant body is multicellular thalloid or leafy in form differentiated into rhizoids, axis and lateral appendages, while in Algae plant body is unicellular, multicellular, filamentous or pseudo parechymatous.
3. In Bryophytes, sexual reproduction is oogamous type while in algae it is isogamous, anisogamous and oogamous type.
4. In Bryophytes, female sex organ is Archegonium while in algae it is oogonium.
5. In Bryophytes, sex organ are covered by a sterile jacket while in algae it is not covered by a sterile jacket.
6. In Bryophytes, zygote remained enclosed in the archegonium while in algae zygote is liberated from the plant.
7. In Bryophytes, zygote develops into embryo while in algae zygote never develops into embryo. Hence embryo stage is present in Bryophytes and absent in algae.
8. In Bryophytes, sporophyte is dependent on gametophyte while in algae it is independent of gametophyte.
9. In Bryophytes, sporophyte is differentiated into foot seta and capsule while in algae no such differentiation is seen in sporophyte.
10. In Bryophytes, mitospores are absent while in algae mitospores are usually present
11. In Bryophytes, alternation of generation is heteromorphic while in algae alternation of generation is isomorphic type.

Similarities between the Bryophyta and Pteridophyta

1. Simple leafless and rootless sporophytes of certain primitive pteridophyte (members of Psilophytales) can be compared with the sporophytes of bryophytes.
2. In both groups plants are archegoniate, and the structure of archegonium is similar.
3. Antheridium in both the groups is surrounded by a sterile jacket.
4. In both the groups, antherozoids are flagellate.
5. In both the groups, water is necessary for fertilization.
6. In both the groups, zygote develops into embryo.
7. The terminal sporangia with columella of Psilophytales are similar to moss capsules
8. Both groups are characterized by the presence of heteromorphic alternation of generation.

Differences between Bryophytes and Pteridophytes

1. In bryophytes, dominant phase of life cycle is gametophyte whereas in Pteridophyta, sporophyte is the dominant phase in the life cycle.

2. In bryophytes, vascular tissue is absent whereas in Pteridophyta, vascular tissue is present.
3. In bryophytes sporophyte is completely dependent upon the gametophyte whereas in Pteridophyta, sporophyte is autotrophic and independent.

9.5 CLASSIFICATION OF BRYOPHYTA

The bryophytes have been classified differently by different authors. Conventionally, they are divided into two classes, the Hepaticae and Musci. These are further divided into the orders as follows:

Bryophyta

Class I: Hepaticae or Liverworts

Order: 1. Marchantiales
2. Jungermanniales
3. Anthocerotales

Class II: Musci or Mosses

Order: 1. Sphagnales
2. Andreales
3. Bryales

Howe (1899) raised Anthocerotales to the status of class called Anthocerotes. He thus divided bryophytes into three classes, Hepaticae, Anthocerotes and Musci. Campbell, Smith and Takhtajan supported this system but they called Anthocerotae instead of Anthocerotes. Rothmaler (1951) suggested the class names as follows:

1. Hepaticopsida for Hepaticae
2. Anthocerotopsida for Anthocerotes
3. Bryopsida for Musci

The new names suggested by Rothmaler have been recognised by the International Code of Botanical Nomenclature. Proskauer (1957) suggested the name Anthocerotopsida for Anthoceropsida. Presently, Bryophyta is classified into the following three classes:

1. Hepaticopsida
2. Anthocerotopsida
3. Bryopsida

Salient features of classes and orders

1. Class Hepaticopsida: Gametophyte is dorsiventral either thallus or leafy axis (foliose), develops directly from spores, sporophyte without any meristematic tissue, sporogenous tissue is endothecial in origin, columella absent.

It is divided into the following orders:

Order1. Sphaerocarpales

2. Marchantiales
3. Metzgeriales
4. Jungermanniales
5. Calobryales

Order: Sphaerocarpales: Thallus is without any internal differentiation of tissues, each sex organ is surrounded by involucres, archegonial neck is composed of 6 vertical rows of cells, capsule wall one cell in thickness.

Order: Marchantiales: Thallus flat, dichotomously branched, internally differentiated into dorsal region of air chambers and ventral region of parenchymatous storage zone, archegonial neck composed of 6 vertical rows of cells, capsule with a jacket of sterile cells and one cell thick.

Order: Jungermanniales: Plant body foliose, no internal differentiation of tissues archegonial neck made up of 5 vertical rows of cells, apical cell is used up in the formation of archegonium, capsule wall more than one layer in thickness.

Order: Metzgeriales: Plant body thallose, rarely foliose, if foliose, then dorsiventral and prostrate at least in certain stages of development, apical cell not used up in the formation of archegonium, jacket of the capsule 2-5 layered thick, involucres of sex organs not formed of leaves.

Order Calobryales: Plant body erect, leafy with leaves in three vertical rows, neck consists of 4 vertical rows of cells, capsule wall one cell in thickness.

2. Class Anthocerotopsida: Plant body simple, lobed thallus with or without midrib, dorsiventral, without internal tissue differentiation, archegonium develops from the superficial cell, antheridium from hypobasal cell, sporophyte long lived ,between cylinrical capsule and foot meristematic zone is present, seta absent, archesporium amphithecial in origin and is dome shaped arching over columella.

Order Anthocerotales: characters are similar to the class Anthocerotopsida.

3. Class Bryopsida: Members commonly known as mosses.The predominant phase of life cycle is gametophyte. The plant body is radially symmetrical and differentiated into stem and leaf like structures. The stem shows a little tissue differentiation into cortex and conducting strand. The gametophyte is in two forms, an initial filamentous protonemal stage followed by the leafy gametophyte form. The branching is monopodial .Moss leaf has a midrib (costa), the rhizoids are multi cellular and branched with oblique septa. Sex organs are stalked. Sporophyte is complex and elaborate with high degree of specialisation and sterilization. Sporogonium elevated on a seta. Spore sac is in the form of hollow cylinder around the columella, Capsule opens by a lid. Calyptra well developed and peristome is present.

Remiers (1954) recognized five sub classes:

(i) Sphagnidae
(ii) Andreaeidae
(iii) Bryidae
(iv) Buxbaumidae
(v) Polytrichidae

Subclass Sphagnidae: Order Spagriales, it has Thallose protonema, globular sporogonium elevated on non leafy gametophytic shoot the pseudopodium, seta absent, columella roofed by the dome shaped spore sac, capsule opens by the separation of lid, calyptra present, peristome absent.

Subclass Andreaeidae: Order Andeales, Ribbon shaped protonema,elongated sporogonium elevated on a pseudopodium,columella roofed over by the spore sac, calyptra massive,capsule dehisces by longitudinal slits but the valves remain united at the tip, peristome absent.

Subclass Bryidae: There are 12 orders, Filamentous protonema, Sporogonium elevated on a seta.Spore sac is in the form of hollow cylinder around the columella, Capsule opens by a lid. Calyptra well developed.

Subclass Buxbaumidae: Order Buxbaumiales, Gametophyte is very small and partially saprophytic .Sporophyte is fully developed. Plants are dioecious .Female plant is larger than the male plant. Capsule is massive and oblique. .

Subclass Polytrichidae: Order Polytricales, Dawsoniales, Gametophores are tall and perennial. The leaf has a green, narrow limb with a broad colourless sheathing base. The capsule has hood shaped or cucculate calyptra. Operculum has a distinct beak. Archesporium is surrounded by a double air space system. The peristome consists of a ring of 32 or 64 pyramidal, solid teeth with their tips joined above to a thin, pale membrane- the epiphragm.

9.6 ECONOMIC AND ECOLOGICAL IMPORTANCE OF BRYOPHYTES

Bryophytes are the simplest and primitive land plants which are one of the first colonizers of the terrestrial habitat. Taxonomically, these plants are placed between algae and Pteridophyta. They are generally represented by about 21000 species (Schofield, 1985) with a worldwide distribution. As a group, bryophyte is divided into three classes: , Hepaticapsida (liverworts, 6000 species) , Anthocerotopsida (hornworts, 300 species) and. Bryopsida, (mosses,14000 species). Owing to their potential to live on a variety of habitats, they are exposed to differential degree of biotic and environmental hazards. To cope up with these adverse conditions, numerous secondary metabolites of several types are synthesized in their tissues as a defense system (Herout, 1990). A lack of commercial value, small size, and inconspicuous place in the ecosystem has made the bryophytes to be of no use to general public. But still bryophytes have been useful in many ways to the mankind.

9.6.1 Ecological Uses of Bryophytes

Both liverworts and mosses are often good indicators of environmental conditions. The terrestrial bryophytes and other plants are used to characterize forest types.

1-Soil Conditioning

Mosses are often used in conditioning of soil. Coarse textured mosses increase water-storage capacity, whereas fine-textured mosses provide air spaces Mosses accumulate potassium, magnesium, and calcium from rainfall. These trapped nutrients may then be released slowly to soil.

2. Erosion control

It was found that ***Barbula, Bryum,*** and ***Weissia*** were important pioneers on new road banks, helping to check soil erosion before the establishment of larger plants.In Japan, it was observed that ***Atrichum, Pogonatum, Pohlia, Trematodon***. ***Blasia,*** and ***Nardia*** play an important role in preventing erosion of river banks.

3. Nitrogen Fixation

Nitrogen is generally a limiting nutrient for plant growth. Bryophyte crusts, enriched with nitrogen fixing Cyanobacteria can contribute considerable soil nitrogen, particularly to dry range land soil. Some of these Cyanobacteria live symbiotically with ***Anthoceros*** thalli.

4. In Pollution studies

Bryophytes play a major role in monitoring changes in the Earth's atmosphere. In Finland, ***Hylocomium splendens*** was used as moss bags to monitor heavy metals around coal-fired plants.

5. UV Radiation

The moss ***Bryum argenteum*** is being used to monitor the thickness of the ozone layer over Antarctica (Hedenas 1991). There is, increased exposure to UV radiation with the decrease of ozone layer and UV radiation stimulate production of flavonoids in this species.

6. Radioactivity Indicators

Because of the ability of bryophytes to trap minerals without any harm to thalli, they are good indicators of accumulated radioactivity. Because of its cation exchange activity, Fischer *et al*. (1968) suggested that ***Sphagnum*** could be used to decontaminate water containing radioactive materials.

7. Indicators

Aquatic Bioindicators

Bryophytes are also useful as monitors in aquatic habitats. The death of bryophytes is slow and the release of accumulated substances permits the bryophytes to retain their toxic load after death (Pakarinen 1977).

At low concentrations of phenol (50 mg phenol dm^{-3}), ***Fontinalis antipyretica*** can decompose 32-43% of the phenol, and ***Platyhypnidium riparioides*** decomposes 20-27% (Samecka-Cymerman, 1983).

8. Other Indicator Species

Both liverworts and mosses are often good indicators of environmental conditions Copper mosses grow almost exclusively in areas high in copper, particularly when copper value is ranging from 30-770 ppm, Some of the copper mosses are ***Mielichhoferia elongata, M.mielichhoferi*** and ***Scopelophila* sp.**

Bryophytes sequester both metals and nutrients by cation exchange to cell walls of leaves. ***Sphagnum*** exchanges hydrogen ion in the water Hydrogen ions make the water more acidic, hence, ***Sphagnum*** is a reliable indicator of acid conditions.

It was found that several other bryophytes also indicate other soil conditions. For example, ***Ceratodon purpureus*** suggests good drainage and high amounts of nitrogen, whereas ***Pogonatum alpinum*** and ***Pogonatum urnigerum*** signal less nitrogen, at least in Iceland.

Bryophytes could be used as indicators of soil quality in steppe forests. Crum (1973) ***Polytrichum*** is a good acid indicator; its ability to live on acidic soils. The rhizoids at the base of this moss probably enchance uptake of water and nutrients from soil.

9. **SO_2 and Acid Rain:**

It was t found that SO_2 could limit distribution, reproductive success, and capsule formation in mosses. ***Grimmia pulvinata*** was used as an indicator of SO_2 in England. .Acid rains due to SO_2 emissions, can actually improve conditions for ***Pleurozium schreberi*** in some Jack pine (*Pinus banksiana*) forests.

Bog Succession

Peat mosses on the banks of lakes and water bodies extend inwards and grow over the surface of water and form thick mats. This moss mat because of the moisture and humus forms a suitable substratum for the germination of seeds of various species and with time the mosses and herbaceous vegetation is replaced by higher plants.

10. As Rock Builders

Certain mosses growing in association with other plants bring about decomposition of bicarbonate ions and liberate carbon di oxide if the underlying rock is rich in calcium. This precipitates as calcium carbonate around the plants which gradually hardens. These deposits continue to grow and are used as building stones.

9.6.2 Economic Uses of Bryophytes

Peat Formation

Sphagnum and other mosses are the chief constituent of Peat. Peat is the partially decomposed plant material in the bogs which is gradually compressed and carbonized under pressure of the overlapping deposits of decaying material. This is hardened by the weight of fresh deposits in due course of time and attains considerable thickness .The compact, partially decomposed and carbonized dead plant deposits are called peat, and used in various ways.

Cleaning Agent

Bryophytes have been used for cleaning up toxic wastes. At some places sewage waste has been diverted through peat land for cleaning as well as to clean up factory effluents containing acid and toxic heavy metal discharge, detergents, and dyes. Microorganisms have also been removed by ***Sphagnum*** perhaps due to the antibiotic properties of the peat.

In Horticulture

In horticulture practices bryophytes have been used traditionally as soil additives for, ground cover, as wll as for dwarf plants, greenhouse crops, potted ornamental plants, and even for seedling beds. ***Sphagnum*** is used in making small poles to support climbing plants and moss-filled wreaths. Other horticultural uses of bryophytes include making baskets and covering flower pots and containers for floral arrangements. Wet ***Sphagnum*** is used typically for shipping live plants.

Mycorrhizal Association

Cryptothallus mirabilis,s a colourless bryophyte that lives at the expense of mycorrhizal fungi It is observed that the association of bacteria with moss is necessary before the bud induction. The association of bryophytes with bacteria is attributed to the capability of bryophytes to retain moisture.

As Medicine

Sphagnum was used as a surgical dressing during world war I. ***Sphagnum*** is superior to cotton dressings in a number of ways. It absorbs three to four times liquid and three times faster, necessitating less frequent change. It is also cooler, softer less irritating and retards bacterial growth.

Bryophytes are traditionally used in North America, Europe, China, and India as herbal medicine to treat illness of cardiovascular system, bronchitis, skin diseases, burns, boils bruises and external wounds.

About 30-40 species of bryophytes are used as herbal medicine. Chinese people used ***Fissidens*** sp. as an antibacterial agent for swollen throats and other symptoms of arterial infections. ***Marchantia polymorpha*** is used to treat liver ailments like jaundice and externally to reduce inflammation. The Chinese also use ***Polytrichum commune*** as a detergent diuretic, laxative and hemostatic agent.

In India, people of Kumaun Himalaya used ***Marchantia polymarpha*** and ***M.palmata*** to cure boils, abscesses and to reduce pus formation, while paste of ***Riccia*** sp. is applied on the ring worm disease of skin. Simlarily ***Plagiochasma appendiculatum*** is used for treating skin disease by Gaddi tribe in Kangra Valley.

Anti-tumor Properties

The extracts of ***Polytrichum juniperinum*** had anticancerous activity against Sarcoma 37 in mice.

Several compounds, like, Marchantin from ***Marchantia palacea, M. plymorpha,*** and ***M. tosana,*** show cytotoxic activity.

Medicinal uses of some bryophytes

Species	Physiological activities and effects
Concephalum conicum	Antimicrobial, antifungal, antipyretic, antidotal activity, for cuts, burns, fractures, poisonous snake bites, gallstones.
Marchantia polymorpha	Antipyretic, Antiseptic, antidotal, diuretic activity, for cuts burns, poisonous snake bites, open wounds.
Bryum argenteum	Antidotal, antipyretic, antithinitic, for bacteriosis
Ditrichum palladium	For convulsions, convulsions of infants.
Leptodictyum riparium	Antipyretic, uropathy.
Mnium cuspidatum	For haemostasis, external wounds, epilepsia.
Rhodobryum giganteum	Antipyretic, diuretic, cuts, antihypertension, for sedative cardiotherapy, expansion of blood vessel of heart.

Production of useful compounds

Ther are about 25 monoterpenes, 172 sesquiterpenes, 44 diterpenoids, 33 steroids and several other compounds have been reported from liverworts. Recent studies indicate that most of the hepaticopsids contain mainly lipophilic mono sesqui-diterpenoids, aromatic compounds and acetogenins which constitute the oil bodies. The biological activities of bryophytes are mainly due to the presence of these compounds.

Bedding, stuffing and caulking:

In ancient times (A.D 90 to 120) people covered the floors of some of the buildings with thick layers of fern straw and mosses. Eighty five per cent mosses belonged to two species ***Hylocomium splendens*** and ***Rhytidiadelphus squarrosus***. Ancient man also packed mosses between the wall timbers in their house. A very important use of moss was as caulking material between the planks of boats built by both Bronze Age and Iron Age man.

Moss Gardens

In Japan, mosses are used in developing gardens instead of grass to prepare lawns. Moss gardens are often associated with Buddhist temples the most famous of which is Kyoto's Kokedera which is also called as mosses temple" ***Pogonatum*** and ***Polytrichum*** species are among the most-often used mosses for gardens. There are some other species also that are used in moss gardens which grow as cushions, creating landscape resembling miniature hills.

Fuel

In Canada there appears to be more energy in native peat deposits than in forests and natural gas reserves. Mosses are important sources of fuel in northern Europe, especially in Finland, Germany, Ireland, Poland, Russia, and Sweden. 25% of the fuel in Ireland is moss-based.

Construction

In countries where bryophytes are common, they have been important constituent in construction of houses, furnishings, boats, and other items and are still used today, especially in construction of log cabins.

Household Use

Mosses are widely used for decoration in store windows and displays, Christmas tree and toy train yards, floral arrangements, and Christmas ornaments.

Clothing

In Germany, ***Sphagnum*** is used to line hiking boots where it absorbs moisture and odor. Women in the villages of Kumaun, India, stuff mosses into cloth sacks to make head cushions (sirona) that also absorb leaking water as they carry water vessels.

As food source

The Chinese consider mosses to be a famine food.

Flavouring

Mosses have been used for flavouring. ***Sphagnum*** contributes to flavour the Scotch whisky. In a drink of wine, ***Marchantia polymorpha*** soaks up the wine and makes a tasty, crunchy treat drink.

9.7 SUMMARY

1. The habit of the bryophyte plant is either thalloid or leafy in nature.
2. In thalloid forms, there is no differentiation into leaf, stem and roots, while leafy forms are differentiated into leaf ,stem and root like structures.
3. Generally bryophytes are world- wide in distribution, but some of the genera or species show restricted distribution and may be endemic.
4. In Indian context, the distribution of bryophytes can be studied by dividing the Indian sub continent into 6 bryo- geographical units.
5. Bryophytes are broadly classified into 3 classes viz. i. Hepaticopsida ii. Anthocerotopsida and iii. Bryopsida. Each class is further divided into a number of orders.
6. Since ancient times, bryophytes are variously used. Ecologically, these plants help in soil formation and conservation, as well as in development of vegetation cover, in succession, as a rock builder, seed bank, pollution indicator etc.

7. Bryophytes are little known for their economic importance. However , they are being used varioully now a days, for example, they are used in peat formation, medicinal use of species of ***Marchantia, Polytrichum*** etc, antibiotic activities against microorganisms, as fuel, food, packing material, in horticulture and moss gardens etc.

9.8 GLOSSARY

Amphibians- Plants that is adapted to live in land and water both.
Antheridium- The male sex organ of the cryptogams.
Antidotal- That related to counteract the harmful effects.
Antipyretic-The drug that reduces fever
Archegonium- The female sex organs of bryophytes, containing the egg inside a cellular jacket.
Archesporium-The first cell generation of sporogenous tissue, or the cell or group of cells from which the spores of a sporangium are ultimately derived.
Bacteriosis- Any infection by bacteria
Boreal- Pertaining to North
Calyptra-A covering developed from the venter of the archegonium in bryophytes, which surrounds the young sporophyte.
Capsule - The part of the sporogonium containing spores.
Cardiotherapy-Treatment of heart diseases
Caulking- A sealing material used to seal joints between heterogenous materials.
Circumboreal- The distribution pattern of organisms around the high latitudes of the northern hemisphere of boreal zone. .
Convulsions- An intense involuntary muscular contraction
Crusts- A solid hard layer on the surface
Cyanobacteria– Photosynthetic prokaryotic microorganisms (blue green algae)
Dichotomous- The state of equal division of the growing point to form two equal branches.
Dioecious- Having unisexual male and female sexual reproductive organs borne on different thalli.
Diploid- Nuclei having double the number of chromosomes (2n).
Diploid generation- The sporophyte.
Diuretic-That increases the frequency of urination
Dorsiventral- An organ having distinct dorsal and ventral surfaces which show difference in colour.
Elaters- Hygroscopic structures helping to disperse spores.
Embryo- Young plant developed within the archegonium from zygote.
Endemic – Restriction of a species or a taxonomic group to a particular geographic region.
Endothecium- The inner layer of a young sporogonium in bryophytes.
Foliose- Having a leafy shoot.
Habit- General form and aspect of a plant.

Habitat- A place or condition suitable for an organism to live in.
Haploid- Having a single set of unpaired or reduced number of chromosomes in each nucleus.
Homosporous- Producing one kind of spores.
Hygrophilous- Plants which need a large amount of moisture for their growth.
Involucres- A protective envelope enclosing the reproductive organs.
Mediterranean- A relatively small region, being restricted to Iberia and Mediterranean coast.
Pan tropical– The distribution pattern of organisms that occur more or less throughout tropics.
Peristome – The ring of hygroscopic teeth round the mouth of mature capsule.
Pharmacology- The study of science of drugs.
Pollution –Contamination of environment by harmful agents.
Prostrate –Trailing on the ground
Protonema–The early filamentous stage produced on germination of the spore in some bryophytes.
Rhizoids- Single or many celled hair like structures for the attachment of gametophyte in bryophytes and perform the function of roots
Sedative-A drug that have a soothing effect
Seta- The stalk of sporogonium in liverworts and mosses.
Sporogonium- The spore producing structure of bryophytes
Terrestrial- Plants living on ground.
Thallose –Having a form of a thallus.
Wreaths-- something intertwined or curled

9.9 SELF ASSESSMENT QUESTION

9.9.1 Fill up the blanks:

(i) The gametophyte of *Riccia* is -------- in habit.
(ii) *Porella* plant represents the ----------- habit
(iii) In *Funaria*, the gametophytic plant body is divided into------, ------,and----
(iv) The leaves are laterally placed in--------.
(v) Indian subcontinent is divided into -------- bryo geographical units.
(vi) The richest bryo-geographical unit is--------
(vii) Scanty rainfall generally occurred in---------.
(viii) The--------- species of liverworts of central India are common with western Himalayan species.
(ix) *Funaria hygrometrica* is known as an ------------------- species.
(x) Bryophyta are divided into -------- classes.
(xi) Class Hepaticopsida is characterised by the presence of--------.
(xii) Mosses are kept in the class---------.
(xiii) Bryophytes include-------- and ----------.

(xiv) The class-------- is represented by maximum number of orders.

9.9.1 Answer Key: (i)- Thallose, (ii) Foliose, (iii) Stem, leaf and rhizoids, (iv) Funaia, (v) Six, (vi) East Himalayan, (vii) Punjab & West Himalayan, (viii) 26, (ix) Cosmopolitan, (x) Three, (xi) Absence of columella, (xii) Bryopsida, (xiii) Thallose & foliose form, (xiv) Bryopsida

9.9.2 State True or False

1. The sporophyte generation is dominant in bryophytes.
2. In Moss, the plant body is differentiated into root, stem and leaves.
3. Bryophytes generally prefer to grow in dry places.
4. In *Funaria* rhizoids are branched and unseptate.
5. The habit of a moss plant is Thallose.
6. *Riccia* is not a leafy form.
7. Bryophytes are amphibians of plant kingdom.
8. Moss protonema is filamentous and branched.
9. Endemic species have world wide distribution.
10. *Funaria* is a weedy species.
11. The richest liverwort territory in India is Eastern Himalaya.
12. India is divided into 5 bryogeographical units.
13. Rajasthan represents the area where the xeromorphic species of bryophytes are found.
14. Bryophyta is divided into three classes.
15. Class Bryopsida includes all mosses.
16. Presence of meristematic zone between foot and capsule is not a feature of class Anthocerotopsida.
17. *Sphagnum* is used as a surgical pads.
18. Peat is formed by compression of *Marchantia*.
19. Anthoceros can increase the fertility of soil.

9.9.2 Answers key:

1. False 2. True 3. False 4. False 5. False 6. True 7. True 8. True 9. False 10. True 11. True 12. False 13. True 14. True 15. True 16. False 17. True 18. False 19. True

9.9.3 Very Short Answer Type Questions:

1. Name a moss used in flavouring the Scotch whisky. (***Sphagnum***)
2. Name a moss used to line hiking boots. (***Sphagnum)***
3. Name the mosses used as pioneers on road banks, helping to control erosion. ***(Barbula, Bryum,*** and ***Weissia***)
4. Name a moss used to make wreaths and crosses. (***Climacium americanum***)
5. Name a moss that in the Himalayan Highlands, shepherds use as chinking in temporary summer homes. (***Actinothuidium hookeri, Anomodon minor)***

6. Name two mosses which are among the most-often used species for moss gardens. ***(Pogonatum*** and ***Polytrichum***)

   Name a species which is used for treatment of fractures and poisonous snake bites. (***Concephalum conicum***)
7. Name a species whose extract had anticancer activity against Sarcoma 37 in mice. (***Polytrichum juniperinum*)**
8. Name the species that people of Kumaun Himalaya used to cure boils, abscesses and to reduce pus formation. ***(Marchantia polymarpha*** and ***M. palmata***)
9. Name a species whose paste is applied on the ring worm disease of skin. (***Riccia)***
10. Name a colourless bryophyte that lives at the expense of mycorrhizal fungi. (***Cryptothallus mirabilis***)
11. Name a moss which is used in making small poles to support climbing plants. ***(Sphagnum)***
12. Name a moss which is the chief constituent of Peat ***(Sphagnum)***
13. *N*ame a moss which is a SO_2 indicator in England. (***Grimmia pulvinata***)
14. Which moss is a reliable indicator of acidic conditions. (***Sphagnum***)
15. Name the mosses which signal less nitrogen, at least in Iceland. (***Pogonatum alpinum*** and ***Pogonatum urnigerum***)
16. Name a moss which .is being used to monitor the thickness of the ozone layer over Antarctica. (***Bryum argenteum***)
17. Name a moss which has a role of soil binder. (***Polytrichum juniperinum***)

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9.12 TERMINAL QUESTIONS

1. Give a brief account of the classification of bryophyte.
2. Describe the characteristic features and classification of liverworts.
3. List the salient features of class Hepaticopsida and Bryopsida.

4. Differentiate between the class Hepaticopsida and Anthocerotopsida.
5. Describe the habit of the liverworts and mosses.
6. Give an account on the distribution of bryophytes in India.
7. How are bryophytes useful in soil formation, soil conservation and succession?
8. Give an account on the role of bryophytes as pollution indicators.
9. What are the medicinal uses of bryophytes?
10. What is Peat? Describe importance of peat.
11. Describe the antibiotic activities of bryophytes.
12. What is a moss garden? Describe.
13. Discuss the role of bryophytes as food, flavouring agent and clothing.
14. Describe the role of bryophytes in construction and horticulture.
15. Describe the anti tumor properties of bryophytes.

UNIT-10-CLASSIFICATION, STRUCTURE AND REPRODUCTION IN HEPATICOPSIDA

10.1- OBJECTIVES

After reading this section you will know:

- What are hepatics?
- Systematic position of *Riccia* and *Marchantia*
- Thallus structure of *Riccia* and *Marchantia*
- Structure and development of sex organs
- Development and structure of mature sporophyte of *Riccia* and *Marchantia*
- Difference between *Riccia* and *Marchantia*

10.2-INTRODUCTION

In the previous unit you have studied the characteristic features of the bryophytes. This group includes non - vascular cryptogams in which zygote divides mitotically and develops embryo. Sporophyte (Embryo) depends on gametophyte for nutrition and support. These are the **amphibians of the Plant Kingdom**.

The name Hepaticopsida has been derived from the Latin word *Hepatica*, which means liver. In the Medieval period these plants were used in treating liver disorders, hence the members of this class are commonly known as hepatics or liverworts.

In India, liverworts are widely distributed in the Himalayas. They flourish in heavy rainfall areas. The number of species and individuals of a species are directly proportional to the amount of rainfall.

10.3- GENERAL CHARACTERS OF HEPATICOPSIDA

The class includes 6 orders, about 280 genera and 9,500 species. The characteristic features of the group are as follows:

(1) The main plant body is gametophyte which is independent, dorsiventral and thalloid or foliose.

(2) In thalloid forms, the plant body is prostrate, lobed and dichotomously branched. In foliose forms central axis bears leaf like structure in 2 or 3 rows. These flat leaf like structures.

(3) The ventral surface of the thallus bears many unicellular, unbranched, smooth walled and tuberculate rhizoids and scales.

(4) The anatomy of the gametophyte is either simple or composed of various tissues. Photosynthetic cells contain numerous chloroplasts without pyrenoids.

(5) The sex organs occupy dorsal or terminal position on the thallus. They develop from a single superficial cell. In thalloid liverworts, the sex organs are either embedded in the

thallus (e.g., *Riccia)* or are stalked (e.g., *Marchantia*). In foliose forms, they are always stalked.

(6) The sporophyte may be simple, represented by capsule only (e.g., *Riccia*) or differentiated into foot, seta and capsule (e.g., *Marchantia)*.

(7) In each case the sporogenous cells develop from the endothecium. The sporogenous tissue either forms only spore mother cells (e.g., *Riccia*) or becomes differentiated into fertile spores mother cells and sterile elater mother cells (e.g.,*Marchantia*, *Pellia*).

10.3.1- *Riccia*

10.3.1.1 Classification:

Division-**Bryophyta** (i) True roots are absent (ii) Presence of multicellular antheridia and archegonia (iii) Vascular tissue is absent. (iv) Embryo stage is present in the life cycle.
Class-**Hepaticopsida** (i) Rhizoids unicellular (ii) Chloroplasts without pyrenoids (iii) Capsule lacks columella

Order**- Marchantiales** (i) Presence of scales (ii) Occurrence of two types of rhizoids

Family- **Ricciaceae** (i) Air pores are simple, (ii) Sex organs are present in the mid- dorsal groove, (iii) Sporophyte composed of capsule only, while foot and seta are absent, (iv) Almost all cells of sporogenous tissue form spores. Elaters are absent

Genus - ***Riccia*** (i) Scales on the margins, (ii) Assimilatory filaments are unbranched and vertical

There are about **130 species** in this genus, which are widely distributed in both tropical and temperate regions of the **world**. The thallus grows predominantly on damp soil, moist and shady rocks. *Riccia fluitans* is an aquatic species floating on stagnant or slowly running water. About **33 species** of *Riccia* have been reported from **India**. The species have been recorded from the hills as well as from plains. *Riccia billardieri* occur up to an altitude of 900 meters in East and Western Himalayas. *R. fluitans,* an aquatic species is reported from different part of **Uttrakhand.** *R. pathankotensis, R. discolor, R. melamspora*, *R. robusta* and *R. cruciate* are endemic to India.

Gametophyte

10.3.1.2 External structure of the thallus:

The gametophyte is flat, prostrate, rosette like, dichotomously branched and dorsi-ventral structure which is deep green in colour and occur on miost places or damp soil. The branches of thallus are linear to wedge shaped. In terrestrial forms, the plant usually takes a typical **rosette form** due to presence of several dichotomies close to each other (Fig.10.1). The thallus is approximately 5-7 mm in length and 1-3 mm in width. A longitudinal **groove** is found on the dorsal side of each branch of the thallus. Each branch of the thallus has a midrib on the dorsal surface (Fig.10.1). It usually extends from the base to the tip of the thallus. The midrib ends in a depression, known as **apical notch**. The growing point is situated in this notch. The ventral surface of the thallus bears a row of the **one celled thick scales**. The **scales are pink or violet**, multicellular and arranged in a single row along the margin of the thallus (Fig.10.3). Their pink or violet color is due to the presence of **anthocyanin** pigments. In the apical region, scales overlap each other and protect the growing point. **The degree of persistence and size of the scales is dependent upon the habitat**. Thallus growing in moist terrestrial habitats usually have small and ephemeral scales, whereas those of dry habitats have large and persistent scales. In *R. crystalline* the scales are either absent or rudimentary. The rhizoids are also found on the ventral surface of the thallus. The rhizoids help in anchorage and absorb the nutrients and water from the substratum, this way they perform the function of the roots. The rhizoids are of two types: (i) **smooth walled rhizoids**, their outer as well as inner walls are stretched and smooth, and (ii**) tuberculate rhizoids**, the inner wall of these rhizoids grows into peg like ingrowths (Fig.10.2). In each case the rhizoids are **unicellular and unbranched**.

Fig.10.1 Rosette

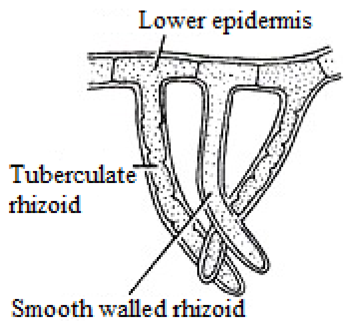

Fig.10.2 *Riccia*: Smooth walled & tuberculated rhizoids

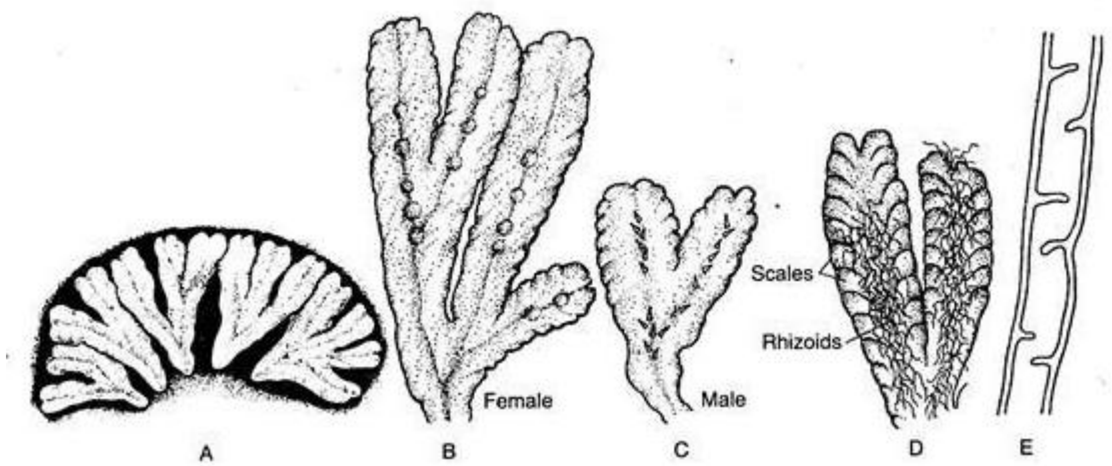

Fig. 10.3, *Riccia*: Gametophytic thalli (A) Female, (B) and Male (C) plants, (D) Ventral surface of same showing scales and rhizoids, (E) Longitudinal sectional view of a tuberculate rhizoid

The aquatic species, *R. fluitans* has long, narrow, flat, light green, ribbon- like, dichotomously branched thallus. It is about 30-50mm in length and 1mm in width. It lacks scales and rhizoids.

Internal structures of the thallus

To study the anatomy of the thallus of *Riccia,* one has to cut the thin transverse section of the thallus. Anatomically, the thallus is differentiated into an upper or **dorsal photosynthetic** and a lower or **ventral storage** region (Fig. 10.3).

a. Photosynthetic region consists of vertical rows of unbranched photosynthetic filaments. All the cells of photosynthetic filament, except the uppermost one, are similar. These cells contain numerous discoid chloroplasts. The terminal cells are somewhat larger and colorless, and form an ill-defined loose and **discontinuous upper epidermis**.

