



Uttar Pradesh Rajarshi Tondon
open University

Bachelor of Science
UGBY -103
Plant Diversity-I

Block-1		3-112
UNIT-1	Bacteria, Virus and Lichen	7
UNIT-2	Algae -I	31
UNIT-3	Algae - II	63
UNIT-4	Fungi	85
Block-2		115-240
UNIT-5	Bryophytes -I	119
UNIT-6	Bryophytes -II	175
UNIT-7	Pteridophytes -I	183
UNIT-8	Pteridophytes -II	195

COURSE INTRODUCTION

This course covers Plant Diversity-I which has information of Bacteria, virus, lichen, algae in one block and bryophytes as well as pteridophytes in other block. The bacteria are prokaryotes and viruses are intermediate between living and non living one. The lichens are dual organisms composed of algae and fungi in symbiotic association. The bryophytes are first land plants usually grow in the moist and shady place. They are terrestrial but require water at every step in the life cycle. The pteridophytes are first vascular land plants which do not produce flowers or seeds. They reproduce by spores with alternation of generation. Their main plant body is sporophyte.

The course is divided into two blocks I and II.

Block-I has four units-1, 2, 3 and 4. Unit-1 deals with structure, reproduction and economic importance of bacteria, virus and lichen. Unit-2 has morphology and life cycle of some algae like *Chlamydomonas*, *Volvox*, *Nostoc*, *Ectocarpus*, *Fucus* and *Polysiphonia*. Unit-3 tells the general information of algae. The Unit-4 deals with life cycle of *Phytophthora*, *Rhizopus*, *Puccinia* and *Cercospora* along with general information of fungi. The block-2 covers information regarding bryophytes and pteridophytes in four units, Unit-5, 6, 7 and 8. Unit-5 and 6 deals with some genera of bryophytes like *Riccia*, *Marchantia*, *Pellia*, *Anthoceros* and *Sphagnum* as well as evolution of sporophyte along with importance of bryophytes. Unit 7 and 8 covers general information regarding pteridophytes along with morphology and life cycle of *Rhynia*, *Lycopodium*, *Selaginella*, *Equisetum* and *Marsilea*.



Uttar Pradesh Rajarshi Tondon
open University

Bachelor of Science

UGBY -103

Plant Diversity-I

BLOCK

1

PLANT DIVERSITY-I

UNIT-1

Bacteria, Virus and Lichen

UNIT-2

Algae-I

UNIT-2

Algae-II

UNIT-4

Fungi

Course Design Committee

Prof. Ashutosh Gupta Director, School of Science UPRTOU, Prayagraj.	Chairman
Dr. Anil Tiwari Botny Department Ewing Christan College. Prayagraj.	Member
Dr. Preeti Singh Botny Department S.S.K.P.G. College Prayagraj.	Member
Dr. Sushma Chauhan Acadmic Consultant, School of Science UPRTOU, Prayagraj.	Member/Secretary

Course Preparation Committee

Dr. Sushma Chauhan Acadmic Consultant, School of Science UPRTOU, Prayagraj.	Author Block - 1 (unit - 01, 03, 04) Block - 2 (Unit - 07, 08)
Dr Achala Srivastava Assistant professor S.S. Khanna, P.G. College Prayagraj.	Author Block- 1 (Unit: 02)
Dr. Alok Malviya Assistant professor S.S. Khanna, P.G. College Prayagraj	Author Block- 2 (Unit: 05, 06)
(Dr.) Amita Pandey Asso. Prof. Deptt. of Botony (C.M.P. P.G College) Prayagraj.	Editor (Unit - 01 - 08)
Dr. Sushma Chauhan Acadmic Consultant, School of Science UPRTOU, Prayagraj.	Coordinator

©UPRTOU, Prayagraj 2020

ISBN :

©All Rights are reserved. No part of this work may be reproduced in any form, by mimeograph or any other means, without permission in writing from the **Uttar Pradesh Rajarshi Tondon Open University, Prayagraj.**

Printed and Published by Vinay Kumar Registrar , Utter Pradesh Rajarshi Tandon Open University-2024.

Printed By : Chandrakala Universal Pvt. 42/7 Jawahar Lal Neharu Road, Prayagraj.

BLOCK INTRODUCTION

This is the first block of the course which includes bacteria, virus, lichen, algae and fungi. The block is divided into 4 units viz unit 1, 2, 3 and 4.

Unit1 Describes the structure reproduction and economic importance of bacteria.

This unit also covers biological status of virus along with structure and replication of bacteriophage and TMV. It also tells you about lichens.

Unit2 This unit tells the morphology and life cycle of some genera like *Chlamydomonas*, *Volvox*, *Nostoc*, *Fucus* and *Polysiphonia*.

Unit3 In this unit you will know about origin and evolution of sex in alga. The classification of alga with the criteria. You will study about economic importance of algae, their habitats along with the distribution.

Unit4 This unit will introduce you about the fungi. The life cycle of some fungal genera like *Phytophthora*, *Rhizopus*, *Puccinia* and *Cercospora* are also explained.

UNIT-I BACTERIA, VIRUS AND LICHEN

Structure :

1.1 Introduction

Objective

1.2 Structure of bacterial cell

Reproduction in bacteria

Economic importance of bacteria

1.3 Biological status of virus

Structure of bacteriophage

Replication of bacteriophage

Structure of TMV

Replication of TMV

1.4 Structure of Lichen

Crustose Lichen

Foliose Lichen

Fruticose Lichen

Special vegetative structure present on Lichen thallus

1.5 Summary

1.6 Terminal Questions

1.7 Answers

1.1 INTRODUCTION

The study of bacteria is known as bacteriology. Bacteria was first discovered by Antonie Van Leeuwenhoek in 1676. The bacteria constitute a highly specialised group of most primitive prokaryotic single celled organism seen only under compound microscope. The shape of bacteria may be rod like, spherical or branched. It occurs every where, in water, air, soil, food stuffs and vegetables. They also flourish in our mouth and intestine.

The branch of science which deals with the study of virus is known as virology. A virus is a small infectious agent that replicates only inside the living cells of an organism. These are made up of nucleoprotein. The nucleic acid may

be either DNA or RNA. Virus is a Latin word which means poisonous fluid that causes infection. The virus causes diseases in plants, animals and human beings. The first viral disease in plant was recorded by Carolus Clusius (1576) in tulip flowers.

The study of Lichen is known as Lichenology. Lichens are small group of curious plant because they are composite or dual organisms. Lichen is composed of two quite different organisms, a fungus and an alga, living together in an intimate symbiotic association. The fungal organism or component is known as mycobiont which belongs to as-comycotina or basidiomycotina. The algal organism or component is known as phycobiont which belongs to green or blue green algae. The association between fungus and alga is so intimate that they appear to be a single plant. The fungal partner provides shelter to the algal partner and in return algal partner provides food to the fungal partner through diffusion. The Lichens are world wide in distribution. They grow every where except the area where atmosphere is polluted therefore, they are known as pollution indicator.

Objective :

After studying this unit you will be able to :

- Know the structure, reproduction and economic importance of bacteria.
- Know the biological status of virus.
- Know the structure and multiplication of bacteriophage.
- Know the structure and multiplication of TMV.
- Know the structure of Lichen.
- Know the economic importance of Lichen.

1.2 STRUCTURE OF BACTERIAL CELL

Bacteria have a rigid cell wall which protects the protoplast and provide definite shape to the cell. Chemically it is made up of polysaccharide called *mucopolysaccharide*. The mucopolysaccharide is made up of glucosamine and N-acetyl *muramic acid*. The bacteria are of two types, gram +ve and gram- ve. The cell wall of gram +ve bacteria are thick and contain less lipid where as of gram-ve bacteria are thin and have more lipid.

External to cell wall is a gelatinous slime layer. This slime layer is secreted by protoplast of the cell. In pathogenic bacteria the slime layer becomes thick and called *capsule*. The capsule protects the bacteria from desiccation, viral attack and antibiotics. The capsulated bacteria are generally non-flagellated.

Next to cell wall is plasma membrane made up of phospholipids, proteins and polysaccharides. The respiratory enzymes are found on the inner surface of plasma membrane. In some gram +ve bacteria infoldings are present. These are called *mesosomes*, which contains respiratory enzymes. The function of

mesosome is in respiration, synthesis of wall and secretion of intracellular substances from inside to outside the cell.

Long thread like flagella are attached to the cell membrane, which helps in movement of bacterial cell.

In some gram-ve bacteria straight hair like minute appendages are found. These are called *pili*, which helps in the attachment of bacterial cell.

Inside the plasmamembrane is cytoplasm, which has a mixture of protein, carbohydrates, lipids, minerals, nucleic acid, enzymes and coenzymes. It also contains ribosome, RNA and nuclear body called nucleoid. The true nucleus is absent in bacteria. Only DNA is present, which is called nucleoid. The DNA is double stranded. Reserve food is in the form of oil globule and volutin granules. Other cellular organelles like mitochondria, endoplasmic reticulum, plastids are absent.

Plasmid- Besides nucleoid extra chromosomal genetic material is found in bacterial cell known as plasmid or F factor or fertility factor. This can automatically reproduce. When plasmid get integrated with bacterial DNA it is called *Episome*.

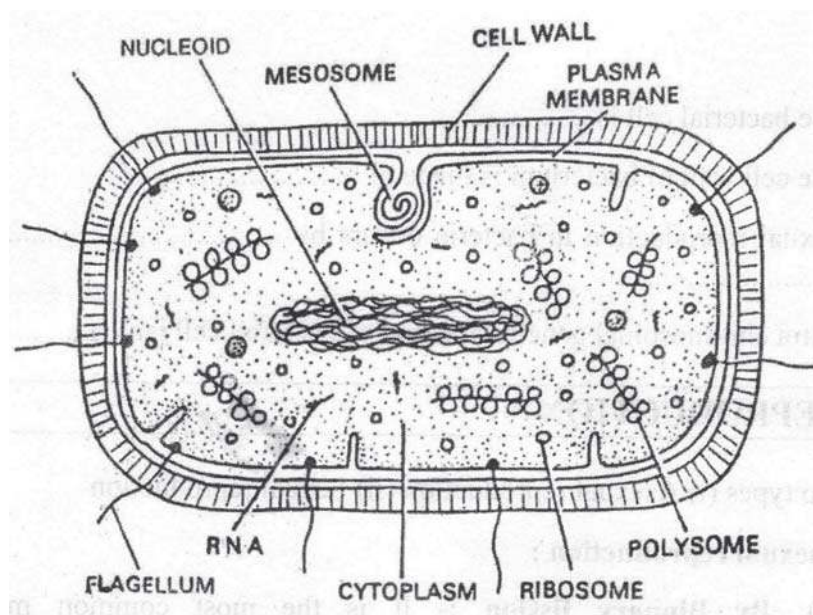


Fig. 1.1 Structure of a bacterial cell.

On the basis of no and mode of attachment of flagella the bacteria are of following types :-

- (1) **Monotrichous** : Single flagellum is attached to one end of bacterial cell.
- (2) **Amphitrichous** : One flagellum is at each pole of bacterial cell.
- (3) **Cephalotrichous** : Two or more flagella are present in bunch at one pole of the bacterial cell.
- (4) **Lophotrichous** : Two or more flagella are present at both the poles of the bacterial cell.

- (5) **Peritrichous** : Large no of flagella are evenly distributed all over the surface of bacterial cell.
- (6) **Atrichous** : Bacteria which lack flagella are called atrichous.

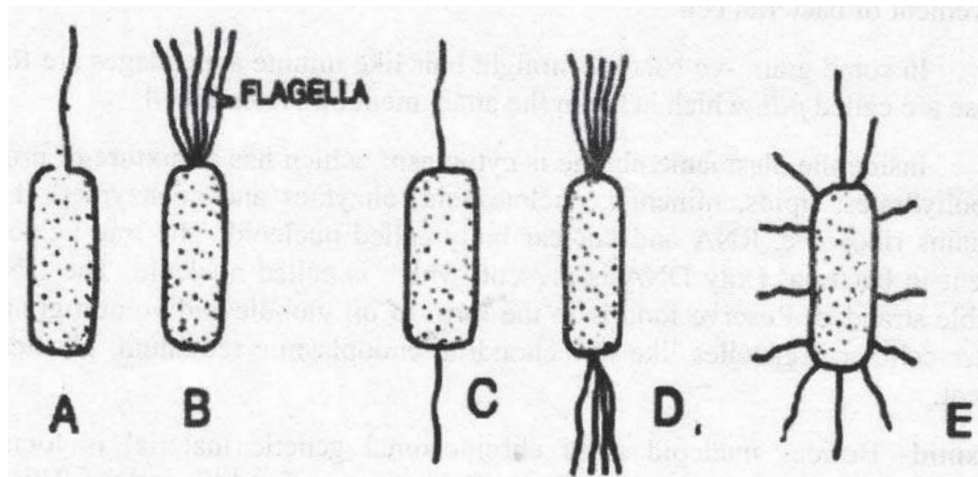


Fig.1.2. Types of flagellar attachment on bacterial cells. A.Monotrichous; B.Cephalotrichous; C. Amphitrichous; D. Lophotrichous; E. Peritrichous.

SAQ1.

- (a) The bacterial cell is
- (b) The cell wall of bacterium is made of
- (c) Sexual reproduction in bacteria occurs by,
- (d) Extra chromosomal genetic material of bacterial cell is

1.2.1 REPRODUCTION

It is of two types (i) Asexual reproduction (ii) Sexual reproduction

(i) Asexual reproduction:

- (a) By Binnary fission-:** It is the most common method of reproduction. The cytoplasm and nucleoid divide into two equal half without mitosis. The DNA replicates into two similar molecules. The cell wall and plasma membrane starts growing inwards from the middle of the cell and divides the cell into two by formation of complete septum. The septum becomes thick and splits. The bacterial cell divide into two daughter cells. Each cell have a nucleoid. Under optimum conditions, the binnary fission is completed in about 20-30 minutes. Therefore, by binnary fission a large number of bacterial cells are produced in 24 hrs.

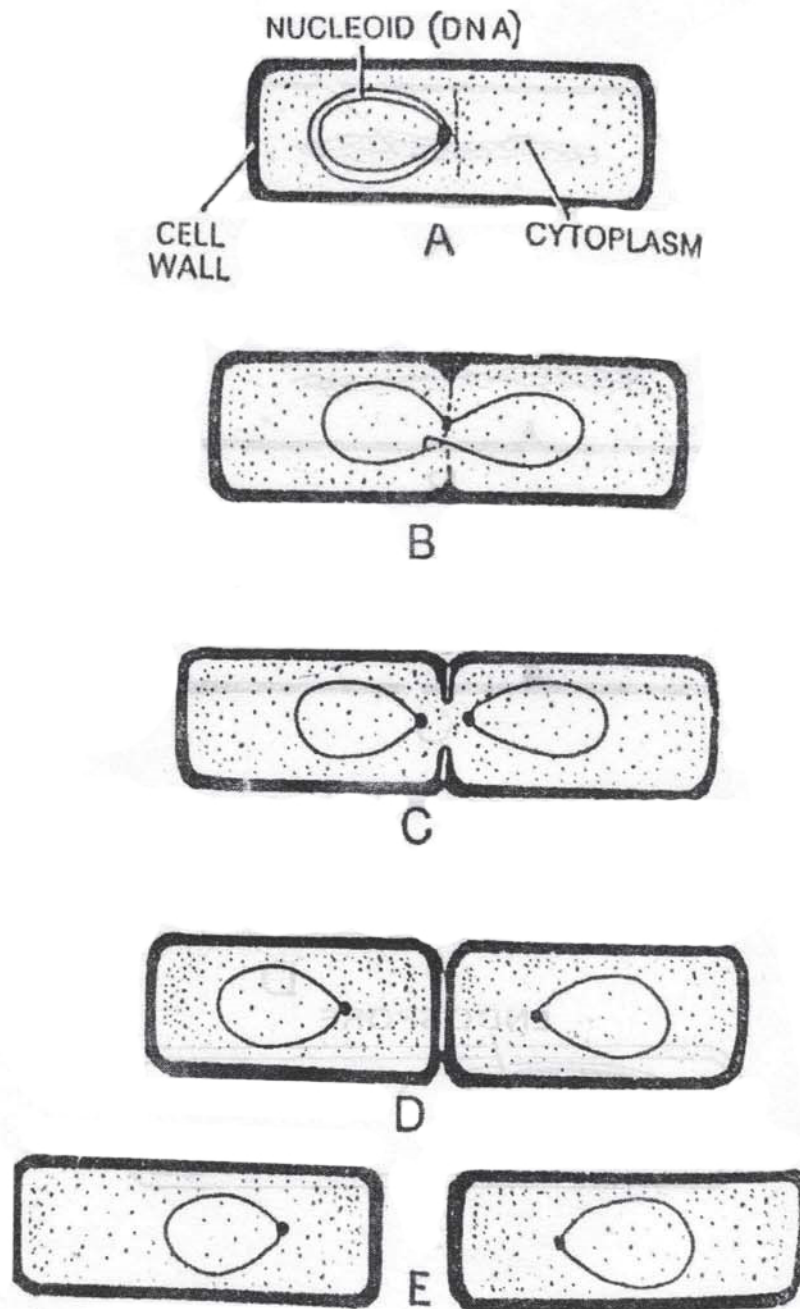


Fig.1.3. Binary fission in a bacterial cell.

- (2) **By endospore :-** Endospore formation generally takes place in few bacilli (rod shaped bacteria). Endospores are highly resistant physiologically dormant single celled bodies. These are formed inside the bacterial cell under unfavourable conditions. Mature endospore is smooth walled multilayered structure. On getting favourable conditions of moisture, temperature and food supply, the endospore absorbs water swell, increases in size. Their wall splits and new vegetative cell comes out which soon develops a new bacterial cell.

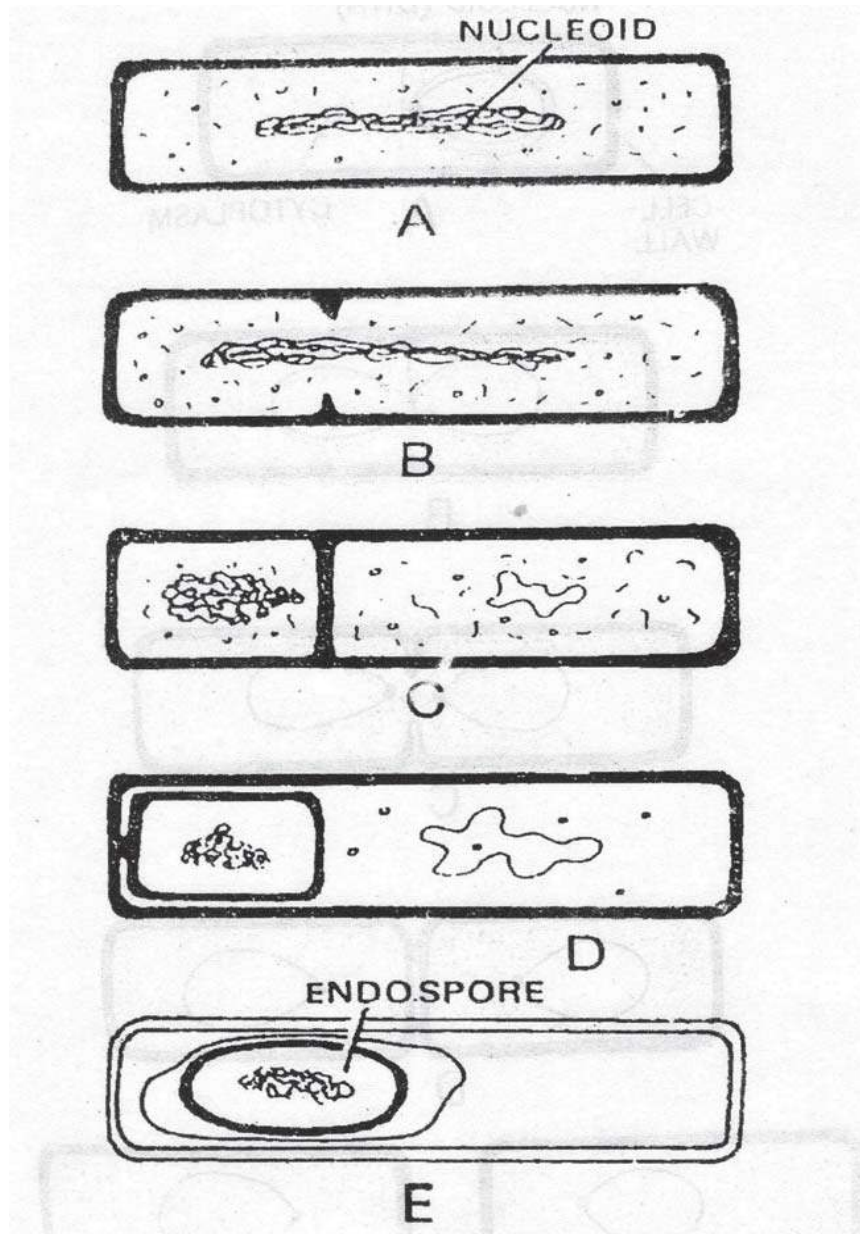


Fig. 1.4. A-E. Stages in the formation of an endospore in a bacterial cell.

- (3) By cyst :** Some bacteria perenate by cyst. Under unfavourable conditions a wall is formed around the entire bacterial cell. This is called cyst. The cyst remain viable for long period. When conditions become favourable, new bacterial cell come out from the cyst.

(ii) Sexual Reproduction :

Sexual reproduction in bacteria were first time demonstrated by Lederberg and Tatum. In bacteria the sexual reproduction is different from eukaryotes. Only a protion of genetic material is transferred from donor bacterial cell to receipient bacterial cell. Thus, genetic recombinants are formed in three ways :

(1) Conjugation (2) Transformation (3) Transduction

(1) **Conjugation** : It was studied in *Escherichia coli* by Wollman and Jacob. Conjugation takes place between donor (male) and recipient (female) bacteria. The donor is F^+ type, while the recipient is F^- type. Conjugation is of two types :

(a) **Conjugation between F^+ and F^- strain :**

The F^+ and F^- strain of bacteria come close to each other. Sexpilus is formed in the lateral wall of F^+ strain, which get attached to the lateral wall of F^- strain. At the place of contacts, wall between F^+ and F^- strain dissolve. A conjugation bridge is formed. The F factor present in F^+ strain divides into two, one remains in the F^+ strain while other passes into the F^- strain through conjugation bridge. Thus, F^- strain becomes F^+ strain.

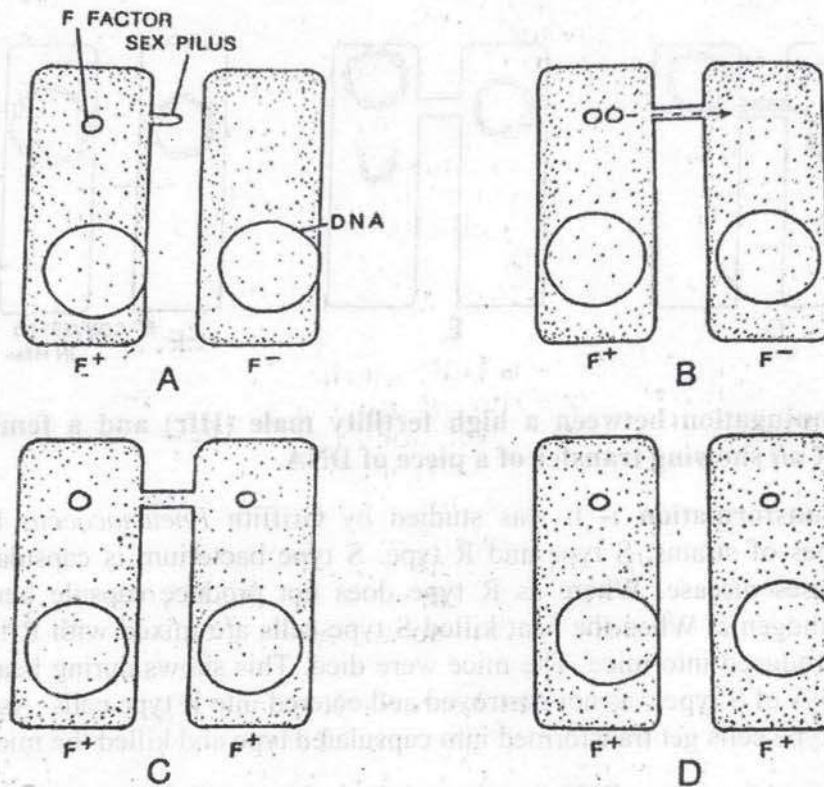


Fig.1.5. Conjugation between sterile male (F^+) and a female (F^-) of *E. coli*

(b) **Conjugation between Hfr and F^- strain :-** Hfr strain is donor strain and also called supermale. When F factor get integrated with bacterial chromosome the bacteria are called Hfr strain (Supermale).

The Hfr and F^- strain come in contact. Sex pilus is developed in the lateral wall of Hfr strain and get attached to F^- strain. At the place of contact the wall between bacterial strains dissolve and a conjugation bridge is formed. The chromosome of Hfr breaks at one point and replicates. The daughter DNA from Hfr strain migrates into F^- strain through conjugation tube. The daughter DNA moves in such a way

that, F factor is last to enter into F^- strain. The complete transfer of DNA takes.

The daughter DNA get ruptured at some point due to which complete transfer of DNA does not take place and F factor remain in Hfr strain therefore, F^- strain is not converted to F^+ strain.

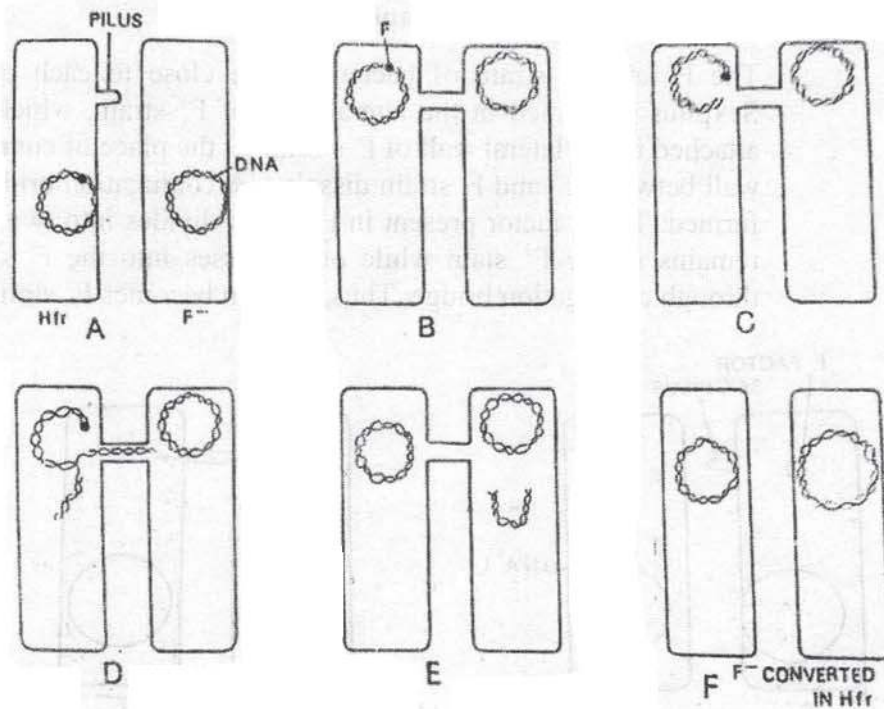


Fig.1.6. Conjugation between a high fertility male (Hfr) and a female (F^-) cell of *E. Coli* showing transfer of a piece of DNA.

- (2) **Transformation :-** It was studied by Griffith *Pneumococcus* has two types of strains, S type and R type. S type bacterium is capsulated and causes disease. Where as R type does not produce capsule hence non pathogenic. When the heat killed S type cells are mixed with R type and introduced into mice. The mice were died. This shows during heating the DNA of S type was not destroyed and entered into R type cells. As a result R type cells get transformed into capsulated type and killed the mice.

In transformation DNA is released from donor cell (S type) after lysis of wall and breaks into pieces. The piece of DNA get adsorbed to the surface of recipient cell (R type) and penetrate into protoplast. The DNA get integrated into recipient DNA and express the genetic information into the recipient cell. Thus, R type strain become S type.

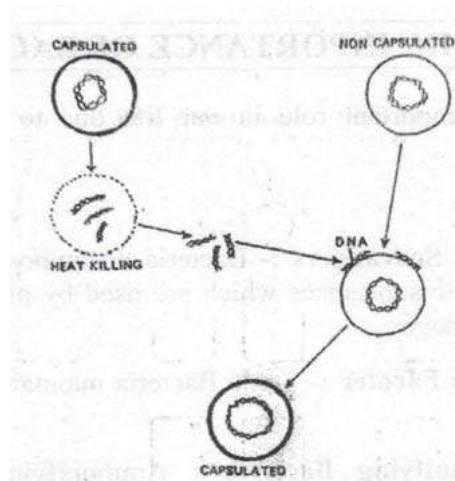


Fig.1.7. Transformation of a non capsulated pneumococcus bacterium into a capsulated type.

- (3) **Transduction :-** It was demonstrated by Zinder & Lederberg. The genetic material of one bacterial cell is transferred into another bacterial cell by lysogenic bacteriophage.

When the bacteria get infected with virus, the viral DNA becomes associated and integrated with bacterial DNA. The virus multiplies inside the bacterial cell. Thus, a large no of viruses are formed, whose DNA besides having viral DNA also have a portion of bacterial DNA. When such virus attacks another bacterial cell the portion of other bacterial DNA present in virus is transferred.

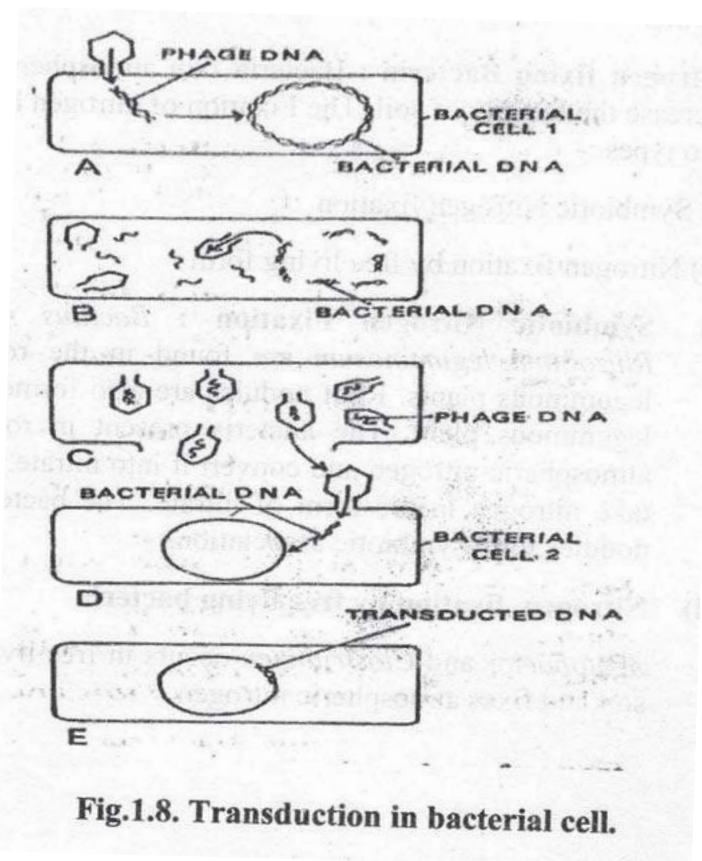


Fig.1.8. Transduction in bacterial cell.

1.2.2 ECONOMIC IMPORTANCE OF BACTERIA

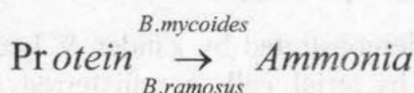
Bacteria play an important role in our life due to their harmful and useful activities.

Useful Activities :-

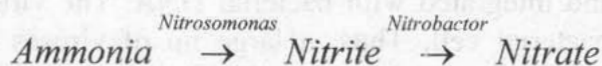
(1) **As nature's Scavengers :-** Bacteria decompose complex organic matter into inorganic substances which are used by plant and thus they act as a natural scavenger.

(2) **As Nature's Farmer :-** Some Bacteria maintain and increase the fertility of soil e.g.

(a) **Ammonifying Bacteria :** Ammonifying bacteria like *Bacillus mycoides* and *B. ramosus* converts protein into Ammonia. This is called Ammonification.



(b) **Nitrifying Bacteria :** *Nitrosomonas* and *Nitrobactor* are nitrifying bacteria which oxidise ammonia into nitrate.



Nitrosomonas is nitrite bacteria which converts ammonia into nitrite, where as, *Nitrobactor* is Nitrate bacteria and converts Nitrite into nitrate.

(c) **Nitrogen fixing Bacteria :** Bacteria fix atmospheric nitrogen and increase the fertility of soil. The Fixation of nitrogen by bacteria is of two types :-

(i) Symbiotic Nitrogen fixation

(ii) Nitrogen fixation by free living form

(i) **Symbiotic Nitrogen Fixation :** *Bacillus radiculicola* and *Rhizobium leguminosum* are found in the root nodules of leguminous plants. Root nodules are also formed in some non leguminous plant. The bacteria present in root nodules fix atmospheric nitrogen and convert it into nitrate. The plants can take nitrogen in the form of nitrate. The bacteria in the root nodules form symbiotic association.

(ii) **Nitrogen fixation by free living bacteria**

Azotobactor and *Clostridium* occurs in free living form in the soil and fixes atmospheric nitrogen.

- Bacteria in Industry :** Curd and Cheese are obtained from the milk by lactic acid bacteria (*Lacto bacillus*). During Cheese formation the milk protein casein is coagulated and fermented.

Vinegar (Acetic Acid) is produced by the activity of *Acetobactor aceti* on

alcohol. Sugar $\xrightarrow[\text{fermentation}]{\text{yeast}}$ *alcohol*. $\xrightarrow{A.aceti}$ *Acetic Acid*.

Species of *Clostridium* are used in the production of acetone and butanol.

Retting of fibre, tea curing, Tobacco curing and tanning of leather are also done by the activity of bacteria.

Sewage disposal :- Sewage contains human excreta and wash water that goes into sewage system. The bacteria which are common in sewage are *Coliforms*, *Streptococci*, *Clostridia*, *Pseudomonas*, *Lactobacilli* etc. These bacteria decompose the solid matter of the sewage.

Medicinal Use :- Bacteria are source of many antibiotics. Antibiotics are chemical substances produced by living micro organisms capable of inhibiting or destroying other microbes. At present more than 5000 antibiotics are known and approximately 100 are available for medicinal use. The bacteria which produce maximum number of antibiotics are *Streptomyces* :-

	Antibiotics		Bacteria
1.	Aueromycin	-	<i>S. aureobacillus</i>
2.	Chloromycetin	-	<i>S. venezuele</i>
3.	Streptomycin	-	<i>S. griseus</i>
4.	Terramycin	-	<i>S. ramosus</i>

Harmful activities :-

- Food poisoning or spoilage of food :** *Staphylococcus* and *Clostridium botulinum* produce toxin in the food and spoiled it. The consumption of such food results in the death. This is called *Botulism*.
- Diseases in Living Organism :** Many Human diseases like cholera, diptheria, influenza, leprosy, meningitis, Pneumonia syphilis, tetanus, typhoid and tuberculosis are caused by pathogenic bacteria. Many plant disease are also caused by bacteria eg. *Citrus Canker*.
- Decreases Soil fertility :** Denitrifying Bacteria like *Bacillus denitrificans* and *Pseudomonas denitrificans* converts nitrates and nitrite of the soil into free nitrogen and decreases the fertility of the soil.

Virus

1.3 NATURE OF VIRUS/BIOLOGICAL STATUS OF VIRUS

The biological status of virus is still not certain as some of the characters of virus are similar to the nonliving one and others are similar to the living one.

Non-living or Inanimate characters of Virus : The non living characters are as follows :

1. They have no complete cellular structure (No cell membrane, cell wall).
2. Viruses have no independent existence. They are active only inside the host cell.
3. They lack cellular metabolism.
4. They can be crystallised like simple chemical substances. The living organism can not be crystallised.
5. They can be precipitated like chemical substances.

Living or Animate characters of Viru : The characters on the basis of which viruses are considered as living are as follows

1. They have definite shape and has genetic material either DNA or RNA.
2. All viruses attack specific host and causes disease.
3. They show mutation.
4. Virus show irritability and respond to environmental conditions.
5. Virus multiply inside the host.

Thus, viruses have some characters of living organism and some characters of non living organism thus, form a bridge between non living and living organisms. They are non living when, free existing and living when, present inside the host. Thus, viruses are exceptionally simple microbes and complex chemicals.

1.3.1 STRUCTURE OF BACTERIO PHAGES

Bacteriophages are virus which attack the bacterial cell.

It has a tadpole like structure made up of head and tail. The head is hexagonal prism shaped with pyramidal ends and encloses DNA as genetic material.

In between the head and tail is collar. The tail is almost equal to the length of the head. At the proximal end of the tail is hexagonal end plate or tail plate. It bears 6 spikes, to which are attached 6 tail fibres. The tail is narrow than the head and has a hallow central core. The tail has sheath protein which contracts in longitudinal direction.

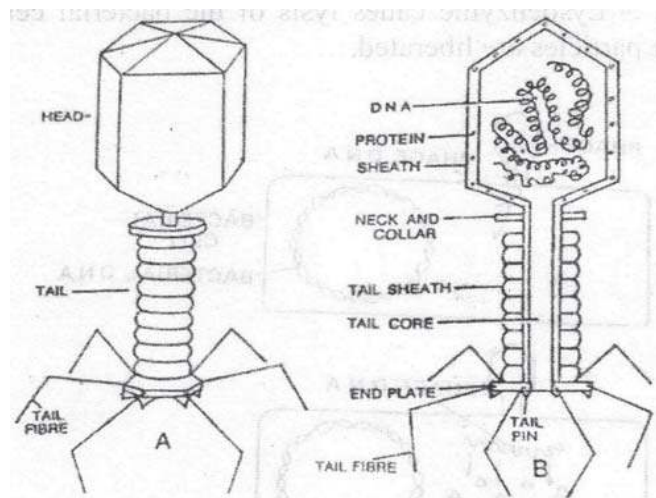


Fig.1.9. A. Bacteriophage; B. Bacteriophage in vertical section showing structure.

1.3.2 REPRODUCTION OR REPLICATION OF BACTERIOPHAGE

Bacteriophage replicates inside the bacterial cell. There are two kinds of life cycles :- (1) Lytic type (2) Lysogenic type

(1) Lytic type :- In this type, the multiplication of virus inside the bacterial cell causes killing of bacterial cell. It occurs in virulent type of virus and involves following steps.

- (i) **Adsorption :-** The bacteriophage come in contact with specific type of bacterial cell and becomes adsorbed to cell wall of bacteria by its distal end of the tail.

Penetration of phage into bacterial cell :- After adsorption the phage particle secretes lysozyme which acts on bacterial wall. A minute pore is formed in the bacterial wall. The tail sheath contracts and DNA of virus is injected into the bacterium through the hole. The empty protein coat is left outside. It is called ghost. Penetration and adsorption is called infection stage.

- (iii) **Latent phage :-** After infection viral DNA synthesizes some nucleases which digest the bacterial DNA. The phage DNA then take over whole machinery and start synthesizing new enzymes.
- (iv) **Vegetative phage :** The phage DNA replicates. Viral DNA synthesizes mRNA which help in synthesizing various parts of bacteriophages. The phage protein coat and tail parts are formed. After this various parts of bacteriophage get assembled to form complete phage particles.

- (v) **Lysis** :- Lysoenzyme causes lysis of the bacterial cell wall and the phage particles are liberated.

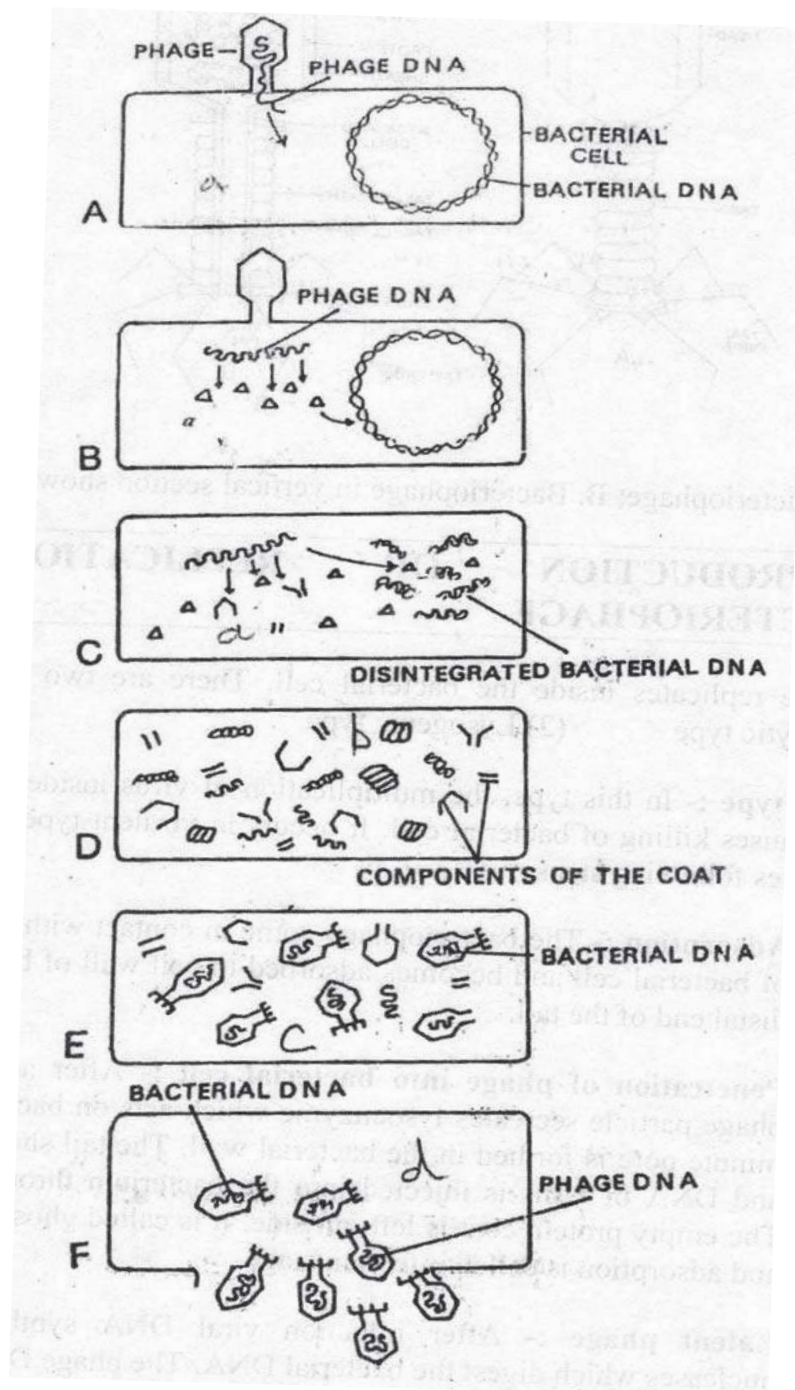


Fig.1.10. A-F. Stages in the multiplication of bacteriophage.

- (2) **Lysogenic Lifecycle** :- It occurs in non virulent phage. In this after infection the phage DNA gets attached to the bacterial DNA as prophage. The bacterial DNA divides along with phage DNA. Thus, the phage DNA is transmitted to bacterial progeny and will act as a gene.

After sometime the phage DNA gets separated from bacterial DNA and starts behaving like virulent DNA. It will take over the machinery of bacterial cell. Synthesis of phage DNA, protein and tail particles will start. Bacteriophages are formed by assemblage of different part. These particles are released after the lysis of host cell.

1.3.3 STRUCTURE OF TOBACCO MOSAIC VIRUS (TMV)

TMV is the first virus to be seen under the electron microscope.

TMV is long slender rod shaped. Its length is 300nm and diameter is **18nm**. It is made up of nucleoprotein. The nucleic acid is RNA, which forms the central core. The Central core is surrounded by protein known as capsid. The capsid is made up of capsomeres. Which are subunits of about 2,200. The capsomeres are closely packed and arranged in a helix around a central hole. The diameter of central hole is 4nm which has spirally coiled RNA.

The protein helix has 130 turn and each turn has 16 capsomeres. The RNA is single stranded and runs along the entire length of the rod.

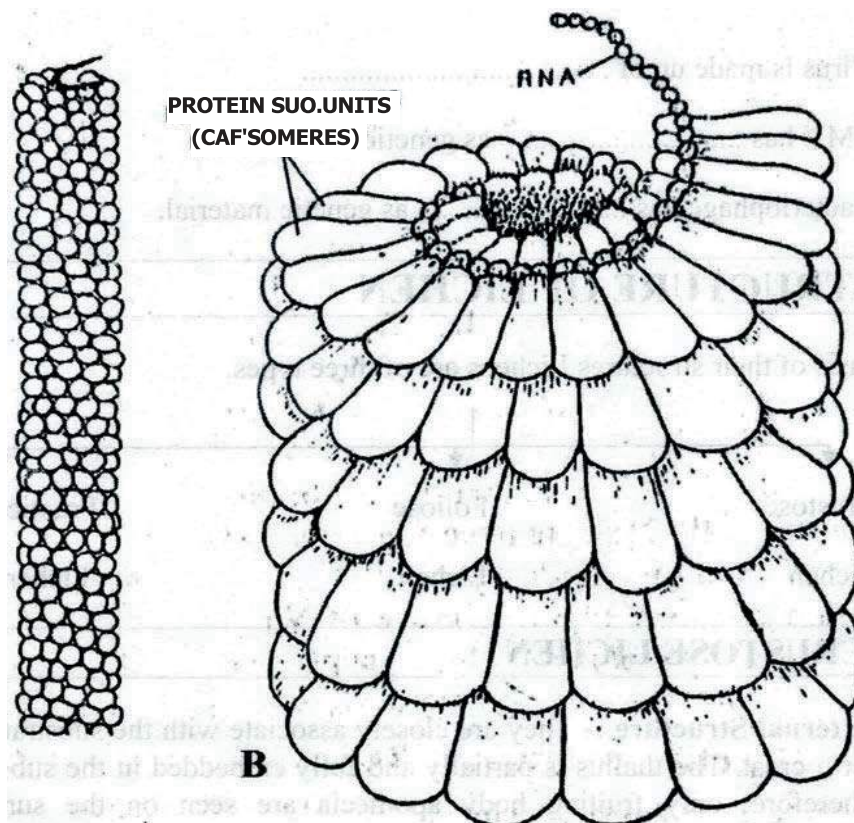


Fig.1.11. Tobacco mosaic virus .A. Single virus crystal; B Structural details.

1.3.4 REPLICATION OF VIRUSES

The TMV infect only Tobacco leaves. The virus is transmitted and introduced into the host cell by insect vector or by mechanical means. In

mechanical method virus is rubbed on the leaves of tobacco plant during transplanting.

Infection takes place with the whole virus particle. Protein coat alone is not infectious. The RNA alone is infectious but much less than that of an intact particle.

The entire virus particle enters into the host cell and causes infection. After entering the host cell, the protein coat degenerates. The viral RNA takes control of cell machinery. It starts producing viral components. Which then assembled into new virus particles. The actual mechanism of multiplication is not clear. There are two views :-

1. The DNA of the host cell uses viral RNA and synthesize a large no of protein and RNA. But it is not clear, why plant DNA starts building the viral components.
2. According to the other view the viral RNA over ride the ribosome of the host cell and elaborate viral components.

SAQ 2.

- (a) Virus is made up of
- (b) TMV has as genetic material.
- (c) Bacteriophage has as genetic material.

1.4 STRUCTURE OF LICHEN

On the basis of their structures Lichens are of three types.



1.4.1 CRUSTOSE LICHEN

1. **External Structure :-** They are closely associate with the substratum and form crust. The thallus is partially and fully embedded in the substratum. Therefore, only fruiting body apothecia are seen on the surface of substratum eg. *Haematomma*.

Internal Structure :

Internal structure of thallus is homoiomorous type. There is no differentiation of layers. The algal cells are scattered irregularly among the fungal hyphae in the gelatinous matrix.

1.4.2 FOLIOSE LICHEN

External Structure : The thallus is dorsoventrally flattened with irregular margin. Their margins remain free. But rest of the portion remain attached to the substratum by means of rhizoid like structures called rhizine. They look like the dried thallus of liver wart. eg. *Parmelia*.

Internal Structure : Internally thallus is heteromorous type. It is differentiated into 4 layers.

1. **Upper Cortex :-** It is the upper most layer made up of compactly interwoven fungal hyphae. This layer may or may not have intercellular spaces. If intercellular spaces are present it is filled with gelatinous material. Some times pores called pseudocephellae are found on lichen thallus. These are for exchange of gases.
2. **Algal Zone :-** cells mixed with loose fungal hyphae. This zone is photosynthetic in function. It is present below the upper cortex. Algal zone has algal
3. **Medulla :-** It occupies the middle part of thallus and present below the algal zone. Medulla consists of loosely interwoven fungal hyphae.
4. **Lower Cortex :-** It is the lower most region of the thallus. This layer consists of compactly arranged dark coloured fungal hyphae. On the under surface of lower cortex several hyphal out growth comes out. These are called rhizine. The rhizine helps the thallus to attached the substratum. The rhizine may be simple, branched, unicellular or multicellular.

1.4.3 FRUCTICOSE LICHEN

External Structure :- These are branched erect or pendent hanging down wards from the substratum. They remain attached to the substratum by means of basal portion. eg. *Usnea*.

Internal Structure :- It shows radial symmetry. The outline is made up of compact thick walled hyphae called pseudocortex. Below the pseudocortex is algal zone. The algal cells are inter mixed with loosely interwoven fungal hyphae. The central part medulla is made up of compact mass of hyphae.

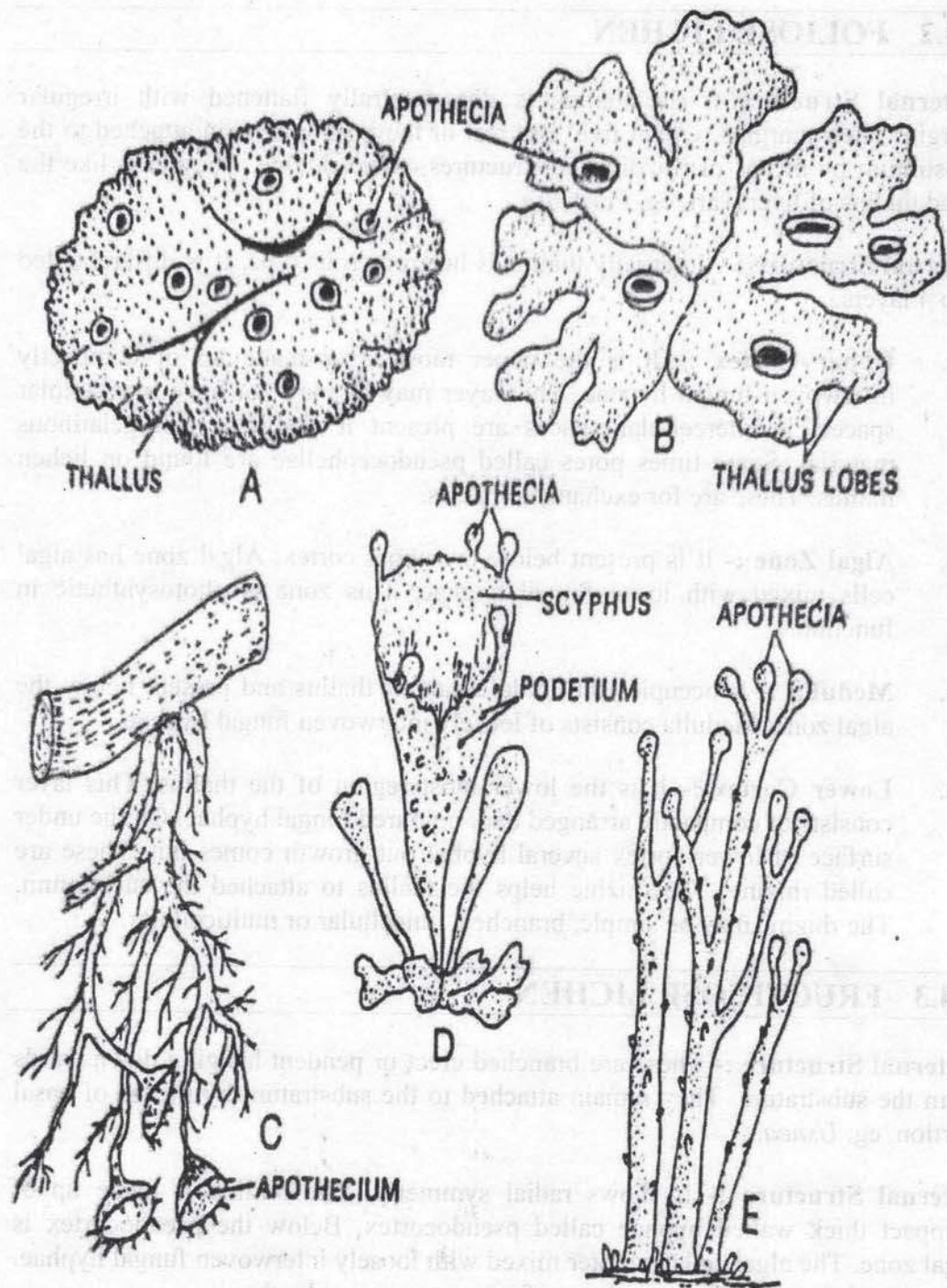


Fig.1.12. Types of lichen thalli. **A.** Crustose (*Haematomma puniceum*); **B.** Foliose (*Parmelia flavicans*); **C.** Fruticose (*Usnea barbata*); **D.** Fruticose (*Cladonia*); **E.** Fruticose (*Cladonia*).

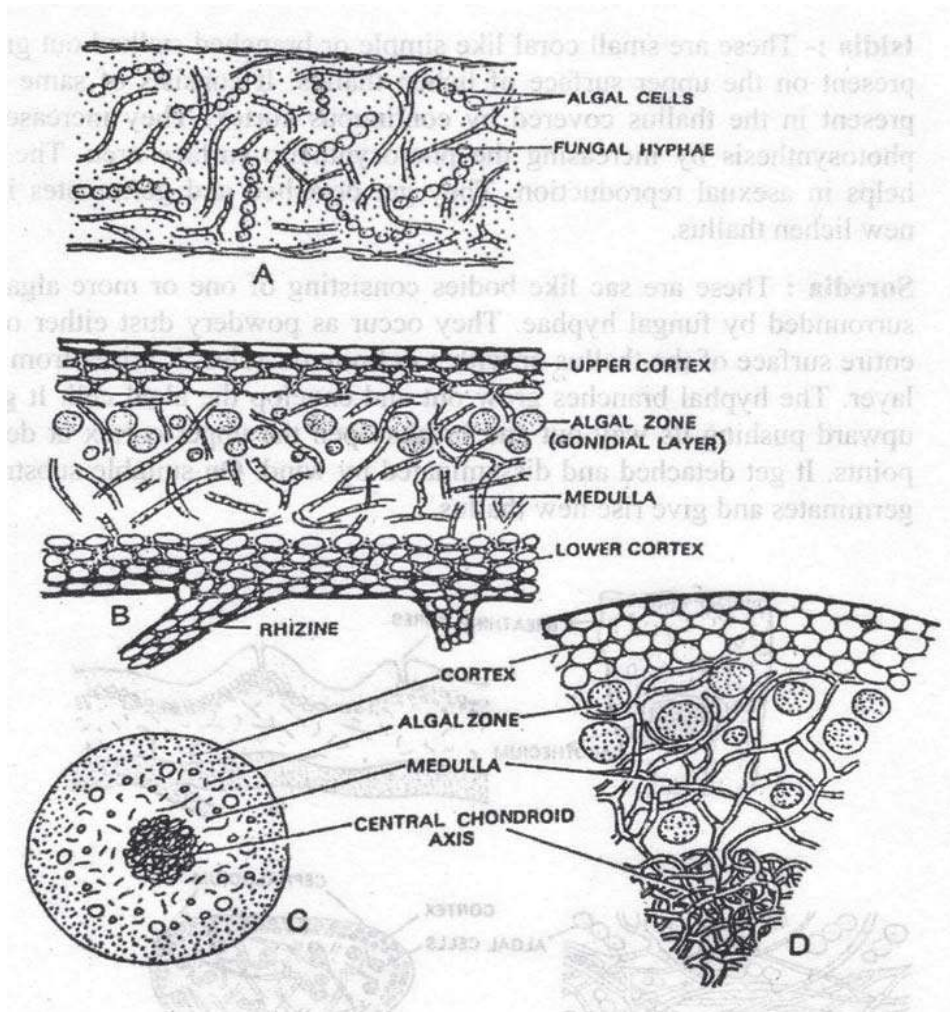


Fig.1.13. A. T.S of a crustose lichen; B. T.S of a foliose lichen; C. T.S. of a fruticose lichen (diagrammatic); D. A part cellular.

1.4.4 SPECIAL VEGETATIVE STRUCTURES PRESENT ON LICHEN THALLUS

The vegetative structures present on Lichen thallus are as follows :-

1. **Breathing pores** : These are found on upper cortex of some foliose lichen or fruticose lichen to facilitate exchange of gases. The compact cortex is interrupted by loosely inter woven fungal hyphae at the place of breathing pore.
2. **Cyphellae** : These are small pits found on ventral surface of lichen thallus. These pits have definite form with apical rims and open into the medulla. They are also meant for aeration.
3. **Cephalodia** : Some times wart like swellings are found on the upper surface of Lichen thallus known as Cephalodia. It encloses algal cell mixed with fungal hyphae. Cephalodia consists of normal fungal hyphae but different algal cell. They are produced as a result of reaction of fungal hyphae to a foreign algal partner.

4. **Isidia** :- These are small coral like simple or branched stalked out growth present on the upper surface of lichen thallus. It consists of same algae present in the thallus covered by continuous cortex. They increase the photosynthesis by increasing the photosynthetic surface area. The isidia help in asexual reproduction. They get detached and germinate into a new lichen thallus.
5. **Soredia** : These are sac like bodies consisting of one or more algal cells surrounded by fungal hyphae. They occur as powdery dust either on the entire surface of the thallus or with definite pustules. It arises from the algal layer. The hyphal branches grow out and envelop the algal cell. It grows upward pushing its way out and breaks open the upper cortex at definite points. It gets detached and disseminated by wind. On a suitable substrate it germinates and gives rise to a new thallus.

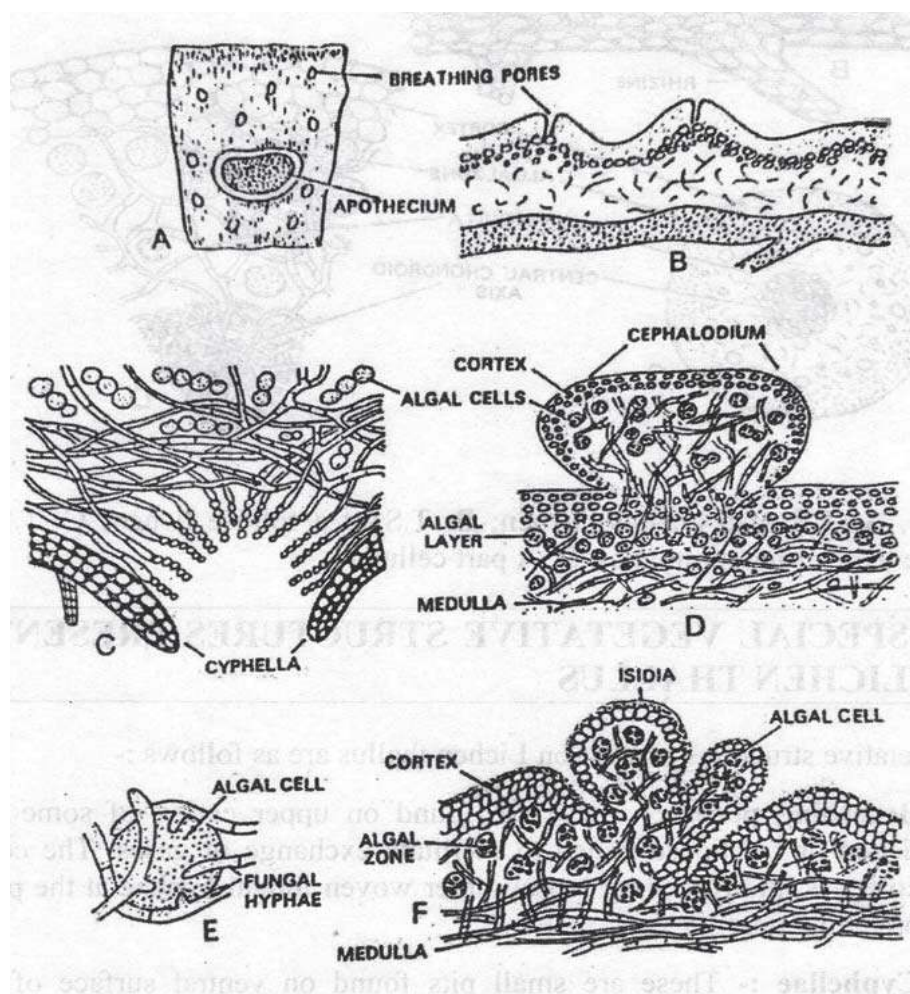


Fig.1.14. Lichen-Special vegetative structures; **A.** Surface view of thallus showing breathing pores; **B.** Section of thallus showing breathing pores; **C.** Cyphella; **D.** Cephalodium; **E.** Soredium; **F.** Isidia.

SAQ 3.

- (a) Lichen is an example ofassociation.

- (b) Lichen has and in symbiotic association.
- (c) Lichens do not grow in area.

1.4.5 ECONOMIC IMPORTANCE

Useful Importance

1. **Pioneers of Rock Vegetation :-** Crustose lichen act as pioneer and initiate vegetation on bare rock. Thus, it play an important role in xerach plant succession.
2. **Soil farmers :-** The lichen establish themselves on bare rock. It secretes some acids known as lichenic acid. The acid causes weathering of rocks into soil. The Coe released by lichen during respiration combines with water to form carbonic acid. This acid dissolves upper layer of rocks and convert it into soil. The fungal hyphae of lichen creep inside the rock crevices, die and add organic matter into it.
3. **Lichen as a food :-** Lichens are used as a food for catterpillars, snails. Reindeer mass (*Cladonia* and *Cetraria*) are eaten by reindeer and musk ox of arctic tundra. *Cetraria* and *Lecanora* are used as a food. *Parmelia* are used as curry powder in India. Lichens are also used in making Pasteries and Chocalates in baking industry.
4. **Lichen as a medicine :-** Lichens are useful in medicines. *Cladonia* and *Cetraria* are used in intermittent fever.

Parmelia saxatilis is used for the treatment of epilepsy.

Usnic acid obtain from Lichen is mixed with streptomycin and used against tuberculosis.

5. **Lichens in perfume industry :-** *Ramalina* and *Evernia* are used in the preparation of Dhup, Havan samagri and soap. Lichens are also used in tanning and dying industry. Litmus dye, a chemical indicator is obtained from lichen. Lichen yields acids eg. carbonic acid, usnic acid.

Harmful Importance :

1. *Usnea* grow abundantly on forest trees. During hot season it becomes dry, highly inflammable and causes forest fire.
2. Lichen reduces the market value of glasses stones, wood and fruits by causing damage due to secretion of acids.
3. Some Lichens destroy colonies of masses by direct parasitic attack.

1.5 SUMMARY

- The bacterial cell is prokaryotic means true nucleus and cellular organelles are absent.
- Bacteria are of two types gram+ve and gram-ye.

- Bacterial cell has plasmid (extra chromosomal genetic material).
- Reproduction is of two types, asexual and sexual.
- Asexual reproduction take place by binnary fission, endospore and cyst.
- True sexual reproduction does not occur in bacteria only genetic recombinant is formed by conjugation, transformation and transduction methods.
- Economically bacteria is useful as well as harmful.
- Viruses are simple organism made up of nucleo-protein.
- It has some characters similar to living organism and some characters similar to non living organism.
- Bacteriophage is tadpole like made up of nucleoprotein. The nucleic acid is DNA.
- It replicates inside the bacterial cell which may be lytic type or lysogenic type.
- TMV or Tobacco Mosaic virus is plant virus. It is rod shaped made up of capsid protein and nucleic acid (RNA).
- TMV multiply inside the tobacco plant.
- Lichens are group of plant in which algae and fungi are in symbiotic association.
- On the basis of their structures lichens are of three types : Crustose lichen, Foliose Lichen and Fructicose Lichen.
- The external as well as internal structure of all the three lichens are different.
- Special vegetative structures like pseudocephallae, cyphellae, cephalodia, isidia and soredia are also found on lichen thallus.
- Economically lichens are useful as well as harmful.

1.6 TERMINAL QUESTIONS

Long Questions

- 1 With the help of labelled diagram describe the structure of bacterial cell.

- 2 Describe the economic importance of bacteria.

- -----

3. With the help of labelled diagram describe the structure and replication of bacteriophage.

- -----

4. Describe the structure and economic importance of lichen.

Short Notes on-

1. Structure of TMV.
2. Structure of bacteriophage.
3. Isidia
4. Soredia.

1.7 ANSWERS

SAQ. 1

- (a) Prokaryotic
- (b) Mucopeptid
- (c) Conjugation, Transformation, Transduction
- (d) Plasmid

SAQ.2

- | | | |
|-------------------|---------|---------|
| (a) Nucleoprotein | (b) RNA | (c) DNA |
|-------------------|---------|---------|

SAQ.3

- | | | |
|---------------|------------------|--------------|
| (a) Symbiotic | (b) Fungus, alga | (c) Polluted |
|---------------|------------------|--------------|

REFERENCE

1. Fungi by Dr. H.N. Srivastava.

UNIT-II ALGAE - I

Structure :

2.1 Introduction

Objective

2.2 Morphology and Life cycle of *Nostoc*

2.3 Morphology and Life cycle of *Chlamydomonas*

2.4 Morphology and Life cycle of *Volvox*.

2.5 Morphology and life cycle of *Ectocarpus*

2.6 Morphology and life cycle of *Fucus*

2.7 Morphology and Life cycle of *Polysiphonia*

2.8 Summary

2.9 Terminal Questions

2.10 Answers

2.1 INTRODUCTION

The term algae (Latin-Sea weeds) was first introduced by Linnaeus in 1753. The study of algae is called phycology. The algae (Singular-alga) comprise several different groups of living organisms. They are usually found in wet places or water bodies. The algae capture light energy through photosynthesis, converting inorganic substances into simple sugars with the captured energy.

Genus *Nostoc* is blue-green alga, placed in cyanophyceae. The blue-green algae is a primitive group of about 1,500 species and 160 genera. Their cell is prokaryotic therefore, blue-green algae have also been named as cyanobacteria. The blue-green colour of algae is because of principal bluish-green pigment C-phycocyanin. Their reserve food is cyanophycian starch.

Genus *Volvox* and *Chlamydomonas* are placed in chlorophyceae. This class is represented by 425 genera and 6,500 species. Chlorophyll a and b, present in their plastids, impart them bright green colour therefore, they are called green algae. The reserve food of chlorophyceae is starch.

Genus *Ectocarpus* and *Fucus* are placed in class phaeophyceae. This class is represented by about 240 genera and 15000 species. The algae have

characteristic brown fucoxanthin pigment in large amount. This gives a characteristic brown colour to the algae, hence the name brown algae. Reserve food is laminarian starch and D-mannitol.

The *Polysiphonia* is placed in *Rhodophyceae*. The members of class Rhodophyceae are commonly known as red algae, due to the presence of red pigment r-phycoerythrin, which completely masks the green colour of chlorophyll a. This group is represented by 831 genera and 5,250 species. The reserve food is floridean starch and galactoside floridoside.

Objective

After studying this unit you will be able to know :-

- The life cycle of *Nostoc*.
- The life cycle of *Chlamydomonas* and *Volvox*.
- The life cycle of *Ectocarpus* and *Fucus*.
- The life cycle of *Polysiphonia*.

2.2 NOSTOC (LIFE CYCLE)

Class- Cyanophyceae

Order- Nostocales

Family- Nostocaceae.

Nostoc is fresh water as well as terrestrial alga and form macroscopic colonies.

2.2.1 THALLUS STRUCTURE

It is unbranched trichome surrounded by a gelatinous sheath. The trichome of *Nostoc* has characteristic heterocyst which may be terminal or intercalary. The intercalary heterocyst has two polar nodules whereas, the terminal heterocyst has only one basal polar nodule.

Each cell of the trichome is spherical or oval surrounded by a cell wall made up of mucopolysaccharide. The protoplast has an outer pigmented region chromatoplasm and a central nucleoplasm. The nucleoplasm has nuclear material. Cyanophycan starch and globules are present as a reserve food. Characteristic pigments are C-Phycocyanin, C-phycoerythrin. Chlorophyll a, carotenoids.

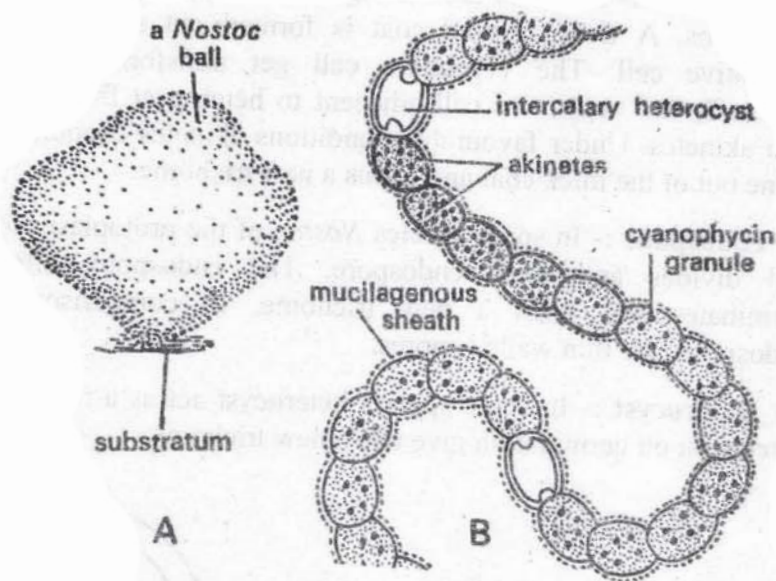


Fig 2.1 A-B *Nostoc* : A. Gelatinous colony, B. Trichome.

2.2.2 REPRODUCTION

It occurs by vegetative and asexual methods. Sexual reproduction is absent in *Nostoc*.

1. **By fragmentation :-** The *Nostoc* colony breaks into small fragments by mechanical or physiological factors. Each fragment grows into a new filament.
2. **By Hormogonia :-** The trichome breaks into small fragments, due to presence of intercalary heterocyst or degeneration of vegetative cell. Each fragment is called hormogonia which, grows into a new trichome.

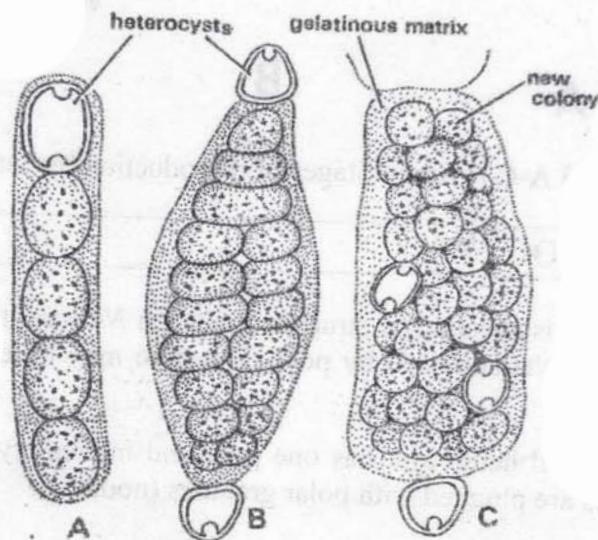


Fig 2.2 A-C. *Nostoc*: Reproduction by hormogonia.

3. **By Akinetes :-** Akinetes are resting spores produced under unfavourable conditions. A three layered coat is formed outside the cell wall of vegetative cell. The vegetative cell gets transformed into Akinetes. Generally the vegetative cell adjacent to heterocyst first metamorphoses into akinetes. Under favourable conditions akinetes become active. They come out of the thick coat and form a new trichome.
4. **By endospore :-** In some species *Nostoc* the protoplasm of vegetative cell divides and forms endospore. The endospore, after liberation, germinates and forms a new trichome. In comparison to akinetes, endospores are thin-walled spores.
6. **By Heterocyst :-** In some species heterocyst acts as a resting spore. This heterocyst on germination gives rise to a new trichome.

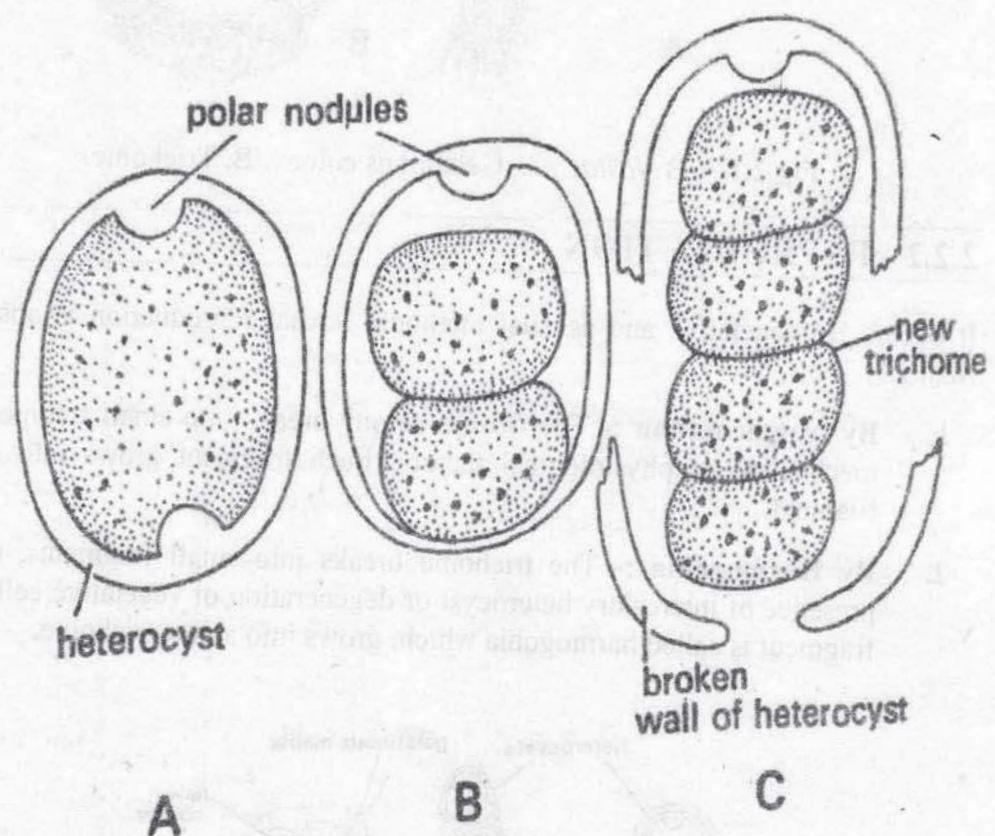


Fig 2.3 A-C *Nostoc* : Stages of reproduction by heterocyst.

2.2.3 HETEROCYST

Heterocyst is a specialized structure found in *Nostoc*. It may be terminal or intercalary and is characterized by a pore. The pore may be either at one pole or both the poles.

The terminal heterocyst has one pore and intercalary heterocyst has two pores. The pores are plugged with polar granules (nodules).

The wall of heterocyst is thick, pale yellow and divided into outer, middle and inner layer. The heterocyst develops from the vegetative cells.

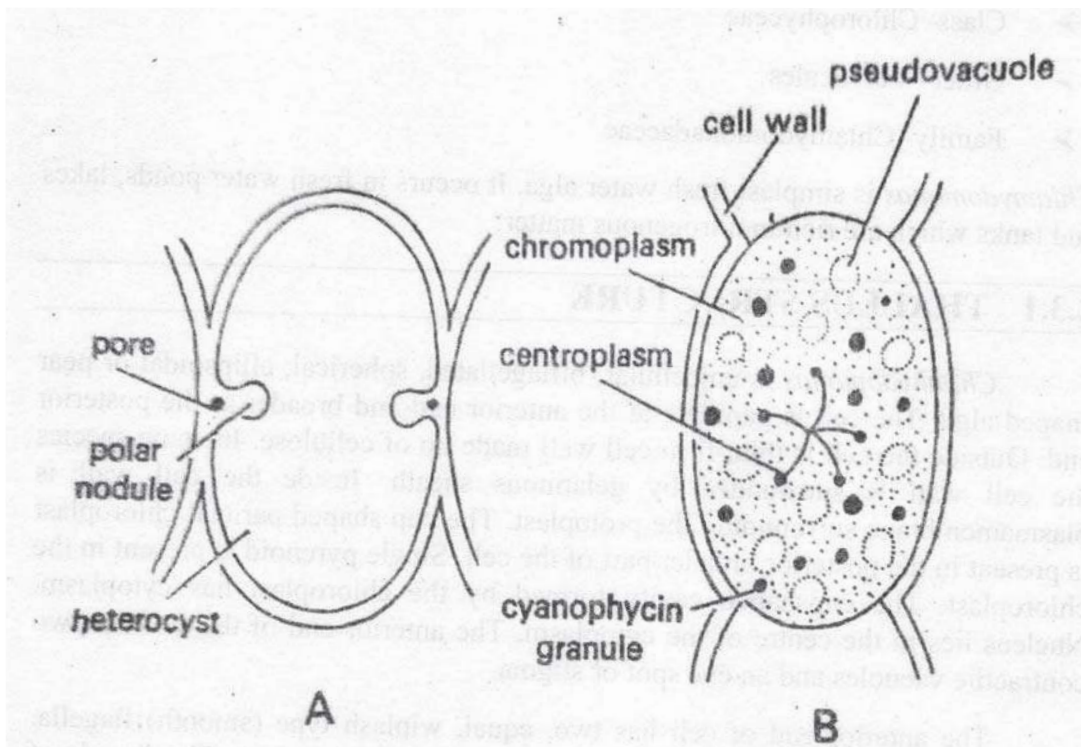


Fig 2.4 A-B *Nostoc* : A. Heterocyst, B. Cell structure as seen under light microscope

Function :- Function of heterocyst is not definitely known. Earlier it was considered simply as a dead cell. But this view is not valid because heterocyst germinates and help in vegetative reproduction.

Now heterocyst is considered as nitrogen fixing organ in blue green algae peuticularly under aerobic conditions. The vegetative cells of blue green algae fixes nitrogen under anaerobic conditions the nitrogenase enzyme becomes inactive due to presence of O_2 . Then the thick walled heterocyst provide anaerobic conditions for nitrogen fixation.

Thus now heterocyst has two main functions-

- (1) Reproduction
- (2) Fixation of nitrogen.

SAQ1

- (a) *Nostoc* belongs to class
- (b) Heterocyst occurs in.....
- (c) The cell of *Nostoc* is
- (d) The reserve food in *Nostoc* is

7.1 CHLAMYDONONAS (LIFE CYCLE)

- Class- Chlorophyceae
- Order- Volvocales
- Family- Chlamydomonadaceae

Chlamydomonas is simplest fresh water alga. It occurs in fresh water ponds, lakes and tanks which are rich in nitrogenous matter.

2.3.1 THALLUS STRUCTURE

Chlamydomonas is unicellular, biflagellated, spherical, ellipsoidal or pear shaped alga. The cell is papillate at the anterior end and broader at the posterior end. Outside the cell is thin, firm cell wall made up of cellulose. In some species the cell wall is surrounded by gelatinous sheath. Inside the cell wall is plasma membrane surrounding the protoplast. The cup shaped parietal chloroplast is present in the posterior broader part of the cell. Single pyrenoid is present in the chloroplast. The cupshaped cavity formed by the chloroplast has cytoplasm. Nucleus lies in the centre of the cytoplasm. The anterior end of the cell has two contractile vacuoles and an eye spot or stigma.

The anterior end of cell has two, equal, wiplash type (smooth) flagella. Each flagellum arises from a basal granule, the blepharoplast. The length of flagella are more than the length of the cell. They are locomotory organs.

The cell has cellular organelles like golgi apparatus, endoplasmic reticulum, ribosomes and mitochondria. The characteristic pigments of alga are chlorophyll a, b, a, f3 carotens and xanthophyll.

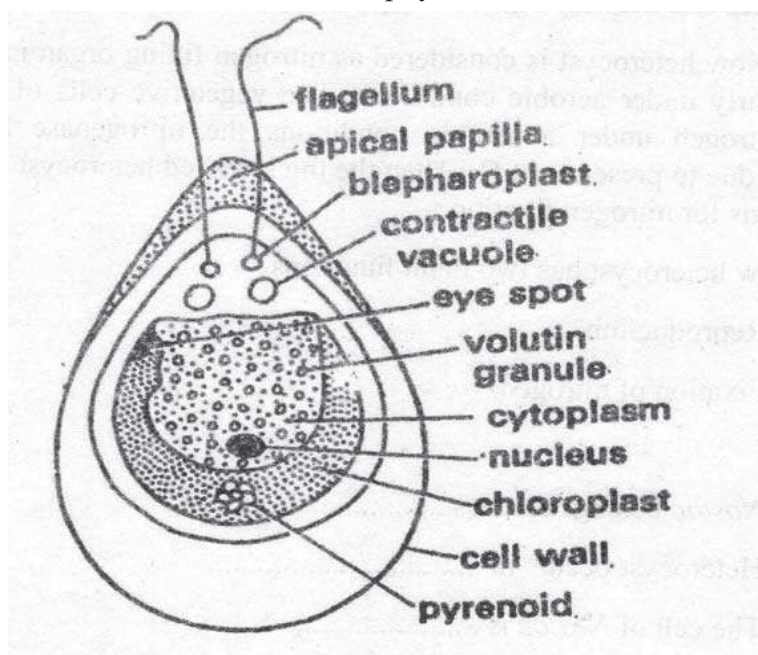


Fig. 2.5. *Chlamydomonas* : Cell structure

2.3.2 REPRODUCTION

It is of two types-

- (i) Asexual reproduction
- (ii) Sexual reproduction.

(i) **Asexual reproduction** : It takes place by the following methods:-

(a) **By Zoospore:** *Chlamydomonas* multiplies asexually by zoospores. Under favourable conditions, the parent cell comes to rest. The cell withdraws its flagella and contractile vacuoles disappear. The protoplast withdraws from the cell wall and divides longitudinally into two daughter protoplasts. This is followed by successive longitudinal divisions at right angle to each other, forming 4, 8, 16 or more uninucleated protoplasts. Each protoplast secretes a wall around itself. Flagella and contractile vacuoles develop in each protoplast. Thus, flagellated daughter cells similar to the parent cell are produced. These are called zoospores, which are released by the rupture of the parent wall. Each zoospore grows in an adult *Chlamydomonas* cell.

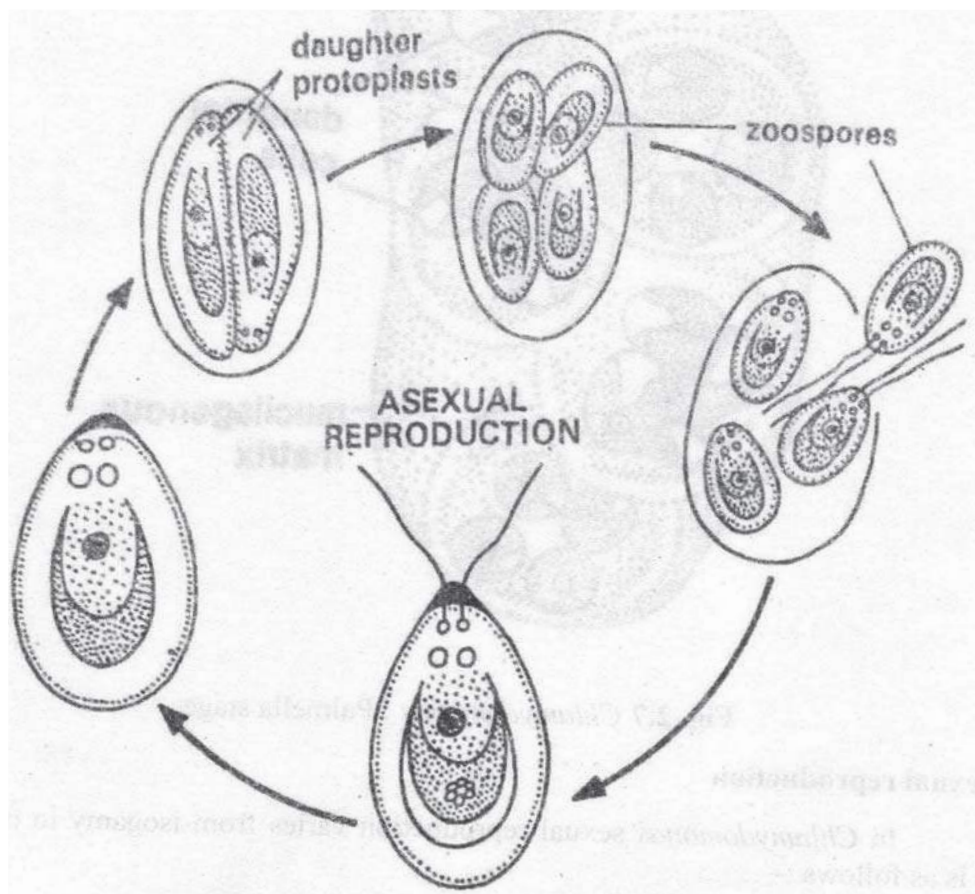


Fig. 2.6 *Chlamydomonas* : Asexual reproduction; Formation of zoospores

- (b) **By Aplanospores :-** Under unfavourable conditions, the cells withdraw flagella and their protoplasts divide into 2-16 daughter protoplasts. Each protoplast secretes a thin wall around itself. Flagella does not develop. Thus, non motile cells are formed, known as aplanospores. The aplanospore develops flagella and grow into vegetative cell.
- (c) **Palmiella stage :-** Under unsuitable conditions the protoplast of the parent cell divides repeatedly into 2, 4 or 8 daughter cells which fail to develop flagella. Numerous aflagellated daughter cells remain embedded in the mucilagenous matrix formed by gelatinisation of the parent cell wall. This aggregation of cells is known as pamella stage. Thus, pamella stage is a non motile and temporary reporductive phase. Under favourable conditions these cells form flagella. They come out of the gelatinous matrix and develop into vegetative cells.

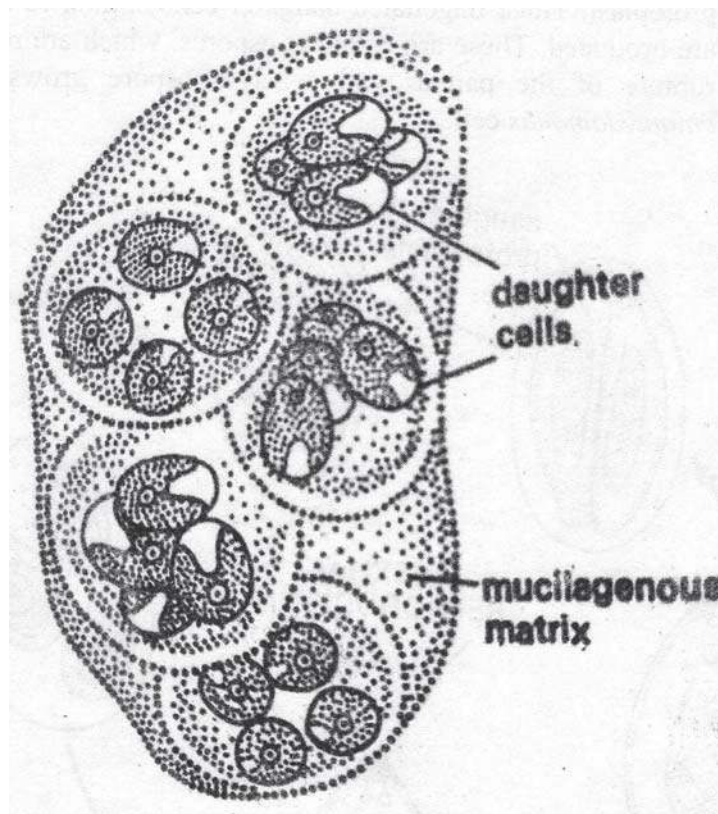


Fig. 2.7 *Chlamydomonas* : Palmella stage.

Sexual reproduction _

In *Chlamydomonas* sexual reproduction varies from isogamy to oogamy. It is as follows :-

1. **Isogamy :-** In sexual reproduction 8, 16, 32 or 64 isogametes are produced either in the same cell if species is homothallic or in different cells if species is heterothallic. The isogametes are morphologically similar but

physiologically different. The flagella of gametes are covered by agglutins, a chemical substance which recognise the gamete of opposite strain. The gametes of plus (+) and minus (-) strains fuse in pair at their anterior ends.

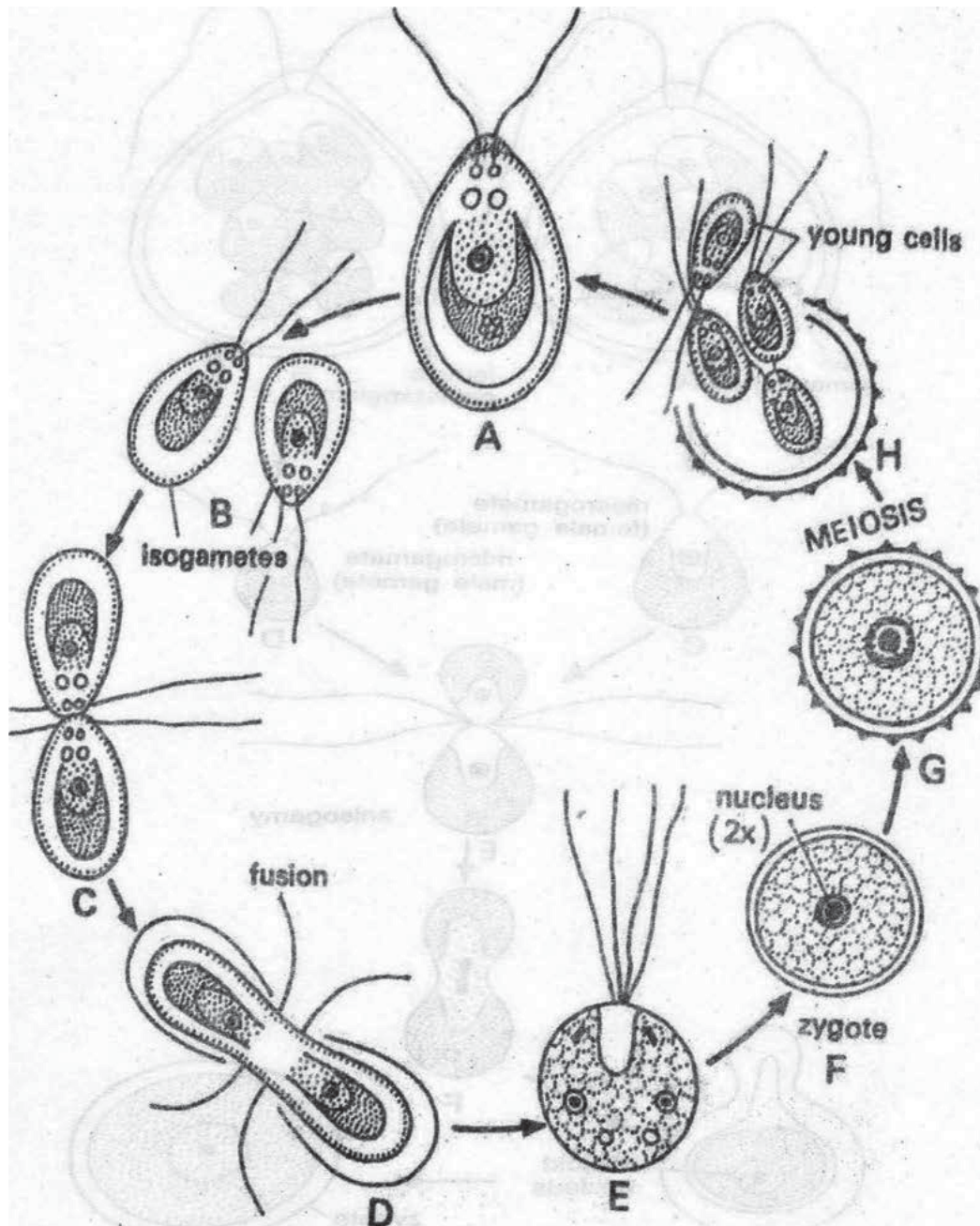


Fig. 2.8 A-H . *Chlamydomonas longistigma* : Isogamy (homothallic); A. Vegetative cell, **B.** Isogametes, **C-E.** Fusion of isogametes, **F-G.** Zygote, **H.** Germination of zygote.

2. Anisogamy :- In anisogamy the fusing gametes are of different size. 2 or 4 female gametes or macrogametes are produced in female gametangium. Whereas 8-16 male gametes or mitogametes; are produced in a

microgametangium. The microgametes are small and more active than the macrogametes. It comes in contact of female gamete and fuse at their anterior end to form zygote.

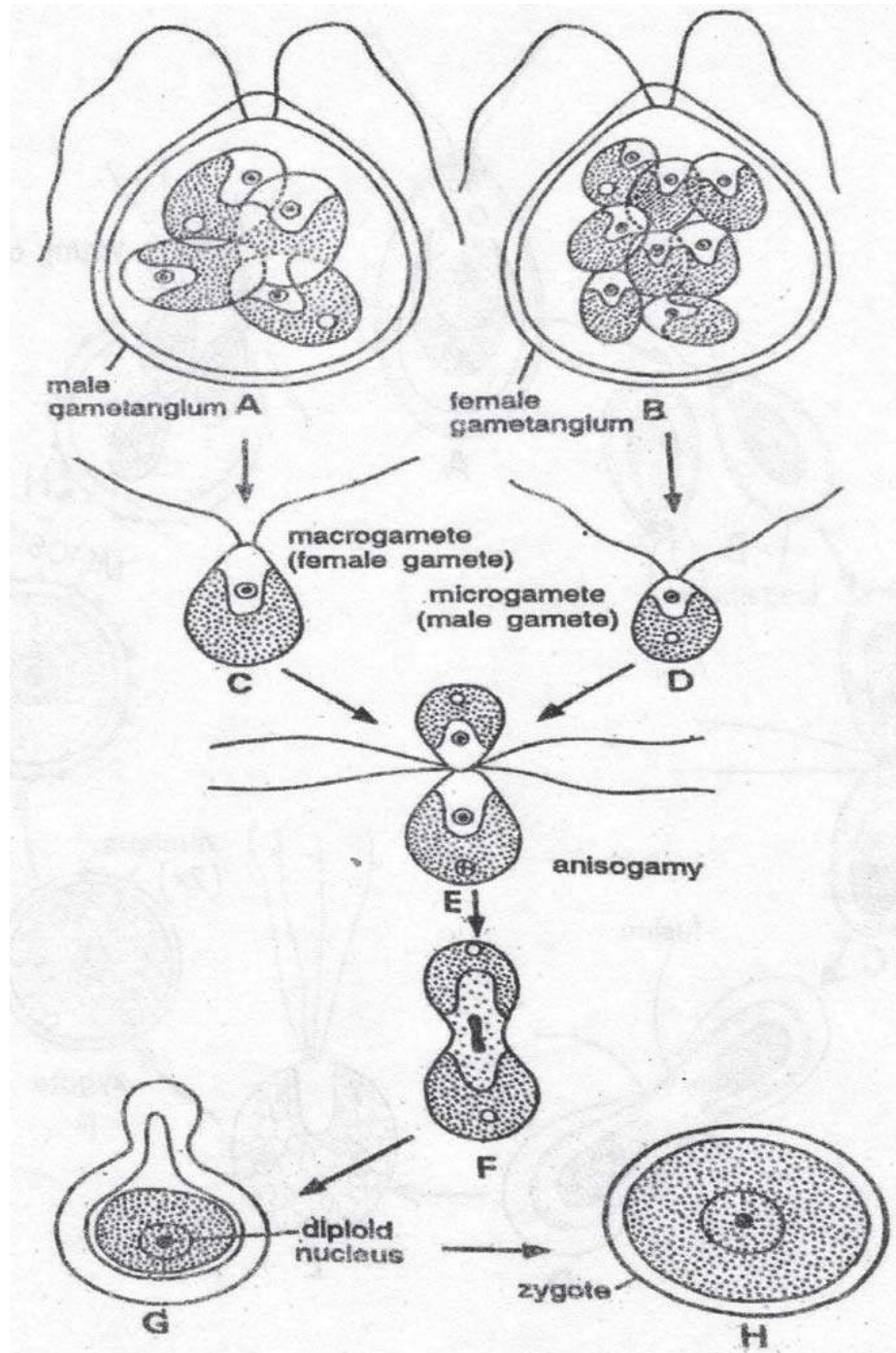


Fig. 2.9 Misogamy (A-H); **A.** Female gametangium, **B.** Male gametangium; **C.** Female gamete; **D.** Male gamete; **E-F.** Fusion of gametes; **G-H.** Zygote.

3. **Oogamy** In oogamy the female gamete is non motile. The female cell withdraw their flagella and function as nonmotile macrogametes. The male cell divides and from 16 segments which, develops into biflagellated

male gametes. These male gametes fuse with non motile female gametes at their anterior end to form zygote.

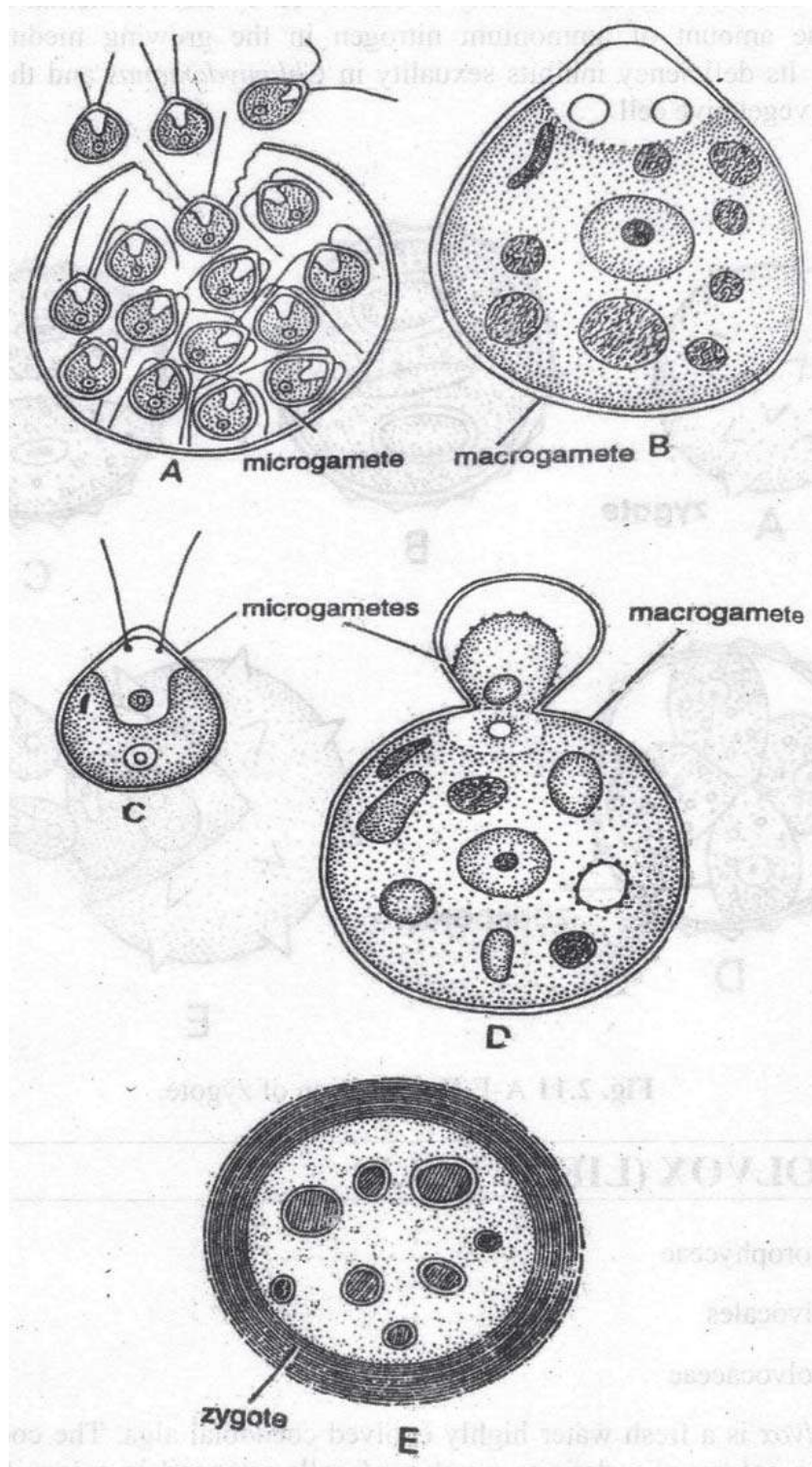


Fig. 2.10- Oögamys **A.** Microgametangium., **B.** macrogametangium, **C.** microgamete, **D.** Fusion of micro and macrogametes, **E.** Zygote

Germination of Zygote :- Zygote germinates in water. Before germination it undergo meiosis and thus, 4 zoospores are produced in a zygote. The zoospore on liberation grows into *Chlamydomonas* plant.

In *Chlamydomonas* sexuality is controlled by environmental and genetic factor. The amount of ammonium nitrogen in the growing medium is very important. Its deficiency inhibits sexuality in *Chlamydomonas* and then gametes behave as vegetative cell.

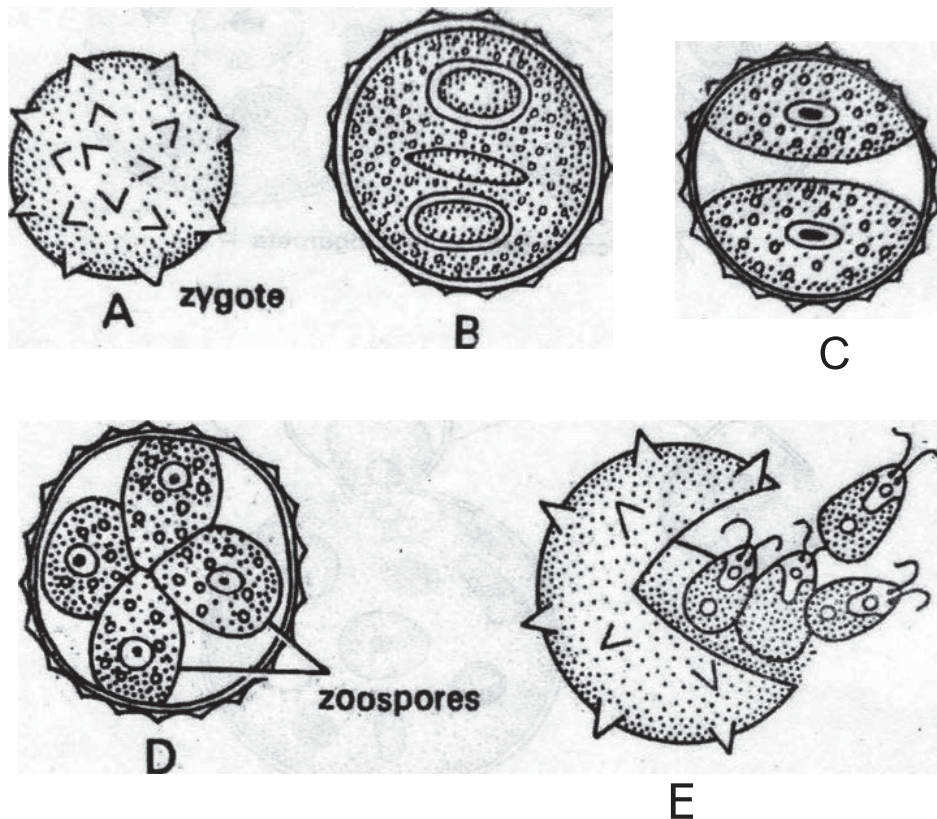


Fig. 2.11 A-E Germination of zygote.

2.4 VOLVOX (LIFE CYCLE)

Class - Chlorophyceae

Order - Volvocales

Family - Volvocaceae

Volvox is a fresh water highly evolved coenobial alga. The coenobium is motile. The colony of a definite number of cells arranged in a specific manner, forming an integrated whole is known as coenobium.

Thallus structure : The coenobium is oval to spherical in shape. Bi-flagellated cells are arranged in a single layer with in the periphery of gelatinous envelop. Each cell also has a gelatinous envelop and are connected to the adjacent cell by

cytoplasmic strand. Central hollow cavity of the colony is filled with the water or gelatinous fluid.

Each cell is pyriform with broad posterior and narrow anterior end. Internally it has a cup shaped chloroplast in the posterior part of the cell. The chloroplast has a single pyrenoid. Besides this a single nucleus, two flagella and two contractile vacuole and an eye spot is also present.

Most of the cell in a colony are vegetative only few cells are reproductive. The reproductive cells are non motile and larger than vegetative cell. Reproductive cells are generally present at the posterior end of the colony.

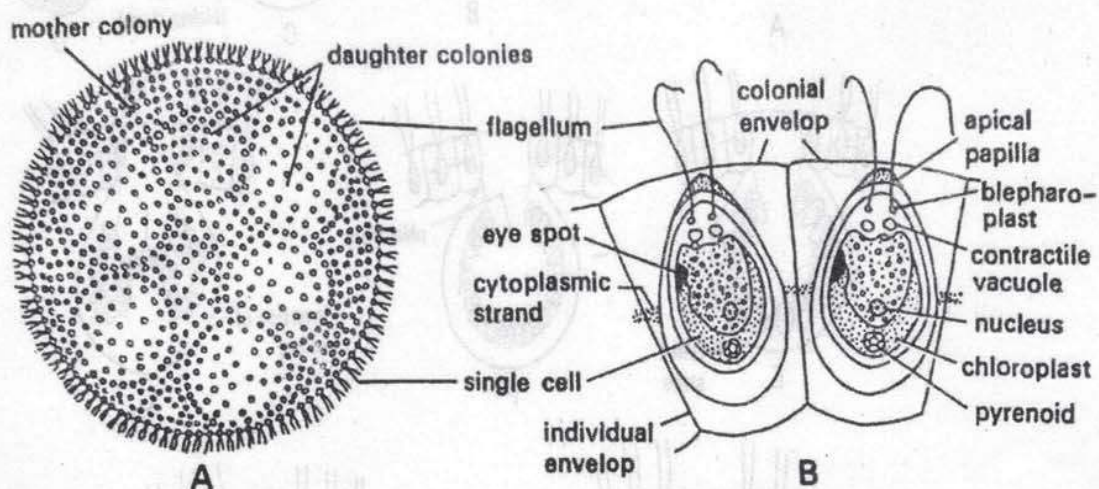


Fig2.12 A-B *Volvox* : A. A coenobium, B. A part of coenobium,

Reproduction : It is of two types -

- (1) Asexual reproduction
- (2) Sexual reproduction

(1) **Asexual reproduction :-** Asexual reproduction take place by Gonidia (special type of cells) present at the posterior end of the colony. A gonidium is larger than vegetative cell and is embedded in gelatinous matrix.

The enlarged gonidium under go three vertical division and forms 8 cells which get arranged in a curved plate called plakea stage. Each cell again divide and forms 16 cells arranged in a sphere with a small opening phialopore present towards the periphery of the colony. The cells again divide and forms about 60,000 cells. At this stage the anterior end of cells are directed towards the center of the hollow sphere. The normal orientation of cells in the colony is achieved by inversion.

A constriction appears at the posterior end of the colony which pushes the cells of the posterior end towards the phialopore. The phialopore becomes broader and cells are pushed through it. At the end of inversion, the anterior end of the cell face towards the periphery.

After inversion the cell secretes gelatinous sheath and develop flagella. In this way daughter colony is formed inside each gonidium. The daughter colony is released after the rupture or disintegration of parent colony.

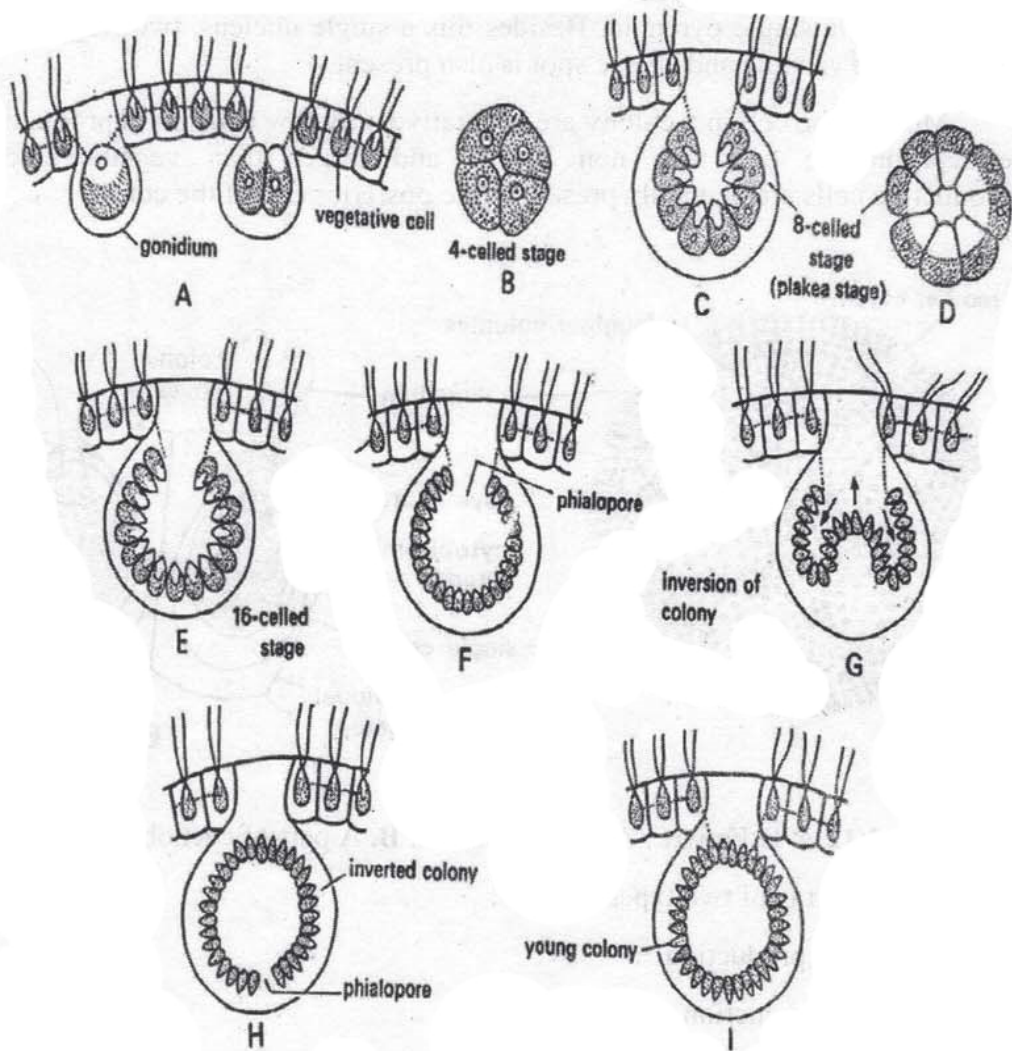


Fig 2.13 *Volvox* : Asexual reproduction (development of daughter colony) ‘ A-D. Formation of plakea stage, E. 16. Celled stage, F-H. Stages of inversion , I. Daughter colony

- (2) **Sexual reproduction :-** Sexual reproduction takes place towards the end of growing season. Species of *Volvox* are either monoecious or dioecious. Male sex organ is antheridium and female sex organ is oogonium. Reproduction is oogamous type. Antheridium and oogonium develops from the gametangium present at the posterior end of the colony.

Antheridium :-

Gametangium is larger than vegetative cell. The protoplast of male gametangium divides and forms biflagellated fusiform antherozoids. The antherozoids are released in bundle.

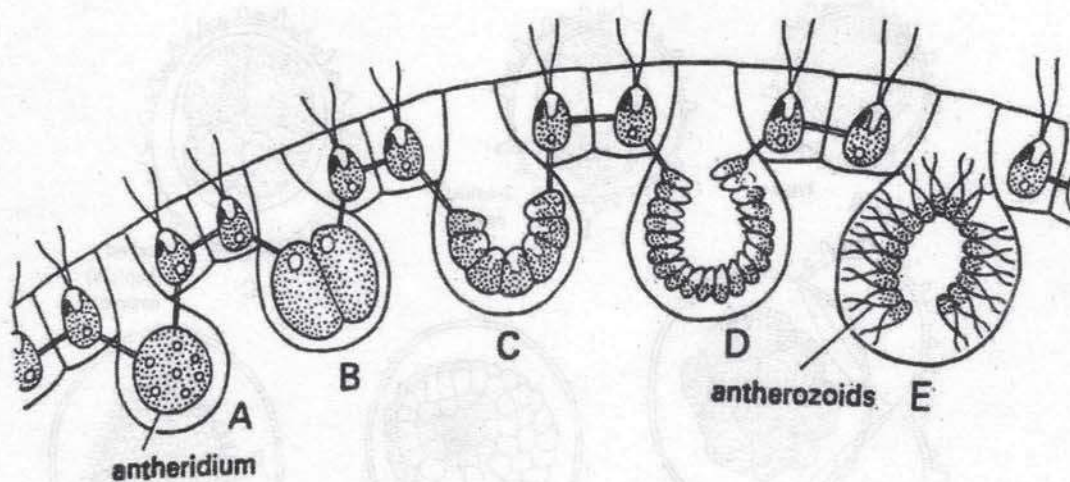


Fig. 2.14 A-E. *Volvox*: Development of antherozoids.

Oogonium :- The female gametangium becomes flask shaped oogonium. Their entire protoplast forms a single uninucleated spherical egg. The flask shaped oogonium open on the surface of colony.

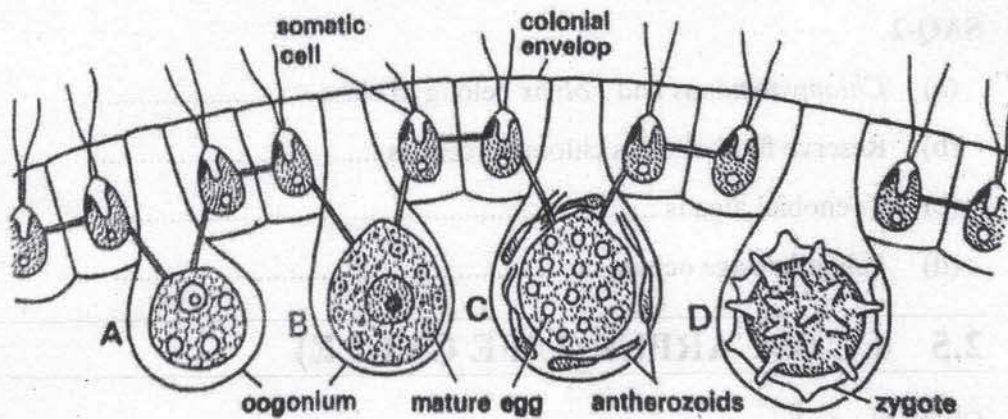


Fig. 2.15 A-D. *Volvox* : A-B. Development of oogonium, C. Fertilization , D. Zygote.

Fertilization :- The antherozoids liberated in the form of colony swim in water. When it comes in contact with a female colony, they break down the colonial matrix. Then antherozoids are liberated into the gelatinous matrix of female colony. One antherozoid fuses with the egg to form the zygote.

The zygote secretes a three layered thick wall around it which may be smooth or spiny. The wall has haematochrome due to which zygote is red coloured.

Germination of Zygote :- Before germination meiosis take place in the zygote and 4 haploid cells are formed. These cells divide repeatedly to form plakea stage as in asexual reproduction. After this inversion results in the formation of a new colony like asexual reproduction.

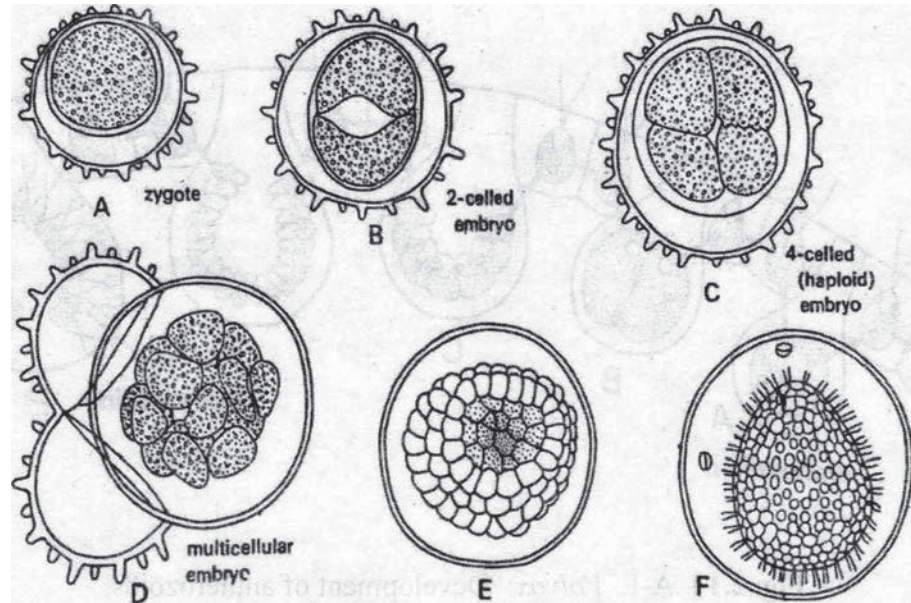


Fig. 2.16 A-F. *Volvox*: Development of young coenobium from the zygote; **A.** Zygote, **B-C.** Reduction division in zygote, **D.** Multicellular embryo, **E.** Inversion, **F.** Young coenobium

SAQ2

- Chlamydomonas* and *Volvox* belong to class
- Reserve food of class chlorophyceae is
- Coenobial alga is
- Palmella stage occurs in.....

2.5 ECTOCARPUS (LIFE CYCLE)

Class- Phaeophyceae

Order- Ectocarpales

Family- Ectocarpaceae

Ectocarpus is cosmopolitan in distribution and grow in littoral and sublittoral region in India. It is found on the western coast.

2.5.1 THALLUS STRUCTURE

Ectocarpus is heterotrichous differentiated into a prostrate rhizoidal system and an erect branched system. Thallus remain attached to the substratum by means of prostrate system.

The erect part is branched and filament is one cell in thickness. Each cell is rectangular uninucleate and has an outer gelatinous layer made up of algin and fluocoiden. Inside the cell is cytoplasm which has chromatophore with pyrenoids.

The pigments are chlorophyll a, c, β and C carotene and xanthophyll. Fucoxanthin the dominant pigment is present in the chromatophore.

Reserve food is laminarian starch and D-mannitol. Vacuoles are present in the cytoplasm.

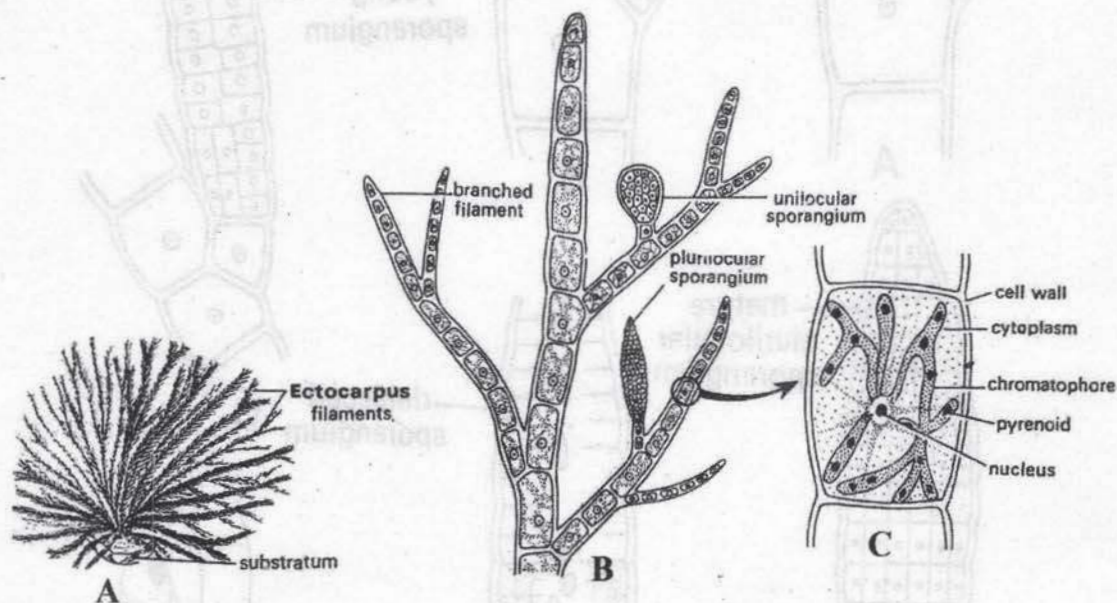


Fig. 2.17 (A,B,C,) *Ectocarpus* A. Thallus structure. B. Thallus with unilocular and plurilocular sporangia: C- structure of a cell

2.5.2 REPRODUCTION

It is of two types :-

- (1) Asexual reproduction
- (2) Sexual reproduction

(1) Asexual reproduction :- Take place by means of biflagellated zoospore produced in unilocular (once chamber) and plurilocular sporangia. Both are produced either on the same plant or on different plant.

Plurilocular sporangium :- It develops from the terminal cell of the branchlet of diploid plant. The cell behaves as sporangial initial and undergo repeated transverse and longitudinal divisions to form about 660 cubical cells arranged in a definite tiers.

Each cell has a diploid nucleus which produces biflagellated diploid zoospore. Mature zoospores are liberated from the zoosporangium, which on germination forms diploid plant of *Ectocarpus*. Thus diploid zoospore helps only

in the multiplication of sporophyte and does not play any role in the alternation of generation.

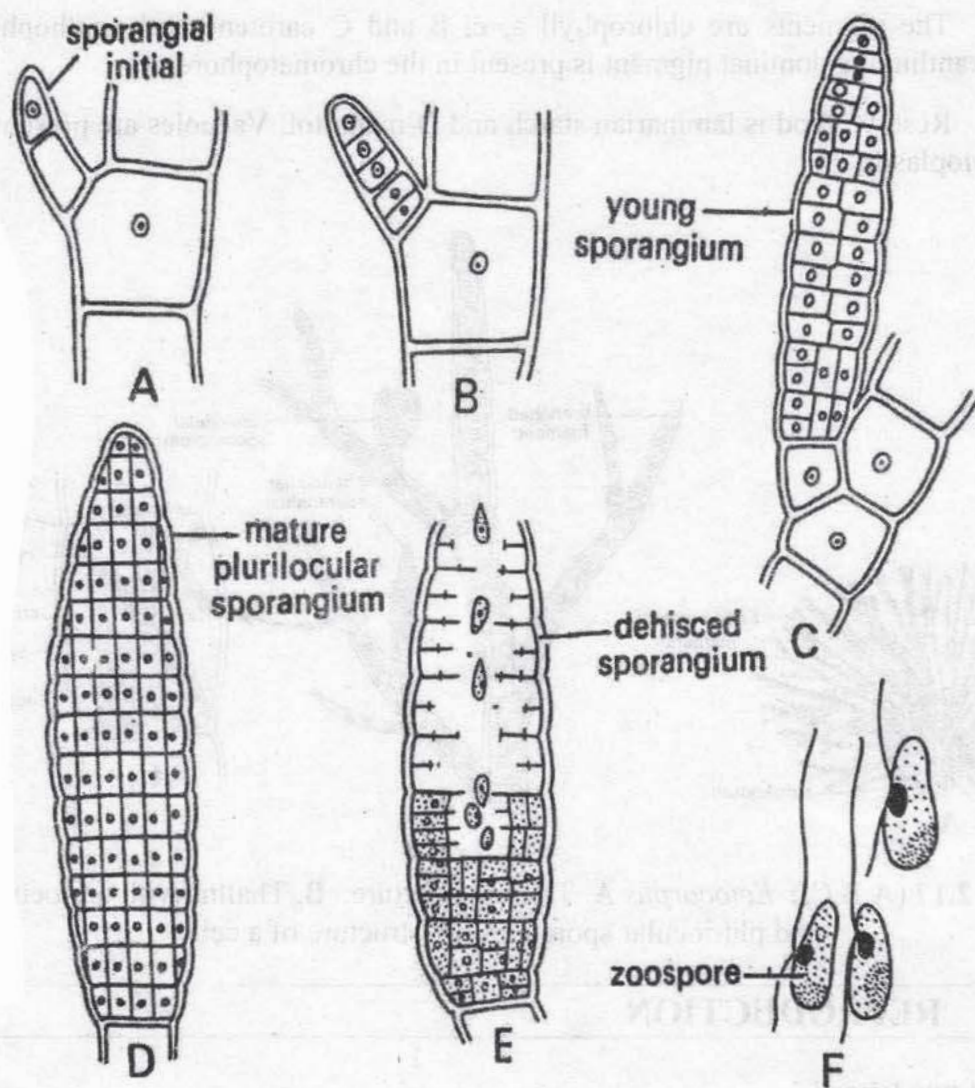


Fig. 2.18 A-F. *Ectocarpus*: A-C. Development of plurilocular sporangium; D. Mature plurilocular sporangium; E. Liberation of zoospores from sporangium; F. Zoospores.

Unilocular sporangium :- it develops singly from the terminal cell of the branch let. The terminal cell behaves as sporangial initial. its nucleus undergo *meiosis* followed by mitosis as a result 32-64 haploid nuclei are formed. Each nucleus under go cleavage and metamorphosis resulting in the formation of *haploid* Zoospore.

Each zoospore is pyriform and has two lateral unequal flagella. One flagellum is smooth (wiplash) and other is *tinsel* (having row of minute hair along the axis of flagellum). The zoospores are liberated from unilocular sporangium. They remain motile for sometime then withdraw their flagella and get attached to

the substratum by their anterior end. It give rise *haploid filament of Ectocarpus* (gametophyte).

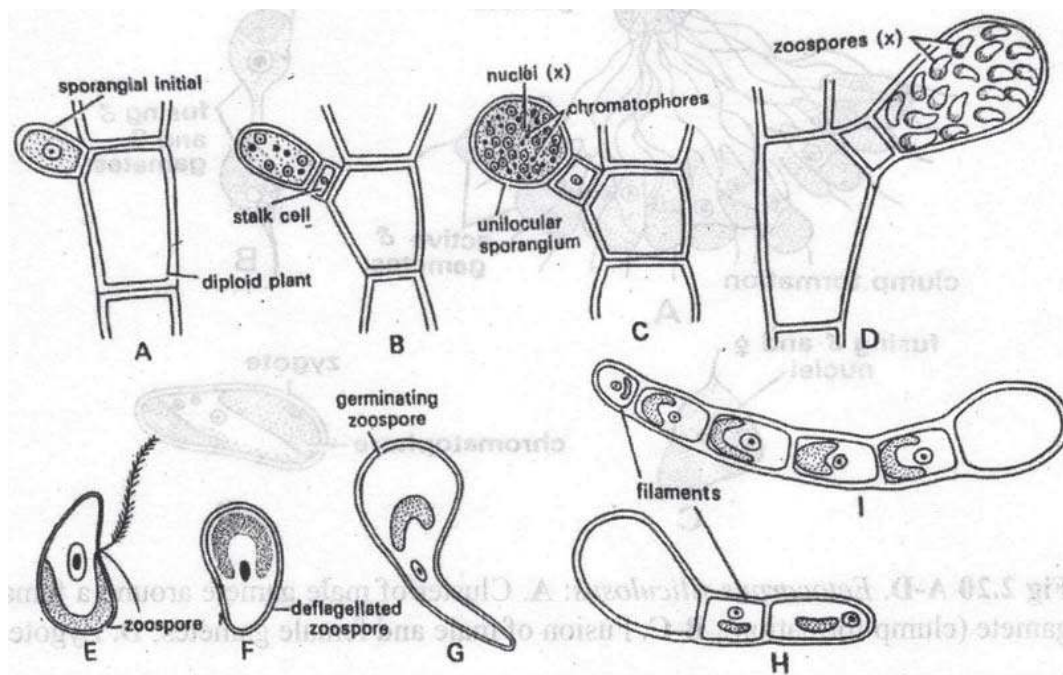


Fig. 2.19 A-I. *Ectocarpus* : **AD.** Successive stages in the development of unilocular sporangium; **E.** A zoospore; **FI.** Stages in the germination zoospore.

Sexual reproduction : May be isogamous, anisogamous and oogamous type. In isogamous type of reproduction the two fusing gametes will be morphologically similar.

In Anisogamous type the male gamete will be smaller than the female gamete.

In oogamous type the female will be nonmotile. The male and female gametes are produced on gametophytic plant.

The terminal cell of lateral branch let function as gametangial initial. It divides repeatedly by transverse and vertical divisions to form many cubical cells arranged in tiers. Each uninucleate cell of the tier metamorphoses into biflagelled pyriform gametes. In case of oogamy the female gamete will be non 'motile. The gametes are released from gametangium.

Fertilization : The female gamete released from gametangium settle down in about 5 minutes. Where as the male gametes remain active. The female gametes secrete a chemical *sirenine* which attracts male gametes as a result a large no of male gametes cluster around a female gamete. The male gametes attach to the female gamete by their long anterior flagella. This is known as clump formation.

After sometime one male gamete contracts its flagella and fuses with the female gamete to form *Zygospore*. After fusion the zygospore loses its attraction for male gametes.

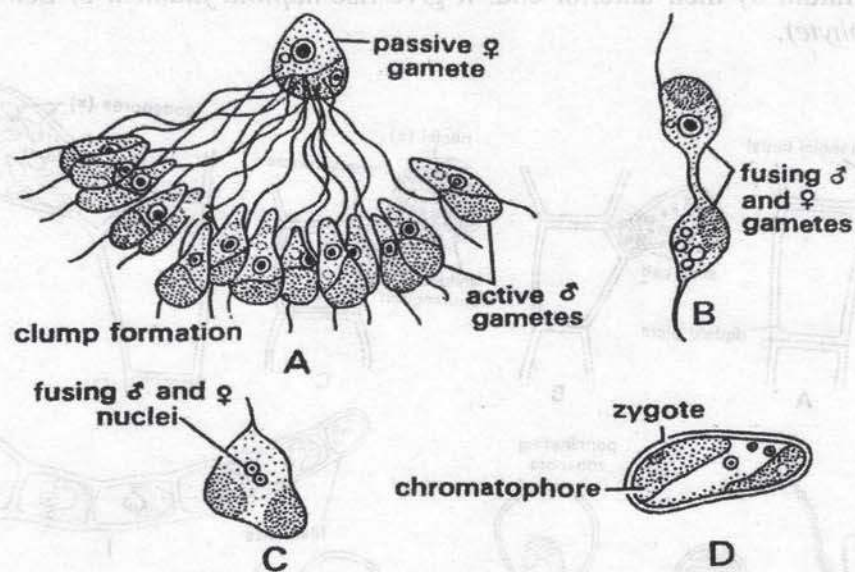


Fig 2.20 A-D. *Ectocarpus siliculosus*: A. Cluster of male gamete around a female gamete (clump formation); B-C. Fusion of male and female gametes; D. Zygote.

2.5.3 GERMINATION OF ZYGOSPORE

The diploid zygospore divide mitotically and give rise diploid plant of *Ectocarpus* which bears both unilocular and plurilocular sporangia.

The haploid and diploid plants are morphologically identical therefore, life cycle is isomarpic type.

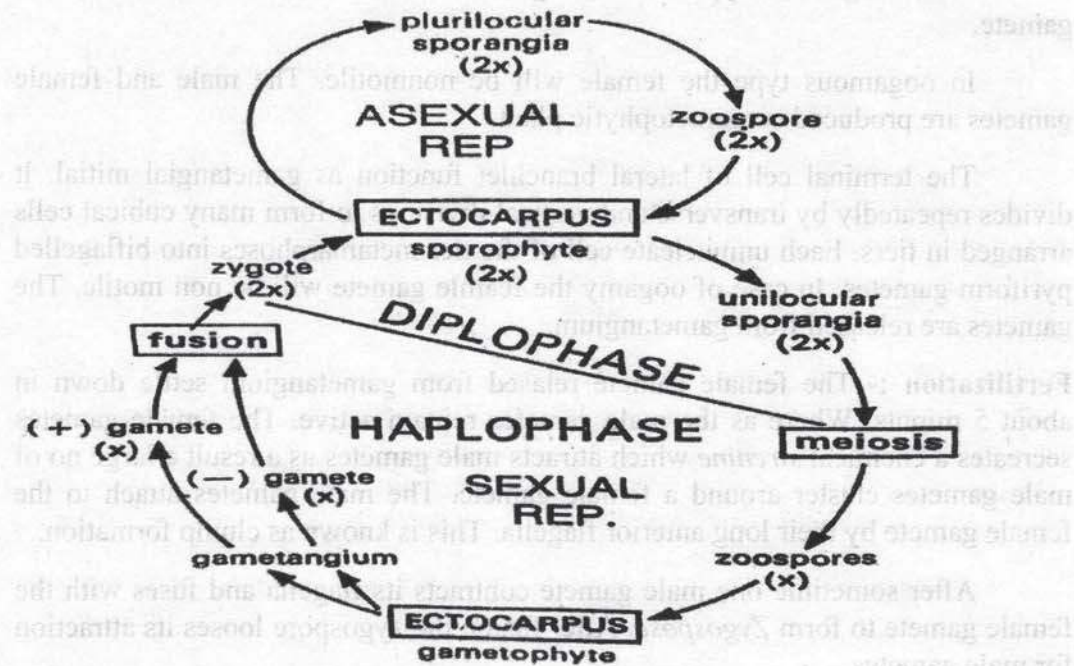


Fig.2.21. *Ectocarpus*: Schematic representation of the life-cycle

2.6 FUCUS (DIPLONTIC TYPE LIFE CYCLE)

Class- Phaeophyceae

Order- Fucales

Family- Fucaceae

Fucus Occurs attached to rocky substratum in the inter tidal belt of littoral zone. *Fucus* is not found in India. Species of *Fucus* occurs in cold water in the North Atlantic and Pacific Shores.

2.6.1 THALLUS STRUCTURE

Plant body is branched leathery, slimy, dark brown in colour. It is divided into holdfast, stipe and flattened frond. By means of hold fast plant remain attached to the substratum. The stipe is continuous in the frond in the form of midrib.