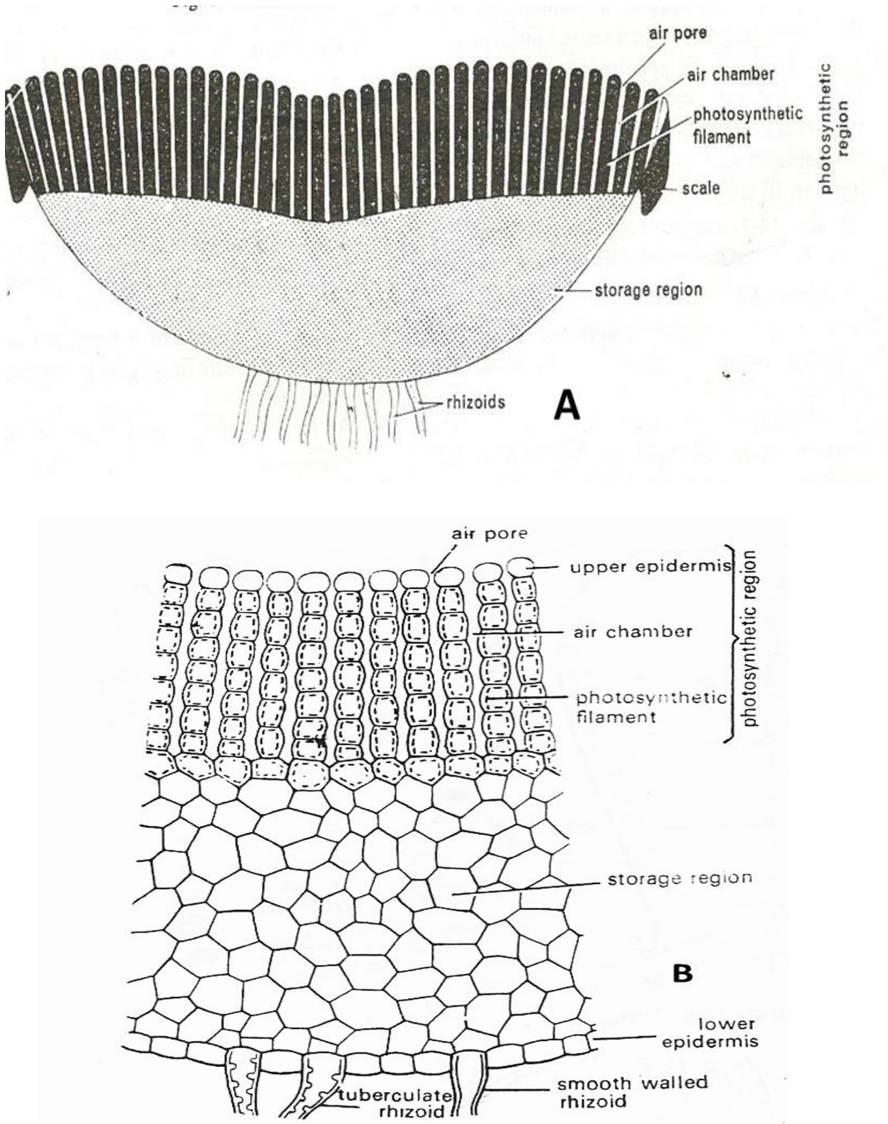

Fig.10.4, *Riccia*: T.S. of thallus A. Diagrammatic (B) Cellular part in detail

The photosynthetic filaments are separated from each other by air chambers. These air chambers open to the exterior through simple air-pores on the dorsal surface of the thallus. These pores help in gaseous exchange. The epidermis is single layered. However, the epidermis is continuous in aquatic species, i.e. *R. fluitans,* but in terrestrial forms each air chamber opens by a very small pore.

b. Storage region: Ventral region of the thallus consists of compactly arranged parenchymatous cells lies below the photosynthetic region. These cells are colorless and intercellular spaces are not found (Fig.10.4).They contain starch as reserve food .The lower rmost layer of the storage region forms the lower epidermis. Some cells of the lower epidermis give rise to unicellular rhizoids and multicellular scales.

Apical Growth: In *Riccia,* the apical growth of the thallus takes place by means of 3-5 or more apical cells. They are arranged in a horizontal row. These cells are situated in the apical notch. The apical cells form derivatives on dorsal and ventral sides alternately. Most part of the thallus is derived from the cells cut off toward the dorsal side. The ventral derivatives of the apical cell form only the lower epidermis, rhizoids and scales.

10.3.1.3 Reproduction

Reproduction in *Riccia* takes place by means of (1) vegetative and (2) sexual methods.

Vegetative reproduction

This type of reproduction takes place by the following methods.

(i) By the death and decay of older parts of the thallus: Thallus of *Riccia* is dichotomously branched. The older parts of the thallus gradually die and the process of death and decay reachs the dichotomy, the young lobes become separated. Each of these by apical growth grows into a new thallus (Fig. 10.5).

(ii) By tubers: It has been reported **that** *R. discolor*, *R. vescata*, and *R. bulbifera*, develop tubers at the apices of the thallus lobes at the end of the growing season (Fig.10.5). Tubers survive during adverse conditions, and develop into new thalli on the approach of favorable conditions.

(iii) By adventitious branches: In several species of *Riccia,* the adventitious branches are produced on the ventral surface of the thallus (Fig. 10.5). These branches, on separation from the parent thallus, grow into new gametophyte.

(iv) By thick apices: In certain species like *R. himalayensis,* at the end of growing season the apex of the thallus grows downward into the soil and become thick. This thick apex survives in the soil and develops into a new plant on the resumption of favorable conditions.

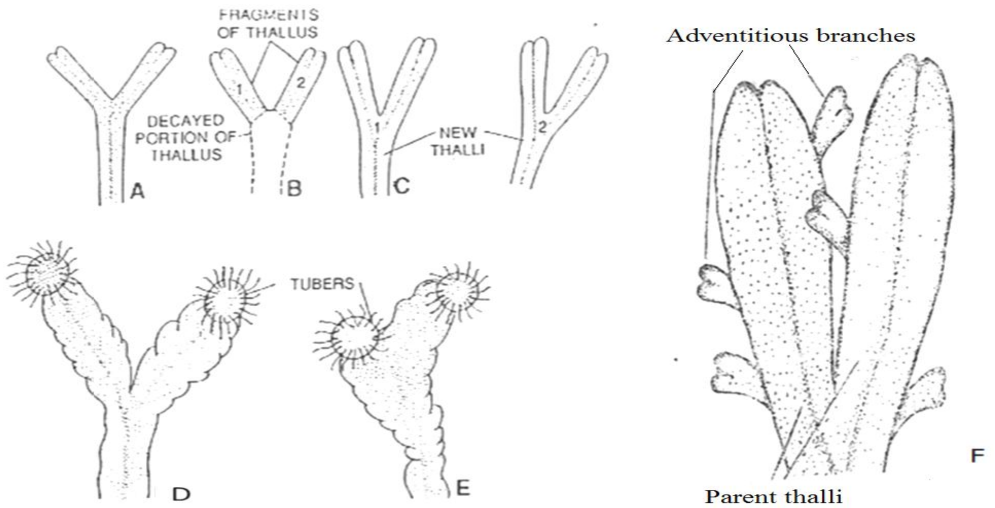

Fig.10.5, *Riccia:* Different modes of vegetative reproduction. A – C. Fragmentation in R. fluitans; D – E. thallus of R. discolor with tubers; F. Riccia thallus with adventitious branches.

Sexual reproduction

Sexual reproduction takes place by means of well-developed sex organs. The male and female reproductive organs are known as **antheridia** and **archegonia,** respectively**.** Most of the species of *Riccia* (e.g. *R. crystalliana, R. cruciate, and R. glauca*) are **homothallic** or **monoecious**, i.e. they bear male and female sex organs on the same thallus. The **heterothallic** or **dioecious** species (*R. discolor, R. frostii and R. personii*) are also common. In such species the antheridia and archegonia develop on different thalli. The sex organs are situated on the dorsal surface of the mature gametophyte in **acropetal succession**, i.e., the mature sex organs are present at the posterior end and younger towards the apex of the thallus. In monoecious species, several alternate groups of antheridia and archegonia occur along the midrib.

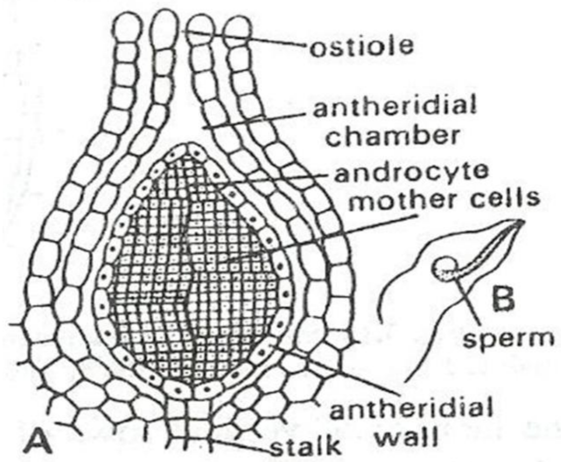

Fig.10.6 *Riccia:* A. Mature antheridium; B. An antherozoid

(a) Antheridium

Structure*:* The mature antheridium is an elongated structure. It consists of an ovoid or pear shaped body seated on a short stalk. Antheridium is attached to the bottom of antheridial chamber by means of its multicellular stalk. Each antheridial chamber opens at the upper surface of the thallus by a narrow porecalled **ostiole.** The body of the antheridium has an outer jacket, made up of single layer of sterile cells. It is called the antheridial wall. The antheridial wall is one cell in thickness and protective in function. It encloses a mass of small, fertile cubical cells called the **androcyte mother cells.** Each androcyte mother cell has a **denser cytoplasm** and a relatively **larger nucleus**. It divides diagonally to form two sperm cells known as the **spermatids or androcytes** (Fig.10.6 A).

The protoplast of each androcyte gets metamorphosed into a single sperm or anthrozoid. In this way several hundred biflagellate sperms are produced in each antheridium. Each **sperm** is a minute, slender, curved structure. It is furnished with a pair of whiplash flagella at its anterior end (Fig. 10.6 B).

Development: Each antheridium develops from a single superficial cell called the **antheridial initial** (Fig.10.7 A). It lies on the dorsal surface of the thallus which is situated two or three cells back of the apical cell. The antheridial initial divides transversely into an **upper cell** and a **lower cell** (Fig.10. 7 B).The lower cell undergoes a few divisions to form the embedded portion of the antheridial stalk. The upper or outer cell, develops into the main antheridium. The upper cell enlarges and divides by a transverse wall into an **upper primary antheridial cell** and a **lower primary stalk cell** (Fig.10.7 C). Both these undergo a **transverse cleavage**. The young antheridium at this stage consists of a row of four cells (Fig. 10.7 D -E).The two lower cells of this row function as the **stalk cells**. They undergo a few further divisions to form the stalk of antheridium. The two upper cells of the row function as **antheridial cells**. Each antheridial cell divides by two successive vertical divisions at right angles to each other forming four cells (Fig. 10.7 F).

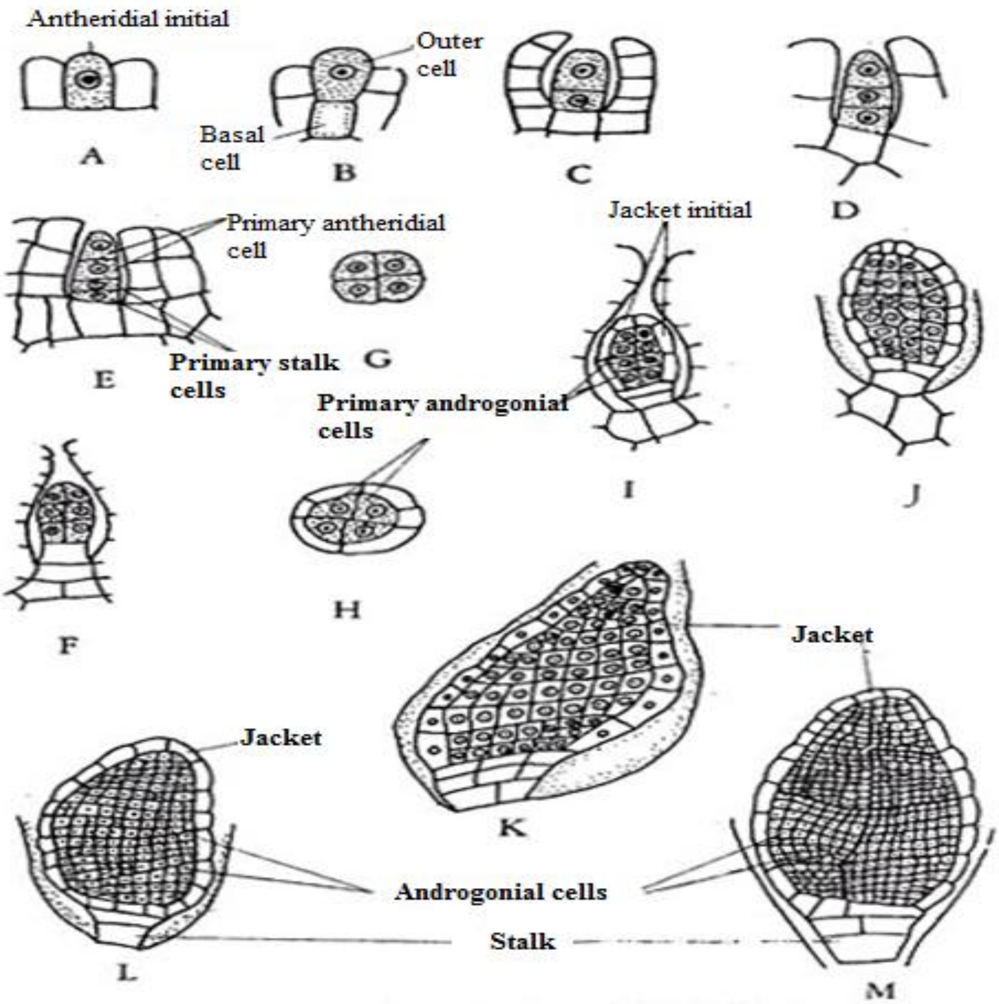

Fig.10. 7, *Riccia:* A-M Stages in the development of the antheridium

The body of the antheridium at this stage consists of two tiers of four cells each. Periclinal divisions now appear in all the cells of both tiers (Fig.10.7 H). The young antheridium is now differentiated into an outer layer of **eight sterile jacket** or **wall initials** enclosing the eight fertile inner cells. The inner fertile cells are called the **primary androgonial cells.** The eight primary androgonial cells divide repeatedly in all possible planes and form mass of **sperm mother cell** or **spermatocytes** or **androcyte mother cell** (Fig.10.7 I-M). Each androcyte mother cell divides diagonally forming two triangular **sperm cells** or **androcytes,** enclosed within a common parent wall (Fig.10. 8 A-F). Each of these gives rise to a minute, biflagellate **sperm.**

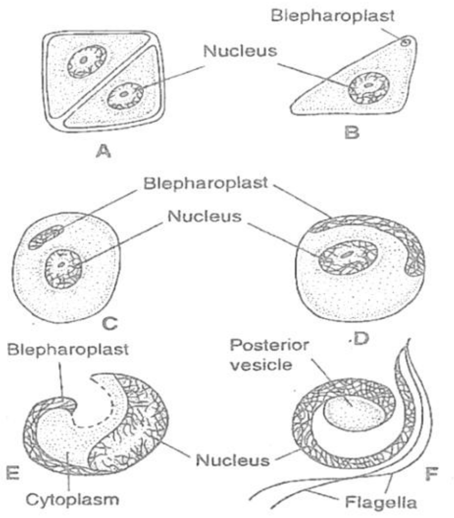

Fig.10.8 ***Riccia:*** **A – F. Metamorphosis of androcyte into antherozoid.**

(b) Archegonium

Structure: Archigonium is a flask shaped organ. It consists of two parts, the basal swollen portion called the **venter** and a long, slender **neck**. Archegonium is directly attached to the tissue of the thallus. There is usually no visible stalk. The neck part encloses **neck canal cells** which are surrounded by a layer of sterile cells (neck cells) forming a protective jacket. The **jacket** or neck cells are arranged in **six longitudinal rows**. Each row is 6-9 cells in height. The tip of the neck is made up of four specialized large **cap** or **cover** or **lid cells** with greater diameter than the neck cells. The **venter** part also has a jacket of sterile cells continuous above with the jacket of the neck. It is **venter wall.** The venter wall is also one cell in thickness. Venter encloses the venter cavity which is filled with two cells, the lower larger **egg cell** (female gamete) and the upper smaller **ventral canal cell**. Each archegonium lies within a cavity. The distal portion of the archegonial neck, projects above the surface of the thallus (Fig.10. 8).

Development: Like antheridium, the **archegonium** also develops from **single dorsal superficial cell**, the archegonial initial which lies close to the apex of thallus. The **archegonial initial** grows and project above the surface of the thallus (Fig 10.9 A). It divides by a transverse wall, separating a lower **basal cell** from the upper **outer cell (**Fig.10.9 B). The lower cell takes no further part in the development of archegonium. The upper cell functions as an **archegonial mother cell**. It enlarges and divides by three successive vertical intersecting walls which separate **three peripheral initials** surrounding **a central axial cell** (Fig.10.9 C). The latter functions as the primary **axial cell**. Each of the three peripheral initial divides longitudinally to form **six jacket initials** or **envelop cells.** At this state a transverse division appears in the six jacket initials and this division differentiates the jacket initials into two tiers of six cells each. The six jacket cells of the upper tier function as **neck initials** and those of the lower tier as **venter initials**. The neck initials divide transversely to form the neck of the archegonium. The neck consists of six vertical rows of **neck cells** with six to nine cells in each row. The venter initials divide repeatedly and eventually form the wall of swollen venter. The **primary axial cell** now undergoes a **transverse division**. This separates an upper **primary cover cell** from an inner **central cell** (Fig.10.9 F). The **primary cover cell** forms a **rosette of four cover cells** by two vertical divisions at right angles to each other. A transverse wall divides the central cell into an upper **primary neck canal cell** and the **primary ventral cell** (Fig.10.9 G). The **former** gives rise to **four to six neck canal cells** by repeated transverse divisions. The venter cell divides transversely into a small **ventral canal cell** and a large **egg cell** (Fig. 10.9 J-K).

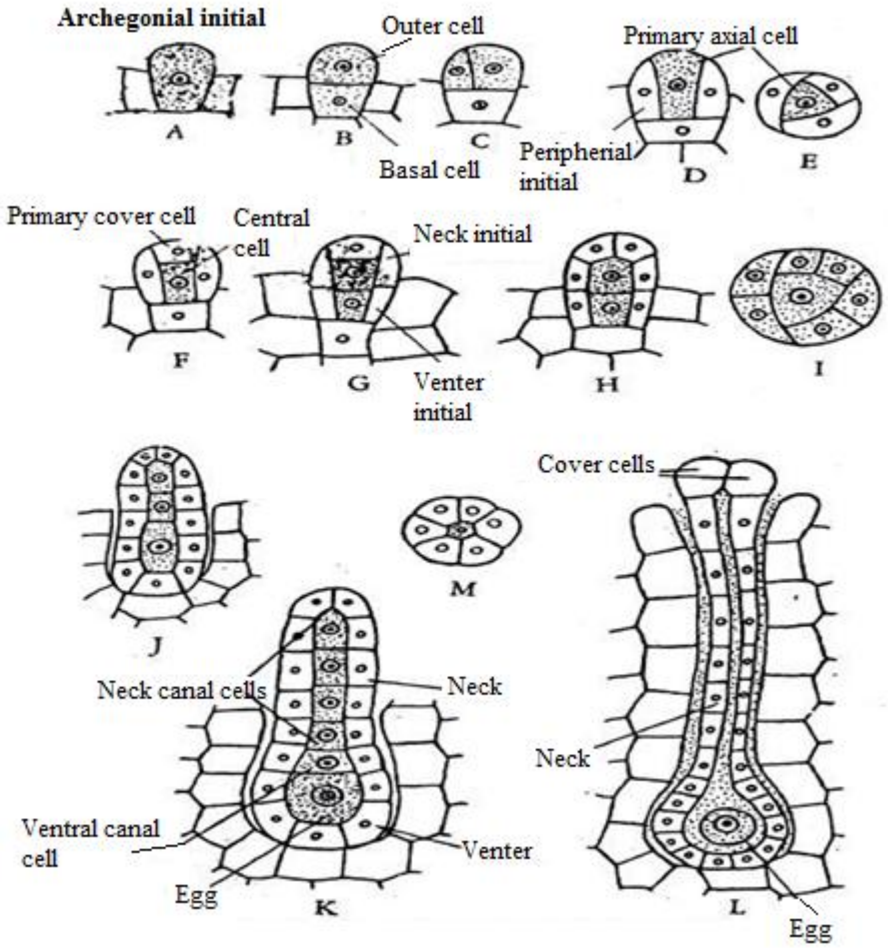

Fig. 10.9 ***Riccia*****: A-L. Successive stages in the development of archegonium**

Fertilization

It takes place in the presence of water. Usually rain or dew water accumulated in the form of a thin layer in the dorsal surface helps in fertilization. Water is essential for (i) the liberation of antherozoids from the antheridium, (ii) the transfer of antherozoids to the archegonium, (iii) disintegration of neck canal cells and venter canal cell.

Presence of moisture is essential for the dehiscence of a mature antheridium. The wall of the anderocytes have dissolved and the sperms lie free in the viscous fluid in the cavity of antheridium surrounded by the jacket layer. Water enters the ostiole. Sterlie jacket cells of the apical region of the antheridium are softened and eventually disintegrate to form a distal **pore**. The antherozoids are thrown out of the antheridium by imbibitional force. Here

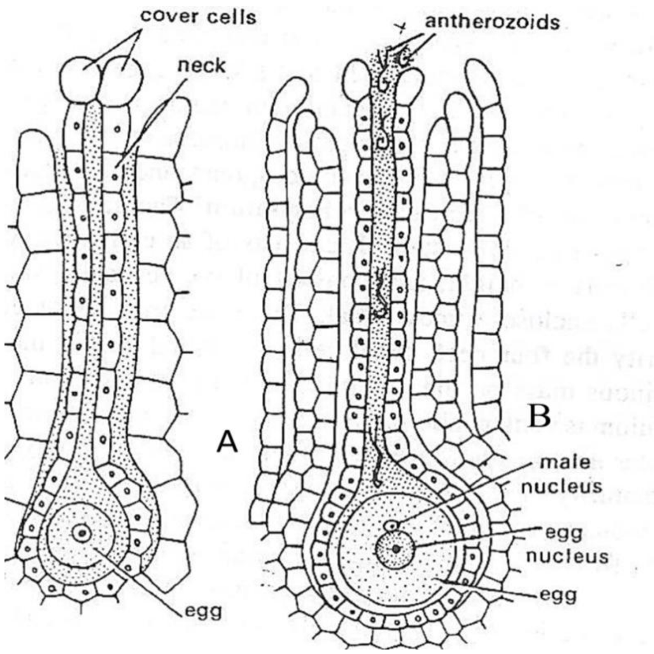

Fig. 10.10 Riccia: A. Mature archegonium; B. Diagram illustrating fertilization

they swim freely in a thin film of water in the dorsal furrow. At the same time the neck canal cell and the ventral canal cell of the mature archegonia degenerate to form a mass of mucilage (Fig. 10.10 A). The mucilage absorbs water and swells. The imbibitional force thus built within the neck results in separation of four cover cells from one another. In this way a passage is formed for the entry of antherozoids in the archegonium. The exuded mucilage contains certain chemical substances such as malic acid, soluble proteins and inorganic salts of potassium which attract the freely swimming antherozoids towards the open neck and then direct them towards the egg (Fig. 10.10 B). This phenomenon of chemical attraction of athrozoids is known as chemotaxis or chemotactic response. Although many antherozoids may enter the neck, usually one, probably the first to arrive, penetrate and fuses with the egg to form a **diploid zygote**. The act of **fertilization ends the gametophytic phase**.

Sporophyte

Zygote is the fusion product formed by the union of sperm with the egg and is the pioneer structure of the sporophytic phase. It secretes a wall around it and enlarges in size. The zygote differs from the unfertilized egg in the following two aspects:

a) Zygote has a diploid nucleus, while egg before syngamy has a haploid nucleus.
b) Zygote has a cellulose cell wall around it and egg is naked.

The zygote lying in the venter undergoes repeated cell division and cell enlargement. The act of fertilization also stimulates the cells of venter wall. They divide anticlinally as well as periclinally and eventually form a two layered calyptra around the young sporophyte. The neck of the archegonium later on withers and disappear.

Development of Sporophyte

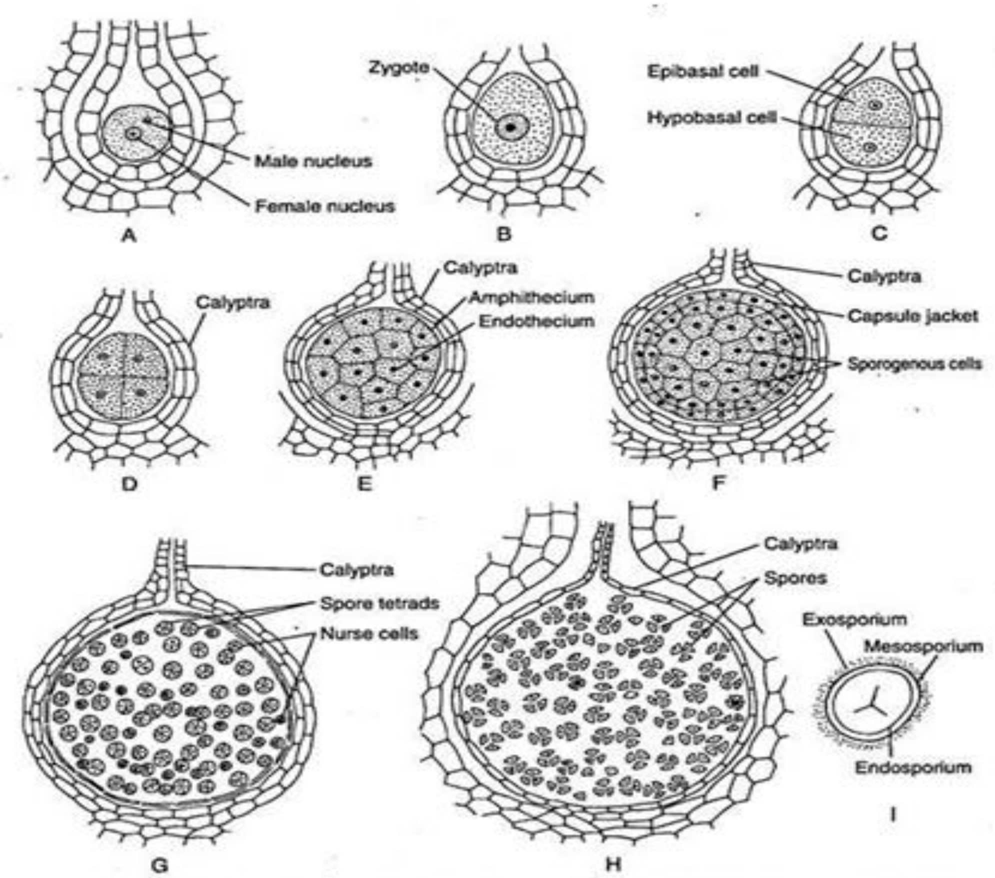

Fig. 10.11 *Riccia:* A-H. Successive stages in the development of sporophyte

The first division of the zygote is by a horizontal wall (Fig. 10.11 C). The next division is at right angles to the first. The young embryo now consists of four cells. It is the **quadrant stage** of the embryo (Fig 10.11 D). Another vertical division at right angles to the preceding one giving rise to an eight celled embryo (**octant stage**). The octant stage is followed by several irregular divisions and a 20 to 30 celled embryo is formed. At this stage in the outermost layer there is a periclinal division and the embryo is differentiated into two regions. The outer layer is **amphithecium** and the inner mass of cells is **endothecium** (Fig. 10.11 F).

The cells of the amphithecium divide only anticlinally and form a **single layered sterile jacket** of the sporogonium. Amphithecium is **protective** in nature. The endothecium behaves as **archesporium** and divides repeatedly giving rise to mass of sporogenous cells. All the cells of the last generation of sporogenous tissue are called the **sporocytes** or **spore mother cells** (Fig. 10.11 G-H). All spore mother cells are fertile and have the potential to form spore tetrads. But in some species of *Riccia* (*R. crystalliana*) a few spore mother cells are supposed to disintegrate to form a nutritive fluid. These are known as the **nurse cells**. Some bryologists consider the nurse-cells as the **forerunners** of the **elaters** of the more advanced members of the Marchantiales.

Sporogenesis is the process of formation of spores from spore mother cell. Spore mother cells increase in size and the diploid nucleus undergo meiosis. This division involves two steps. In the first step, the chromosome number becomes half of the somatic number and in the second step, the two daughter nuclei divide mitotically. After the first step, the wall formation is partial but towards the end of the second step walls are laid down simultaneously around each haploid nucleus. Thus a tetrad of four spores is resulted. In the beginning all the four spores of a tetrad remain adhered to each other and surrounded by a common sheath (Fig. 10.11 I). The spores become separated from each other only on maturation. In *R. crustisii* the spores are united in permanent tetrads even after maturation. The spores are haploid.

Structure of the mature sporophyte

The **sporophyte** or sporogonium of *Riccia* is the **simplest among the liverworts**. It lacks both the **foot** and the **seta.** It is just a **spore sac** or **capsule** spherical in outline, embedded on the dorsal surface of the gametophyte. The spore mother cells are enveloped by a single layered jacket, the **capsule wall**. The capsule has a protective covering of two layered **calyptra** which is a part of the gametophyte. Before the spore mother cells divide to form spores, the single layered wall of the sporangium disintegrates (Fig. 10.12). Later the inner layer of calyptra also break down. The mature spores lie free in a cavity or sac surrounded by the outer layer of calyptra. There are **no elaters**. The mature sporogonium of *Riccia* thus has no diploid or sporophytic structures at this stage. Thus at this stage the **spores** of *Riccia,* which **represents the new gametophyte generation**, are housed in a cavity or sac provided by the parent gametophyte. This is **an anomaly in which the new gametophyte is enclosed within the old gametophyte**.

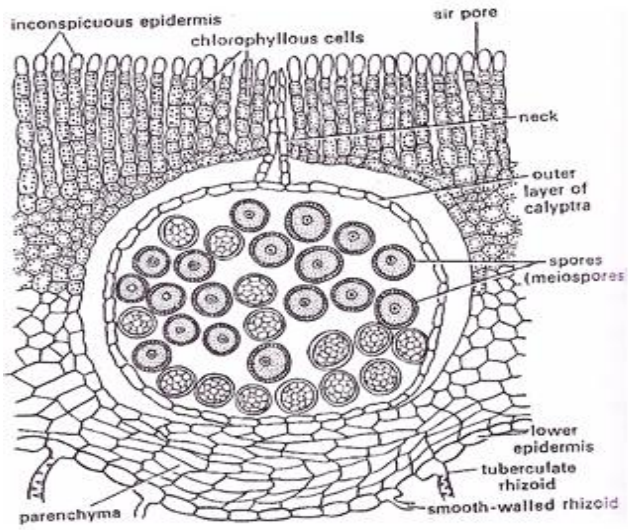

Fig.10.12 *Riccia*: Mature sporophyte or sporogonium

Dehiscence of spore sac

The **capsule** of *Riccia* **never dehisces**. The sporophyte does not have any mechanism for the dehiscence and dispersal of spores. It is primitive as compared to other members of Hepaticopsida. The **spores are liberated by the decay of surrounding outer layer of the calyptra and thallus tissue**. The spores remain on the soil. In this condition they may be **dispersed by the wind**. They remain alive for some time. Finally they germinate with the onset of favorable conditions for growth.

Spore*:* Each spore is uninucleate and haploid structure. The food is largely stored in the form of oil globules. The mature spore is three layered. The outermost cutinized layer is **exosporium**. The middle layer is **mesosporium**, which is thick walled and the innermost homogenous layer is **endosporium.** The endosporium is composed of callose and pectose. The complete spore wall which surrounds the spore is irregularly thickened and protective is known as the **sporoderm**. There is a tri-radiate mark present at one end of the spore, spore wall is thin at this mark.

Germination of spore and formation of young gametophyte

Spore is the first cell of the gametophytic generation (Fig. 10.13A). Presence of moisture is an important and essential factor for spore germination. The exosporium and *the* mesosporium rupture at the tri- radiate ridge and the endosporium comes out in the form of tubular outgrowth, the **germ tube** (Fig.10. 13 B). The germ tube elongates rapidly and forms a club shaped structure. Most of the protoplasm which contains oil globule and chloroplasts has been shifted to the terminal end. A transverse wall appears separating a large, terminal cell at the distal end of the tube (Fig.10.13 C). Meanwhile the **first rhizoid** appears at its base near the point of its emergence from the spore. The large cell at distal end undergoes two vertical divisions at right angles to each other, followed by a transverse division. As a result giving rise to two tiers of four cells each (Fig.10.13 D). One of the four cells of the upper tier becomes an **apical cell** (Fig.10.13 E)**.** This apical cell possesses two cutting faces which regularly cut off cells on the dorsal and ventral sides. These derivatives form a new thallus. As the new thallus grows at the tip of the germ tube, a large number of rhizoids develop from the ventral epidermis of the thallus (Fig.10.13 F-G). In this way new gametophyte of *Riccia* develops completing its life cycle.

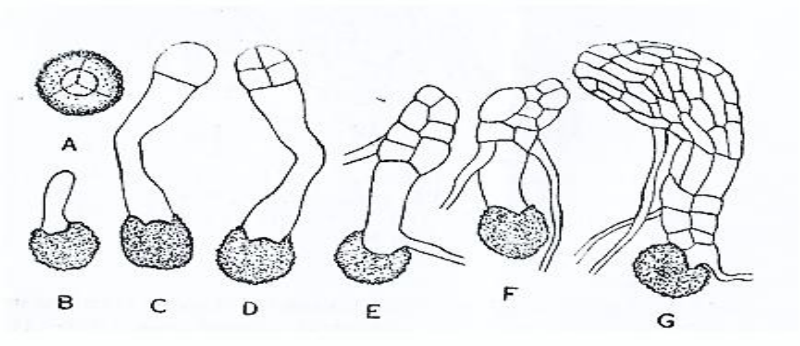

Fig. 10.13 *Riccia,* A- G: Successive stages in germination of spore

10.3.2 *Marchantia*

10.3.2.1 Classification

Division-Bryophyta
Class- Hepaticopsida
Order- Marchantiales

Family-Marchantiaceae i) Sex organs borne on stalked receptacles (ii) Barrel shaped air pores (iii) Elaters present in the capsule

Genus - *Marchantia* (i) Assimilatory filaments branched (ii) Scales ligulate and appendiculate both (iii) Gemma cups present but not semicircular shaped.

Marchantia is a genus of cosmopolitan distribution with about 65 species. About 11 species are known from India occurring in the Himalaya and all the hills in India. The species grow best in cool, moist and shady places. ***M. polymorpha* grows best in the burnt soil**. They commonly grow as a pioneer after the forest fires in the burnt soil. This species reported from **Mukteshwar (Nainital) an altitude of 2175 m on moist rocks**. *M. palmata* reported from Kumaun, Kashmir, Punjab, Assam and South India. *M. nepalensis* reported from **Nainital, Kausani, Ranikhet, Mussoorie, Dhanolti** and Punjab plains. *M. nepalensis* and *M. simlana* are exotic to India. The thalli with gemma cups are found throughout the year, whereas the plants with sex organs occur abundantly during February –March in Himalayas and October –November in the hills of South India.

Gametophyte

10.3.2.2 External structure of the thallus: The thallus of *Marchantia* is prostrate, dichotomously branched and dorsiventral (Fig.10. 14 A). The rhomboidal or polygonal small areas are found on the dorsal surface of thallus which demarcates the outline of underlying air chambers (Fig.10.14 B **).** Each polygonal area has a pore at its center through which the air chamber is connected to the external environment.