Air bladders are present in the upper part of the frond which provided buoyancy to the plant. Many small openings are present through out the surface of the thallus known as sterile conceptacle. At the tip of the frond are receptacle which has fertile conceptacles.

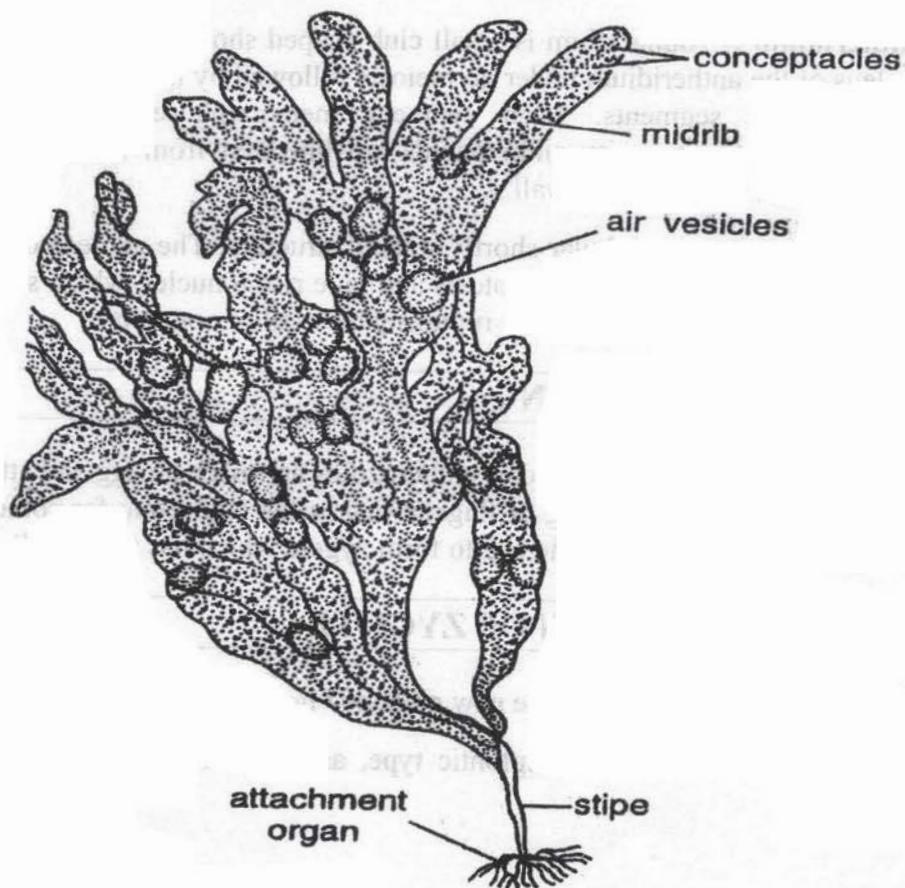


Fig. 2.22 *Fucus*: Thallus structure,

2.6.2 REPRODUCTION

It is of two types :

- (1) Vegetative reproduction
- (2) Sexual reproduction

(1) Vegetative reproduction :-

Sexual reproduction :- It is oogamous type. Male sex organ is antheridium and female sex organ is oogonium. The sexorgans are produced in flask shaped cavities called conceptacle born on receptacle.

Coceptacle :- The conceptacle develops from the superficial cell present on the receptacle. The superficial cell is large and prominent. It divides at a slower rate than the adjoining cell as a result the conceptacle initial is pushed at the base of the flask shaped cavity. The conceptacle initial divide by a transverse wall into an outer tongue cell and a basal cell. The basal cell give rise fertile layer from which antheridium and oogonium develops.

In monoceious species the male and female sex organs are found either in the same conceptacle or in different conceptacle present on the same plant. But in dioecious species male and female sex organs are found in different conceptacle on separate plant.

Antheridium :- Antheridium is small club shaped shortly stalked structure. The nucleus of the antheridium under go meiosis followed by mitosis and forms about 64 or more segments. Each segment metamorphoses into biflagellated antherozoids. On maturity antherozoids are liberated from the antheridium by gelatinization of antheridial wall.

Oogonium is globular shortly stalked structure. The nucleus of oogonium under go meiosis followed by motosis and give rise 8 nuclei, which serve as egg. The eggs are released in water by rupturing the wall of oogonium.

2.6.3 FERTILIZATION

It is external. A large no of antherozoids approach an egg and attaches to it by their flagella. The beating of flagella makes the egg rotate for sometime then one antherozoid fuses with the egg to form zygote which has thick wall.

2.6.4 GERMINATION OF ZYGOTE

On germination zygote give rise new plant of *Fucus*.

The life cycle of *Fucus* is diplontic type, as most of the part of life cycle is diploid.

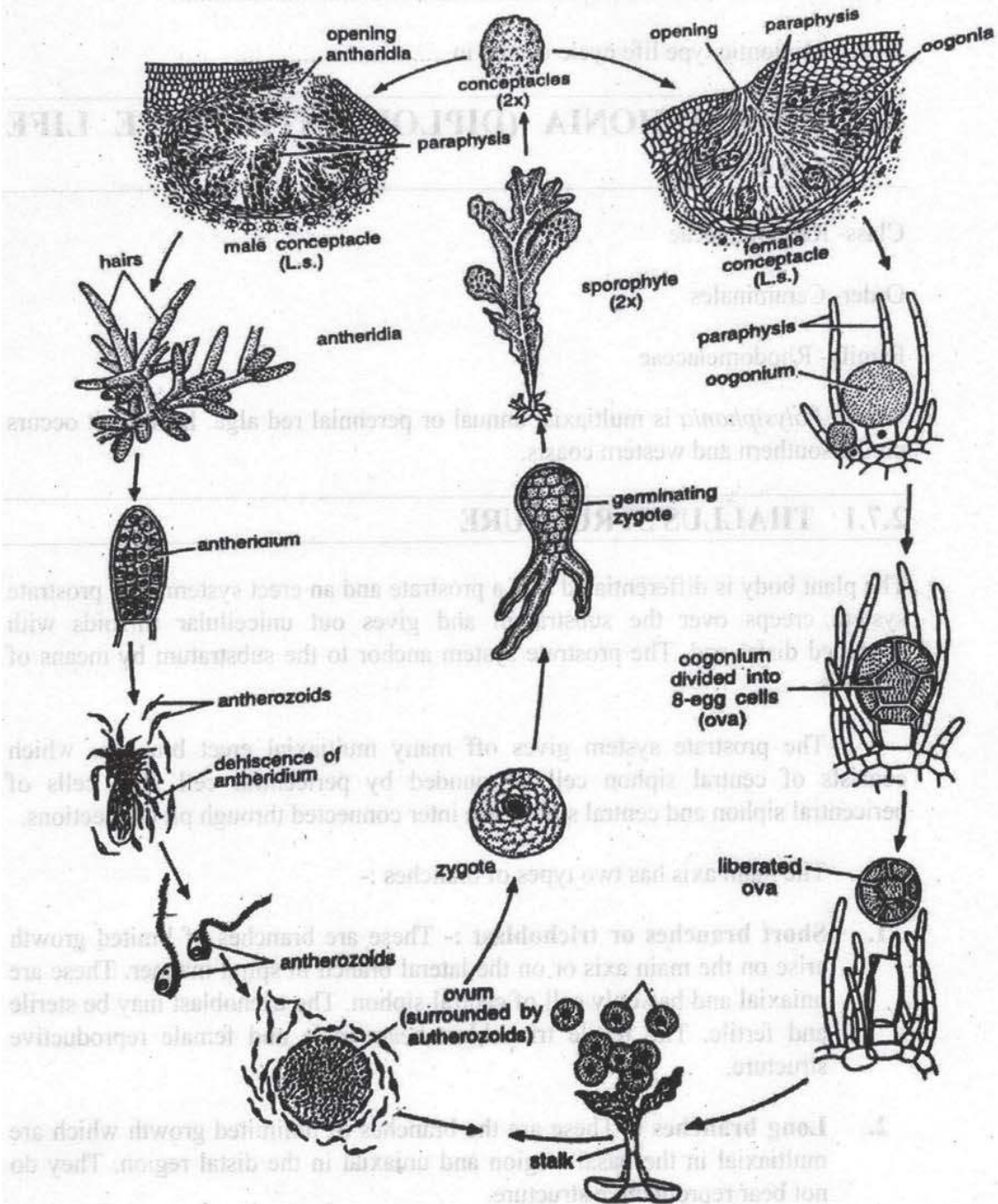


Fig. 2.23 *Fucus* : Life-cycle,

SAQ-3

- Clustering of a number of male gametes around a female gamete is known as
- The brown colour of *Fucus* and *Ectocarpus* is due to pigment.

(c) In *Fucus* and *Ectocarpus* fertilization is

(d) Diplontic type life cycle occurs in.....

2.7 POLYSIPHONIA (DIPLOBIONTIC TYPE LIFE CYCLE)

Class- Rhodophyceae

Order- Ceraminales

Family- Rhodomelaceae

Polysiphonia is multiaxial annual or perennial red alga. In India it occurs on the southern and western coasts.

2.7.1 THALLUS STRUCTURE

The plant body is differentiated into a prostrate and an erect system. The prostrate system creeps over the substratum and gives out unicellular rhizoids with branched distal end. The prostrate system anchor to the substratum by means of rhizoids.

The prostrate system gives off many multiaxial erect branches which consists of central siphon cell surrounded by pericentral cell. The cells of pericentral siphon and central siphon are inter connected through pit connections.

The main axis has two types of branches :-

- 1. Short branches or trichoblast :** These are branches of limited growth arise on the main axis or on the lateral branch in spiral manner. These are uniaxial and has only cell of central siphon. The trichoblast may be sterile and fertile. The fertile trichoblast bears male and female reproductive structure.
- 2. Long branches :** These are the branches of unlimited growth which are multiaxial in the basal region and uniaxial in the distal region. They do not bear reproductive structure.

Cell structure : The cell is elongated cylindrical uninucleated with perital discoid chromatophore which has no pyrenoid. The pigments are chlorophyll a, d, a, 13 carotens, r-phycoerythrin and r-phyocyanin. Cell wall has agar-agar and carageenan. Inside the cell wall is a nucleus 4 cytoplasm has reserve food is floridian starch and galactoside floridoside. Cellular organell are present in the cytoplasm.

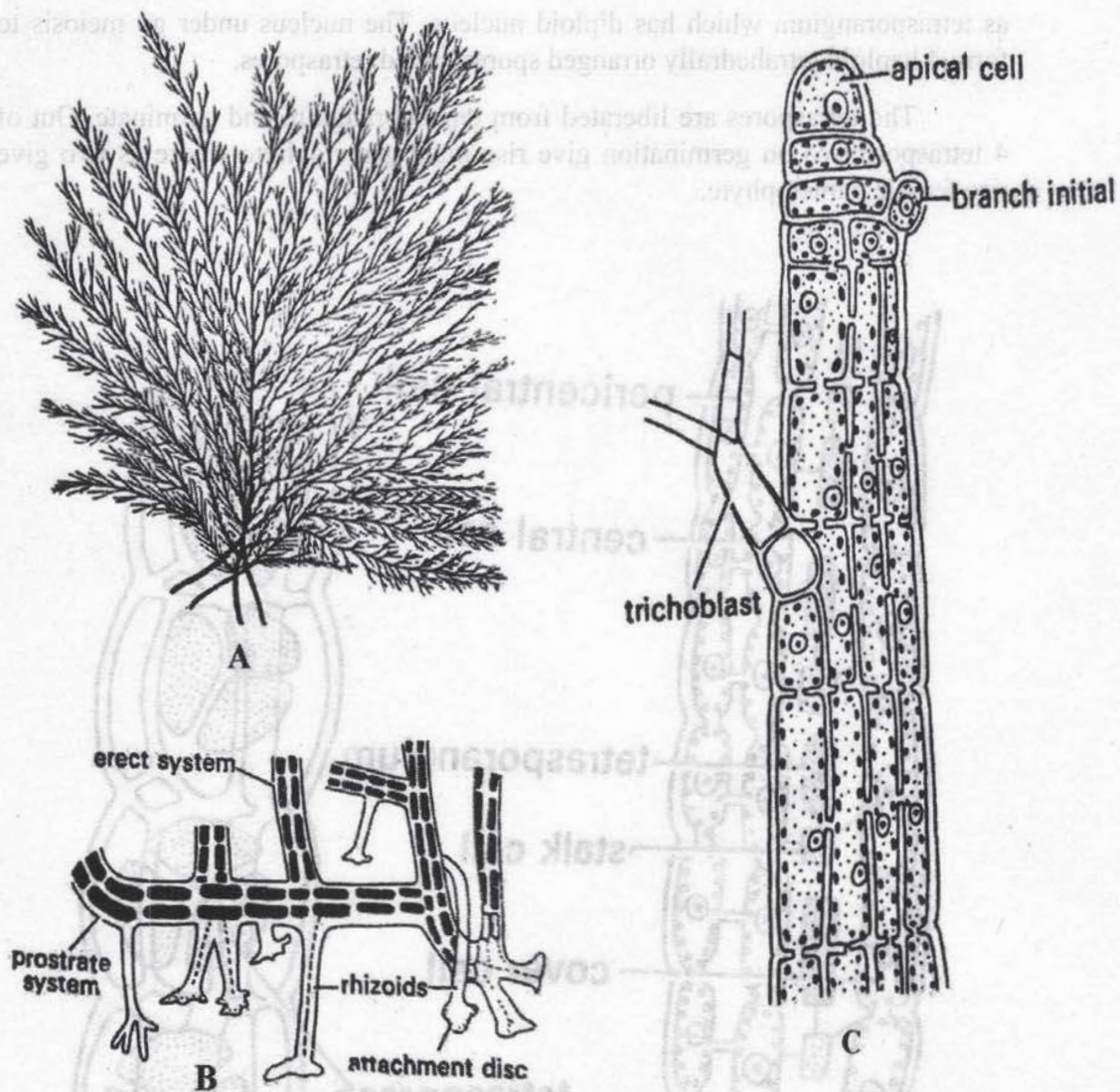


Fig. 2.24 (A,B,C). A. *Polysiphonia*; B. *Polysiphonia urceolata*: Prostrate and aerial system of filaments; C. *Polysiphonia*: Showing trichoblast

2.7.2 REPRODUCTION

It is of two types -

- (1) Asexual reproduction
- (2) Sexual reproduction

(1) Asexual reproduction :

It takes place by means of haploid nonmotile tetraspores produced in tetrasporangium present on diploid plant.

The pericentral cell which is smaller than other pericentral cell behaves as tetrasporangial initial. It divides to form a cover cell and an inner sporangial mother cell. The sporangial mother cell which again divides to form a lower stalk cell and an upper sporangial cell. The sporangial cell enlarges in size and function

as tetrasporangium which has diploid nucleus. The nucleus under go meiosis to form 4 haploid tetrahedrally orranged spores called tetraspores.

The tetraspores are liberated from tetrasporangium and germinate. Out of 4 tetraspore two on germination give rise male gametophyte where as two give rise female gametophyte.

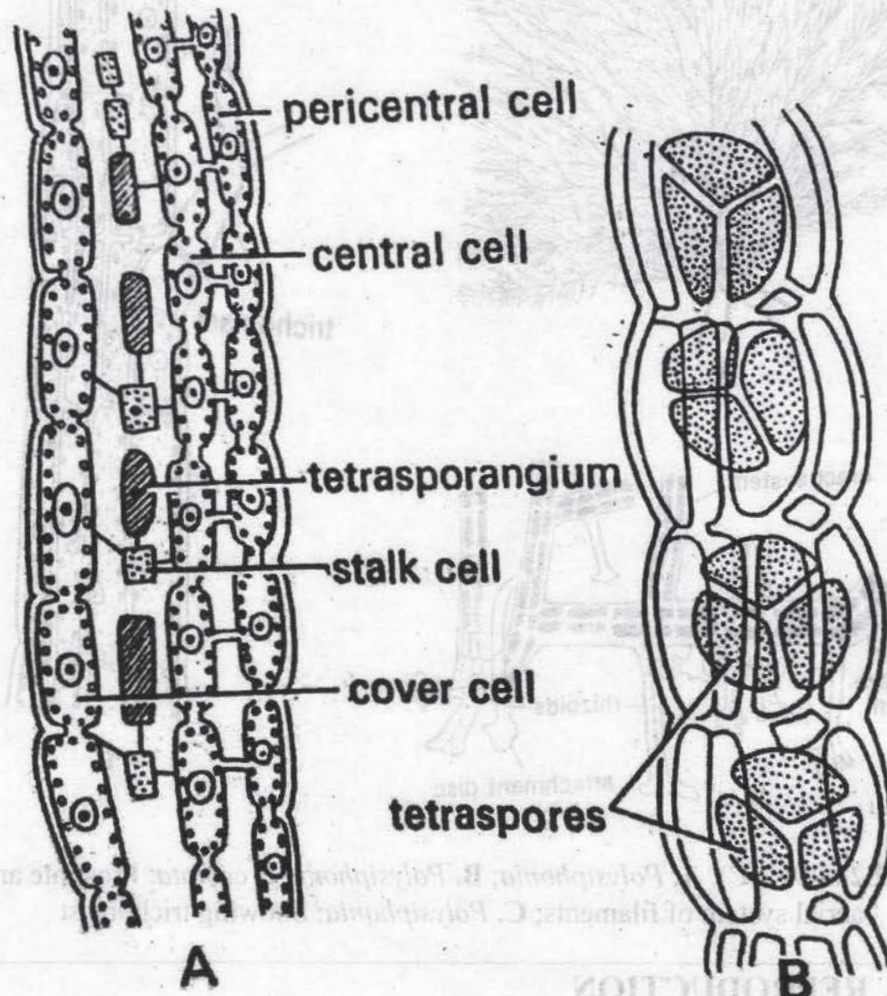


Fig. 2.25 A. Differentiation of tetrasporangium, B. Tetraspores.

- (2) **Sexual reproduction :-** It is oogamous type. Plant is dioecious male gametophyte bears male reproductive structure spermatangia and female gametophyte bears carpogonia.

Spermatangia:- Spermatangia are globose unicellular structure develops on the fertile trichoblast present on the male gametophyte. The pericentral cell of fertile trichoblast divide and form spermatangial mother cell. The spermatangial mother cell which divide to produce varying number of spermatangia. The spermatangia cluster and form a compact cone shaped structure. Each spermatangium has single non motile spermium. It is liberated through a narrow slit present at the tip of spermatangium.

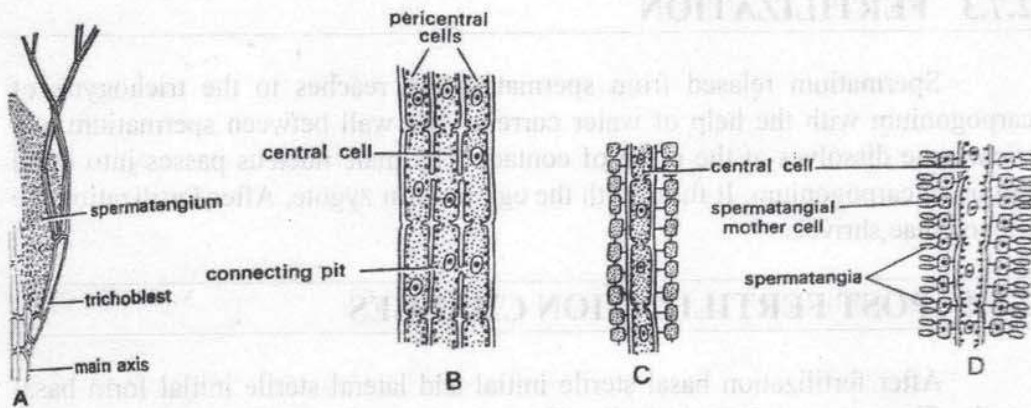


Fig 2.26 (A-D) *Polysiphonia*: Development of spermatangium; **A.** Trichoblast with spermatangium, **B-D.** Stages in the of development of spermatangium.

Carpogonium :- Carpogonium develops on fertile trichoblast present on female gametophyte. One of the pericentral cell of fertile trichoblast on the adaxial side function as a supporting cell. It divides transversely to form 2-5 celled carpogonial filament. The terminal cell of the filament becomes flask shaped and function as corpogonium. The carpogonium has a swollen base and a trichogone. The egg is present in the basal swollen part of carpogonium. The supporting cell cuts off a basal sterile initial (at the base) and lateral sterile initial (on the lateral side).

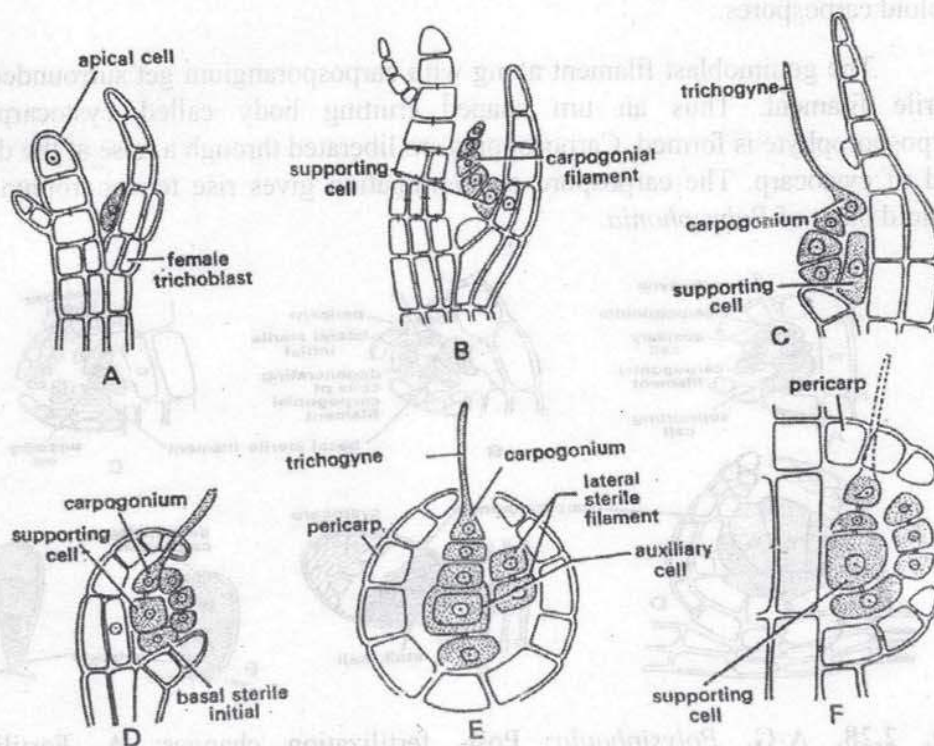


Fig. 2.27. A-F. *Polysiphonia*: Successive stages in the development of carpogonium; **A.** Differentiation of supporting cell. **B-C.** Development of carpogonial filament and formation of carpogonium, **D-E.** Formation of basal and lateral sterile cells, **F.** Defferentiation of auxillary cell.

2.7.3 FERTILIZATION

Spermium released from spermatangium reaches to the trichogyne of carpogonium with the help of water current. The wall between spermium and trichogyne dissolves at the place of contact. The male nucleus passes into basal region of carpogonium. It fuses with the egg to form zygote. After fertilization the trichogynae shrivels.

2.7.4 POST FERTILIZATION CHANGES

After fertilization basal sterile initial and lateral sterile initial form basal sterile filament and lateral sterile filament respectively. These filaments are nutritive in function. The supporting cell divides again to form an auxiliary cell. A tubular connection is established between auxiliary cell and carpogonium. The remaining cell of carpogonial filament present between carpogonium and supporting cell degenerates. The diploid nucleus of carpogonium divides mitotically and passes to auxiliary cell through pit connection. The carpogonium, auxiliary cell and supporting cell fuse together to form an irregular shaped large placental cell. The diploid nucleus present in placental cell undergo many mitotic divisions. A no of tubular out growths arise from the placental cell. A diploid nucleus passes into each out growth from the placental cell to form gonimoblast initial. The gonimoblast initial give rise gonimoblast filament. The terminal cell of each gonimoblast filament function as carposporangium and bears single diploid carpospores.

The gonimoblast filament along with carposporangium get surrounded by sterile filament. Thus an urn shaped fruiting body called cystocarp or carposporophyte is formed. Carpospores are liberated through a pore at the distal end of cystocarp. The carpospore on germination gives rise tetrasporophyte or diploid plant of *Polysiphonia*.

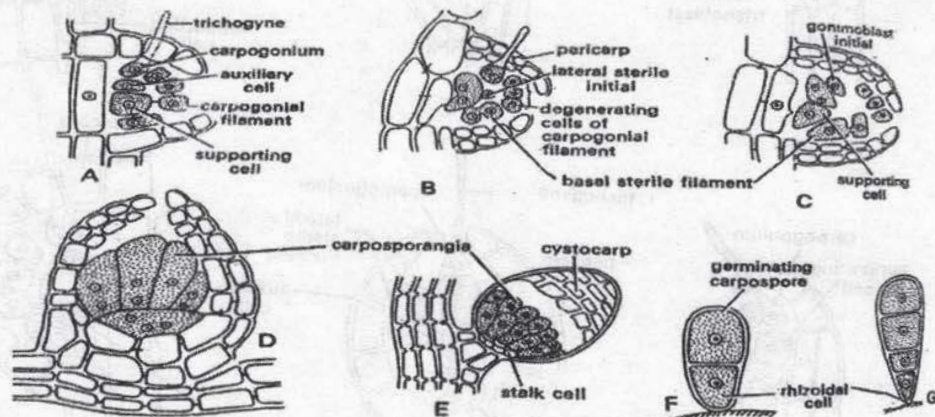


Fig. 2.28. A-G. *Polysiphonia*: Post-fertilization changes; A. Fertilized carpogonium (note the position of auxiliary cell) B. Division in diploid zygote of carpogonium, C. Development of gonimoblast initial, D. Carposporophyte with young carpospore, E. Mature carposporophyte (cystocarp), F-G. Germination of carpospore.

The life cycle of Polysiphonia is diplobiontic and triphasic. It has two diploid phases and one haploid phase.

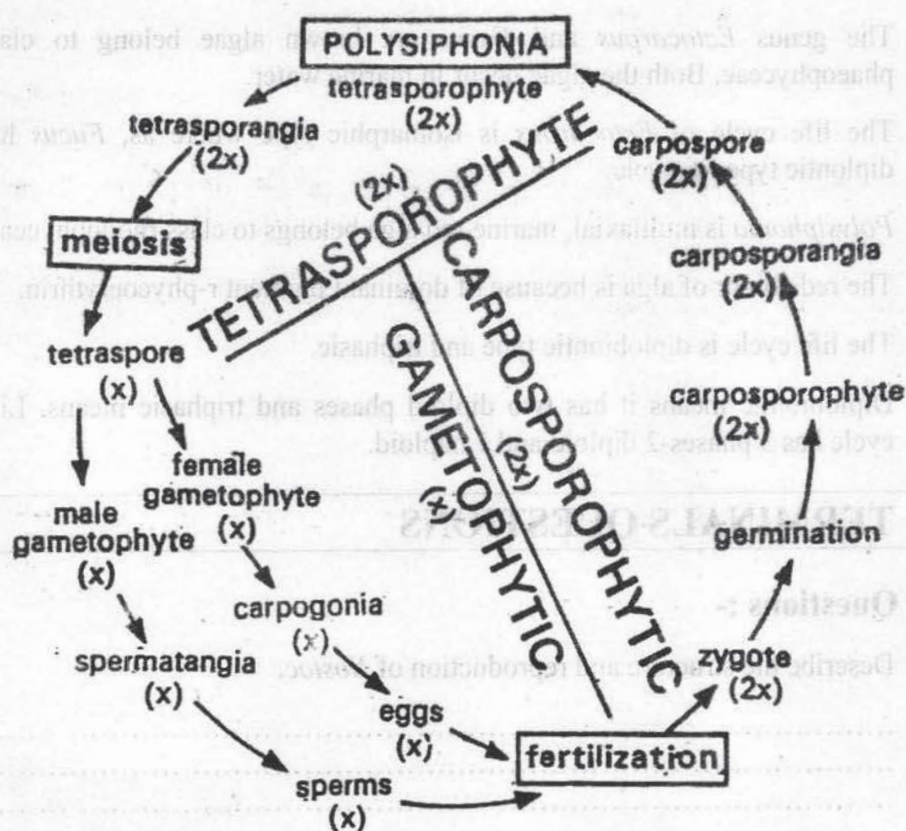


Fig. 2.29 *Polysiphonia*: Life-cycle (diagrammatic)

SAQ-4

- Pit connections occur in
- Polysiphonia* belongs to class
- Diplobiontic, triphasic life cycle occurs in
- In *Polysiphonia* are formed in asexual reproduction.

2.8 SUMMARY

- *Nostoc* is a blue-green alga of class cyanophyceae.
- The blue-green colour of Alga is due to dominant pigment c-phyococyanin.
- Special structure heterocyst occurs in *Nostoc* filament.
- Reproduction is by asexual methods only.
- *Chlamydomonas* and *volvox* are green algae belong to class chlorophyceae.
- The green colour of Alga is due to dominant pigments chlorophyll a and b.

- Sexual reproduction in algae starts from chlorophyceae and in genus *chlamydomonas* it occurs by isogamy, anisogamy and oogamy.
- The genus *volvox* is a coenobial alga.
- The genus *Ectocarpus* and *Fucus* are brown algae belong to class phaeophyceae. Both the algae occur in marine water.
- The life cycle of *Ectocarpus* is isomarpic type where as, *Fucus* has diplontic type lifecycle.
- *Polysiphonia* is multiaxial, marine red alga belongs to class rhodophyceae.
- The red colour of alga is because of dominant pigment r-phycoerythrin.
- The life cycle is diplobiontic type and triphasic.
- Diplobiontic means it has two diploid phases and triphasic means. Life cycle has 3 phases-2 diploid and 1 haploid.

2.9 TERMINALS QUESTIONS

Long Questions :-

1. Describe the structure and reproduction of *Nostoc*.
.....
.....
.....
.....
.....
2. Describe the sexual reproduction in *chlamydomonas* with the help of suitable diagram.
.....
.....
.....
.....
.....
3. Give an account of asexual and sexual reproduction in *Volvox*.
.....
.....
.....
.....
.....
4. Describe the life cycle of *Ectocarpus*.
.....
.....
.....
.....
.....

5. Describe the diplontic type of life cycle. (Life cycle of *Fucus*)

6. Describe sexual reproduction in *Polysiphonia*.

Short Questions :

1. Write short notes on -
 - (a) Asexual reproduction in *Polysiphonia*.
 - (b) Thallus structure of *Fucus*
 - (c) Plurilocular sporangia.
 - (d) Thallus structure of *Volvox*
 - (e) Heterocyst.

2.10 ANSWERS

SAQ-1.

- (a) Cyanophyceae (b) *Nostoc* (c) Prokaryotic (d) Cyanophycian
starch

SAQ-2

- (a) Chlorophyceae (b) Starch (c) *Volvox* (d) *Chlamydomonas*

SAQ-3

- (a) Clump formation (b) Fucoxanthin (c) External (d) *Fucus*

SAQ-4

(a) *Polysiphonia* (b) Rhodophyceae (c) *Polysiphonia* (d) Tetraspore

REFERENCE

1. A text book of botany by Singh, Pande & Jain.

UNIT-III ALGAE II

Structure :

- 3.1 Introduction
- 3.2 Origin and evolution of sex
 - 3.2.1 Organisation and Evolutionary Trends among Vegetative Structure / Thallus
 - 3.2.2 Evolutionary Trends among Reproductive Structures
- 3.3 Classification of Algae: Criteria for classification
 - 3.3.1 Fritsch's Classification
 - 3.3.2 G. M. Smith's Classification
 - 3.3.3 Papenfuss's Classification
 - 3.3.4 G.W. Prescott's Classification
- 3.4 Economic Importance of Algae
 - 3.4.1 Uses of Algae
 - 3.4.2 Harmful Algae
- 3.5 Habitats and distribution – Algae: Aquatic algae: Fresh water, Marine habitats, Special Habitats: Soil and sub aerial algae
 - 3.5.1 Hydrophytes (Aquatic Algae)
 - 3.5.2 Edaphophytes (Soil Algae)
 - 3.5.3 Aerophytes (Air Algae)
 - 3.5.4 Cryophytes
 - 3.5.5 Endophytes
 - 3.5.6 Endozoophytes
 - 3.5.7 Special Habitats
- 3.6 Summary
- 3.7 Terminal Questions
- 3.8 Answers

3.1 INTRODUCTION

Linnaeus in 1753-54 first time used the term 'Algae, derived from Latin word Alga i.e. sea weeds. The study of algae is called algology or phycology (phykos, a Greek word i.e. sea weeds). According to *Fritsch* (1935) the term alga includes all holophytic organisms that fail to reach the higher level of differentiation characteristics of higher plants. G. M. Smith defines algae as simple autotrophic plants.

Algae are generally aquatic, primitive and less evolved, chlorophyll bearing i.e. autotrophic plants with simple plant body. These plants are thalloid i.e. not differentiated into root, stem and leaves.

SAQ.1:

- The study of algae is known as.....
- The term Algae is Latin word that refers to..
- The vegetative structure of algae is mainlyand their mode of nutrition is

3.2 ORIGIN AND EVOLUTION OF SEX

Blue green alga is considered as most primitive group among all. These are prokaryotic and resembles with bacteria. The scientists believed that algae and fungi both are showing parallel evolution. The algae are autotrophic whereas fungi are heterotrophic in nature.

3.2.1 ORGANISATION AND EVOLUTIONARY TRENDS AMONG VEGETATIVE STRUCTURE / THALLU

There is a wide range of thallus structure found in algae i.e. from unicellular motile, and non motile to heterotrichous branched filamentous forms via colonial simple filamentous forms.

a. Unicellular Forms:

- **Non motile-** Unicellular non motile forms belonging to blue green algae considered to be most primitive algae e.g. *Gleocapsa* etc. bearing single celled thallus without motile phase. These are prokaryotic cells like bacterial cells.
- **Motile-** Unicellular motile forms are considered advanced than unicellular motile forms. These plants are prokaryotic and possess flagella e.g. *Euglena* is unflagellate and *Chlamydomonas* is biflagellate. *Chlamydomonas* is eukaryotic, unicellular, motile primitive algae.

b. Multicellular Colonial Forms:

The aggregation of cells evolved into the colonial forms i.e. palmelloid colony and coenobium type of colonies. When definite number of cells arranged in a definite manner is called coenobium e.g. *Volvox*, a motile coenobium and *Hydrodictyon*, non motile coenobium.

- **Multicellular Motile Colony.** The evolutionary line of motile or flagellated forms begins with aggregation of *Chlamydomonas* like cells known as **Volvocine line** which is as follows. The series started from:

Ohmansiella (with 4 *Chlamydomonas* like cells in a row), next is *Gonium* (with 4-16 cells arranged plate like), then *Pandorina* (16-32 celled usually 16 celled), *Eudorina* (16-64 celled usually 32 celled), and finally to highly evolved *Volvox* (1500-2000 celled).

- **Multicellular Non Motile Colony.** The non motile colonial forms may have developed from unicellular non motile forms and evolved parallel to the multicellular motile forms from same ancestral stock. This evolutionary line is called **Chlorococcine line**. It is believed that flagella must be lost during the course of evolution and became developed into non motile forms e.g. *Chlorella* and *Chlorococcum*. When such type of cells aggregated into definite or indefinite manner developed into free floating colonies e.g. *Scenedesmus* (with 4 cells), *Pediastrum*, *Hydrodictyon* (water net coenobium with many cells).

c. Filamentous Forms:

It is widely accepted that filamentous forms have been evolved by unicellular motile forms like *Chlamydomonas* like cells. Firstly there is a loss of flagella during evolution than frequent cell division occurred in one plane give rise to **simple unbranched filamentous forms** e.g. *Ulothrix*, *Spirogyra*, *Oedogonium* etc. and among prokaryotic forms like *Oscillatoria*, *Lyngbya* etc. and bead like cells of *Nostoc*. **False or Pseudo branching** is seen in *Scytonema*. The simple filaments further evolved into branched filamentous forms by the cell division in other planes give rise to **simple branched** and **heterotrichous branched filamentous forms** e.g. *Ectocarpus*, *Batrachospermum*, *Polysiphonia* etc. The **plate like** algal body like *Ulva* might have been evolved by cell division in two planes.

d. Massive Multicellular Forms:

Most of Phaeophyceae (brown algae) is showing most evolved and highly specialised structure. Some of these forms are macroscopic frond like structure e.g. *Sargassum*, *Laminaria*, *Macrocystis* etc. There are some largest sea weeds like *Macrocystis pyrifera* and Giant kelp like *Laminaria* etc. have advanced structure having external and internal differentiation.

3.2.2 EVOLUTIONARY TRENDS AMONG REPRODUCTIVE STRUCTURES

The sexual reproduction which involves fusion of two different gametes including plasmogamy and karyogamy is a major phenomenon for reproduction and variation among all life forms. But among algae in case of blue green algae sexual reproduction is not reported, they multiply only by the vegetative and asexual means of reproduction.

In general on the basis of nature, structure and the mode of fusion of gametes in different genera of algae may be categorised following three types;

i. Isogamy ii. Anisogamy iii. Oogamy

i. **Isogamy:** When the fusion occurs between two morphologically and physiologically similar types of gametes. These gametes are usually motile, flagellated e.g. *Ulothrix*, *Chlamydomonas* and sometimes non motile. Both gametes are mostly monoecious and sometimes dioecious. These gametes can be distinguished only by (+) and (-) strains. It has also been observed that all gametes do not fuse randomly, the fusion occurs only in between the gametes belonging to different strains to develop zygote. The similar strains of gametes never fuse.

ii. **Heterogamy or Anisogamy:** When the both fusing gametes can be distinguished as male and female gametes.

a. **Physiological Anisogamy:** There are some algae in which both gametes are morphologically similar but they can be differentiated only on the basis of their activity i.e. physiologically different called as **physiological anisogamy**. It is considered as next evolutionary step after isogamy. In such type of cases both gametes are identical in their shape and size but physiologically one is active referred as male and another is passive act as female. Both gametes come in contact at their anterior end. After contact they withdraw their flagella and the wall at the point of contact dissolves. The male nucleus is transferred into female where fusion occurs and zygote develops e.g. *Spirogyra*, *Ectocarpus* etc.

b. **Morphological Anisogamy:** It is considered to be the next evolutionary step after physiological anisogamy. The fusing gametes are differentiated by their activity as well as morphologically by having their uneven size. The smaller gametes are more active and act as male gamete, which migrates towards female gamete which is larger and passive e.g. *Chlamydomonas*, *Pandorina* etc. The male and female gametes are produced in male and female gametangia respectively. The male gamete moves and come in contact with female gamete.

iii. **Oogamy:** It is advanced type of sexual reproduction i.e. next to the morphological anisogamy. The primitive type of oogamy is reported in *Chlamydomonas coccifera*, *Eudorina* etc. after anisogamy.

Oogamous forms usually develop sex organs in the organisms like male reproductive structure; antheridium and female reproductive structure; oogonium. The female gametes are non motile and larger in size. It also stores food material to nourish the zygote and developing embryo after fertilization. In the advanced forms of oogamy; the female gamete i.e. only single **ovum** is retained inside the oogonium. On the other hand male gametes are smaller, motile i.e. flagellated. They are produced in larger number inside the antheridia and are active; known as **sperms**. Oogamy is usually found in filamentous forms and not in unicellular forms e.g. *Oedogonium*, *Vaucheria*, *Chara* etc. In advanced type of oogamy fusion occurs inside oogonium.

The members of rhodophyceae (red algae) exhibit highly specialised type of oogamous reproduction. Here motile stages are entirely absent. The male gametes are non motile known as **spermatia**. It is small in size and are transported towards the female reproductive structure i.e. **carpogonium** through the water currents. The male nucleus is discharged from spermatia into trichogyne. The trichogyne is a flask shaped tubular hair like structure helps to receive the male nucleus and passed towards female nucleus which is present at the base, where both nuclei fuse to form diploid nucleus and developing into zygote. After discharging the nucleus the spermatia gets empty this later on shrivels off or degenerated.

SAQ.2:

-is a unicellular motile alga.
- An example of heterotrichous branched filamentous form is.....
- The gaint sea weeds belonging to.....
- is known as primitive type of sexual reproduction.

3.3 CLASSIFICATION OF ALGAE: CRITERIA FOR CLASSIFICATION

19th century was considered as golden age of classification. Algae have been classified by many algologists in various ways. Some of the salient classifications are listed below.

Harvey (1836) first time classified algae into three groups: 1. Chlorospermae 2. Melanospermae 3. Rhodospermae.

Engler and Prantl (1932) proposed another widely accepted classification in their publication 'Syllabus der pflanzen familien'. According to them fungi have been evolved from algae, therefore both groups were mixed and then of classified.

West (1916) classified algae on the basis of flagella and their nature:

1. Isokontae (flagella equal in size)
2. Heterokontae (flagella unequal in size)
3. Stephanokontae (flagella crowned)
4. Akontae (flagella absent)

Later on Pascher (1931) divided algae into eight divisions as follows:

1. Chrysophyta 2. Phaeophyta 3. Pyrrophyta 4. Euglenophyta
5. Chlorophyta 6. Charophyta 7. Rhodophyta 8. Cyanophyta

Tilden (1933) first time classified algae on the basis of pigmentation, reserve food materials etc. After Pascher's classification she proposed her classification which has 5 classes i.e.:

1. Chlorophyceae 2. Myxophyceae 3. Rhodophyceae 4. Phaeophyceae
5. Chrysophyceae

F.E.Fritsch (1935) proposed a phylogenetic classification of algae which is widely accepted till today, though there are several other classifications given by various algologists. His classification was published in his book in 2 volumes entitled, '*Structure and Reproduction of Algae*'. **M.O.P.Iyengar** 'Father of Indian Algology' has also accepted and followed his classification. Key points of **Fritsch's** classification of algae are as follows:

- It is based on interrelationships, affinities and phylogeny among various groups of algae.
- It supports the classification given by **Pascher** and **Tilden**.
- Classification was based on five main characteristics i.e.
 1. Pigments 2. Reserve food Materials 3. Structure 4. Reproduction
 5. Occurrence
- He considered algae as one group equivalent to a division and has divided all living forms of this group into 11 classes.
- Each class has given its distinguishing above mentioned five characteristics.

3.3.1 FRITSCH'S CLASSIFICATION

Class I: Chlorophyceae (Green Algae)

- a. **Pigments:** The chief pigments are chl-a, chl-b and two yellow pigments (Carotenoids). The chromatophores are grass green in colour
- b. **Reserve Food material or Photosynthetic Product:** Starch.
- c. **Structure:** The structure ranges between unicellular motile or non-motile to heterotrichous filamentous forms. Cell wall consists of cellulose. Pyrenoids usually surrounded by starch sheath. Motile cells have 2-4 equal similar type of flagella.
- d. **Reproduction:** Sexual reproduction ranges from isogamous to advanced oogamous type.
- e. **Occurrence:** Mostly fresh water rarely marine sometimes terrestrial forms.

e.g. *Chlamydomonas*, *Chlorella*, *Chara*, *Oedogonium*, *Hydrodictyon*, *Volvox* etc.

Class II: Xanthophyceae (Yellow-Green Algae)

- a. **Pigments:** The chief pigments are chl-a and chl-e, β -carotene yellow xanthophyll pigments. The chromatophores are yellow green in colour.
- b. **Reserve Food material or Photosynthetic Product:** Oil.
- c. **Structure:** The structure ranges between unicellular motile to simple filamentous forms. Cell wall made up of pectic compounds and composed of two equal or unequal pieces with overlapping edges. Pyrenoids absent. Motile cells with unequal flagella.
- d. **Reproduction:** Sexual reproduction is rare and always isogamous.
- e. **Occurrence:** Mostly fresh water rarely marine.

e.g. *Vaucheria*, *Choramoeba*, *Tribonema*, *Botrydium*, *Heterothrix* etc.

Class III: Chrysophyceae (Brown or Orange Algae)

- a. **Pigments:** The chief pigments are chl-a and Phycochrysin as accessory pigments. The chromatophores are brown or orange in colour.
- b. **Reserve Food material or Photosynthetic Product:** Fat and Leucosin.
- c. **Structure:** The structure ranges between unicellular motile to branched filamentous forms. Cells usually possess one or two parietal chromatophores. Motile cells with unequal flagella attached anteriorly.
- d. **Reproduction:** Sexual reproduction rarely occurs and is always isogamous.
- e. **Occurrence:** Mostly in cold fresh water rarely marine.

e.g. *Phaeothamnion* etc.

Class IV: Bacillariophyceae (Yellow or Golden Brown Algae)

- a. **Pigments:** The chief pigment is chl-a as generally found in all algae but the accessory pigments are not fixed. The chromatophores are yellow or golden in colour.
- b. **Reserve Food material or Photosynthetic Product:** Fat and Volutin.
- c. **Structure:** These are unicellular or colonial forms. Cell wall is made up of silica and pectic substances, makes cell wall ornamented. Each cell has two or more pieces.
- d. **Reproduction:** These are diploid. It exhibits special type of reproduction which occurs among the two different protoplasts.
- e. **Occurrence:** Found everywhere such as fresh water, marine, soil and terrestrial habitat.

e.g. *Pinnularia*, *Asterionella*, *Navicula*, *Nitzschia*, *Melosira*, *Synendra* *Gomphonema* etc.

Class V: Cryptophyceae (Nearly Brown Algae)

- a. **Pigments:** The pigments are chl-a along with various diverse pigments. The chromatophores are parietal and have different shades of brown colour.
- b. **Reserve Food material or Photosynthetic Product:** Solid Carbohydrates and sometimes starch.
- c. **Structure:** Mostly motile advanced type of coccoid having unequal flagella.
- d. **Reproduction:** Isogamous type.
- e. **Occurrence:** Both fresh water and marine habitat.
e.g. *Cryptomonas* etc.

Class VI: Dinophyceae (Dark Yellow or Brown Algae)

- a. **Pigments:** The pigments are chl-a along with various diverse special pigments. The chromatophores are discoid, numerous and have different shades as dark yellow, brown.
- b. **Reserve Food material or Photosynthetic Product:** Starch and oil.
- c. **Structure:** Mostly motile advanced type of coccoid having unequal flagella.
- d. **Reproduction:** Sexual reproduction very rare and if present is isogamous type only.
- e. **Occurrence:** Both fresh water and marine habitat.
e.g. *Gymnodinium* etc.

Class VII: Chloromonadineae (Bright Green Algae)

- a. **Pigments:** Chl-a with large amount of xanthophyll pigments. The chromatophores are numerous and discoid.
- b. **Reserve Food material or Photosynthetic Product:** Oil.
- c. **Structure:** Motile having two unequal flagella.
- d. **Reproduction:** Sexual reproduction if present is Isogamous type.
- e. **Occurrence:** Fresh water only.
e.g. *Trentonia*.

Class VIII: Eugleninae (Pure Green Algae)

- a. **Pigments:** The chromatophores are green in colour and several in number.
- b. **Reserve Food material or Photosynthetic Product:** Polysaccharide and paramylon.

- c. **Structure:** Unicellular motile with one or two flagella with a large prominent nucleus and a complex vacuolar system. Flagella arise from the base of invagination at anterior side.
 - d. **Reproduction:** Usually sexual reproduction not known and if it is present is isogamous type.
 - e. **Occurrence:** All forms are fresh water habitat.
- e.g. *Euglena*, *Phacus* etc.

Class IX: Phaeophyceae (Brown Algae)

- a. **Pigments:** The pigments are chl-a, chl-c with brown, yellow fucoxanthin pigments. The chromatophores are parietal and have different shades of brown colour.
 - b. **Reserve Food material or Photosynthetic Product:** Alcohols (manitol) polysaccharide (laminarian) and fats.
 - c. **Structure:** Simple filamentous to heterotrichous branched, parenchymatous forms. Some plants are very gaint sized with external and internal differentiation. Many cells possess characteristic fucosan vesicles.
 - d. **Reproduction:** Sexual reproduction ranges from isogamous to oogamous type. Motile gametes may possess two lateral dissimilar flagella.
 - e. **Occurrence:** Rarely fresh water, mostly marine habitat.
- e.g. *Fucus*, *Ectocarpus*, *Sargassum*, *Dictyota*, *Laminaria* etc.

Class X: Rhodophyceae (Red Algae)

- a. **Pigments:** The pigments are chl-a with blue phycocyanin-r and red phycoerythrin-r pigments. The chromatophores are red in colour.
 - b. **Reserve Food material or Photosynthetic Product:** Floridean starch and polysaccharides similar to starch.
 - c. **Structure:** Simple filamentous to branched, parenchymatous complex forms.
 - d. **Reproduction:** Sexual reproduction is advanced oogamous type. Motile stages completely absent. A special types of spores produced after sexual reproduction i.e. Carpospores.
 - e. **Occurrence:** Rarely fresh water, mostly marine habitat.
- e.g. *Batrachospermum*, *Polysiphonia*, *Porphyra*, *Asparigopsis*, *Gelidium* etc.

Class XI: Myxophyceae or Cyanophyceae (Blue-green Algae)

- a. **Pigments:** The pigments are chl-a with carotene, blue phycocyanin-c and red phycoerythrin-c pigments. The ratio of blue phycocyanin-c and red phycoerythrin-c exhibit colour variation. The chromatophores are blue green in colour.

- b. **Reserve Food material or Photosynthetic Product:** Sugar and glycogen.
 - c. **Structure:** Prokaryotic group of algae with incipient nucleus, no proper chromatophores and pigments hence now shifted to cyanobacteria. Simple unbranched filamentous forms. Sometimes showing pseudobranching e.g. *Scytonema*. No motile phase.
 - d. **Reproduction:** Sexual reproduction is entirely absent.
 - e. **Occurrence:** Mostly fresh water habitat.
- e.g. *Nostoc*, *Anabaena*, *Oscillatoria*, *Spirulina*, *Lyngbya* etc.
- Later on the majority of phycologists separated class Myxophyceae or Cyanophyceae (blue green algae) from algae and placed it as separate division because of various specific characteristics which are not found in rest of the algal classes.

3.3.2 G. M. SMITH'S CLASSIFICATION

G.M. Smith (1955) classified algae on the basis of phylogenetic interrelationships and divided it into 7 divisions having 13 classes as follows:

Division I	Chlorophyta	Class 1.	Chlorophyceae
		Class 2.	Charophyceae
Division II	Euglenophyta	Class 3.	Euglenophyceae
Division III	Pyrrophyta	Class 4.	Desmophyceae
		Class 5.	Dinophyceae
Division IV	Chrysophyta	Class 6.	Chrysophyceae
		Class 7.	Xanthophyceae
		Class 8.	Bacillariophyceae
Division V.	Phaeophyta	Class 9.	Isogeneratae
		Class 10.	Heterogeneratae

		Class 11.	Cyclospora
Division VI	Cyanophyta	Class 12.	Cyanophyceae
Division VII	Rhodophyta	Class 13.	Rhodophyceae

3.3.3 PAPENFUSS'S CLASSIFICATION

The term 'phyco' (phykos=Algae) was proposed by **G.F.Papenfuss (1955)** and introduced phyla or division to distinguish from other groups of plants.

Alexopolous C.J. and **Bold H.C.** (1976) proposed their classification on the basis of idea given by **Papenfuss** having 11 divisions by inserting word 'phyco' which is as follows:

- I-Division:* Cyanophycophyta
- II-Division:* Chlorophycophyta
- III-Division:* Charophycophyta
- IV-Division:* Euglenophycophyta
- V-Division:* Xanthophycophyta
- VI-Division:* Chrysophycophyta
- VII-Division:* Bacillariophycophyta
- VIII-Division:* Phaeophycophyta
- IX-Division:* Pyrrophyphyta
- X-Division:* Cryptophycophyta
- XI-Division:* Rhodophycophyta

- This classification was not accepted by many phycologists because of having long and complicated nomenclature.

In 1967 **Ian Morris** divided algae into 10 divisions with suffix 'phyta' as follows:

- I-Division:* Cyanophyta
- II-Division:* Chlorophyta
- III-Division:* Xanthophyta
- IV-Division:* Chrysophyta
- V-Division:* Bacillariophyta
- VI-Division:* Pyrrophyta

VII-Division: Cryptophyta

VIII-Division: Euglenophyta

IX-Division: Phaeophycophyta

X-Division: Rhodophyta

3.3.4 G.W. PRESCOTT'S CLASSIFICATION

The classification of algae on the basis of their pigments, colour, reserve food materials, flagella, cell wall, nucleus and life cycle was given by **G.W. Prescott** (1968-69). **Prescott** divided algae by considering above characteristics into 9 phylums as follows:

Phylum I	Chlorophyta (Green Algae)
Class 1.	Chlorophyceae
Class 2.	Charophyceae
Phylum II	Euglenophyta
Class 1.	Euglenophyceae
Phylum III	Chrysophyta (Yellow green Algae)
Class 1.	Chrysophyceae
Class 2.	Bacillariophyceae
Class 3.	Heterokontae (Xanthophyceae)
Phylum IV	Pyrrophyta
Class 1.	Desmokontae (Desmophyceae)
Class 2.	Dinokontae (Dinophyceae)
Phylum V	Phaeophyta (Brown Algae)
Sub Phylum	Phaeosporae
Class 1.	Isogeneratae

Class 2.	Heterogeneratae
Sub Phylum	Cyclospora
Phylum VI	Rhodophyta (Red Algae)
Sub Phylum	Bangiodeae
Sub Phylum	Florideae
Phylum VII	Cyanophyta (Blue green Algae)
Sub Phylum	Coceogoneae
Sub Phylum	Hormogoneae
Phylum VIII	Cryptophyta (Blue and red flagellates)
Phylum IX	Chloromonadophyta

SAQ.3:

- All members of have prokaryotic cells resembling with bacteria.
- The father of modern Algology in India is.....
- Fritsch F.E. proposed his classification on the basis ofbasic characteristics of algae and divided algae into classes.

3.4 ECONOMIC IMPORTANCE OF ALGAE

Algae are an important group of autotrophic plants having a great economic significance, mostly found in aquatic habitats. To study about economic importance of algae, useful and harmful aspects of it must be considered separately which are as follows.

3.4.1 USES OF ALGAE

- As Food:** Sea weeds are used as food by the people residing near coastal areas since ancient times. It has been investigated by the researchers from all over the world that nutritional value of per unit area field of algae is more than any continental crops. Marine algae are commonly known as sea weeds and some of them are edible. Many algae are also cultivated in large scale in China and Japan. It is reported that Japan is depending its

25% diet on sea weeds. The cultivation of *Chlorella* a green algae, in Japan is very common, to use as food supplement. There are certain other algae which are used as various forms of food such as *Porphyra*, *Alaria*, *Ulva*, *Chondrus*, *Nostoc*, *Spirogyra*, *Sargassum*, *Caulerpa*, *Oedogonium* etc. These are rich source of proteins and several vitamins.

Porphyra is a marine red algae growing in shallow sea, is a good source of vitamin B, C and Niacin and also contains 30-35% protein and 40-45% carbohydrate, which enhances its nutritional value.

Chlorella is also very nutritious. Several species of this genus are found rich in carbohydrates, lipid and proteins i.e. containing approximately 30% carbohydrate, proteins and 15% lipids.

Chondrus crispus is used to obtain gelatinous carbohydrate, used in pudding.

Laminaria saccharina of Phaeophyceae i.e. brown algae is used as to obtain food known as 'Kombu', having 75% carbohydrates.

Some other brown algae are commonly used in ice-cream and jelly e.g. *Gelidium*, *Corneum* and *Gelidium*.

2. **As Fodder:** Brown algae are rich in iodine and carotene. Some brown algae are also used as fodder for cattle worldwide e.g. *Ascophyllum*, *Fucus*, *Laminaria*, *Sargassum*, *Macrocystis* etc. used as fodder for sheep chiefly in Scotland and Ireland which helps in enhancing the production of milk by the cattle as well as egg laying capacity of poultry.
3. **As Medicine and Antibiotics Production:** *Chlorella*, a green algae is well known for production of a useful antibiotic Chlorellin. There are some other members of algae used for their medicinal values and production of other antibiotics like *Cladophora*, *Lyngbya*, *Polysiphonia*, *Laminaria* etc. Charales are found to have larvicidal property hence used to kill mosquito larva.
4. **As Sources of Vitamins, Minerals etc.:** *Chlorella* is a unicellular edible alga, it is rich in various vitamins like thiamine, pyridoxin, biotin, vitamin B₁₂, lipoic acid etc. *Alaria valida* is rich in soda potash, iodine and alginic acid and also yields ammonium, tar and charcoal etc. Sea weeds are mostly found rich in having minerals like copper, iron, zinc, cobalt, vanadium, manganese, boron and chromium etc. Thus sea weeds are used as supplement in stock feed and natural fertilizers. Laminariales or kelps are the richest sources of iodine. They also contain soda, potash and alginic acid.
5. **Used in Sewage Disposal and Water Purification:** Sewage is the domestic and industrial waste effluent which contains organic and inorganic materials either as soluble or as suspended impurities. Some of the like *Chlamydomonas*, *Chlorella*, *Euglena* etc. help the sewage decomposing bacteria by providing oxygen which is emitted during photosynthesis. Members of Charales are very useful in clearing water.

6. **Industrial Uses:** Algae are used in different industries as sources of various commercial products such as Agar-agar, Alginic acid, Carragenin, Diatomite etc.

Agar-agar, a gelly like substance is obtained from the cell wall of *Gelidium*, *Gracillaria*, *Hypnea*, *Chondrus*, *Sarconema* etc. It is used in preparation of ice creams, puddings, jellies etc. It is a complex polysaccharides also used as stabilizer and emulsifier agents in leather, pharmaceutical and cosmetic industries. In microbiological labs it is widely used to prepare culture media due to the convertible property of sol and gel easily.

Algenic acid is isolated from cell wall of *Laminaria*, *Sargassum*, *Ascophyllum* etc. It is used in preparation of soups, sauces cream, ice-cream etc. This acid is also used in synthetic creams, polishes, emulsion etc.

Carragenin, a polysaccharide extracted from cell wall of *Chondrus crispus*, used in manufacturing some medicines, cosmetics, shoe polish etc.

Diatomite is extracted from diatoms, with siliceous cell wall making the soil porous used as filter for oil filtrations and solvent cleaning agents.

7. **Agricultural Applications:** Blue green algae play an important role in nitrogen fixation mainly found in paddy fields e.g. *Nostoc*, *Anabaena*, *Tolypothrix* etc. also enhances its productivity. Brown and red algae possess nitrogen, phosphorus and also rich in potassium, so they may be used as organic manures. Marine algae are also useful in farms adjacent to coastal areas as fertilizers.
8. **Other Uses:** Current researches in United States reveal that *Chlorella* and *Synechoccus* may be used in space travel and nuclear submarines as regenerating oxygen and food water recycling.
9. **Ecological Significance:** Now-a-days in Japan efforts are made to develop 'Farm Algae' to enhance the production of oxygen and reducing air pollution during the course of photosynthesis on one hand as well as production of food on the other hand. Algae are the chief producer of any ecosystem and in food chain.

3.4.2 HARMFUL ALGAE

1. **Parasitic Algae:** Few algae lives as parasite on plant e.g. *Cephaleuros*, a chlorophycean algae causes red rust disease on tea and coffee plants, causing a great loss in production.
2. **Toxic Algae:** Some aquatic algae causing mortality among fishes and other domestic animals by producing toxic substances in water such as species of *Anabaena*, *Microcystis*, *Gymnodinium* etc. these algae may cause gastric trouble and respiratory disorder either consumed by those humans and animals consuming such fishes.

Species of *Lygbia*, *Chlorella* etc. may cause skin diseases through water which may be used by animals or human beings for bathing and washing clothes and utensils.

- 3 **Water Pollution:** *Anabaena*, *Microcystis*, etc. may decompose potable water while growing in tanks and causing bad odour and taste. The growth of these algae producing toxic substances which may affect nervous system and brain muscles. It also interfere water purification treatment. It has also been reported that species of *Anacystis* and *Chaetophora* erosion of water pipes and boilers etc.

SAQ.4:

- a. The species of are found rich in carbohydrates, lipid and proteins thus edible.
- b. A gelly like substance , is obtained from the cell wall of *Gelidium*,
- c.a chlorophycean algae causes red rust disease on tea and coffee plants.

3.5 HABITATS AND DISTRIBUTION - ALGAE: AQUATIC ALGAE: FRESH WATER, MARINE HABITATS, SPECIAL HABITATS: SOIL AND SUB AERIAL ALGAE

Algae are widely distributed under wide range of habitats. Generally it prefers to grow in aquatic habitat but it is found everywhere i.e. cosmopolitan. Some of them also found to grow in a very special habitat such as at extreme high temperature as well as very low temperature, fresh water and marine, free floating and as benthos, as autotrophic and some of the members grow as parasites and as in symbiotic association. Thus the scientists categorised six major habitats of algae as follows:

- | | | |
|---------------------|-----------------|------------------|
| 1. Hydrophytes | 2. Edaphophytes | 3. Aerophytes |
| 4. Cryophytes | 5. Endophytes | 6. Endozoophytes |
| 7. Special habitats | | |

3.5 .1 HYDROPHYTES (AQUATIC ALGAE)

Aquatic plants may be categorising into two habitats i.e.

- Fresh water habitats e.g. like ponds lakes, springs, rivers etc.
- Marine habitats e.g. sea or saline water.

Benthophytes or Benthos These plants are found attached with the substratum beneath the water eg. *Cladophora*, *Chara*, *Enteromorpha*, *Fucus*, *Sargassum* etc.

- a. **Epactiphytes** Algae growing along the shores of lakes and ponds.

- b. **Thermophytes-** Growing in hot or thermal water upto 85°C temperature. Majority of thermal algae are members of Myxophyceae, Bacillariophyceae, some of Chlorophyceae (Zygnemaceae) etc. Algae have been classified according to the range of temperature as follows:
- Hypothermae: Below 18°C
 - Hilarothermae: Between 18°C-30°C
 - Euthermiae: 30°C-50°C
 - Acrothermae: 50°C-70°C
 - Hyperthermae: above 70°C
- c. **Planktophytes-** Floating on the surface of water e.g. *Chlorella*, *Scenedesmus*, *Spirulina*, *Oscillatoria*, *Hydrodictyon*, *Chlamydomonas*, *Volvox* etc. These phytoplankton may be *Euplanktophytes* i.e. true floating algae and *Tycophytes* i.e. becomes floating due to accident.
- d. **Halophytes-** Some algae are found in saline water having higher percentage of salts such as *Dunaliella* and *Stphenophora* etc. and some species of *Chlamydomonas* and *Ulothrix* like *C.ehernbergii* and *U.flacca* are also found in such habitat.
- e. **Epiphytes-** Some algae are found attached on other plants grow as epiphytes. They require support from the other plants and prepare their own food e.g. *Bulbochaete*, *Oedogonium* *Ulothrix* etc.
- f. **Epizoophytes-** Grow on animals like snails etc.

3.5.2 EDAPHOPHYTES (SOIL ALGAE)

The terrestrial algae which is growing in soil, i.e. called edaphophytes. The 'edophon' was proposed by **France** (1913). The soil algae are *Vaucheria*, *Zygnema*, *Botrychium*, *Nostoc*, *Oscillatoria* etc. These soil algae may be of following types of soil habitats:

- **Saphophytes:** Found on surface of soil.
- **Cryptophytes:** Found below the soil i.e. from few inches to few feet under the soil.
- **Friedmann and Ocampo** (1976) have categorised as follows:
- **Endedaphic:** Living inside the soil.
- **Epidaphic:** Lives on the surface of soil.
- **Hypolithic:** Found on the surface of stones on soil.

3.5.3 AEROPHYTES (AIR ALGAE)

These types of algae usually need to grow on various types of substratum like leaves of other plants, barks of trees, on animals, on rocks etc where adequate

moisture is available to provide favourable conditions for their growth. There are following types of algal habitat found to occur:

- **Epiphylliphytes:** Growing on leaves.
- **Epiphloeophytes:** Algae which grows on barks of tree.
- **Epizoophytes:** Growing on animals.
- **Lithophytes:** Grow on or in rocks.

3.5.4 CRYOPHYTES

The algae present in the Polar Regions, growing on ice and snow at very low temperature are known as cryophytes. Certain algae gives attractive colour to snow or ice e.g. *Chlamydomonas yellowstonensis* gives yellow green colour to snow in yellow stone National Park, *Haematococcus nivalis* causes red snow balls in alpine regions, *Chlamydomonas nivalis* develops red coloured haematochrome in cell walls of akinetes and develop red snow, *Raphidonema* imparting green colour to European mountains etc.

3.5.5 ENDOPHYTES

Some algae grow inside the tissues of the other plants e.g. *Nostoc* grows inside the thalli of *Anthoceros* (Bryophyte), *Anabaena* grows inside the *Azolla* (Pteridophyta).

3.5.6 ENDOZOOPHYTES

When the algae grow inside the body of animals are known as endozoophytes e.g. *Chlorella* (Chlorophyceae) grown inside the tissues of *Hydra* and sponges.

3.5.7 SPECIAL HABITATS

- **Symbiotic Algae:** Lichen is well known example of symbiotic association of algae and fungi. *Nostoc* and *Anabaena* are found as symbiotic association with the coralloid roots of *Cycas* as phycorrizal association, these algae are also found in the thallus of *Anthoceros* and *Azolla* plants.

3.3 PARASITIC ALGAE

Some algae are parasitic and causing diseases on plants e.g. Red rust disease on leaves of tea caused by *Cephleuros virescens* and red rust on coffee leaves caused by *C. coffeae*. The other example of parasitic algae are *Ceratocolex*, *Choreonema* etc.

SAQ.5:

- a. Algae growing along the shores of lakes and ponds are called as.....

- b. The algae present in the Polar Regions, growing on ice and snow at very low temperature are known as.....
- c.and.....are found as symbiotic association with the coralloid roots of *Cycas* as phycorrhizal association,

3.6 SUMMARY

- Algae are simple, aquatic, primitive and less evolved autotrophic thalloid plants.
- The term 'Algae, derived from Latin word Alga i.e. sea weeds.
- The study of algae is called algology or phycology (phykos, a Greek word i.e. sea weeds).
- The organisation of thallus structure found ranges from unicellular motile, and non motile to heterotrichous branched filamentous and upto gaint thalloid forms via colonial simple filamentous forms.
- Sexual reproduction ranges between Isogamous to oogamous type.
- Classification of Algae was basically focused on five main characteristics i.e. Pigments, Reserve food Materials, Thallus Structure, Types of Reproduction and their Occurrence.
- Algae are economically very important having many beneficial aspects as well as some harmful aspects too. It may be used as food, fodder, as medicine and antibiotics production, as sources of vitamins, minernals etc., used in sewage disposal and water purification, in industries, agriculture and also have ecological significance.
- Sometimes some algae are harmful to humans and environment such as those which are parasitic, toxic and as water pollutant.
- Algae are mostly aquatic i.e. fresh water, marine habitats. These may be categorised on the basis of habitats such as: hydrophytes (aquatic), edaphophytes (soil algae), aerophytes (in air), cryophytes (in ice or snow), thermal (at high temperature), endophyte, endozoophytes and some special habitats as parasite and symbiotic association.

3.7 TERMINAL QUESTIONS

OBJECTIVE TYPE QUESTIONS :

Q.1. The term 'Algae' was first introduced by:

- | | |
|---------------|-------------------|
| a. Linnaeus | b. F.E. Fristch |
| c. G.M. Smith | d. G. W. Prescott |

Q.2. The 'Father of modern Algology of India is:

- | | |
|-----------------|------------------|
| a. F.E. Fristch | b. M.O.P.Iyengar |
|-----------------|------------------|

- c. Gregor Johann Mendel d. Hugo de Vries
- Q.3. When male and female gametes are morphologically similar in a sexual reproduction is called:
- a. Oogamous b. Anisogamous
- c. Heterogamous d. Isogamous
- Q.4. A unicellular non motile edible green alga is:
- a. *Volvox* b. *Chlamydomonas*
- c. *Chlorella* d. *Nostoc*
- Q.5. The heterotrichous branched filamentous form is found in:
- a. *Batrachospermum* b. *Hydrodictyon*
- c. *Oscillatoria* d. *Scytonema*
- Q.6. Red rust disease of tea and coffee is caused by:
- a. *Polysiphonia* b. *Sargassum*
- c. *Cephaleuros* d. None of these
- Q.7. Agar-agar is obtained from the cell wall of...
- a. *Agaricus* b. *Gelidium*
- c. *Spirogyra* d. *Spirulina*
- Q.8. There are prokaryotic cells in the members of Class.....
- a. Xanthophyceae b. Myxophyceae
- c. Phaeophyceae d. Chlorophyceae
- Q.9. The example of non motile coenobium is:
- a. *Nostoc* b. *Anabaena*
- c. *Hydrodictyon* d. None of these
- Q.10. The red snow or ice in alpine zone is due to the presence of...
- a. *Haematococcus* b. *Batrachospermum*
- c. Diatoms d. *Fucus*
- Q.11. The sexual reproduction is not reported in
- a. Cyanophyta b. Chlorophyta
- c. Xanthophyta d. Rhodophyta

SHORT ANSWER TYPE QUESTIONS:

- Q.1. Distinguish between the following:

- a. Hydrophytic and Cryophytic algal forms
- b. Morphological and Physiological Anisogamy
- c. Pigmentaion of Chlorophyceae and Xanthophyceae
- d. Motile and non-motile colony

Q.2 Write briefly about the role of algae in agriculture.

Q.3 What is a Heterotrichous habit? Illustrate your answer with examples.

Q.4 What are the characteristic features of Phaeophyceae.

Q.5 What is coenobium, explain it with examples?

LONG ANSWER TYPE QUESTIONS:

Q1 Write about the economic value of algae.

.....

.....

.....

.....

.....

.....

Q.2 Give an account of classification proposed by F.E. Fristch and G.M. Smith and also focus the basis of their classification.

.....

.....

.....

.....

.....

.....

Q.3 Describe the range of vegetative structures of algae with suitable examples.

.....

.....

.....

.....

.....

.....

Q.4 Give an account of origin and evolution of sexual reproduction among algae.

.....

.....

.....

.....

.....

.....

Q.5 What do you know about the occurrence and habitat of algae?

.....
.....
.....
.....
.....

3.8 ANSWER

Objective type questions:

1.a 2.b 3.d 4.c 5.a 6.c 7.b 8.b 9.c 10.a 11.a

SAQ.1:

a. Algology or Phycology b. Sea weeds c. Thallus & autotrophic

SAQ.2:

a. *Chlamydomonas* b. *Batrachospermum* c. Phaeophyceae (Brown Algae)
d. Isogamous

SAQ.3:

a. Myxophyceae or Cyanophyceae b. M.O.P.Iyengar c. 5 (Five) and 11 (Eleven)

SAQ.4:

a. *Chlorella* b. Agar agar c. *Cephaleuros*

SAQ.5:

a. Epactiphytes b. Cryophytes c. *Nostoc*, *Anabaena*

UNIT-IV FUNGI

Structure :

4.1 Introduction

Objective

4.2 General Habitats, Habits, Morphology, Nutrition and Reproduction in Fungi

4.3 Life cycle of *Phytophthora*

4.5 Life cycle of *Rhizopus*

4.6 Life cycle of *Puccinia*

4.7 Life cycle of *Cercospora*

4.8 Economic importance of fungi

4.9 Summary

4.10 Terminal Questions

4.11 Answers

4.1 INTRODUCTION

The branch of botany that deals with the study of fungi is called mycology. The scientist who is concerned with fungi is called mycologist. Fungus (pl. fungi) is a Latin word means mushroom (Gr Mycos = Mushroom, Logos means study of). The fungi (singular, fungus) include several thousand species of eukaryotic, spore bearing organisms that obtain simple organic compounds by absorption. After animals and plants, fungi are the third largest kingdom of eukaryotic organisms. They are more related to animals than the plant kingdom. For many people fungi are less important than plants and animals in terms of role they play. However, due to their ability to convert organic dead matter into mineral resources, they play an important role in the global substance flow.

Thus, the fungi are non green (chlorophyll absent) nucleated thalloid plants whose cell has definite cell wall made up of chitin (fungal cellulose). The reserve food of fungus is glycogen and oil drops.

Objective :

After studying this unit you will be able to know :-

- Habitats, habits, morphology, nutrition and reproduction in fungi.
- Life cycle of *Phytophthora*

- Life cycle of *Rhizopus*
- Life cycle of *Puccinia*
- Life cycle of *Cercospora* and economic importance of fungi.

4.2 GENERAL HABITATS AND HABITS, MORPHOLOGY, NUTRITION AND REPRODUCTION IN FUNGI

4.2.1 HABITATS

Fungi are found every where on earth where organic material (living or dead) is present. Terrestrial fungi occur in humus soil. Saprophytic fungi grow on dead organic matter. Parasitic fungi grow on living organism (Host). The primitive fungi eg. *Saprolegnia* grow in water. The fungi grow on food stuffs such as bread, jams, pickles, fruits, vegetables etc. They also grow on clothes, leather, paper etc. Most of the fungi flourish in moist, dark and warm conditions.

4.2.2 HABITS

Fungi exhibit heterotrophic mode of nutrition. They either live on dead organic matter or on living organism. Some of them live in symbiotic association with other plants or as mycorrhiza. Thus, on the basis of mode of nutrition they are classified as follows :

- (i) **Obligate Parasite :** They are true parasite which grow only upon suitable living host. eg. *Puccinia*.
- (ii) **Obligate Saprophyte :** They are saprophyte which grow only upon dead organic matter eg. *Rhizopus*.
- (iii) **Facultative parasite :** Normally fungus is saprophyte in their habit but now and then it becomes parasite. eg. Species of *Fusarium*.
- (iv) **Facultative Saprophyte :** Normally fungus is parasite in their habit but now and then it becomes saprophyte eg. *Phytophthora*.

Some fungi grow in symbiotic association with other organisms. eg. Lichen where algal and fungal partners benefit each other. Mycorrhiza is another symbiotic association between fungus and roots of higher plants.

4.2.3 MORPHOLOGY/VEGETATIVE PHASE

- It may be unicellular single celled and becomes reproductive unit at the time of reproduction (Holocarpic) eg. yeast.
- It may be filamentous. Majority of fungi are filamentous. The filament is known as hypha. Collection of hypha is called mycelium. The hypha may be branched, aseptate. Coenocytic (multinucleated) eg. *Phytophthora*.

- The hypha may be branched, septate, uninucleate or binucleate. The binucleated hypha is known as dikaryon eg. *Puccinia*. The dikaryon may be homokaryon or heterokaryon. In homokaryon the two nuclei have same genetic constitution where as, in heterokaryon the two nuclei have different genetic constitution.
- The septum between two cell is not complete. It has a pore through which cytoplasm and nucleus of one cell passes into the other. The pore may be simple pore or complex pore (dolipore).
- When the septum has simply a pore it is called simple pore.
- In complex pore or Dolipore, the pore has barrel shaped cells with open end surrounded by cap like thickenings called parenthosome. Such type of pore occurs in *Puccinia*.

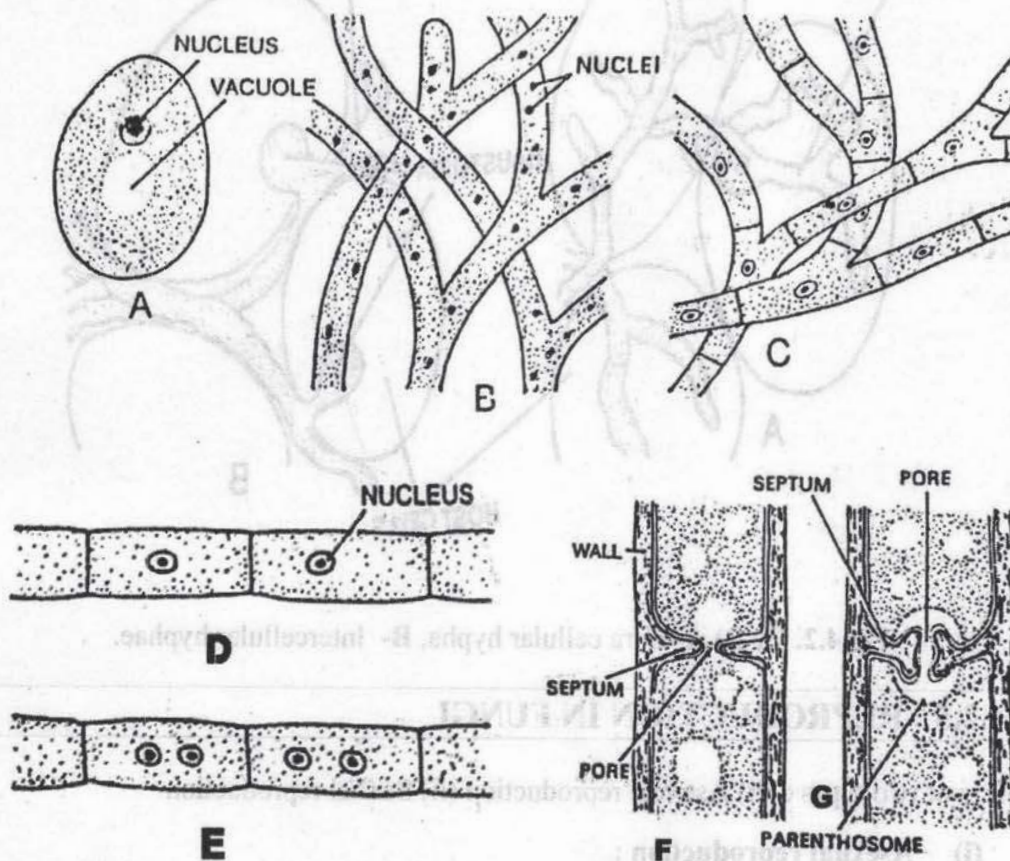


Fig.4.1. (A-G) Different forms of fungal thalli. A. Unicellular form; B. Coenocytic hyphae; C. Multicellular septate hyphae; D. Hypha with uninucleate cells; E. Dikaryotic hypha; F. Septum with simple pore; G. Septum with dolipore.

4.2.4 NUTRITION

Fungi lack chlorophyll therefore, they are incapable of synthesizing their own food. Thus, they are heterotrophic in their mode of nutrition. Fungi need both organic and inorganic food for their normal growth and metabolism. According to their method of obtaining food, the fungi may be saprophyte or parasite. The

saprophytes absorb organic nutrient directly through the cell membrane from the substratum. The parasite absorbs organic molecules as nutrients through the cell walls from the tissue of the host. In saprophytic fungi, the hyphae come in contact with substratum and secrete enzymes. The complex food materials of substratum are converted to soluble ones by enzymes and then absorbed by direct diffusion through the hyphal walls. The parasites take their food from the host. Their hyphae may be intercellular (ramify in the intercellular space between the host cell) or intracellular (penetrate into the host cells). The intercellular hyphae come in direct contact with host protoplasm therefore, obtain food by direct diffusion. The intercellular hyphae absorb food by specialized feeding organ called haustorium which penetrates into the host cell.

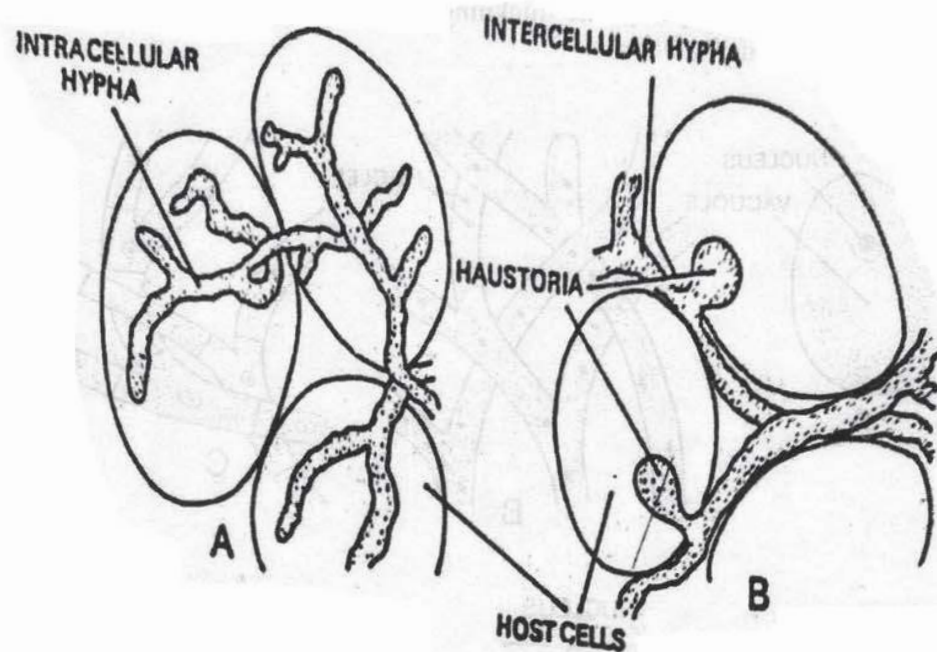


Fig.4.2. (A-B) A- Intra cellular hypha, B- Intercellular hyphae.

4.2.5 REPRODUCTION IN FUNGI

It is of two types :- (i) Asexual reproduction (ii) Sexual reproduction

(i) Asexual reproduction :

- (1) **By fragmentation :-** Fungal mycelium get broken into small fragments accidentally or through external force. Each fragment develops into a new individual.
- (2) **By Budding :-** The parent cell produces one or more bud like protuberance which get detached and grow into a new individual.

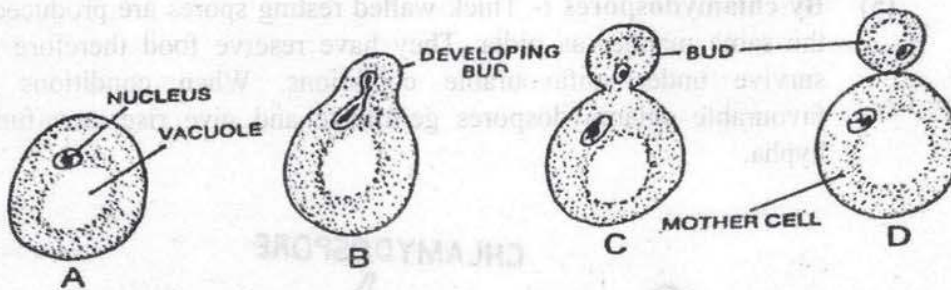


Fig.4.3. (A-D) Budding.

- (3) **By Fission :-** The parent cell splits into two equal halves by a constriction and formation of wall. Each half develops into a new cell.

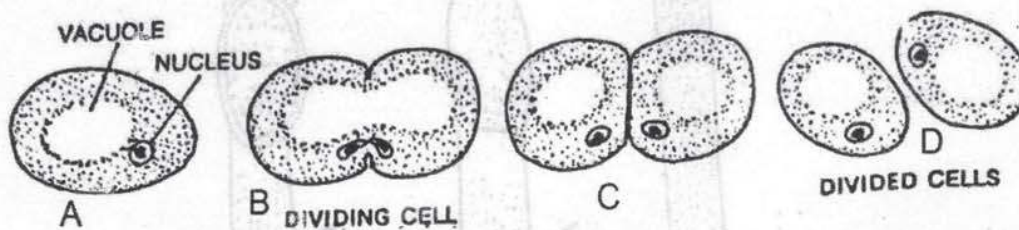


Fig.4.4. (A-D) Fission.

- (4) **By oidia :-** The hypha breaks into small pieces which behaves like spores called oidia. These are thin walled spores which do not have reserve food and germinates immediately after liberation. They can not survive under unfavourable conditions.

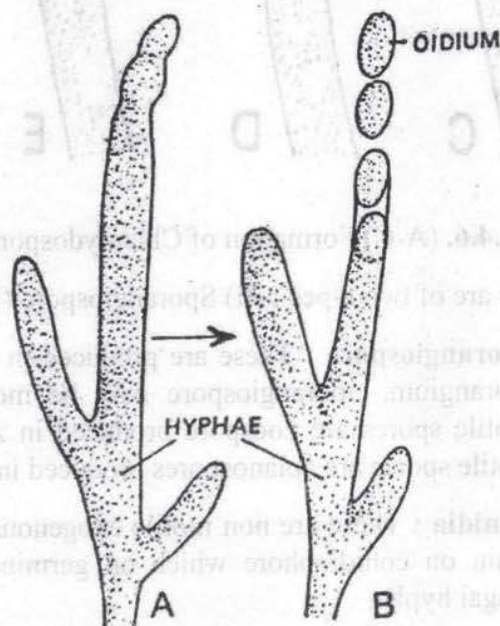


Fig. 4.5. (A-B) Oidia formation.

- (5) **By chlamydospores :-** Thick walled resting spores are produced in the same manner as oidia. They have reserve food therefore can survive under unfavourable conditions. When conditions are favourable chlamydospores germinate and give rise new fungal hypha.

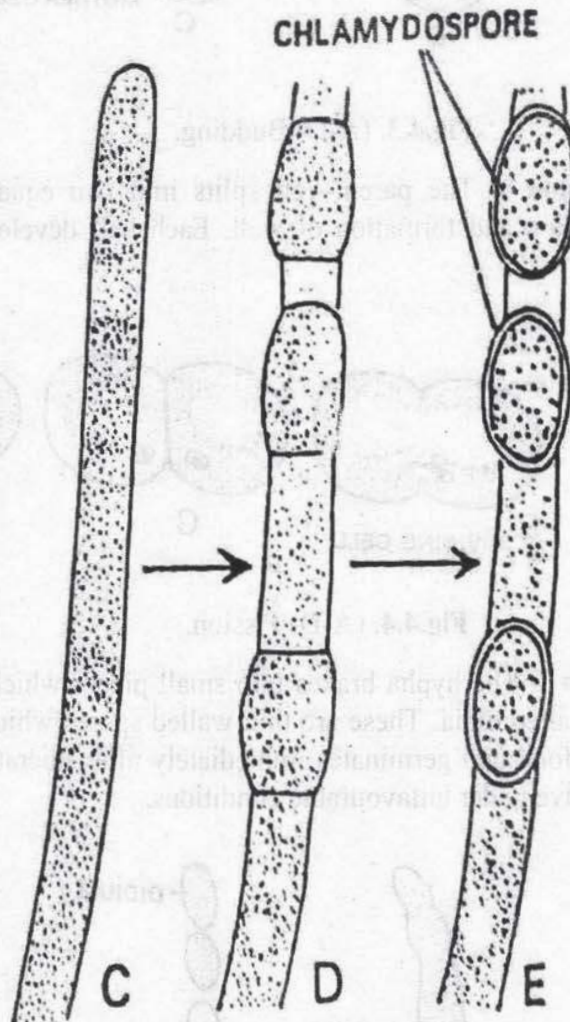


Fig.4.6. (A-C) Formation of Chlamydospores.

- (6) **Spores :** are of two types :- (i) Sporangiospore (ii) Conidia
- (i) **Sporangiospore :** These are produced in sac like body called sporangium. Sporangiospore may be motile or non motile. Motile spores are zoospore produced in zoosporangium. Non motile spores are aplanospores produced in aplanosporangium.
 - (ii) **Conidia :** These are non motile exogenous spores produced in chain on conidiophore which on germination give rise new fungal hypha.

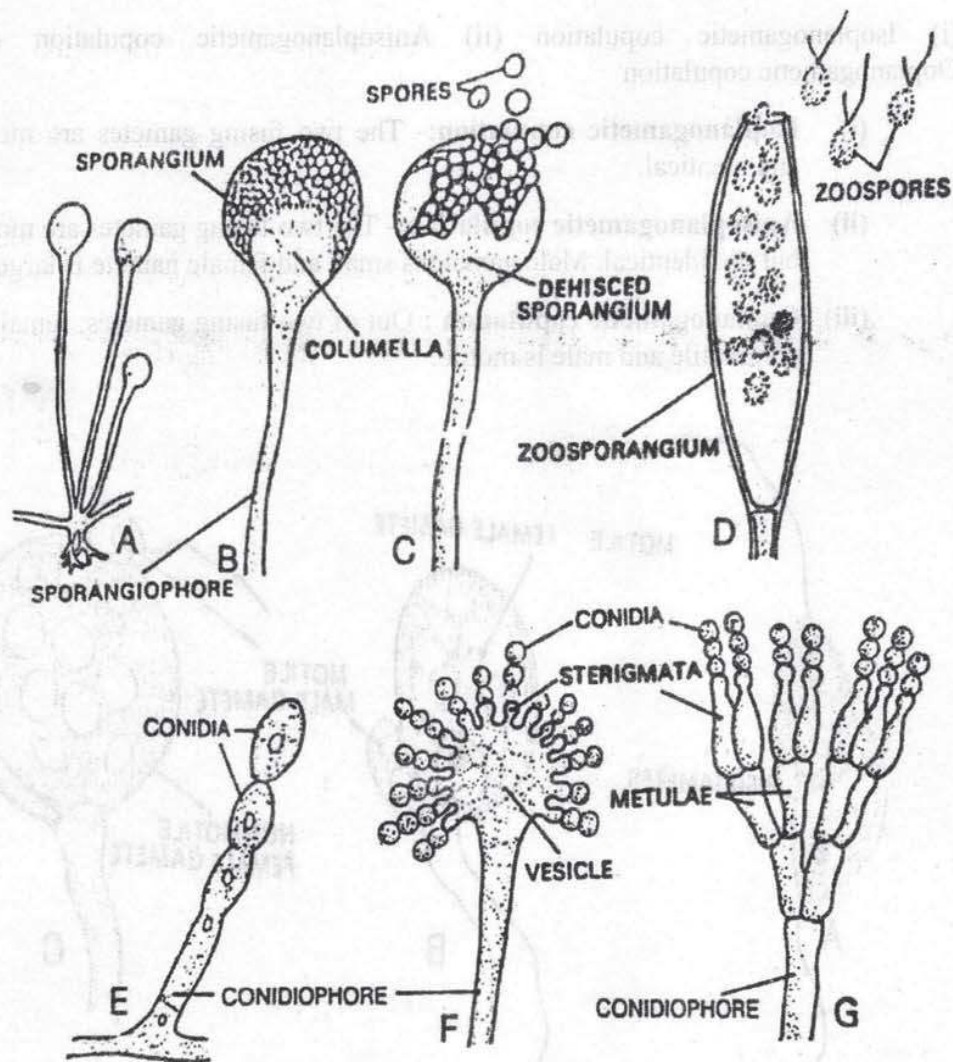


Fig.4.7. (A-G) Asexual reproduction. A-C. Spores; D. Zoospores; E-G. Conidia.

- (ii) **Sexual reproduction** : Sexual reproduction occurs in almost all the group of fungi except deuteromycetes or fungi imperfecti.

The sexual reproduction completes in three phases-

- (1) Plasmogamy- Fusion of protoplasm.
- (2) Karyogamy- Fusion of nucleus.
- (3) Meiosis- Reduction division.

In lower fungi (phycomycetes) plasmogamy is immediately followed by karyogamy and meiosis but in higher fungi (Ascomycetes and Basidiomycetes) karyogamy is delayed as a result dikaryon is formed. The karyogamy occurs in the later stage in the life history followed by meiosis.

Mode of Sexual reproduction

- (1) **Planogametic copulation** :- It is Fusion between motile gametes and occurs as follows :-

- (i) Isoplanogametic copulation (ii) Anisoplanogametic copulation (iii) Ooplanogametic copulation

- (i) **Isoplanogametic copulation:-** The two fusing gametes are motile and identical.
- (ii) **Anisoplanogametic copulation:-** The two fusing gametes are motile but not identical. Male gamete is small and female gamete is large.
- (iii) **Ooplanogametic copulation :** Out of two fusing gametes, female is non motile and male is motile.

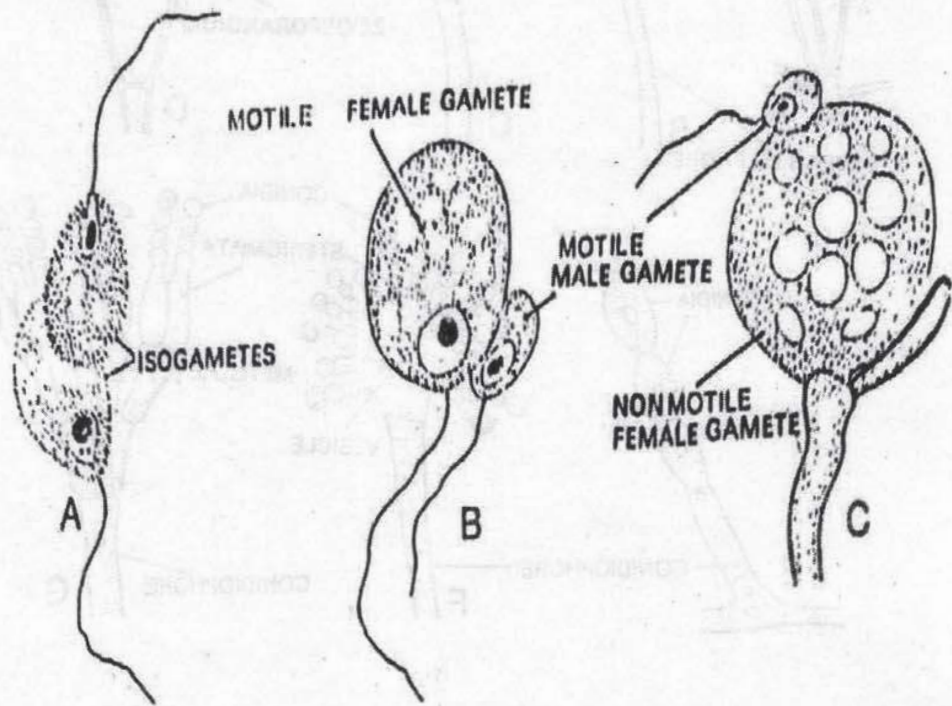


Fig.4.8. (A-C). Planogametic copulation : A. Isoplanogametic copulation; B. Anisoplanogametic copulation; C. Ooplanogametic copulation.

- (2) **Gametangial contact :-** The male (Antheridium) and female (oogonium) gametes come in contact. The wall of oogonium bulge out at the place of contact and antheridium send a fertilization tube through this thin place into the ooplasm region of oogonium and carry male nucleus. The tip of fertilization tube burst and male nucleus is released in the oogonium which fuses with the egg. The fertilized egg secretes thick wall around itself to become oospore. The gametes do not loose their identity after fusion.

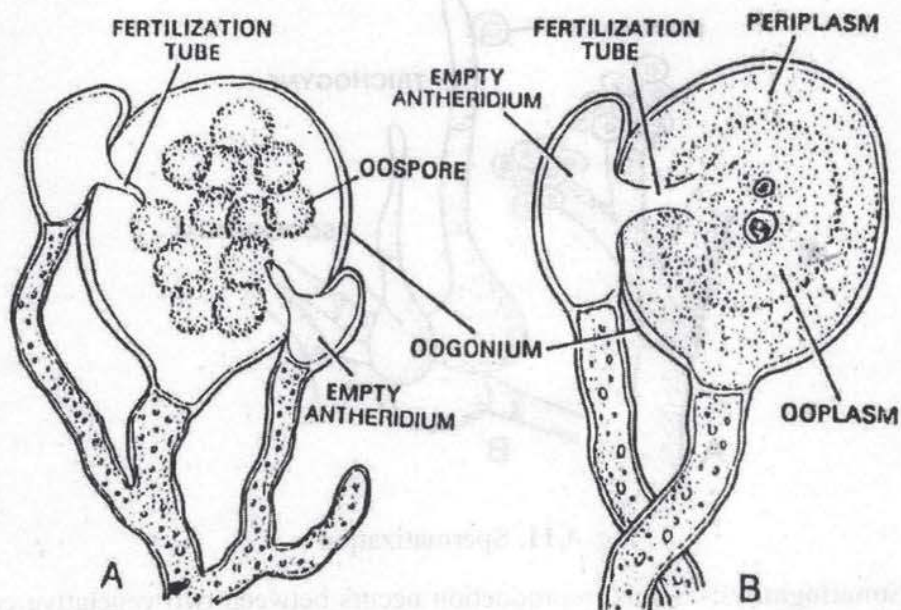


Fig.4.9. A-B. Gametangial contact type of sexual fusion.

(3) Gametangial Copulation :-

Sexual reproduction by gametangial copulation occurs in *Mucor* in which the fusing gametes fuse together to form fusion cell in which the nuclei of + and - strain fuse together to form Zygospore. Thus as a result of fusion the gametes lose their identity.

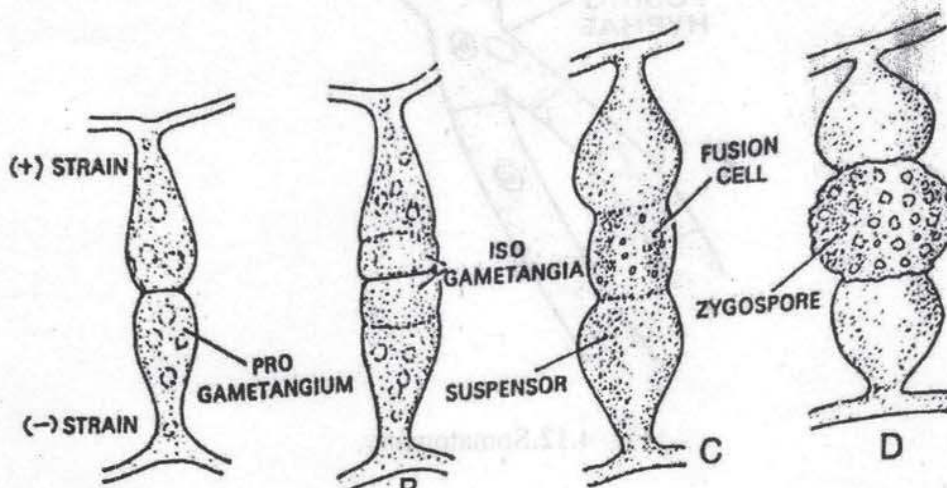


Fig.4.10. A-D. Gametangial copulation type of sexual fusion.

- (4) **Spermatization :-** In some advanced genera eg. *Puccinia*, the spermatia represents the male gametes and receptive hypha represents the female gamete. The spermatia are carried by air, water or insect to receptive hypha. The male nucleus enter into the receptive hypha through septal pore and it reaches in lower region of the hypha. Thus, the dikaryon is formed.

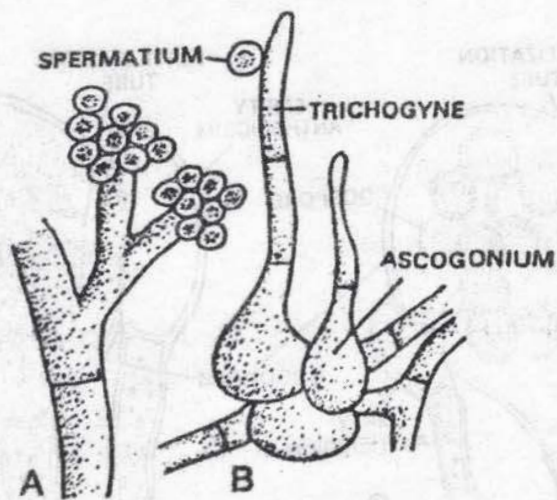


Fig. 4.11. Spermatization

- (5) **Somatogamy** :- Sexual reproduction occurs between two vegetative cells of opposite strained hypha. Such type of reproduction occurs in higher fungi.

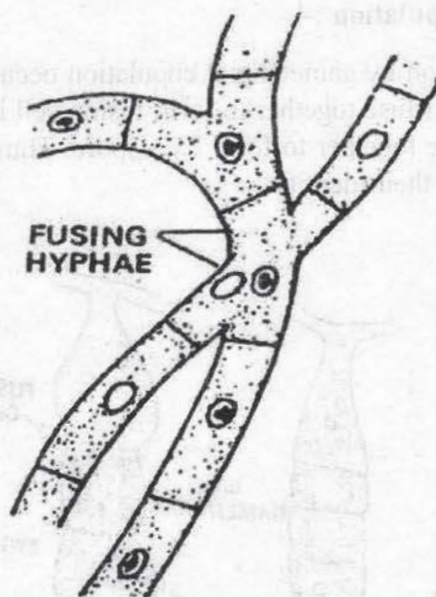


Fig. 4.12. Somatogamy.

SAQ.1

- Fungi are in mode of nutrition.
- Unicellular single celled fungus is
- Parasite grows on suitable living
- Saprophyte grows on dead

4.3 LIFE CYCLE OF *PHYTOPHTHORA*/LATE BLIGHT OF POTATO

Division- Eumycota

Class- Oomycetes

Order- Peronosporales

Family- Phythiaceae

Genus- *Phytophthora*

Phytophthora infestans is facultative saprophyte, facultative parasite and causes a disease in potato known as Late Blight of Potato

4.3.1 SYMPTOMS

Disease usually appears in the month of January with small patch at the margin and tip of lower leaf. The spot then become necrotic (dead) and turns brown to black in colour. In moist weather the spot spreads and cover the whole plant. The skin of the diseased tuber becomes brown and black and decay before harvest.

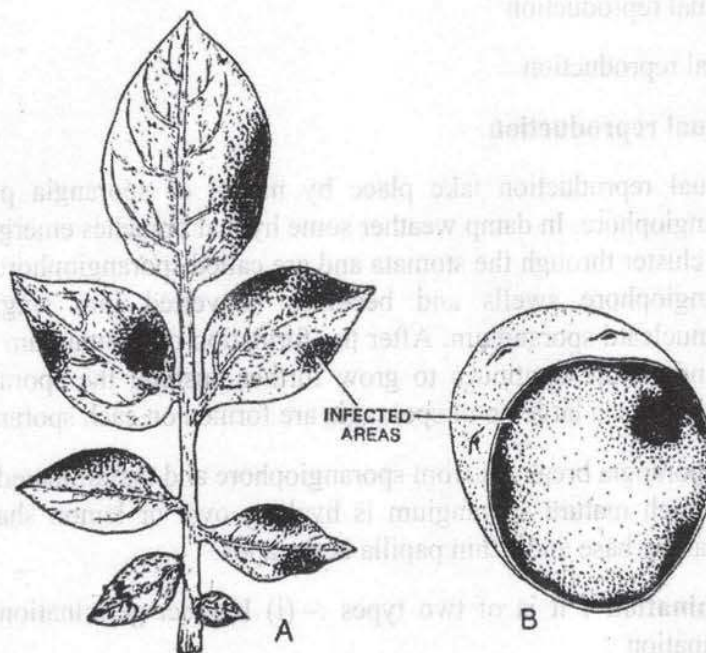


Fig. 4.13. *Phytophthora infestans*. Infected potato leaf (A) and tuber (B) Showing symptoms of late blight disease

4.3.2 VEGETATIVE STRUCTURE

Plant body is branched aseptate coenocytic hypha which may be intercellular as well as intracellular. Intercellular hypha produces intracellular cylindrical short haustoria.

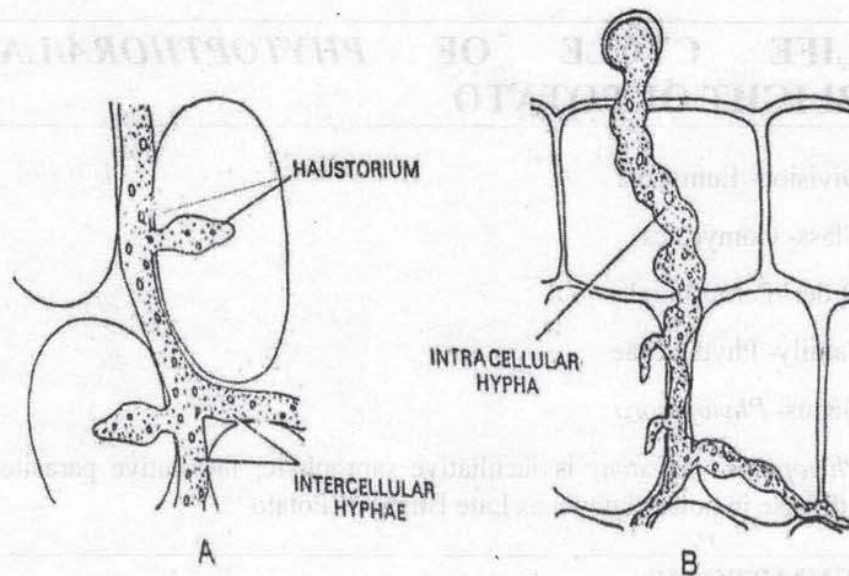


Fig. 4.14. *Phytophthora* sp. Coenocytic hyphae; A. Intercellular, B. Intracellular

4.3.4 REPRODUCTION

It is of two types

- (i) Asexual reproduction
- (ii) Sexual reproduction
- (i) **Asexual reproduction**

Asexual reproduction takes place by means of sporangia produced on sporangiophore. In damp weather some hyphal branches emerge out singly or in cluster through the stomata and are called sporangiophore. The tip of sporangiophore swells and becomes converted into single terminal multinucleated sporangium. After the formation of sporangium the apex of sporangiophore continues to grow further pushing the sporangium to a lateral. Thus, a large no of sporangia are formed on each sporangiophore.

The sporangia break off from sporangiophore and disseminated by wind or rain. Each mature sporangium is hyaline, oval or lemon shaped with a stalk at the base and a thin papilla at the apex.

Germination : It is of two types :- (i) Indirect germination (ii) Direct germination

- (i) **Indirect germination :-** The sporangia germinates within a few hours of dissemination. Under moist weather and low temperature (below 15°C) the sporangium behaves as zoosporangium and produces biflagellate zoospores. The zoospores are released from zoosporangium. Each zoospore withdraws their flagella becomes round off and then germinates by germ tube.

(ii) **Direct germination** :- Under high temperature (20-23°C) conditions, sporangia germinate directly by germ tube and function as conidia. Therefore, these sporangia are called conidiosporangia.

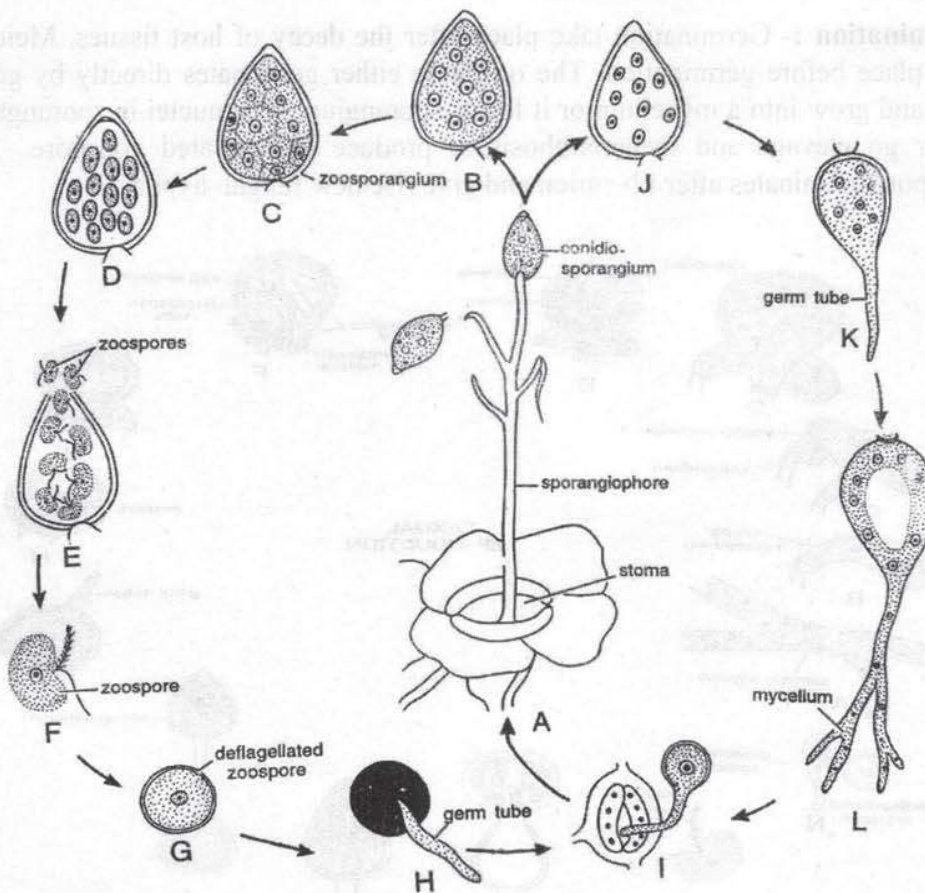


Fig. 4.15. A-L *Phytophthora*: Asexual reproduction: **B-H.** Indirect germination, **J-L.** Direct germination.

(ii) **Sexual reproduction** :- It is oogamous type. Male sex organ is antheridium whereas female sex organ is oogonium. The sex organs develop on different hypha in heterothallic species.

Antheridium :- It arises earlier than oogonium and develops as a terminal more or less clavate swelling on a lateral hypha. The mature antheridium is funnel shaped and forms a collar like structure at the base of mature oogonium (Amphigynous type). Antheridium has about 12 nuclei but on maturity it has only one functional nucleus. Other nuclei degenerate.

Oogonium :- It arises laterally on female hypha which is near to developing. Antheridium. The oogonium grow through the center of the antheridial cell. As a result Antheridium forms a collar like structure at the base of oogonium. The oogonium has outer periplasm region and inner ooplasm region which, has an egg, oosphere or female nucleus.

Fertilization :- At the time of fertilization antheridium and oogonium come in contact. The wall of oogonium bulge out at the place of contact. This place is called receptive spot. The wall of oogonium dissolves at this point and an opening

is formed through which antheridium pushes a fertilization tube into the oogonium. Which carry the male nucleus and releases it into the oogonium after rupture. The male nucleus fuses with the female nucleus and secretes wall around itself to form a resting spore oospore.

Germination :- Germination take place after the decay of host tissues. Meiosis take place before germination. The oosphere either germinates directly by germ tube and grow into a mycelium or it forms sporangium. The nuclei in sporangium under go cleavage and metamorphosis to produce biflagellated zoospore. The zoospore germinates after liberation and give rise new fungal hypha.

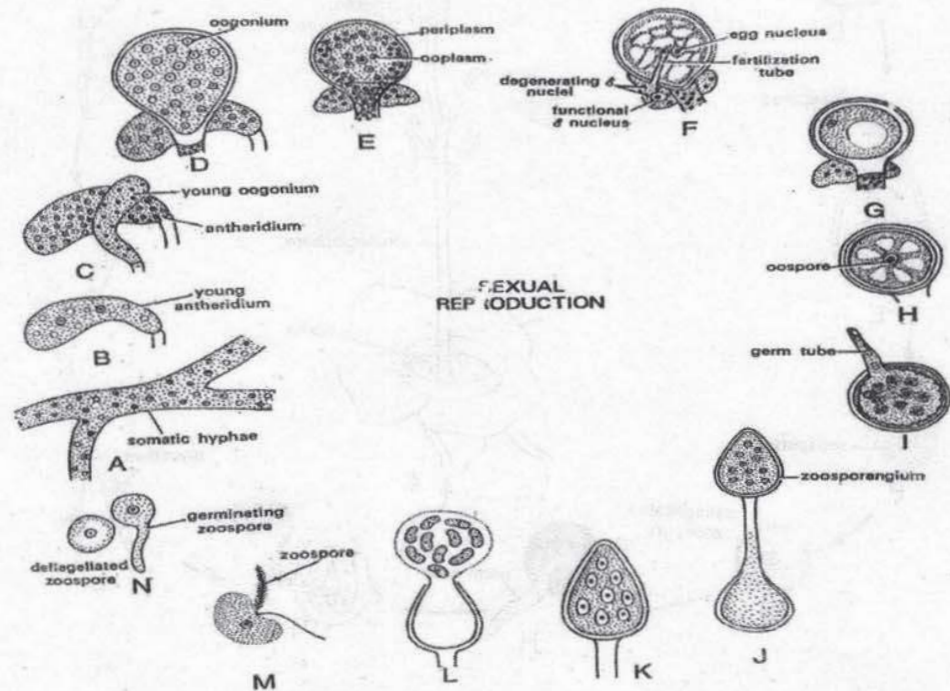


Fig. 4.16. A-N. *Phytophthora* : Sexual reproduction : A-E. Stages in the development of antheridium and oogonium, F. Fertilization, G-H. Formation of oospore, I-L. Germination of oospore and development of zoosporangium, M. Zoospore, N. Germination of zoospore.

SAQ.2

- Late blight of potato is caused by
- Asexual reproduction in *Phytophthora infestans* take place by
- Sexual reproduction is type.

4.5 LIFE CYCLE OF RHIZOPUS

Division - Eumycota

Class- Zygomycetes

Order- Mucorales

Family- Mucoraceae

The genus *Rhizopus* is saprophyte grows on organic substances like bread, jellies, leather etc. The most widely known species is *Rhizopus stolonifer*. It is commonly known as bread mould.

4.5.1 VEGETATIVE STRUCTURE

The mycelium consists of white cottony, coenocytic (multinucleated) branched hyphae. The hyphae are of three types : stolones, rhizoids and sporangiophores. Stolons grow horizontally above the substratum. The rhizoids develop in tufts at certain points of stolons. It is branched structured which penetrates the substratum to absorb water and nourishment. Sporangiophores are erect, aerial and branched hyphae which grow upwards in tufts from the stolons. Sporangia are present at the tip of sporangiophore.

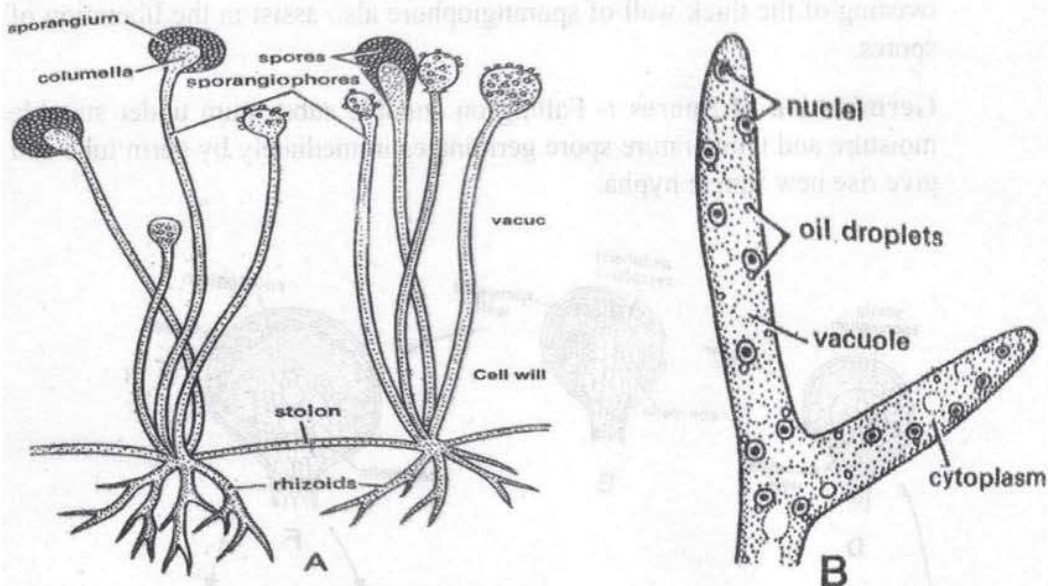


Fig. 4.17. *Rhizopus stolonifer* ; A. Mycelium with sporangiophores. B. Vegetative mycelium.

4.5.2 REPRODUCTION

Rhizopus reproduces by :

- (i) Vegetative reproduction
- (ii) Asexual reproduction
- (iii) Sexual reproduction

- (i) **Vegetative reproduction :-** It takes place by fragmentation. The stolons break up into smaller fragments. Each fragment develops into new mycelium.
- (ii) **Asexual reproduction :-** It takes place by non motile spore produced in sporangium. The sporangia are produced at the terminal end of single

unbranched sporangiophore. The sporangiophores develop from the stolon opposite the rhizoids.

The tip of the sporangiophore swell into a knob like structure which has outer sporiferous zone and inner dome shaped sterile part columella. The protoplast of columella is in continuation of sporangiophore.

The sporiferous zone has many unicellular non motile spores known as aplanospores.

Dehiscence of Sporangium :- As the spore matures there is an increase in the quantity of fluid in the sporangiophore and columella. It exert a pressure due to which columella bulge more strongly into the sporangium. The wall of sporangium crakes into small fragments in dry air and powdery mass of spores get exposed.

The spores are blown away to great distance through air. The jerking and twisting of the thick wall of sporangiophore also assist in the liberation of spores.

Germination of Spores :- Falling on suitable substratum under suitable moisture and temperature spore germinates immediately by germ tube and give rise new fungal hypha.

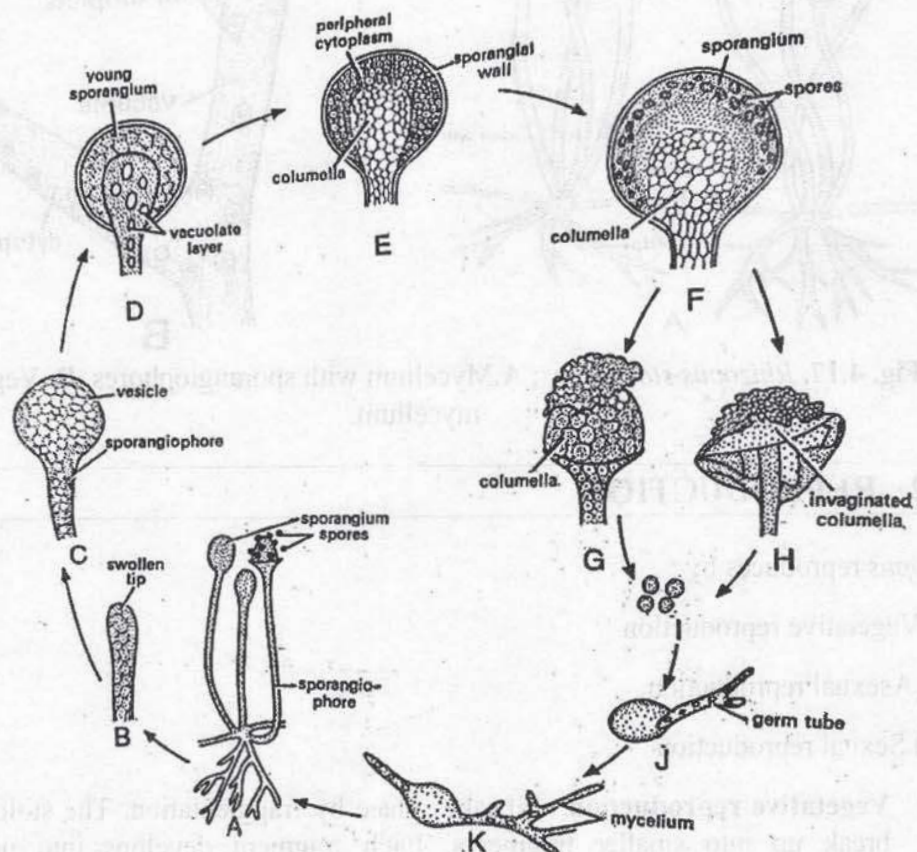


Fig. 4.18. A-K. *Rhizopus* : Asexual reproduction; A-F. Development of sporangium, G-H.. Dehiscence of sporangium, I. Aplanospores, J-K. Germination of spores.

(iii) **Sexual Reproduction :-** It is gametangial copulation. Sexual reproduction generally take place towards the end of growing season. At the time of reproduction two hypha of opposite strain (+ and -) are known as zygophore which are attracted towards each other. The zygophore meet and put out a copulating branch called progametangia.

The progametangia grow outwards and cuts off a small terminal cell called gametangia from the proximal part called suspensor.

The two gametangia mature and come close to each other. The wall between two gametangia dissolve and a fusion cell is formed which has both + and - strain nuclei. The + and - strained nuclei fuse together whereas the unpaired nuclei degenerate.

The combined protoplast in fusion cell is known as *Zygospore*.

The zygospore secretes a thick two layered wall around itself. The outer layer is exine and inner layer is intine. The exine is thick and warty whereas intine is thin.

As the zygospore increases in size the wall of fusion cell ruptures and zygospore get exposed. By the time the suspensor wither and zygospores are set free.

Germination : Zygospore germinates under suitable conditions. At the time of germination it has several haploid nuclei of + and - strain. The protoplast of zygospore absorbs water and swell. The exine ruptures and intine grow out into a small stout vertical hyphae called promycelium.

The promycelium grow and soon bears a typical terminal sporangium called zygosporangium. The protoplast of zygosporangium undergo cleavage and produces non motile germ spore of + and - nuclei. The promycelium dies after the liberation of germ spore.

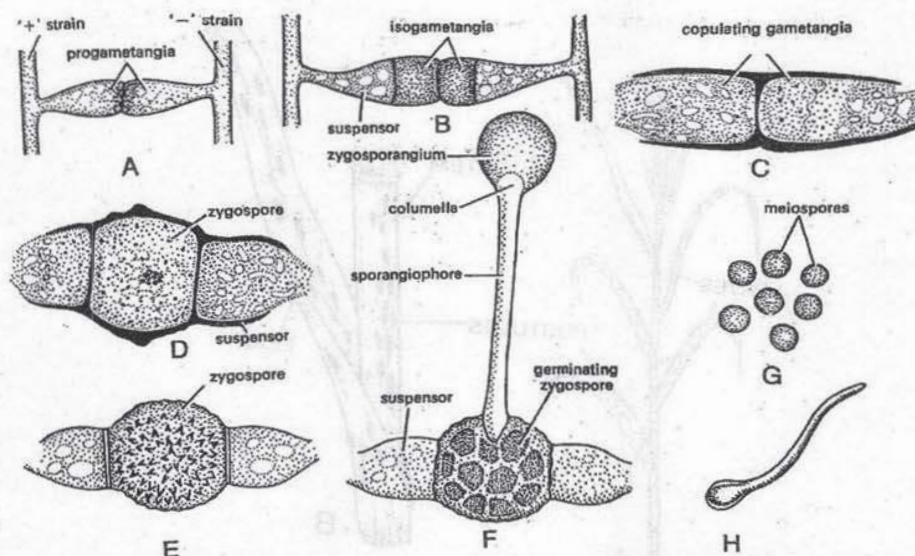


Fig. 4.19. A-H. *Rhizopus* : Sexual reproduction; **A-B.** Formation of gametangia; **C-E.** Gametangial copulation and formation of zygospore; **F.** Germination of zygospore; **G.** Meiospores, **H.** Germinating meiaspore.

SAQ.3

- (a) *Rhizopus* is a fungus.
- (b) Vegetative reproduction in *Rhizopus* takes place by
- (c) Sporangia are produced in
- (d) is formed after sexual reproduction.

4.6 LIFE CYCLE OF *PUCCINIA* (RUST FUNGI)

Division- Eumycota

Class- Basidiomycetes

Order- Uredinales

Family- Pucciniaceae

Genus- *Puccinia*

Puccinia graminis tritici is a heterocious fungus and requires two host to complete their life cycle. The primary host is wheat plant and alternate host is barberry leaf. The phenomenon in which fungus requires two host to complete their life cycles is known as heterocism. On wheat plant fungus causes a disease known as Black Rust of Wheat.

4.6.1 SYMPTOMS

Symptom appears on leaf sheath and stem in the form of streaks. It is brown coloured when uredospores are produced and becomes black coloured when teleutospores are produced on wheat plant.

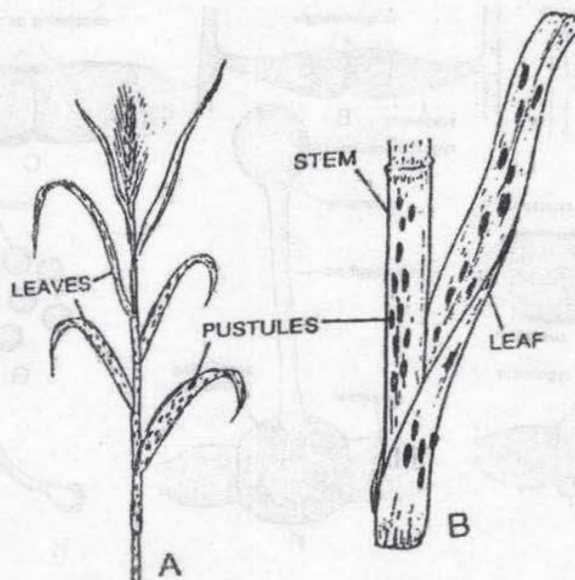


Fig. 4.20. *Puccinia graminis*. A-B. Symptoms of black rust on stem and leaves of wheat.

4.6.2 LIFE CYCLE

In the life cycle 5 types of spores are produced-

1. Uredospore in uredosori
2. Teleutospore in teleutosori
3. Basidiospore an Basidium
4. Pycnidia in Pycnidial cup
5. Aecidiospore in Aecidial cup

4.6.3 LIFE CYCLE ON WHEAT PLANT

Wheat plant get infected either by germination of aecidiospores produced on barberry leaf or uredospore produced on infected wheat plant. In both the cases secondary mycelium is formed in the intercellular spaces of the host cell and following two types of spores are produced.

- (1) **Uredospore in Uredosori :-** Uredospores are produced in early summer on stem and leaves. The dikaryotic mycelium accumulates below the epidermis and develop several two celled branches resulting in bulging of epidermis. The outer cell of each branch forms oval Uredospores and lower cell forms stalk. the Uredospores get exposed due to the rupture of epidermis.

Mature uredospores are one celled oval binucleated double layered brown coloured structure. The outer layer is thick and spiny exine where as inner layer is thin and smooth intine. At maturity Uredospores are liberated by breaking stalk and dissaminated by wind. Each Uredospore has four germ pore.

Uredospore germinates on healthy host and causes infection. Next crop of Uredospore matures on wheat plant in 10-12 days after the initial infection.

- (2) **Teleuto stage :-** It develops in late summer either in the same sorus or in separate sorus. The development of teleutospore is same as that of Uredospore. The only difference is that the apical cell of branch divides again as a result a three celled branch is formed. Each cell of branch is dikaryotic. The two nuclei in the cell fuse together and thus, diploid nucleus is formed. The upper two cells of the branch form body of teleutospore where as, the lower cell forms stalk of teleutospore.

Each mature teleutospore is bicelled spindle shaped with rounded or conical apex. It has two layered wall. The outer thick smooth exine and inner thin smooth intine. Each cell is diploid and has one germ pore.

The teleutospores get exposed due to rupture of epidermis and liberated by breaking stalk. They are dissaminated by wind. The teleutospore can not

germinate on wheat plant therefore, with the formation of teleutospore the life cycle of *Puccinia* ends on wheat plant.

4.6.4 LIFE CYCLE IN SOIL

Basidiospores on Basidium :- Teleutospores undergo a period of 30 days rest. Then it germinates in soil under favourable conditions (high humidity and low temperature).

On germination each cell of teleutospore give rise a promycelium from the germ pore. The protoplasm along with nucleus migrates into the promycelium. The nucleus then divide by meiosis and 4 haploid nuclei are formed. The promycelium is divided into 4 cells by the formation of 3 septa. Each uninucleate cell of promycelium forms a small projection on lateral wall called sterigma. The nucleus migrates into the sterigma. The tip of sterigma swells and become differentiated into basidiospores.

The Basidiospores are small unicellular, Uninucleate haploid. spherical structure. Out of 4 basidiospores two are of (+) strain and two are of (-) strain. They are dissminated by wind and germinate on alternate host the barberry plant.

4.6.5 LIFE CYCLE ON BARBERRY LEAF

Under suitable conditions the basidiospores germinate on barberry leaf and give rise primary mycelium (Uninucleated). The (+) strain basidiopore germinates and give rise (+) strain hypha where as, (-) strain on germination give rise (-) strain hypha. With in the 4 days of infection, on the upper surface of leaf flask shaped Pycnidia or Spermogonia is produced. The (+) strain hypha give rise (+) strain Pycnidia and (-) strain hypha give rise (-) strain Pycnidia.

- (i) **Sial in Pycnidialcup :-** It is oval to flask shaped structure situated on the upper surface of barberry leaf. It opens on the upper surface by an opening called ostiole guarded by periphysis. The wall of Pycnidia has many spermatophore which cuts off small oval *spermatia* or *Pycnidia*. It represents male sex cell. Many long hyphal branches called receptive hyphae are also present. The receptive hypha represents female sex organ.

The (+) strain pycnidia has (+) strain receptive hypha and phycnidia or spermatia where as, (-) strain phycnidia has (-) strain reseptive hypha and phycnidia or spermatia.

With the formation of Pycidia a mat of hyphae accumulates near the lower epidermis. The hyphal branches arise from the base of pycnidia and forms aecidial primordia.

Spermatization take place. The spermatium of (+) strain is carried by insect to the receptive hypha of (-) strain. At the place of contact the wall between them dissolves. The male nucleus migrates into the receptive hypha and reaches in the aecidial primorida through septal pore. Thus dikaryon is formed in the aecidial primordia which function as aecidiospore mother cell.

(ii) **Aecidiao spore in aecidial cup :-** The binucleate basal cell of aecidiospore mother cell longates. Its nucleus divide and a terminal binucleate cell is formed. The terminal cell again divides into a small and a large cell. The large cell forms binucleated aecidiospore where as small lower cell forms binucleated disjunctor. This process continues and a chain of aecidiospore alternating with disjunctor grows towards lower epidermis. Due to pressure the lower epidermis ruptures and aecidiospores get exposed.

The aecidiospores are more or less polygonal in shape due to compression but becomes rounded on liberation.

The aecidiospores are liberated by disintegration of intercalary disjunctor cell. The aecidiospore is unicellular, binucleated, heterokaryotic surrounded by two layered wall. Each spore has six germ pores. The aecidiospores are dissaminated by wind and remain viable for long period. It germinates on wheat plant like uredospore.

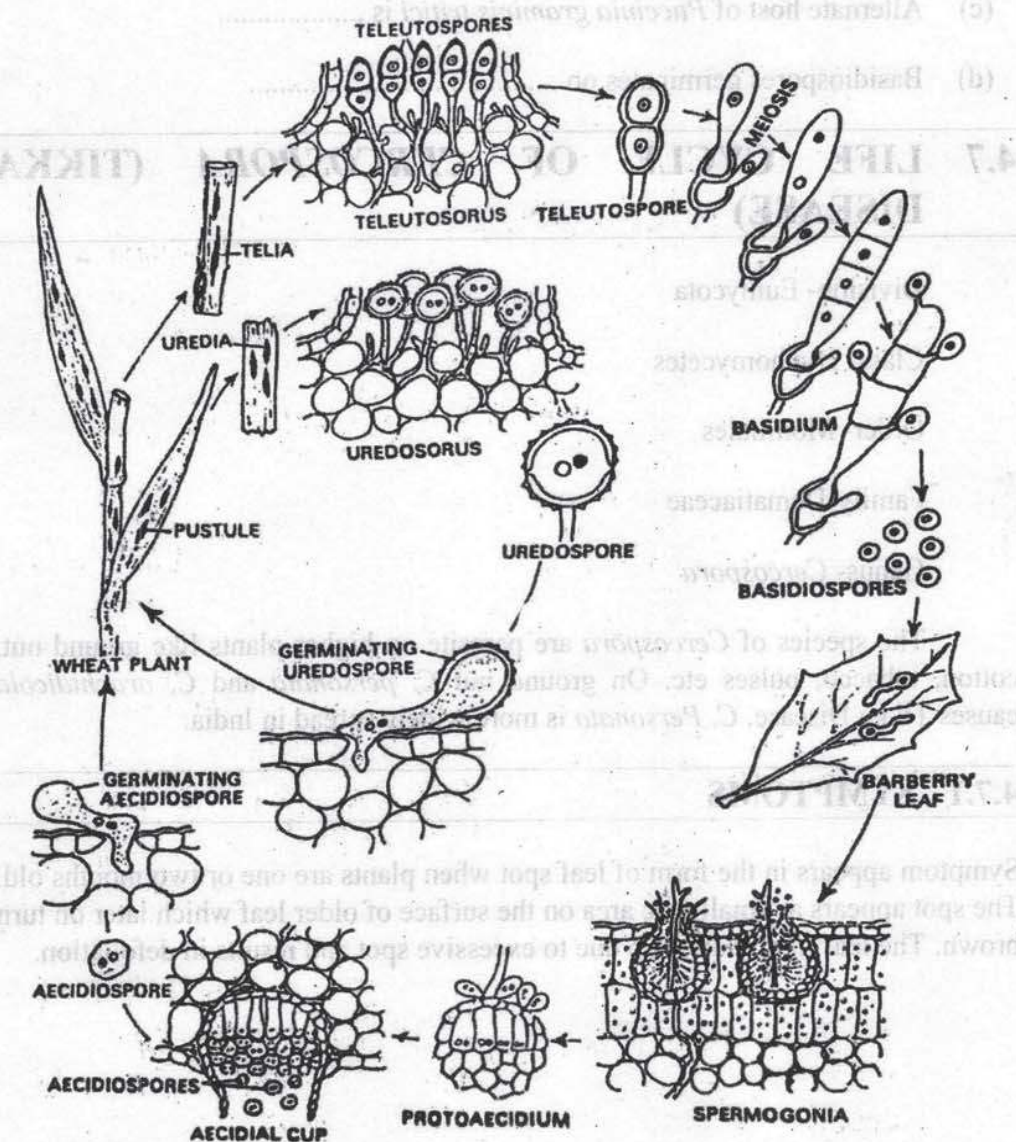


Fig. 4.21. Life cycle of *Puccinia graminis*.

Annual recurrence of Puccinia;- In the plains of Northern India the alternate host barberry is absent. The Uredospores produced in the plains can not survive in the high temperature of summer. Thus, no inoculum is found to infect the next year wheat crop but infection occurs every year.

The uredospores survive on the hill due to favourable temperature function as inoculum for the next season crop. The uredospore of hills first infect the wheat crop in the foot hill region then in the plains. The wheat is sown earlier in the hill then, in the plains. The direction of wind which remains from hill to the plain also favours the infection.

SAQ.4

- (a) Rust fungi is
- (b) Primary host of *Puccinia graminis tritici* is
- (c) Alternate host of *Puccinia graminis tritici* is
- (d) Basidiospores germinates on.....

4.7 LIFE CYCLE OF *CERCOSPORA* (TIKKA DISEASE)

Division- Eumycota

Class- Hyphomycetes

Order- Moniliales

Family- Dematiaceae

Genus- *Cercospora*

The species of *Cercospora* are parasite on higher plants like ground nut, cotton, tobacco, pulses etc. On ground nut *C. personata* and *C. arachidicola* causes Tikka Disease. *C. Personata* is more widely spread in India.

4.7.1 SYMPTOMS

Symptom appears in the form of leaf spot when plants are one or two months old. The spot appears as small pale area on the surface of older leaf which later on turn brown. The leaf finally dries up due to excessive spot and results in defoliation.