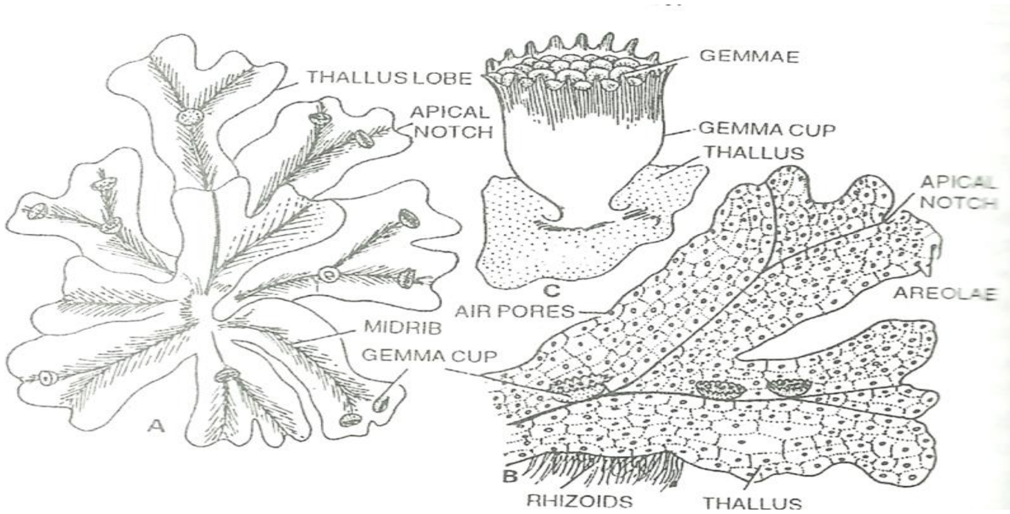

Fig.10. 14 *Marchantia* : A. Thalli showing growth habit; B. Part of thallus; C. Gemma cup on thallus

The apex of each branch of the thallus bears a notch in which the growing point is situated. Each branch of the thallus grows indefinitely by means of growing point. On the dorsal surface of the thallus, the gemma cups are found along the mid-rib. The margins of the gemma cups are smooth or spiny. The **gemma cups** contain the vegetative bodies, the **gemmae** helping in vegetative reproduction as they give rise to new gametophytic plants (Fig. 10.14C).

On the ventral surface of the thallus, on either side of the mid-rib two or more rows of the pinkish, multicellular and one cell thick scales are present(Fig.10. 14 B). Violet color of scales is due to the presence of anthocyanin pigments in their cytoplasm.

The scales in *Marchantia* are of two types: (i) **appendiculate** –these are characterized by having a narrow construction dividing the scale into two parts, the body and the appendage (Fig. 13 B); they usually form the inner row of scales, close to the midrib, and (ii) **ligulate** – these are relatively small without construction and do not have any appendages (Fig. 10.15 A). The primary function of scale is to protect the growing point. Moreover, they also retain some water by capillary action. The **colorless, unicellular and unbranched rhizoids** are found on the ventral surface. There are three or four rows of rhizoids on either side of the midrib. They are of two types: **smooth walled and tuberculate** (Fig.10.15 C - D).The thallus remains attached to the substratum by means of these rhizoids. They help in absorbing water and nutrients.

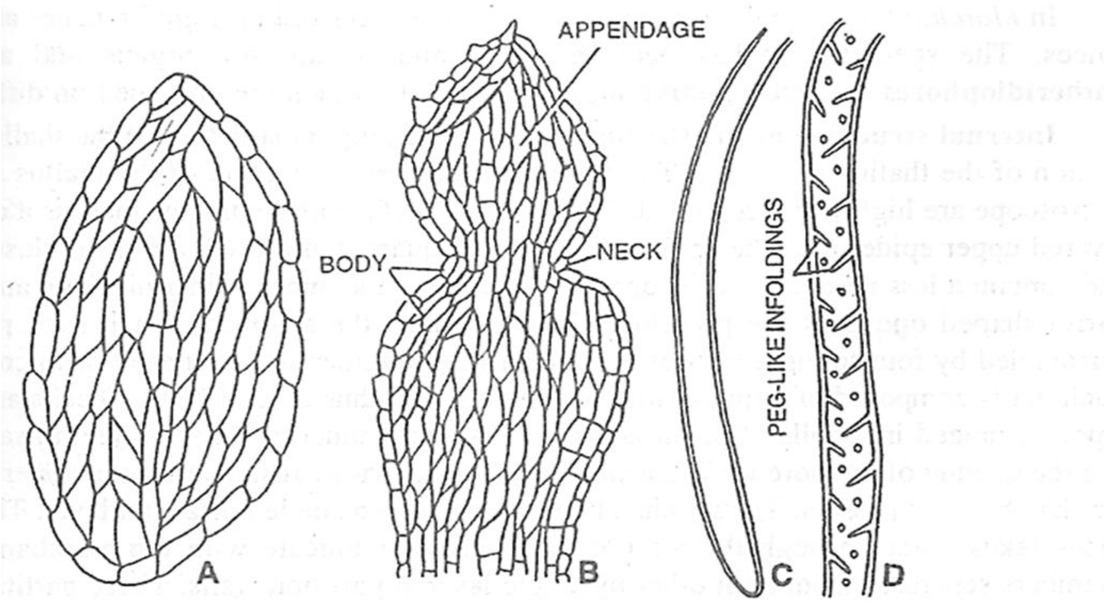

Fig.10.15, *Marchantia*: A. Simple scale; B. Appendiculate scale; C. Smooth walled rhizoid; D. Tuberculate rhizoid.

In *Marchantia,* mature thalli produce special erect and up-right sexual branches at their growing apices. The special branches bear the male and female sex organs and are called the antheridiophore and archegoniophore respectively, which are produced on different thalli.

Internal structure of the thallus: A transverse section of the thallus shows three distinct regions: (i) **epidermal region**, (ii) **photosynthetic region**, and (iii) **storage region** (Fig.10. 15 C - D).

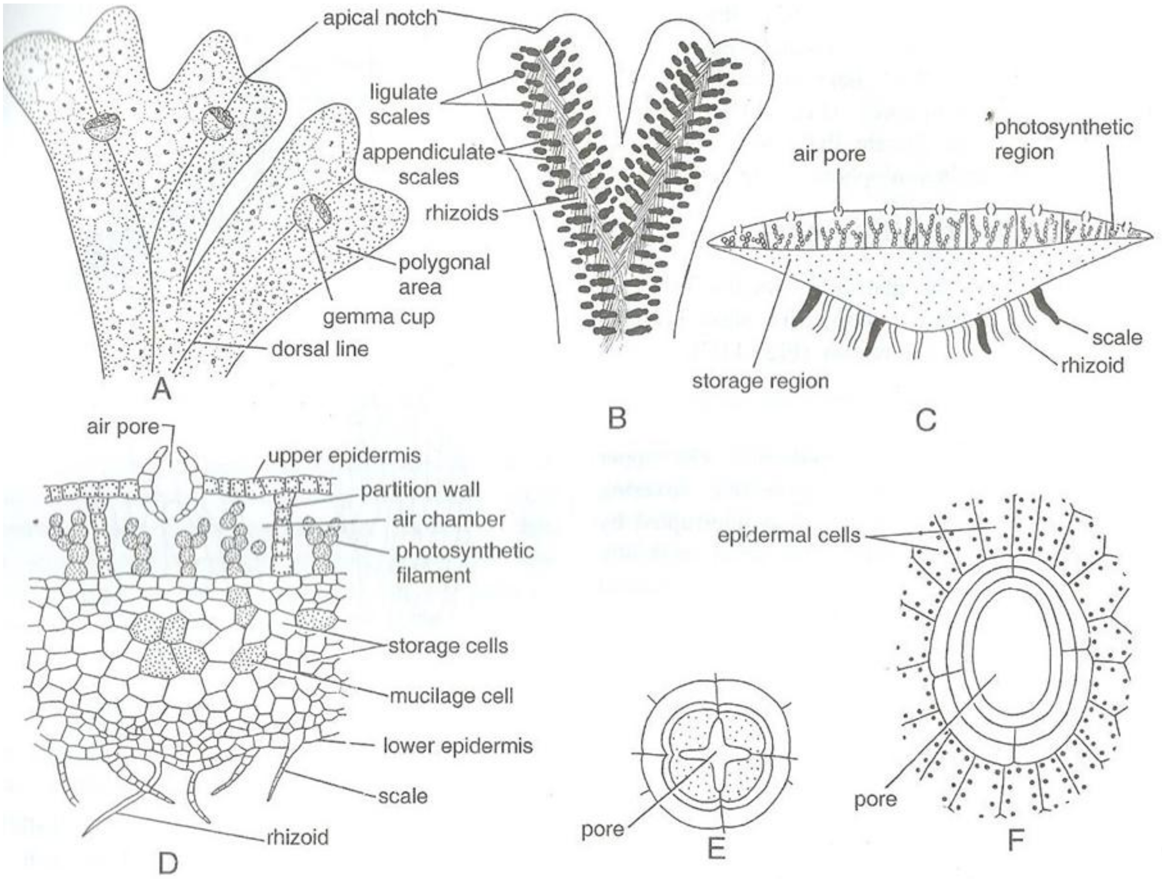

Fig. 10.16, *Marchantia:* A. Dorsal surface of thallus; B. Ventral surface of thallus; C. T.S. of thallus (diagrammatic); D. T.S. of thallus (cellular); E. Air pore as seen from below; D. Air pore as seen from the upper surface.

i. epidermal region: It includes upper and lower epidermis. The upper or dorsal epidermis is single layered, Cells are square, thin walled, arranged close to each other and contain less number of chloroplasts. It is interrupted by many **barrel shaped air-pores** that open internally into air chambers. Each pore is usually surrounded by four to eight super imposed tiers of cells and each tier consists of a ring of four to five cells and thus in total 16-40 cells are there around pore arranged in collar. The cells of the inner most tier project inward in the pores, and **opening of the pore looks star like in its surface view** (Fig.10.16E). Half of the tiers project above the level of the dorsal epidermis and the other half protrude into the air chamber below the epidermis. **Apparently the pore resembles to the stomata of higher plants but the cells around the air-pore do not regulate the opening as guard cells do in the stomata.** The lowermost layer of the storage region forms the lower epidermis. From some cells of this lower epidermis, rhizoids and scales are known to develop.

ii. **Photosynthetic region:** Beneath the upper epidermis are the air chambers. The air chambers are uniform in shape and are arranged in a single horizontal row. Air chambers are formed by the splitting of the cell wall (schizogenously). These chambers are separated from each other by a single layered partition wall. The partitions are three or four cells in height. Each air chamber communicates with the exterior through pore. From the floor of each chamber arise short, simple or branched filaments known as the **assimilatory or photosynthetic filaments**. The filaments are composed of chloroplast containing cells (Fig. 10.16 D).

iii. Storage region: It lies just below the photosynthetic region as a zone of several layers of polygonal parenchymatous cells which usually lack chloroplast and are compactly arranged, no intercellular spaces in between them. It is thickest in the center. Towards the margins it is reduced to 3-4 layers of cells in the thickness. Most of the cells contain starch and protein grains. A few cells are filled with oil bodies and mucilage.

10.3.2.3. Reproduction: *Marchantia* reproduces by **vegetative** and **sexual** methods.

1. **Vegetative reproduction.** The thallus reproduces vegetatively under favorable condition by the following methods:

(a) **By progressive death and decay of older parts of the thallus (Fragmentation):** It is brought about by the ageing of the vegetative cells. It takes place in similar way as we have studied in case of *Riccia*. The aged cells in the basal part of the thallus rot and disintegrate. When this decay of cells reaches dichotomy the two apical lobes or parts of thallus separate and develop into two independent thalli (Fig. 10.17 A-C).

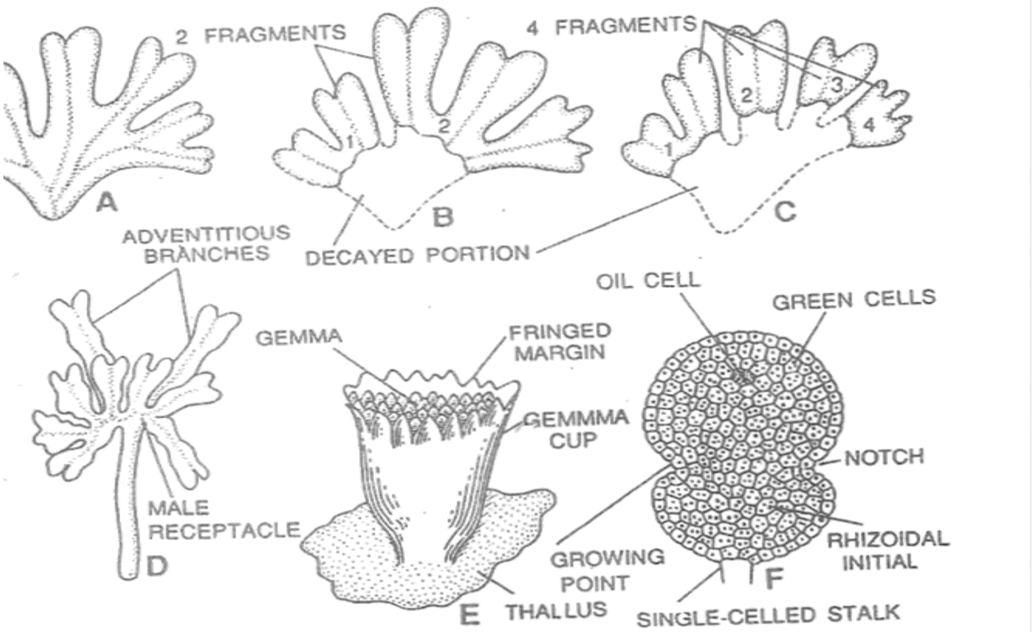

Fig. 10.17 ***Marchantia :*** **Vegetative reproduction: A-C. By death and decay of the older parts of the thallus; D. By adventitious branches; E- F: By gemmae.**

(b) By adventitious branches: These may develop from any part of the thallus particularly from its ventral surface (Fig. 10.17 D). In *M. palmata* development of adventitious branches from the stalk and disc of the female gametophore was reported by Kashyap. These branches when detached from the parent plant by the decay of the connecting tissue develop into new individuals.

(c) By gemmae: The most common method of vegetative reproduction in *Marchantia* takes place by means of especially designed vegetative bodies, the gemmae. The gemmae develop inside little, shallow, cup-like growth with fringed margins, known as gemma cups, present on the dorsal surface of the thallus in the mid rib region (Fig.10.17 E-F).The gemma cup is approximately 2 mm in diameter and 3 mm in height. Each gemma cup contains a large number of gemmae in it (Fig. 10.17 A-D).

Cups are formed a short distance back from the growing point. Each gemma develops from a single superficial cell present on the floor of gemma cup. Any of the superficial cells protrude out from the floor and act as a gemma initial. The gemma initial divides by a transverse wall into a lower and an upper cell. The lower cell does not divide further. It forms the one celled stalk. The upper cell divides further by transverse, longitudinal and periclinal divisions giving rise to the gemma proper. In the beginning the gemma is flat and one cell in thickness, but at the later stage, due to further periclinal divisions, it becomes three or four celled in thickness at the center (Fig.10.18 C).

The gemma at maturity is discoid, biconvex and multicellular structure. It is several cells thick in the median portion and deeply notched on the lateral margins opposite to each other. In each marginal notch lies the growing point. The growing point consists of meristematic cells. All the cells of gemma contain abundant chloroplast and are called the chlorenchymatous cells. There are certain isolated cells, here and there on the gemma, which contain oil in them and called the **oil cells**. Both the surfaces possess isolated, superficial colorless, somewhat larger cells are known as the **rhizoidal cells**. The cytoplasm of these cells is dense and granular. These cells give rise to rhizoids on germination. Some minute **club-shaped mucilage hairs** also arise from the floor of gemma cup. The mucilage secreted by these hairs imbibes water and the imbibitional force thus generated helps in dissemination of gemmae from the gemma cup

The gemmae are bilaterally symmetrical and are not differentiated into dorsal and ventral surfaces. The mature gemmae fall on the ground and if conditions are favorable their germination starts immediately. The surface of the gemma which comes in contact of the soil gives out many rhizoids. This surface eventually becomes the lower or ventral surface of the thallus. From each growing point, a young thallus develops. This way, **two young thalli develop in opposite directions from a single gemma. Eventually, the central part of gemma dies and the two thalli are separated, which grow in opposite directions.**

Sexual reproduction: In *Marchantia*, the sex organs are borne on the special erect stalked branches, called **antheridiophore** and **arhegoniophore** (Fig. 10.19 A-B), respectively. The **sexual branches are apical or terminal in position**.

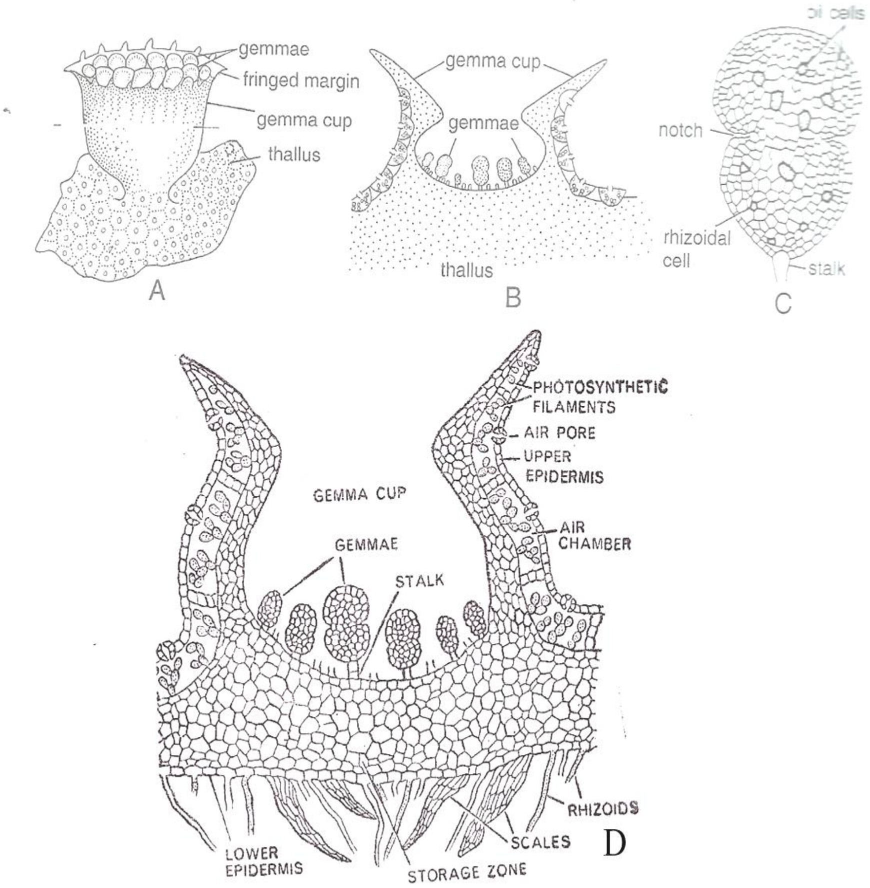

Fig.10.18 ***Marchantia:*** **A. Gemma cup ; B. Gemma cup in vertical section; C. Gemma; D. V.T.S. of thallus passing through a gemma cup.**

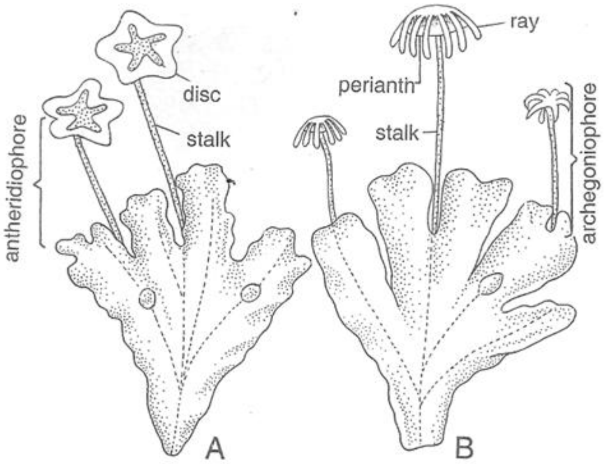

Fig. 10.19, ***Marchantia*** **: A. Antheridiophore ; B. Archegoniophore**

In their formation, the growing points of the lobes are fully utilized, therefore, after the formation of gametophores the vegetative growth of the thallus ceases completely. Thus each upright sexual branch is a direct continuation of the prostrate thallus lobe from which it arises. The thallus like nature of the gametophore is the presence of rhizoids and scales in the groove on the ventral side. The dorsal side of it possesses the air chambers with photosynthetic filament. The development of the reproductive branches depends on several environmental factors. In *Marchantia* the male and female reproductive branches develop on different thalli, *i.e.* **the genus is strictly heterothallic** (dioecious). In some specimens of *M. palmata* and *M. polymorpha,* both antheridia and archegonia have been found on the same receptacle. Such receptacles are known as **androgynophore.**

Antheridiophore: It is 1-3 cm. long stalk that bears a slightly convex 8-lobed peltate disc at its apex. At the tip of each lobe a growing point is situated. Each lobe represents a branch. In certain species, the number of lobes is reduced to four. The rhizoids and scales are present in the grooves situated on the ventral surface of antheridiophore. The internal structure of the peltate disc is similar to that of the thallus. The upper epidermis is interrupted by several barrel shaped air pores. These pores open in the air chambers, containing photosynthetic filament in them. The antheridial cavities or chambers alternate in position with the air chambers. Each antheridial chamber contains a single antheridium and opens externally by a pore, the **ostiole** (Fig. 10.20 A). Antheridia arise in acropetal succession, i.e., the oldest being near the center and young ones towards the margin of the disc.

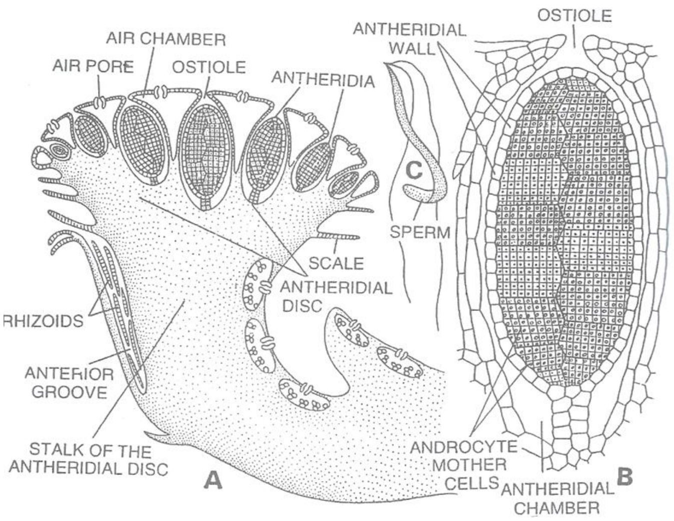

Fig.10.20, *Marchantia*: A. Longitudinal section of antheridiophore with antheridia; B. A mature stalked antheridium; C. A mature biflagellate sperm.

The development of antheridium in *Marchantia* is similar to that of *Riccia.*

Mature antheridium: The mature antheridium is a globular or pear shaped structure, attached to the floor of antheridial chamber by a multicellular stalk (Fig. 10.20 B). The body of the antheridium has a single layered sterile jacket enclosing a mass of anderocyte which eventually metamorphose into antherozoids. Each androcyte mother cell divides diagonally to form two triangular androcyte cells, which are enclosed within a common parent wall. Each androcyte cell metamorphoses into an antherozoid. The antherozoid is a minute rod like biflagellate structure (Fig. 10.20 C). The antherozoid swim in the water with the help of their flagella.

Dehiscence of antheridium: Water collected on the peltate disc or in the rhizoidal grooves of antheridiophore enters into antheridial chambers through the ostiole. Some cells at the distal end of the antheridial jacket disintegrate when they come in contact with water. The antheridial wall thus ruptures and a large mass of androcytes comes out of the ostiole just like a smoke column. The androcytes spread on the surface of the disc, it breaks up into individual androcyte. Very soon, the antherozoids are liberated from the androcytes.

Archegoniophore or carpocephalum: The archegoniophore arises at the apical notch of the female thallus. It becomes specially modified like antheridiophore. It consists of a stalk bearing lobed disc at its distal end. In its external and internal structure the stalk resembles that of antheridiophore. The **stalk of the archegoniophore is slightly longer (2-5 cm) than that of antheridiophore.** The terminal disc, which is formed by three successive dichotomies of the apex of the young archegoniophore, is usually **8-lobed** (7 -9 lobed in *M. nepalensis* and 7-11 in *M. palmata*). The lobes are dorsiventral and a growing point is located at the tip of each lobe.

Position of archegonia on archegoniophore: The archegonia in very young receptacle are borne on the upper surface of the receptacle with their necks directed upwards. They also develop in **acropetal order** i.e., the mature archegonia are towards the center and young ones towards the margin of the disc (Fig. 10.21). There is one row to each lobe and 12-14 archegonia in each row.

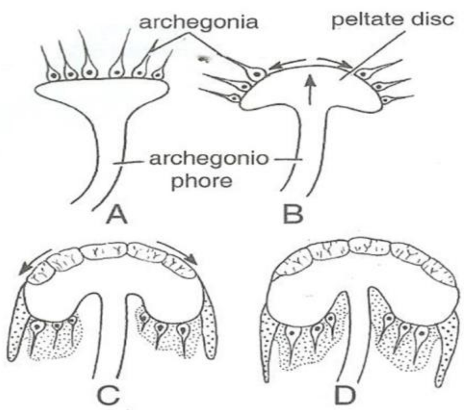

Fig.10.21. ***Marchantia:*** **A. Position of archegonia on archegoniophore before fertilization; B-D. Stages in inversion of archegonia after fertilization**

The archegonia are sub-sessile. The fertilization takes place at this stage. After fertilization the stalk of the archegoniophore elongates and the central portion of the the disc on the dorsal side grows more rapidly than the ventral surface. As a result of this differential growth of the two surfaces, the marginal region of the disc bearing archegonia is pushed downward and inward (Fig. 10.21 C). Consequently thus the archegonia become transferred to the lower surface. In a mature female receptacle they are pendulous, hanging downwards from the under surface of the disc with the youngest now near the stalk (Fig. 10.21 D).The inversion of the archegonia is accompanied by the development of plate like tissue on either side of each row of archegonia. It is the **parechaetium** or the **involucre**. It is a single layer of cells in thickness. Thus in a mature archegoniophore, archegonia of a lobe are separated from those of the adjacent one by perichaetium (Fig.10.22). In the meanwhile from the upper surface or margin of the disc develop long, stout and green finger like projections between the groups of archegonia. These appendages, which are usually nine in number, are known as **rays**. In young stage they give the archegonial disc an **umbrella like appearance**. At maturity they spread widely apart giving the female receptacle a **stellate** or **star shaped** appearance.

The mature female receptacle has the same internal structure as the male. There is the upper epidermis with air pores embedded in it. Beneath it are the air chambers arranged in a single layer. From the floor of the air chambers arise the assimilatory filaments. There are **no pits** alternating with air chambers as are found in the male receptacle.

Development of archegonium. The archegonium arises from a single superficial dorsal cell. It lies just close to the apical cell of each lobe of the female receptacle. It is called the archegonial initial. The archegonial initial enlarges. It then divides into an inner primary stalk cell and an outer primary archegonial cell. Development of archegonium from primary archegonial cell in *Marchantia* is similar as in *Riccia*.

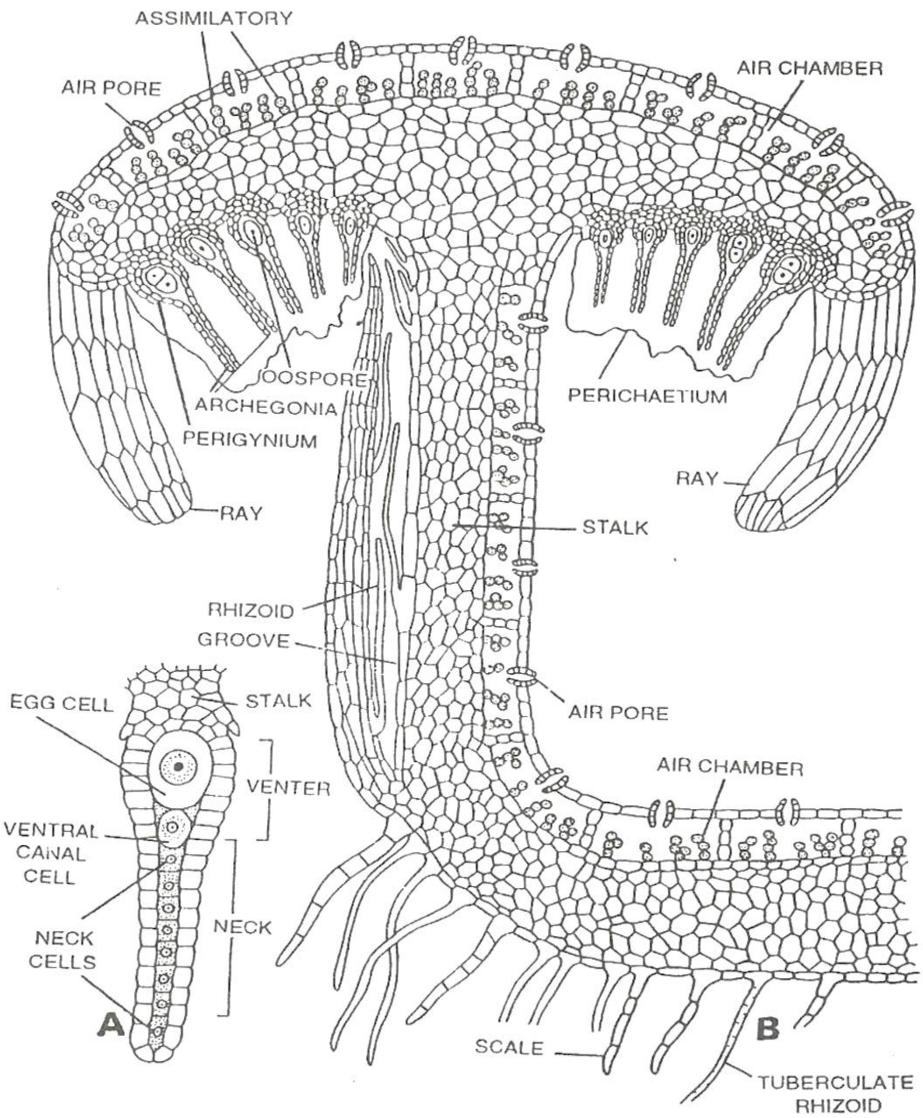

Fig.10.22 ***Marchantia:*** **A. A mature archegonium; B. Longitudinal section of archegoniophore.**

Structure of archegonium: The mature archegonium is pendulous and attached to the ventral surface of the archegonial disc by a short stalk. The archegonium consists of an elongated neck and bulbous venter. The neck consists of six vertical rows of **neck cells,** which encloses 4-8 **neck canal cells.** The venter is surrounded by single layered sterile jacket. It contains a large **egg** and the **ventral canal cell**. The egg is also called **oosphere.** At the top of neck there are four cover cells, which give way for the entrance of the antherozoids at the time of fertilization.

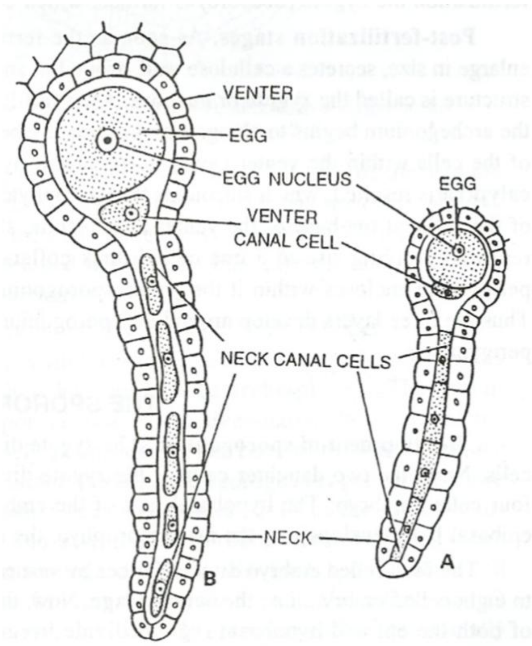

Fig. 10.23 ***Marchantia*****: A. Young archegonium; B. Mature archegonium**

Fertilization

The sex organs in *Marchantia* develop in long receptacles. Most of the species of *Marchantia* are dioecious or heterothallic and receptacles borne on different thalli. These facts present difficulties in the way of fertilization**. Because of uncertainty of fertilization, reproduction by vegetative methods is very common, efficient and effective in** *Marchantia***.** Fertilization is dependent on the presence of water and is possible when the male and female plants grow together. It takes place when the plants are wet with rain or dew. Fertilization takes place at a stage when archegonia are placed upright on the dorsal of the disc of the archegoniophore. Just before fertilization, the neck canal cells and ventral canal cell of the archegonium degenerate and form mucilaginous substance. The pressure built by the imbibition of water by this substance results in the separation of cover cells. Thus a free passage is formed for the entry of antherozoids in the archegonium. The antherozoids , which swim freely on the surface of the antheridial disc, are splashed by rain water on the disc of the archegoniophore. The free-swimming antherozoids are attracted towards the mouth of the archegonium, because of the presence of certain chemicals, which ooze out from the mouth. In other words the antherozoids are positively chemotactic to these chemical substances. Theses chemical substances are certain proteins, malic acid and inorganic salts of potassium. Although many antherozoids may enter the archegonium, only one fuses with the egg. At the time of fertilization the archegonia have their necks directing upward.

Post fertilization stages

The diploid **zygote** (oospore) is the first cell of the sporophytic generation. As soon as the fertilization is over the fertilized egg begins to enlarge in size. secretes a cellulose wall around it, and ultimately fills the cavity of the venter. Immediately after fertilization many changes take place. There is an elongation of the archegoniophore. It is accompanied by the rapid growth of the central part of the archegonial disc that ultimately leads to inversion of archegonia. The act of fertilization stimulates the cells of the venter wall which divide periclinally and give rise to a 2-3 layered **calyptra**. The calyptra forms a protective covering around the young sporophyte. Some of the cells, at the base of the venter also become stimulated by fertilization. These cells divide repeatedly giving rise to a one celled thick collar – like **perigynium** or **pseudoperianth.** Thus three layers develop around the sporophyte, *viz.*, the perichaetium, perigynium and calyptra.

Sporophyte

The zygote enlarges in size and fills the cavity of venter (Fig. 10.25 A). The zygote divides by transverse wall, resulting in an outer **epibasal cell** and an inner **hypobasal cell (**Fig. 10.25 B). The next division is at right angles to the first. The globular embryo at this stage consists of four cells. It is the quadrant stage (Fig. 10.25 C). In *M. chenopoda* and some other species, the second division of the zygote is parallel to the first division and it results in the formation of **3-celled filamentous embryo.** In quadrant embryo, the epibasal cells form capsule and a part of seta, whereas the hypobasal cells form the remaining part of seta and foot. In a filamentous embryo the epibasal cell forms capsule, the middle cell seta and the hypobasal cell develops into foot. The four-celled embryo divides further by vertical wall intersecting at right angles and giving rise to eight celled embryo, i.e., the **octant stage**. Now, the embryo elongates to some extent. The cells of the hypobasal region divide repeatedly giving rise the parenchymatous bulbous mass of the cells, the **foot**.

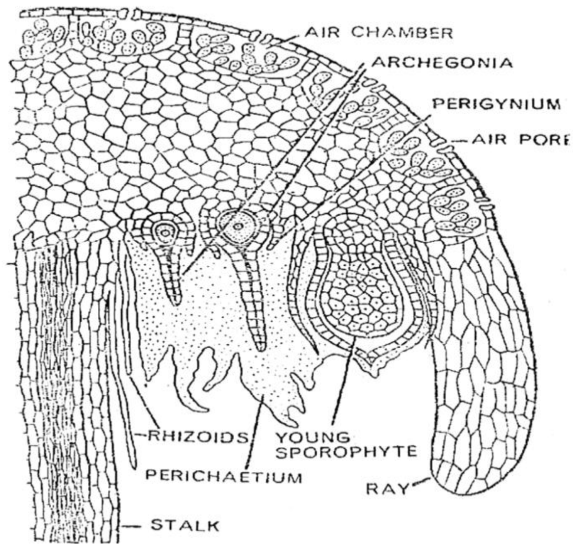

Fig. 10.24, ***Marchantia:*** **Post fertilization changes**

The outermost cells destined to form capsule divide periclinally. Thus a peripheral single layered **amphithecium** becomes distinct from a central many celled **endothecium** (Fig.

10.25 D). The cells of the amphithecium divide only anticlinally and form a single layered wall of the capsule. As the sporophyte matures, the cells of the capsule wall develop annular thickenings. The endothecium develops into the **archesporium.** The cells of this region divide repeatedly giving rise to sporogenous tissue. Initially all cells of this tissue are almost of the same shape and size but subsequently about half of the sporogenous cells, by repeated transverse divisions, forms vertical rows of more or less cuboidal **spore mother cells or sporocytes**. The number of spore mother cells derived from a sporogenous cells varies in different species. In *M. polymorpha* each sporogenous cell undergoes five successive divisions giving rise to 32 spore mother cells, whereas in some other species a sporogenous cell divides 3-4 times forming 8-16 spore mother cells. Each spore mother cell divides meiotically to form a spore tetrad. Half of the or remaining sporogenous cells which do not divide become elongated and give rise to sterile **elaters**. The elaters are tapering at both the ends and possess spiral thickening on their walls. The elaters are diploid cells and they have many spiral thickening bands. They are hygroscopic in nature and their coiling and uncoiling movements help in scattering of the spores. In *Marchantia polymorpha* to each elater there are 32 sporocytes, which give rise to 128 spores. This way, there are 128 spores to each elater. Cells destined to form seta divide slowly and simultaneously forming a short structure connecting foot and capsule. Cells of seta are arranged in vertical rows with the formation of spore tetrad in capsule, seta elongate slightly.

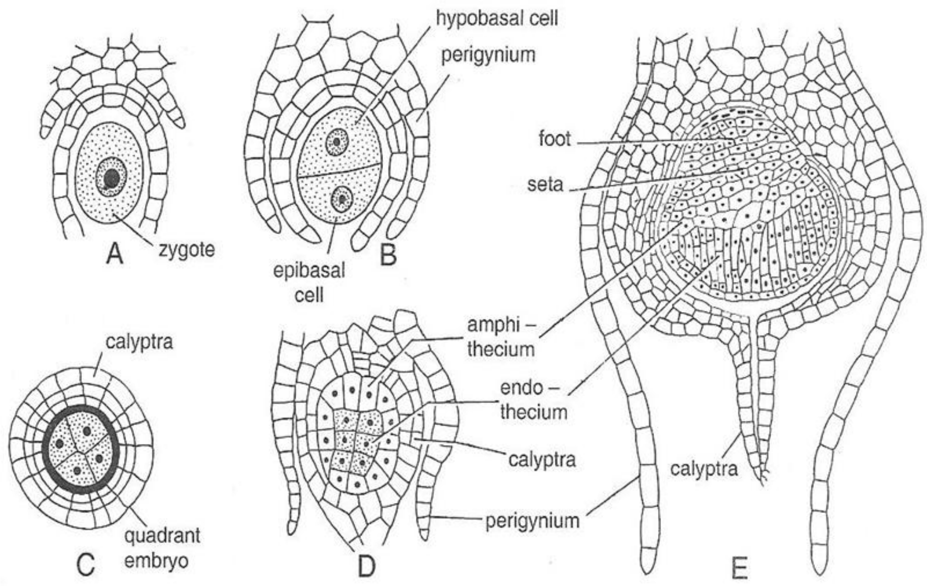

Fig. 10.25, *Marchantia:* Successive stages in the development of sporophyte

Structure of mature sporophyte

The sporophyte of *Marchantia* is differentiated into **foot, seta and capsule** (Fig. 10.26 A).

1. **Foot.** This is the bulbous part which penetrates the disc of the archegoniophore and composed of parenchymatous cells. The foot also absorbs nutrition from the gametophyte.

2. **Seta.** It is a short and stout stalk that connects foot to the capsule. It is made up of parenchymatous cells. As the capsule matures, these cells undergo repeated transverse divisions and elongation. Thus the seta increases in length, and pushes the capsule out of the three layers, the calyptra, perigynium and perichaetium. At maturity, the cells of seta become vacuolated.
3. **Capsule.** The mature capsule is yellow colored oval structure. It is covered by a single layered jacket and has annular thickening bands. The capsule contains spores and spindle shaped, sterile and hygroscopic elaters (Fig. 10.26 C).

The spores are small and spherical. They range from 12-30µ in diameter. Each spore is covered by two layers. The outer thick layer of the spore is exospore and the inner relatively thin endospore (Fig. 10.26 B). In some species an additional layer, known as **perisporium,** is present outside the exospore. The spore contains vacuolated granular cytoplasm with a distinct haploid nucleus. *M. polymorpha* has approximately 3, 00, 000 spores per capsule.

Dehiscence of capsule

With the ripening of spores there is slight elongation of the seta. The capsule breaks through the calyptra. It projects beyond the perigynium and the perichaetium. The single layered capsule wall then splits and open along **four to six** lines. Each split starts from the apex to about the middle of the capsule (Fig.10.27 A). The annular thickening in the jacket cells cause the valve to roll backward exposing the spores and elaters. The jerky movements of the elaters, due to their hygroscopic nature, assist in the loosening up of the spore mass and scattering the spores in the air.

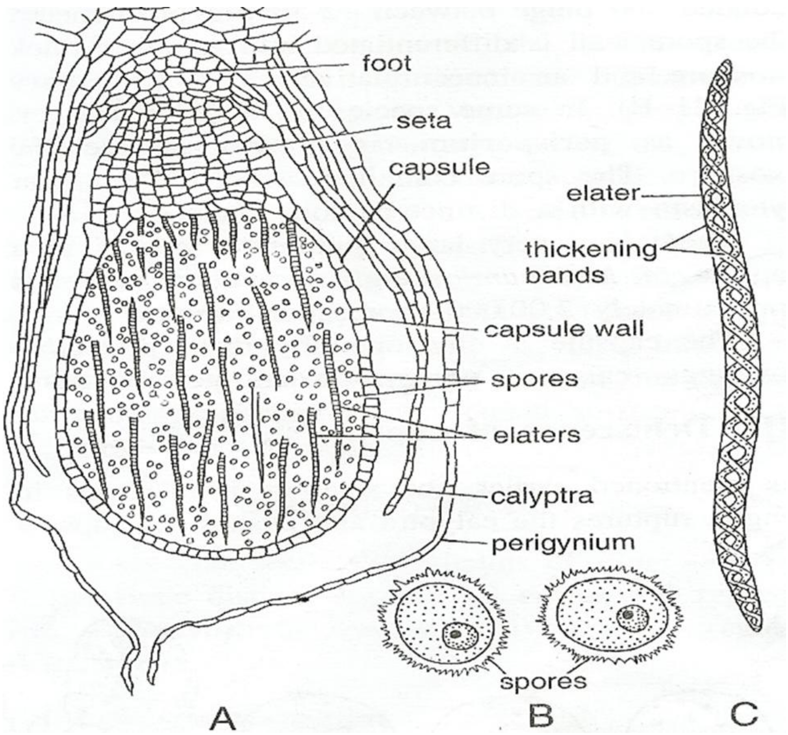

Fig.10.26, ***Marchantia*** **: A. Mature sporophyte in longitudinal section; B. Spores; C. Elater.**

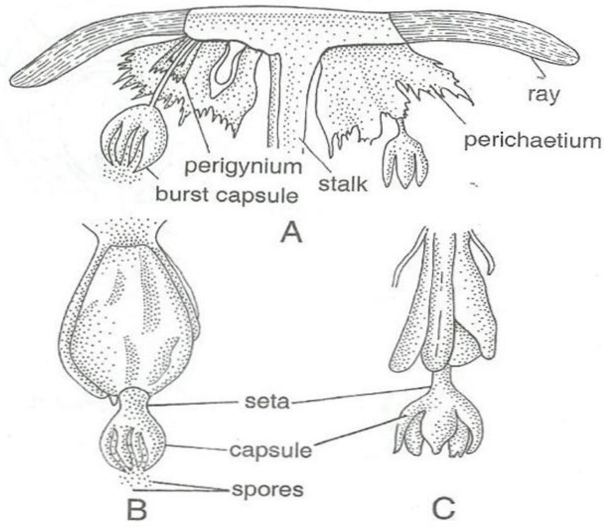

Fig. 10.27, *Marchantia*: A. V.L.S. of archegoniophore after the formation of capsule; B-C. Dehiscence of capsule

Germination of spores

The spores of *Marchantia* remain **viable for about a year**. If the conditions are favorable they absorb moisture from the substratum and germinate immediately. The increase in size of the spore's protoplast accompanied by the reappearance of chlorophyll. The germinating spore immediately produces a long irregular filament of 6 to 8 cells. At the apex it is two celled wide. One of the cells act as an apical cell with two cutting faces. This cell cuts alternatively 5 to 7 segments both on right and left faces and contribute to the development of a new thallus (Fig. 10.28 A-G). *Marchantia* is a dioecious plant. Two spores of a tetrad grow into male and the other two into female thalli.

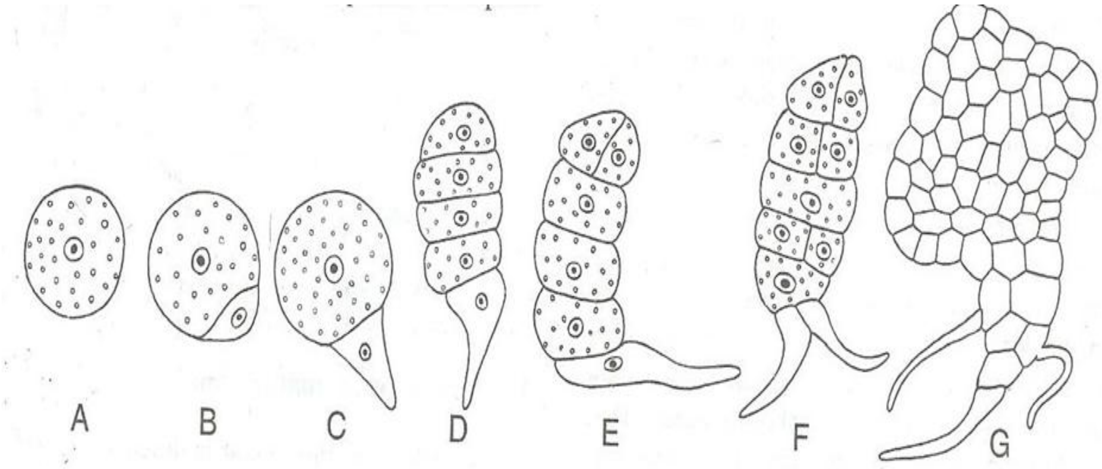

Fig. 10.28, *Marchantia*: Successive stages in the germination of spores

10.4 SUMMARY

The life cycle of **Hepaticopsida** consists of two phases: (i) Gametophye (ii) Sporophyte. Total number of species of Riccia is about 130 of which about 33 are reported from India. *Marchantia* with about 65 species and 11 are reported from India. In *Riccia*, the sporophyte is the simplest known among the Hepaticopsida. It is simply a sac of spores and incapable of nutrition. On the other hand the sporophyte of *Marchantia* is complex one and also completely dependent on the gametophyte for its nutrition. There is gradual and progressive sterilization of the fertile cells of the sporogenous tissue in the sporophyte.

The differences between *Riccia* and *Marchantia* are as follows:

S. No.	***Riccia***	***Marchantia***
1 (i) (ii)	Scales arranged in single row, near margin Scales are one type (ligulate)	Scales arranged in two to four rows on each side of the midrib, Scale are of two types, ligulate and appendiculate.
2	Gemma cups are absent.	Gemma cups are present on the dorsal surface of the thallus
3	Pores simple and narrow vertical air chambers, photosynthetic tissue consist of chlorophyll containing one cell thick photosynthetic unbranched filaments.	Pores compound, composed of 4 to 8 superimposed tiers of cells, each tier consists of 4-5 cells, single horizontal layer of air chambers separated by partitions, the photosynthetic tissue consists of branched or unbranched filaments of chlorophyllous cells arising from the floor of air chambers.
4	Monoecious or dioecious	*Marchantia* is dioecious as the antheridiophores and archegoniophores are borne on different thalli.
5	The antheridia are situated on dorsal surface of thallus and remain immersed in antheridial chambers.	The antheridia are borne in groups on the upper surface of the disc of antheridiophore, and remain immersed in antheridial chambers.
6	The archegonia are situated on dorsal surface of thallus; archegonia are protected by archegonial chambers, usually 4 neck canal cells are present.	The archegonia are situated on the dorsal surface of disc of stalked archegoniophore; archegonia are protected by perichaetium and rays. Generally 4-6 neck canal cells are present.

7	The jacket of sporophyte develop from amphithecium ; the endothecium gives rise to archesporium; archesporium gives rise to sporocytes and abortive nurse cells; the foot and seta are absent; sporophyte is globose ; wall of sporophyte is single-layered and abortive; elaters are absent; spores are liberated by the decay of thallus tissue.	The amphethecium gives rise to the jacket of capsule, the endothecium gives rise to archesporium ; archesporium gives rise to sporocytes and elaters; the foot is bulbous ; seta elongates rapidly after the maturity of spores; capsule is nearly spherical structure; wall of capsule is single layered and persistent; long, narrow, unicellular diploid,spindle shaped elaters with two spiral thickenings; the wall of capsule splits longitudinally into four to six lobes and elaters become helpful in spore dispersal

10.5 GLOSSARY

Amphibians: Adapted for life either on land or water
Androcyte: A cell arising by growth from an antheridium and giving rise to antherozoids
Antheridiophore: A gametophore bearing antheridia
Anticlinal: In anticlinal cell division the plane of division is at right angles to the or the periphery
Archesporium: A cell or mass of cells dividing to form sporogenous tissue
Bulbous: like a bulb
Cryptogams: Plants without flower & seeds and reproduce by forming spores
Dehiscence: Release of spores by splitting of capsule
Dichotomy: Is a partition of a whole (or a set) into two parts (subsets) or repeated forking
Dorsiventral: Thallus where upper and lower surfaces are distinct
Gametophyte: The gamete forming phase responsible for sexual reproduction
Groove: furrow or depression
Growing point: A part of plant body at which cell division is localized generally terminal and composed of meristematic cells
Nurse cells: Cells providing nourishment to the developing spores in the sporangium
Perichaetium: Membranous envelop on either side of archegonial row
Periclinal: Parallel to the periphery or surface of an organ
Perigynium: Membranaous envelop of archegonium in liverworts
Sporogenous: Spore producing
Sporophyte: The diploid (2n) spore-producing phase responsible for production of haploid spore (meiospore)

10.6 SELF-ASSESSMENT QUESTIONS

10.6.1 Very Short answer type questions:

(1) Name an aquatic species of *Riccia.*
(2) *Marchantia* is monoecious or dioecious plant?
(3) Name the protective layer of sporogonium of *Riccia.*
(4) In *Marchantia* specialized branch bearing female sex organs are called?
(5) How many protective layers surround the sporophyte of *Marchantia* from outside to inside?
(6) In *Riccia* nurse cells develop from?
(7) Name the bryophyte in which appendiculate scales are present.
(8) The most primitive type of sporogonium is present in which bryophyte.

10.6.2 Multiple choice type questions:

(1) Elaters are seen in
(a) Antheridium (b) Archegonium
(c) Sporogonium (d) None of the above

(2) The nurse cells are present in the sporogonium of
(a) *Riccia* (b) *Marchantia*
(c) *Porella* (d) *Anthoceros*

(3) The most primitive type of sporogonium is seen in
(a) *Anthoceros* (b) *Marchantia*
(c) *Porella* (d) *Riccia*

(4) A sporophyte of *Marchantia* is enveloped by
(a) Two protective sheath (b) One protective sheath
(c) Three protective sheath (d) Four protective sheath

(5) Spores are liberated from the sporogonium only by the decay of the outer layer of calyptras and thallus tissue in
(a) *Marchantia* (b) *Riccia*
(c) *Funaria* (d) *Anthoceros*

(6) In archegonium the cell above the egg cell is
(a) Neck - canal cell (b) Neck cell
(c) Cover cell (d) Ventral – canal cell

(7) Barrel shaped pores are found in
(a) *Riccia* (b) *Anthoceros*

(c) *Marchantia* (d) *Funaria*

(8) A dioecious gametophyte is seen in the case of

(a) *Funaria* (b) *Riccia*

(c) *Marchantia* (d) *Anthoceros*

10.6.3 Fill in the blanks:

(1) In *Marchantia* the endothecium ultimately give rise to ……and…….

(2) The nurse cells are present in the sporogonium of……….

(3) Appendiculate scales are present in………………..

(4) In *Marchantia* vegetative reproduction is brought about by special bodies called…..

(5) The elaters are hygroscopic in nature and so serve in the dispersal of………

(6) Spores are liberated from the sporogonium only by the decay of gametophyte in……

(7) The true elaters are found in the sporophyte of………………….

(8) The most primitive type of sporogonium is seen in…………………..

10.6.4 True or False statement:

1. The sporogonium of *Riccia* consists of foot, seta and capsule.
2. In *Marchantia* archesporium is derived from the amphithecium.
3. Vegetative propagation in *Marchantia* takes place by the gemmae.
4. The nurse cells are present in the sporogonium of *Riccia*.
5. In *Riccia* the sex organs are borne on special sexual branches of the thallus.
6. In *Riccia* the antherozoids are elongated curved and biflagellate.
7. The archegoniophore of *Marchantia* is also known as carpocephalum.
8. The true elaters are present in capsule of *Riccia.*

10.6.1 Answer Key: *Riccia fluitans*, (2) dioecious, (3) calyptras, (4) archegoniophore/carpocephalum, (5) three

10.6.2 Answers Key: (1) c, (2) a, (3) d, (4) c, (5) b, (6) d, (7) c, (8) c

(6) endothecium (7) *Marchantia* (8) *Riccia*

10.6.3 Answers Key: (1) spores and elaters, (2) *Riccia,* (3) *Marchantia,* (4) Gemma (5) spores, (6) Riccia, (7) *Marchantia,* (8) *Riccia*

10.6.4 Answers Key: (1) False (2) False (3) True (4) True (5) False (6) True (7) True (8) False

10.7 REFERENCES

- V. Singh, P.C. Pande & D.K. Jain (2013) **A Text Book of Botany**. Rastogi Publications , Meerut, New Delhi
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- B. R. Vashishta, A.K. Sinha & Adarsh Kumar (2008) **Botany for degree students bryophyta**. S. Chand & Company Ltd. Ramnagar, New Delhi.
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10.8 SUGGESTED READING

- V. Singh, P.C. Pande & D.K. Jain (2013) **A Text Book of Botany**. Rastogi Publications , Meerut, New Delhi
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10.9 TERMINAL QUESTIONS

10.9.1 Short answer type questions

1. Why the sporophyte of *Riccia* is considered to be primitive?
2. Describe briefly the structure of gemma cup of *Marchantia*.
3. Draw the transverse section *of Marchantia* thallus and label the parts.
4. Draw labelled diagram of longitudinal section of sporophyte of *Marchantia*.
5. Describe the sporophyte of *Riccia*.
6. How will you differentiate between the antheridiophore and archegoniophore of *Marchantia.*

10.9.2 Long answer type questions:

1. With the help of labelled diagrams illustrate the life cycle of *Riccia*.
2. Describe the structure of the sporophyte of *Riccia* and compare it with that of *Marchantia*.
3. Describe the morphology and anatomy of *Marchantia* thallus and compare it with the thallus of *Riccia.*
4. Describe the structure of antheridiophore of *Marchantia* and how it is different from the archegoniophore.
5. Describe the post- fertilization changes in the female receptacle of *Marchantia.*
6. Give a comparative account of the position and structure of the archegonia of *Riccia* and M*archantia.*

UNIT–11 CLASSIFICATION, STRUCTURE AND REPRODUCTION IN ANTHOCEROTOPSIDA

11.1 OBJECTIVES

After reading this unit you will know:

- What are hornworts
- Salient features of Anthocerotopsida
- Gametophyte of *Anthoceros* and *Notothylas*
- Structure and development of sex organs in *Anthoceros* and *Notothylas*
- Reproduction in *Anthoceros* and *Notothylas*
- Structure and development of sporophyte in *Anthoceros* and *Notothylas*

11.2-INTRODUCTION

As in the previous units you have studied the characteristic features of the bryophytes. The Bryophytes generally form a group where the common plant body is a gametophyte. The sporophyte is a very rudimentary structure, completely parasitic on the gametophyte and devoid of common organs as leaf, stem and root. Vascular tissues are absent. This much you have learnt so far. In this unit we will study about Anthocerotopsida. This group differs in many respects from the other Bryophytes. Anthocerotopsida occupies an intermediate position between the two important classes, the Hepaticopsida and Bryopsida.

The members of this group are commonly known as hornworts because capsules arise from the thalli in the form of small horn like structures.

11.3 GENERAL CHARACTERS OF ANTHOCEROTOPSIDA

The class Anthocerotopsida is represented by 6 genera and 300 species. According to Muller (1940), Reimers (1954) and Proskauer (1951) the order Anthocerotales includes two families (i) Anthocerotaceae and (ii) Notothylaceae. The characteristic features of Anthocerotopsida are as follows:

1-The gametophytic plant body is simple, thalloid and dorsiventral.

2- The rhizoids are simple and smooth walled. Tuberculate rhizoids and ventral scales are absent.

3-The tissue of the thallus is uniform, not differentiated into photosynthetic and storage region. Air chambers and air-pores are absent but intercellular mucilage cavities are present which open on the ventral surface by slit like structure called slime pore. Each cell of the thallus possesses a large chloroplast and a visible pyrenoid within it.

4 Sex organs are embedded in the thallus. The antheridia are endogenous i.e. they develop on the dorsal surface from the hypodermal cells of the thallus. The antheridia develop within the antheridial chambers, singly or in groups.

5-The archegonia are found in sunken condition on the dorsal surface of the thallus.

6- Sporophyte is elongated and cylindrical structure. It consists of foot, meristematic region and capsule. It possesses intercalary meristem, and continues its growth throughout the growing season. The wall of sporogonium contains chlorophyll hence sporophyte is partially independent. The central sterile portion is columella, which is surrounded by sporogenous tissue and spores. Sporogenous tissue develops from the amphithecium.
7- Elaters do not have thickening bands and are known as pseudoelaters.

11.3.1 *Anthoceros*

About 200 species of *Anthoceros* are found throughout the world in temperate and tropical regions. The genus is represented in India by about 25 species. The plants grow mostly in very shady and moist places. They are found in the crevices of the moist rocks in dense patches and some species are growing on the decaying wood. The three species viz. *Anthoceros himalayensis, A. erectus* and *A. chambensis are* common in various hilly regions of Mussoorie, Kumaon, Chamba valley and other places ranging from 5,000 to 8,000 feet. *Anthoceros crispulus* reported from Munsyari and Dharchula (Uttarakhand). Some species have been reported from South India. The species of *Anthoceros* may be annual (e.g., *A. erectus, A. punctatus*) or perennial (e.g., *A. fusiformis*, *A. himalayensis*).

11.3.1.1 - Classification

Division-Bryophyta (1) True roots are absent and rhizoids are present (2) No vascular strand.

Class - Anthocerotopsida (1) Thalloid (2) Rhizoids are without septa (3) Each cell of the thallus has generally a single large chloroplast, with pyrenoid. **Order-Anthocerotales** (1) Internal structure of the thallus is homogenous (2) Only smooth walled rhizoids are present (3) Scales and tuberculate rhizoids are absent.

Family–Anthocerotaceae (1) Capsule is erect and cylindrical (2) Capsule wall has stomata (3) Archesporium develops from amphithecium (4) Elaters are without thickening bands and multicellular.

Genus –*Anthoceros* (1) Capsule is cylindrical and erect (2) Capsule wall has stomata

11.3.1.2 – Structure of gametophyte

External Structure: The plant body is small, dark green, dorsiventral and prostrate thallus. The thallus is lobed and the lobes are somewhat divided (Fig.11.1 A, B, C). The thallus is thick in the middle but it is without sharply defined mid rib. The dorsal surface of thallus of *A. laevis* is smooth, whereas it is velvet like in *A. crispulus* or rough in *A. fusiformis.*

The ventral surface bears unicellular **smooth walled rhizoids** along the median line (Fig.11.1D, G, H). Tuberculate rhizoids and scales are altogether absent. On the ventral side of the thallus, a few **bluish green spots** are seen indicating the presence of blue green alga (viz. *Anabaena* or *Nostoc*). Spots may be easily seen with the help of lens on the underside of the thallus.

Internal structure: The internal structure of the thallus is simple. The thallus tissue shows little or no differentiation (Fig.11.1 F, G). The thallus is composed of uniform, thin walled parenchymatous cells which are many cells thick in the middle (Fig. 1.11G). There is a distinct and continuous epidermis, made up of comparatively small cells. Each cell of the thallus contains a single oval chloroplast with a central pyrenoid resembling some green alga like *Coleochaete* (Fig.1.11I). The nucleus remains very near to the chloroplast. The chloroplasts of the superficial cells are longer than the chloroplasts of the other cells. Such a chloroplast with pyrenoid is unknown in the whole group of embryophyta except in *Selaginella*. Air chambers and air pores are absent but the lower ventral surface of the thallus shows small, rounded, bluish green spots which may be detected with hand lens. These spots are cavities filled with mucilage and opening on the ventral side by means of narrow slits called slime pores (Fig.11.1G). These pores are formed by the partial separation of adjacent cells of the epidermis. These mucilage cavities always contain colonies of endophytic *Nostoc*. There is no symbiotic relationship between these *Nostoc* colonies and thalli. *Nostoc* lives in thalli of *Anthoceros* possibly as a space parasite.

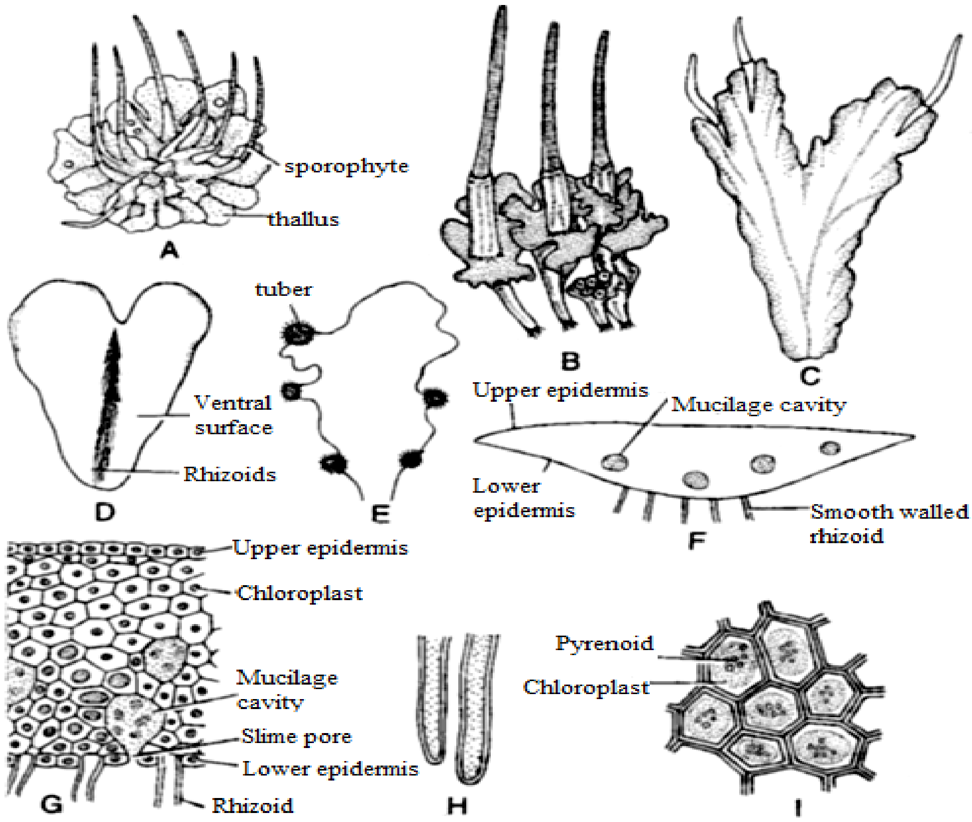

Fig.11.1, *Anthoceros:* Thallus structure; Dorsal surface A. A. crispulus B. A. erectus C. A.himalayensis D. Ventral surface, E. Thallus with tubers, F. Transverse section of thallus (Diagramatic), G. T. S. of thallus showing cellular details, H. Smooth walled rhizoids, I. Cells of thallus

Apical growth: The thallus usually grows by a single apical cell with four cutting faces – two laterals, a dorsal and a ventral. The derivatives of the dorsal and ventral faces contribute to the thickness of the thallus, whereas those from the lateral faces contribute to its lateral expansion. *A. erectus* and *A. himalayensis* have been shown to grow by a group of apical cells.

11. 3.1.3 Reproduction

The reproduction takes place by means of (1) vegetative and (2) sexual methods.

1. Vegetative reproduction: The vegetative reproduction takes place by various ways:

(a) By progressive death and decay of thallus: The vegetative propagation is by progressive death and decay of the posterior part of thallus which reaches to the point of dichotomy, the lobes get separated and each lobe grows into an independent thallus. But this method is less common in *Anthoceros* as compared to *Riccia* and *Marchantia*.

(b) By tubers: In many species of *Anthoceros* (*A. laevis, A, tuberosus, A hallii, A. pearsoni* and *A. himalayensis*), the thallus becomes thickened at several places on the margin under unfavorable condition (Fig.1E). Such marginal thickenings are called the tubers. These tubers are perennating structures. They survive in the drought conditions. Each tuber germinates into a thallus on the return of the favorable conditions.

(c) By gemmae: In some of the species of *Anthoceros,* the gemmae are known to develop on the margin of the thallus. The gemmae have been reported from the species, *A. glandulosus, A. formosae,* etc. These gemmae germinate into new gametophyte as in Marchantia.

(d) By persistent growing apices: Species like *A. pearsoni* and *A. fusiformis* completely dry up in summers, leaving growing apices with adjacent tissues. These apices face the drought conditions. On the approach of favorable conditions, these apices develop into new thalli.

2. Sexual reproduction

The species of *Anthoceros* may be **homothallic or monoecious** (*A. fusiformis, A. punctatus*) or heterothallic or dioecious (*A. himalayensis*).The monoecious species are **protandrous**, i.e., the antheridia mature before archegonia. The sex organs, i.e., antheridia and archegonia are found embedded on the dorsal side of the thallus.

Antheridium

Development of antheridium: The antheridia are produced singly or in groups within closed cavities, known as **antheridial chambers**. The development is **endogenous**. A dorsal superficial cell of the thallus, situated near the growing apex divides periclinally giving rise to **two** daughter cells. The upper daughter cell acts as **roof initial** and the lower one acts as an antheridial initial. The **antheridial initial** is thus endogenous rather than superficial as in other bryophytes (Fig.11.2 A-B). Eventually, a mucilage filled space appears in between the roof initial and antheridial initial (Fig.11.2C). This mucilage cavity enlarges in size and ultimately becomes the antheridial chambers. The roof initial is nothing to do with the development of an antheridium. It divides and re- divides several times anticlinally and periclinally giving rise to a two layered roof of the antheridial chamber (Fig.11.2 D-H). Simultaneously, the antheridial initial develops into a single antheridium or in a group of antheridia. A single antheridium develops in *A. pearsoni* and sometimes in *A. himalayensis*. According to Mehra and Handoo (1953), in *A. erectus* a number of antheridia develop in an antheridial chamber. Here, the antheridial initial divides many times anticlinally producing many cells and each cell thus produce, an antheridium. The further development of an antheridium is as follows:

The antheridial initial divides twice by vertical walls intersecting each other at right angles, giving rise to four cells (Fig.11.2D). This is followed by another transverse division giving rise to two tiers of four cells each (Fig. 11.2E). The cells of the lower tier are called stalk cells, they divide by transverse walls and form a multicellular stalk of the antheridium. The cells of the upper tier form the body of the antheridium. The four cells of the upper tier divide transversely giving rise to eight cells, the octant stage (Fig. 11.2F).All of the cells of octant stage divide periclinally giving rise to eight outer primary jacket cells and eight inner primary androgonial cells (Fig.11.2G). Outer primary jacket cells divide anticlinally forming single layerd jacket. The primary androgonial cells divide repeatedly to form a mass of androcyte mother cells (Fig.11.2 H). Each androcyte mother cell divides diagonally producing two androcytes. Each androcyte metamorphoses into a spindle like biciliate antherozoid (Fig.11. 2K).

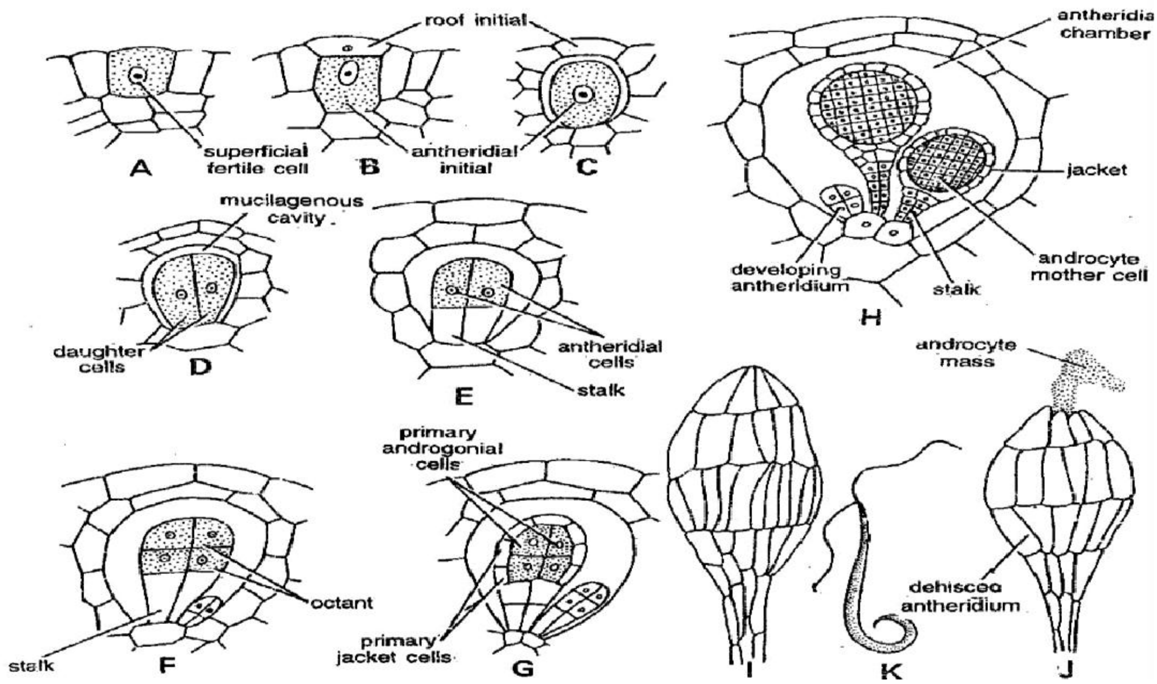

Fig.11.2, ***Anthoceros:*** **A-H.Sequential stages in development of antheridium; I. Mature antheridium; J. Mature dehisced antheridium releasing out androcyte mass; K. Biflagellate antherozoid with long anterior flagella**

Structure of mature antheridium and its dehiscence:

The mature antheridium is stalked and club shaped (Fig.11.2 I). The stalk of the antheridium may consist of the mass of cells (*A. laevis*) or it may consist of the four rows of the cells (*A. erectus* and *A. punctatus*). The antheridium proper is covered by a single layered jacket. Inside the jacket, there are numerous androcytes which metamorphose into antherozoids.

On the maturation of an antheridium, roof of the antheridial chamber disintegrates, with the result the antheridia are exposed to outside. Soon after, the antheridia absorb water and burst at their apical ends, giving way to the antherozoids to move outside. The androcytes come out in the form of a smoky mass at the opening of an antheridium. Within few minutes they metamorphose into the antherozoids (Fig.11.2 J). The antherozoid is spindle like and biciliate. The cilia are attached to the anterior end of the body (Fig.11.2 K). The antherozoids swim in the water with the help of their flagella.

Archegonium

Development of archegonium:

Archegonia arise in an acropetal sequence on the dorsal surface of the thallus. The development of archegonium also begins from a single superficial cell. This cell becomes prominent and acts as archegonial initial. This archegonial initial divides by a transverse wall to form an outer primary archegonial cell and an inner primary stalk cell. But according to Mehra and Handoo (1953), the archegonial initial functions directly as a primary archegonial cell. The primary archegonial cell, by three intersecting periclinal divisions, producing three jacket initials which surround an axial cell (Fig. 11.3 A-C). The axial cell divides transversely to form two cells of almost equal size. The lower one becoming the primary ventral cell and the upper cell divides again forming a top cover initial and a lower primary neck canal cell. The cover initial forms a rosette of four cover cells while the primary neck canal cell divides repeatedly, producing a linear row of 4-6 neck canal cells. The primary venter cell divides transversely once, giving rise to two cells, upper a ventral canal cell and lower an egg (oosphere). The three jacket initials also divide by transverse wall, forming two tiers, and three cells in each tier (Fig.11.3 D-G). The cells of the upper tier divide anticlinally and form six cells. The neck wall or neck is formed by six vertical rows of cells. The further development of the jacket is difficult to follow as the archegonium is embedded in the tissue of gametophyte. The neck cells are indistinguishable from the surrounding vegetative cells of the thallus. The cells of the lower tier, by transerve and vertical divisions form the venter wall.