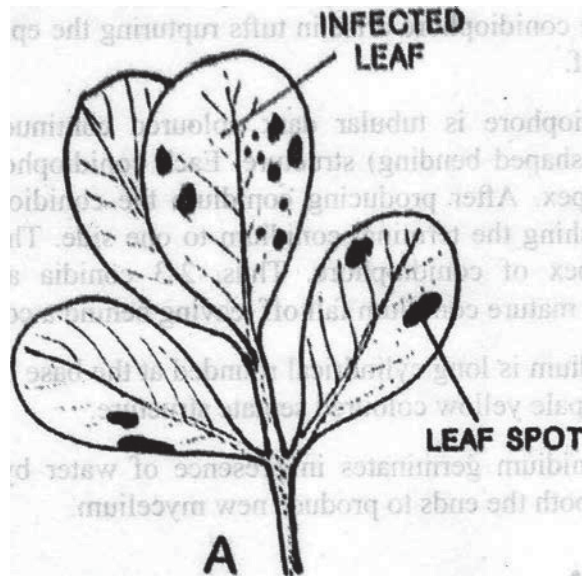


Fig. 4.22. Infected leaf of ground nut showing symptoms of tikka disease.

4.7.2 VEGETATIVE STRUCTURE

The plant body is branched septate mycelium which, is intercellular. Some of the hyphal branches penetrates inside the host cell becomes intracellular and worked as lobed haustoria.

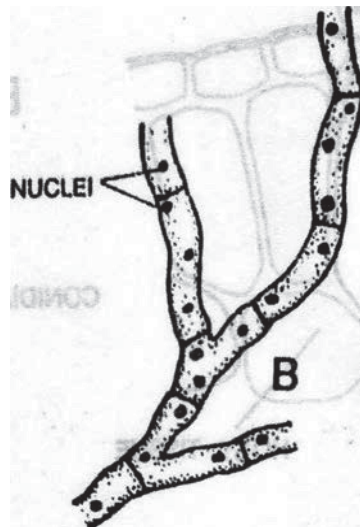


Fig.4.23. A part of mycelium.

4.7.3 REPRODUCTION

it take place by asexual method. Sexual reproduction is either absent or not known.

Asexual reproduction :- It take place by means of conidia produced on conidiophore. The conidiophore arise in tufts rupturing the epidermis on both the surface of host leaf.

The conidiophore is tubular dark coloured continuous or 1-2 septate geniculate (Knee shaped bending) structure. Each conidiophore produces single conidium at its apex. After producing conidium the conidiophore continues to grow laterally pushing the terminal conidium to one side. The next conidium is formed at the apex of conidiophore. Thus, 2-3 conidia are produced on a conidiophore. The mature conidium fall off leaving behind a conidial scar.

Each conidium is long cylindrical rounded at the base and tapering at the apex. It is hyaline pale yellow coloured septate structure.

Mature conidium germinates in presence of water by germ tube either from one or from both the ends to produce new mycelium.

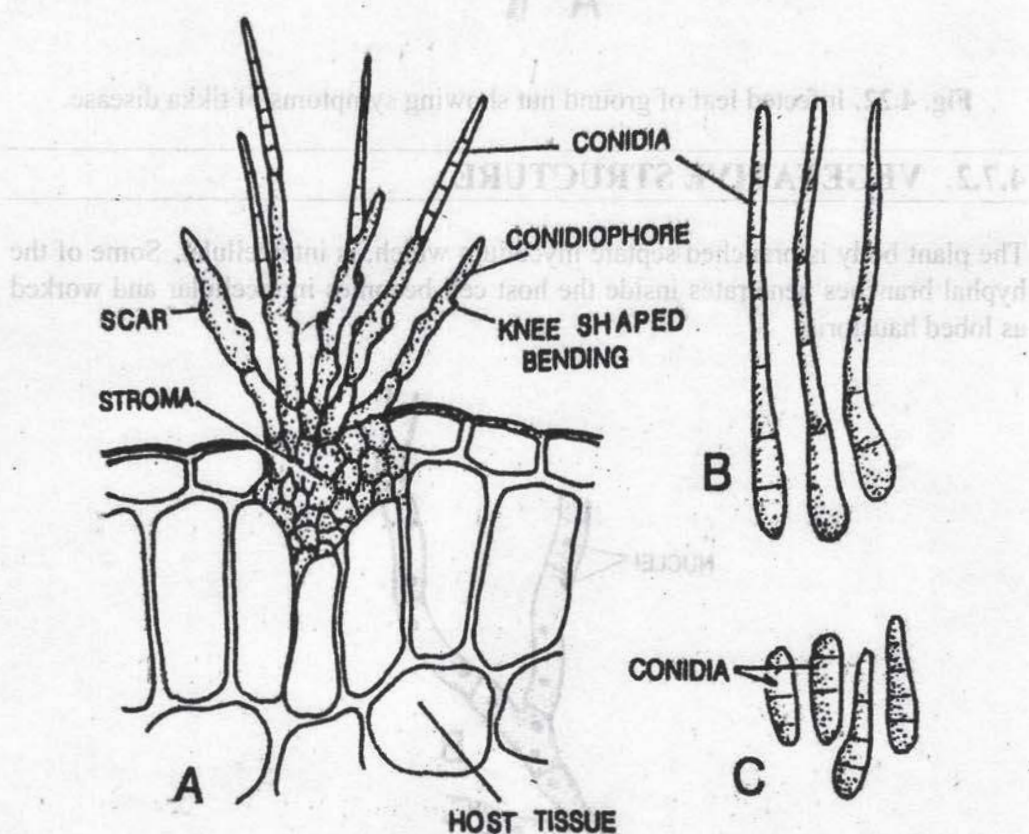


Fig. 4.24. *Cercospora* . A. Transverse section of host leaf through infected portion; B. Conidia of *C. arachidicola*; C. Conidia of *C. personata*.

SAQ.5

- Tikka disease is caused by
- Cercospora* reproduce by method.
- Geniculate conidiophores are produced in

4.8 ECONOMIC IMPORTANCE OF FUNGI

Fungi play a significant role in our daily life by useful and harmful activities.

4.8.1 USEFUL ACTIVITIES

- (i) **Fungi as a food :-** The Mushrooms eg. *Agaricus bisporus*, *Amanita vaginata*, *Morchella*, are used as a food. They are rich in protein, carbohydrates, vitamins and minerals. Yeast is an important source of vitamins and single cell protein.
- (ii) **As medicine :-** Ergot is obtained from *Claviceps purpurea*. It is used to induce uterine contraction for abortion. Ephedrine is synthesized from benzaldehyde by the action of yeast. Steroids (complex organic compounds) are prepared from fermentation of glycosides by *Aspergillus niger* and *Rhizopus* sp. Antibiotics are obtained from fungi eg. Penicillin from *Penicillium notatum*.
- (iii) **In production of organic acids :-** Citric acid, Itaconic acid, Gluconic acid and Kojic acid are produced by activity of species of *Aspergillus*. Fumaric acid is prepared from fermentation of sugar by *Rhizopus stolonifer*.
- (iv) **Fungi in Industry :** Fungi helps in brewing industry. Wine is prepared by fermenting rice with *Aspergillus oryzae* and beer is prepared by *Saccharomyces cerevisiae*.

CO₂ released in fermentation of carbohydrates by yeast is used in baking industry. *Penicillium* is used in the manufacture of cheese.
- (v) **Fungi in enzyme production :-** Invertase enzyme and zymase enzyme are obtained from yeast. Amylase are produced by activity of *Aspergillus niger* and *Trichoderma reesei* is used in the production of cellulase enzyme.
- (vi) **Fungi in Agriculture :-** Fungi play an important role in biological control of diseases eg. *Trichoderma* suppress the growth of root rot fungus *Pythium*. Fungal pathogen also play an important role in control of weeds.

Mycorrhiza (symbiotic relationship between fungal hyphae and roots of higher plant) are important organs for water absorption in plants growing in dry conditions and play a dominant role in uptake of less mobile plant nutrients.

Fungi like *Aspergillus*, *Penicillium* and *Rhizopus* have soil binding property. Many *Phylloplane* fungi have nitrogen fixing capability. Thus fungi play an important role in increasing fertility of soil. Growth hormones eg. Gibberellin is produced by *Gibberella fujikuroi*.

Some soil fungi eg. *Trichoderma* sp. and *Fusarium roseum* act as soil nibblers. They kill some roots to promote more fibrous root development and increases total area of root absorption.

Fungi decomposes the plant and animal debris thus act as a scavenger and maintains the ratio of CO₂ in the atmosphere.

- (vii) **Fungi as test organism** : Several fungi are used as important research tool for the study of various fundamental biological processes. eg . *Neurospora crassa* is used as a test organism to detect the presence and quantity of vit B in a given sample.

4.8.2 HARMFUL ACTIVITY

- (i) **Fungi as a pathogen** : The parasitic fungi causes disease in plant and thus reduces the yield and quality of the crop. eg

- White rust of crucifer is caused by *Albugo candida*.
- Late Blight of Potato caused by *Phytophthora infestans*.
- Many fungi are parasite on animals and cause disease eg.
- *Mucomycosis* is caused by *Mucor*, *Rhizopus*.
- *Aspergillosis* is caused by *Aspergillus*.

Fungi also causes disease of skin, lungs, eyes, liver, kidney and respiratory tract in human being eg. *Aspergillosis* is caused by *Aspergillus*.

- (ii) **Spoilage of food stuffs** : *Mucor*, *Rhizopus*, *Aspergillus*, *Penicillium* and yeast spoils food stuffs. Many fungi produce mycotoxins which are responsible for food poisoning and other distressing symptoms.

SAQ.6

- (a) Ergot is obtained from
- (b) Yeast is used in industry.
- (c) Mycotoxins are produced by.....
- (d) Aspergillosis is caused by.....

4.9 SUMMARY

- Fungi are non green nucleated thalloid plants. Their cell wall is of Chitin and reserve food is glycogen and oil drops.
- They are saprophyte or parasite.
- Fungi reproduce by asexual and sexual reproduction.
- Asexual reproduction is by fragmentation, budding, oidia, chlamydospores and spores.
- Sexual reproduction is by isoplanogametic copulation, anisoplanogametic copulation and ooplanogametic copulation.
- *Phytophthora infestans* causes late light of potato. The fungus reproduce asexually and Sexually.
- *Rhizopus* is saprophytic fungus and reproduce vegetatively, asexually and sexually.
- *Puccinia graminis tritici* causes black rust of wheat. The fungus requires two host to complete their life cycle. The primary host is wheat plant and

alternate host is barberry leaf. In the life cycle 5 types of spores are produced.

- *Cercospora* causes tikka disease on ground nut. The fungus reproduce by asexual method only.

4.10 TERMINAL QUESTIONS

Long Questions :-

1. Describe the lifecycle of *Phytophthora* or late blight of potato.

.....

.....

.....

.....

2. Describe the life cycle of *Rhizopus*.

.....

.....

.....

.....

3. Give an account of life history of *Puccinia* or rust fungi.

.....

.....

.....

.....

4. Describe the life cycle of *Cercospora* or Tikka disease.

.....

.....

.....

.....

5. Give an account of economic importance of fungi.

.....

.....

.....

.....

Short Questions :-

Write short notes on :-

- (a) Gametangial contact.
- (b) Sexual reproduction in *Rhizopus*.
- (c) Uredostage.
- (d) Teleutostage
- (e) Tikka disease

4.11 ANSWERS

SAQ.1

- (a) Heterotrophic
- (b) Yeast
- (c) Organism
- (d) organic matter.

SAQ.2

- (a) *Phytophthora infestans*
- (b) Sporangia
- (c) Oogamous

SAQ.3

- (a) Saprophytic
- (b) Fragmentation
- (c) Sporangiphore
- (d) Zygospor

SAQ.4

- (a) *Puccinia*
- (b) Wheat plant
- (c) Barberry leaf
- (d) Barberry leaf

SAQ.5

- (a) *Cercospora*
- (b) Asexual
- (c) *Cercospora*

SAQ.6

- (a) *Claviceps purpurea*

- (b) Baking
- (c) Fungi
- (d) *Aspergillus*

REFERENCE

1. A text book of botany by Singh, Pande & Jain.
2. Fungi by Dr. H.N. Srivastava.



Bachelor of Science
UGBY -103
Plant Diversity-I

BLOCK **2**

PLANT DIVERSITY -I

UNIT 5

:

Bryophytes -I

UNIT 6

:

Bryophytes -II

UNIT 7

:

Pteridophytes-I

UNIT 8

:

Pteridophytes-I

Course Design Committee

Prof. Ashutosh Gupta Director, School of Science UPRTOU, Prayagraj.	Chairman
Dr. Anil Tiwari Botny Department Ewing Christan College. Prayagraj.	Member
Dr. Preeti Singh Botny Department S.S.K.P.G. College Prayagraj.	Member
Dr. Sushma Chauhan Acadmic Consultant, School of Science UPRTOU, Prayagraj.	Member/Secretary

Course Preparation Committee

Dr. Sushma Chauhan Acadmic Consultant, School of Science UPRTOU, Prayagraj.	Author Block - 1 (unit - 01, 03, 04) Block - 2 (Unit - 07, 08)
Dr Achala Srivastava Assistant professor S.S. Khanna, P.G. College Prayagraj.	Author Block- 1 (Unit: 02)
Dr. Alok Malviya Assistant professor S.S. Khanna, P.G. College Prayagraj	Author Block- 2 (Unit: 05, 06)
(Dr.) Amita Pandey Asso. Prof. Deptt. of Botony (C.M.P. P.G College) Prayagraj.	Editor (Unit - 01 - 08)
Dr. Sushma Chauhan Acadmic Consultant, School of Science UPRTOU, Prayagraj.	Coordinator

©UPRTOU, Prayagraj-2020

ISBN :

©All Rights are reserved. No part of this work may be reproduced in any form, by mimeograph or any other means, without permission in writing from the **Uttar Pradesh Rajarshi Tondon Open University, Prayagraj.**

BLOCK INTRODUCTION

As you know the Algae are simplest photosynthetic plants and originated in water. Most of the plants grow on land, so in evolutionary line some plants show the character of water plants as well as land plants. These plants are "Bryophyta". Bryophytes are also known as "Amphibians" in plant kingdom.

After the Bryophyta, Pteridophytes comes in evolutionary line. They are first land plants, they possess root, stem and leaves.

In this block you study about amphibian plants (the plant lives in water and land) as well as primitive land plants which have the characters of land plant, the block comprises 4 units. In unit 5 the introduction of bryophytes will be discussed with general characters of bryophytes. In which Morphology, anatomy general patterns of reproduction and lifecycle will be discussed. In addition to this, some species of all the three groups will be studied in details.

In unit 6 we will discuss evolutionary trends in sporophyte of Bryophyta and economic importance of Bryophytes in different fields.

In unit 7 we will discuss land plant characteristics as well as general characteristics of pteridophytes. Structure and evolution of stele will also be studied. In this unit Apogamy and Apospory also will be studied .

In unit 8 general pattern of morphology anatomy and life cycle of selected genera will be studied.

UNIT-V BRYOPHYTES-I

Structure :

5.1 Introduction

Objective

Study Guide

5.2 General character of Bryophytes

5.3 Adaptations to land plants

5.4 Morphology, Anatomy & life history of selected genera.

Hepaticopsida

Riccia

Marchantia

Pellia

Anthocerotopsida

Anthoceros

Byopsida

Sphagnum

5.5 Summary

5.6 Terminal questions

5.7 Answers

5.1 INTRODUCTION

The group Bryophyta (Greek word; Bryon = moss, Phyton= plant) includes the simplest and most primitive land plants. They are essentially terrestrial but require water at every step in the life cycle. They fail to complete their life cycles without water. The plants usually grow in the moist and shady places on the sides of ditches, ponds , pools , lakes, on the bank of streams; damped soil; moist rocks; wet hills and many other similar habitats. However, a few grow under diverse habitats such as aquatic submerged in water (e.g., *Riella*, *Riccia fluitans*, *Ricciocarpus natans*), in bogs (e.g., *Sphagnum*), as epiphytes in tree trunks and branches (e.g., *Dendroceros*) epiphyllous growing on the surface of the leaves (e.g., *Radula protensa*), in dry heat (e.g., *Polytrichum juniperinum*).

THE BRYOPHYTES CONSIDERED AS AMPHIBIANS OF THE PLANT KINGDOM:

The amphibians in the animal Kingdom (e.g., frog) live in water as well as on land. Similarly the bryophytes, represented by liverworts, hornworts and mosses, grow well in the area in between the aquatic and terrestrial habitats i.e. amphibious zone. The bryophytes are fundamentally terrestrial plants adapted certain special features to grow under land environments.

OBJECTIVE

After study of this unit you will be able to understand –

- Why bryophytes are amphibians in plant kingdom.
- How they differ from land plant & aquatic plant.
- Morphology and Anatomy of Bryophytes
- Reproduction in Bryophytes..
- Life cycle in general and life cycles of selected genera

STUDY GUIDE

Before study this unit study any book of class 11th on biology

5.2 GENERAL CHARACTERS OF BRYOPHYTES

1. Plant body is gametophytic, dominant, autotrophic, either thalloid (i.e., thallus like, not differentiated into roots, stem and leaves) or foliose (Fig 5.1) containing a rootless leafy shoot.

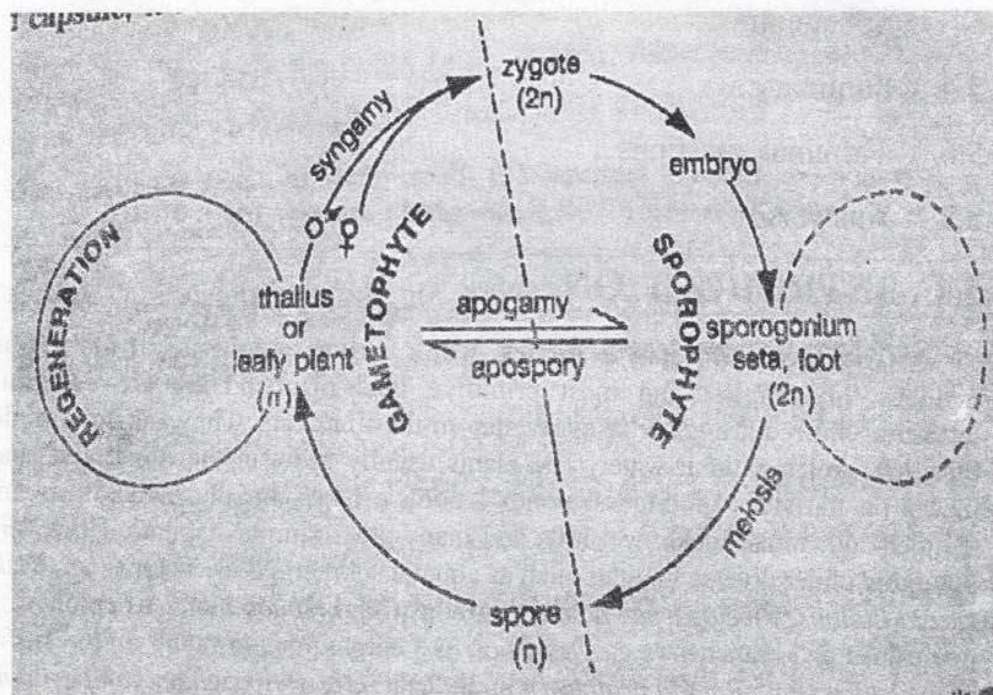


Fig 5.1 Heteromorphic alternation of generation in Bryophytes

2. Plant body is very small and ranges from few mm to several cms. Zoopsis is the smallest bryophyte (5 mm) while the tallest bryophyte is *Dawsonia* (50- 70 cm).
3. Leaves and stems found in vascular plants are absent, Koch (1956) termed these 'leaf' and 'stem' like structures as 'axis' and 'phylloids' respectively.
4. Roots are absent functions of the roots are performed by rhizoids. Cells are also capable to absorb moisture directly from the ground or atmosphere. Therefore , Bryophytes can also survive on the moist soils.
5. Rhizoids may be unicellular , unbranched (e.g , *Riccia* , *Marchantia* , *Anthoceros*), multicellular and branched (e.g. *Sphagnum* , *Funaria*)
6. In members of order Marchantiales (e.g. *Riccia* , *Marchantia*) scales are present. These are violet coloured, multicellular and single cell thick. They protect the growing point and help to retain the moisture.
7. Vascular tissue (xylem and phloem) is completely absent. Water and food material is transferred from cell to cell. However in some Bryophytes (e.g. mosses) a few cells in groups of 2-3 are present for conduction of water and food (photo assimilate). These cells are known as hydroids (collectively hydrome) and leptoids respectively. Cuticle and stomata are absent.

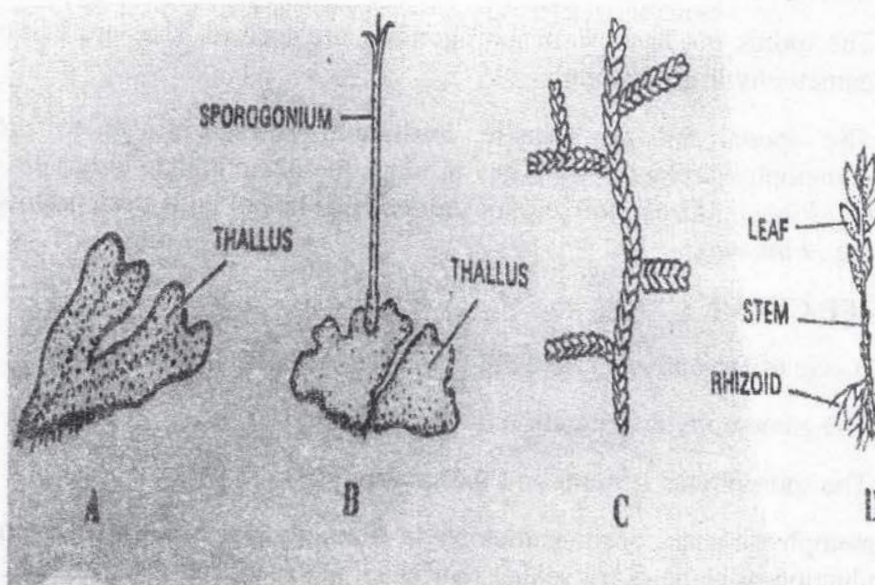


Fig 5.2 Different forms of gametophytes (A) thalloid liverworts ,(B) hornworts,(C) leafy jungermanniales,(D) leafy shoot of moss

8. The sexual reproduction is always oogamous (i.e , the male gametes are small and motile antherozoids and the female gametes are large and non-motile egg).
9. The male reproductive organs are anthridia and female reproductive organs are archeogonia. Both the reproductive organs are multi-cellular and jacketed with sterile jacket.

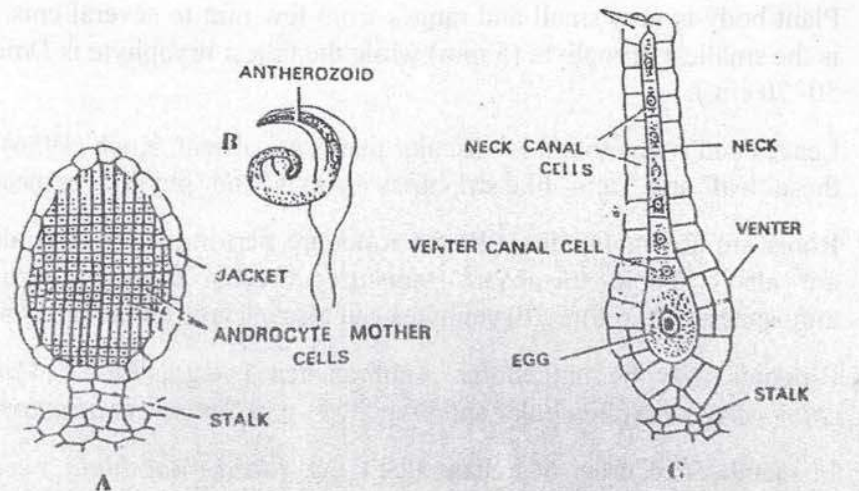


Fig 5.3 Sex organs of bryophytes, (A) antheridium, (B) antherozoid, (C) archegonium.

10. Fertilization takes place in presence of water. The fertilized egg (zygote) is retained within the venter and undergoes repeated divisions to form an embryo.
11. The diploid zygote is the first cells of sporophytic plant body known as sporogonium.
12. The spores, produced from sporogonium, are haploid. They are first cell of gametophytic generation.
13. The spores fall on suitable substratum and germinate to produce gametophytic plant body. They produce the gametophyte either directly (e.g. *Riccia*, *Marchantia*, etc) or indirectly as lateral buds from protonema (e.g., *Funaria*).

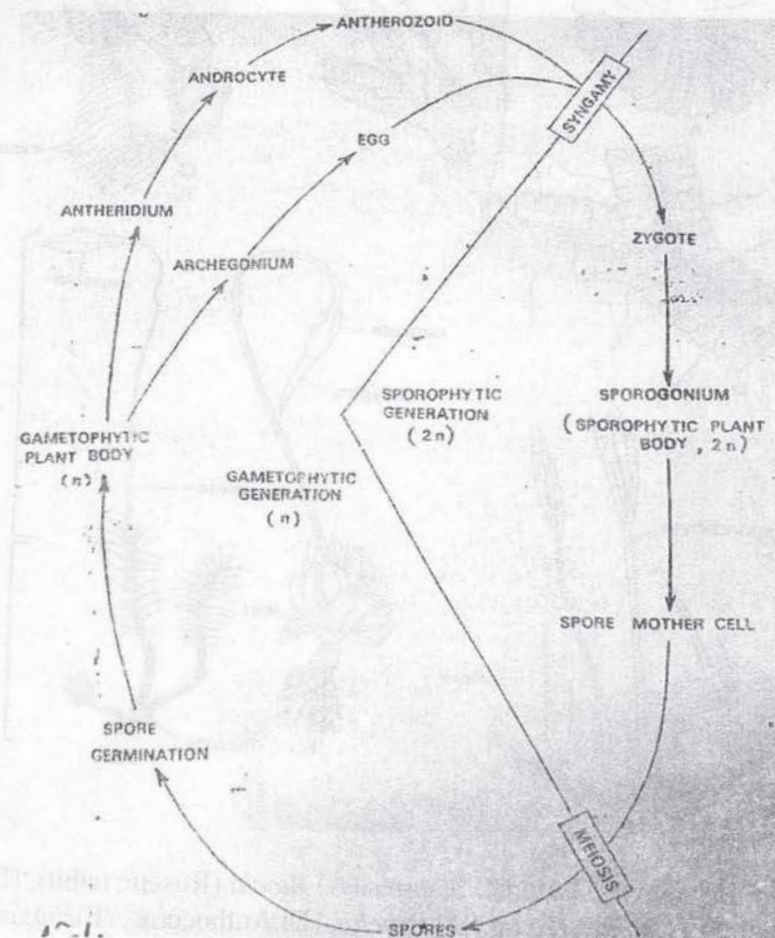
THE LIFE CYCLE :

The life cycle of Bryophytes consist of two distinct phases or generations-

- (i) The gametophytic generation (the gametophyte) and
- (ii) The sporophytic generation (the sporophyte)

The gametophytic phase or the gametophyte is mainly concerned with main plant and production of gametes (or sexual reproduction). Each cell of the gametophyte has a single set of chromosome number i.e., haploid (n). It begins with the production of haploid spores. The spores fall on suitable substratum and germinate to produce gametophytic plant body. The gametophyte is an independent plant body which may be thalloid or leafy axis. It develops sex organs. The male sex organ is antheridium, which produces biflagellate motile male gametes called antherozoids. The female sex organ is archegonium, which produces non-motile female gamete called egg. The sexual reproduction is oogamous antherozoid fuses with the haploid, egg and forms diploid **zygote**.

The zygote is the first cell of sporophytic generation. It is retained within the archegonium and multiplies to produce the embryo, which later develops into sporophytic plant body the **sporogonium**.



Fig; 5.4 Graphic representation of the sexual life cycle of bryophytes.

The spores mother cell produced from the sporogenous tissue in sporophyte, divide by meiosis. Each diploid spore mother cell divides by meiosis and forms 4 haploid spores. Spore germinates and gametophytic generation begins.

5.3 ADAPTIONS OF BRYOPHYTES TO LAND HABIT

Bryophytes are **first land plants**. Evidences support that **Bryophytes are evolved from Algae**.

During the process of origin they developed to certain adaptions to land habit. These are:

1. Development of compact plant body covered with epidermis
2. Development of organs for attachment and absorption of water e.g., rhizoids.

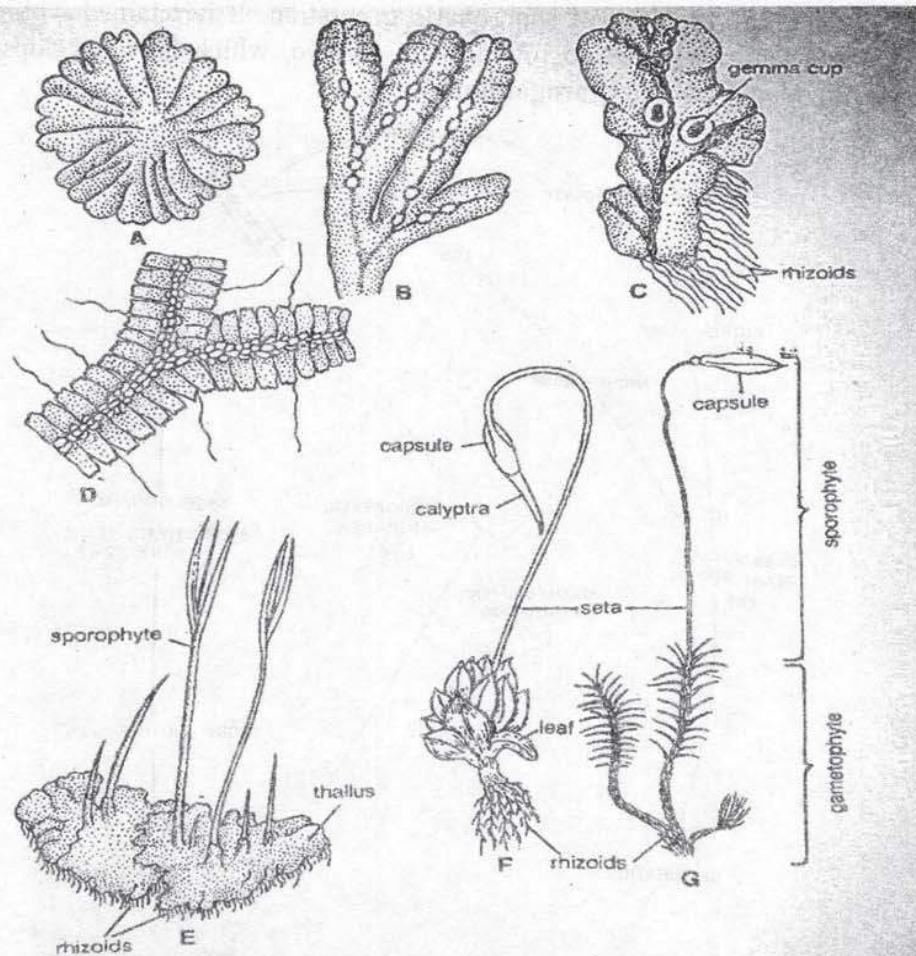


Fig 5.5 Bryophytes. External features. (A) *Riccia* (Rosette habit), (B) *Riccia* (thallus), (C) *Marchantia*, (D) *Porella*, (E) *Anthoceros*, (F) *Funaria* (G) *Polytrichum*

3. Absorption of carbon dioxide from atmosphere for photosynthesis e.g., air pores.
4. Protection of reproductive cells from drying and mechanical injury i.e., jacketed sex organs .
5. Retention of zygote within the archegonium.
6. Production if large number of thick walled spores.
7. Dissemination of spores by wind.
8. Presence of primitive vascular system in the form of conducting strand.

CLASSIFICATION OF BRYOPHYTES :-

After accepting the International code of Botanical Nomenclature (ICBN) Rothmare (1951) changed the class names, he divides the Bryophyte in 3 classes

Class I Hepaticopsida

Class II Anthocerotopsida

Class III Bryopsida /Musci

Hepaticopsida: contains thalloid and leafy plant body. This class is commonly known as liverworts e.g. *Riccia*, *Marchantia*, *Porella* etc.

Anthocerotopsida: contain only six genera, shows thalloid structure. Tuberculated rhizoid, scales, Air chambers are absent. Each cell contains single chloroplast with single pyrenoid.

Bryopsida: contains leafy plant body with mid rib (gametophyte) differentiated into rhizoids stem and leaves.

5.4 MORPHOLOGY, ANATOMY & LIFE HISTORY OF SELECTED GENERA

5.4.1 HEPATICOPSIDA

The Gametophyte of Hepaticopsida are known as liverworts because the thallus resemble with liver in appearance. Hepaticopsida comprises two forms first is thalloid form which is dorso-ventral flattened while other form is leafy.

In this unit you will study three members e.g. *Riccia*, *Marchantia* and *Pellia* in details.

Riccia

Systematic position:

Division : Bryophyta

Class : Hepaticopsida

Order : Marchantiales

Family : Ricciaceae

Genus : *Riccia*

DISTRIBUTION AND HABITAT

Riccia is represented by about 200 species (Reimer, 1954) distributed in both tropical and temperate regions of the world, this genus is represented in India by about 33 species (Puri, 1973). However, Srivastava (1964) recorded 29 species from different parts of India.

All species are terrestrial and prefer to grow on moist and shady places except *Riccia fluitans* which is an aquatic species and occurs floating in still stagnant water or submerged below the surface of standing water. Some of the common terrestrial Indian species are :

R. gangetica, *R. discolor*, (*R. himalayensis*), *R. glauca*, *R. crystalline*, *R. frostii*, *R. hirsuta* and *R. melanospora*. *Riccia gangetica*, *R. kashyapii*, *R. pandei* are common species of India.

GAMETOPHYTIC PHASE

The plant body of *Riccia* is gametophytic. The plant body is fleshy, prostrate and dichotomously branched. Repeated dichotomy results into a typically rosette like appearance (Fig 5.6). In *Riccia cruciata* only two dichotomies result in a cruciate form (FIG 5.6 B).

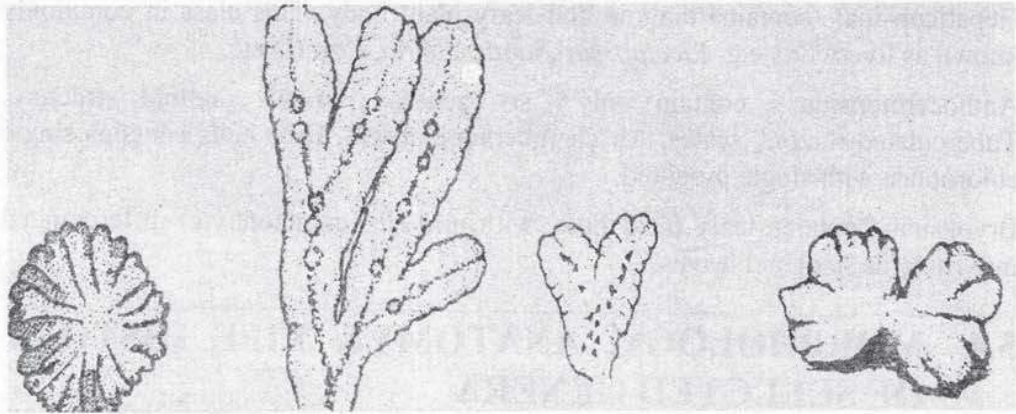


Fig 5.6 A. *Riccia* Rosette B. *Riccia*, Robust male thalli. C. *Riccia*, Cruciate Habit thallus.

Each branch of the thallus is linear, wedge – shaped or obcordate. Thallus is 5-7 mm long and 1.2 mm broad in all terrestrial species however in *R. flutains* it is 30-50 mm long 1-2 mm broad.

Dorsal surface

The dorsal surface is light green or dark green body, each branch having a thick midrib. It is traversed by a conspicuous median longitude groove which ends in a depression at the apical notch. The main function of the mid- dorsal groove is to retain water required for fertilization. Some hairy epidermal outgrowth are also seen (Fig 5.7)

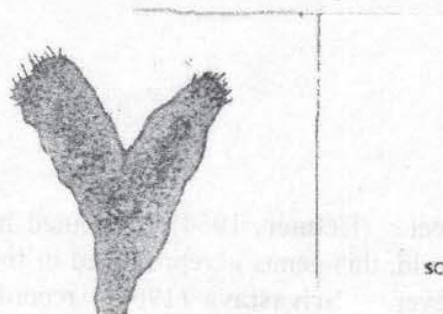


Fig 5.7 Thallus of *R. melanospora*



Fig 5.8 *Riccia*, Scale

VENTRAL SURFACE

The ventral surface of thallus bears many scales and rhizoids. **Scales** are violet coloured, multicellular and one celled thick structure (Fig 5.8). Scales are arranged all along the margin in a single row.

In hygrophilous species (species which need a large supply of moisture for their growth) the scale ephemeral (i.e. short lived) but in xerophilous species the scales are leafy and persistent. In *Riccia crystallina* the scales are inconspicuous and absent.

Rhizoids are unicellular and unbranched. They develops as prolongations of the lower epidermal cells. They are of two types (i) smooth – walled rhizoids

and (ii) Tuberculate rhizoids. In smooth-walled rhizoids both the inner and the outer wall are fully stretched while in tuberculate rhizoids the inner wall layers modifies into peg-like or plate-like in growth which projects into the cell lumen (Fig 5.9) The main functions of rhizoids is to anchor the thallus on the substratum and to absorb water and mineral nutrients from the soil.

In *Riccia fluitans* the only aquatic species, thallus is long, narrow, ribbon-like and dichotomously branched. Rhizoids and scales are absent (Fig 5.10 A) This species can also grow on soil. In terrestrial species thallus bears many rhizoids and small, colourless or violet scales near the apex. (Fig 5.10 B)

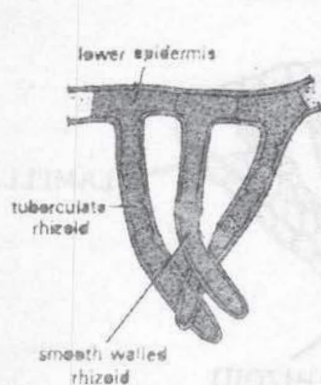


Fig 5.9

(A)

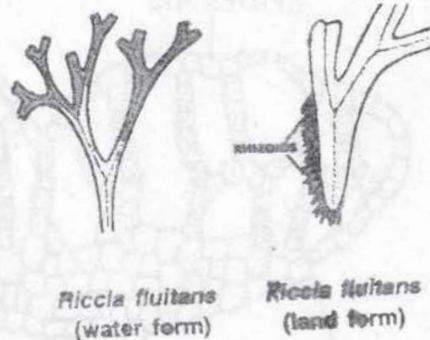


Fig 5.10

(B)

ANATOMY OF THE GAMETOPHYTE

A vertical cross section of the thallus two distinct zones, viz., upper photosynthetic zone and lower storage zone (Fig 5.11)

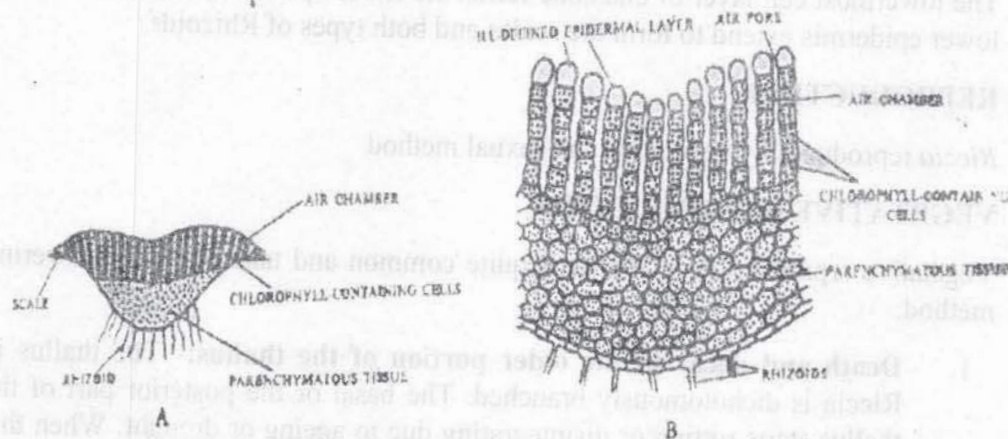


Fig 5.11 (A,B) *Riccia*. (A) Transverse section of thallus (diagrammatic); (B) A part cellular

Upper photosynthetic zone

It is green, dorsal on upper region of the thallus. It is made of somewhat vertical rows of unbranched photosynthetic filaments. All the cells of the photosynthetic filament except the uppermost one, are isodiametric and possess

many discoid chloroplast. The terminal cells of photosynthetic filaments are large, hyaline and form loose, ill-defined and discontinuous one celled thick epidermis. Photosynthetic filaments are separated from each other by narrow longitudinal vertical canals called air chambers. Each air chamber opens on the dorsal surface by an air pore. Air chambers help in gaseous exchange.

In aquatic form of *Riccia fluitans* epidermis is continuous and air chamber are almost completely closed. However, in the terrestrial form of this species each air chamber opens on the upper surface by a small opening

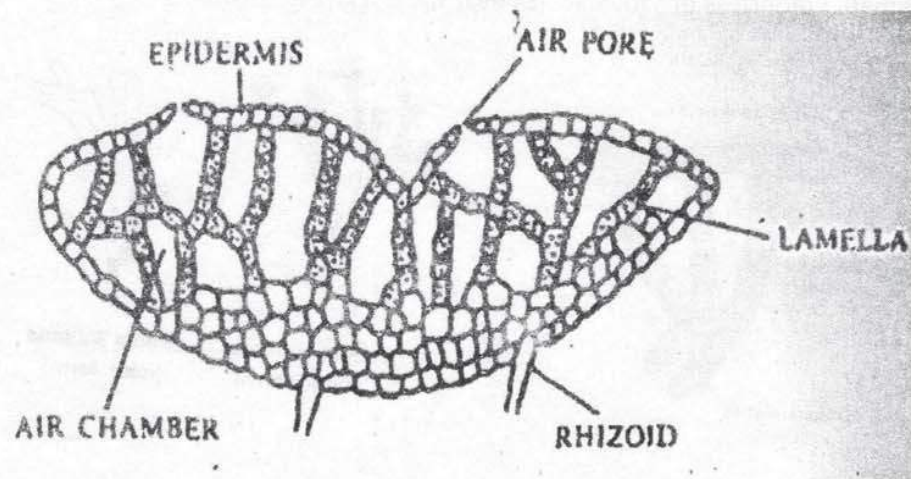


Fig 5.12 *Riccia fluitans* . Transverse section of thallus of land form

LOWER STORAGE ZONE

This zone represent the ventral tissue of the thallus and lies below the photosynthetic zone. It consists of compactly arranged parenchymatous cells. These cells are devoid of chlorophyll and contain starch as reserve food material. The lowermost cell layer of this zone forms the lower epidermis. Some cell of the lower epidermis extend to form the scales and both types of Rhizoids.

REPRODUCTION

Riccia reproduces by vegetative and sexual method

VEGETATIVE REPRODUCTION

Vegetative reproduction in *Riccia* is quite common and take place by flowering method:

1. **Death and decay of the older portion of the thallus:** The thallus in *Riccia* is dichotomously branched. The basal or the posterior part of the thallus starts rotting or disintegrating due to ageing or drought. When this process of decay reaches upto the place of dichotomy, the lobes of the thallus gets separated. Thus detached lobes develop into independent plants by apical growth. It is the most common method of vegetative reproduction in *Riccia*.

2. **By adventitious branches:** The adventitious branches develop from the ventral surface of the thallus in species like *Riccia fluitans*. On being detached, these branches develop into new thalli.
3. **By persistent apices:** Due to the prolonged dry summer or towards the end of growing seasons the whole thallus in some species (e.g., *Riccia discolor*) dries and gets destroyed except the growing point. Under favorable conditions it develops into a new thallus.
4. **By tubers:** Towards the end of the growing season the apices of the thallus lobes get thickened and form the perennating tubers. These are capable to pass on the unfavorable conditions. On resumption of favorable conditions tubers produce new thalli. Tubers are common in *Riccia discolor*, *R. billardieri*, *R. perennis* and *R. vesicata* (Fig 5.13)

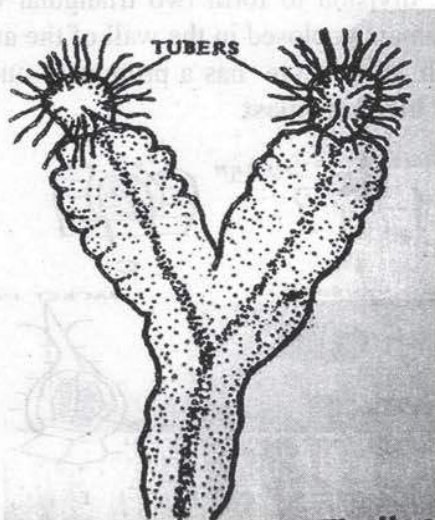


Fig 5.13 *Riccia* Thallus showing tubers

5. **By rhizoids:** The apical part of the young rhizoids to form a gemma like mass of cells in some species (e.g, *Riccia glauca*) these cells contains chloroplast and are capable of developing into new thallus.

SEXUAL REPRODUCTION

Sexual reproduction in *Riccia* is oogamous. Male reproductive bodies are known as antheridia and female as archeogonia. Some species of *Riccia* like *R. crystalline*, *R. gangetica*, *R. billardieri* are monoecious or homothallic while other species like *R. curtisii*, *R. bischoffi*, *R. discolor* are dioecious or hetrothallic. Antheridia and archeogonia remain enclosed with in the antheridial and archegonial chambers and develop on dorsal surface of the thallus. Sex organs develop in acropetal succession (i.e., mature sex organs are present at the posterior end, the young ones towards the apex of the thallus)

ANTHERIDIUM

Development

The development of antheridium starts from a superficial antheridial cell situated on the dorsal surface of the thallus (Fig 5.14). The antheridial initial enlarges in size, becomes papillate and divides first by a transverse division to form an upper

outer cells and a lower basal cell (Fig 5.14 B). Basal cell remains embedded in the tissue of thallus. Outer cell divides by transverse division to form a filament of 4 cells. Upper two cells of the 4 called filaments are known as **primary antheridial cells** and lower two cells are known as **primary stalk cells** (Fig C-E). Primary stalk cells form the stalk of the antheridium. Primary antheridial cells divide by two successive vertical divisions at right angle to each other to form two tiers of four cells each (Fig 5.14 F-G). A periclinal division is laid down in both the tiers, there is formation of eight outer **sterile jacket initials** and 8 inner **primary androgonial cells** (Fig H-J). Jacket initials divide by several anticlinal divisions to form a single layer of antheridial jacket. Primary androgonial cells divide by several repeated transverse and vertical divisions resulting in the formation of large number of small cubical androgonial cells (Fig 5.14 K-M). Androgonial mother cell is converted into androcyte mother cell. Each androcyte mother cell divides by a diagonal mitotic division to form two triangular cells called **androcytes**. Both the androcytes remain enclosed in the wall of the androcyte mother cell with one separate wall each **androcyte** has a prominent nucleus and a small extra-nuclear granule called **blepharoplast**

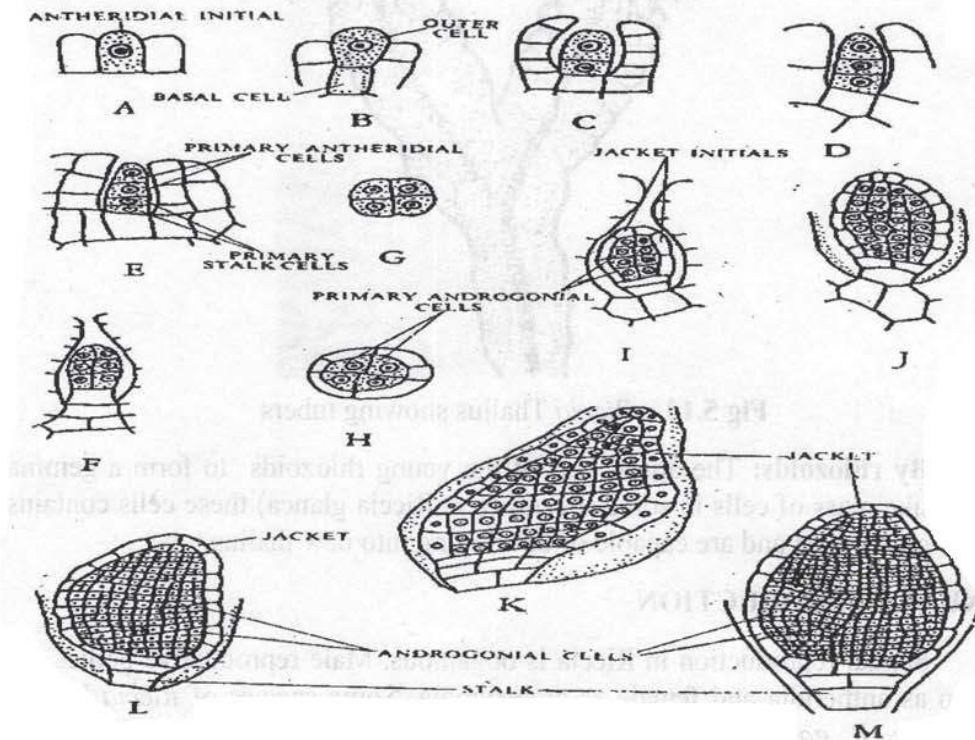


Fig 5.14 (A-M) Riccia Development of antheridium

its blepharoplast elongates into a chord. Simultaneously the nucleus also becomes crescent shaped, and ultimately comes in contact with the blepharoplast. Two large flagella develop from the conspicuously thickened end of the blepharoplast. Each androcyte thus metamorphoses into an antherozoid.



Fig 5.15 *Riccia*, antherozoid.

Dehiscence

Water helps in the dehiscence of the antheridium. As water enters in the antheridial chamber, the sterile apical cells of the antheridial jacket enlarged by absorbing water becomes softened and ultimately break open. The mature antherozoids along with semi fluid mass come out of antheridium to the antheridial chamber and then to the dorsal surface of the thallus.

ARCHEGONIUM

Development

Single superficial cell, which acts as an archeogonial initial (Fig 5.16 B). There is no further division in the basal cell and it forms the embedded portion of the archegonium. **The entire archeogonium develops from the outer cell.** This outer cell divides by three successive interesting walls or periclinal vertical walls resulting in the formation of three peripheral initials and a fourth median cell, the **primary axial cell** (Fig 5.16 CE).

Each of the three peripheral initials divides by an anticlinal vertical division forming two cells. In this way the primary axial cell gets surrounded by six cells (Fig 5.16J-M). These cells are called **jacket initials**. Six jacket initials divide transversely into upper **neck initials** tier and lower venter initial tier (Fig 5.16 G). Neck initials tier divides by repeated transverse division to form tube-like neck. Neck of the archegonium consists of **six vertical row** and each row consists six to nine cells. Venter initial tier also divide by repeated transverse division to form a single layer of swollen venter.

Simultaneously the primary axial small cell divides transversely and unequally to form small **upper primary cover cell** and **large lower central cell** (Fig 5.16F). The central cell divides into an upper primary **neck canal cell** and a **lower venter cell**. Primary neck canal divides by a series of transverse division to form four neck canal cells. Primary venter cell divides only once and forms a small **venter canal cell** and a large **egg**. (Fig 5.16 JK).

The primary cover cell divides by two vertical division forming four **cover cells** which form the mouth of the archegonium.

Mature archegonium

A mature archegonium is a flask shaped structure. It remains attached to the thallus. It consists of upper elongated slender **neck** and basal globular portion

called **venter**. The neck consists of six vertical rows enclosing four neck canal cells. The venter consists of a small venter canal cell and large egg. Four cover cells are present at the top of the neck (Fig 5.16 L)

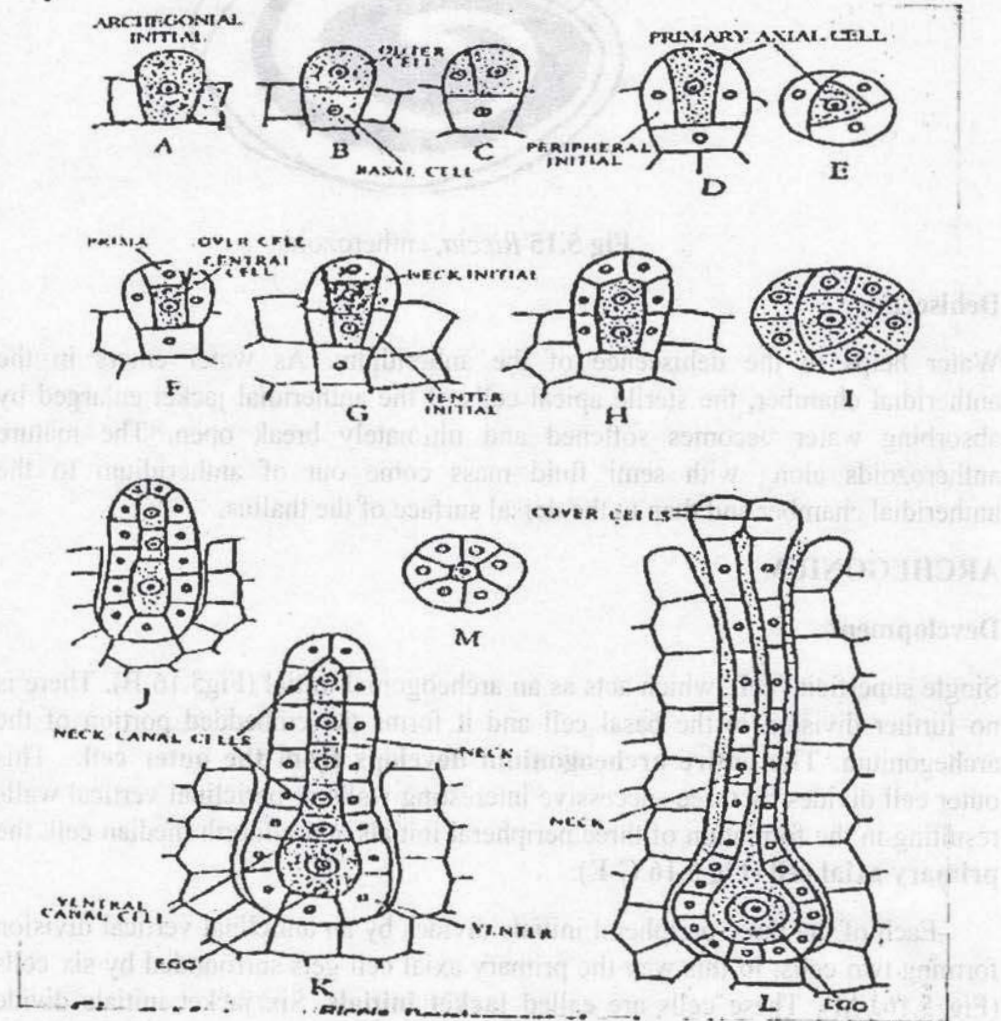


Fig 5.16 *Riccia* Development of archegonium.

Fertilization

Water is essential for fertilization. It enters the antheridial chamber. Apical cells of the antheridial wall get swollen by absorbing water. These cells become softened and finally breakdown to release mass of antherozoids. These antherozoids come up to dorsal surface of the thallus from the antheridial chamber where they swim in the thin film of water and reach the mouth of the neck of the archegonium.

In the mature archegonium the venter canal cell and neck cell disintegrate and form a mucilaginous mass. It absorbs water, swells up and comes out of the archegonial mouth by pushing the cover cell apart. Many antherozoids enter the archegonial neck up to egg. One of the antherozoids penetrates the egg and fertilization is effected (Fig 5.16 A-C) with the formation of diploid **zygote** or **oospore**.

SPOROPHYTIC PHASE

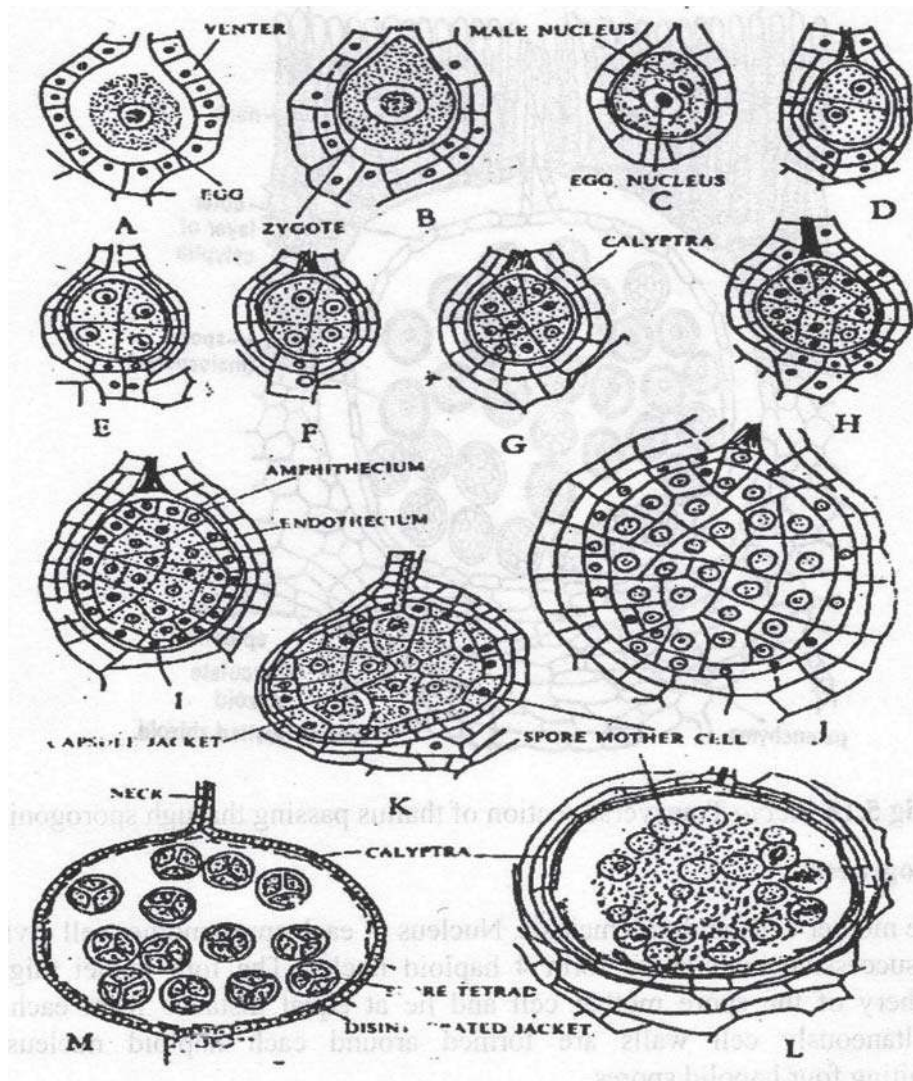


Fig 5.17 Development of Sporogonium

After fertilization the diploid zygote or oospore enlarge and fills cavity of the venter of the archegonium. A wall is then secreted around the oospore. The zygote divides first by a transverse division to form two almost equal sized cells (Fig 5.17 D). The second division is at right angle to the first and results in the formation of four cells. This represent quadrant stage (Fig 5.17E). The next division is also vertical. It is called octant stage (fig 5.17 D). The cells of the octant stage divides in all the possible planes to form a spherical mass of 20- 40 cells (Fig 5.17 E-H). The cells of the peripheral region divide by a periclinal division to form an outer layer of **amphithecium** and the central mass of cells called **endothecium**. The cells of the amphithecium divide only by anticlinal division to form a single-layered sterile jacket or capsule wall. The endothellium forms the archesporium. Its cells divide and redivide to form a mass of sporogenous cells (sporocytes) Fig 5.17 (I—L.)

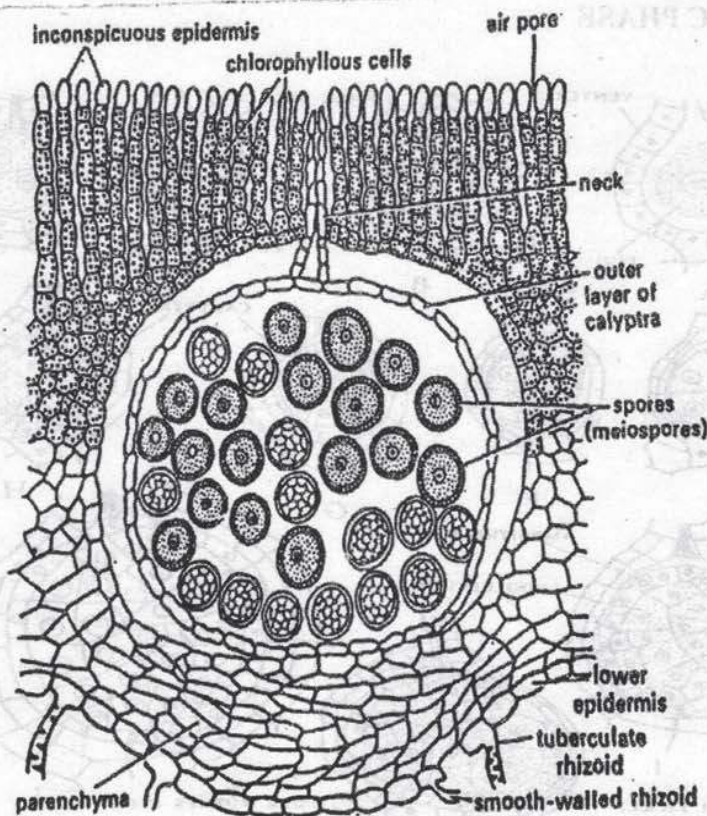


Fig 5.18 *Riccia* Transverse section of thallus passing through sporogonium

Sporogenesis

Spore mother cells undergo meiosis. Nucleus of each spore mother cell divides by two successive division to form 4 haploid nuclei. The four nuclei migrate to periphery of the spore mother cell and lie at equal distance from each other. Simultaneously cell walls are formed around each haploid nucleus, thus delimiting four haploid spores.

The spores are tetrahedrally arranged. However, in *Riccia personii* four spores are iso bilaterally arranged (Khan, 1953). The haploid number of chromosome is 8 in species like *Riccia arvensis*, *R. campbelliana*, *R. donellie*.

Mature sporogonium

A mature sporogonium is represented only by spherical spore sac or capsule. It lacks foot and seta (Fig 5.18). It has a single-layered capsule wall which encloses spores. There are no elaters. A bilayered calyptras forms a protective covering around the capsule. The capsule wall and inner layer of calyptras break down before the spore mother cell divides to form spores. After meiosis the mass of spores lies free in the outer layer of calyptra. The newly formed young gametophyte remains enclosed within the old gametophyte.

The spore

Spores are very small (0.05-0.12mm in diameter). They are haploid uninucleate and pyramidal in shape. Each spore remains surrounded by three layers i.e. an

outermost ornamented cut inside layer called **exosporium**, the middle layer called **mesosporium** (differentiated into 3 concentric zones) and the innermost layer called the **endosporium**. The endosporium is made up of cellulose and pectose (Beer,1906). There is no special method of spore dispersal and disperse after death and decay of calyptras and surrounding tissue.

Germination of spores and formation of young gametophyte

Water is essential for spore generation. According to Campbell (1918) the exosporium and mesosporium rupture at the triradiate mark and endosporium comes out in the form of a tubular outgrowth called germinal tube (Fig 5.19A-C). The germ tube elongates rapidly to form a club-shaped structure because the content of the cytoplasm move to the distal end. At the end it divides by a transverse division to form a small cell (Fig 5.19D). It again divides by a transverse division which is parallel to first division. Both these cells divide by two vertical division at right angle to one another and form two tiers of four cell each. This represents **octant stage** (Fig 5.19E). The distal tier of four cells of the octant stage functions as an apical cell with 2 **cutting faces**. It cuts a number of cells on its left and right side to form the multicellular thallus

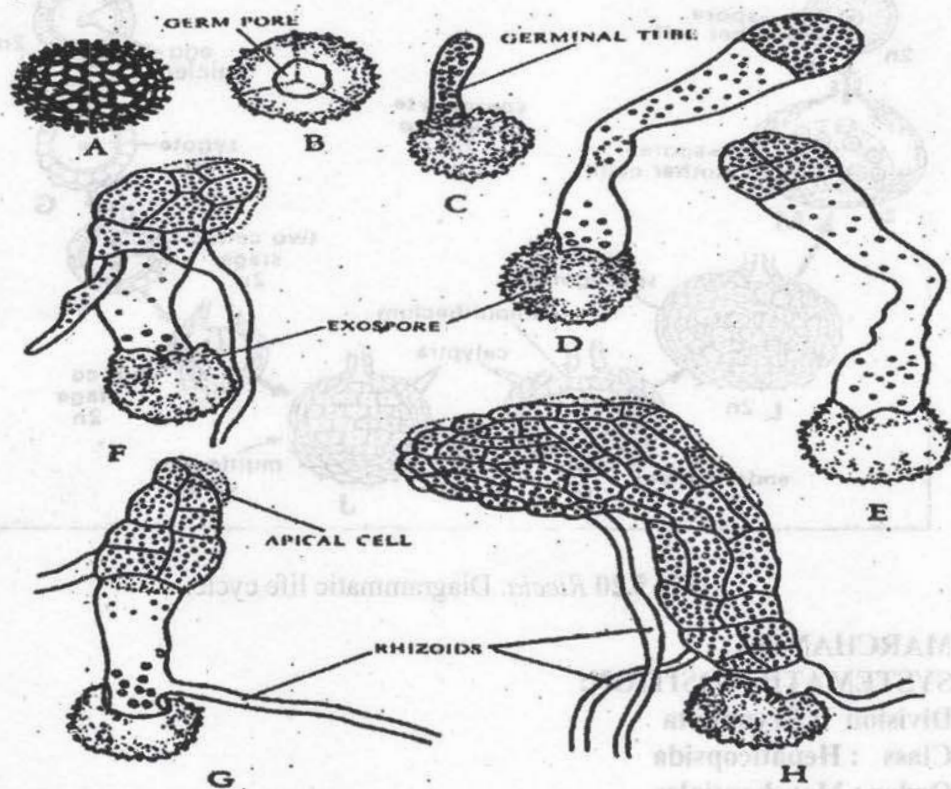
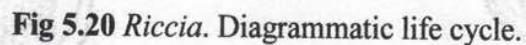


Fig 5.19 Riccia .Germination of spore and formation of young gametophyte.

Along with these division the first rhizoid develop at the base of the germ tube. Many rhizoids develop later on from multicellular thallus and fix it in the soil.(Fig 5.19A-H). Formation of rhizoids is affected by light intensity (**Chopra** and **Sood** , 1973). Rhizoids develop in the light of medium intensity (200 Lux). In *Riccia crustissi* two spores of a tetrad develop into male thalli and two spores develop into female thalli (**Mc Allister**,s1928).



DISTRIBUTION AND HABITAT:

UGBY-103/136

France. All species are terrestrial and cosmopolitan in distribution. These species prefer to grow in moist and shady places like wet open woodlands, banks of streams, wood rocks or on shaded stub rocks.

In India, *Marchantia* is represented by about 11 species (Chopra, 1943). Udar (1970) reported only 6 species from different parts of the country. These species are commonly found growing in the Himalayan region at altitude of 4000-8000 feet. Some species are also found growing in plains of Haryana, Punjab, Uttar Pradesh and hilly regions of South India. Some of the common Indian species are *M. palmata*, *M. polymorpha*, *M. simlana* etc. *M. polymorpha* is most widely distributed species.

GAMETOPHYTIC PHASE

EXTERNAL FEATURES OF GAMETOPHYTE

The plant body is gametophytic, thalloid, flat prostrate, plagiotropic, 2-10 cm. long and dichotomously branched (Fig 5.21 A)

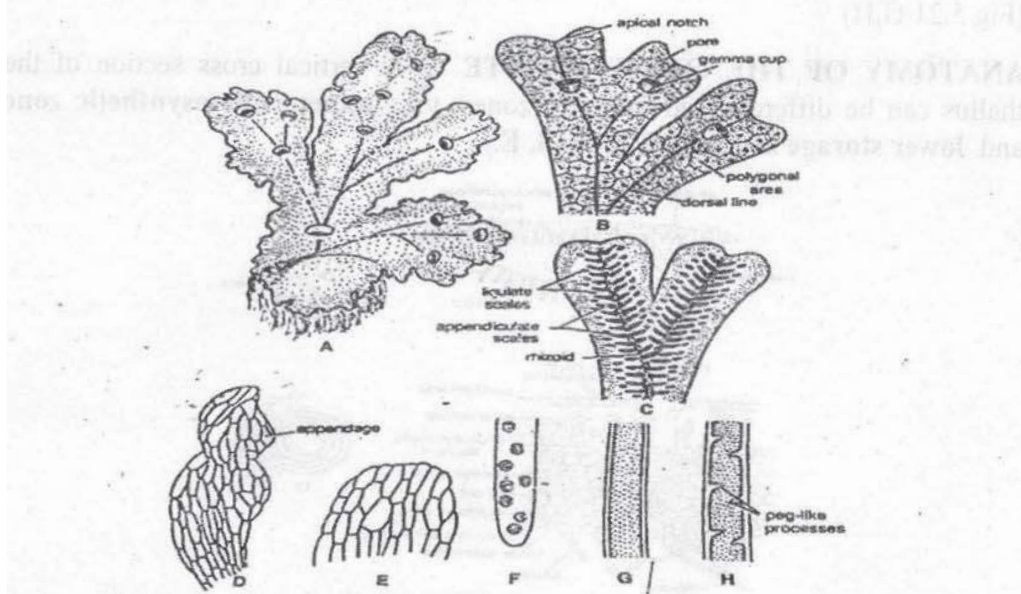


Fig 5.21 *Marchantia* Thallus structure (A) Vegetation thallus (B) Dorsal surface (C) Ventral surface (D) Scale (E) Ligulate scale (F) Tuberculated rhizoid surface view (G) Smooth walled rhizoid (H) Tuberculated rhizoid showing internal view

Dorsal surface. Dorsal surface is dark green. It has a conspicuous midrib and a number of polygonal areas called **areolae**. The midrib is marked on the dorsal surface by a shallow groove and on the ventral surface by a low ridge. Each polygonal area represents the underlying **air chamber**. The boundaries of these areas, represents the walls that separate each air chamber from the next. Each air chamber has a central pore. The midrib ends in a depression at the apical region forming an **apical notch** in which growing point is situated (Fig 5.21 B).

Dorsal surface also bears the vegetative and sexual reproductive structures. The vegetative reproductive structures are **gemma cup** and develop along the midrib. These are crescent/shaped with spiny or fimbriate margins and are about one eighth of an inch in diameter. Sexual reproductive structures are borne on special stalked

structures **gametophores** or **gametangiophores**. The gametophores bearing archegonia are called **archegoniophores** and that bearing antheridia **antheridiophores**

Ventral surface. The ventral surface of the thallus bears scales and rhizoids along the midrib. Scales are violet coloured, multicellular, one cell thick and arranged in 2-4 rows. Scales are of type : (i) **simple** or **ligulate** and (ii) **appendiculate**. Appendiculate scales form the inner row of the scales close with midrib. Ligulate scales form the outer or marginal row and are smaller than the appendiculate scales (Fig 5.21 A).

Rhizoids are unicellular, branched. They are of two types: (i) **smooth-walled rhizoids**, (ii) **tuberculate rhizoid**. In smooth-walled rhizoids, both the inner and outer wall layers are fully stretched while in tuberculate rhizoids appear circular dots in surface view. The inner wall layer modifies into peg like in growth which projects into cell lumen. The main functions of the rhizoids are to anchor the thallus on the substratum and to absorb water and mineral nutrients from the soil. (Fig 5.21 G,H)

ANATOMY OF THE GAMETOPHYTE A vertical cross section of the thallus can be differentiated into two zones, viz., **upper photosynthetic zone** and **lower storage zone**(Fig 5.22 A, B, E.)

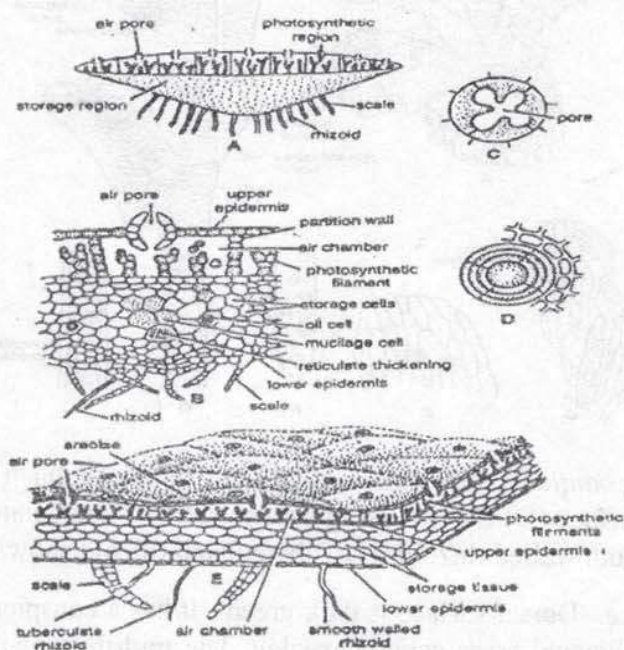


Fig 5.22 *Marchantia*. Internal structure of the thallus. (A) Vertical Transverse Section (V.T.S) of the thallus (diagrammatic) (B) V.T.S of thallus (a part cellular) (C) Air pore as seen in the ventral view, (D) Air pore as seen in the dorsal view (E) V.T.S of the thallus in three dimensional view.

Upper Photosynthetic zone. The outermost layer is upper epidermis. Its cells are thin walled square, compactly arranged and contain few chloroplast. Its continuity is broken by the presence of many barrel shaped air pore. Each pore is surrounded by four to eight superimposed tiers of concentric rings with four to three cells in each tier. The lower tier consists of four cells which projects in the

pore and the opening of the pore look like in the surface view. The walls of the air pore lie half below and half above the upper epidermis (Fig 5.22B)

Just below the upper epidermis photosynthetic chambers are present in a horizontal layer (Fig 5.22B). Each air pore opens inside the air chamber and helps in exchange of gases during photosynthesis. Cells contain chloroplast. Many simple or branched photosynthetic filaments arise from the base of the air chambers (Fig 5.22 B)

Lower storage zone .It lies below the air chamber. It is more thickened in the centre and gradually tapers towards and the margins. It consists of the several layers of compactly arranged, thin walled parenchymatous isodiametric cells. The cells of this zone contain starch. Some cells contain a single large oil body or filled with mucilage. Some cells of the middle layers of lower epidermis to form both types of scales and rhizoids (Fig 5.22B).

REPRODUCTION

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

Vegetative reproduction

In *Marchantia* it is quite common and takes place by following methods :

1. **By Gemmae.** Gemmae are produced in the **gemma cups** which are found on the dorsal surface of the thallus (Fig 5.23A) Gemma cups are crescent shaped, 3 mm in diameter with smooth, spiny differentiated into two regions : **upper photosynthetic region** and **inner storage region**. Mature gemmae are found to be attached at the base of the gemma cup by a single celled stalk. Intermingled with gemmae are many mucilage hairs. Each gemma is autotrophic, multicellular, bilaterally symmetrical thick in the centre and thin at the apex. It is notched on two sides in which lies the growing point (Fig 5.23C)

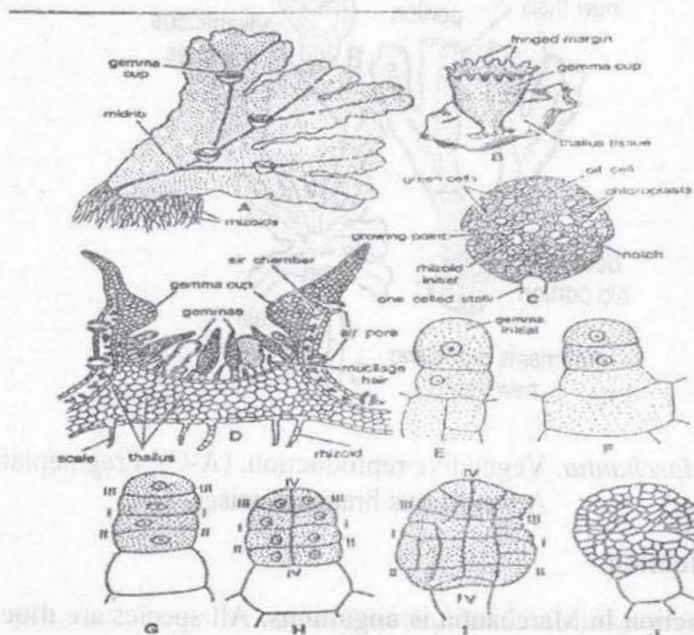


Fig 5.23 *Marchantia*. Gemma Cup (A) Thallus showing gemma cup on the dorsal surface. (B) A gemma cup, (C) Gemma (D) Gemma cup in vertical section (E-J) Different stages in the development of Gemma.

Dissemination of Gemmae. Mucilage hairs secrete mucilage on absorption of water. It swells up and presses the gemmae to get detached from the stalk in the gemma cup. They may also be detached from the stalk due to the pressure exerted by the growth of the young gemmae.

Germination of Gemmae. After falling on suitable substratum gemmae germinate. The growing point in which lies the two lateral notches from the thalli in opposite direction. Thus, **from a single gemmae two thalli are formed.** Gemmae which develop on the male thalli form the male plants and those on the female thalli form the female plant.

2. **Death and decay of the older portion of the thallus or fragmentation.** The thallus dichotomously branched. The basal part of the thallus rots and disintegrates due to ageing. When this process reaches up to the place of dichotomy, the lobes of the thallus gets separated. The detached lobes or fragments develop into independent thalli by apical growth (Fig 5.24 A-C).
3. **By adventitious branches.** The adventitious branches develop from any part of the thallus or the ventral surface of the thallus or rarely from the stalk and disc of the archegoniophore in species like *M. palmata* (Kashyap, 1919). On being detached these branched develop into new thallus (Fig 5.24D).

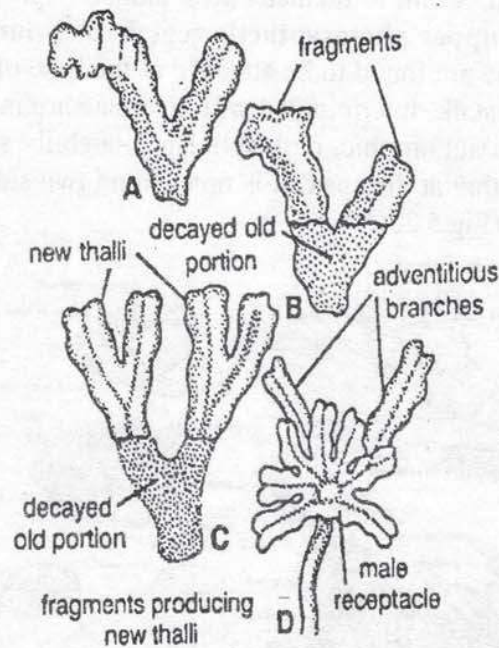


Fig 5.24 *Marchantia*. Vegetative reproduction, (A-C), Fragmentation (D) Adventitious branches arises.

Sexual reproduction

Sexual reproduction In *Marchantia* is **oogamous**. All species are **dioecious**. Male reproductive bodies are known as **antheridia** and females as **archegonia**. Antheridia and archegonia are produced on special erect modified lateral branched of thallus called **antheridiophore** and **archegoniophore** (carpocephalum) respectively.

Antheridiophore . It consists of 1-3 centimeter long stalk and a lobe disc at the apex (Fig 5.25 A). The disc is usually eight lobed. The disc is a result of repeated dichotomies.

L.S. through disc of Antheridiophore. The disc consists of air chambers alternating with antheridial cavities. Air chambers are more or less triangular and open on the upper surface by pore called **ostiole** . antheridia arise in acropetal succession i.e. the older near the centre and youngest at the margins

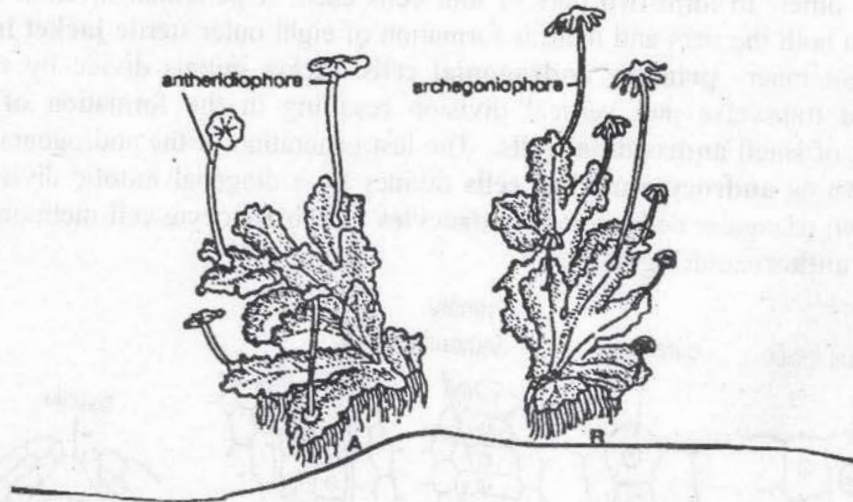


Fig 5.25 *Marchantia* Gametophores (A) Thallus bearing antheridiophores, (B) Female thallus bearing archegoniophores,

Mature antheridium. A mature antheridium is globular in shape and can be differentiated into two **stalk and body** . Stalk is short multicellular and attached the body to the base of the antheridial chamber. A single layered sterile jacket encloses the mass of **androcyte mother cell** which metamorphosis into antherozoids. The antherozoid is a minute rod like biflagellate structure.

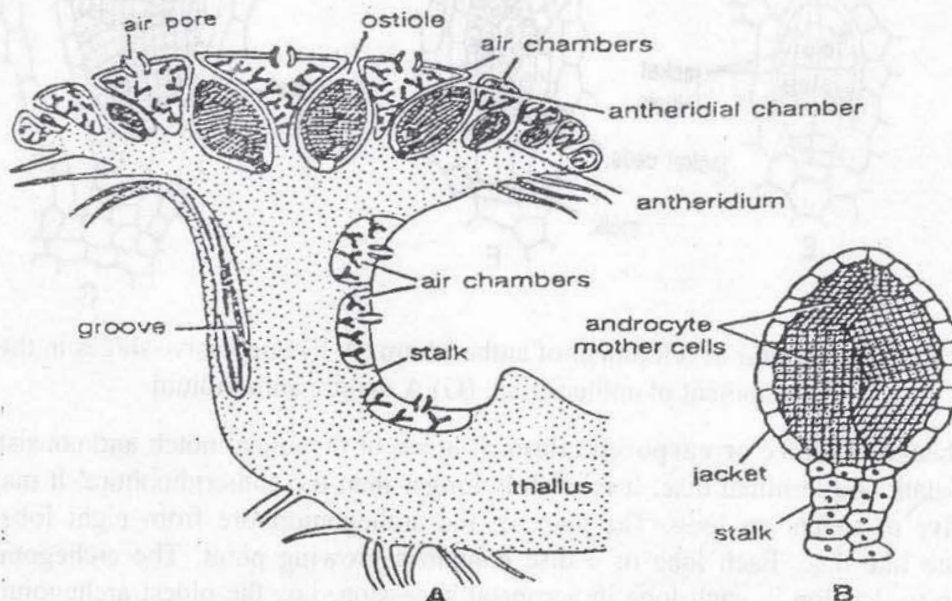


Fig 5.26 (A-B) *Marchantia* Antheridia (A) Vertical or longitudinal section passing through disc of antheridiophore (B) a mature antheridium.

Development of Antheridium : The antheridial initial divides by a transverse division to form an outer upper cell. Basal cell undergoes a little further development and forms the embedded portion of the antheridial stalk. Outer cell divides to form a filament of four cells. Upper two cells of the four celled filament are known as **primary antheridial cells** and lower two cells are known as **primary stalk cells**. Primary stalk cells from the stalk of the antheridium. primary antheridial cells divides by two successive vertical division at right angle to each other to form two tiers of four cells each. A periclinal division is laid down in both the tiers and there is formation of eight outer sterile **jacket initials** and eight inner **primary androgonial cells**. Jacket initials divide by several repeated transverse and vertical division resulting in the formation of large number of small **androgonial cells**. The last generation of the androgonial cells is known as **androcyte mother cells** divides by a diagonal mitotic division to form two triangular cells called **androcytes**. Each androcyte cell metamorphosis into an **antherozoid**(Fig 5.27).

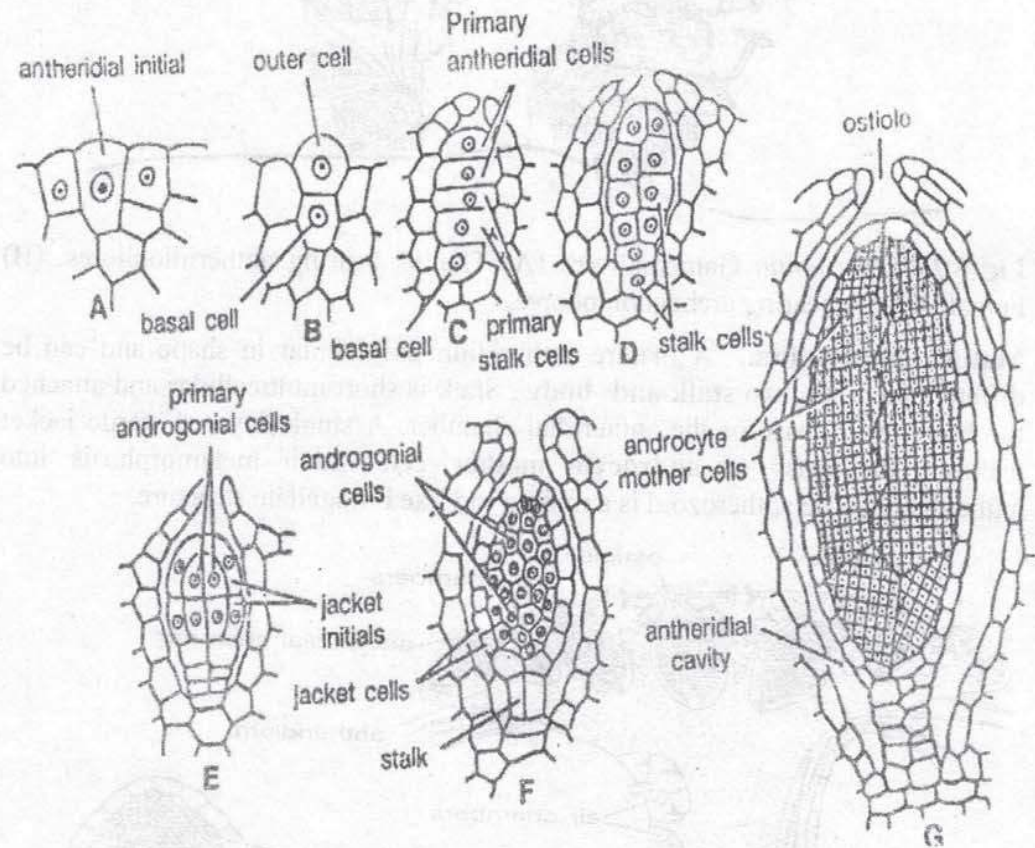


Fig 5.27 *Marchantia* development of antheridium (A-F) Successive stages in the development of antheridium, (G) A mature antheridium

Archeagoniophore or carpocephalum. It arises at the apical notch and consists of a stalk and terminal disc. It is slightly longer than the antheridiophore. It may be five to seven cm long. The apex of the archeagoniophore from eight lobed rosette like disc. Each lobe of a disc contain a growing point. The archeogonia begin to develop in each lobe in acropetal succession, i.e., the oldest archeogonium near the centre and the young archeogonium near the apex of the disc.

Development of archegonium : The development of the archegonium starts on the dorsal surface of the young receptacle in acropetal succession. A single superficial cell which acts as **archegonial initial** enlarges and divides by transverse division to form a **basal cell or primary stalk cell** and an **outer cell or primary archegonial cell**. The primary stalk undergoes irregular division and forms the stalk of the archegonium. The primary archegonial cell divides by three successive periclinial vertical walls resulting in the formation of three **peripheral initials** and a fourth median cells, the **primary axial cell**. Fig (5.28)

Each of the three peripheral initials divide **jacket initials**. Six jacket initials divide transversely into upper **neck initials** and lower **venter initials**. Neck initial divides by repeated transverse division to form a tube like **neck**. Neck of the archegonium is of six vertical rows.

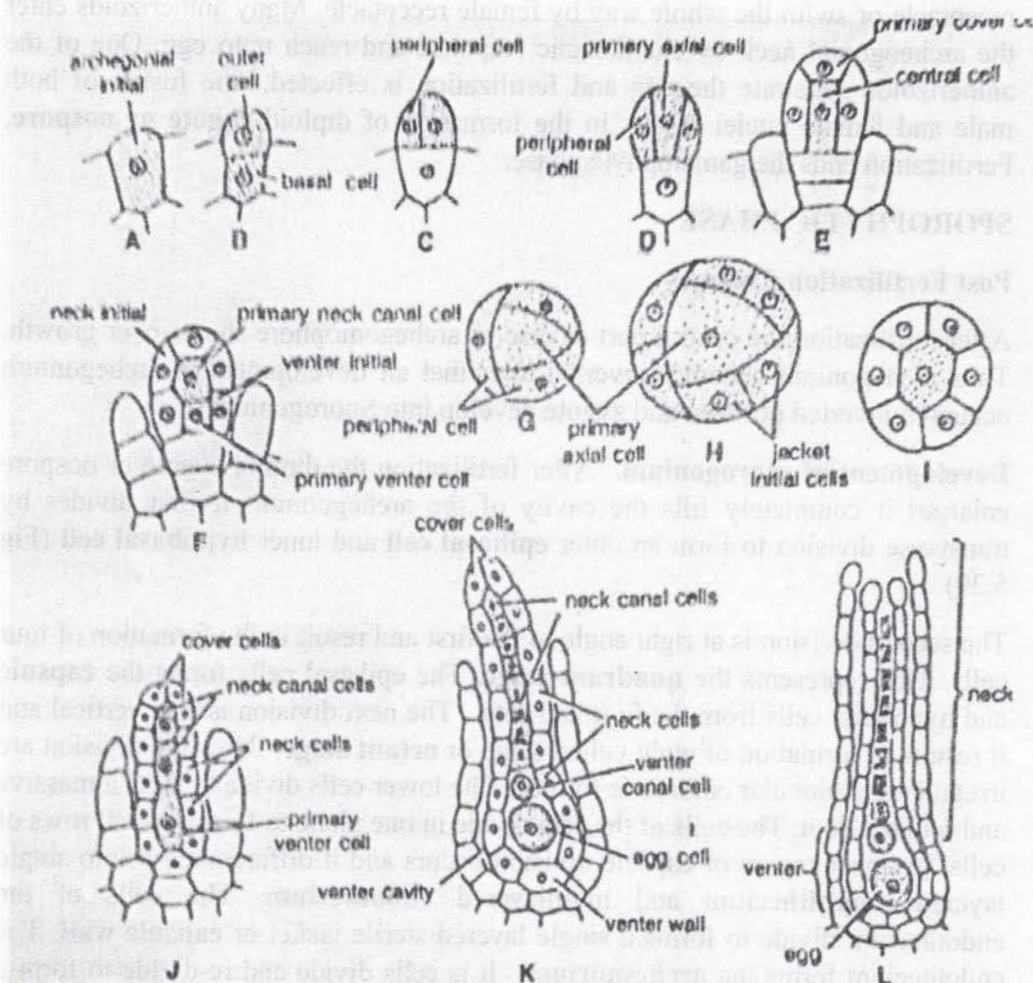


Fig 5.28 *Marchantia* Development of archegonium (A-K) successive stages in the development of archegonium.

Simultaneously, the primary axial cell divides transversely and unequally to form upper small **primary cover cell** and lower large **central cell**. The central cell divides into **primary neck canal cell** and a lower **venter cell**. Primary neck canal cells divide by a series of transverse divisions to form a row of about eight thin walled **neck canal cells**. Primary venter cell divides only once and forms a small upper **venter canal cell** and a lower large **egg or ovum**.

Mature Archegonium A mature archegonium is a flask shaped structure. It remains attached to the archegonial disc by a short **stalk**. It consist upper elongated slender **neck** and basal globular portion called **venter**. The neck consists of six vertical rows enclosing eight neck canal cells and large egg. Four cover cells are present at the top of the neck.

Fertilization:- Fertilization takes place when male and female thalli grow near each other. Water is essential for fertilization. In the mature archegonium the venter canal cell and neck canal cell disintegrate and form a mucilaginous mass. It absorbs water, swells up and comes out of the archegonial mouth by pushing the cover cells apart. This mucilaginous mass consist of chemical substance.

The antherizoids are splashed by rain drops. They may fall on the nearby female receptacle or swim the whole way by female receptacle. Many antherizoids enter the archeogonial neck by chemotactic response and reach upto egg. One of the antherizoids penetrate the egg and fertilization is effected. The fusion of both male and female nuclei results in the formation of diploid **zygote or oospore**. Fertilization ends the gametophyte phase.

SPOROPHYTIC PHASE

Post Fertilization Changes

After fertilization the central part of disc of archegoniophore shows over growth. Thus archegonium becomes inverted after that all development in archegonium occurs in inverted position and zygote develop into Sporogonium

Development of sporogonium. After fertilization the diploid zygote or oospore enlarges it completely fills the cavity of the archegonium. It first divides by transverse division to form an outer **epibasal cell** and inner **hypobasal cell** (Fig 5.29)

The second division is at right angle to the first and result in the formation of four cells. This represents the **quadrant stage**. The epibasal cells forms the **capsule** and hypobasal cells from the **foot** and **seta**. The next division is also vertical and it results in formation of eight celled stage or **octant stage**. Now the division are irregular and globular embryo is formed. The lower cells divide to form a massive and bulbous foot. The cells of the seta divide in one plane to form vertical rows of cells. In upper region of capsule division occurs and it differentiate it into single layered **amphithecium** and multilayered **endothecium**. The cells of the endothecium divide to forms a single layered sterile jacket or **capsule wall**. The endothecium forms the **archesporium**. It is cells divide and re-divide to form a mass of **sporogenous cells** (sporocytes). Half of the sporogenous cells became narrow and elongated to form the **elater mother cells**. The elater mother cells elongates considerably to form long, slender **diploid** cells called **elaters**. Elaters are pointed at both the ends and have two spiral bands or thickenings in the surface of the walls. These are hygroscopic in nature and helps in dispersal of spores. The spore mother cells are diploid and divides meiotically to form four haploid spores which remain arranged tetrahedrally for quite sometimes. The spores later become free and remain enclosed by the capsule wall along elaters (Fig 5.29H)

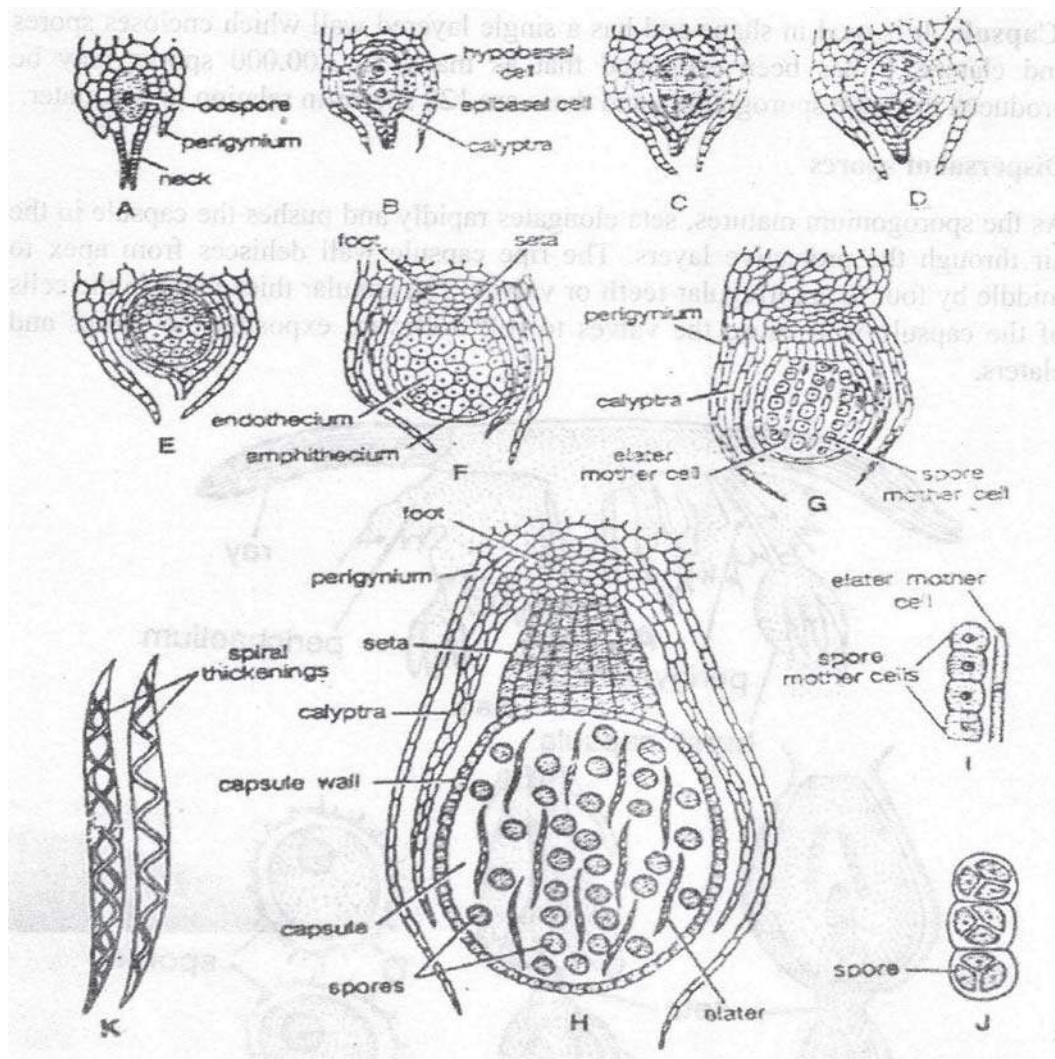


Fig 5.29 *Marchantia* Development of sporophyt (A-3) Successive stages in the development of sporogonium (H) L.S. of mature sporogonium (J) Spores tetrad (K) Two elaters

The quadrant type of development of sporogonium is quite common in many species of *Marchantia* (e.g. , *M polymorpha*) but in a few species zygote divides by two transverse division to form the 3- celled filamentous embryo. In it the hypobasal cell forms the foot, the middle seta and the epi.basal cell develops into capsule. However, it is the rare type of embryo development in *M. ch2nopoda*.

Mature sporogonium

A mature sporogonium can be different into three parts. viz., the footseta and capsule (Fig 5.29 H).

Foot. It is bulbous and multicellular. It is composed of parenchymatous cells, It acts as anchoring and absorbing organ. It absorbs the food from the adjoining gametophytic cells for the developing sporophyte.

Seta. It connects the foot and the capsule. At maturity, due to many transverse division it elongates and pushes the capsule through three protective layer viz., calyptra, perigynium and perichactum

Capsule. It is oval in shape and has a single layered wall which encloses spores and elaters. It has been estimated that as many as 3,00,000 spores may be produced in single sporogonium and these are 128 spores in relation to one elater.

Dispersal of spores

As the sporogonium matures, seta elongates rapidly and pushes the capsule in the air through the protective layers. The ripe capsule wall dehisces from apex to middle by four to six irregular **teeth** or **valves**. The annular thickening in the cells of the capsule wall cause the valves to roll backward exposing the spores and elaters.

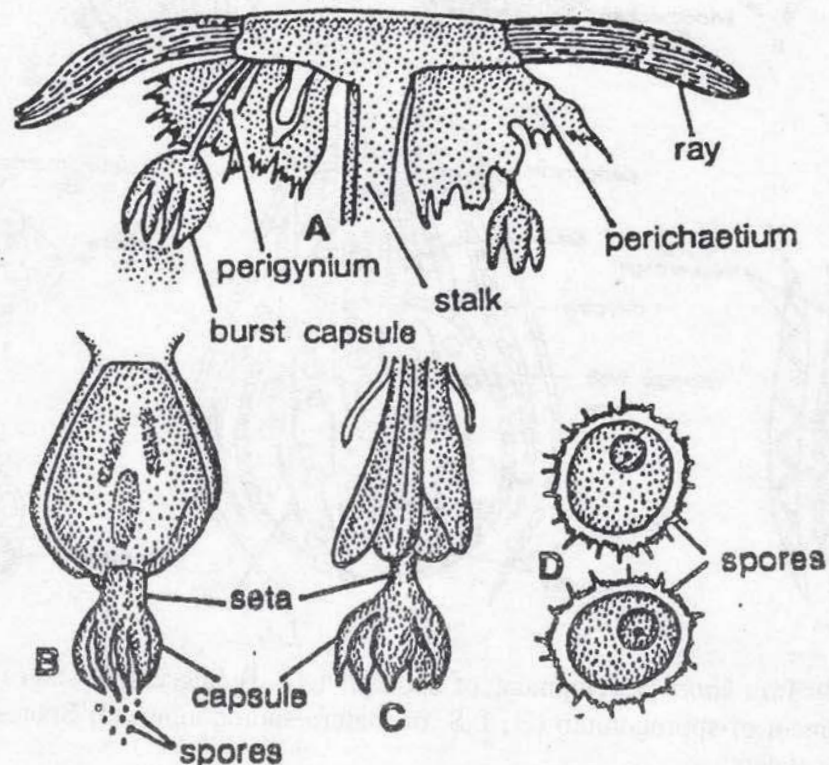


Fig 5.30 *Marchantia* Dehiscence of capsule (A) V.L.S. of archegonophore after the formation of capsule (B-C) Dehiscence of capsule (D) Spores

Germination of spore and development of Gametophyte

Under favorable conditions, the spores germinate immediately. Before germination it divides by transverse division to form two unequal cells. The lower cell is small in size. It is relatively poor in cell contents, achlorophyllous and extend to form **germ-rhizoid**. The large cell is chlorophyllous and undergoes division to form a six to eight cell **germ-filament or protonema**. The apex is cut off from the rest of the sporeling by a division. It behaves as apical cell. These cells by repeated division form a plate like **structure**. According to **O' Hanlson's** (1976) a marginal row of cells appears in the apical region in this plate. By the activity of these marginal cells, the expansion of the plate takes place into thallus, a characteristics of *Marchantia*, (Fig 5.31)

Marchantia is **dioecious**, 50% of the spores develop into male thalli and 50% develop into female thalli.

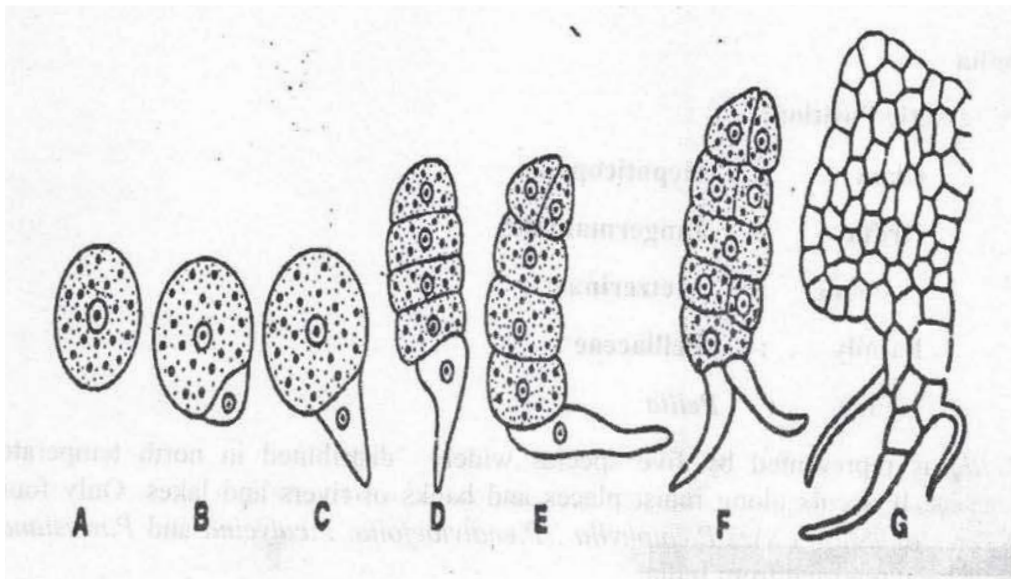


Fig 5.31 *Marchantia* Successive stages in the germination of spore and development of sporophyte.

Alternation of Generation. The life cycle of *Marchantia* shows regular alternation of two morphologically distinct phases. One of the generation is **Haplophase** and the other is **Diplophase**.

Haplophase or gametophytic phase. In *Marchantia* this phase is dominant and produces the sex organs. Sex organs produce gametes to form a diploid zygote.

Diploid phase or sporophytic phase. Zygote develop into sporophyte. In *Mrarchantia* sporophyte is represented by the foot, seta and capsule. The sporophyte produces the spores in the capsule. The spores on the germination produces the gametophyte.

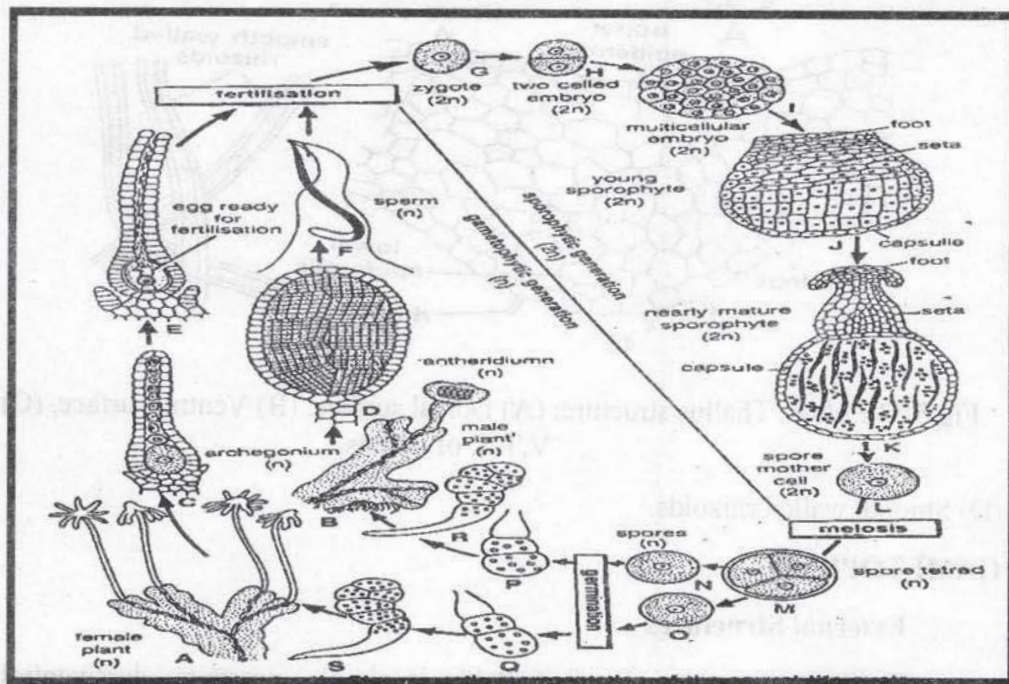


Fig 5.32 *Marchantia*: sexual life cycle.

Pellia

Systematic Position:

Class	:	Hepaticopsida
Order	:	Jungermaniales
Suborder	:	Metzerinae
Family	:	Pelliaceae
Genus	:	<i>Pellia</i>

Pellia is represented by five species widely distributed in north temperate regions. It occurs along moist places and banks of rivers and lakes. Only four species of *Pellia*, viz; *P. epiphylla*, *P. endiviaefolia*, *P. calycina* and *P. neesiana* have been reported from India.

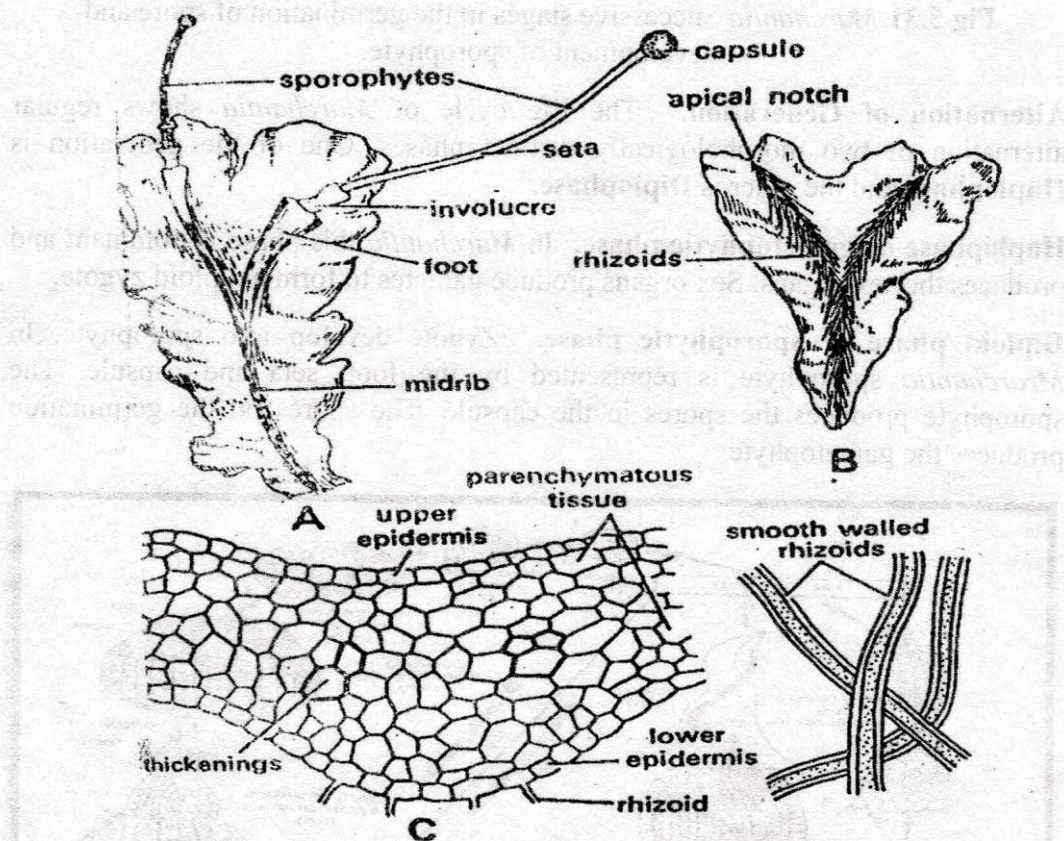


Fig 5.33 *Pellia* : Thallus structure; (A) Dorsal surface, (B) Ventral surface, (C) V.T.S. of thallus,

(D) Smooth walled rhizoids.

GAMETOPHYTE

(i) External Structures

The mature gametophyte of *Pellia* is simple, prostrate, dorsiventrally flattened, usually thin and dichotomously branched. There is an indistinct

midrib on the dorsal surface of the thallus. The thallus is irregularly lobed with sinuous margins. The lobes are dichotomously. On the ventral surface numerous unicellular smooth walled rhizoids are present (Fig 5.33). They are restricted only to the midrib regions the growing part of the thallus.

[II] Internal Structure

The internal structure of the thallus of *Pellia* is very simple. It is uniformly composed of parenchymatous cells, without any differentiation into photosynthetic and storage regions. The dorsal epidermis is continuous. The thallus is 8-16 cells thick in the midrib regions and gradually tapers towards margins. The cell of the dorsal epidermal layers and those of the few upper layers of the midrib regions and margins have abundant chloroplast. The cells of the lower layer of the midrib regions are devoid of the chloroplast.

Reproduction

In *Pellia* reproduction takes place by **vegetative** and **sexual** reproduction.

[I] Vegetative Reproduction

Vegetative propagation takes place by the following two methods

1. **By adventitious branches.** In some species the dorsal superficial cells of the marginal or apical region form adventitious branches. These branches are the form of small thalli, and on separation from the parent thallus they develop into independent plants.
2. **By fragmentation.** The progressive death and decay of the older parts of the thallus results in the separation of lobes. Each lobe develops into new plant by apical growth.

[II] Sexual Reproduction

Sexual reproduction is of **oogamous** type. The male and female reproductive structures are known as **antheridia** and **archegonia** respectively. Some species of *Pellia* are **monoecious** (e.g., *P. epiphylla*) while others are **dioecious** (e.g., *P. calcyina*, *p. neesiana*).

Antheridium.

- (a) **Structure.** Antheridia are present on the dorsal surface of the thallus in irregular rows along the midrib (fig 5.34A). They appear as wart-like projection in the midrib region. Each projection marks the position of an antheridial cavity in the thallus.

The antheridium is attached to the floor of the antheridial chamber by a multicellular stalk (Figs 5.35 K). The body of the antheridium has a singly layered **Jackets** of sterile, enclosing a multicellular mass of **ANDROCYTE MOTHER CELLS**. Each androcyte mother cell eventually forms two antherozoids.

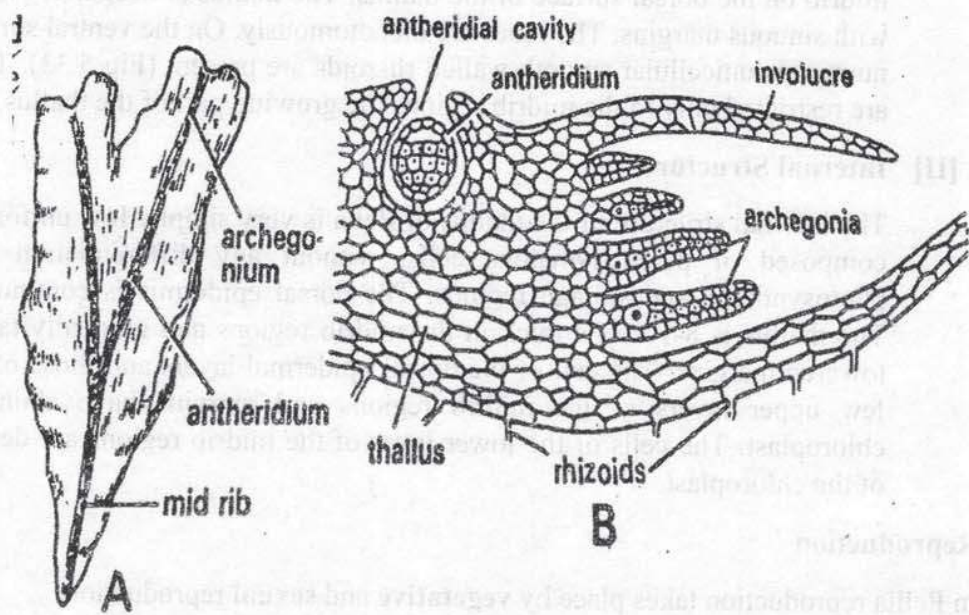


Fig 5.34 *Pellia* : Reproductive structures; (A) Thallus showing the position of antheridium and archegonium, (B) Longitudinal section of thallus showing position of sex organs.

- (b) **Development.** The antheridium develops from a single dorsal cell of the thallus (Fig 5.35) The outer cell protrudes above the thallus in the form of papilla. The later divides again by a transverse wall into a lower **primary stalk cell** and an upper **primary antheridial cell** (fig 5.35 C , D). The primary stalk cell undergoes many transverse and vertical divisions and eventually forms a multicellular stalk of the antheridium (Fig 5.35 E, F, I-K).

The primary antheridial cell, by a median vertical division, forms two daughter cells. Each of these cells divides by a nearly periclinal wall to form an outer or **second jacket initial** and an **primary androgonial cell** (fig 5.35). The first and the second jacket initial divides anticlinally and give rise to a single layered jacket of the antheridium. The primary androgonial cell divides repeatedly in all possible planes and forms a mass of androcyte mother cells, which by a diagonal division forms two androcytes (fig 5.35).The androcytes metamorphoses into antherozoids. The antherozoid is a spirally coiled structure, measuring about 70µm. it has two flagella at the apical end (fig 5.35).

- (c) **Dehiscence of antheridium.** Antheridium dehisces in the presence of water. The cells are apical part of the antheridial jacket rupture as soon as they come in contact of the water. A brown or white mucilaginous mass, containing a large number of androcytes is violently extruded. The androcyte swim freely for something and then a single antherozoid is liberated from each androcyte. The entire process of dehiscence takes about 15-20 minutes.

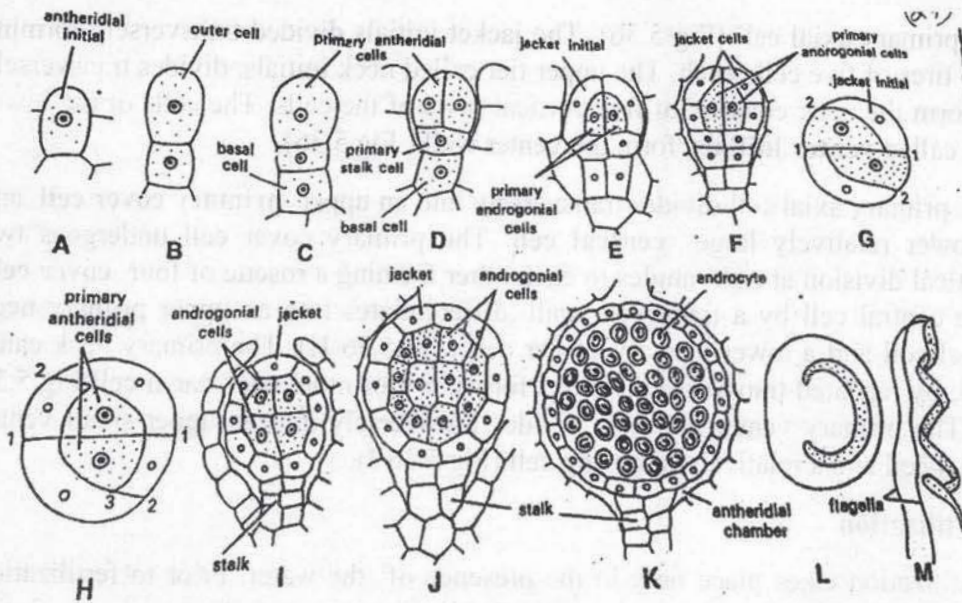


Fig 5.35 *Pellia* : Development of antheridium; (A-J) Successive stages in the development of antheridium, (K) Mature antheridium

2. Archegonium.

- (a) **Structure:** Archegonia are born in groups of 4-7, close to the apex of the thallus. Each group is protected by an involucre (Fig 5.34). The archegonia are horizontally placed with their neck directed towards the apex of the thallus.

The archegonium is differentiated into a basal venter and a long a neck. However there is a little difference in the diameter of the neck and the venter. The neck is composed vertical rows of neck cells, which encloses 6-8 neck canal cells. A rosette of four cover cells is present at the apex of the neck. The venter has a venter canal cell and a relatively large egg cell (Fig 5.36 J). The venter and the basal part of the neck of the archegonium is protected by a two layered sterile jacket.

- (b) **Development:** Archegonia are formed in groups on the dorsal surface of the thallus. Each archegonium develops from a single superficial cell, the archegonial initial, which appears as a papillate protrusion on the dorsal surface of the thallus. A transverse wall divides the archegonial initial to a basal stalk cell and an upper **archegonial mother** cell. The stalk cell divides repeatedly and eventually forms a multicellular stalk of the archegonium (Fig 5.36). The main body of the archegonium develops from the archegonium mother cell. It divides by three vertical walls (as in *Riccia* and *Marchantia*) forming three peripheral initials enclosing a primary axial cell.

Of the three peripheral initials two are comparatively large than the third one. Each of the two initials undergoes a vertical division but the smaller initials does not divide thus a ring of the five cell now called **jacket initials** is formed around

the primary axial cell (Fig 5.36). The jacket initials divided transversely forming two tiers of five cells each. The upper tier called neck initials, divides transversely to form the neck consists of five vertical rows of the cells. The cells of the lower tier called **venter initials**, form the venter wall (Fig 5.36),

The primary axial cell divides transversely into an upper **primary cover cell** and a lower relatively large **central cell**. The primary cover cell undergoes two vertical division at right angles to each other forming a rosette of four **cover cell**. The central cell by a transverse wall ,differentiates into an upper primary neck canal cell and a lower primary venter cell (Fig 5.36 H). The primary neck canal cell, by repeated transverse divisions forms, 6-9 or more neck canal cell (Fig 5.36 I). The primary venter cell also divides transversely into an upper small venter canal cell and a relatively large egg cell (Fig 5.36 J).

Fertilization

Fertilization takes place only in the presence of the water. Prior to fertilization the neck canal cells and the venter canal cells disintegrate to form a mucilaginous mass. Thus a wide passage is formed for the entry in the antherozoids. The antheridia also ruptured almost at the same time liberating antherozoids, which reach near the archegonium, they are attracted toward its neck. Although a large number of antherozoids enter into the neck of the archegonium but only one of them (usually the one which reaches first) fuses with the egg to form zygote.

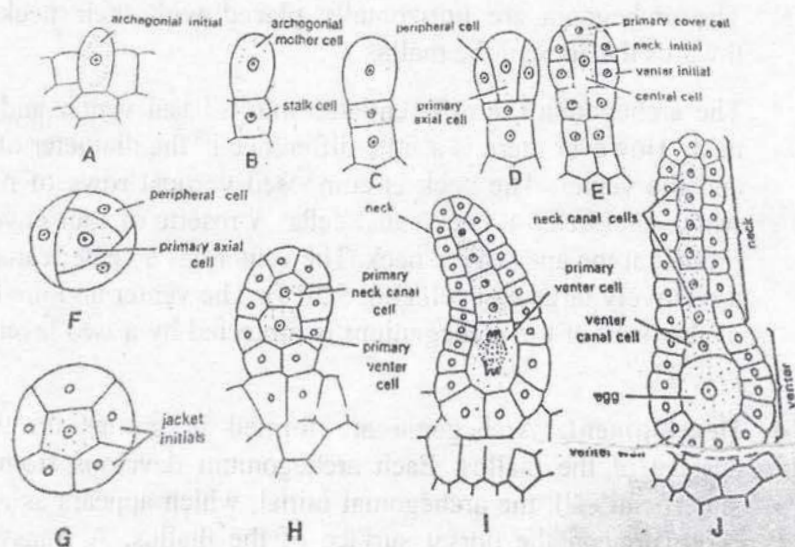


Fig 5.36 Pellia : Development of archegonium; (A-I) Successive stages in the development of archegonium, (J) Mature archegonium.

Sporophyte

The fertilized egg (Fig 5.37 A) secretes a wall and functions as the mother cell of the sporophytic generation.

(I) Development of sporophyte

The zygote increases in size and almost completely fills the venter. The first division of the zygote is transverse and with the result a lower

hypobasal cell and **outer epibasals cell** are formed. The hypobasal cell usually does not divide and it forms unicellular suspensor (or haustorium, Fig (C-D)). The epibasal cell divides first by transverse wall, followed by a vertical division and thus a 4-celled embryo is formed, which divides by a transverse wall thus two tiers of four cells are formed. The cell of the upper tier forms the capsule, whereas those of the lower, form the foot and the seta.

The cell of the upper tier is differentiated into a peripheral amphithecium and a central endothecium by a periclinal wall. The cells of the amphithecium undergo a periclinal division followed by repeated anticlinal divisions. Eventually a two layered jacket of the capsule is formed.

The endothecium functions as primary sporogenous tissue. The cells of the endothecium divide repeatedly to form a sporogenous tissue. A few sporogenous cells, located at the base, become sterile quite early in the development of the capsule. They elongate and radiate towards the center of the capsule and this mass of sterile cells constitutes **elaterophore**.

The fertile sporogenous cells undergo repeated mitotic division forming a large number of spore mother cells, which are diploid in nature. Now the nucleus of the spore mother cell divides meiotically into four haploid nuclei. This is followed by simultaneous laying down of walls and as such a tetrad of four spores is formed.

The cells of the lower tier divide repeatedly to form a parenchymatous foot and seta. The foot is conical; its upper edges project upward and surrounds the basal part of the seta like a collar. The seta is composed of several longitudinal rows of the cells.

The young sporophyte is covered by a protective sheath the **calyptra**, which develops from the cells of the venter wall.

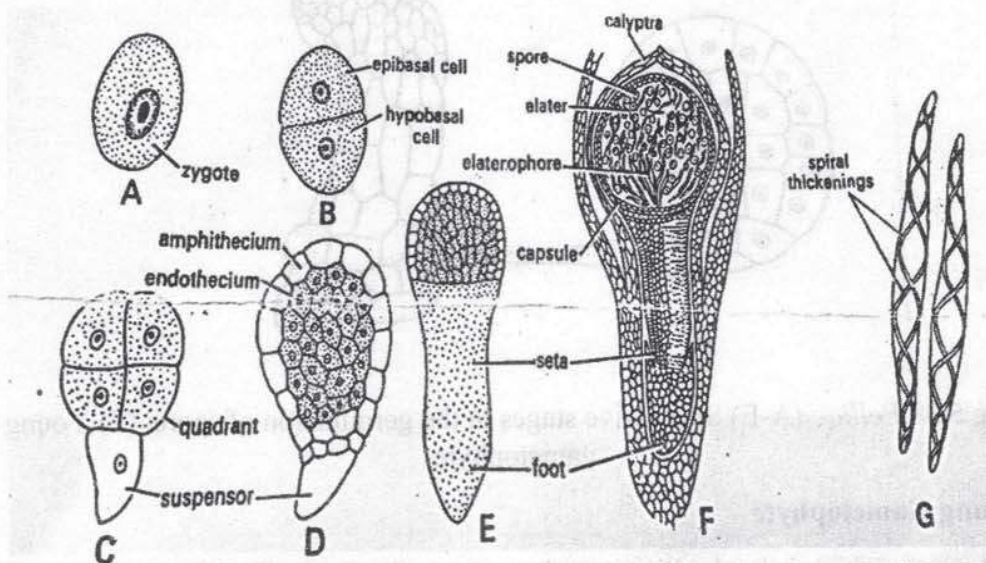


Fig 5.37 *Pellia* : Development of sporophyte; (A-E) Successive stages in the development of sporophyte, (F) Mature sporophyte, (G) Elaters.

(II) Structure of mature sporophyte

The sporophyte of *Pellia* is differentiated into foot, seta and capsule (Fig 5.37 F)

The foot is a conical parenchymatous structure. The sporophyte remains attached to the gametophyte with the help of the foot which extends like a collar around the base of the seta.

The seta is also composed of non-chlorophyllous parenchymatous cells arranged in definite longitudinal rows.

The mature **capsule** is an almost spherical structure with a two or more layered jacket. The cells of the outer layer of the jacket are polygonal with the radial thickening bands which helps in the dehiscence of the capsule. The jacket encloses a mass of spores and elaters. A characteristic feature of the sporophyte of *Pellia* is the presence of a basal elaterophore. It consists of 20-100 elongated elaters which radiate from the apex. Each elater has two spiral thickening bands (Fig 5.37G).

Dehiscence of capsule

As the capsule matures the cells of the seta undergo enormous elongation. Consequently the capsule is pushed out by rupturing the calyptra valves. Now the capsule wall splits into four petal like downwards due to hygroscopic nature of the thickening bands present in the capsule wall. The exposed mass of spores and elaters are set free.

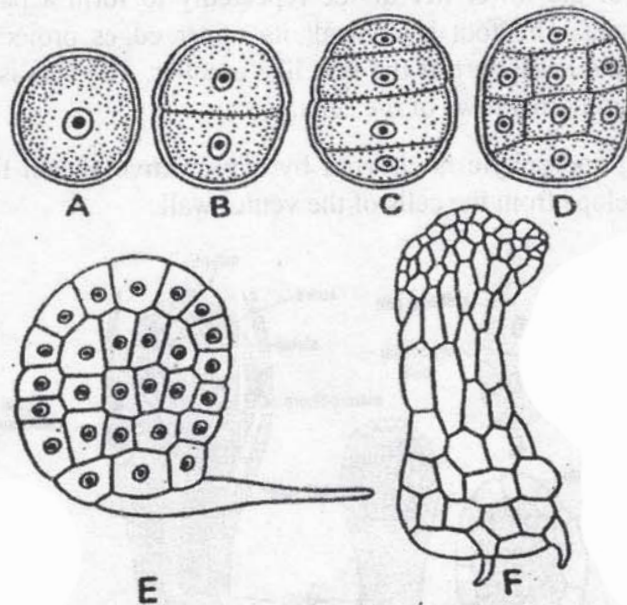


Fig 5.38 *Pellia* : (A-E) Successive stages in the germination of spore, (F) Young gametophyte.

Young Gametophyte

The spores which is haploid in nature represents the first cell of the gametophytic generations. It gives rise to gametophytic thallus on germination.

In *Pellia*, the germination of spores starts while they are encased within the capsule. It is a characteristic feature of the genus. The spores are liberated at various stages of development in different species of *Pellia* e.g., *P. epiphalla*, they are discharged at 4-6 celled stage and in *P. neesiana* at 6-9 celled stage.

The first division of the spores is transverse and the two daughter cells again divide transversely thus a four-celled filamentous structure is formed which has a terminal cell, two central cells and a basal cell. All these cells except the basal cell contain chloroplast the terminal cell undergoes two diagonal divisions intersecting each other. Thus a wedge-shaped apical cell is differentiated the central cells along with the apical cell divide rapidly and form the gametophytic thallus. The basal cell simply elongates and forms a protuberance known as **first rhizoid** it may also form secondary rhizoids.

ANTHOCEROS

SYSTEMATIC POSITION :

Division	: Bryophyta
Class	: Anthocerotopsida
Order	: Anthocerotales
Family	: Anthocerotaceae
Genus	: <i>Anthoceros</i>

DISTRIBUTION AND HABITAT

Anthoceros is represented by about 200 species. All species are terrestrial and cosmopolitan in distribution. The species grow in very moist and shady places like slopes, rocks or sides of the ditches.

GAMETOPHYTIC PHASE

EXTERNAL FEATURES

The gametophytic plant body is thalloid, dorsiventral, prostrate, dark green in colour.

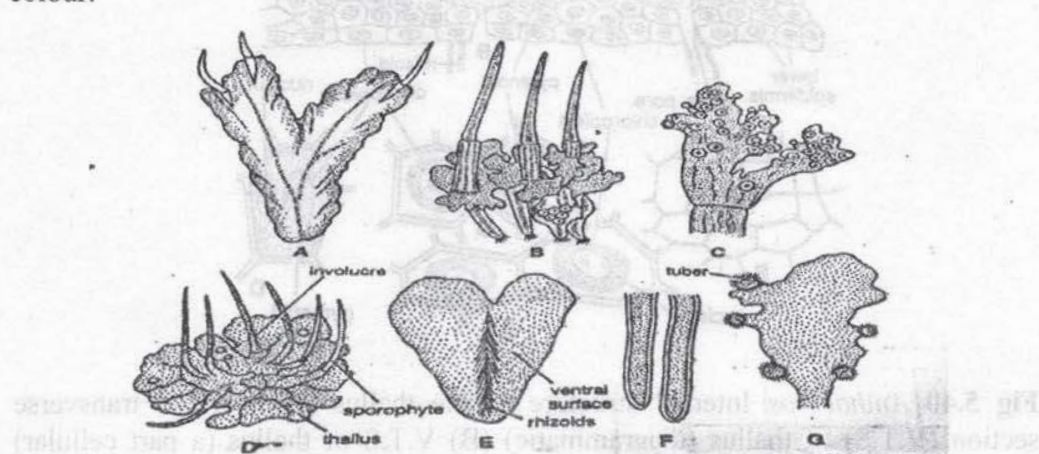


Fig 5.39 (A-F).*Anthoceros*. External features (A) *A. himalayensis*, (B) *A. erectus*, (C) *A. gemmulosus*, (D) *A. crispulus* (dorsal surface), (E) Ventral surface, (F) Smooth-walled rhizoids, (G) Thallus with tubers.

Dorsal Surface. The dorsal surface of the thallus may be smooth (*A. laevis*) or valvety because of the presence of several lobed lamellae (*A. crispuluse*) or rough with spines and ridges (*A. fusiformis*). It is shining thick in the middle and without a distinct midrib (Fig 5. 39D)

Ventral Surface. The ventral surface bears many unicellular, smooth-walled rhizoids (Fig 5.39 E ,F). Their main function is to anchor the thallus on the substratum and to absorb water and mineral nutrients from the soil. Tuberculated rhizoids, scales or mucilaginous hairs are absent. Many small, opaque, rounded, thickened dark bluish green spots can be seen on the ventral surface. These are the **mucilage cavities** filled with *Nostoc* Colonies.

INTERNAL STRUCTURES

The vertical transverse section (V.T.S) of the thallus shows a very simple structure. It lacks any zonation (Fig 5.40 A,B) The outer most layer is **upper epidermis**. The epidermal cells are regularly arranged, smaller in size and have large lens shaped chloroplast.

Each cell of the thallus contains a single large discoid or oval shaped **chloroplast** which encloses a single large **pyrenoid**. This characteristics feature of the *Anthoceros* resembles with green algae.

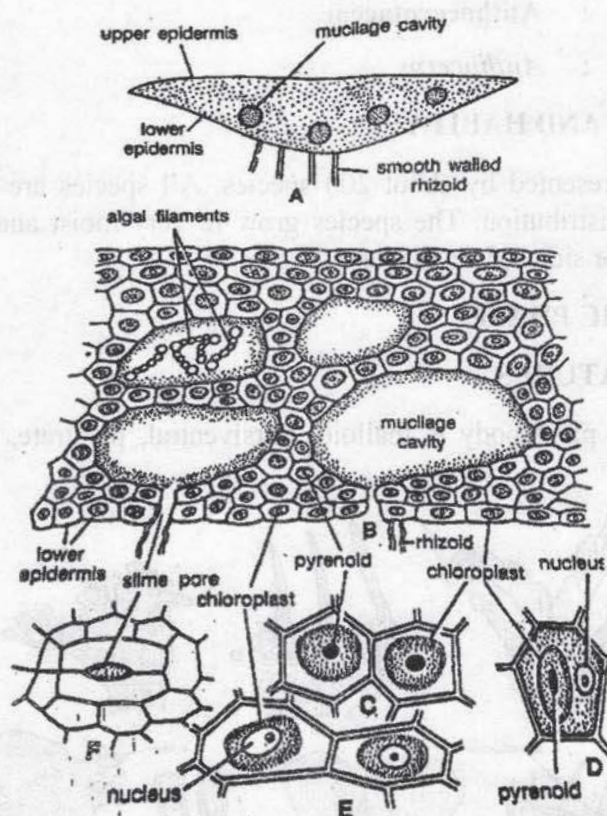


Fig 5.40 *Anthoceros* Internal structure of the thallus (A) Vertical transverse section (V.T.S) of thallus (diagrammatic) (B) V.T.S of thallus (a part cellular) (C) Cells showing chloroplast and pyrenoid (D) cells showing chloroplast pyrenoid

and nucleus, (E) Parenchymatous cells with chloroplast and nucleus (F) Surface view of slime pore.