Structure of mature archegonium:

The mature archegonium is embedded in the dorsal surface of the thallus, but the cover cells protrude above the surface of the thallus. The neck is composed of six vertical rows of neck cells and the narrow cavity of the neck is occupied by an axial row of 4-6 or more neck canal cells. The lower swollen venter contains a large egg and relatively small ventral canal cell (Fig. 11.3 H).

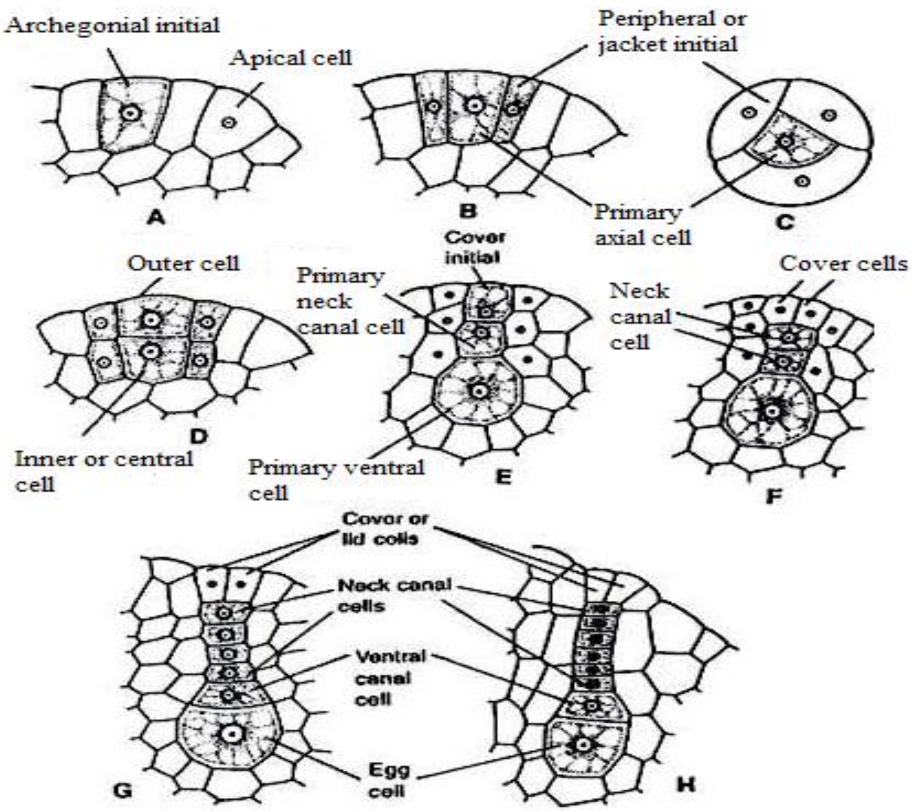

Fig. 11.3, *Anthoceros*: A- G. Successive stage in the development of archgonium H. Mature archegonium

On the maturation of the archegonium, the venter canal cell and neck canal cells become gelatinized. Thus a mature archegonium is flask-like in shape, without neck canal cells, venter canal cell and with an egg (oosphere) in its venter. At the tip of an archegonium there are four cover cells.

Fertilization (syngamy):

Prior to fertilization, the cover cells present at the tip of archegonium get separated. The neck canal and the venter canal cell become gelatinized forming a mucilagenous mass. The mucilage collects at the tip of archegonium. The antherozoids are attracted chemotactically. Through the medium of water, many antherozoids enter the mouth of an archegonium. Ultimately, one antherozoid penetrates the egg, and the fertilization takes place. The male and female nuclei unite to each other, producing a zygote (oospore), zygote is diploid, and **this is the beginning of the sporophytic stage.**

Sporophyte

Development of sporophyte: After fertilization, the zygote secretes a cellulose wall around it and enlarges, and completely fills the venter of the archegonium. The first division of the zygote is vertical. But in certain cases it may be transverse.With the result of the first vertical division, two almost equal daughter cells are produced. Two cells now divide

transversely forming a four celled embryo. These four cells may be equal in size or the upper two are larger. These cells again divide vertically, developing eight celled embryo, the octant. In the octant stage cells are arranged in two tiers of, four cells each (Fig.11. 4 A-D).
Further development of the sporophyte shows variation in different species. In *A. erectus* the octant does two tiered only, the lower tier forms the foot while capsule develops from the upper tier. In *A. gemmulosus* the cells of one of the two tiers divide by a transverse wall and as such three tiers of four cells each are formed. The lower most tier forms the foot and the upper two tiers develop the capsule. In *A. crispulus* the cells of both the tiers of octant divide transversely thus forming a four tiered embryo. The cells of upper two tiers give rise to the capsule, while those of the lower two tier, the foot.

The cells of embryo destined to give rise to foot divide regularly or irregularly many times, producing the bulbous foot which is made up of thin walled vacuolated cells. The lower most cells of the foot grow short rhizoid – like projection increasing the absorptive surface for sucking food from the gametophyte for the developing sporophyte.

The cells of the upper tier or tiers of an embryo, which are destined to give rise to capsule, divide periclinally, separating out the central part, the endothecium forms the outer, the amphithecium (Fig.11.4E). The whole endothecium gives rise to the sterile columella. In the young sporophyte, the columella consists of four vertical rows of the sterile cells, but later on it is made up of sixteen rows of cells. According to Bhardwaj (1958) in *A. gemmulosus* the columella consists of 36 to 49 vertical rows of the cells. The amphithecium divides periclinally producing an outer sterile layer of the jacket initials and an inner fertile layer of archesporium

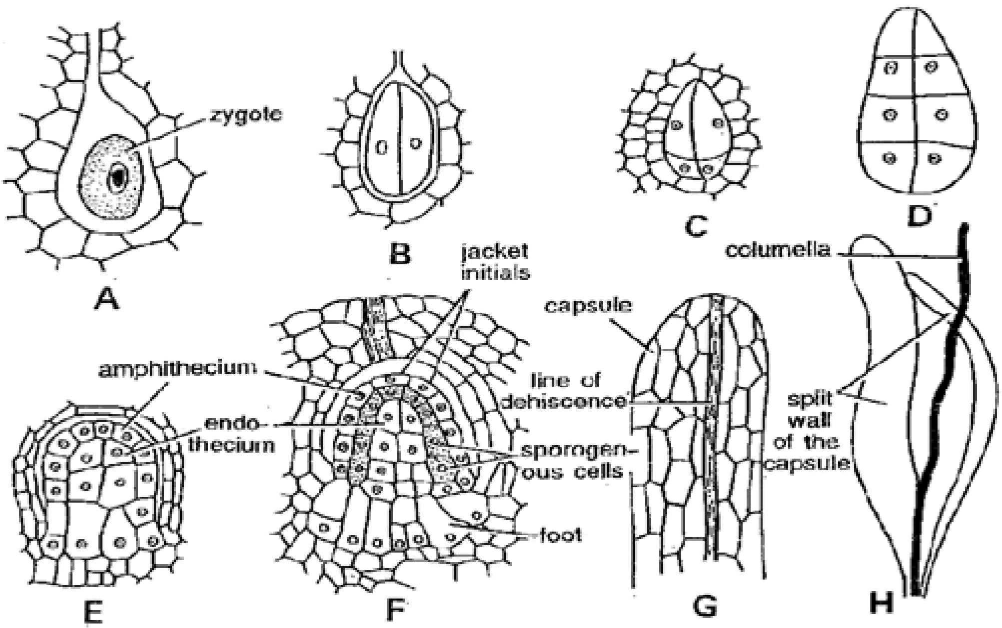

Fig.11. 4, *Anthoceros* : A – F. Successive stages in the development of sporophyte; G . Sporophyte showing line of dehiscence; H. Dehisced capsule.

The jacket initials divide again and again periclinally producing the 4 to 6 layered wall of the capsule. The outermost layer develops into the single layered epidermis. The epidermal cells are cutinized. Regular stomata with guard cells occur on the epidermis. The inner cells of the jacket are parenchymatous and usually contain two chloroplast in place of the single chloroplast of the gametophytic cells, but this number may vary. These chlorophyllous cells, however, help in synthesizing the food. The inner cells of the amphithecium become the archesporium, which overarches the rounded apex of the columella and may or may not extend to the base of the columella. Subsequently, the archesporial layer divide periclinally and thus the mature capsule has two or more layered archesporium or sporogenous tissue. In some species (*A. erectus*),the archesporium remains single layered throughout, in *A. pearsoni* and *A. himalayensis* it may become two, three or even four cells in thickness. In younger stages all the cells of sporogenous tissue are small, rectangular and densely cytoplasmic. They mature in basipetal sequence, i.e., the cells of apical part mature earlier than the basal cells. At maturity the archesporium or sporogenous tissue differentiate into two types of cells, i.e., (i) sporocytes (spore mother cells), these are large, spherical or oval fertile cells with dense cytoplasm and larger nucleus (ii) sterile cells (elater mother cell) which are smaller in size with comparatively small nucleus. The two types of cells are almost equal in number and are arranged in regular alternate rows in the young capsule. But they intermingle as the capsule matures. The spore mother cells undergo the reduction division, each producing a spore tetrad. The sterile cells soon divide obliquely or transversely producing 1 - 4 celled simple or branched elaters, which lose their protoplasmic contents when mature and remain thin walled. The elaters of *Anthoceros* do not have thickening bands and that is why called pseudoelaters. The pseudoelaters help in the dehiscence of the capsule and behave like true elaters. In earlier stages their function seems to be nutritive. The apical growth of the sporophyte ceases after the differentiation of jacket, archesporium and columella in the capsule. At this stage, an intercalary meristem differentiates at the base of the capsule and this meristem is responsible for further growth of the capsule.

The young sporophyte of *Anthoceros* is covered by a protective sheath, the calyptras or involucre. It develops mainly from the tissue of gametophyte surrounding the archegonium. In early stages, growth of the calyptra keeps pace with that of the sporophyte and the young sporophyte is completely surrounded by the involucre. Subsequently, the sporophyte grows faster and pushes up through the involucre. In this way the calyptra or involucre occurs as a collar at the base mature sporophyte.

Structure of mature sporophyte

External structure: The mature sporophyte is an elongated structure, present on the dorsal surface of the thallus. The capsules arise from the thalli in the form of small horny structures. Usually they are two to three centimeters long. But in some species they range from five to fifteen centimeters in their height and because of their horny appearance, the species are called ‘hornworts’. The collar like involucre surrounds the base of the sporophyte. The young sporophyte is green in color, but at maturity it gradually turns dark yellow or black from the apex to base. The mature sporophyte consists of a bulbous foot and a slender and erect capsule. There is no distinct seta but an intercalary meristematic zone is present in between the foot and the capsule. This meristem continuously adds new tissues to the capsule from the base.

Internal structure: Basal bulbous part of the sporophyte is composed of vacuolated parenchymatous cells and known as foot. In some species the superficial cells of the foot are palisade like, whereas in others some of these cells elongate and grow as haustoria in the adjoining tissue of the gametophyte. The foot absorbs water and nutrients from the gametophyte for the developing sporophyte (Fig.11.5A). Capsule wall is composed of 4-6 layers of parenchymatous cells. The outermost layer, which forms an epidermis, is composed of elongated cells. On the outer side the epidermal cells are cutinized. Epidermis is interrupted by stomata at several places. These stomata have guard cells like those of the higher plants. The stomata open in the intercellular spaces of the chlorophyllous cells. Usually each cell possesses two chloroplasts. Thus the sporophyte is capable of synthesizing food by itself. However, the sporophyte remains dependent on the thallus for the supply of water and other nutrients throughout its life. The apical region of the capsule has two or four shallow grooves in the epidermis. The capsule dehisces along these grooves. In between the jacket and the columella is the cylindrical archesporial zone or sporogenous tissue. In contrast to liverworts, the sporogenous tissue in *Anthoceros* overarches the columella like a dome. Archesporium matures in a basipetal sequence (Fig.11.5A). The archesporium is single layered and is undifferentiated at the base of the capsule, but in the upper region the spore tetrad and pseudoelaters are arranged in regular alternate blocks (Fig.11.5D,E). Elaters are simple or branched and are composed of 1-4 cells of irregular shape. In some species, elaters are unicellular. The elaters of *Anthoceros* are characterized by the absence of thickening bands (Fig.11.6 D). Columella is the central sterile part of the capsule extending almost to entire length. It is composed of 16 vertical rows of thick walled elongated cells. The main function of columella is to provide mechanical support to tender and elongated capsule. It also helps in the dispersal of spores. Under certain conditions the elongated cells of columella also function as water conducting tissue.

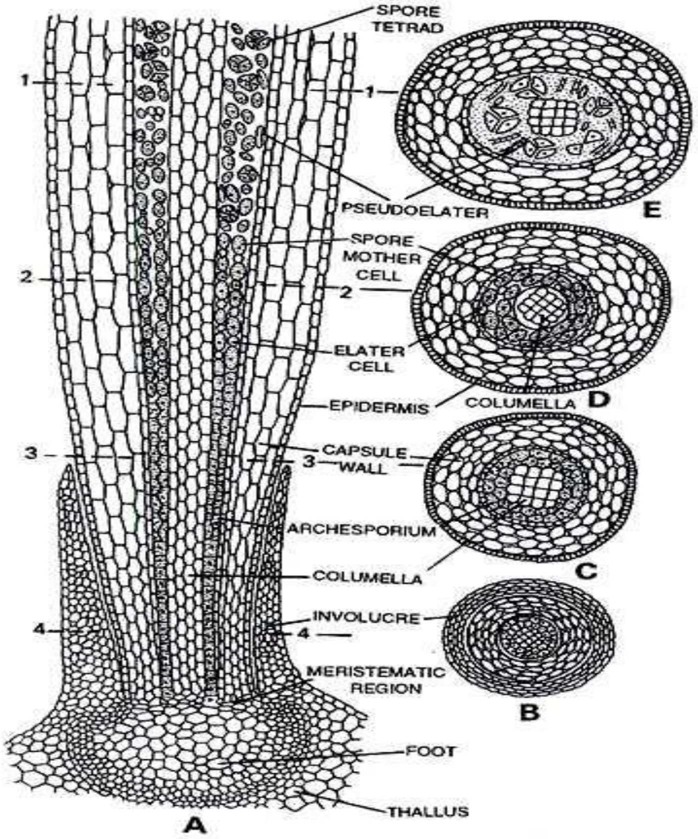

Fig. 11.5 ***Anthoceros:*** **A. Longitudinal section of mature sporophyte, B-E. Transverse sections of sporophyte at different levels**

Dehiscence of the capsule: On maturation, the tip of the sporogonium becomes yellow, black or dark-brown in color. The dehiscence of the capsule is more or less dependent upon the loss of water. This way the dry atmosphere helps in the dehiscence of the capsule. The dehiscence begins from the tip region of the capsule. At first a small longitudinal slit appears, which widens, enlarges and extend towards the base. Thus capsule wall splits into two or four valves depending on the species. Initially, the valves remains attached at the tip but as the valves dry and twist, they separate from each other, exposing the spores and elaters. Hygroscopic movement of the pseudoelaters release the mature spores at the top. The liberated spores are dispersed by wind from one place to another.

The spore and its germination: The haploid spore is the mother cell of the gametophytic generation. In earlier stages the spores are found to be arranged in tetrads. After being separated from each other they are dispersed. Each spore is somewhat spherical and possesses two wall layers. The outer wall layer is exine and the inner wall layer is intine. The intine is smooth and thin, whereas the exine is somewhat thick and ornamented (Fig.11.6 C). The color of the mature spores varies from species to species; this may be yellow, brown, dark brown or black. Each spore possesses a single nucleus, a colorless plastid, few oil droplets and food material within it. The spore germinates either immediately after their liberation or undergoes a period of rest prior to germination which ranges from few weeks to few months. The exine (exospore) ruptures along the tri-radiate ridge and the intine (endospore) comes out in the form of a long germ tube through the slit thus formed (Fig. 11.7A- B).

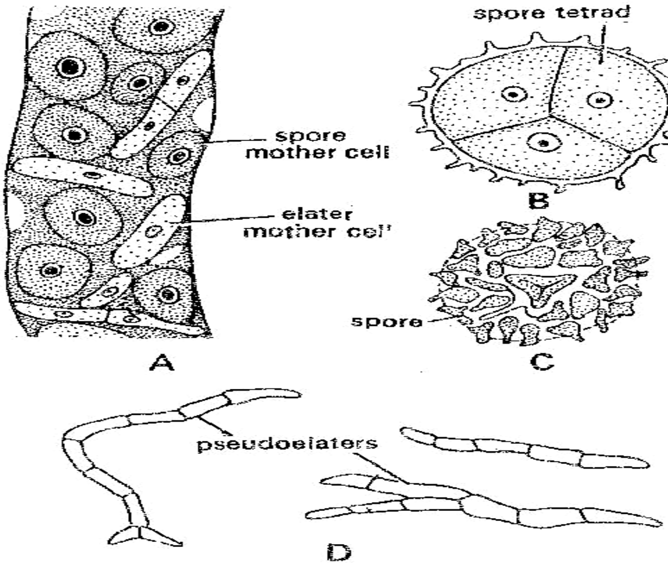

Fig.11.6, *Anthoceros*: A- Archisporial tissue in young sporophyte. B- Spore tetrad. C- Spore. D- Pseudoelaters.

Development of young gametophyte: The contents of the spore migrate into the germ tube. The colorless plastid of the spore turns green in the germ tube. Two successive transverse divisions differentiate two cells at the tip of the germ tube (Fig.11.7 D). Both these cells divide by two vertical walls, at right angles to each other forming an 8- celled octant at the tip of the germ tube (Fig. 11.7 E). This 8-celled structure is known as sporeling. The four distal cells of the octant function as apical meristem. The activity of these cells results in the formation a new gametophyte (Fig.11.7 F).

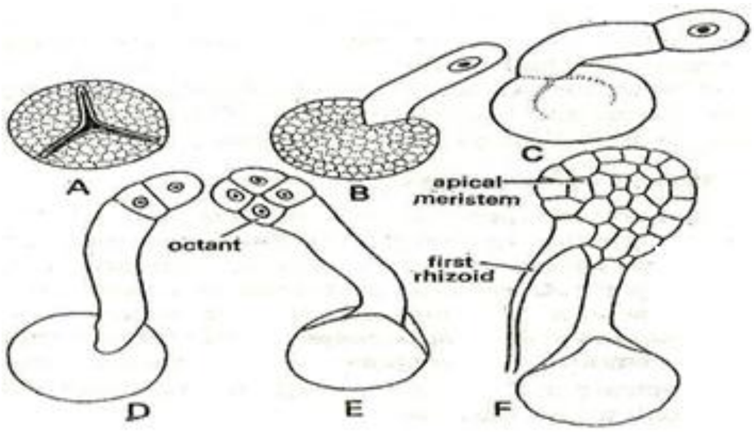

Fig.11.7- Anthoceros: Spore and its germination. A. Spore with triradiate ridge, B. Germinating spore producing germ tube, C-E. Further stages of spore germination, F. Development of new thallus and first rhizoid

11.3.2- *Notothylas*

11.3.2.1Classification

Division- **Bryophyta**

Class – **Anthocerotopsida**

Family – **Notothylaceae** (1) The capsule is cylindrical and horizontal (2) The capsule wall does not contain stomata (3) Elaters have irregular thickening bands.

Genus- ***Notothylas*** (1) Capsule is cylindrical and horizontal (2) Capsule wall does contain stomata.

There are 13 species in this genus. Five of them are reported from India, viz. *N. indica, N.levieri, N. pandei, N. chaudhurii* and *N. javanicus.* This genus is widely distributed in the tropical and temperate parts of the world. The plants grow in moist and shady places, on rocks or on the floors and walls of old buildings.

11.3.2.2 Structure of gametophyte

External structure: The gametophytic plant body is thin, delicate, thalloid, dorsiventral, prostrate somewhat lobed. The thallus is light green or yellowish green in color and has a characteristic lobed appearance. The lobes of the thallus have serrated or entire margins (Fig.11.8 A,B). Numerous smooth walled unicellular rhizoids are present on the ventral surface of the thallus (Fig.11.8 C,F). The thallus remains attached to the substratum by means of rhizoids. The tuberculate rhizoids and scales are altogether absent.

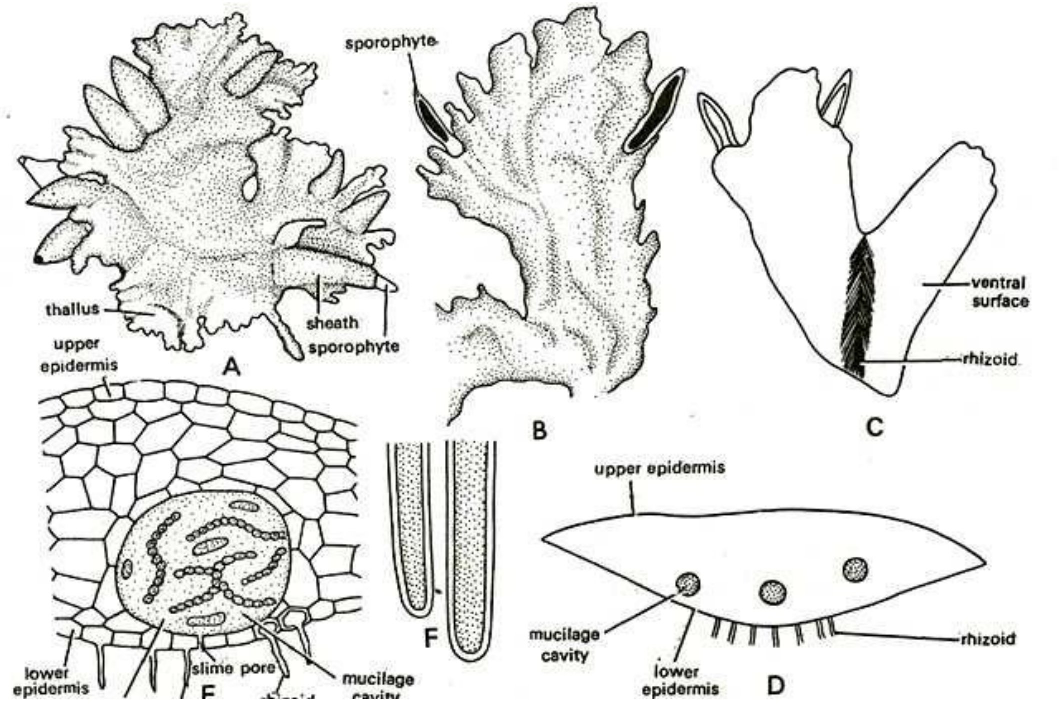

Fig.11.8, *Notothylus*: A. Gametophyte of N. orbicularis with sporophyte, B. Gametophyte of N.levieri, C. A lobe of the gametophyte (ventral view), D. Diagramatic representation of transverse section of the thallus, E. T.S. of thallus showing cellular details, F. Smooth walled rhizoids

Internal Structure: The thallus, when examined in its cross section shows no internal differentiation of tissues (Fig.11.8, D-E). It is 6-8 cells thick in the middle, gradually thinning out towards the margins and only one cell thick at the extreme margins. The cells in the middle region are twice big as compared to the cells of the upper and lower epidermal layers. The chloroplasts of superficial cells are usually larger than those in other cells and are lens shaped. Each chloroplast possesses a single large pyrenoid. All species of *Notothylas* possesses mucilage- filled intercellular cavities which often contain a blue green alga, *Nostoc*. These cavities open to the ventral surface by narrow slits. However, the thallus of *N. javanicus* is solid and does not contain any colonies of blue green alga. The apical growth of a thallus is initiated by a single apical cell.

11.3.2.3 – Reproduction: It takes place by vegetative and sexual methods.

1-Vegetative reproduction: The methods of vegetative reproductions are same as we have studied in *Anthoceros*. The vegetative reproduction takes place by progressive death and decay of posterior or older parts of the thallus. When the process of decay reaches near the apex of the thallus, the apical lobes separate and each grow into a new individual. Sometimes the margins of the gametophytes become thickened and the superficial cells develop into a corky layer. These structures are called tubers which remain viable during drought period when other portions of a thallus die. On the approach of favorable conditions each tuber develops into a new thallus.

2- Sexual reproduction: Species may be homothallic (monoecious) or heterothallic (dioecious). *N. indica, N. chaudhurii and N. levieri* are monoecious and protandrous (i.e. antheridia mature before archegonia).

Antheridia: The antheridia develop endogenously on the dorsal surface of thallus and these are formed near the growing point. The development of antheridium in *Notothyla* is similar to that of *Anthoceros*. They are formed in groups of 2-6 and are enclosed within antheridial chamber (Fig.11.9 A-B). The antheridium is oval or globose steructure, attached to the floor of the antheridial chamber by a short multicellular stalk (Fig.11.9 C). The body of the antheridium has a single layered sterile jacket, enclosing a mass of anderocyte. Each androcyte metamorphoses into uninuleate and biflagellate antherozoids.

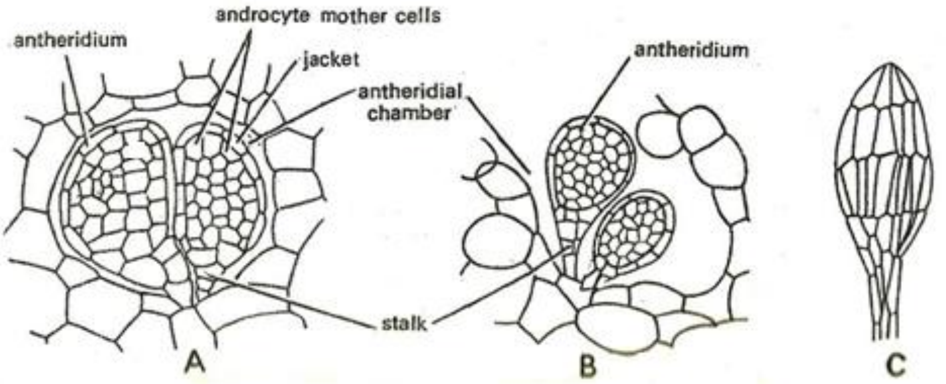

Fig.11.9, *Notothylus* : Antheridium ; A. Transverse section of thallus showing two antheridia in an antheridial chamber, B. Transverse section of thallus showing opening of antheridial chamber, C. A mature antheridium

Archegonia: Archegonia develop from the superficial cells of the thallus close to the growing apex. Archegonia are sessile and are embedded in the dorsal surface of the thallus. The mature archegonium similar to that of *Anthoceros* consists of a neck and a venter. The neck is composed of six vertical rows of neck cells which enclose 3-5 neck canal cells. A rosette of four cover cell is present at the tip of the neck, which protrudes out on the dorsal surface of the thallus. The venter contains a ventral canal cell and an egg. The development of archegonium is similar to that of *Anthoceros* (Fig.11.10 A-G).

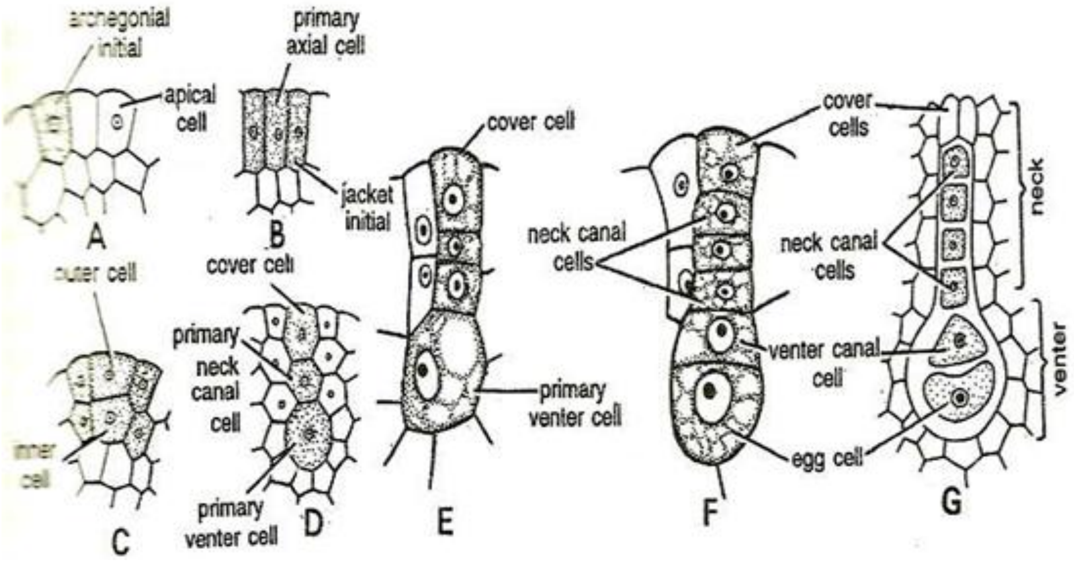

Fig.11.10. *Notothylas:* Successive stages of the development of archegonium

Fertilization

Water is essential for fertilization. Through the medium of water, the antherozoids enter through the separated cover cells into the archegonim. Ultimately one of the antherozoids penetrates the egg and fertilization takes place. The male nucleus fuses with the female forming a zygote (oospore).

Sporophyte: The zygote, formed after the fusion of antherozoid with the egg, enlarges in size and occupies almost the entire venter cavity. The development and structure of mature sporophyte varies in different species. The first division of the zygote may be vertical or transverse. It is vertical in *N. javanicus, N. levieri and N. breutelli.* In *N. indica* and *N. orbicularis,* the division of zygote is transverse. If the first division is vertical it is followed by a transverse division and four cells are formed. The third division of the zygote is vertical, at right angles to the first vertical division. Thus an eight –celled embryo is formed with two tiers of four cells each. A transverse division in the cells of the upper tier results in the three tiered embryo. In both types, whether the first division is vertical or transverse, of the three tiers, the uppermost tier forms the capsule and seta or meristematic zone while the lower two tiers forms, the foot. The cells of the uppermost tier divide periclinally resulting in the formation of a central endothecium and the peripheral amphithecium. Further development of the sporophyte varies and the species of *Notothylus* can be placed in the following three categories:

A. Columellate species: In *N. indica* and *N. orbicularis* the amphithecium divides periclinally forming inner and outer layer. The inner layer forms the archesporium and the outer layer gives rise to the wall of capsule. The entire endothecium gives rise to the columella. This way, in these species the sporogenous tissue develops exclusively from amphithecium like that of *Anthoceros* (Fig.11.11 A).

B. Intermediate species: These species form a connecting link between the columellate and non-columellate species. For example, in *N. javanicus* (a columellate species) the endothecium usually develops into a normal columella, but sometimes it is much reduced and confined to the basal part of the capsule and in the upper part the endothecium forms fertile sporogenous cells. In *N. breutellii* (a non-columellate species) though the endothecium develops into archesporium, but in many cases the endothecium forms sterile tissue towards the end of development, which give rise to a reduced columella(Fig.11.11 B).

C. Non-columellat species- In *N. chaudhurii*, *N. flabellata* and *N. levieri* columella is absent. The amphithecium is entirely utilized in the formation of wall layers of the capsule and the endothecium forms the fertile part, the archesporium (Fig.11.11C).

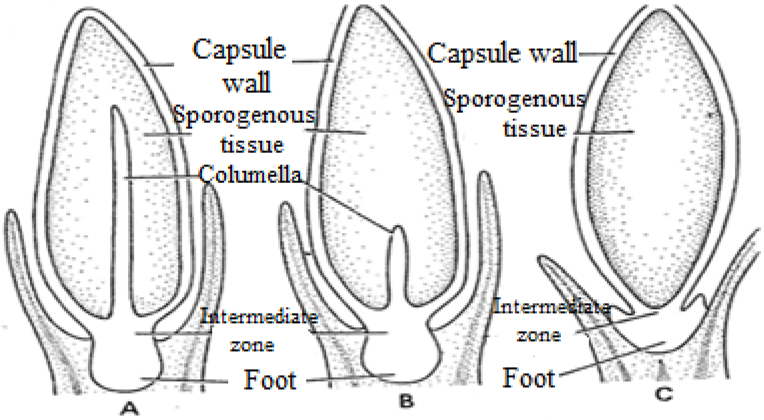

Fig. 11.11, A-C .*Notothyla:* Various type of sporophytes ; A. Columellate (N. indica), B. Intermediate (N. javonicus), C. Non-columellate (N. chaudhurii)

Structure of mature sporophyte

The fully mature sporophyte is cylindrical and 2 to 3 mm. long. The sporophytes are found along the margin of the thallus in between the lobes. They are tapering at both the ends and usually found horizontally on the thallus. In *N. levieri*, sporophytes arise in pairs. Usually sporophyte is completely enclosed with in membranous involucres, but in *N. indica* and *in N. levieri* it projects slightly beyond the involucre. The sporophyte is differentiated into foot, seta and capsule. The foot is more or less triangular and much smaller than that of *Anthoceros*. The seta is represented by a small narrow intercalary meristematic zone which shows limited meristematic activity. The capsule wall is made up of four layers. The outermost layer, the epidermis has thick brown colored cells. There are no pores or stomata. The three sub-epidermal layers have comparatively thin walled cells. There is little or no chloroplast in the wall layers and thus the capsule is completely dependent upon the parent thallus for nutrition and water. The capsule wall encloses the sporogenous tissue surrounding the columella, whereas in non-columellate species, sporogenous tissue completely occupies the cavity of capsule. Sporogenous tissue, at maturity differentiates into fertile spore mother cells and sterile cells. These two types of cells are arranged in alternate transverse rows. The spore mother cells undergo meiosis to form spore tetrads. The sterile cells form short unicellular elaters, which are irregular in shape, and have thickenings on their walls (Fig.11.12 A-B).

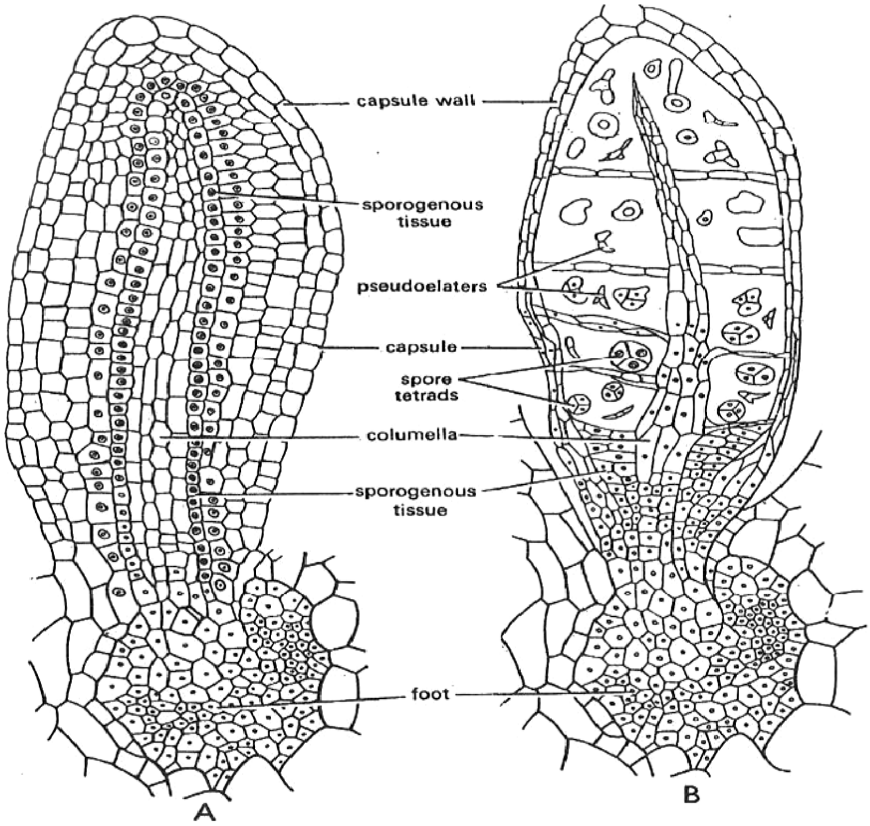

Fig.11.12 A-B. *Notothyla*: Structure of sporophyte; A. Longitudinal section of young columellate sprophyte, B. Longitudinal section of mature columellate sporophyte

Dehiscence of capsule

The capsule ruptures lengthwise, generally by one suture only. In *N. orbicularis*, the capsule splits into two to four valves. The dispersal of spores takes place by air currents.