However in few species cavities are formed due to break down cells (schizogenous). The cavities are filled with mucilage and are called **mucilage cavities** open on the ventral surface through stomata like slits or pores called **slime pores**. The blue green *Nostoc* invades these air cavities through slime pores and form a colony. In these cavities presence of *Nostoc* colonies in the thallus of *Anthoceros* is beneficial for the growth of gametophyte.

REPRODUCTION

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

Vegetative reproduction

It takes place by the following method:

By death and decay of the older portion of the thallus or fragmentation. The older portion of the thallus starts rotting or disintegrates due to ageing or droughts. As it reaches upto the place of the dichotomy the lobes of the thallus gets separated by **tubers**. Under unfavourable conditions the marginal tissue of the thallus gets thickened and forms the perennating tubers. (Fig 5.39G) these tubers have outer two to three layers of corky hyaline cells which encloses the tissue containing globules, starch grains and aleurone granules. On the resumption of favourable condition tubers produce new thalli.

By Gemmae. In some species on *Anthoceros* like *A. glandulosus*, *A. propaguliferus* many multicellular stalked structures develop along the margins of the dorsal surfaces of the thallus. These structures are called **Gemmae**. When detached from the parent thallus, each gemma develop into new plant.

By persistent growing apices. Due to prolonged dry summer the whole thallus in some species of *Anthoceros* dries and get destroyed except the growing point. Later it develops into new thallus.

Sexual reproduction

Sexual reproduction is **oogamous**. Male reproductive bodies are known as **antheridia** and female as **archeogonia**. Some species of *Anthoceros* like *A. longyi*, *A. golliani*, *A. fusiformis*, *A. punchantants*, *A. crispusulas* and *A. himalayensis* are **monoecious** while some species like *A. erectus*, *A. chambensis*, *A. hallii*, *A. personia* and *A. laevis* are **dioecious**.

Antheridium

A mature antheridium has a stalk and club or pouch like body. The stalk attaches the antheridium to the base of the antheridial chamber. A single layered sterile jacket encloses the mass of androcytes which metamorphoses into antherozoids. Jacket is composed of many relatively smaller and less regularly arranged cells (Fig 5.41).

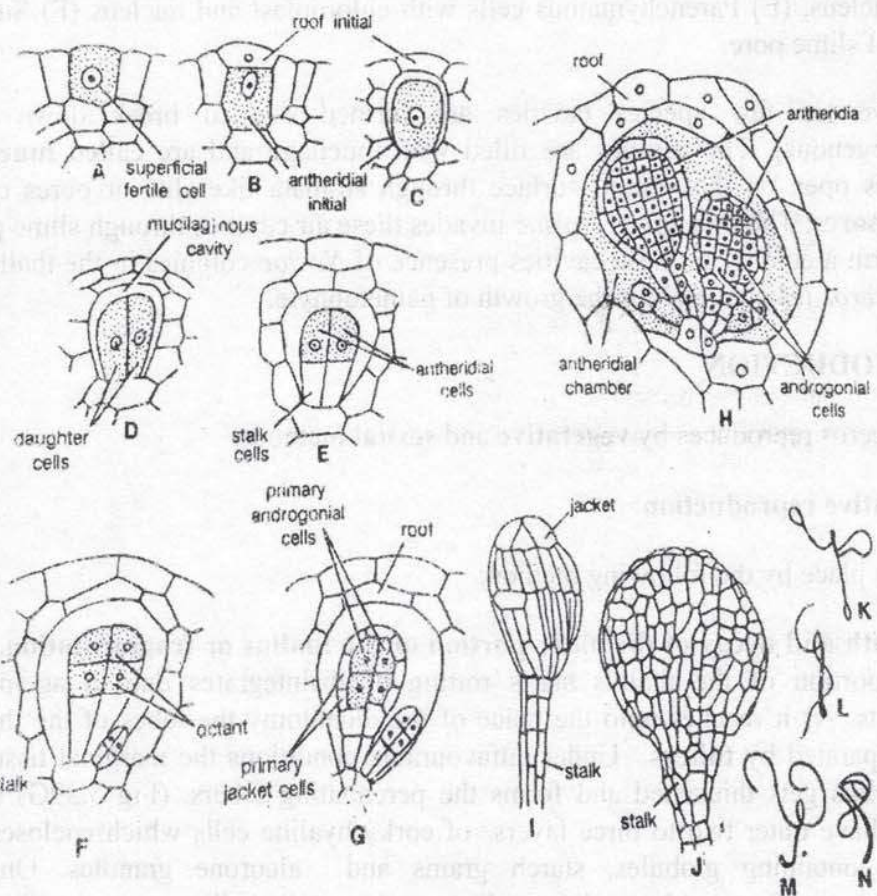


Fig 5.41 (A-N) *Anthoceros* (A-H) Successive stages in the development of antheridium (I) Mature Antheridium of *A. punctatus* (J) Mature Antheridium of *A. laevis*, (K,L) Antherozoids of *A. laevis* (M-N) Antherozoids of *A. punctatus*.

Antherozoid. A mature antherozoid is unicellular, uninculeate, biflagellated and has a linear body. The flagella are of almost the same length as the body (Fig 5.41 M.N) in the body of antherozoids show some degree of residual curvature (Fig 5.41 M.N). when Antheridia mature it absorbs water and upper most tier of cells fall and a mass of antherozoid released.

Aechegonium. Archegonia develop on dorsal surface of the thallus. A mature archegonium consists of two to four cover cells, an axial row of four to six neck canal cells, a venter canal cell and an egg. The jacket layer Is not distinct from the other vegetative cells like other Bryophytes (Fig 5.42)

Development. The development of the archegonium starts on the dorsal surface of the thallus from a single superficial an **archegonial initial**. It divided by transverse division to form an upper primary archegonial cell and lower **primary stalk cell**. The primary archegonial cell divides by three successive intersecting walls or periclinal vertical walls to form the **jacket initials** and a median cell, the **primary axial cell**. Jacket initials divides by the transverse and vertical divisions to form venter wall. The primary axial cells divided by a transverse division to form an **outer cell** and **Inner (central) cell** (Fig 5.42). The outer cell divides by a transverse division to form terminal **cover cell** and inner **primary neck canal**

cell. The inner cell directly functions as **primary venter cell** and divides only once to form upper small venter canal cell and a lower range egg. Primary neck canal cell divides by series of transverse division to form four to six neck canal cells.

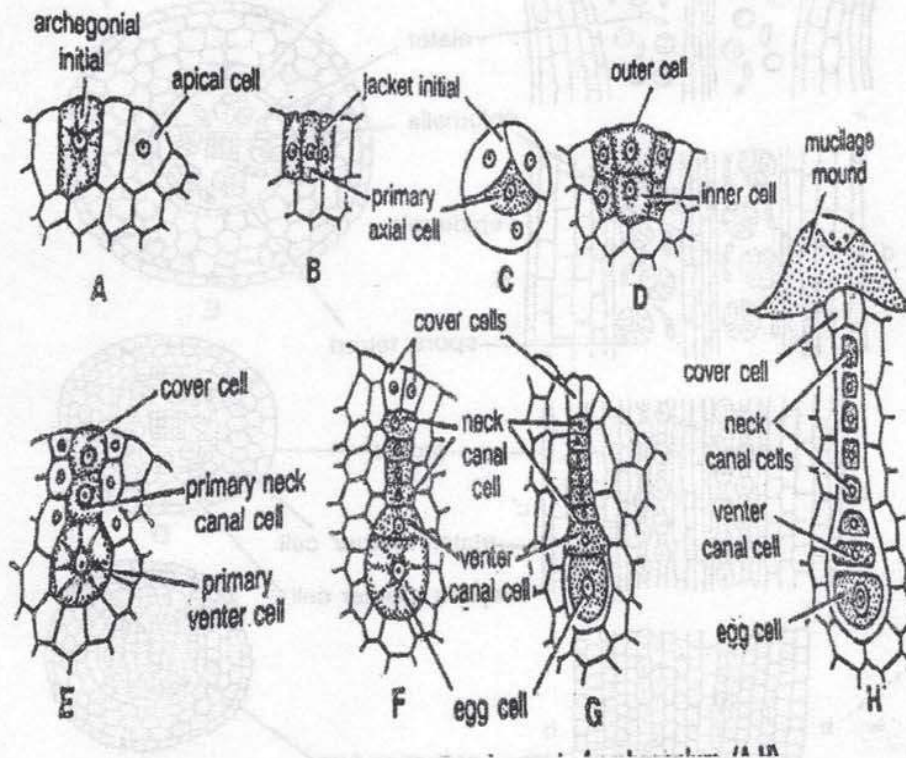


Fig 5.42 (A-H) *Anthoceros*. Development of archegonium. (A-H). Successive stages in the development of archegonium.

FERTILIZATION

Water is essential for fertilization. The venter canal cell and neck canal cell disintegrate and form a mucilaginous mass. It traps the antherozoids which pass up to egg and form diploid zygote or oospore.

SPOROPHYTIC PHASE

After fertilization the diploid zygote enlarges in size & divides to form sporophyte in which spores are formed after meiosis which are haploid in nature.

Structure of sporophyte

The mature sporophyte consists of a bulbous **foot** and a smooth, slender, erect, cylindrical structure called **capsule**. Capsule varies in length from two to fifteen centimeters in different species.

The sporogonium appears like a BRISTLE OR HORN; hence, the *Anthoceros* is called 'hornworts' (Fig 5.43). It is bulbous, multicellular, and made up of a mass of parenchymatous cells. It acts as an haustorium and absorbs food and water from the adjoining gametophyte cells.

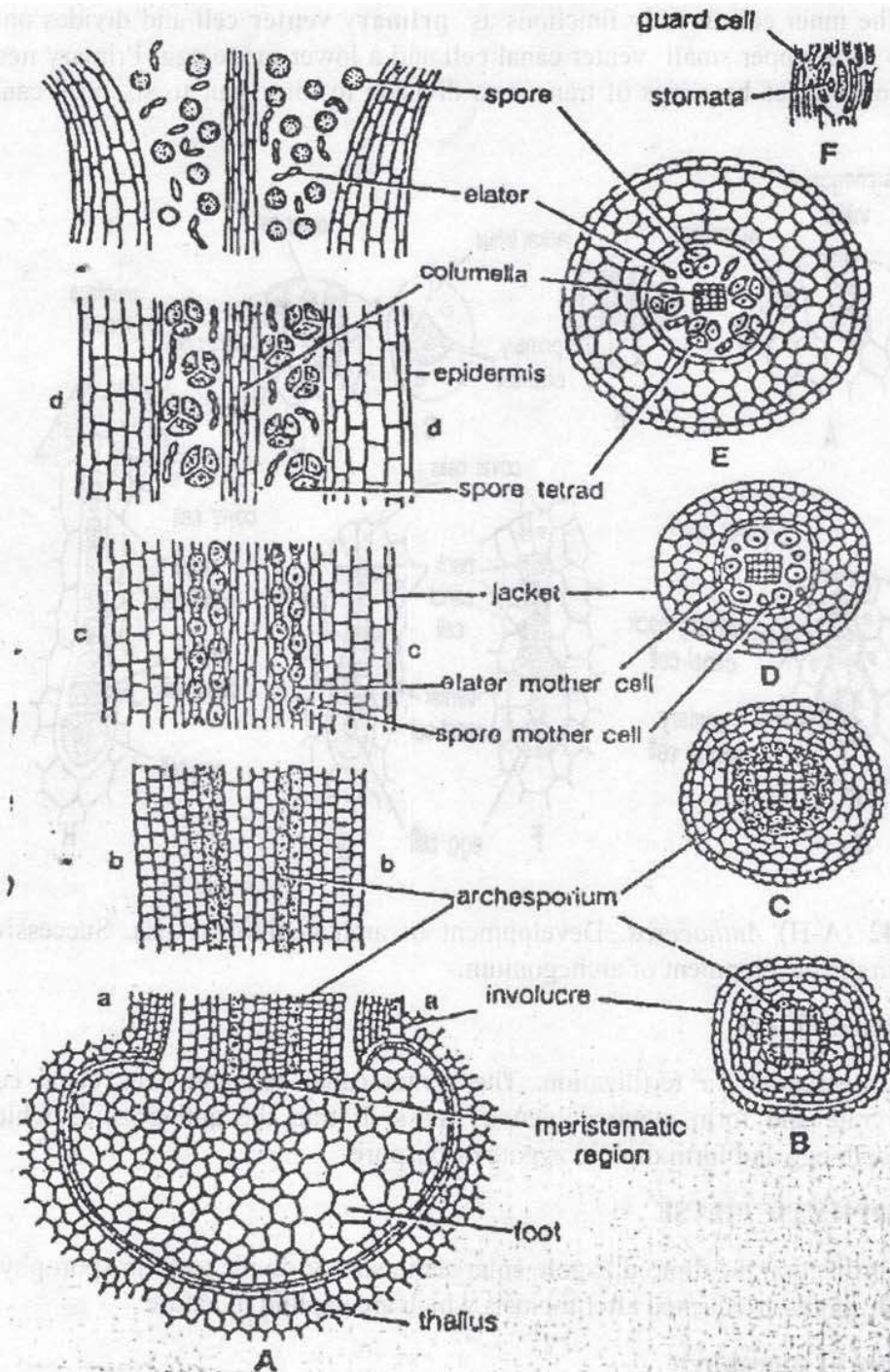


Fig 5.43 (A-F) *Anthoceros*. Internal structure of the sporogonium (A) Longitudinal Section (L.S.) through the mature sporogonium. (B) Cross section of the sporogonium at a-a level (C) cross section of sporogonium at b-b level (D) cross section of the sporogonium at c-c level (E) Cross section of the sporogonium at d-d level (F) Structure of stomata from the epidermis of sporogonium wall.

Meristematic Zone or Intermediate Zone or Intercalary Zone. Seta is represented by meristematic zone. This is present at the base of the capsule and consists meristematic cells.

Capsule: Its internal structure can be differentiated into following parts :
Columella: It is central sterile part extending nearly to its tip. It provides mechanical support, functions as water conducting tissue and also helps in dispersal of spores. **Archegonium:** it is presented between the capsule wall and the columella. It extends from base to the capsule.

In upper part of the capsule it is differentiated into sporogenous tissue which produces spores and pseudoelaters. Pseudoelaters may be unicellular or multicellular, branched or unbranched and may consists more or less elongated cells. The spiral thickening are absent (characteristics of *Anthoceros*)

Capsule wall: It consists of four to six layer of cells, of which the outermost layer is epidermis. The cells of the epidermis are vertically elongated and have deposit of the cutin on their walls. The stomata are presented in epidermal cells. Thus, the sporogonium is partially self sufficient to synthesize its own organic food but partially it depends on the gametophyte for the supply of water and mineral nutrients.

Dehiscence of capsule : Capsule dehisces from apex to base usually by two longitudinal lines results in the formation of two valves thus spores becomes free in air.

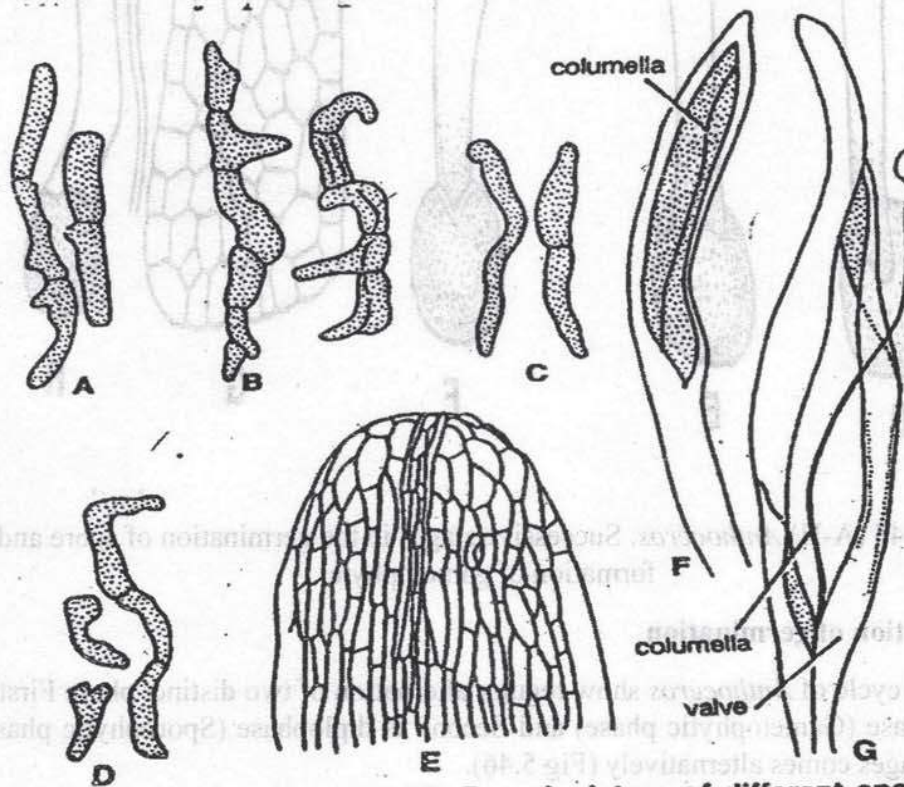


Fig 5.44 (A-G). *Anthoceros* (A-D). Pseudoelaters of different species, (E). Apex of the capsule with line of dehiscence, (F) Single line of dehiscence, (G) Bivalved dehiscence

Spore structure and germination

The spores are haploid uninucleate semicircular with triradiate mark (Fig 5.45). Spore germinates in favorable condition. It absorbs water and exospore ruptures at

triradiate mark, endospore comes out in form of germ tube, after several division it form new haploid thallus (Fig 5.45)

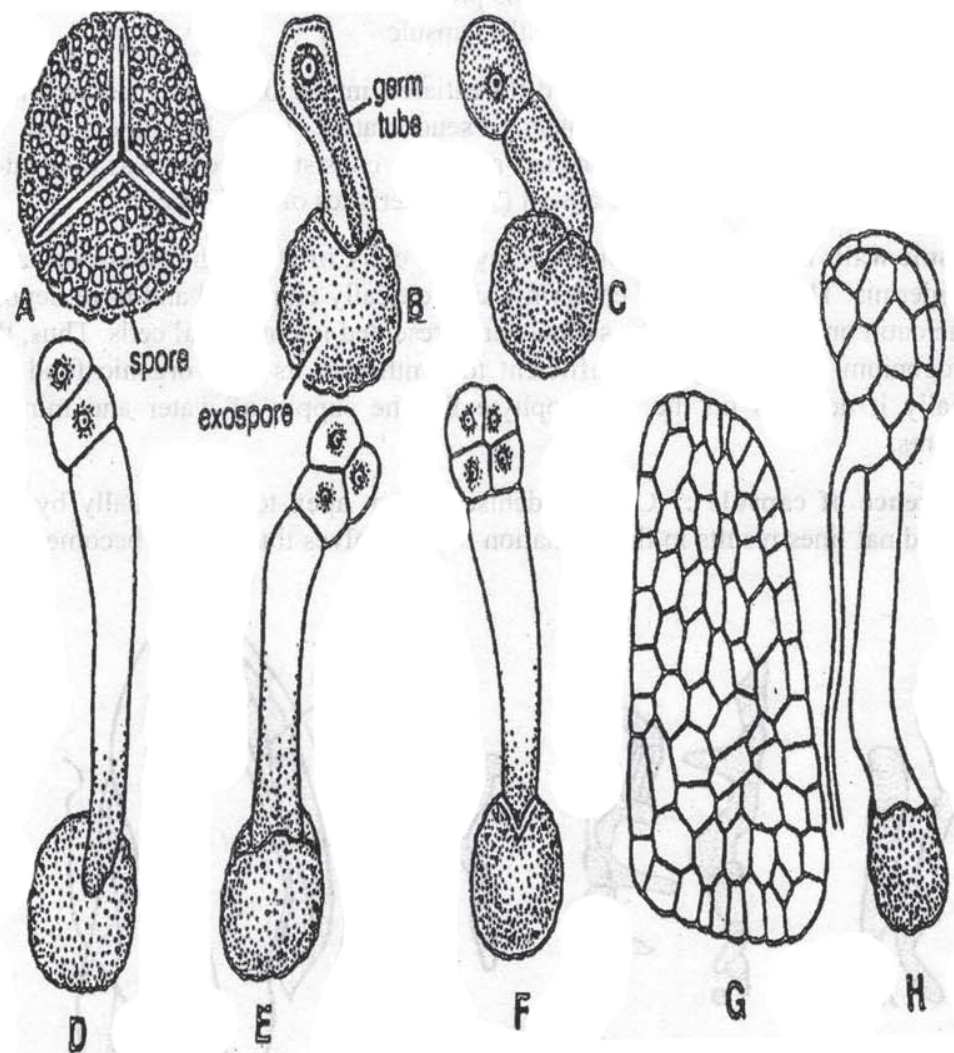


Fig 5.45 (A-H) *Anthoceros*. Successive stages in the germination of spore and formation of gametophyte.

Alternation of germination

The life cycle of *Anthoceros* show regular alternation of two distinct phase First is haplophase (Gametophytic phase) and Second is diplophase (Sporophytic phase) these stages comes alternatively (Fig 5.46).

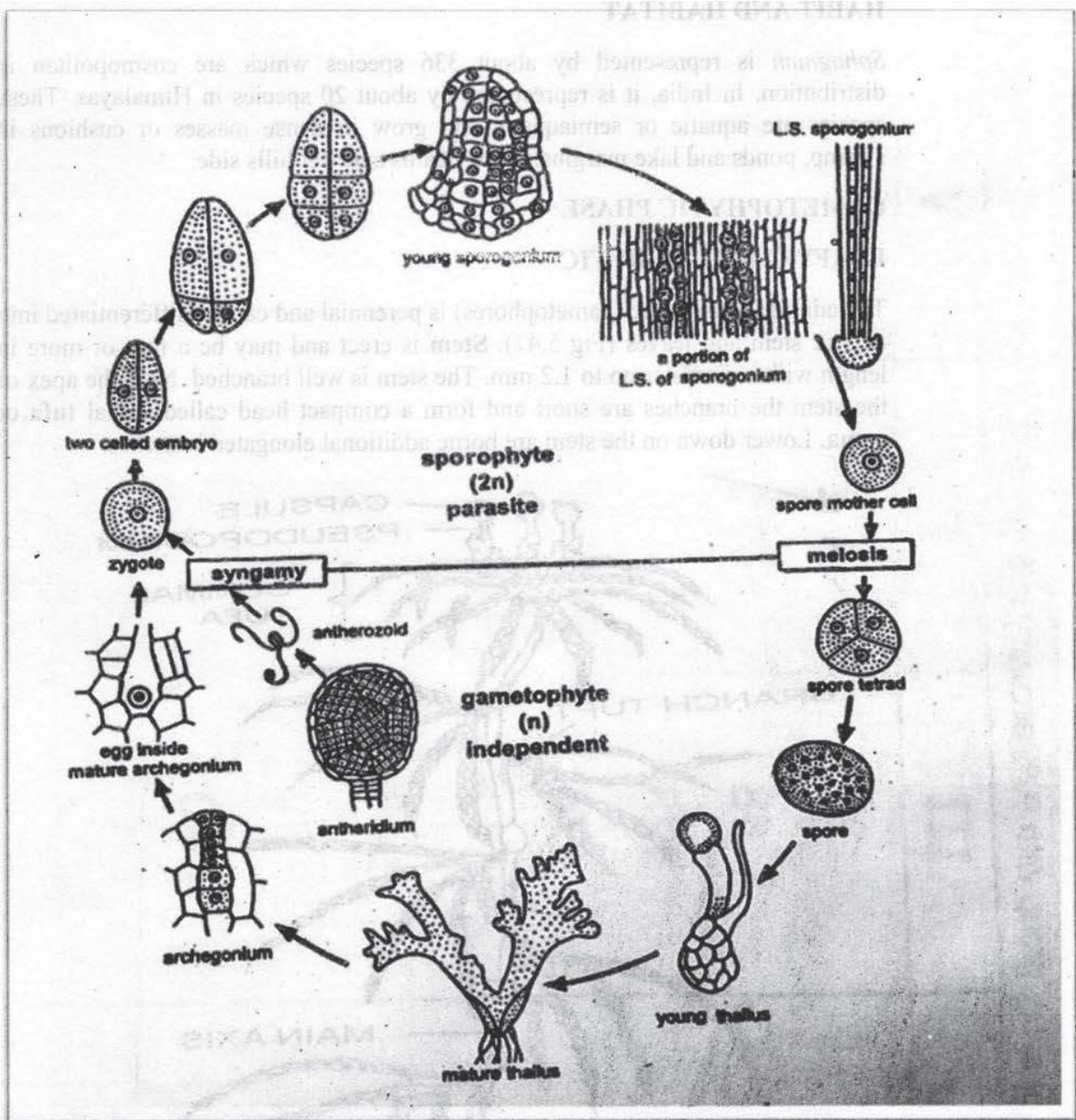


Fig 5.46 *Anthoceros*. life cycle.

Sphagnum

SYSTEMATIC POSITION:

DIVISION : BRYOPHYTA
CLASS : BRYOPSIDA
SUB-CLASS : SPHAGNIDAE
ORDER : SPHAGNALES
FAMILY : SPHAGNACEAE
GENUS : *Sphagnum*

HABIT AND HABITAT

Sphagnum is represented by about 336 species which are cosmopolitan in distribution. In India, it is represented by about 20 species in Himalayas. These species are aquatic or semiaquatic and grow in dense masses or cushions in swamp, ponds and lake margins, moist heaths and wet hills side.

GAMETOPHYTIC PHASE

LEAFY GAMETOPHYTIC

The adult gametophytic (gametophores) is perennial and can be differentiated into axis or stem and leaves (Fig 5.47). **Stem** is erect and may be a foot or more in length with a diameter up to 1.2 mm. The stem is well branched. Near the apex of the stem the branches are short and form a compact head called **comal tuft** or **coma**. Lower down on the stem are borne additional elongated branches.

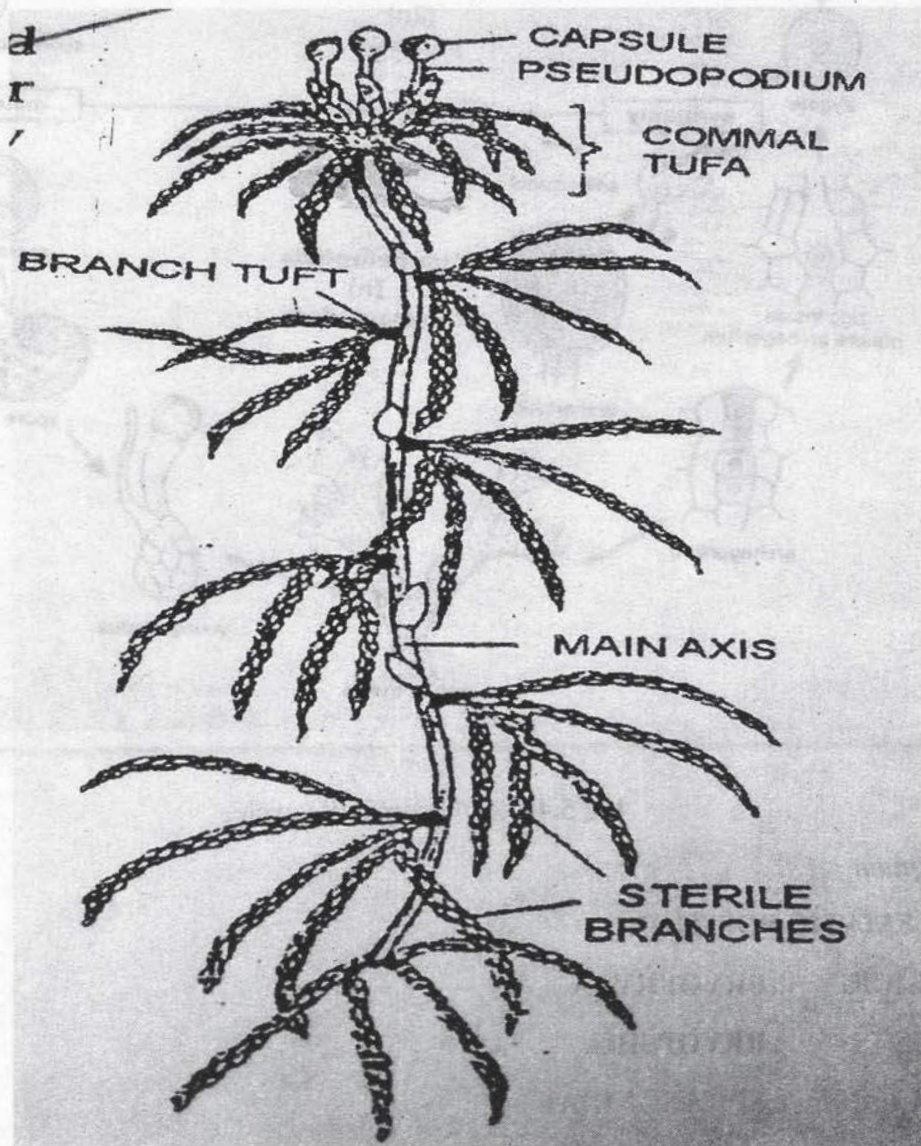


Fig 5.47 *Sphagnum*. An adult leafy gametophyte showing the comal tuft.

- (a) **Divergent branches:** These branches grow out laterally from the stem and extend outward in a horizontal position.
- (b) **Drooping or Pendent branches:** These branches grow out laterally from the stem; hang or run very close to the stem.

LEAF

Leaves are borne on the main stem as well as on the branches. Leaves are arranged in a spiral manner they are thin, small, fleshy, oblong with a broad base. Mid rib is lacking (Fig 5.49).

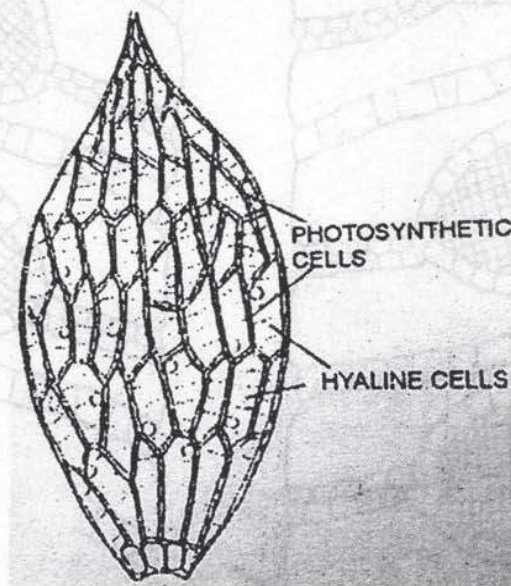


Fig 5.48 *Sphagnum*. A single leaf.

REPRODUCTION

Sphagnum reproduces by vegetative and sexual methods.

Vegetative Reproduction: it takes place by the following method:

Innovation: It is the common method of reproduction. It takes place by the formation of special vegetative branches known as **innovations**. This branch shows all the characteristic of main axis and develop into a new plant when detach from the parent plant.

Regeneration : The growth of new tissues or organs to replace those lost or damaged in injury is known as **regeneration**. *Sphagnum* has great power of regeneration.

Sexual reproduction

Sexual reproduction is **oogamous**. It takes place by the formation of male and female reproductive organs which develop on special branches. *Sphagnum* may be **monoecious** or **dioecious**. Monoecious species are **protandrous**.

THE ANTHERIDIUM

The anteridia or the male sex organs develop on short lateral branches known as the **antheridial** or **male** branches (Fig 5.49).

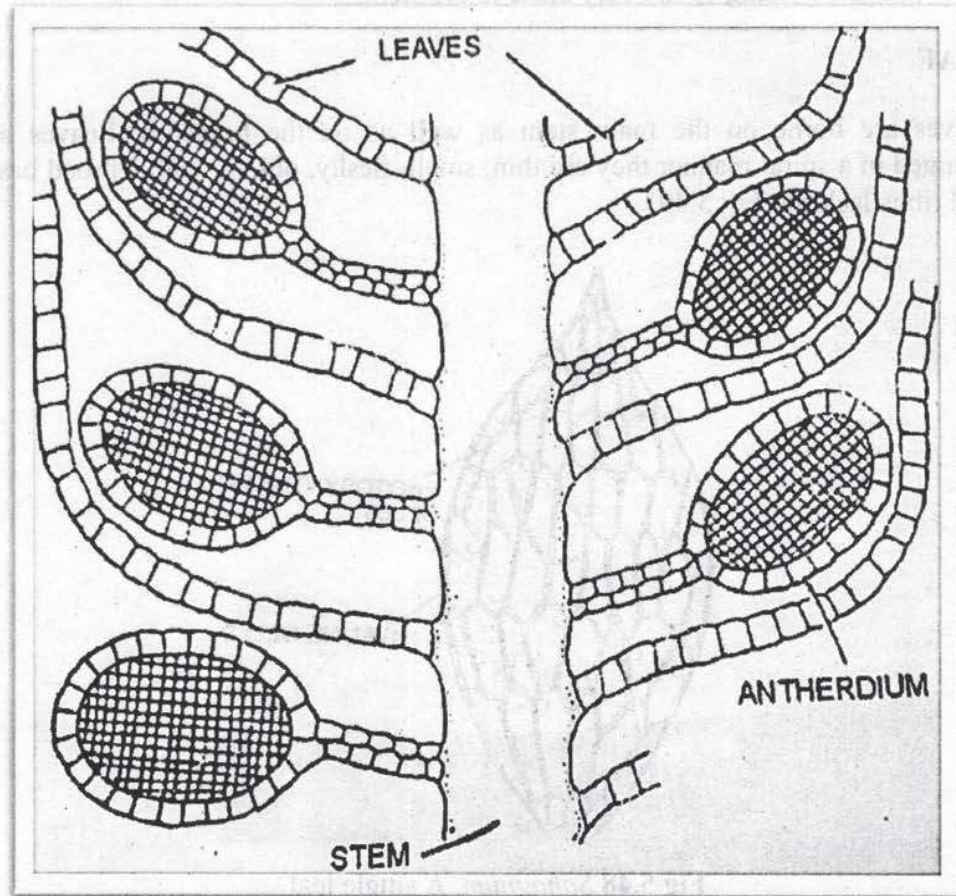


Fig 5.49 *Sphagnum*. Longitudinal section of antheridial branch.

These branches develop near the apex of the main shoot of the plant. A mature antheridium consists of a long stalk and a globular body. The antheridial body is covered by a single layered sterile jacket which encloses many androcytes. Each androcyte metamorphoses into a spirally coiled biflagellate antherozoid. When the antheridium is mature, the apical cell of the jacket absorbs water, swells and undergoes irregular separation which turns backwards. The antherozooids are liberated and swim in water.

THE ARCHEGONIUM

One to five archegonia develop at the tip of the short archegonial branches. The leaves of the archegonial branches are green and much larger than the vegetative branches. These leaves are called **perichaetium** (Fig 5.50 A). A mature archegonium is a long, stalked structure possessing a **venter** and a long **neck** enclosing 8 or 9 **neck canal cells**, a **venter canal cell** and an **egg cell**. (Fig 5.50B).

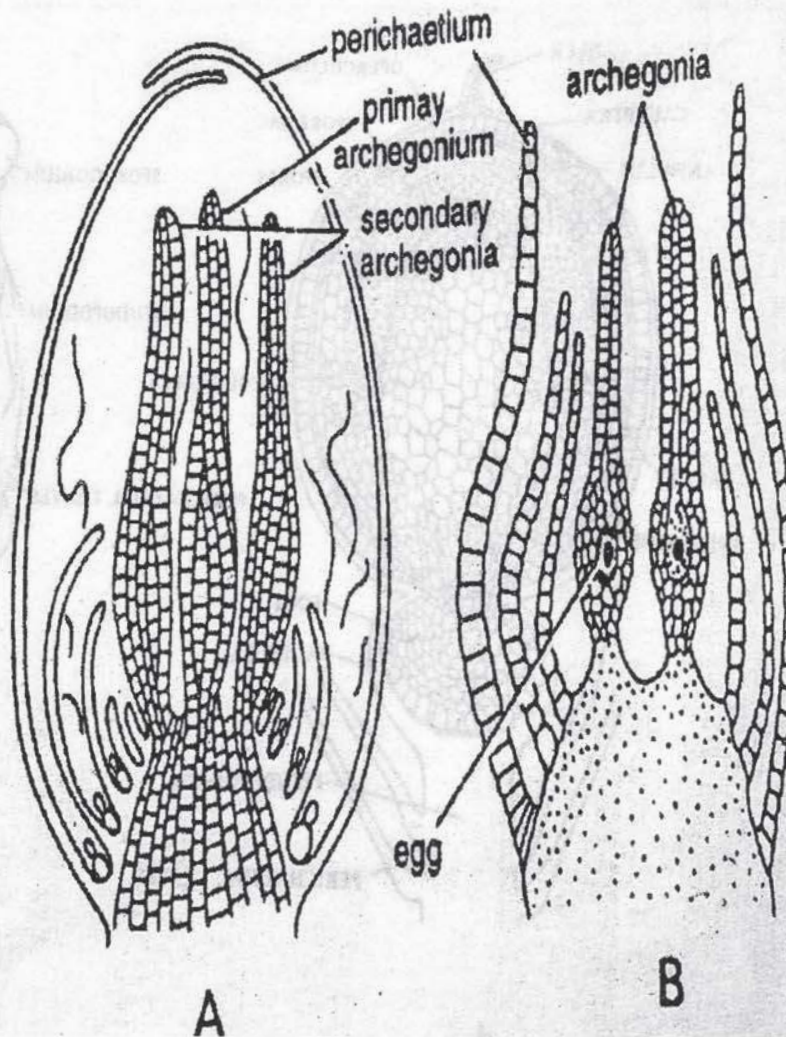


Fig 5.50 (A,B) *Sphagnum*. Longitudinal section of archegonial branches showing archegonia.

FERTILIZATION

Water is essential for fertilization, at the time of fertilization the neck canal cell along with the venter canal cell disintegrate to form a clear passage for the antherozoids. They enter through the cover cells and reach up to the egg, but only one fuses with the egg to form the zygote.

THE SPOROPHYTE

The sporogonium develops from only one archegonium. The other archegonium, however, may also persist for some time. The mature sporogonium is differentiated into foot and capsule. Both are connected by a short narrow neck like constriction which represents the suppressed **seta**. Sporogonium is elevated on a short cylindrical, leafless stalk, the **pseudopodium** (Fig 5.51 B). The pseudopodium together with the basal portion of the calyptra forms a sac-like structure, the **vaginula** which encloses the foot.

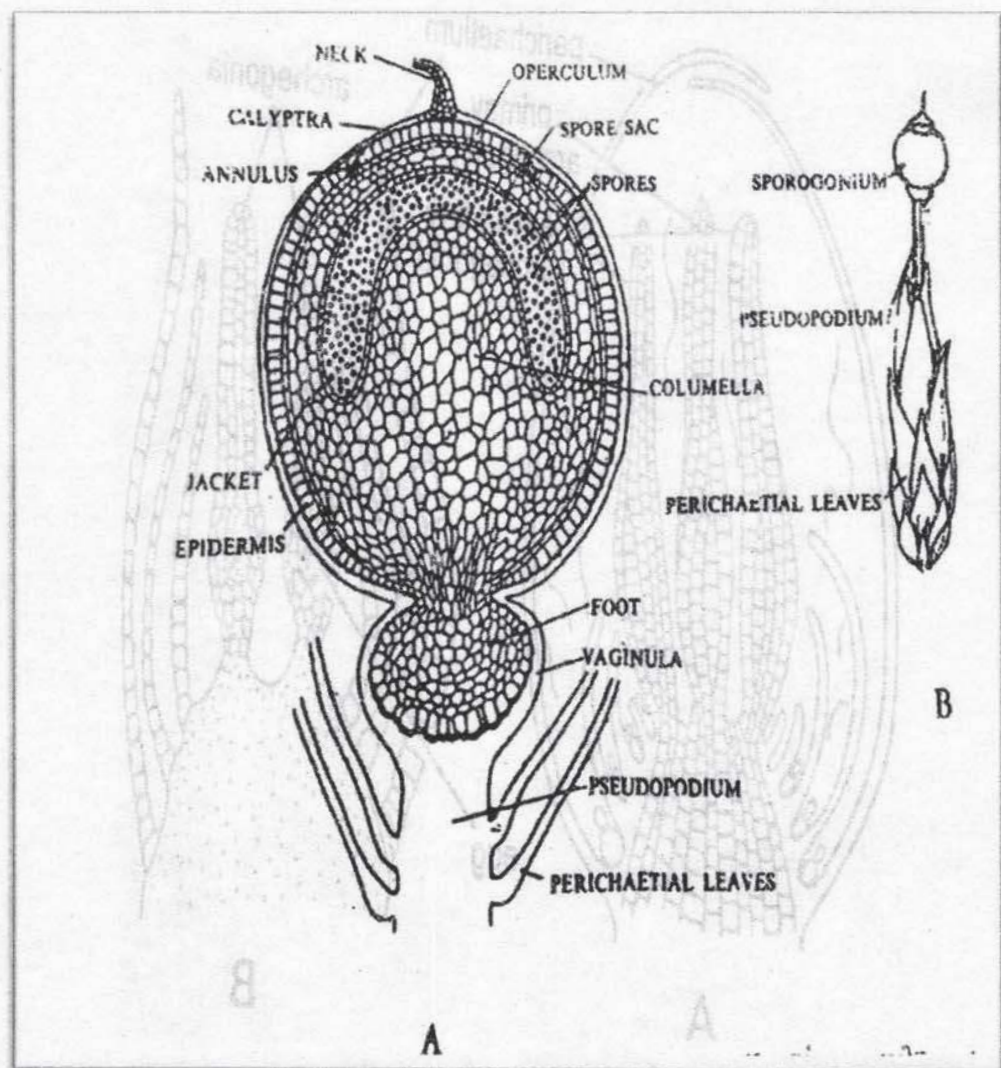


Fig 5.51 (A,B). *Sphagnum*. (A) L.S. of mature sporogonium, (B) Female branch with sporogonium.

Foot : It is bulbous and made up of parenchymatous cells. The main function is to absorb the food material for the developing sporophyte.

Capsule : It is spherical and dark brown in color. It contains central columella which is over arched by a dome shaped spore sac containing haploid spores (Fig 5.51 A). The wall of the capsule is 4-6 layers thick. The outer layer of the capsule wall is called **epidermis**. The cells of the epidermis contain chloroplast. It has many non-functional and rudimentary stomata. In young sporogonium a circular convex disc is present at the top of the capsule. It is called **operculum**. It is separated from the rest of the capsule region by a circular (ring like) groove of thin walled cells called **annulus**.

Dispersal of spores or Dehiscence of capsule : On sunny days the columella of mature capsule dries up, breaks down and form a large air cavity below the air sac. The wall of the capsule dries up under the influence of the sun. Spherical form of the capsule gradually becomes cylindrical (Fig 5.52 A, B). The

imprisoned air in the capsule is compressed and held under considerable pressure the operculum also dries and shrinks. Due to this, a little difference in the tension is thus set up. It puts a strain on the thin celled annulus cells which finally rupture. The operculum is blown off with explosive force. The pressure of imprisoned air also ruptures the spores sac and the cloud of yellow or orange colored spores are blown to a height of several centimeters in the atmosphere (Fig 5.52 C, D). The method of spore discharge is, therefore known as the **air gun** or **explosive mechanism**.

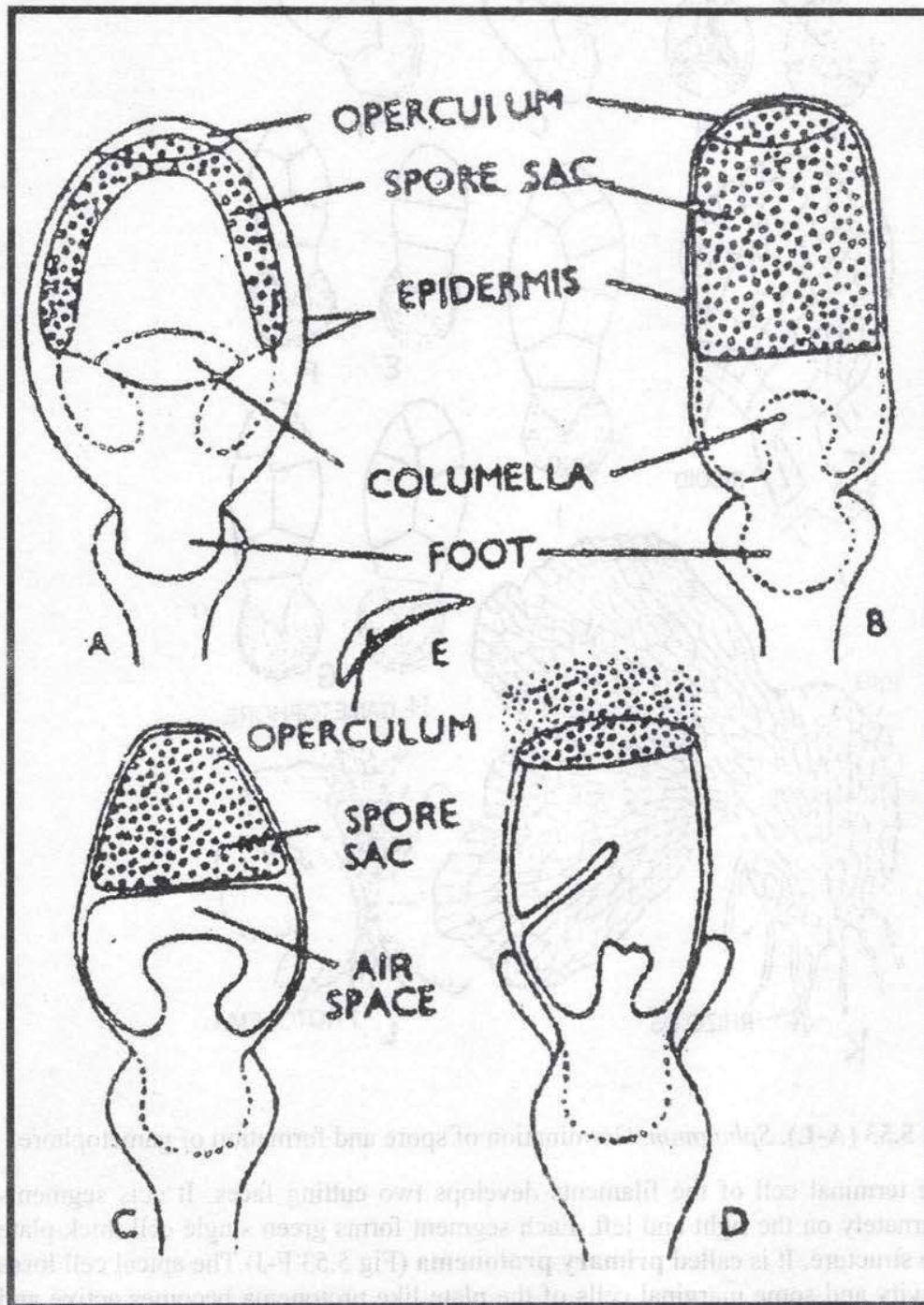


Fig 5.52 (A-D). *Sphagnum*. Stages in the dispersal of spores.

STRUCTURE AND GERMINATION OF SPORE

Each spore is unicellular triangular to spherical and has two layered wall. The spores remain viable for few months and germinate under favorable conditions. Exine form a **germ Tube**. The germ tube divides transversely to form 2-4celled green filament (Fig 5.53 C-E).

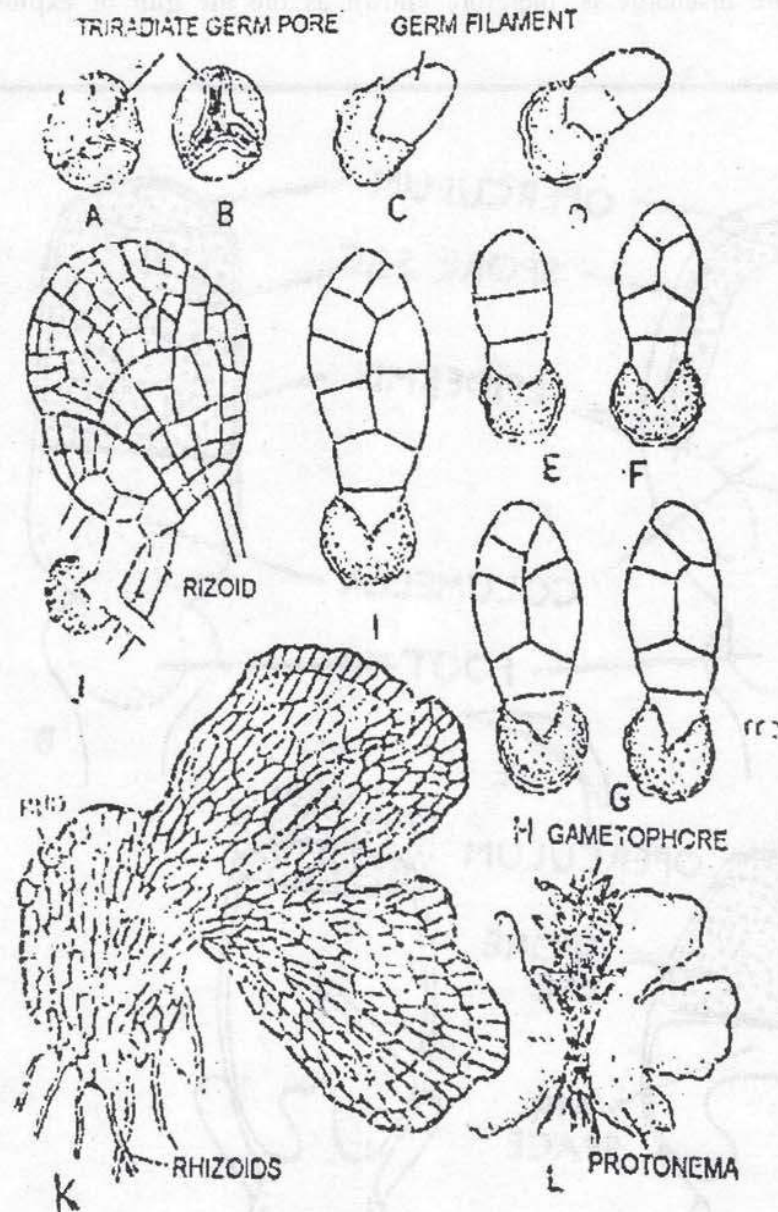


Fig 5.53 (A-L). *Sphagnum*. Germination of spore and formation of gametophore.

The terminal cell of the filaments develops two cutting faces. It cuts segments alternately on the right and left. Each segment forms green single cell thick plate like structure. It is called **primary protonema** (Fig 5.53 F-J). The apical cell loses activity and some marginal cells of the plate like protonema becomes active and form **secondary protonema** with rhizoids and leaf buds. These buds gradually develop into leafy gametophores (Fig 5.53 K, L).

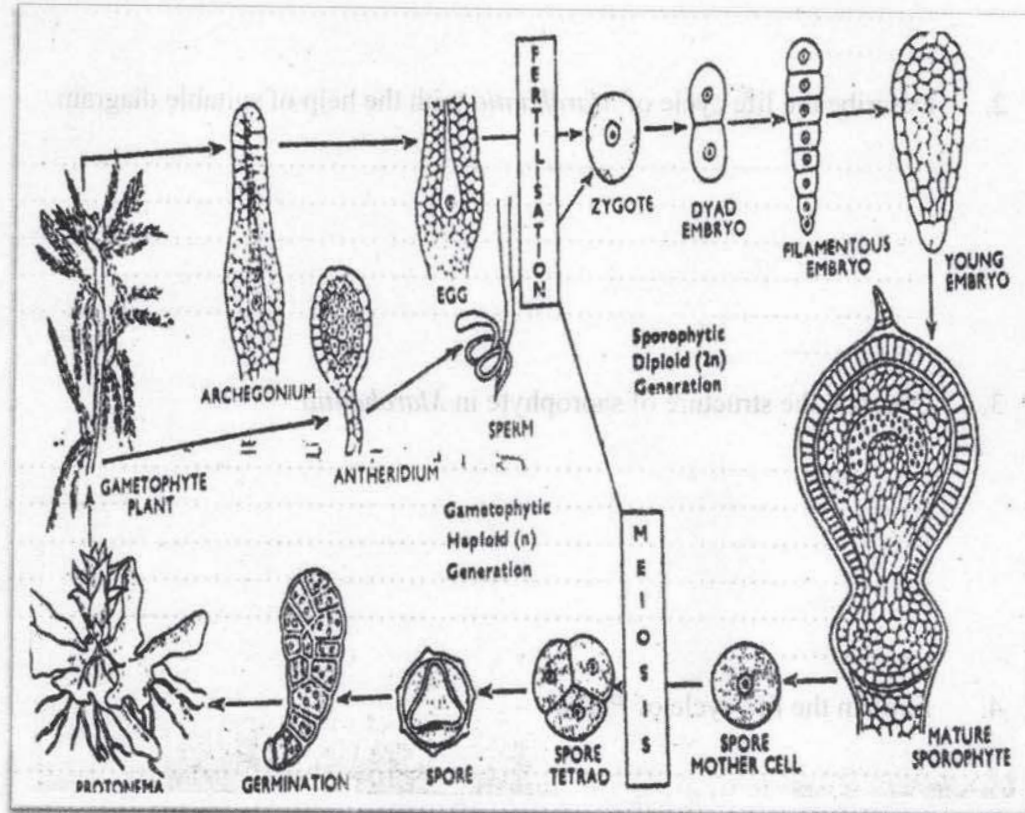


Fig 5.55 *Sphagnum*. Life Cycle.

5.5 SUMMARY

In this unit you have learnt that:

- Bryophytes are the simplest land plant in Embryophytes.
- They are haploid in nature.
- Haploid and diploid phases are distinct.
- *Riccia*, *Marchantia*, *Pellia* and *Anthoceros* are thalloid and simple.
- Leafy structure can be seen in sphagnum.
- Sporophyte in bryophyte are very important they play an important role in formation of gametophyte, after formation of haploid spores.

5.6 TERMINAL QUESTIONS

Long Answers Type

1. Describe the life cycle of *Riccia* with the help of suitable diagram.

.....

.....

.....

.....

-
.....
2. Describe the life cycle of *Marchantia* with the help of suitable diagram.

-
.....
.....
.....
.....
3. Describe the structure of saprophyte in *Marchantia*.

-
.....
.....
.....
.....
4. Explain the life cycle of *Pellia*.

-
.....
.....
.....
.....
5. Explain the life cycle of *Anthoceros*.

-
.....
.....
.....
.....
6. With the help of labelled diagram explain the structure of sporophyte of *Anthoceros*.

-
.....
.....
7. Describe the life cycle of sphagnum with the help of suitable diagram.

.....
.....
.....
.....

Short Answers Type

1. Structure and type of rhizoids in *Marchantia* and *Riccia*?
2. Scales in *Riccia* and *Marchantia*?
3. Gemma cup?
4. V.S. of thallus of *Marchantia* through Gemma cup?
5. Elaterophores?
6. Elaters?
7. Pseudoelaters?
8. Vegetative reproduction in *Anthoceros*?
9. Meristematic zone in sporophyte of *Anthoceros*?
10. Protonema?
11. Pseudopodium?
12. Retart cells?

True/False:

- i. Zoopsis is a microscopic Bryophyte.
- ii. Bryophytes are completely adapted to land habitat.
- iii. Bryophytes are pioneer of the land plants.
- iv. Bryophytes are characterised by dependent sporophyte.
- v. In Bryophytes, spores and gametes are diploid.
- vi. The life cycle of Bryophytes shows a distinct heteromorphic alteration of generation.
- vii. In Bryophytes roots are present.
- viii. All Bryophytes possess unicellular rhizoids.
- ix. The sporophyte of *Riccia* is represented by foot, seta and capsule.
- x. In *Riccia* the archegonial neck is made up of six vertical rows of cells.
- xi. The inner layer of calyptra in *Riccia* degenerates before the maturity of sporophyte.
- xii. Gemma cup are situated on the ventral surface of thallus of *Marchantia*.
- xiii. Sporophyte of *Marchantia* is not differentiated into foot, seta and capsule.

- xiv. In *Marchantia* capsule wall is 4 to 6 layered.
- xv. The gemmae in *Marchantia* are unicellular and sessile.
- xvi. Pseudoelaters are present in *Anthoceros*.
- xvii. Leaves of the foliose gametophytic plant body are with midrib.
- xviii. The branches of *Sphagnum* arise laterally from the axil of the leaves of the stem.
- xix. In *Sphagnum* plant body is sporophytic.
- xx. In *Sphagnum* dispersal of spore takes place by peristomial teeth.

5.7 ANSWERS

True/False

(i) T (ii) F (iii) T (iv) T (v) F (vi) T (vii) F (viii) F (ix) F (x) T (xi) T (xii) F (xiii) F (xiv) F (xv) F (xvi) T (xvii) F (xviii) T (xix) F (xx) F.

UNIT-VI BRYOPHYTES-II

Structure :

- 6.1 Introduction
 - Objective
- 6.2 Evolution of sporophyte in Bryophytes
 - Theory of progressive sterilization of sporogenous tissue.
 - Reduction theory
- 6.3 Economic importance of bryophytes
- 6.4 Summary
- 6.5 Terminal questions
- 6.6 Answers

6.1 INTRODUCTION

The bryophytes are small creatures of God. They occupy an intermediate position between green thallophytes and simple tracheophytes. They are first land plant. Their life cycle is characterized by regular alternation of two morphologically distinct phases, the gametophyte and sporophyte.

In bryophytes the gametophyte are independent, autotrophic, haploid while, the sporophyte is physically and physiologically dependent on gametophyte. The other land plants have dominant sporophytic phase. The sporophytic phase of bryophyte begin with the formation of diploid zygote with in the venter of archegonium. The sporophyte of bryophytes is called sporogonium which generally consists of a single terminal sporogonium with a bulbous foot and with or without an unbranched stalk or seta. The sporogonium is very delicate, short lived and nutritionally dependent on its gametophyte.

According to the complexity of structure, the sporophytes of bryophytes may be arranged in a series between the simple and the most elaborate. The series starts with the simple sporophyte of *Riccia*, runs through that of *Sphaerocarpos*, *Targionia*, *Marchantia*, *Pellia*, *Anthoceros* and finally ends in a highly complex sporophyte of *Funaria* and *Pogonatum*.

Economically bryophytes have no direct significant role to human welfare but it play an important role in solving evolutionary mystery of land plants considering the economic significance and their silent role in nature, bryophytes offer numerous opportunities to the genetics, ecologists, physiologist and taxonomists.

In this unit Evolution of Sporophyte in Bryophytes and indirect uses or economic importance of bryophytes in various filed is discussed.

OBJECTIVE :

After studying this unit you will be able to know-

- Evolution of sporophyte
- Various Theories of evolution
- Economic importance of bryophytes

6.2 EVOLUTION OF SPOROPHYTE IN BRYOPHYTES

Looking to the development and structure of sporophyte in the genera of bryophytes, a wide range from most simple form (as in *Riccia*) to the most elaborate form (as in *Funaria*) can be seen. The absence of sterile cells or the presence of a few sterile cells in most simple sporophyte of *Riccia* and the presence of a lot of sterile cells with specific division of labour and comparatively less amount of spores in *Funaria*, led the Bryologist to think about the evolution of sporophyte in two directions-(i) The primitive sporophyte might be having most elaborate and complex sporophyte with a large amount of sterile cells and (ii) The primitive sporophyte might be having simple structure with less sterile cells. These two view points are critically discussed below –

(1) Theory of progressive sterilization of sporogenous tissue

The most elaborate and complex sporophytes having a large amounts of sterile tissue must have been evolved from most simple sporophytes with a few sterile cells by progressive sterilization of sporogenous tissue. Bower called it **theory of sterilization** which got the support of Cavers, Campbell and Smith. During the course of evolution the zygote must have retained within the archegonium and divided mitotically to produce multicellular plant body. In the beginning, all the cells must have been fertile, but later on a few cells must have become sterile. Subsequently the number of sterile cells increased and that of fertile cells decrease, to perform various somatic functions. The example can be produced as evidence in support of this hypothesis.

- i. ***Riccia* sporophyte (Fig 6.1.1 A):** The sporophyte of *Riccia* is considered as most primitive among the bryophytes. The amphithecium forms single layered wall whereas all the cells of endothecium become converted into fertile spore mother cells. Each spore mother cell divides by meiosis and forms 4 haploid spores. The mature sporophyte has all haploid cells (i.e. the spores).
- ii. ***Corsinia* and *Sphaerocarpos* sporophyte. (Fig 6.1.1 B-C):** The next stage is considered as the sterilization of basal portion forming a few celled foot (e.g. *Corsinia*). Single layered wall encloses a mass of spores.

iii. **Marchantia sporophyte:** Further sterilization of sporogenous tissue results in the formation of elaters, e.g. *Targionia* (Fig 6.1.1 D). In case of *Marchantia* (Fig 6.1.1 E), zygote forms foot and seta whereas epibasal half gives rise to capsule. The mature sporogonium is differentiated into sterile massive foot, sterile broad seta and partly sterile oval capsule. Nearly half of the cells of sporogenous tissue form spore mother cells and the remaining half differentiate into sterile elaters.

iv. **Pellia sporophyte (Fig 6.1.1 F):** Further sterilization takes place in *Pellia*. The complete sporogonium (i.e. foot, seta and capsule) is formed from epibasal cell whereas the lower hypobasal cell remains haustorial. The capsule has 2-4 layered sterile jacket enclosing the sporogenous tissue. The sporogenous tissue gives rise to elaters, spores and basal elaterophores. The capsule itself has a little percentage of fertile spores because it has sterile cells of jacket, elaters, and elaterophores.

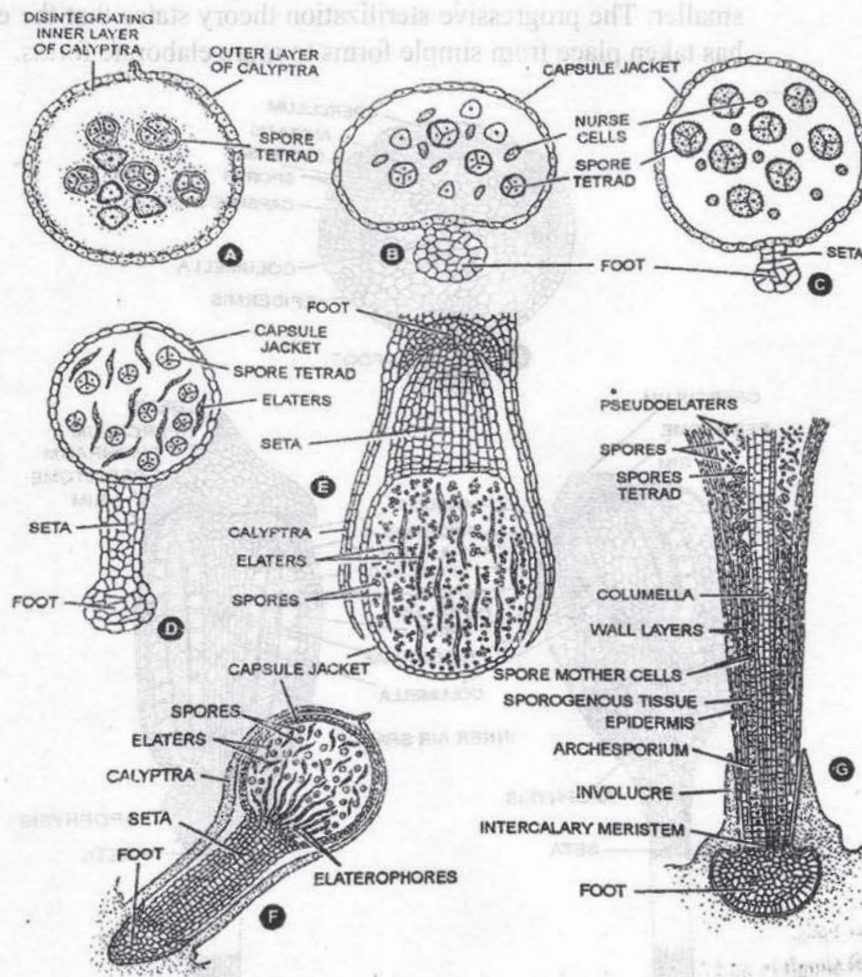


Fig 6.1.1 Sporophytes of Hepaticopsida and Anthocerotopsida (A) *Riccia*; (B) *Corsinia*; (C) *Spharocarpos*; (D) *Targionia*; (E) *Marchantia*; (F) *Pellia*; (G) *Anthoceros*.

v. ***Anthoceros* sporophyte (Fig 6.1.1):** Further reduction in the fertile tissue (spores) can be seen in *Anthoceros* sporogonium. The complete sporogonium is differentiated into foot and elongated capsule. The capsule has a broad sterile zone of columella located centrally, which gives mechanical support and serves the function of conduction. The sterile cells develop pseudoelaters. Thus the sporogonium of *Anthoceros* shows marked sterilization of sporogenous tissue consisting of foot, wall layers, columella and pseudoelaters.

vi. ***Funaria* and *Polytrichum* sporophyte (Fig 6.1.2):** The greatest degree of sterilization in the sporogenous tissue among the bryophytes is found in the members of Bryopsida (e.g. *Funaria*, *Polytrichum*, *Pogonatum*, etc.). The sporogonium consists of sterile bulbous foot, sterile long seta and complex capsule. The sterile portions in capsule are apophysis, multilayered wall, central board zone of columella the wall of spore sac, cap like operculum and peristome. The zone of fertile cells (spores) is comparatively much smaller. The progressive sterilization theory states that the evolution has taken place from simple forms to more elaborate forms.

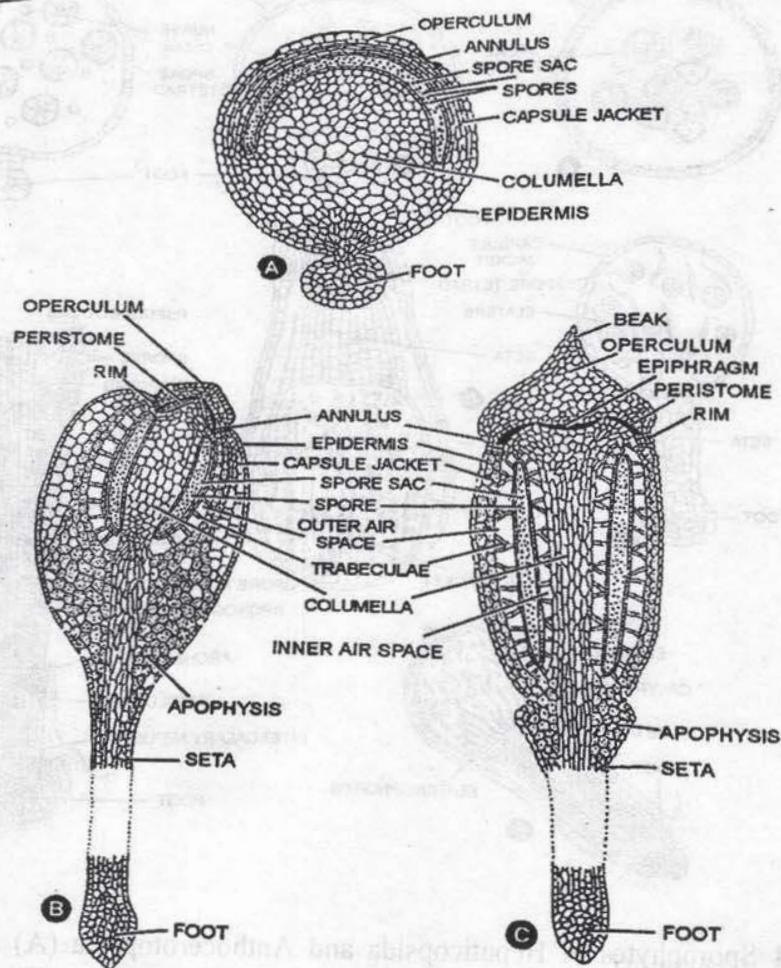


Fig 6.1.2 Sporophytes of Bryopsida. A. *Sphagnum*; B. *Funaria*; C. *Polytrichum*

SAQ1.