Spore germination and young gametophyte

The spores are dark brown and each spore remains surrounded by two layers, inner thin endospore and outer thick exospore. The spores usually germinate immediately after their liberation, if they get suitable substratum. Prior to germination, the spore absorbs water, with the result the exospore ruptures and the endospore comes out in the form of a small papilla. The germ cell or papilla divides by repeated transverse and longitudinal divisions, forming a cellular mass which differentiates into a new gametophyte. Thus young gametophyte develops in the same manner as we studied in case of *Anthoceros*.

11.4 - SUMMARY

Anthoceros is represented in India by 25 species and *Notothylas* by 5 species. Thallus is thin, dorsiventral with an indistinct midrib; tendency towards dichotomous branching; rhizoids-unicellular, smooth walled and unbranched; tuberculate rhizoids and scales are absent. All cells are photosynthetic, each cell of the thallus possesses a large chloroplast and a visible pyrenoid within it. Species of *Anthoceros* and *Notothylas* are monoecious as well as dioecious. Antheridia are endogenous, developing inside closed antheridial cavity on the dorsal surface of the thallus, stalk is massive or slender, jacket of body is single layered, antherozoid is biciliate. Archegonia are embedded in the dorsal surface of the thallus, its neck is made up of 6 vertical rows of cells, venter wall is single layered thick, in *Anthoceros* 4-6 or more neck canal cells while 3-5 in *Notothylas*. In *Anthoceros* amphithecium gives rise to wall of capsule and archesporium and endothecium gives rise to columella. In case of *Notothylas* there is the formation of amphithecium and endothecium, but the further development of sporophyte varies and the species may be columellate or non-columellate. Archesporium gives rise to sporocytes and pseudoelaters, foot is bulbous, seta is absent; capsule is long and cylindrical and its wall is made up of 4-6 layers; pseudoelaters help in spore dispersal. Difference between *Anthoceros* and *Notothyla* are following:

Anthoceros	***Notothylas***
1- The capsule is erect and cylindrical 2- Capsule wall has stomata 3-Archesporium develops from amphithecium 4- Elaters are without thickening bands (pseudoelaters)	1-The capsule is cylindrical and horizontal 2-capsule wall without stomata 3-Archesporium develops from the amphithecium in some species and from endothecium in others 4-Elaters have thickening bands (elaters)

11.5 - GLOSSARY

Archegonium: a multicellular female reproductive structure.
Antheridium: a multicellular male reproductive structure.
Capsule: the sporangium of bryophytes.
Diploid: having two sets of chromosomes; characteristic of the sporophytic generation
Dioecious: having male and female reproductive structures on different thalli.
Globose: spherical
Haploid: having one set of chromosomes; characteristic of the gametophytic generation.
Protandrous: when male reproductive part develops before female parts.
Rhizoid: a thread like structure present on the lower surface in bryophytes; important for anchorage and absorption.
Sexual reproduction: the fusion of gametes followed by meiosis.
Sporocyte: a diploid cell that divides by meiosis to produce four spore cells
Tetrad: group of four; that cluster together as a group.
Vegetative: asexual parts of the thallus.
Venter: swollen basal portion of archegonium, containing egg
Ventral canal cell: cell just above the egg in the vetnter of archegonium which disintegrates before fertilization
Zygote: product of fusion of two gametes or the fertilized egg.

11.6– SELF-ASSESSMENT QUESTIONS

11.6.1 Very short answer type questions

1. In which bryophyte pyrenoids are present in chloroplast?
2. Name the tissue which gives rise to columella in *Anthoceros*.
3. What is the function of pseudoelaters in *Anthoceros*?
4. Name non- collumelate species of *Notothylas*.
5. Name the tissue which gives rise to spore mother cells in *Anthoceros*.
6. The members of which class are commonly known as hornworts.
7. Name any bryophyte where pseudoelaters are found.
8. Name the bryophyte in which mucilage cavities are present.

11.6.2 Multiple choice type questions:

1. Meristematic tissue is present in the sporophyte of

(i)*Riccia* (ii)*Marchantia*
(iii)*Anthoceros* (iv) *Funaria*

2. Sporogenous tissue in *Anthoceros* is derived from

(i) Endothecium (ii) Amphithecium
(iii) Gametophyte (iv) Tissue of columella

3. Development of antheridia in *Anthoceros* is of ……………….type

(i) Endogenous (ii) Exogenous

(iii) Endosporic (iv) Exosporic

4. Pseudoelaters without thickening bands occur in:

(i)*Marchantia* (ii) *Anthoceros*

(iii) *Porella* (iv) None of these

5. In the presence of pyrenoids in the cells of the thallus, *Notothylus* resembles

(i) Algae (ii) Fungi

(iii) Bryophytes (iv) Pteridophytes

6. Like *Anthoceros, Notothylas* thallus also contains

(i) Fungi (ii) Green algae

(iii) Red algae (iv) Blue green algae

7. Stomata are present on the capsule wall of the genus

(i) *Riccia* (ii) *Marchantia*

(iii) *Anthoceros* (iv) *Porella*

8. Scales and tuberculate rhizoids are absent in:

(i) *Riccia* (ii) *Marchantia*

(iii) *Anthoceros* (iv) none of the above

11.6.3 Fill in the blanks:

1. *Nostoc* colonies are present in the thallus of……………………
2. In the genus………………stomata are present on the capsule walls.
3. In *Anthoceros* columella develops from……………………………….
4. Thallus cells have chloroplasts with pyrenoids in………
5. Pseudoelaters occur in……………………
6. The bryophyte in which the sporophyte has an intercalary meristematic zone is ………
7. Vegetative reproduction in *Anthoceros* takes place by…………………….
8. Anthocerotopsida differ from the Hepticopsida by the absence of…….……and………

11.6.4 True and false statements:

(a) Tuberculate rhizoids are present in *Notothylas*.

(b) The columella of *Anthoceros* sporophyte corresponds to the vascular tissue of some primitive higher plants.

(c) *Anthoceros* is commonly known as hornwort.

(d) In *Anthoceros*, the antheridia develop endogenously.

(e) The sporophyte of *Anthoceros* grows continuously for a long period due to basal meristematic tissue.

(f) In *Anthoceros* pseudoelaters are found in sporogonium.

(g) The rhizoids are always smooth walled in Anthocerotopsida.

(h) The antheridial jacket is two layered and has stomata in *Anthoceros*.

11.6.1 Answers Key:

1. *Anthoceros* 2.Endothecium 3.Help in the dispersal of spores 4. *N. chaudhurii* 5.amphithecium 6.Anthocerotopsida 7.*Anthoceros* 8.*Anthoceros*

11.6.2 Answers Key:

(1) iii (2) ii (3) i (4) ii (5) i (6) iv (7) iii (8) iii

11.6.3 Answers Key:

(1) *Anthoceros* (2) *Anthoceros* (3) Endothecium (4) *Anthoceros* (5)*Anthoceros* (6) *Anthoceros* (7) Tubers (8) Tuberculate rhizoids and scales.

11.6.4 Answers Key:

(a) False (b) True (c) True (d) True (e) True (f) True (g) True (h) False

11.7 REFERENCES

- Singh, P.C. Pande and D.K. Jain (2013) A Text Book of Botany. Rastogi Publications , Meerut, New Delhi
- P. Pandey (2011) College Botany Volume I. Published by S. Chand & Company Ltd. Ramnagar, New Delhi.
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- 4 - H. C. Gangulee and A.K. Kar (1989) College Botany, Volume II.Published by New Central Book Agency (P) Ltd. Kolkata.

11.8 SUGGESTED READING

- Singh , P.C. Pande and D.K. Jain (2013) A Text Book of Botany. Rastogi Publications , Meerut, New Delhi
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11.9 TERMINAL QUESTION

11.9.1 Long answer type questions:

1. Give an account of the gametophyte of *Anthoceros* with necessary diagrams.
2. Give an illustrated account of sporophyte of *Anthoceros* and compare it with that of *Marchantia*.
3. Describe the structure and development of sex organs in *Anthoceros*.
4. Explain the external and internal features of the gametophyte of *Notothylas*.
5. With the help of labelled diagrams describe the structure of sporophyte of *Notothylas.*
6. Give a comparative account of the sporophyte of *Anthoceros* and *Notothylas*.

11.9.2 Short answer type questions:

1. What do you understand by hornworts?
2. Write important features of class Anthocerotopsida.
3. Describe male reproductive structure of *Anthoceros*.
4. What variations are found in the structure of sporophyte in different species of *Notothylas*.
5. Describe various types of vegetative reproduction in Anthocerotopsida.
6. Draw T.S. of *Anthoceros* thallus (Cellular).

UNIT: 12 CLASSIFICATION, STRUCTURE AND REPRODUCTION IN BRYOPSIDA

12.1-OBJECTIVES

This unit focuses on the structure and reproduction in ***Funaria*** and *Polytrichum***.***
After reading this unit student will be able:

- To know about mosses.
- To know about the distribution and habitat of the moss *Funaria* and *Polytrichum*
- To get an idea of the morphological characters of *Funaria* and *Polytrichum* gametophytes.
- To study the anatomical features of the leaf, axis of *Funaria* and *Polytrichum* and rhizome of *Polytrichum.*
- To study the vegetative reproduction in *Funaria* and *Polytrichum*.
- To know about the sexual reproduction in *Funaria* and *Polytrichum* by studying the structure of sex organs (antheridium and archegonium) and fertilization process.
- To study the structure of sporogonium, seta, foot, spore, spore germination and, protonema formation.

12.2 – INTRODUCTION

In unit – 9 you must have studied the general characteristics of bryophytes. I hope that you will be aware of the term Moss. The moss is a bryophyte with a leafy axis with an upright or prostrate shoot. In this unit we will study the structure and reproduction of two mosses viz., *Funaria* and *Polytrichum*. The genus *Funaria i*s a member of order Funariales. It is a weedy species and mostly found in nitrogen rich soil, in burnt areas of the forest. The important features of this genus are: the gametophyte is the dominant phase of the life cycle .It has two stages, the juvenile, short –lived filamentous phase, the protonema and the leafy gametophores –the moss plant. It has multicellular , branched rhizoids with oblique septa. The sex organs (antheridia and archegonia) are borne in separate branches of the leafy gametophyte. The sporophyte grows by two growing points. The mature sporogonium is divided into foot, seta and capsule.
The genus *Polytrichum* belongs to the order Polytrichales. This genus is much advanced with respect to structure. It has a prominent underground rhizome from which aerial shoots arise. The foliage leaves are large and has two distinct parts, the sheathing base and the blade. Multicellular rhizoids form a wick like structure that help in conduction of water. Anatomically, stem rhizome show presence of well developed conducting strand carrying hydroids (water conducting elements) and leptoids (sieve tube like elements)the apical cell is not used up in the formation of antheridia ,therefore the shoot may resume growth in the next year. On drying, the calyptra becomes brown and appears like a hairy hood covering the capsule, therefore, the moss is named as **Hair Cap Moss**.

12.3 –BRYOPSIDA

Class -Bryopsida is represented by 5sub classes with about 660 genera and about 14500 species. The characteristic features of this class are:

1. The plants have well differentiated plant body constisting of axis, leaves and multi cellular rhizoids.
2. The leaves are arranged in 3-8 rows on the axis, Generally, the leaf has a midrib(costa).
3. The sex organs are terminal in position and develop at the tip of the leafy axis.
4. The sporophyte is differentiated into foot, seta and capsule.
5. The sporogenous mass or archesporium develops from the outer layer of the endothecium and columella.
6. The capsule wall is made up of several layers of chlorophyllous cells and stomata.
7. The peristome teeth are present in one or two rows and surround the terminal opening of the capsule. The peristome teeth are absent in few cases.

Order- **Funariales**

1. The broad and spathulate leaves form terminal rosette like structure.
2. The capsule is wide without beak like operculum.
3. The calyptra is usually distended.
4. The peristome is usually double, the endostome (inner peristome) processes opposite to exostome(outer peristome).
5. The endostome lacks a basal membrane and the cilia are absent.

Order- **Polytrichales**

1. The gametophore is tall and perennial.
2. The leaves are narrow. The longitudinal lamellae are on the upper surface of the midrib.
3. The capsule is erect to horizontal.
4. The peristome arises from a single annual series of cells, in the inner zone of the amphithecium forming a ring of 32 or 64 short pyramidal teeth.
5. The tip of the peristome teeth are joined above to a thin membrane, the epiphragm, which covers the mouth of the capsule
6. The capsule is cucullate, and is either smooth, spinulose or hairy.

12.3.1 -*Funaria*

12.3.1.1- Classification

Division - Bryophyta
Class - Bryopsida
Order - Funariales
Family - Funariaceae
Genus - *Funaria*

Habitat: It usually grows on the ground in close tufts, frequently on recently burnt lands where ashes of plants are present. Sometimes it also occurs on rocks, walls or crevices.
Distribution: It is a very common moss and widely distributed throughout the world.

12.3.1.2- Structure

This moss plant has a dominant gametophyte phase and a dependent diploid sporophyte phase.

Gametophyte

The gametophyte phase of *Funaria* consists of two stages.

1. The juvenile stage, represented by the protnema.
2. The leafy stage, represented by the adult leafy gametophores.

Adult gametophores

External features

The mature plant of *Funaria* is a small gametophore, about 1 to 3 cm high, and consists of a slender, erect, radial central axis(stem) .It is covered with small, simple leaves which are spirally arranged on the axis (**Fig.12.1**).The stem is branched. Branching is monopodial. The branch originates below a leaf, that is, extra-axillary. The branches are also erect and grow in a vertical direction like the main stem. At the base of the gametophores, numerous branched, slender, multi cellular rhizoids arise. Each rhizoid arises from a superficial cell on the lower part of the stem and consists of a branching row of cells with oblique septa. The rhizoids are colourless in the young stage, but become red or brown at maturity. The colour of the rhizoids is due to the coloured walls. They usually contain oil and when exposed to light, they develop chlorophyll.

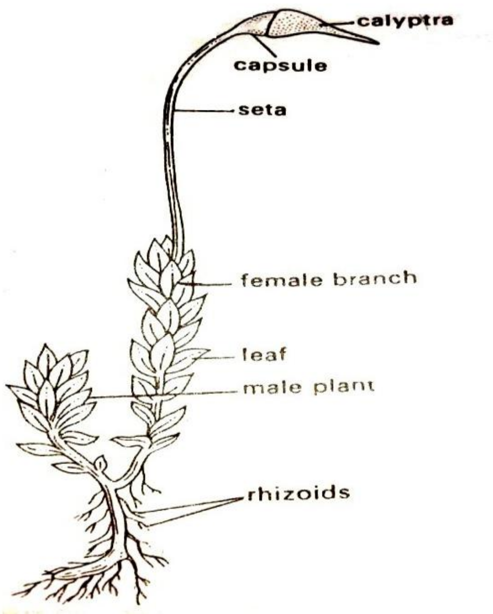

Fig.12.1, *Funaria hygrometrica*, A leafy gametophore

Leaves

The leaves are spirally arranged on the stem. The younger leaves at the apex are arranged in three vertical rows corresponding to the three cutting faces of the apical cell of the gametophores. The lower leaves are smaller and scattered, while the upper ones are larger and crowded at the apex of the stem. The leaves are sessile, ovate in form with a pointed apex and entire margin. They are attached to the stem by broad base. The leaves have a distinct midrib. The apical growth of the shoot takes place by means of a single pyramidal (tetrahedral) apical cell with three cutting faces.

Anatomy

Stem

The transverse section of stem shows a very simple internal structure. The cells exhibit a well- marked differentiation of tissues into a central cylinder, cortex and epidermis (Fig.12.2 A&B).The central cylinder consists of long, narrow, thin walled, colourless cells without protoplasm. The central cylinder is surrounded by the cortical tissue. The cells of the cortex in the young part contain chloroplast. In the mature stem the outer cells of the stem have the thicker walls and are reddish brown in colour. The cells of the inner cortex are thin walled. The epidermis is one cell thick and contain chlorophyll. The stomata are absent. The chlorophyll- containing epidermal cells perform the photosynthesis.

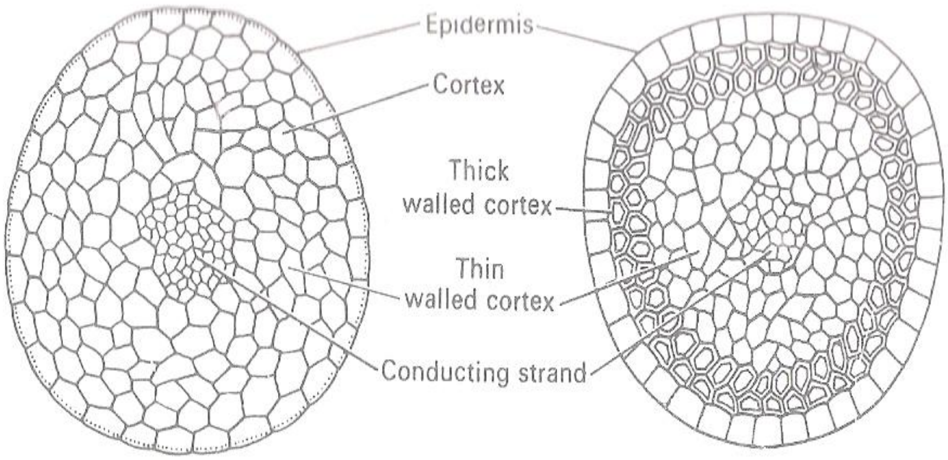

Fig. 12.2 ***Funaria hygrometrica*****, Transverse sections of the young(A) and mature (B) stem**

The Leaf

The leaf has a well defined midrib, which is several cell thick. The wing on either side of the midrib is single layered.(Fig.12. 3 B) The centre of the midrib is occupied by a small central strand of narrow thin walled cells forming a simple type of conducting strand. This is surrounded by a sheath of narrow thick walled cells and on the surface above and below there is a sheath of green cells. The cells of the thin marginal part of the wing are polygonal (parenchymatous) and contain numerous large and prominent chloroplasts. The chloroplasts are peculiar as they continue to multiply by division even after the cells are fully mature.

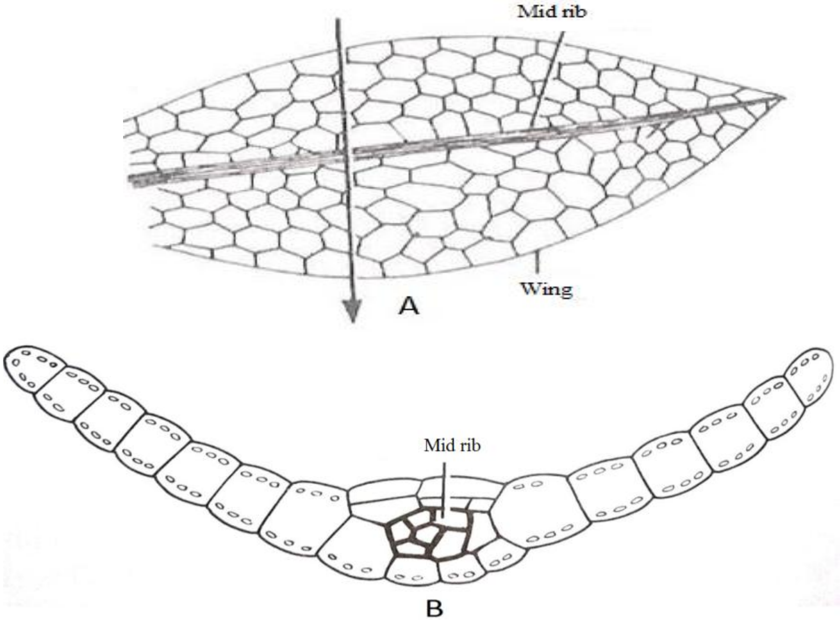

Fig.12. 3, *Funaria hygrometrica*

(A. A leaf as seen under microscope, B. Vertical cross-section of leaf.)

Apical growth

The stem grows by means of a single pyramidal (tetrahedral) apical cell with three cutting faces, which cut off segments parallel to the three sides. Each segment divides by a periclinal wall into an inner and outer cell. The inner cells by repeated divisions give rise to the inner tissue of the stem .The outer cells give rise to three leaves, the outer part of the stem and to the lateral branches. The growth of the leaf is carried out by the three sided apical cell.

12.3.1.3 - Reproduction

1-Vegetative Reproduction

The gametophyte of *Funaria* multiplies vegetatively by following means:

Multiplication of Protonema: The primary protonema multiplies vegetatively either by the breaking up of branches or small terminal groups of cells, which may grow into new protonema. In *Funaria*, certain separation cells, which have colourless contents, are formed by intercalary division. These cells break up the protonema into single celled or many celled filaments.These filaments grow into new protonema thus giving rise to a fresh crop of leafy gametophores.

By Gemmae: In *F. hygrometrica* gemmae were formed from the terminal cells of the protonemal branches by division in various planes. These gemmae are thin walled, with many chloroplasts and readily regenerat to protonemata. During unfavourable conditions, the gemmae develop on leafy plants on the axis and leaves.

By Bulbils: The bulbils, resting buds, are formed on the rhizoids. During favourable conditions they produce protonema.

By Secondary Protonema: The protonema may also be formed by other methods, other than the spores. These are known as secondary protonema, and are similar to primary protonema. Various methods of the formation of secondary protonema are: (i) the rhizoids of a leafy gametophores, exposed to light in moist conditions develop protonema.(ii) any detached living part of the gametophores (stem, leaves, antheridium, archegonium, paraphysis or the sterile cells of capsule or seta) may develop protonema

2-Sexual Reproduction

The Sex Organs The sex organs develop in terminal clusters and limits the growth of the axis that bears it. *Funaria hygrometrica* is a monoecious, and autoicous (i.e., the antheridia and archegonia are borne on separate branches on the same plant).The main shoot of the gametophores bears a group of antheridia at its apex, and acts as a male branch. The female branch develops later as a lateral branch from the base of the male branch, but eventually grows higher than the male branch.

The Male Branch: The antheridia are formed in groups at the apex of the male shoots which are about one centimetre in height. The leaves on the lower part of the male shoot are small and scattered but at the top they are crowded together to form a rosette of spreading leaves (the **perigonial leaves**), thus simulating a "flower"(not homologous with the flower of angiosperms).The central part of the rosette is of reddish colour. At the convex expanded apex of the male branch, within the rosette, a large number of antheridia are formed in long continued succession without any fixed order, with the result all the stages in development can be traced in a single head (Fig.12.4A).

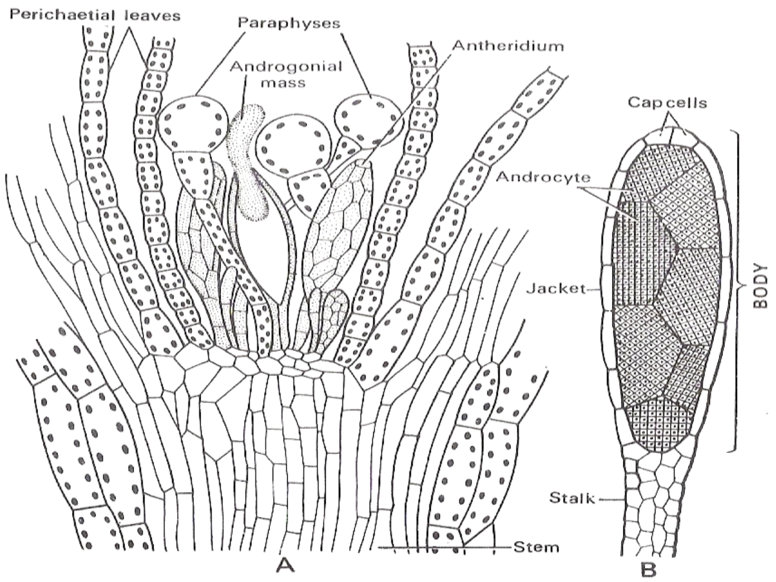

Fig. 12. 4 *Funaria hygrometrica,* (A. Longitudinal section of the tip of male shoot (adapted from Parihar. N.S.) B. A mature antheridium)

The Mature Antheridium: It has a short massive stalk and a body about 0.25mm.in length .The body is club-shaped. The body has a single layered outer jacket formed of polyhedral flattened cells containing numerous chloroplasts when young, and which often turn orange or red at maturity (Fig.12. 4 B) .The apex of the jacket is closed by one or two large colourless opercular cells with thicker walls. Within the jacket a dense central mass of numerous androcytes is present. On the rounded apex of the male branch there are a number of upright multicellular hairs which are intermingled with the antheridia. These are known as paraphyses. Each paraphysis is composed of a single row of 4 to 5 cells .The cells at the base are narrow, but the distal cells are greatly enlarged and almost globular in form. All the cells of the paraphyses contain chloroplasts .The function of paraphyses is not definitely known. They probably help in ensuring sufficient moisture for the developing antheridia, and thus prevent drying of these organs, either by holding water between them by capillarity, or by secreting water. The enlarged sub-spherical terminal cells of the paraphyses meet over the antheridia .The cells of the paraphyses being rich in chloroplasts may also help in photosynthesis, though to a limited extent.

Dehiscence of Antheridium: Dehiscence of mature antheridium takes place when water is collected in the cup formed by the perigonial leaves as a result of rain or dew. According to Muggoch and Walton (1942) if water comes in contact with the anteridium the inner surface of the outer wall of the opercular cell becomes mucilaginous and swells .The inner wall of the opercular cell then bursts inwards and the whole content of the opercular cell slips into the antheridial cavity at the top of the androcyte mass before actual dehiscence of antheridium occurs. The outer wall of the opercular cell also ruptures shortly after and the mass of the androcytes comes out in the form of stream throuth it. As this mass reaches the surface of water in the perigonial cup, the androcytes separate and spread out in a film. The androcyte masses break up and the individual androcytes spread apart on the surface of water. The antherozoids are liberated from the androcytes in a few minutes.

The Female shoot: Archegonia are found at the apex of the female branch. The leaves surrounding the archegonial group are known as **perichaetial leaves**. These are similar to ordinary foliage leaves and within the leaves there are a large number of archegonia and paraphyses. The axis of the female branch has a limited growth as the apical cell itself is used up in the formation of archegonium (Fig.12.5 A).

The Mature Archegonium: The archegonium has a relatively long and massive stalk, a slightly enlarged venter and a long neck. The jacket of the archegonium is double –layered in the region of the venter but the neck usually consists of only a single layer made up of six ventral rows of cells, somewhat obliquely placed. Inside the jacket there is the central row of cells, consisting of egg, and ventral canal cell in the venter, and six or more neck canal cells in the long neck. When the archegonium is mature, the neck canal cells and the ventral canal cells disintegrate forming a mucilaginous substance, and the terminal cells of the neck separate widely from each other, leaving a passage leading to oosphere (Fig. 12.5 B).

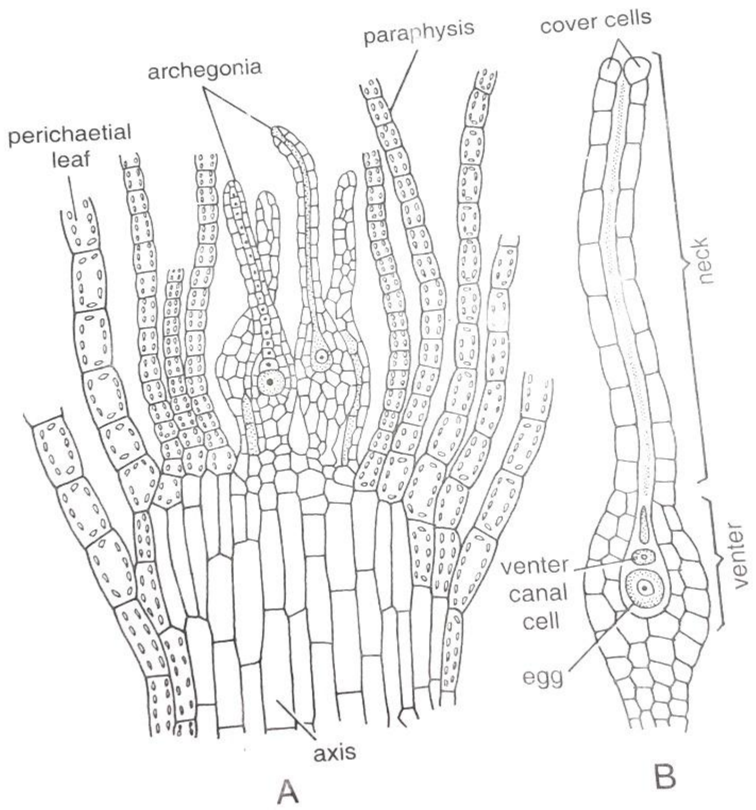

Fig. 12.5 ***Funaria hygrometrica*****, (A. Longitudinal section of the female shoot (adapted from Parihar, N.S.) B. A mature archegonium)**

Fertilization: The presence of water is essential for the antherozoids to swim upto the archegonium. The splashing of rain drops from the heads containing mature antheridia to those with archegonia may facilitate the transit of antherozoids to the archegonium. After the antherozoids reach near the archegonium, they are attached towards the neck of the archegonium on account of some chemotactic substances, possibly sugars, emitted by the archegonium. Many antherozoids pass through the fluid remains of the neck canal cells and ventral canal cell, but only one fuses with the egg.

The Sporophyte

After fertilization the zygote is formed which secretes a wall and inceases in size. The zygote divides by a transverse wall into an upper epibasal cell and a lower hypobasal cell (Fig. 12.6 B). In the epibasal cell two successive oblique walls are laid down, thus forming a two sided apical cell .In hypodermal cell, apical cell is also formed similar to the epibasal cell. In this way, in the early developmental stages of sporogonium with two growing points are formed.
The upper apical cell cuts off segments right and left alternately and finally these cells form the capsule and upper part of the seta.

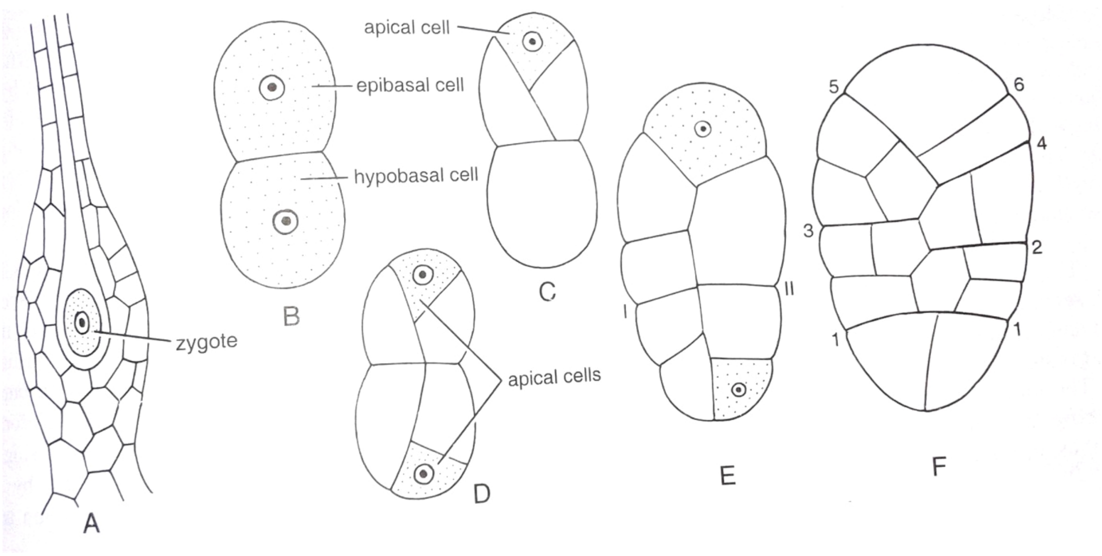

Fig.12.6 *Funaria hygrometrica,* Early developmental stages of sporogonium

The lower apical cell cuts off segments into irregular fashion and give rise to foot and lower part of seta. The apical growth goes on and the young sporogonium becomes cylindrical in shape.

The Mature Sporogonium

A mature sporogonium is composed of three parts: (i) foot (ii) seta and (iii) capsule.

Foot: The foot is poorly developed. It is small dagger-like conical structure which is embedded in the apex of the archegonial branch. From the archegonial branch, it absorbs water and mineral nutrients for the developing sporogonium.

Seta: The seta is long, slender, twisted structure and bears the capsule at its upper end. The axial tissue of the seta forms a strand of elongated cells, which is continued upwards into the tapered base of the capsule. The axial cylinder is surrounded by a thick-walled cortex and epidermis. The strand has the function of conduction of water. It also functions as a mechanical tissue.

Capsule: The mature capsule is a pear shaped slightly oblique structure (Fig.12.7). Its upperportion is covered b a conical hood or cap, the calyptras. The capsule is divided into three distnict regions: (i) a sterile basal region, the apophysis, (ii) the central fertile region, the theca proper, (iii) upper region, the operculum and peristome.

The Apophysis

The seta extends above to form the basal region of the capsule, called apophysis. In the centre of the apophysis conducting strand is present .It is in continuation with the central strand of the seta. The central tissue is surrounded by a zone of spongy green palisade like tissue with intercellular space. The epidermis has true stomata which are formed by the division of the epidermal cell and at early stage the stoma has two guard cells. In the later stages, there is single annular guard cell with two nuclei surrounding the pore. The stomata are oriented with their long axis parallel to the long axis of the sporogonium.

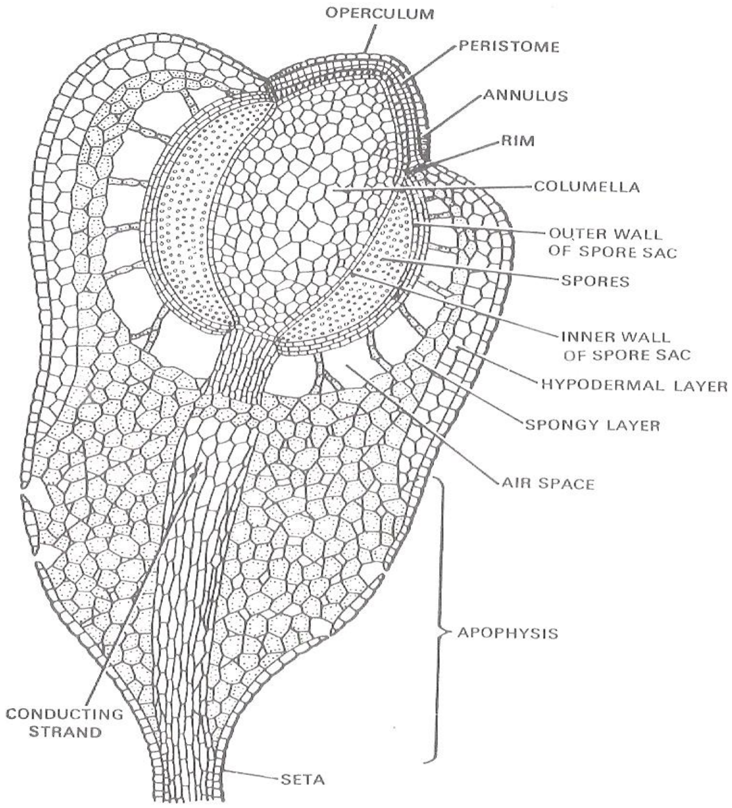

Fig. 12.7 *Funaria hygrometrica,* A longitudinal section of capsule

The Fertile Region (The Theca Proper)

In the centre of the fertile region, there is a sterile column of thin-walled parenchymatous cells, the columella. The upper end of the columella is cone-shaped, and extends upwards into the concave inner portion of the operculum, while its basal tapered end is connected with the central tissue of the apophysis by filaments of cells.

The columella is surrounded by a barrel shaped spore sac. In L.S. of the capsule, the spore sac appears U-shaped, which is interrupted at its base by columella. The spore sac has an outer wall of 3 to 4 layers of cells, and inner wall of one layer of cells. Between these are the spore mother cells, each of which divides to form four spores by the usual meiotic division. Outside the spore sac there is a wide cylindrical air space, which is traversed by filaments of 2 to 4 narrow green cells, joined externally to the inner surface of the capsule wall. The capsule wall in this region consists of 2 to 3 layers of cells bounded by a well-defined epidermis. The two outer layers of wall just below the epidermis consist of compact, colourless, parenchymatous cells forming a hypodermis, while the innermost layer is composed of loosely arranged cells containing chloroplasts. The colourless hypodermal tissue of the capsule wall thins out below the fertile region, whereas the green inner tissue increases in thickness and is continuous with the green tissue of the apophysis.

The Upper Region

The upper region of the capsule is highly modified in relation to the dispersal of spores. This region is marked off from the theca by a constriction. Just below the constriction there is a diaphragm composed of 2 to 3 layers of radiately elongated, pitted cells. The rim has the form of a circular ledge perforated by the thin walled tissue. The rim stretches inwards from the epidermis of the capsule wall and joins the peristome to the epidermis. When the operculum separates from the capsule these layers form the thickened rim of the open capsule.

Above the rim is the annulus, which consists of 5 to 6 superimposed layers of epidermal cells that occupy the periphery of the broadest part of the operculum. The upper rows of cells are narrow, thick-walled and radiately elongated and form the lower edge of the loosened operculum. The cells of the two lowest layers of annulus have thinner walls and are swollen. Dehiscence eventually takes place by the destruction of these swollen cells.

Below the edge of the diaphragm, peristome is attached. Peristome consists of two rows (inner and outer) of curved narrow, triangular plate-like teeth (Fig.12.8). Each row has sixteen teeth. The teeth of the outer peristome are red and are ornamented with thick transverse bars. These teeth are twisted spirally to the left and converge together at the tip, where they are joined to a small central disc of persistent tissue. The teeth of the inner peristome are colourless and are shorter and more delicate than the outer ones. At their bases they are directly covered by the teeth of the outer peristome, but towards the centre of the capsule mouth they curve, so that they narrow the position, where the slits between the teeth of the outer peristome are widest (Fig.12.9).

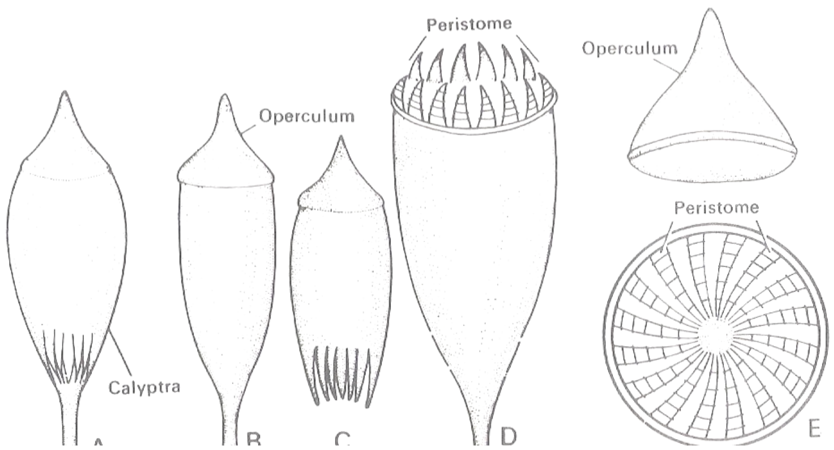

Fig.12.8 *Funaria hygrometrica*, Capsule showing calyptra, operculum and peristome

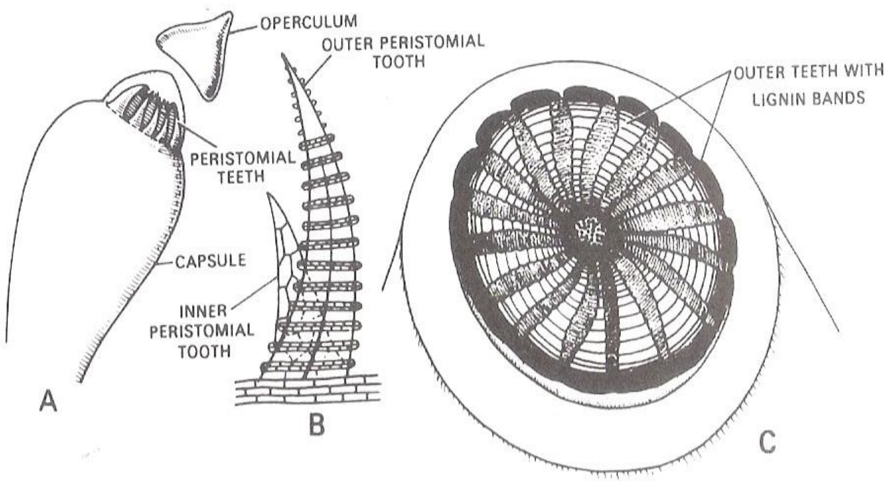

Fig.12.9: ***Funaria hygrometrica,*** **Capsule showing calyptra, operculum and peris**

The mouth of the capsule is closed by the operculum which consists of about three layers of small thin-walled cells bounded by a superficial epidermal layer, with thickened outer walls.

Dehiscence of Capsule

At maturity the capsule begins to dry up, and the columella along with other thin walled tissues looses water. They shrivel up, tearing open the space in which the spores lie. The annulus proper, which consists of peculiarly elastic and hygroscopic cells, aids in the removal of the operculum. When moisture is available the mucilaginous walls of cells of annulus proper swell rapidly with the result that the annulus breaks free from the rim of the capsule and suddenly rolls back, that results into throwing off the operculum. Thereafter, the peristome teeth by their hygroscopic movements assist in emptying the spores from the capsule. Each tooth of the outer peristome is a two ply structure and is composed of two layers joined together, one forming the outer surface and the other the inner surface. The outer layer of each tooth lengthens when wet and shortens when dry, but the inner layer is not affected by changes in moisture content. When the outer peristome teeth absorb water, the outer layer increase in length to a greater extent than the inner and they curve together inwards and the dome is reconstituted, resulting into the opening of the capsule. The inner peristome teeth do not show hygroscopic movements. In dry weather, the outer peristome teeth loose water and their outer layers shorter more than the inner, with the result that they bend outwards, with jerky movements as they separate from one another and the slits between the outer teeth become wider, and the inner peristome teeth act as a sieve allowing only gradual discharge of the spores, a few at a time (Fig.12.10).

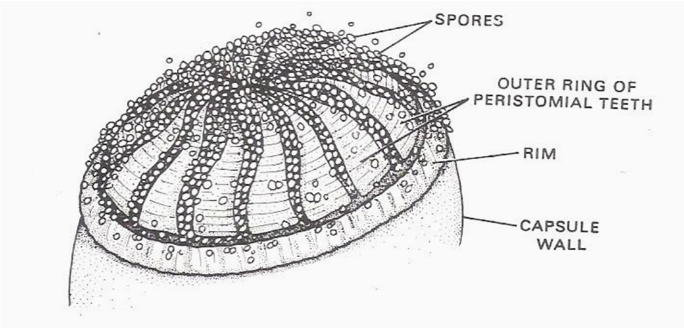

Fig.12.10 *Funaria hygrometrica*, Spore dispersal

The long slender seta of ripe capsule is wavy and twisted and also shows the hygroscopic movements. When moistened the seta becomes untwisted, swinging round. As it dries up its movements are reversed. Thus by the combined effort of the hygroscopic seta and peristome, the spores are liberated in smaller amounts over a longer period.

The Young Gametophyte

The Spores: The spores are more or less spherical with a smooth surface. Spore diameter ranges from 0.012 to 0.020 mm. The spore has two wall layers, an inner hyaline endosporium; and a coloured but smooth exosporium. The spore has single nucleus, numerous oil globules and chloroplasts.

Spore Germination and Protonema formation: Under favourable conditions, spore begins to germinate within a few days. Heitz (1942) found that they remain viable at least for two years. Upon absorbing moisture, spore increases in size and the exospore bursts. The endospore protrudes out as one or two germ tubes, partitioned by cross walls. These cells divide to form a branched, filamentous multi-cellular structure, the primary protonema. The protonema grows apically by the divisions of the apical cell. The filaments of protonema grows in two different directions and form two types of branches. The branches that grow prostrate on the surface of the substratum and upright branches the chloronemal branches (Fig.12.11).

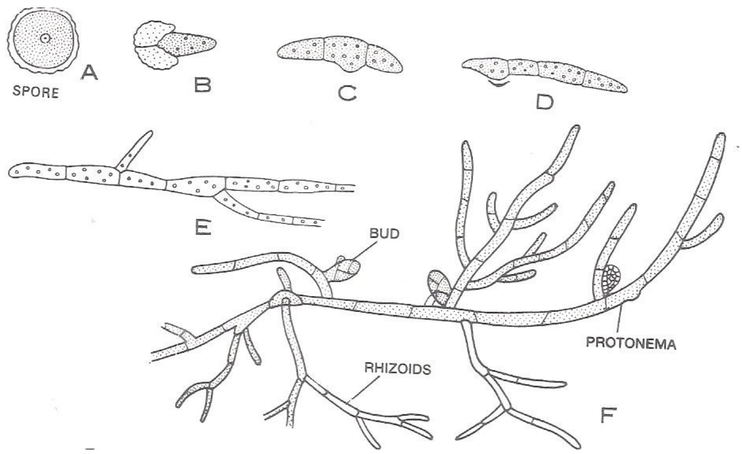

Fig.12.11. *Funaria hygrometrica*, Stages of Spore germination and protonema formation

The chloronemal branches are thick, with hyaline cell walls and which are divided by transverse walls. The cells are chlorophyllous (many discoid small chloroplasts) thus photosynthetic.
The rhizoidal branches are thin, with brown outer walls, and with oblique cross walls. The cells either contain small chloroplasts or leucoplasts. The main function of these branches is attachment, but in juvenile stage they also absorb water and minerals. These branches may develop chlorophyll on exposure to light and transformed into chloronemal branches.

Sironval (1947) studied the development of the protonema in *Funaria hygrometrica* in culture and opined that it consisted of two clear-cut stages, the chloronema and caulonema. Accordingly, the chloronema is formed immediately on spore germination and differs from the caulonema, which succeeds it, in morphological characters.

The chloronema has the following features: (i) it has sparse and irregular branching; (ii) the cross walls are at right angles to the long axis of the protonemal thread; (iii) the cell walls are colourless; (iv) numerous chloroplasts, circular in outline and evenly distributed; (v) nucleus is complete, not visible in light microscope;(vi) positively geotropic; (vii) does not form buds; (viii) it forms a thermolabile growth promoting substance.

According to Sironval the chloronema persists for 20 days thereafter most of its cells degenerate, but certain apical cells persists and give rise to the second stage, the caulonema. The caulonema has the following features: (i) it is profusely and regularly branched; (ii) the cross walls are oblique to the long axis of the filaments;(iii) the cell walls are brownish; (iv) the chloroplasts are fewer, spindle shaped and less evenly distributed; (v)the nucleus shows degeneration of nucleolus and easily visible in light microscope;(vi) negatively geotropic; (vii) the buds of the gametophores are formed only on the branches of caulonema; (viii) in caulonema, after about 10 days, a substance is formed which is thermostable and functions as a growth inhibitor (Bopp, 1963).

Bud Formation

The bud arises as a lateral swelling from a cell of a parent filament, just behind a cross wall. The main position of the bud is near the base of the principal filament of the aerial erect branch system, but sometimes develop directly on the brown filaments. The lateral protrusion after cutting off one or two stalk cells, swells at the end and divides by three oblique walls to form the terminal tetrahedral cell of the future gametophores, with three cutting faces. It begins to function as the apical cell of the young gametophores and cuts off three sets of lateral segments. The first few segments of the apical cell do not form any leaf, but contribute only to the base of the leafy gametophores; and rhizoids may also grow from this region before any leaves are formed. Later on the segments give rise to the leaves and the tissue of the stem. After the establishment of the leafy gametophores with several leaves and rhizoids, the primary protonema withers and disappears and the several gametophores borne on a protonema become independent.

Life Cycle of *Funaria hygrometrica*

In a single life cycle, two distinct vegetative individuals are seen.Such a life cycle is called diplobiontic (Fig.12.12).One of the vegetative individual is the leafy shoot and the other is the sporogonium. The green leafy shoot represents the dominant phase and is gametophytic in nature It is related with sexual reproduction.This is the gametophytic or haploid (n) generation of the *Funaria* plant. It begins with the formation of spores and ends with the gametes (egg and antherozoids). The second individual is the sporophyte, which represents the sporophytic or diploid (2n) generation. It begins with the formation of zygote. The zygote, the embryo and the sporogonium(foot, seta and capsule) form the sporophytic generation.

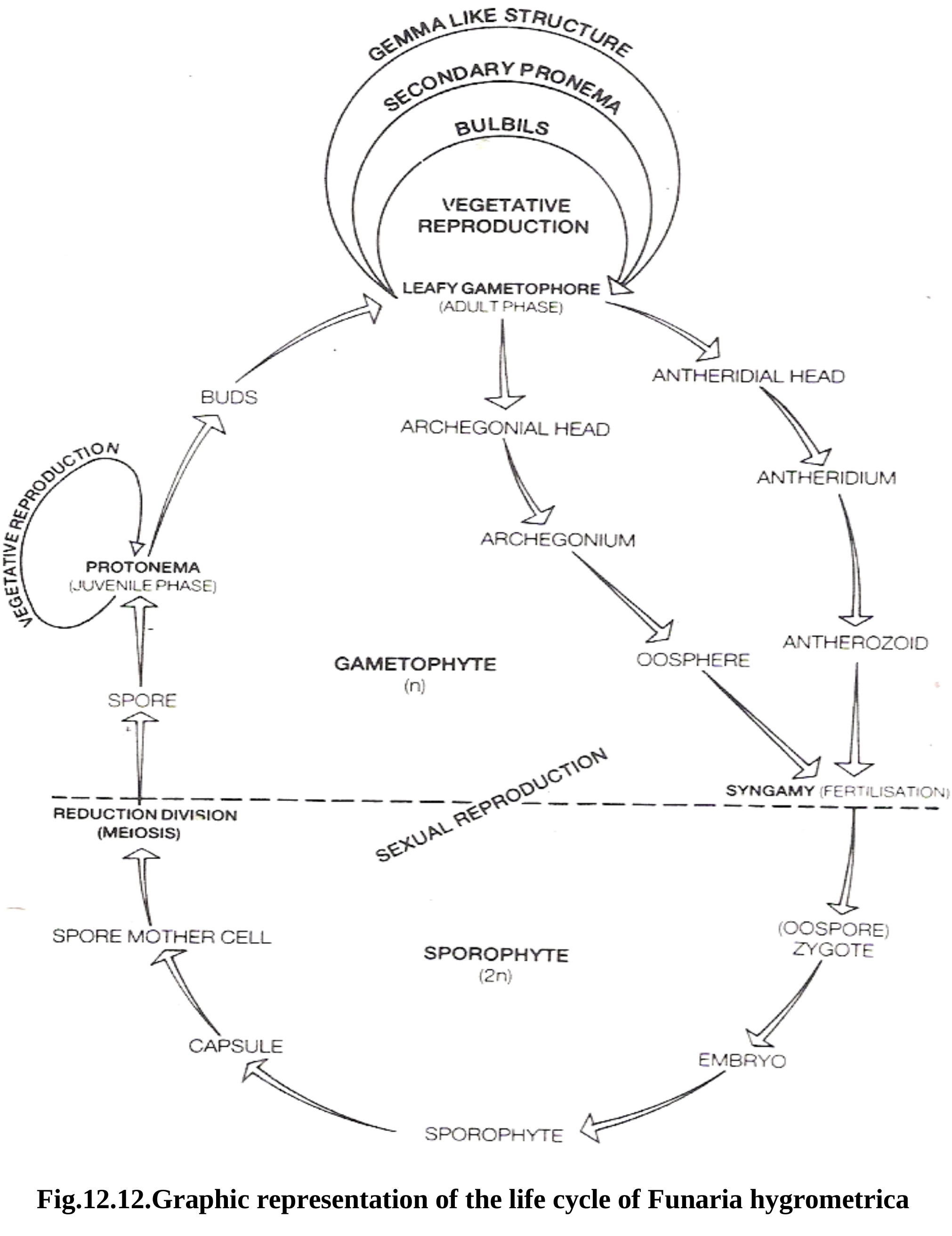

Fig.12.12.Graphic representation of the life cycle of Funaria hygrometrica

Alternation of generation

The alternating individuals in the life cycle are morphologically different. This kind of alternation of generation is called heterologous or heteromorphic. The difference in two generations is due to the different modes of life .The gametophyte is independent, while the sporophyte is partially dependent on the gametophyte.(Fig.12.13)

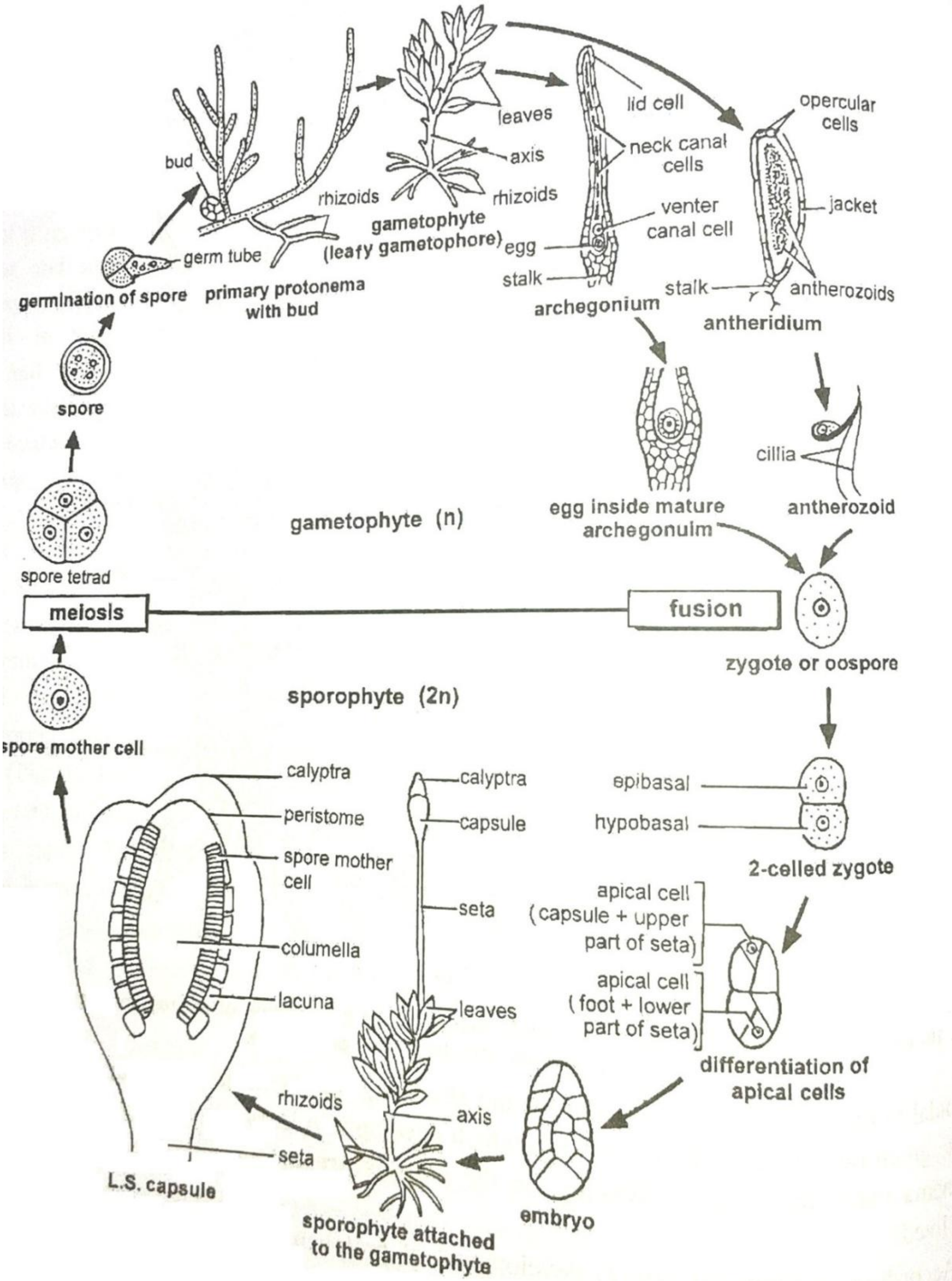

Fig.12.13 Diagrammatic representation of the life cycle of *Funaria hygrometrica*

12.3.2. *Polytrichum*

12.3.2.1-Classification

Divison- Bryophyta
Class - Bryopsida (musci)
Order - Polytrichales
Family - Polytrichaceae
Genus - *Polytrichum*

Distribution: It is a large genus of about 100 species which are worldwide in distribution, but mainly found in cool temperate and tropical regions. *P. commune* is a cosmopolitan species. The common species of *Polytrichum* in India are *P.densifolium, P. xanthofolium* and *P.juniprerinum. Polytrichum* is commonly called as hairy root moss.

Habitat: *Polytrichum* grows in a variety of habitats, such as sandy ground, on banks and heaths, dry and stony places, dry woods, marshy moors, peat bogs, and damp soil along the margin of lakes and ponds.

12.3.2.2- Structure

The Gametophyte: The gametophore of *Polytrichum* is differentiated into two regions, the horizontal underground rhizome and the branched erect leafy stems. The aerial leafy stems may attain a height up to 20 centimetres or more in some species of *Polytrichum*, for example *P. commune.* (Fig.12.14)

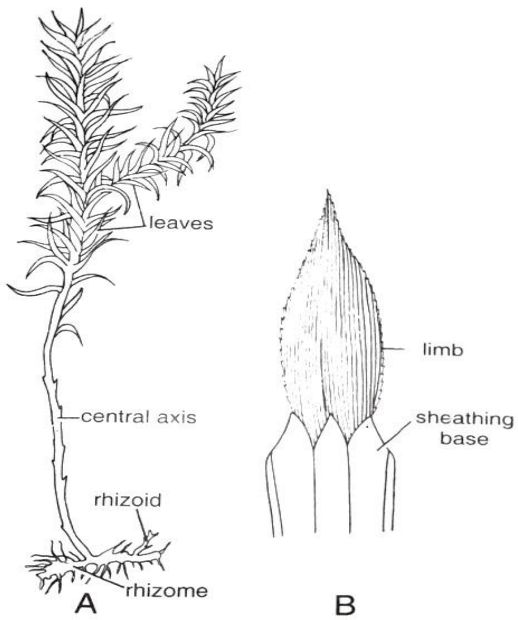

Fig. 12.14. *Polytrichum*, gametophores (A) and foliage leaf (B)

In *P. commune* between the rhizome portion and the upper leafy shoot, a transitional middle region is present which is brown in colour, and three sided. At the base and on the lower side of every 12th leaf, bud initials are present throughout the axis. These initials along the leafy shoot usually remain dormant but may grow if the tips of the main shoots are cut or if shoots are kept in a moist atmosphere (Wigglesworth, 1959).

Leaves

The leaves on the rhizome and the middle transitional region are brown or colourless and sealy. They are borne in three vertical rows with a divergence of 1/3. The leaves on the aerial leafy shoot are relatively large, thick and rigid and are arranged on the stem in a complicated spiral manner.

Each leaf has a broad, colourless membranous unistratose sheathing base, which narrows above into a `limb' which is lanceolate to linear lanceolate. The limb is occupied mainly by a broad midrib (costa) and the rudimentary wing .The wing is developed slightly at the extreme margin of the limb which is entire to coarsely toothed. The midrib has close set rows of longitudinal plates of green tissue (lamellae) of one cell thick on its upper surface. These lamellae are attached to the surface of the midrib by one edge. As a result the midrib becomes firm, opaque and dark green (Fig.12.14).

Rhiozoids

The numerous rhizoids are borne on the rhizome of the gametophores. The rhizoids are long, thick-walled, multicellular and with oblique septa. The rhizoids coil round one another to form dense tangled mass looking like a badly twisted string, as thick as half the diameter of the rhizome, or sometimes more. The water besides passing through the lumen of the rhizoids also passes upwards through the wick-like strands of rhizoids by external capillarity and, therefore, many species of *Polytrichum* are able to live in relatively dry places. In species which attain sufficient height, these strands of rhizoids provide mechanical support also.

Anatomy

The internal structure of the subterranean rhizome and the aerial leafy stem are different in anatomical features.

The Rhizome: In transverse section (Fig.12.15) the rhizome is triangular with round corners and slightly convex sides but may be roughly circular in outline, *e.g.* in *P. formosum*.

Epidermis: On the outside there is a superficial layer of thin walled or thick walled cells bearing a large number of rhizoids which form a dense tangled mass.

Cortex: Below the superficial layer, there are two or three layers of living cortical parenchyma.

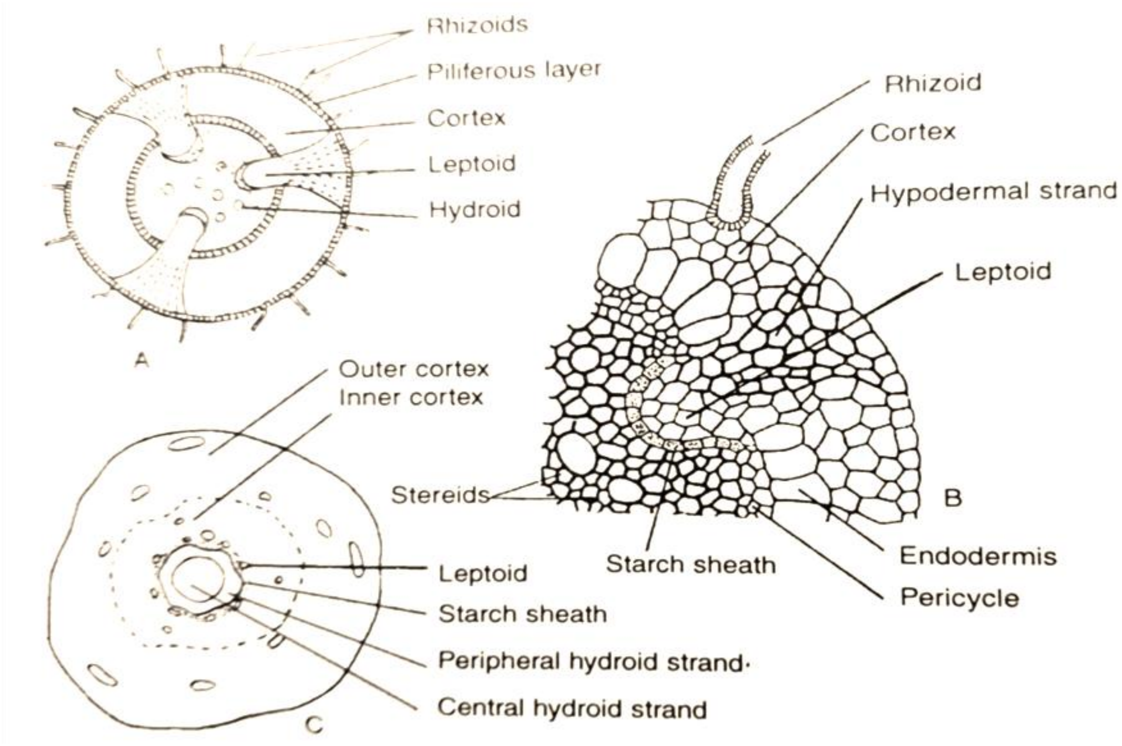

Fig.12.15 ***Polytrichum:*** **T.S. of rhizome diagrammatic (A); A portion enlarged (B); T.S. of aerial shoot diagrammatic (C)**

Radial Strands

This tissue is interrupted opposite the three ridges by the sclerenchymatous cells of three hypodermal strands .The cells of the hypodermal strands are distinctly prosenchymatous with pointed ends. They are living cells sometimes containing starch. Passing radially inwards from the hypodermal strands there are cells of greater diameter but with thinner and lignified walls .They show no sharp line of demarcation from those of the hypodermal strands, and form together with a wedge-shaped mass of tissue gradually narrowing inwards and are called the radial strands.

Endodermis: At the inner limit of the cortex is a layer of radially elongated cells with thickenings and suberization on their radial and horizontal walls. This layer resembles the endodermis of roots, but is discontinuous and consists of three arcs separated by the larger cells of the radial strands.

Pericycle: In most cases the three-lobed central strand is surrounded by an interrupted pericycle composed of two to three layers of cells

Central Cylinder: The central cylinder consists of an inner compact mass of tissue with three broad projecting regions and three narrower furrows opposite its angles.

Stereom: The central mass consists mainly of very thick-walled elongated living cells often with oblique end walls with little starch. These are steroids, as a whole being called stereom**.**

Hydrom: Scattered among these are elements of about same diameter, but quite destitute of contents. These are often united in bands of 2 or 3, the cells of each band being separated by extremely delicate cellulose walls; which are really the very oblique walls of the cells. For these elements, which are exactly like and continuous with those of central strand of the aerial stem, these named are hydroids, the water conducting tissue and as a whole being called hydrom.

Leptoids: In the furrows, the centre of the bay is occupied by a group of 6 to 8 polygonal cells, containing thick granular contents of protein nature. These sieve tube like cells are known as leptoids, as a whole being called leptom (Tansley and Chick (1901).

Amylom: The leptoids are surrounded by starchy parenchyma which was named amylom. The amylom is situated between hydrom and leptom.

Aerial Leafy Stem

The outline of the section is irregular. It shows the following structures (Fig.12.15 C).

Epidermis: The superficial layer is single layered but not clearly defined as an epidermal layer.

Cortex: Cortex is well defined. The peripheral cortical region consists of compact elongated prosenchymatous cells which gradually merge into the compact parechymatous cells of the inner cortex. The cortical cells contain starch. In the cortical region the leaf traces are seen passing through it to join the central cylinder.

Pericycle: Inside the inner cortex, a layer with abundant starchy contents represents the rudimentary pericycle interrupted by incoming leaf traces.

Leptome: Internal to this is an irregular zone of typical sieve tube like cells, interrupted by starchy cells, with protoplasm but no starch. This is the leptom mantle. This is equivalent to the phloem of vascular plants.

Hydrom Sheath: Inside this is the hydrom sheath (amylom layer) composed of one or two layers of cells with dark brown suberized walls and copious starchy content.

Hydrome Mantle: Inside the hydrom sheath is the hydrom mantle composed of thin-walled cellswithout contents.

Water conducting tissue: In the centre of the stem is the hydrom cylinder composed of thick walled cells. This tissue is concerned with the conduction of water and is equivalent to the xylem of vascular plants physiologically.

The Leaf

In the T.S. of the limb (Fig 12.16) the broad midrib is several cells thick in the centre and gradually merges into the rudimentary wing (lamina) at the margins. On the lower surface there is a well defined epidermis made up of large cells whose outer walls are strongly thickened. Within the epidermis are one or two layers of small, sclerenchymatous elongated cells, in which the lumen is almost obliterated.

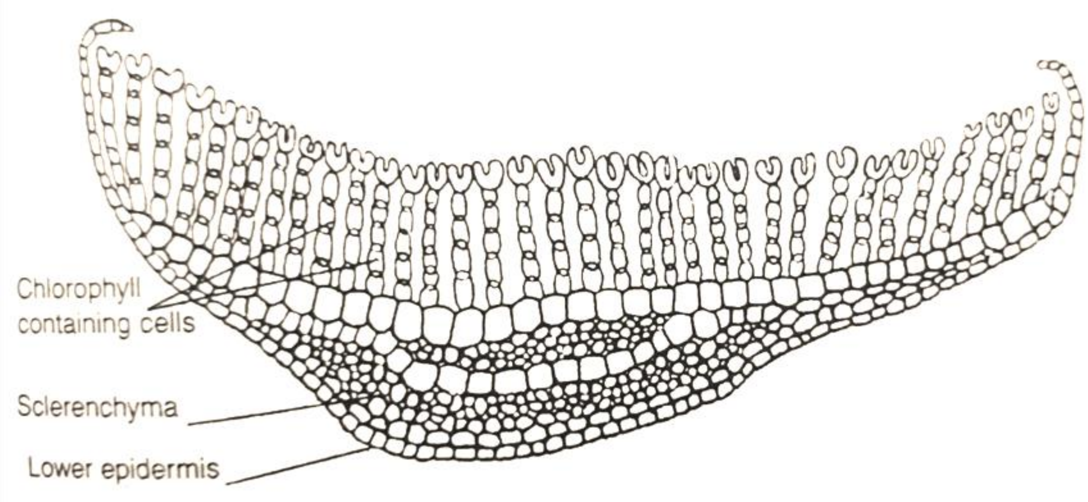

Fig. 12.16 *Polytrichum,* V.T.S. of leaf (limb)

The central tissue of the leaf is formed by large thin-walled parenchymatous cells, among which are scattered here and there small groups of sclerenchymatous cells. On the upper surface there is layer of large cells from which arise numerous parallel thin, longitudinal plates of chlorophyll containing cells, which represent the transverse sections of the longitudinal plates or lamellae observed on the upper surface of the leaf in a surface view. Each plate is 5 to 8 cells high and the terminal cell of each plate is wider or papillose, and differs from rest of the cells. The slightly enlarged terminal cells of the adjoining plates almost touch one another. The lamellar outgrowths of the midrib are the chief photosynthetic tissue of the leaf, and they compensate for the reduction of the ordinary assimilatory tissue of the reduced wing. These lamellae besides serving as organs of assimilation, also act in a capillary manner and hold water between them, as they stand very close to each other.

In *Polytrichum*, the wing of the leaf usually consists of hyaline cells and in some species they bend over the assimilatory portion of the leaf (midrib) when the air is dry. This feature is marked in *P. piliferum* and *P. juniperinum* which grow in comparatively dry or exposed places.

Conduction of Water

Bowen (1931, 1933) is of the opinion that the main water supply of *P. commune* and many other mosses passes up` over the external surface of the plant in the form of a series of capillary films between the closely adherent sheathing leaf bases and the stem. This water is then absorbed through the unthickened external walls which are generally to be found in the cells aggregated at the apex of the plant and in the leaves and branches. The central conducting strand in the stem takes very little part, if any, in the upward conduction of water. On the other hand, Blaikley (1932) and Magdefrau (1935), however, hold that there is a high rate of internal conduction of water through the central conducting strand.

12.3.2.3- Reproduction

Vegetative reproduction

Wigglesworth (1947) reported that the rhizoid system is important in vegetative reproduction. These wick-like rhizoid strands bear buds which develop into leafy axes. In these buds, food is stored in the form of starch to be used when required. Intact and unwounded leaves of *P commune* may be induced to initiate growth leading to production of new and separate plants when placed on suitable media, in sterile culture and under high humidity (Ward, 1960) (Fig. 12.17).

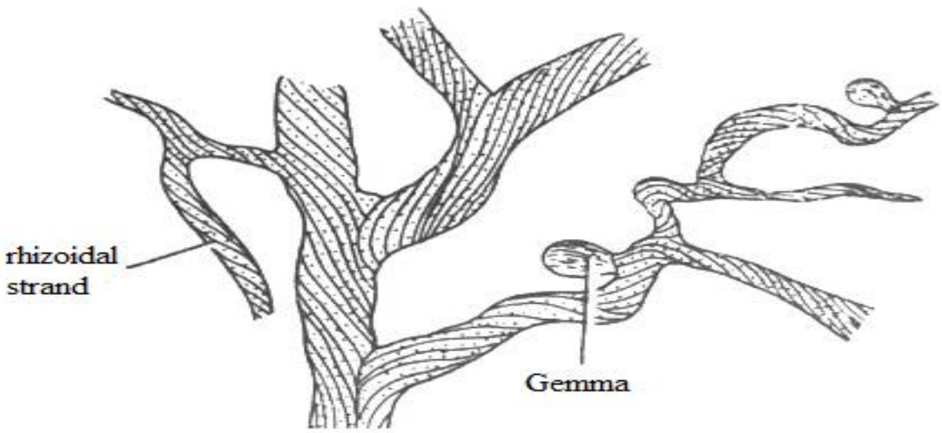

Fig.12.17 Polytrichum rhizoids with gemma

Sexual reproduction

Polytrichum is usually dioecious and the archegonia and antheridia are borne in terminal clusters at the apex of separate gametophores.

Antheridial Head

The terminal part of the male shoot forms a conspicuous almost flower-like open cup. This cup is formed by perigonial leaves which are different in form and colour from the other vegetative leaves on the gametophores. These leaves are red-brown, or dull red in colour, and each consists of a very broad sheathing base and a short bristle point (Fig.12.18).

The growth of the male shoot is not stopped by the development of the antheridia, as the apical cell of the shoot is not used up in the formation of an antheridium. After the antheridia have been formed and matured, the vegetative axis may grow out in the following year through the antheridial group and produce a new shoot (proliferation) which may bear antheridia at its apex. This proliferation of the vegetative shoot upwards through the antheridial head may be repeated several times and it gives the appearance of an axis through a series of antheridial cups.

The antheridia are produced in groups at the base of each perigonial leaf in the position of lateral buds. According to Leitgeb, each group of antheridia represents a shortened lateral branch, and the whole anheridial head is a compound structure, in contrast to the simple male head of *Funaria.*

Mature Antheridium

The mature antheridium consists of a short stalk and a club shaped body. The body has a single-layered jacket surrounding a central mass of androcytes. Androcytes metamorphose into biflagellate atherozoids at maturity. Associated with the antheridia there are paraphyses. Some of these are simple filamentous, others are broadened at their tips into a spathulate single-celled thick mass of cells (Fig.12.18).

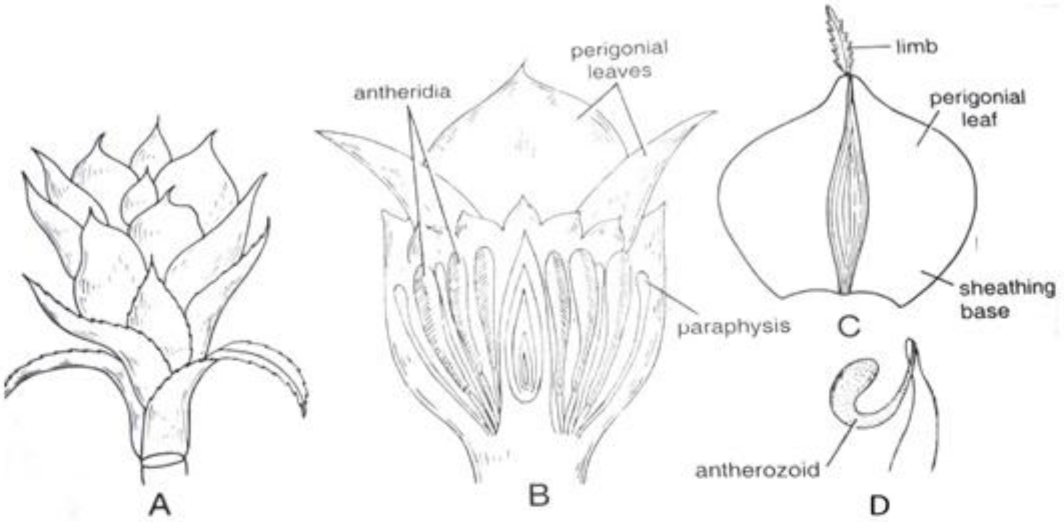

Fig.12.18 Polytrichum male shoot (A); L.S. of male shoot showing antheridia (B); A perigonial leaf (C); An antherozoid

The Archegonial Head

The archegonia are borne in terminal clusters at the apex of the leafy shoot of female gametophore. In *P. commune* there are usually three archegonia in each cluster. The apical cell of the leafy shoot itself forms the initial of an archegonium with the result that the further growth in length of the shoot stops with the formation of a sporogonium (Fig.12.19). The archegonium in structure it is more or less similar to that of *Funaria.*

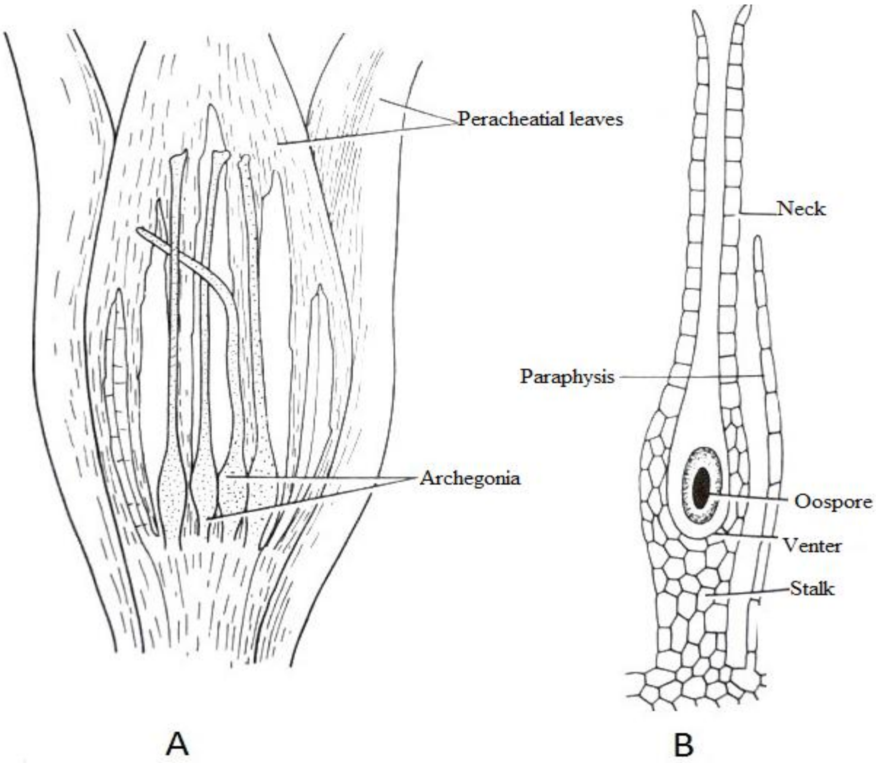

Fig.12.19, *Polytrichum*, (A) female shoot showing archegonia; (B) An argegonium

Fertilization

Is accomplished by the union of male (antherozoid) and female (egg) gametes with the aid of water. The diploid zygote thus formed does not pass the resting period but undergoes several divisions and forms the sporophytic plant-the sporogonium.

The Sporophyte

The mature sporogonium consists of a foot, a long seta and a capsule (Fig. 12.20).

Foot: The foot is embedded in the tissue of the apex of an archegonial branch and consists of thin-walled parenchymatous cells.

Seta: Just above the foot and continuous with it is the long slender seta, which supports the capsule at its apex. In T.S. of the seta, there is a superficial layer of thick-walled cells. Inside it is a band of brown sclerenchymatous cells, which merges internally into thin-walled green parenchymatous cells with intercellular spaces. The axial tissue of the seta forms a central strand, without intercellular spaces and consists of cells essentially similar to those in the gametophores axis, but usually of much simpler structure.

At the base of the capsule the seta enlarges to form the apophysis which is marked off from the sporogenous portion (theca proper) by a groove. The apophysis has a distinct epidermis with stomata followed by a mass of chlorophyllose tissue. The stomata are usually restricted to the groove and are long pored and range in number from 20 in *P. alpstre* to nearly 200 in

P. formosum. The stomata are large and are raised above the level of the epidermis. The number of guard cells is usually two, but occasionally single annular guard cells are seen (Paton, 1957).

Capsule: The capsule is angular and shows a polygonal outline in a cross section. The wall of the capsule is composed of several layers of chlorophyllose cells, the outermost layer of which is differentiated into an epidermis with thick external layer. Inside the wall there is an outer space (air space) filled with filaments of chlorophyll-containing cells, in a radial direction, which are connected internally with the outer wall of the spore sac. The spore sac is limited internally by an inner lacuna which is again bridged over by filaments of cells connecting the spore sac with the central columella (Fig.12. 21).

The spore sac is bounded on both the sides by two layers of thin walled cells. According to the age of the sporogonium the archesporium consists of one layer (in young), or 4 to 6 layers of cells (in adults). All cells of the sporogenous tissue give rise to spores. In the centre is the columella.

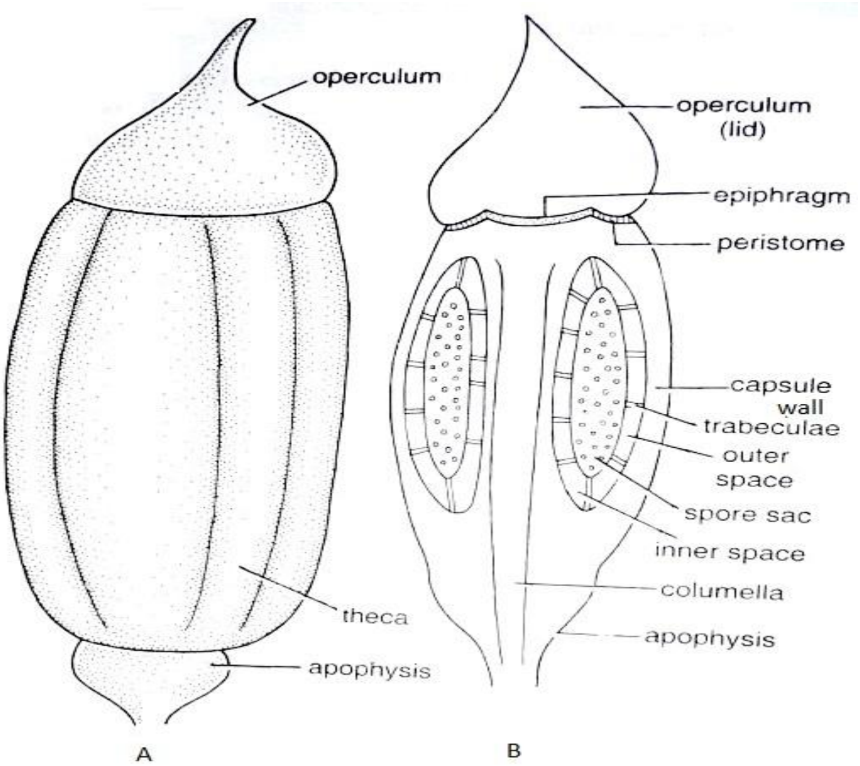

Fig.12. 20, Polytrichum sporophytes

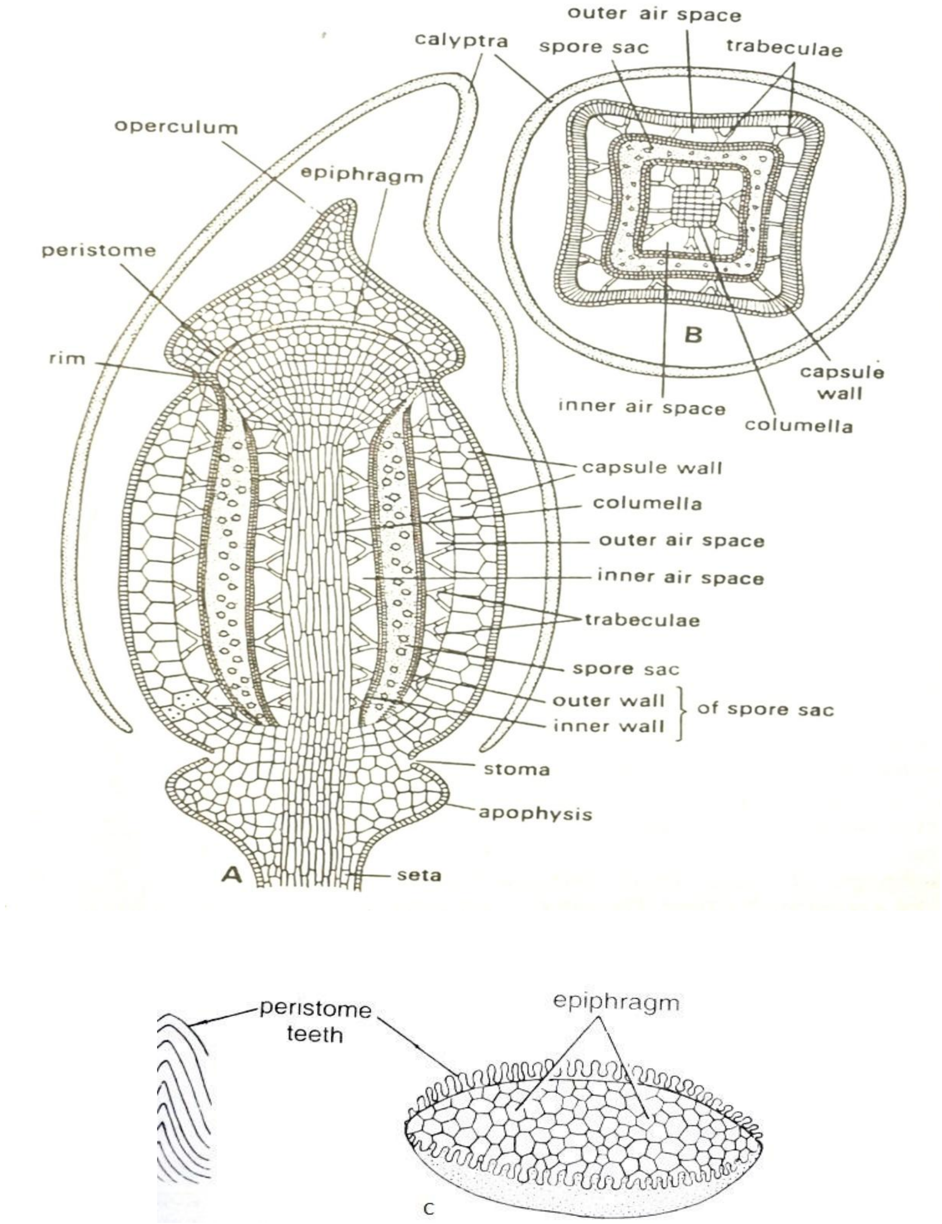

Fig.12.21, *Polytrichum:* (A) L.S of sporophyte; (B) T.S. of capsule and (C)Peristome teeth

Operculum: At the top of the capsule there is an operculum which appears as a conical lid with a beak or rostrum. A distinct annulus is not present in *Polytrichum* though the thickened diaphragm (rim) is present.

Epiphragm: At the base of the operculum there is a transparent membranous tissue composed of pale compressed cells without intercellular spaces. This tissue stretches like a drum- head (tympanum) over the opening of the capsule and closes it. This is the epiphragm.

Peristome: The peristome consists of bundles of mostly curved crescent-shaped thickened fibrous cells. The ends of the crescent are directed upwards and join the ends of the adjacent horse shoe-shaped bundles. At maturity the peristome is composed of 32 or 64 short pyramidal teeth, connected below with the wall of the capsule, and united above with the margin of the epiphragm by their tips (Fig 12.21. C).

Dispersal of spores: the capsule matures, operculum goes off and the cells beneath may dry up. By drying up of the thin walled cells between the teeth, small openings are formed in the margin of the epiphragm through which the small spores sift out, a few at a time, as the capsule sways by the forces of wind (censer mechanism).

Like *Funaria,* the calyptra is ruptured by the continuous growth of the sporogonium, and the upper part is separated as a cap. It is carried upwards on the top of the capsule forming a dry fibrous hood covering the apex of the capsule. The calyptra consists externally of dry, branched hypha-like filaments loosely mated together.

The Gametophyte

The Spores: The spores represent the gametophytic phase. They are uninucleate small in size ranging from 0.005 to 0.01 millimetres in diameter. They remain viable for a long time. The spores have two layers, outer exospore and inner smooth endospore. Spores start germination under favourable conditions.

Germination of Spore and Formation of Protonema

Wigglesworth (1947) observed the spore germination in *P. commune*. The yellow spore soon turns green due to the formation of chloroplasts (Fig.12. 22). The exospore ruptures and the spore protoplast bound by endospore protrudes as one or more germ tubes. The germ tube enlarges rapidly and soon gives rise to separate branched filamentous protonema by repeated transverse divisions. The growth of the filament is apical. Some filaments grow upwards and turn green while others penetrate the substratum remaining colourless. These latter filaments are of small diameter and with cross wall oblique to the axis. Later on buds appear near the base of the upright filaments. Eventually a pyramidal apical cell of the future shoot is differentiated, which cut off segments and an axis bearing leaves is formed. This young shoot bears two kinds of rhizoids at the base. The mature type of leaves does not appear on the young plant until the third year.

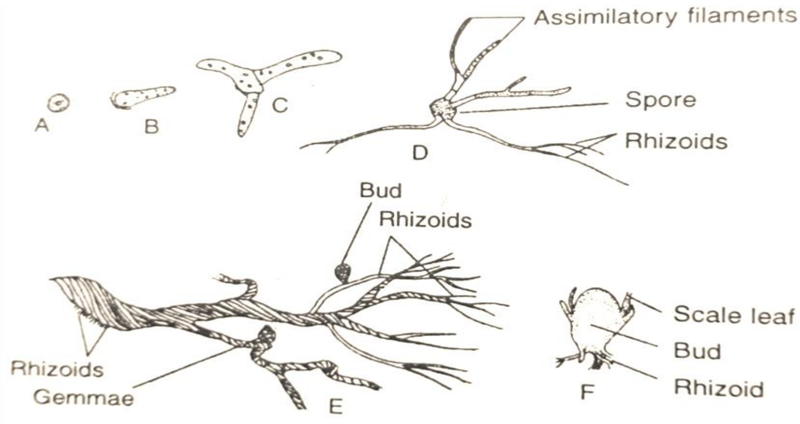

Fig. 12.22. Polytrichum stages of germination of spores

Life cycle of *Polytrichum*

Lik**e** *Funaria,* the life cycle of *Polytrichum* also exhibits, two distinct vegetative individuals in a single life cycle. Such a life cycle is called diplobiontic (Fig.12.23). One of the vegetative individual is the leafy shoot and the other is the sporogonium. The green leafy shoot represents the dominant phase and is gametophytic in nature It is related with sexual reproduction. This is the gametophytic or haploid (n) generation of the plant. It begins with the formation of spores and ends with the gametes (egg and antherozoids). The second individual is the sporophyte, which represents the sporophytic or diploid (2n) generation. It begins with the formation of zygote. The zygote, the embryo and the sporogonium (foot, seta and capsule) form the different phases of sporophytic generation.

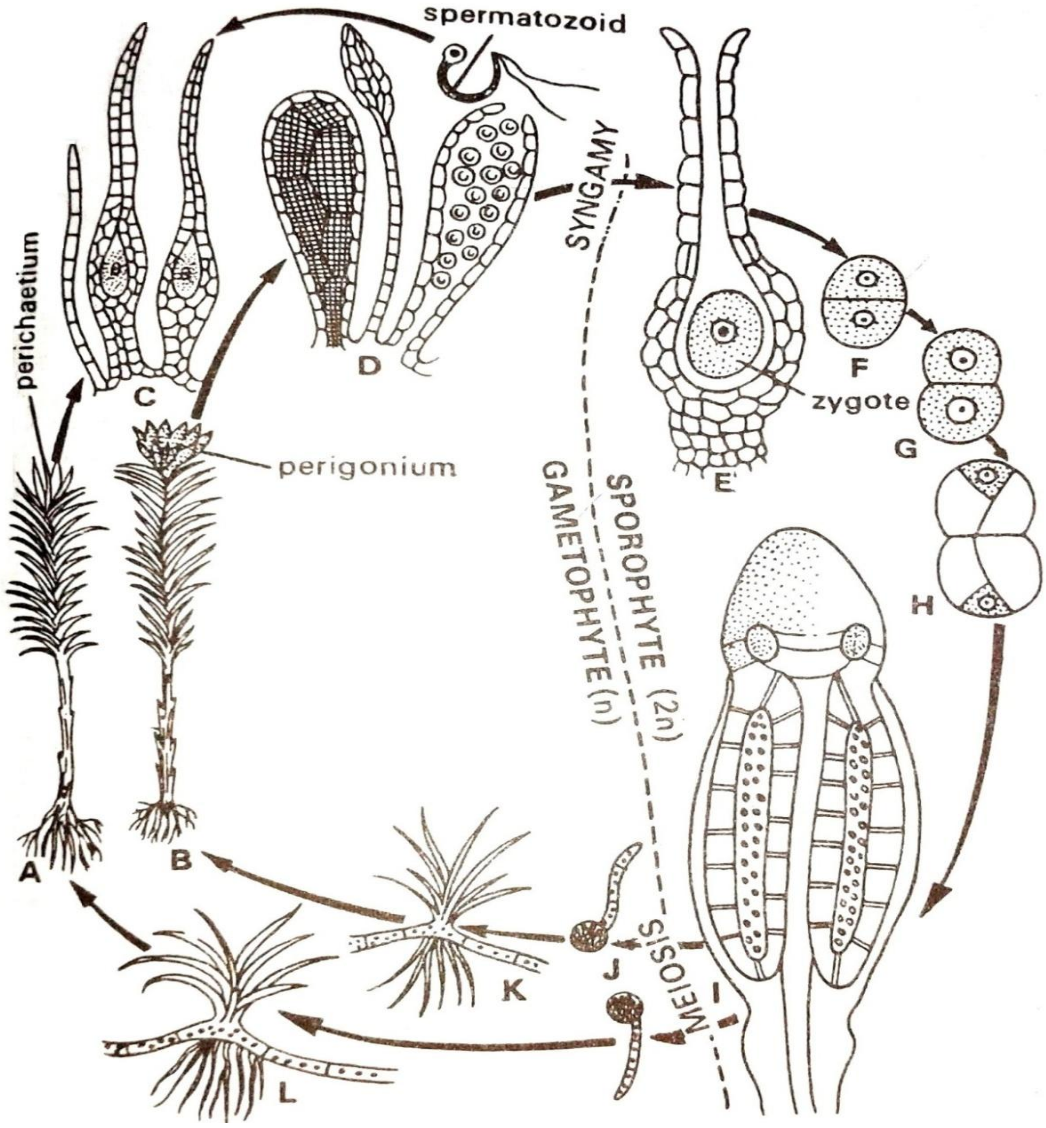

Fig. 12.23. Diagrammatic representation of the life cycle of Polytrichum

Alternation of generation

The alternating individuals in the life cycle are morphologically different. This kind of alternation of generation is called heterologous or heteromorphic. The difference in two generations is due to the different modes of life .The gametophyte is independent, while the sporophyte is partially dependent on the gametophyte (Fig.12.24).

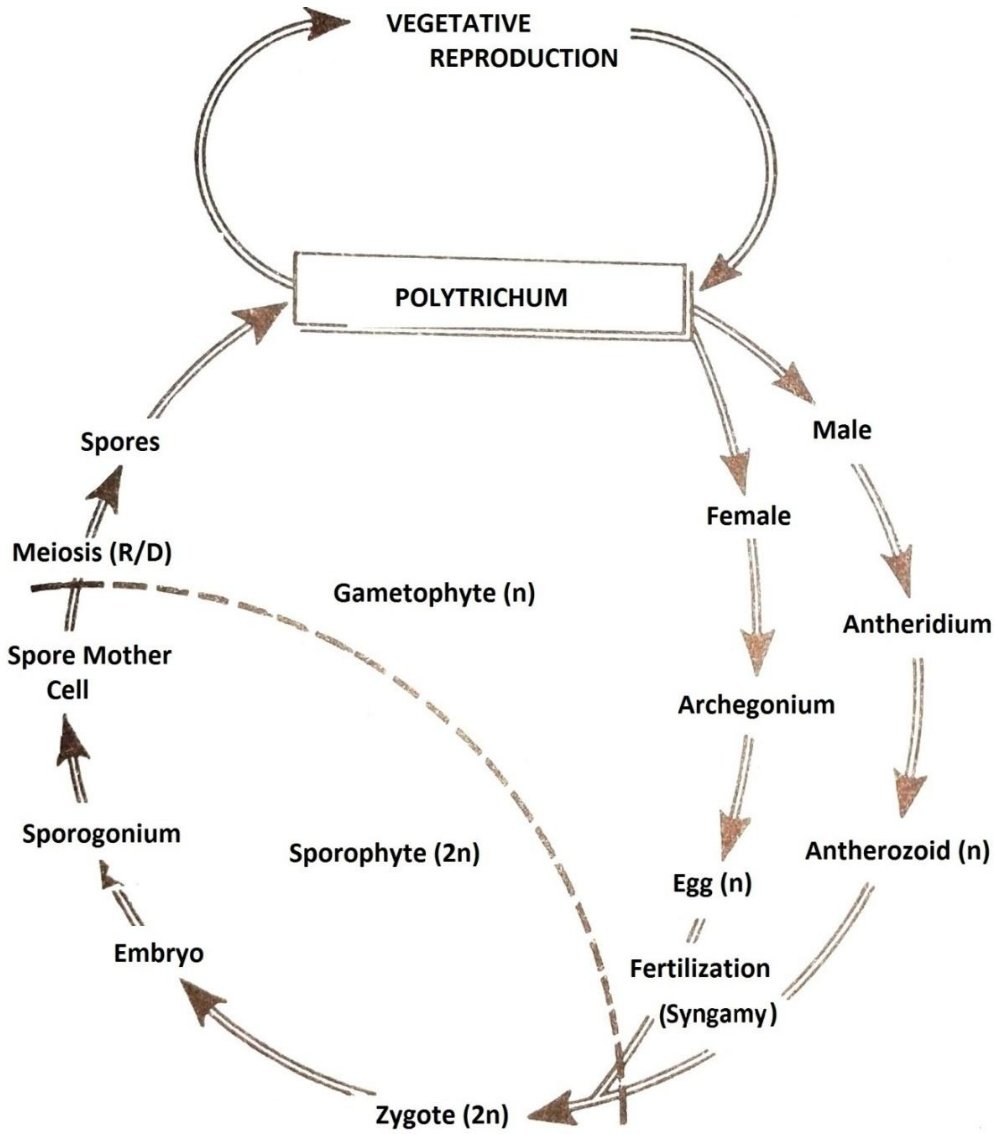

Fig.12.24, Graphic representation of the life cycle of Polytrichum

12.4 SUMMARY

(A) Life cycle of *Funaria*

A. Gametophyte.

1. It consists of (a) a branched, green, alga-like filament, the protonema and (b) a leafy gametophores, the moss plant. The protonema is short lived.

2. The leafy gametophore consists of a slender, stem-like central axis bearing rhizoids at its base and leaf like expansions throughout its length. It is independent.
3. The so called leaf is traversed by a definite midrib more than one cell in thickness.
4. The rhizoids are branched, septate and multicellular. The septa between the cells are obliquely placed.
5. The sex organs (antheridia and archegonia) are borne in terminal clusters at the tips of separate branches of the leafy gametophores.
6. The mature antheridium consists of a short multicellular stalk and the globose body.The body has a one celled thick jacket wall. Within the jacket, androcytes are present which give rise to biflagellate sperms. The mature archegonium is flask shaped borne on a short multicellular stalk. The neck is long with six rows of neck cells. They enclose 6 or more neck canal cells, the venter wall is two layer thick and has a vetral canal cell and an egg.
7. The antherozoids after liberation from the antheridium splashed out of the perichaetial leaves by rain drops on the arcegonial cluster and swim down to the open necks of arhegonia and fertilize the egg.

B. Sporophyte

1. The zygote represents the first cell of sporophyte and diploid in nature. The zygote divides and forms an embryo with two growing points at each end.
2. The growth of the embryo is apical and by cutting off the segments it becomes a long slender structure.
3. The mature sporogonium is differentiated into a foot, a seta and a pear- shaped capsule of great complexity.
4. The seta is long and carries the capsule far above the leafy gametophores.
5. The foot is embedded in the tissues of female branch and functions as an anchoring and absorbing organ.
6. The mature capsule is differentiated externally into apophysis, theca and operculum region0s.
7. The apophysis is a swollen sterile basal portion. It is associated with photosynthesis and conduction. It has well defined epidermis with functional stomata connected with substomatal air space.
8. The theca has centrally located thin walled sterile parenchyma cells, the columella. On either side of columella spore sac is located which does not arch over the columella. Outside the spore sac, there is a wide air space traversed by green filaments, the trabeculae. The spore sac contains the spore mother cells which undergo meiotic division to form haploid spores. Outside the air space is the wall of the theca, It is made up of one to two layer thick spongy layer followed by two layers thick hypodermis which is bounded by a single layered epidermis.
9.The apical portion above the theca is operculum. A transverse ring of modified epidermal cells separates the theca with operculum. This is called annulus. Below the operculum a double row of conical teeth is present which collectively form the peristome. In each row 16

teeth are present. The teeth are hygroscopic and they play an important role in spore dispersal.

(B) Life cycle of *Polytrichum*

Gametophyte

1. It is a perennial plant. It consists of (a) a short lived, branched, green protonema and (b) leafy gametophores.
2. The leafy gametophore arises from an underground rhizome. The gametophore has a slender, stem-like central axis bearing leaf like expansions throughout its length. It is independent.
3. Rhizoids arise from the rhizome and often entangle with each other and form wick like structure. These rhizoids help in retention in water and give mechanical strength to the plant. The rhizoids are branched, septate and multicellular. The septa are oblique.
4. The rhizoid system is important in vegetative reproduction. These wick-like rhizoid strands bear buds which develop into leafy axis.
5. The leaves on the rhizome and the middle transitional region are brown or colourless .They are borne in three vertical rows with a divergence of 1/3.
6. The leaves on the aerial leafy shoot are relatively large, thick and rigid and are arranged on the stem in a complicated spiral. Each leaf has a broad, colourless membranous unistratose sheathing base, which narrows above into a `limb' which is lanceolate to linear lanceolate
7. In Transverse section the rhizome is triangular with round corners and slightly convex. The conducting tissue is advanced containing water conducting (hydroids), and food conducting (leptoids) tissues.
8. Plant is dioecious and the archegonia and antheridia are borne in terminal clusters at the apex of separate gametophores.
9. The terminal part of the male shoot forms a conspicuous almost flower-like open cup. This cup is formed by perigonial leaves which are different in form and colour from the other vegetative leaves on the gametophores The growth of the male shoot is not stopped by the development of the antheridia, as the apical cell of the shoot is not used up in the formation of an antheridium.
10. The mature antheridium consists of a short stalk and a club –shaped body. The body has a single-layered jacket surrounding a central mass of androcytes
11. The archegonia are borne in terminal clusters at the apex of the leafy shoot. The apical cell of the leafy shoot itself forms the initial of an archegonium with the result that the further growth in length of the shoot stops with the formation of a sporogonium.

B. Sporophyte

1. The mature sporogonium consists of a foot, a long seta and a capsule.
2. The foot is embedded in the tissue of the apex of an archegonial branch and consists of thin-walled parenchymatous cells.
3. Seta is continuous with foot andt is long and slender, which supports the capsule at its apex.

4. At the base of the capsule the seta enlarges to form the apophysis which is marked off from the sporogenous portion (theca proper) by a groove.
5. The capsule is angular and shows a polygonal outline in a cross section
6. The apophysis has a distinct epidermis with stomata followed towered by mass of chlorophyllose tissue.
7. The spore sac with the central columella is present in the ca region. According to the age of the sporogonium the archesporium consists of one layer (in young), or 4 to 6 layers of cells (in adults).
8. All cells of the sporogenous tissue give rise to spores.
9. At the top of the capsule there is an operculum which appears as a conical lid with a beak or rostrum.
10. At the base of the operculum there is a transparent membranous tissue composed of pale compressed cells without intercellular spaces. This is the epiphragm.
11. At maturity the peristome is composed of 32 or 64 short pyramidal teeth, connected below with the wall of the capsule, and united above with the margin of the epiphragm by their tips.
12. The capsule matures, operculum goes off and the cells beneath may dry up.
13. By drying up small openings are formed in the margin of the epiphragm through which the small spores sift out, a few at a time, as the capsule sways by the forces of wind(censer mechanism
14. The spore represents the gametophytic phase. They are uninucleate small in size.
15. The spore germinates and gives rise to filamentous protonema the gametophyte.
16. Buds appear near the base of upright filament of protonema, leafy gametophores develops from the buds.

12.5 GLOSSARY

Abaxial surface: The side of the lateral organ (leaf), away from the axis (dorsal).
Acrocarpus: Of mosses, bearing the archegonia at the tip off stem or main branches.
Acropetal: Development of organs towards the apex, the oldest at the base, youngest towards the apex.
Adaxial: The side of the lateral organ (leaf), nearest to the main axis (ventral).
Androcyte: Antherozoid mother cell.
Antheridium: The male sex organ of the cryptogams.
Antherozoid: Small, motile male gamete with flagella.
Anticlinal: Perpendicular to the surface.
Apophysis: The swollen sterile tissue at the base of capsule, of some mosses, next to seta and below the spore sac.
Archegonium: The female sex organs of bryophytes.
Archesporium: Sporogenous tissue or group of cells from which the spores ultimately derived.

Basipetal: Development of organs in which the youngest structures are at the base and the oldest at the apex.
Calyptra: A covering developed from the venter of the archegonium in bryophytes.
Capsule: The part of the sporogonium containing spores.
Chlorophyllose: Containing chlorophyll.
Cortex: The region of a vascular plant that lies between the epidermis and the stele.
Diploid generation: The sporophyte.
Dorsiventral: An organ having distinct dorsal and ventral surfaces.
Elaters: Hygroscopic twisted structures helping to disperse spores.
Epibasal: Forming the upper part of the embryo.
Epidermis: The outer most layer of cells of a plant body.
Epiphragm: A membrane which closes the opening of the theca in some mosses, *e,g.*, *Polytrichum*.
Epiphyllous: Growing on leaves.
Epiphyte: A plant growing on another plant.
Exine: The outer layer of the cell wall of spore.
Gametophyte: The haploid or gamete producing generation of any plant.
Gemma: Organ of vegetative reproduction, consisting of one to many cells, that becomes detached from parent plant and develops into a new plant.
Germ tube: The first tubular outgrowth from a germinating spore.
Guard cells: Specialized chlorophyllous cells which bound the stoma and regulate its opening.
Habit: General form and aspect of a plant.
Habitat: The place where an organism lives.
Haploid generation: Gametophyte generation.
Haustorium: The absorbing organ of a parasite.
Homosporous: Producing one kind of spores.
Hygrophilous: Plants which need a large amount of moisture for their growth.
Hypobasal: Forming the lower part of the embryo.
Peristome: The ring of hygroscopic teeth round the mouth of dehiscent capsule in mosses, concerned with spore dispersal.
Protonema: The early filamentous stage produced on germination of spore in some bryophytes.
Perigonial leaves or bracts: Leaves surrounding the antheridia.
Perichaetial leaves or bracts: Leaves surrounding the archegonia.

12.6 SELF ASSESSMENT QUESTIONS

12.6.1 Fill in the blanks:

(i) Rhizoids in *Polytrichum* are multicellular, branched and-------------.
(ii) The number of peristome teeth in *Polytrichum* is--------.

(iii)*Polytrichum* is commonly called---------.
(iv)The horizontal underground part of the gametophores of *Polytrichum* is called-------.
(v) The rhizoids are borne on the -------of the gametophores.

12.6.2 Multiple choice Questions:

1. Plants of *Funaria* generally grow
(a) In pairs (b) Solitary
(c) In aggregates (d) As saprophyte

2. The middle sterile part of *Funaria* capsule is known as
(a) Columella (b) Apophysis
(c) Operculum (d) Spore sac

3. In *Funaria* the leaves are arranged on the stem
(a) Oppositely (b) Spirally
(c) Alternately (d) All of the above

4. Which part of the *Funaria c*apsule is haploid
(a) Annulus (b) Columella
(c) Operculum (d) Calyptra

5. Leptome mantle in *Polytrichum* is equivalent to:
(a) Rudimentary pericycle (b) Starchy layer
(c) phloem (d) xylem

6. Number of peristome teeth in *Polytrichum* are
(a) 8-16 (b) 32-64
(c) 72-128 (d) more then 128

7. Hair cap moss is the name given to
(a) *Polytrichum* (b)*Pogonatum*
(c) *Funaria* (d) None of the above

8. In *Polytrichum* the spore liberation is regulated by
(a) Operculum (b) Columella
(c) Peristome (d) Annulus

9. In *Polytrichum* the leaves are arranged in
(a) Two rows (b) Three rows
(c) Four rows (d) Six rows

12.6.2 Answer keys: 1.(c), 2. (a), 3.(b), 4. (d), 5. (c), 6.(b), 7.(a), 8. (c), 9.(b)

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12.8 SUGGESTED READINGS

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12.9 TERMINAL QUESTIONS

1. Give an illustrated account of the sporophyte of *Funaria* or *Polytrichum*.
2. Draw the labelled Diagrams of the following:
 (i) L.S. of *Funaria* capsule (ii) T.S. of Rhizome of *Polytrichum.*
3. Describe the Structure of the leaf and the axis of *Polytrichum.*
4. Write Short notes on:
(i) Salient features of Bryopsida (ii) Sex organs of *Funaria* (iii) Vegetative Reproduction in *Funaria* (iv) Rhizoids
5. Describe the life cycle of *Funaria* or *Polytrichum* by making suitable diagrams.