1. is considered as most primitive sporophyte among the bryophytes.
2. Elaters aretissue.
3. Elaterophores are found in the sporophyte of
4. Columella and pseudoeleaters aretissue occur in the sporophyte of
5. The greatest degree of sterilization in sporogenous tissue among the bryophyte is found in the members of

(2) Reduction theory

Kashyap, Church, Goebel and Evans hold the view that the simple sporophyte of *Riccia* has evolved from much elaborated sporophytes of *Funaria* or *Polytrichum* (the members of Bryopsida) by progressive elimination of sterile tissues. The progressive simplification has taken place in the following steps-

- i The sporophyte of *Funaria* and *Polytrichum* (the members of Bryopsida) are considered most primitive.
- ii The spore dispersal by peristome has been eliminated (e.g. *Sphagnum*).
- iii The photosynthetic tissue in the wall layers has been gradually reduced.
- iv The multilayered jacket of capsule gradually became single layered (e.g. *Riccia*, *Marchantia*).
- v The foot and seta gradually disappeared so that the complete sporogonium remained embedded in the gametophytic thallus (e.g. *Riccia*). It is highly advanced type.

6.3 ECONOMIC IMPORTANCE OF BRYOPHYTES

The Bryophytes are not considered to be of much economical value, none of these are of direct use to man. However, they play an important role in the economy of the nature. We can study their economic importance under the following heads:

1. **Ecological importance.** Bryophytes are of great ecological importance due to following reasons:
 - a) **Pioneer of the land plants.** Bryophytes are pioneer of the land plants because they are the first plants to grow and colonize the barren rocks and lands.

- b) **Soil erosion.** Bryophytes prevent soil erosion. They usually grow densely and hence act as soil binders. They prevent soil erosion by bearing the impact of falling rain drops.
 - c) **Formation of soil.** Mosses and Lichens are slow but efficient soil formers. The acid secreted by the lichens and progressive death and decay of mosses help in the formation of soil.
 - d) **Bog succession.** Peat mosses change the banks of lakes or shallow bodies of water into solid soil which supports vegetation e.g. *Sphagnum*.
 - e) **Rock builders.** Some mosses in association with some green algae (e.g. *Chara*) grow in water of streams and lakes which contain large amount of calcium bicarbonate. The insoluble calcium carbonate precipitates and on exposure hardens, forming calcareous (lime) rock like deposits.
2. **Formation of peat.** Peat is a brown or dark colour substance formed by the gradual compression and carbonisation of the partially decomposed pieces of dead vegetative matter in the bogs. *Sphagnum* is an aquatic moss which secretes acid. This acid makes conditions unfavourable for the growth of decomposing microorganisms slows down the decaying process of dead material and a large amount of dead material is added year by year. It is called peat. Various uses of peat are:
- a. Used as fuel in Ireland, Scotland and Northern Europe.
 - b. In production of various products like ethyl alcohol, ammonium sulphate, peat, tar, ammonia, paraffin, dye, tannin materials etc.
 - c. In horticulture to improve the soil texture.
 - d. In surgical dressings.
3. **As packing material.** Dried mosses and Bryophytes have great ability to hold water. Due to this ability the Bryophytes are used as packing material for shipment of cut flowers, vegetables, perishable fruits, bulbs, tubers etc.
4. **In medicines.** Some Bryophytes are used medicinally in various diseases for e.g.
- a. Pulmonary tuberculosis and affliction of liver-*Marchantia* spp.
 - b. Antitumor properties-Extracts of *Marchantia polymorpha*, *M. stellata*, *Polytrichum commune* etc.
 - c. Acute haemorrhage and diseases of eye-Decoction of *Sphagnum*.
 - d. Stone of kidney and gall bladder-*Polytrichum commune*.
 - e. Antiseptic properties and healing of wounds-*Sphagnum* leaves and extract of some Bryophytes for e.g. *Conocephalum conicum*,

Dumortiera, *Sphagnum protoricense*, *S. strictum* show antiseptic properties.

5. **As food.** Some bryophytes e.g. mosses are used as food by chicks, birds and Alaskan reindeer etc.
6. **In experimental botany.** The liverworts and mosses play an important role as research tools in various fields of Botany such as genetics. For the first time in liverworts, *Sphaerocarpos*, the mechanism of sex determination in plants was discovered.

SAQ2.

1. Bryophytes are of the land plants.
2. Bryophytes preventerosion.
3. Driedare used as a packing material.
4.are used as medicinally in various diseases.
5.andare used a tools in research work.

6.4 SUMMARY

- There are two theories regarding evolution of sporophyte in bryophytes.
- According to theory of progressive sterilization of sporogenous tissue, *Riccia* has most primitive sporophyte with more fertile and less sterile tissue. Whereas, the most advanced genus like *Funaria* and *Polytrichum* has less fertile and more sterile tissue.
- The reduction theory of evolution of sporophytes states that the sporophyte of *Funaria* and *Polytrichum* are most primitive whereas, sporophyte of *Riccia* is most advanced.
- Economically bryophytes have importance in ecology as rock builders, packing material, in medicines, food and as a tool in research work.

6.5 TERMINAL QUESTIONS

Long Answer type

1. Discuss evolution of sporophyte in bryophytes.
.....
.....
.....
.....
.....
2. Describe the theory of progressive sterilization of sporogenous tissue in bryophytes.

3. Write note on economic importance of bryophytes.

Short Answer Type

Write Note on -

1. Reduction theory of evolution of sporophyte in bryophytes.
2. Formation of Peat.
3. Use of bryophytes in medicines.

6.6 ANSWERS

SAQ1

1. *Riccia*, 2. Sterile, 3. *Pellia*, 4. Sterile, *Anthoceros*, 5. Bryopsida

SAQ2.

1. Pioneer, 2. Soil erosion, 3. Mosses, 4. Bryophytes
5. Liverworts and mosses

UNIT-VII PTERIDOPHYTES-I

Structure :

7.1 Introduction

Objective

7.2 General Characteristic

7.3 Life cycle of pteridophytes

7.4 Relationship with other groups

or

Affinities of Pteridophytes

7.5 Stelar structure and evolution

7.6 Apogamy and Apospory

7.7 Summary

7.8 Terminal questions

7.9 Answers

7.1 INTRODUCTION

In this unit we are going to use the term pteridophyte for nonseed vascular plants. The pteridophytes (GK words Pteron = feather and Phyta = plants, means plants with feather like fronds or ferns) includes a group of primitive land plants with well developed vascular system. The pteridophytes occur in most terrestrial habitats on earth and are also present in some aquatic communities. They are an important part of the ground vegetation in many forest communities. About one third of the species of pteridophytes grow on tree trunks and branches of trees. They are also an important component of many epiphytic plant communities. This group has been referred to as vascular cryptogams and classified by Carlolus Linnaeus (1754) under the class cryptogamia (GK words Kruptos = hidden and gamos = Weeded; means plants with concealed flowers or the plants without visible sex organs.

The pteridophytes donot produce flowers or seeds. They reproduce by producing spores. Their life cycle has alternating free living gametophytic and sporophytic phases that are independent at maturity.

Objective :-

After studying this unit you will be able to :-

- Know the general characters of pteridophytes.

- The pattern of their lifecycle and relationship with other groups.
- Evolution of stelar system and their structure.
- Phenomenon of apogamy and apospory in fern.

7.2 GENERAL CHARACTERISTIC

- Most of the pteridophytes are terrestrial and grow in moist and shady places. A few pteridophytes are aquatic eg. *Marsilea* while others are xerophytic eg. *Equisetum arvense*.
- The plant body is sporophyte differentiated into root, stem and leaves.
- The sporophytic plant may be megaphyllous type or microphyllous type. In megaphyllous type, the leaves are large in relation to stem while in microphyllous type, leaves are small in relation to the stem.
- All the vegetative organs of the sporophyte possess Vascular supply. The vascular system may be a simple protostele, siphonostele or a dictyostele. Companion cells are absent in phloem and vessels are absent in xylem. Primitive vessels are present in some members eg. *Marsilea*, *Equisetum* etc.
- The sporophytic plant body reproduces asexually by means of spores produced in sporangia. The sporangia are born either on the leaves or in their axils (between the leaves and stem). Leaves bearing the sporangia are called Sporophyll.
- The sporophylls may be widely scattered on a plant or clustered in definite structures called cone or strobilus.
- The development of sporangia are of two types, the eusporangiate or leptosporangiate. In eusporangiate type sporangium develops from many sporangial initials. In leptosporangiate type, sporangium develops from single sporangium initial.
- Within the sporangia diploid spore mother cells are developed. These spore mother cells undergo meiosis to form spores (haploid). If all the spores are of same size, the plant is said to be homosporous. If the spores are of two different size, the plant is called heterosporous. In heterosporous type small spores are known as microspores and large spores as megaspores. Microspores are produced in microsporangium. The megaspores are produced in megasporangium.
- The haploid spores on germination give rise gametophytes which are prothalli. The gametophyte bears sexorgans antheridia and archegonia. In homosporous pteridophyte antheridia and archegonia are born on the same gametophyte (Monoecious). Where as, in heterosporous pteridophyte antheridia are born on male gametophyte and archegonia on female gametophyte (dioecious).
- The antheridium is a globular structure surrounded by sterile jacket. Inside jacket are large number of androcytes which give rise motile antherozoids.

- The archegonium is a flask shaped structure having a basal swollen venter and a short neck. The venter has venter canal cell and an egg. The neck has neck canal cells covered by cover cell.
- At maturity the neck canal cells degenerate forming a passage for antherozoids to reach the egg cell. One antherozoid fuses with the egg cell and results in the formation of zygote (diploid).
- The zygote undergoes repeated divisions to form a new sporophyte.

SAQ.1

- The main plant body of pteridophyte is
- The pteridophytes have system.
- The sporophytic plant body reproduce asexually by
- is essential for fertilization in pteridophyte.

7.3 LIFE CYCLE OF PTERIDOPHYTES

The life cycle of pteridophyte has two distinct phases or generations, each of which produces other. One phase is sporophyte while other is gametophyte. The sporophyte is diploid and dominant phase. This phase is organised into root, stem and leaf. It bears sporangia within which are spore mother cells (diploid). Each spore mother cell undergo meiosis to produce haploid spores.

In homosporous pteridophyte, the spores are alike. These spores on germination give rise gametophyte. The gametophytic generation is small, inconspicuous and bears male gametes (antherozoids) and female gametes (eggs).

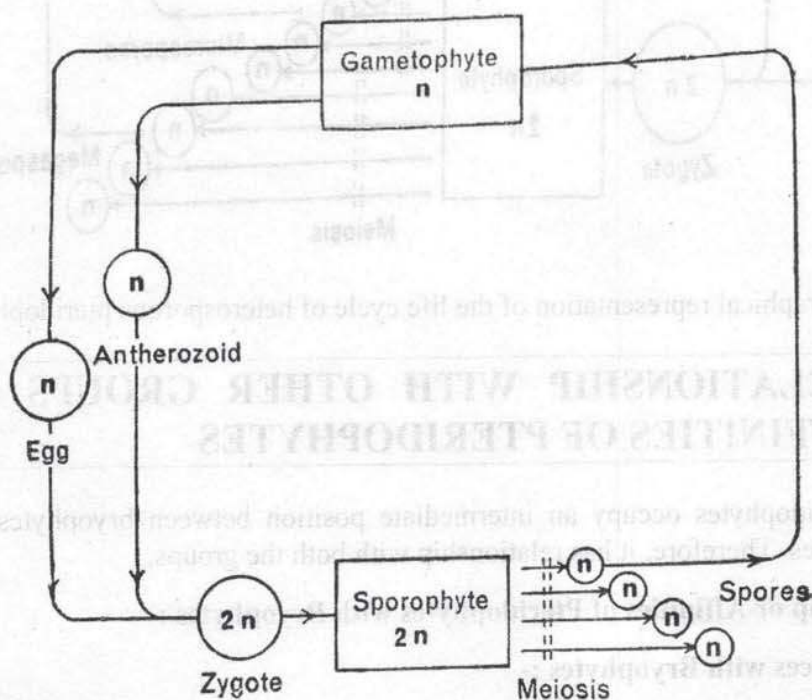


Fig.7.1. Graphical representation of the life cycle of a homosporous pteridophyte.

In heterosporous pteridophytes, spores are of two types, the microspores (smaller spores) and megaspores (larger spores). Microspores on germination give rise male gametophyte which bears antherozoids (male gametes). Megaspores on germination give rise female gametophyte which bears eggs (female gametes). Fertilization take place in presence of water. Single antherozoid fertilizes an egg to form diploid zygote which on germination give rise new sporophyte.

Thus, the life cycle of pteridophyte has an alternate succession of sporophytic and gametophytic generations.

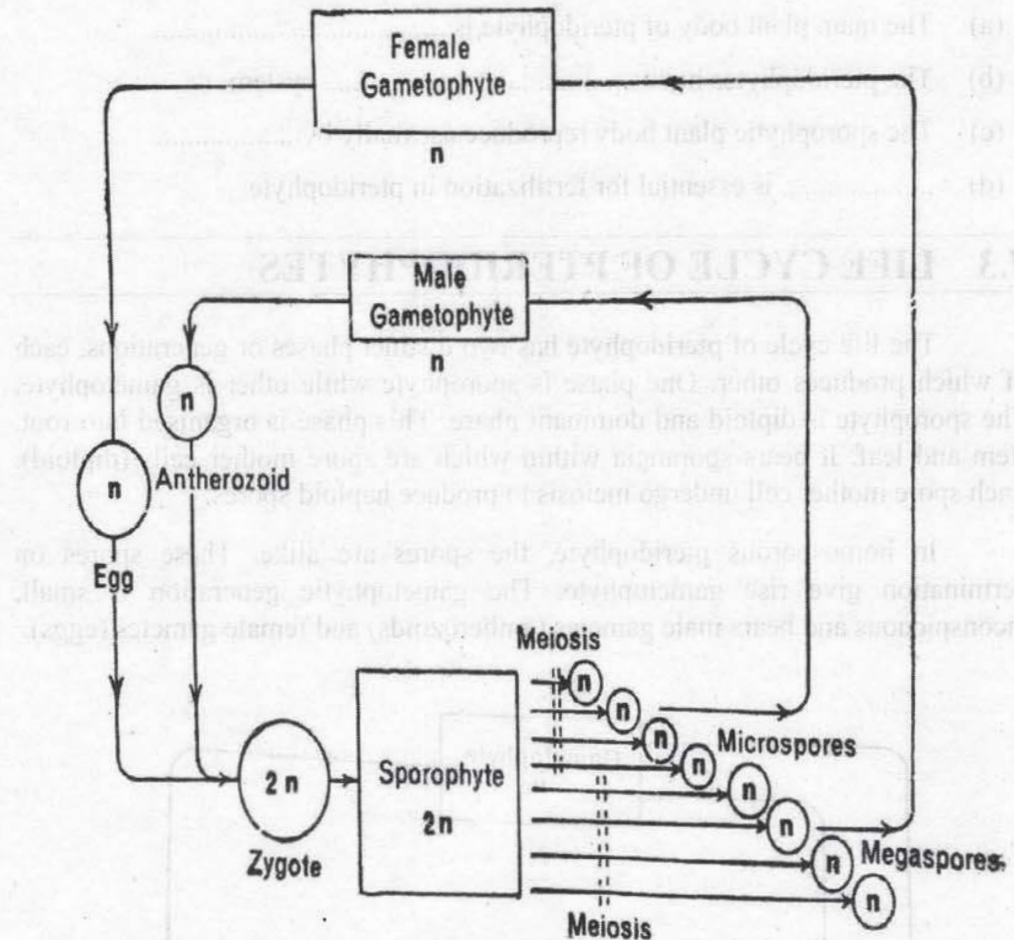


Fig.7.2. Graphical representation of the life cycle of heterosporous pteridophyte.

7.4 RELATIONSHIP WITH OTHER GROUPS OR AFFINITIES OF PTERIDOPHYTES

Pteridophytes occupy an intermediate position between bryophytes and pteridophytes. Therefore, it has relationship with both the groups.

Relationship or Affinities of Pteridophytes with Bryophytes :-

Resemblances with Bryophytes :-

The pteridophytes resemble the bryophytes in the following features :-

1. Both show heteromorphic alternation of generation.
2. Both reproduce asexually by means of spores.
3. The sex organs, antheridia and archegonia are identical.
4. In both, sex organs have sterile jacket around them.
5. In both male gamete is flagellated and female gamete is non flagellated.
6. Fertilization take place in presence of water.

SAQ.2

- (a) The spores are alike in pteridophytes.
- (b) Two types of spores are produced in pteridophytes.
- (c) Microspores on germination give rise gametophyte.
- (d) Megaspores on germination give rise gametophyte.

II. Differences with Bryophytes :- The pteridophytes differ with bryophytes in following features.

1. The plant body of pteridophyte is sporophyte where as of bryophyte is gametophyte.
2. Pteridophytes are differentiated into root, stem and leaf whereas bryophytes are thalloid.
3. Pteridophytes have vascular system whereas bryophytes have no vascular system.
4. Vegetative reproduction is common in bryophytes than in pteridophytes.
5. Bryophytes are always homosporous, whereas many pteridophytes show heterospory.
6. The sporophyte of some bryophytes has elaters along with spores, but elaters are absent in pteridophytes.

III. Resemblances with Gymnosperms :-

The pteridophytes resemble with Gymnosperms in following features :-

1. In both the groups sporophytic plant body is differentiated into root, stem and leaves.

- Both the groups have well developed vascular system. The xylem without vessels and phloem without companion cells.
- Like Gymnosperms, many pteridophytes show heterosporous conditions.
- There is regular alternation of sporophytic and gametophytic generations in both groups.

IV. Differences between pteridophytes and gymnosperms :-

- Pteridophytes occur in moist and shady places, whereas gymnosperms grow in xerophytic places.
- Gymnosperms have tap root but in pteridophytes tap root is replaced by adventitious roots.
- Secondary growth is absent in pteridophytes but present in gymnosperms.
- The archegonium in pteridophytes has neck canal cells but they are absent in gymnosperms.
- Ovule is found in gymnosperms but not in pteridophytes
- In gymnosperms pollen grain gives rise pollen tube on germination, but not in pteridophytes.
- The gametophyte of pteridophyte is independent of the sporophyte, whereas it is dependent on the sporophyte in gymnosperm.

7.5 STELAR STRUCTURE AND EVOLUTION

The central vascular cylinder of primary axis of pteridophyte is called stele. Besides xylem and phloem it includes pericycle and pith if present.

Types of stele :-

There are two main types of stele.

- Protostele
- Siphonostele

I. Protostele :- It is the simplest and most primitive stele made up of central solid mass of xylem surrounded by phloem and delimited by pericycle.

Protostele is of following types :-

- Haplostele :-** It is the most primitive stele among the protostele made up of central solid mass of xylem surrounded by phloem. eg. Stele of *Selaginella kraussiana*, *Rhynia* (fossil).

2. **Actinostele** :- This type of stele is found in stem of *Lycopodium selago*. It has radiating xylem rays alternating with phloem.
3. **Plectostele** :- This type of stele is found in *Lycopodium clavatum*. In this the xylem is in the form of parallel bands alternating with the phloem.
4. **Mixed protostele** :- This type of stele is found in *Lycopodium cernuum*. The xylem is in the form of irregular groups embedded in the ground mass of phloem.

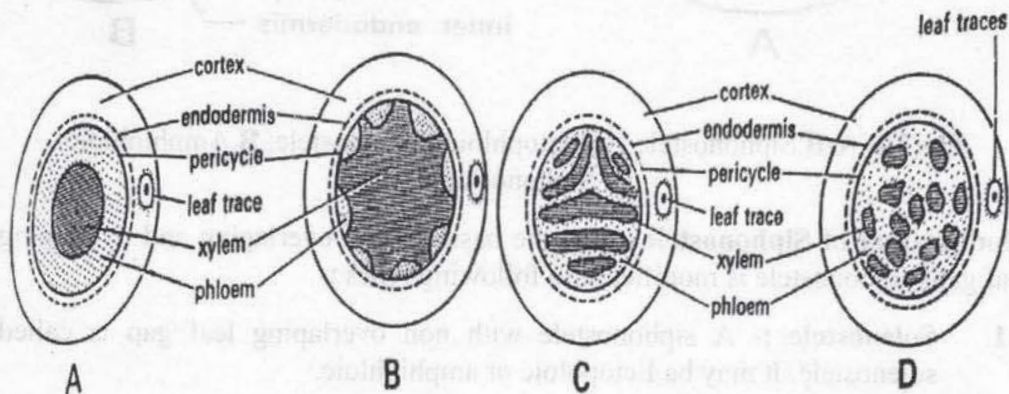


Fig.7.3. A-D. Different types of protosteles : A. Haplostele, B. Actinostele, C. Plectostele, D. Mixed protostele.

- II. **Siphonostele** :- Siphonostele originate from protostele by appearance of pith in the center. This stele is advance than protostele and also known as *medullated protostele*.

Origin of Siphonostele :- There are two theories regarding the origin of siphonostele.

1. **Intrastelar theory** :- According to this theory pith originates by metamorphosis of the inner vascular element into parenchyma eg. in *Osmunda regalis* the central region of protostele has both tracheids and parenchyma cells.
2. **Extrastelar Theory** :- It is given by Jeffery. According to this theory pith originated as a result of the invasion of cortical tissues into the stele through the leaf gap and branch gap in course of phylogenetic development of the vascular plant. Thus, according to this theory pith is of cortical nature.

Types of Siphonostele :-

1. **Ectophloic Siphonostele** :- This type of stele is found in stem of *Equisetum*. Here phloem is present only outside the xylem.
2. **Amphiphloic Siphonostele** :- This type of stele is found in Rhizome of *Marsilea*. In this case xylem is in the form of ring having protoxylem and metaxylem inter mixed. Phloem is present on both the side of xylem.

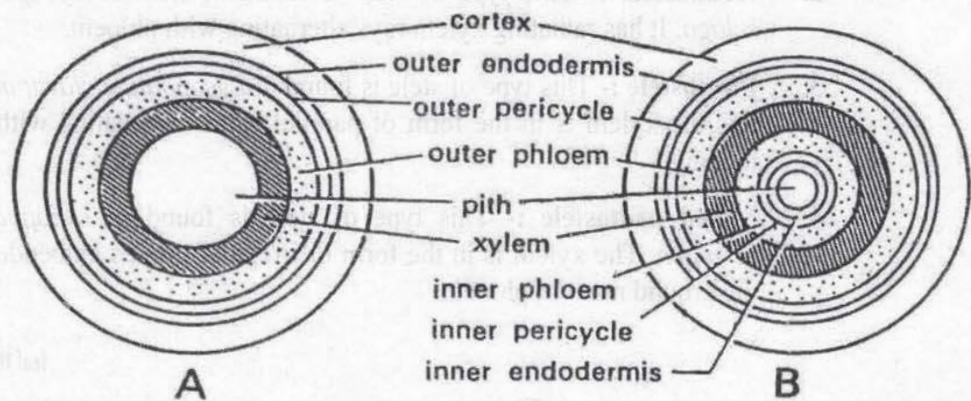


Fig.7.4. A-B. Siphonostele : A. Ectophloic Siphonostele. B. Amphiphloic Siphonostele

Modification of Siphonostele :- On the basis of non overlapping and overlapping leaf gaps siphonostele is modified into following types :-

1. **Solenostele :-** A siphonostele with non overlapping leaf gap is called solenostele. It may be Ectophloic or amphiphloic.

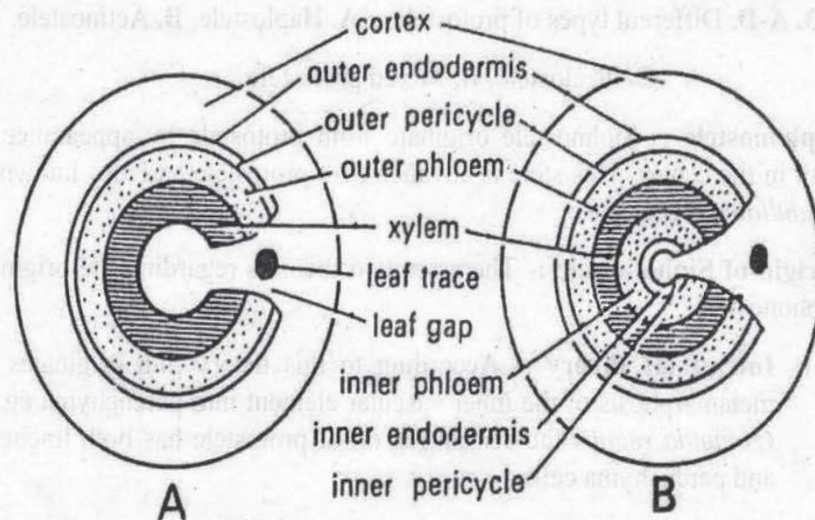


Fig.7.5.A-B. Solenosteles : A. Ectophloic Solenosteles.

B. Amphiphloic Solenosteles

Dictyostele :- A siphonostele with overlapping leaf gaps is called Dictyostele. It has many scattered vascular strands called meristele. eg. Rachis of *Pteris*, *Dryopteris*, *Ophioglossum*.

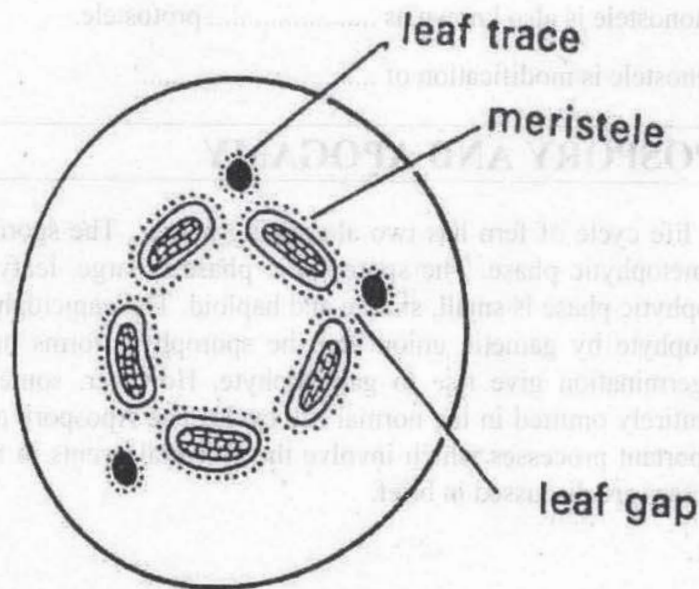


Fig.7.6. Dictyostele.

3. **Polycyclic stele :-** When two or more concentric rings of vascular tissues are present it is called polycyclic stele eg. *Pteridium aqualinum*.

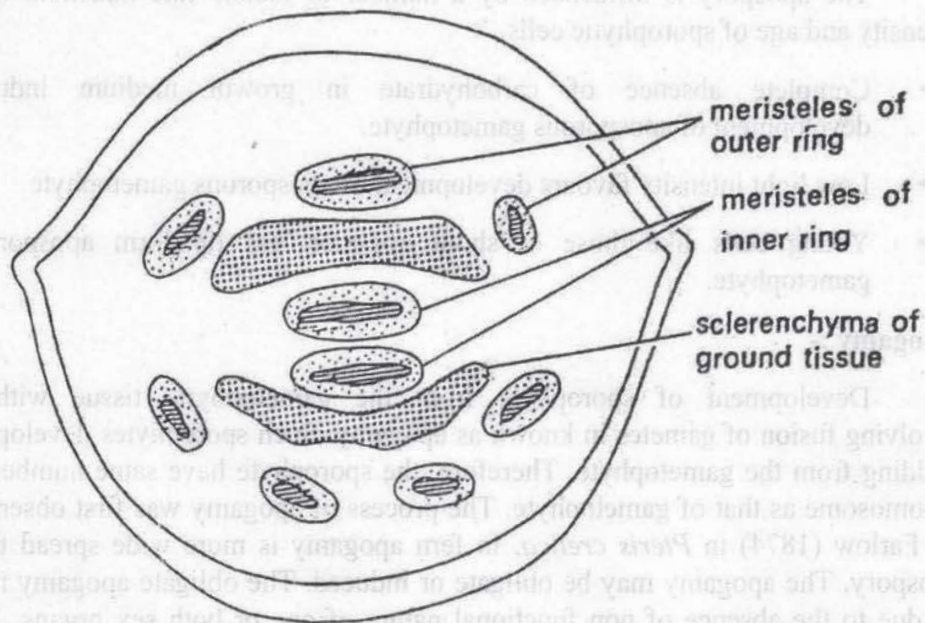


Fig. 7.7. Polycyclic stele.

SAQ.3

- (a) There are main types of stele.

- (b) The simplest and primitive stele is
- (c) Siphonostele is also known as protostele.
- (d) Solenostele is modification of

7.6 APOSPORY AND APOGAMY

The life cycle of fern has two alternating phases. The sporophytic phase and the gametophytic phase. The sporophytic phase is large, leafy and diploid. The gametophytic phase is small, simple and haploid. The gametophyte gives rise to the sporophyte by gametic union and the sporophyte forms haploid spores which on germination give rise to gametophyte. However, sometimes certain stages are entirely omitted in the normal life cycle. The Apospory and Apogamy are two important processes which involve the essential events in the life cycle. These processes are discussed in brief.

Apospory :

Development of gametophyte directly from the vegetative cells of the sporophyte without formation of spores is known as apospory. Thus in apospory the production of spore from the life cycle of fern is omitted. Therefore, aposporous gametophyte have the same number of chromosomes as the sporophyte, i.e. the gametophytes are diploid. Apospory was first demonstrated by Druery (1884) as a natural phenomenon in *Athyrium filix-femina*.

The apospory is influenced by a number of factors like nutrition, light intensity and age of sporophytic cells.

- Complete absence of carbohydrate in growth medium induces development of aposporous gametophyte.
- Low light intensity favours development of aposporous gametophyte.
- Young cells like those of shoot apex or leaf tip form aposporous gametophyte.

Apogamy :-

Development of sporophyte from the gametophytic tissue without involving fusion of gametes is known as apogamy. Such sporophytes develop by budding from the gametophyte. Therefore, the sporophyte have same number of chromosome as that of gametophyte. The process of apogamy was first observed by Farlow (1874) in *Pteris cretica*. In fern apogamy is more wide spread than apospory. The apogamy may be obligate or induced. The obligate apogamy may be due to the absence of non functional nature of one or both sex organs. The induced or facultative apogamy can be induced in the sporophyte having functional sex organs.

The ferns growing in dry habitats do not get sufficient water for fertilization. Therefore, they fail to reproduce sexually. Thus in such forms obligate apogamy is an adaptation to dry conditions.

There are many factors like nutrition, light quality, hormones and number of chromosomes which regulates apogamy.

- Maximum number of apogamous sporophytes are obtained if the gametophyte is placed in 4% sucrose solution at the initial stage.
- Far-red light is more effective in inducing apogamy.
- Hormones like 2,4-D (2, 4-dichlorophenoxy acetic acid), gibberellic acid, indole 3-acetic acid (IAA) and typtophan induce apogamy.
- Apogamy is more common in polyploid gametophytes than the normal haploid gametophyte.

7.7 SUMMARY

- The main plant body is sporophyte divided into root, stem and leaf. It reproduce by means of haploid spores.
- The spores on germination give rise gametophytic phase which bears antheridia and archegonia.
- Water is required for fertilization which results in the formation of diploid zygote. The zygote give rise sporophytic plant.
- The pteridophytes resemble with bryophytes on one hand and gymnosperms on other hand.
- The stelar system evolved in pteridophytes. Therefore, they have simple stelar system.
- The phenomenon of apogamy and apospory occur in fern.

7.8 TERMINAL QUESTIONS

Long Questions :-

1. Describe the general characteristic of pteridophytes.
.....
.....
.....
.....
.....
2. With the help of labelled diagram describe the structure and evolution of stele in pteridophytes
.....
.....
.....
.....
.....
.....

Short Questions :-

Write short notes on :

1. Affinities of pteridophytes with bryophytes.
2. Affinities of pteridophytes with gymnosperms.
3. Apogamy
4. Apospory

7.9 ANSWERS

SAQ.1

- (a) Sporophyte (b) Vascular (c) Spores (d) Water

SAQ.2

- (a) Homosporous (b) Heterosporous
(c) Male (d) Female

SAQ.3

- (a) Two (b) Protostele (c) Medulated (d) Siphonostele

UNIT-VIII PTERIDOPHYTES II

Structure :

8.1 Introduction

Objective

8.2 *Rhynia*

Morphology

Anatomy

Life cycle

8.3 *Lycopodium*

Morphology

Anatomy

Life cycle

8.4 *Selaginella*

Morphology

Anatomy

Life cycle

Heterospory and seed habit

8.5 *Equisetum*

Morphology

Anatomy, Hydrphytic and xerophytic characters

Life cycle

8.6 *Marsilea*

Morphology

Anatomy, characters of water plant and land plant in *Marsilea*

Life cycle

8.7 Summary

8.8 Terminal Questions

8.1 INTRODUCTION

The Pteridophytes are the spore-bearing vascular plants different from other cryptogams. It has vascular tissue-xylem and phloem. Therefore, they are commonly called "Vascular cryptogams. They includes most primitive living and fossil vascular plants. This unit includes morphology, anatomy and life cycle of some genera of pteridophytes like-*Rhynia*, *Lycopodium*, *Selaginella*, *Equisetum* and *Marsilea*. *Rhynia* is the fossil vascular plant whereas, rest are living vascular plants.

Objective :

After studying this unit you will be able to know :-

- Morphology, anatomy and life cycle of fossil genus *Rhynia*.
- Morphology, anatomy and Life cycle of living genera i.e. *Lycopodium*, *Selaginella*, *Equisetum* and *Marsilea*.

8.2 RHYNIA

Systematic position

Division	-	Psilophyta
Class	-	Psilopsida
Order	-	Psilophytales
Genus	-	<i>Rhynia</i>

The fossil genus *Rhynia* were discovered from the Rhynie village of North Scotland by kidston and lang in 1917 from Siliceous Rocks of lower Devonian age. It was a petrified fossil. The age of plant is 375 million years ago.

The two species of *Rhynia* are-

1. *R. major* - *Aglaophyton major* (new name)
2. *R. gwynne-vaughanii*.

8.2.1 MORPHOLOGY

The plant body of *Rhynia* was a sporophyte consists of dichotomously branched aerial stem. The aerial branch of *R. major* were 50cm in height whereas of *R. gwynne-vaughanii* i were 20cm in height. Roots and leaves were absent in *Rhynia*. Rhizoids were present on the rhizome. Terminal sporangia were present at the tip of aerial branches. The *R. gwynne-vaughanii* had many adventitious branches which had no vascular connection with main axis and helps in vegetative propogation.

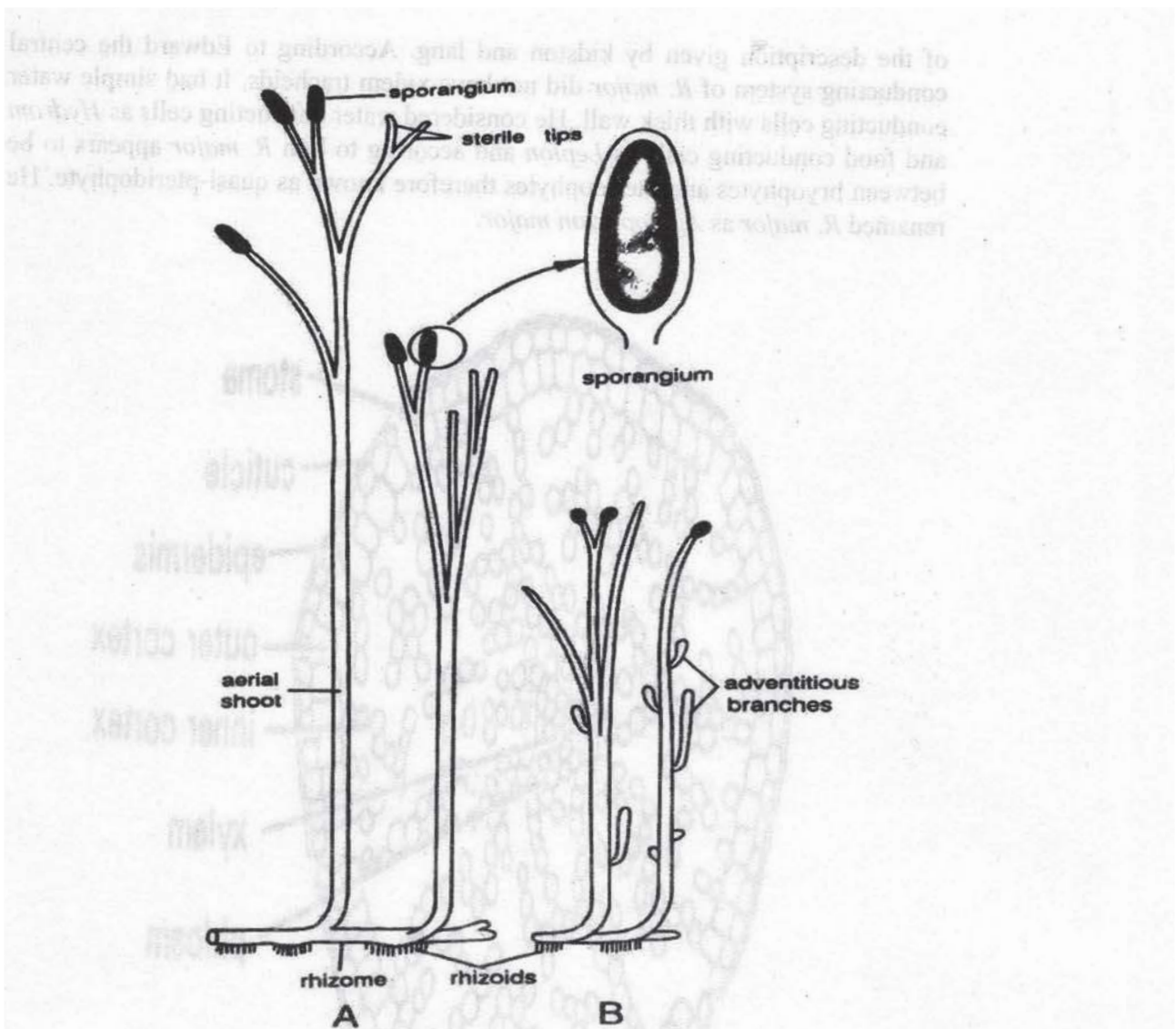


Fig.8.1. A-B. *Rhynia* : Morphology. A. *R. Major*, B. *R. gwynne-vaughanii*. (after Kidston and Lang).

8.2.2 ANATOMY

Axis stem :- The outermost layer was single layered epidermis surrounded by thick layer of cuticle. The epidermis of aerial axis was interrupted by stomata. Epidermis was followed by cortex divided into outer and inner cortex. The outer cortex is 1-4 layered thick made up of compactly arranged parenchymatous cells and represent hypodermis. The inner cortex was made up of parenchymatous cells with large inter cellular spaces. This region was main Photosynthetic region.

In the center was a protostele which has xylem surrounded by phloem. Endodermis and pericycle were absent. The xylem had few tracheids which has annular thickening. The phloem was simple with elongated thin walled cells with oblique end walls.

In 1986, Edward has reinvestigated the internal structure of the axis of two species of *Rhynia* and observed that anatomy of *R. major* was different from that

of the description given by Kidston and Lang. According to Edward the central conducting system of *R. major* did not have xylem tracheids. It had simple water conducting cells with thick wall. He considered water conducting cells as *Hydrom* and food conducting cells as *Lepton* and according to him *R. major* appears to be between bryophytes and pteridophytes therefore known as quasi-pteridophyte. He renamed *R. major* as *Aglaophyton major*.

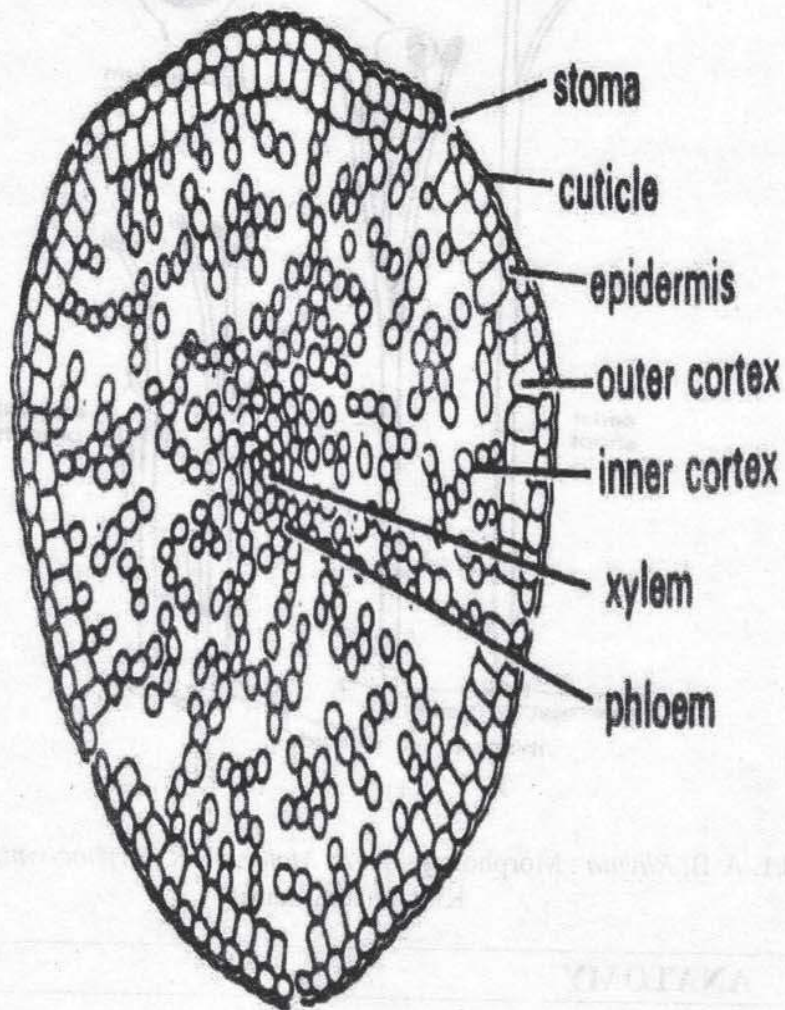


Fig. 8.2. *Rhynia*. Anatomy of stem.

8.2.3 LIFE CYCLE

Reproduction :- Sporangia were born singly at the tip of the aerial branches. Sporangia were oval or slightly cylindrical. The sporangium was surrounded by multilayered Jacket. The outer layer was cuticularised followed by 2-3 layered thin walled cells. The innermost layer of jacket was known as Tapetum which was nutritive layer. Many spore tetrad were in the sporangial cavity.

All the spores were of same type with typical triradiate marking. The sporangia did not have any special mechanism of dehiscence. The spores were liberated by the decay of sporangial jacket.

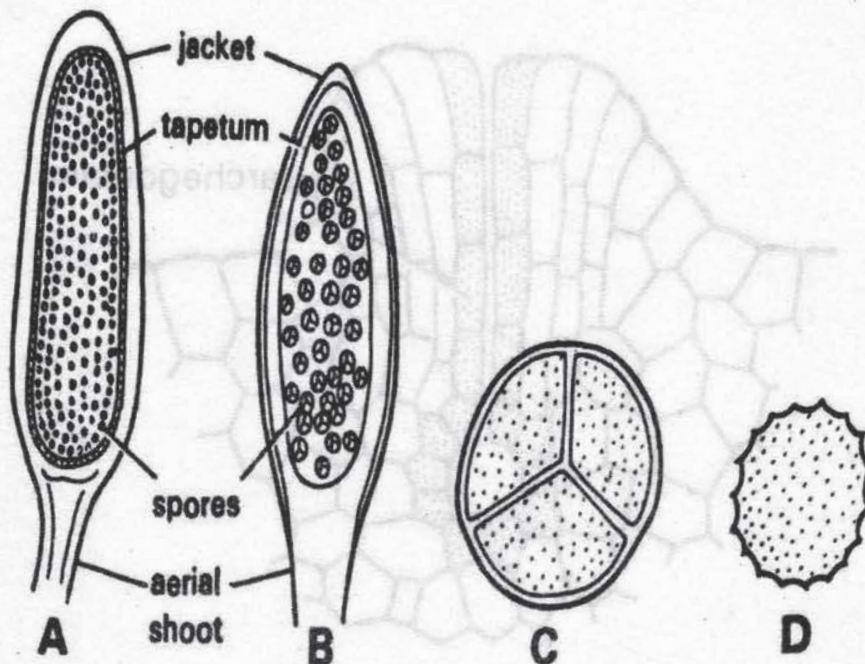


Fig. 8.3. A-D. *Rhynia* : Sporangium and spores; **A-B.** Longitudinal section of sporangium of *R. gwynne-vaughanii*, **C.** Spore tetrad, **D.** spore

The Gametophyte :- The gametophyte of *Rhynia* was not definitely known. It was represented by spores only. The spore in tetrad indicates that they were produced as a result of meiosis. Thus spore represents the first cell of gametophytic generation.

Layon (1957) observed some germinating spores from Rhynie chert which look like *Rhynia*. He described them young gametophyte of *Rhynia*.

Marker (1958-59) considered underground rhizomatous axes of *Rhynia* as the gametophyte which produced erect aerial sporophyte. He regarded flask shaped cavities in the rhizomatous part as disintegrated sex organs and four celled marking with central pores as embedded archegonia.

Prof. D.D. Pant (1962) made a careful review of Kidston and Lang's works. According to him small sized *R. gwynne-vaughanii* might be the gametophyte of large sized *R. major*. This conclusion was based on the facts that-

1. The sporangia of *R. gwynne-vaughanii* were not found in connection with its aerial axes.
2. Hemispherical bulges and adventitious branches were probably young embryos.

Pant's view was supported by Lemoigne (1968) who described the archegonia of *R. gwynne-vanghanii*. According to him the gametophyte and sporophyte of *Rhynia* were isomorphous.

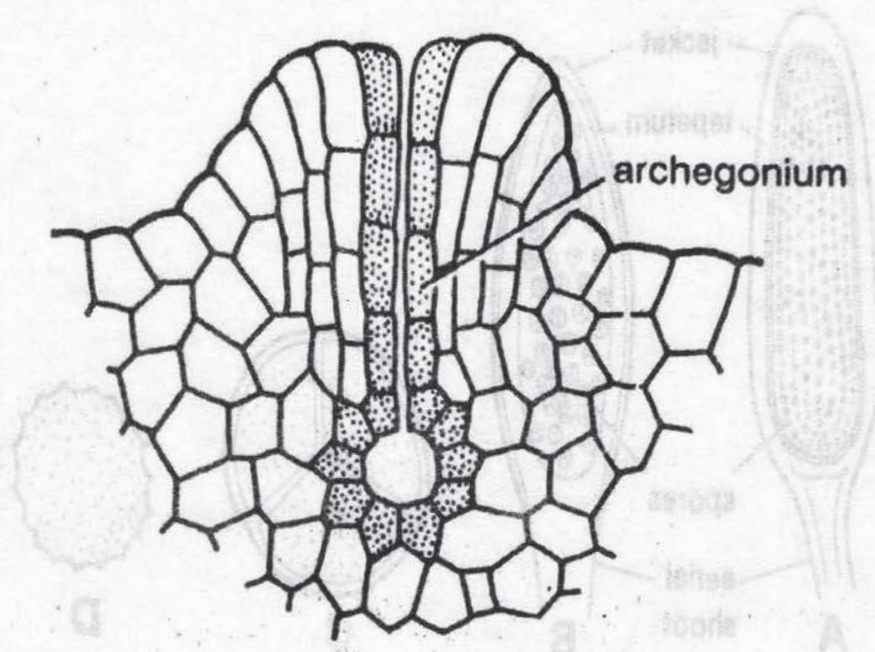


Fig.8.4. *Rhynia gwynne-vanghanii* : 'Archegonium'.

Later on Edward (1980 and 86) established the attachment of sporangia at the apex of axis of *R. gwynne-vanghanii* and confirmed it as a sporophyte.

Remy (1982) discovered radially symmetrical axes from rhynie chert and identified it as gametophyte. The axis had concave disc like pad bearing either antheridia or archegonia or both. Thus the gametophyte of *Rhynia* is still not clearly known and is an open question.

SAQ-1

- Who discovered *Rhynia*.
- The two species of *Rhynia* were and
- Rhynia* was a fossil.
- Rhynia* was discovered from Rhynie village of

8.3 LYCOPODIUM : (CLUB MOSS)

Systematic position

Division - Lycophyta

Order- Lycopodiales

Family- Lycopodiaceae

Genus- *Lycopodium*

Lycopodium is represented by about 400 species which are world wide in distribution. About 33 species are in India mainly found in Eastern Himalaya and South Indian Hills. It is commonly known as Club Moss and majority of them are moist and shade loving.

8.3.1 MORPHOLOGY

The sporophytic plant body is differentiated into root, stem and leaves.

The Genus *Lycopodium* is divided into two sub genera.

(1) *Urostachya*

(2) *Rhopalostachya*

	Urostachya	Rhopalostachya
1.	In <i>Urostachya</i> the stems are erect or pendent and never creep.	In <i>Rhopalostachya</i> stem is prostrate with upright branches.
2.	Roots arise from the basal part of the stem.	Adventitious roots are borne along the entire length of the prostrate stem.
3.	Foliage leaf and sporophylls are of approximately same size.	Sporophylls are smaller than the foliage leaves
4.	Sporophylls are not organised into compact cone eg. <i>L. selago</i> .	Sporophylls are in compact cone.
5.	Vegetative reproduction take place by bulbils eg. <i>L. Phlegmaria</i> .	Vegetative reproduction does not take place by bulbils eg. <i>L. Clavatum</i> , <i>L. cernuum</i>

The root are adventitious dichotomously branched and fibrous in appearance. In *Urostachya* root arises from the base of the stem where as, in *Rhopalostachya* roots arise along the entire length of the prostrate stem.

Leaves are simple, small, sessile lens shaped with broad base and single unbranched midrib. The leaves are arranged in close spiral (*L. clavatum*) or in whorl (*L. cernuum*). Plant bears two types of leaves:-

(i) Vegetative leaves :- Which are purely photosynthetic.

(ii) Sporophylls :- Bears sac like sporangia on the upper surface of leaf.

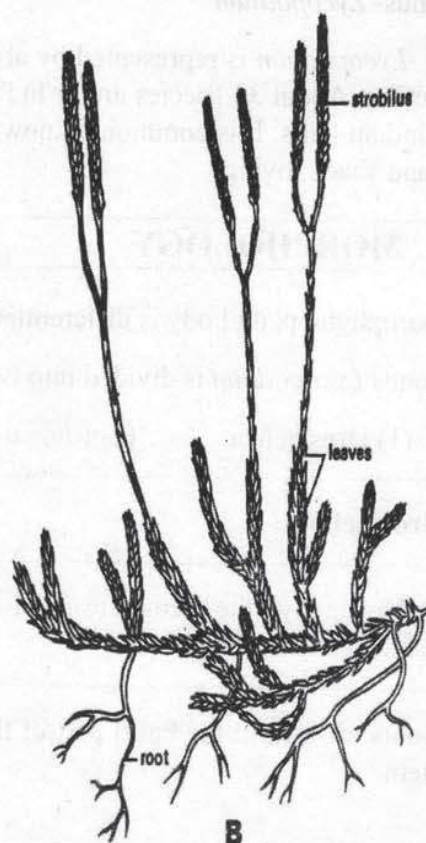


Fig. 8.5. A-B. Morphology A. *Lycopodium phlegmaria*. B. *L. clavatum*.

8.3.2 ANATOMY

Stem : The outermost layer is epidermis, which is single layered in thickness. Outside the epidermis is cuticle. Stomata are present on epidermis. Below the epidermis is many layered cortex. In *L. clavatum* the outer and inner cortex is sclerenchymatous and middle cortex is parenchymatous.

In *L. Cernuum* the outer and inner cortex is parenchymatous and middle cortex is sclerenchymatous. The cortex is limited by endodermis which has thickened radial wall known as casparian strip. Endodermis is followed by 3-6 layered pericycle.

The centre of the stem is occupied by a protostele. The arrangement of xylem and phloem varies greatly from species to species.

In *L. clavatum* the stele is plectostele in which xylem and phloem occur in parallel row.

In *L. selago* the stele is actinostele. The xylem has radiating arm and phloem lie in between the arms of xylem.

In *L. cernuum* stele is mixed protostele in which xylem and phloem are intermixed.

The xylem is differentiated into protoxylem and metaxylem. The protoxylem is towards the outer edge of xylem arm/band/patch and metaxylem in the centre. The condition of xylem is exarch.

The tracheids of protoxylem have annular or spiral thickenings where as, the tracheids of metaxylem have scalariform and pitted thickening. The phloem is composed of sieve cells with sieve areas distributed over the lateral walls and end walls.

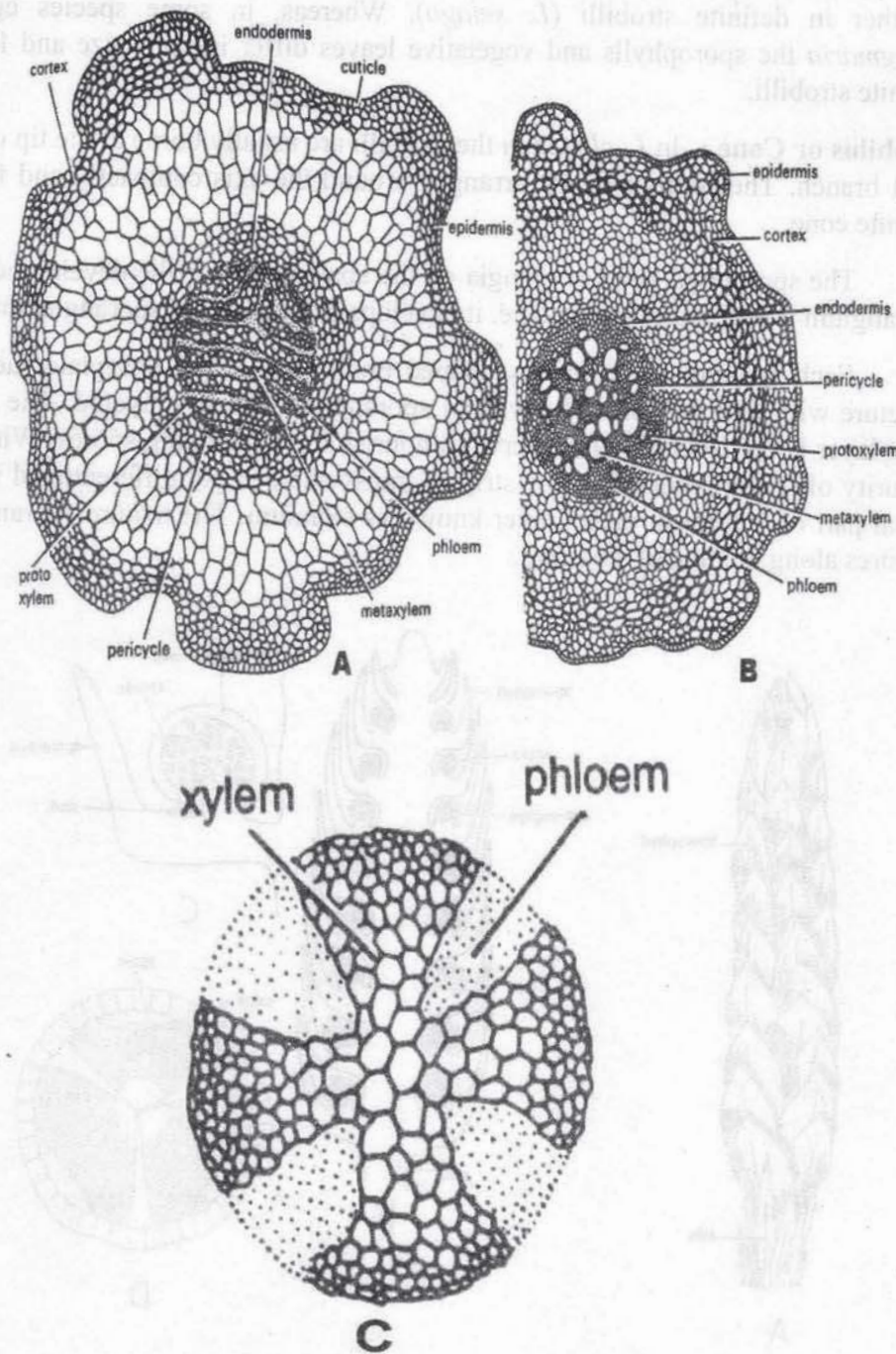


Fig.8.6. A-B. Anatomy of stem : A. *Lycopodium clavatum*.

B. *L.cernuum*, C. Actinostele : *L. selago*.

8.3.3 LIFE CYCLE

Strobilus or Cone :- In *Lycopodium* the sporophytic plant body reproduce asexually by means of spores produced in sporangia.

The sporangia are found singly on the upper surface (abaxial) of the sporophyll near the base or in their axils. In most of the species of urostachya, the sporophylls are very much similar to vegetative leaves and are not grouped together in definite strobilli (*L. selago*). Whereas, in some species eg. *L. Phlegmaria* the sporophylls and vegetative leaves differ in their size and forms definite strobilli.

Strobilus or Cone :- In *L. clavatum* the strobilli are usually borne at the tip of the erect branch. The sporophyll get arranged around the axis compactly and forms definite cone.

The sporophyll bears sporangia on the abaxial surface the development of sporangium is eusporangiate type i.e. it develops from group of sporangial initial.

Each sporangium is kidney shaped orange to yellow unseptate sac like structure with narrow stalk. The wall of sporangium is many layered. The inner most layer is the tapetum which serve to nourish the developing spores. With the maturity of sporangium, a narrow strip of transverse cell get differentiated in the apical part of outermost jacket layer known as stomium. The mature sporangium ruptures along the line of stomium.

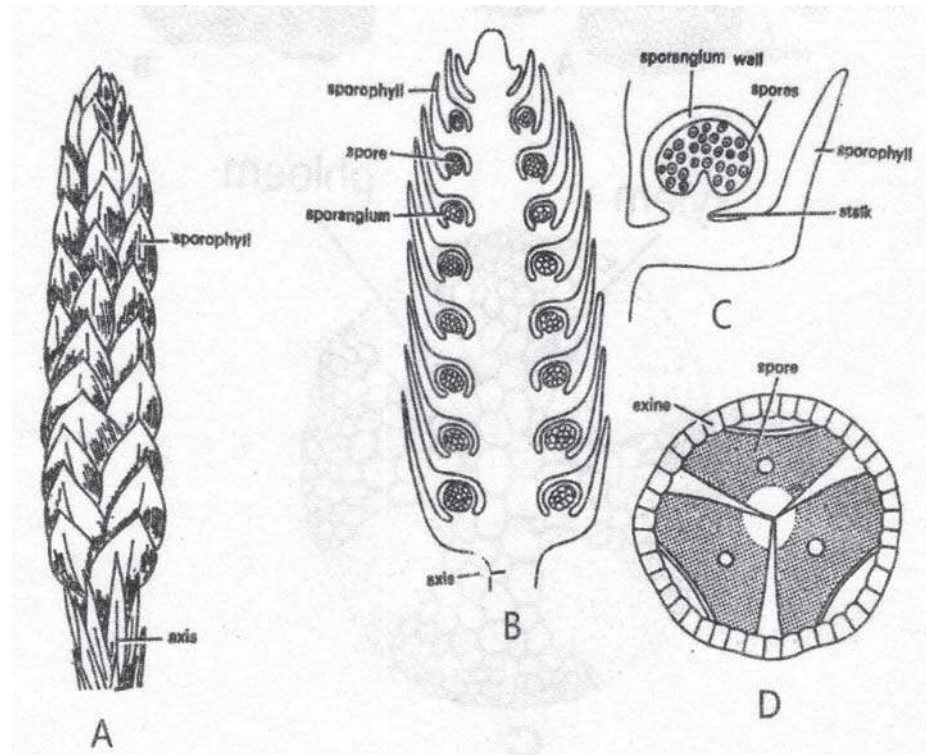


Fig. 8.7. A-D. *Lycopodium*. **A.** An entire strobilus, **B.** Longitudinal section of strobilus, **C.** Single sporophyll showing an sporangium, **D.** Spores.

Selago Condition :- In *L. selago* the sporophylls are similar to foliage leaves and do not produce organised strobilus. The fertile and sterile zones are alternating on sporophyll.

The fertile zone has sporophylls, which has sporangia on adaxial side at the base of sporophylls. Where as, the sterile zone bears only foliage leaves.

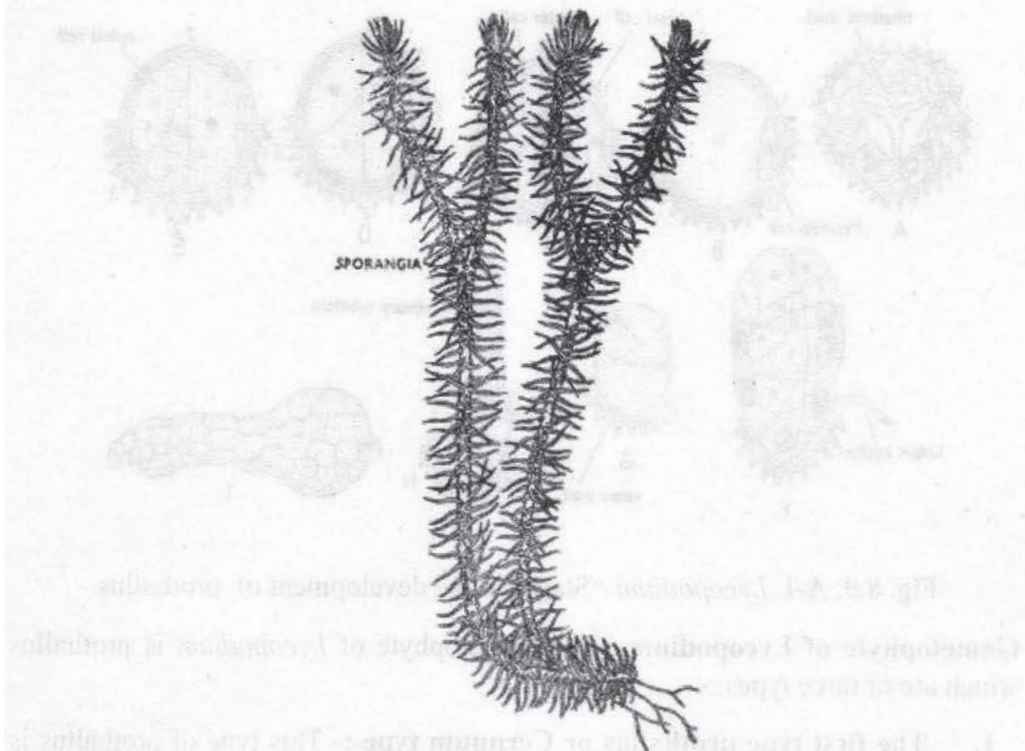


Fig. 8.8. *Lycopodium selago*.

The gametophyte :- The spore is haploid therefore, it represents the gametophytic generation. *Lycopodium* is homosporous since, spores are alike in size and shape. The spores are unicellular with triradiate ridge and thick spore wall. Each spore has a haploid nucleus and reserve food material.

Germination of Spore and development of the prothallus :-

The time of spore germination varies in various species of *Lycopodium*.

In case of *L. clavatum* the spore takes longer time to germinate. It produces subterranean prothalli as they get burried in soil.

In *L. cernuum* the spore germinates with in a few days of their liberation from the sporangium and produce surface or aerial prothalli.

Just before germination the spore absorbs water due to which their exine ruptures. The first division in the spore takes place which is assymetrical and give rise a large cell and a small rhizoidal cell. The rhizoidal cell do not participate in the development of prothallus. The large cell divide by a vertical division into a basal cell and an outer cell. The outer cell divide by two cutting faces. Further development of gametophyte proceeds only after the entry of symbiotic fungus into the basal cell of gametophyte. The fungus forms endophytic mycorrhiza. It is

believed that physiologically the fungus supplies certain substances vital for the proper development of prothallus. If there is no fungal infection further development of gametophyte is checked. After infection the apical cell becomes active and cuts off six segments. Later on apical cell is replaced by meristematic cell which divide and redivide to give the prothallus of *Lycopodium*.

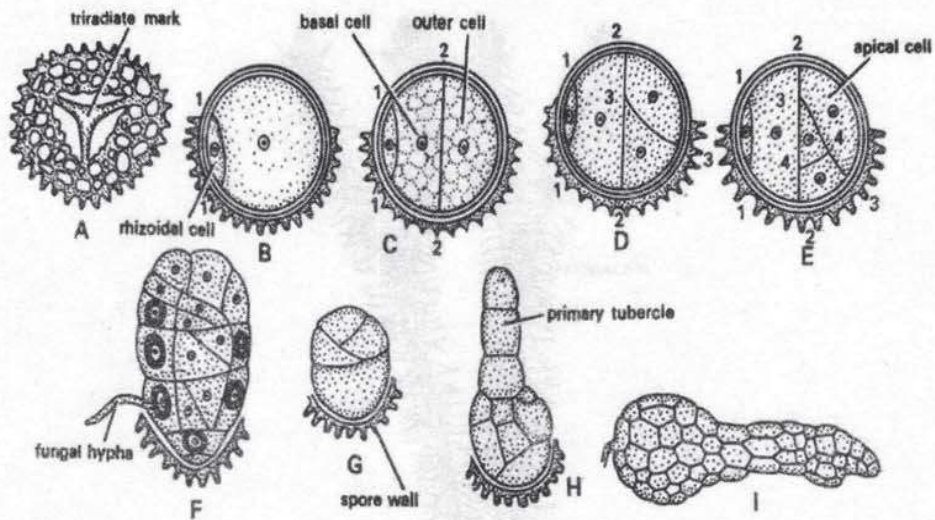


Fig. 8.9. A-I. *Lycopodium* ; Stages in the development of prothallus.

Gametophyte of *Lycopodium* : The gametophyte of *Lycopodium* is prothallus which are of three types :-

1. **The first type prothallus or Cernuum type :-** This type of prothallus is found in the tropical species eg. *L. cernuum* and temperate species eg. *L. inundatum*. The prothallus of *L. cernuum* is usually small, annual partially aerial and partially underground. The rhizoids arise from the lower buried part. The underground part has endophytic fungus. The upper aerial part has lobes which bears antheridia and archegonia at the base.

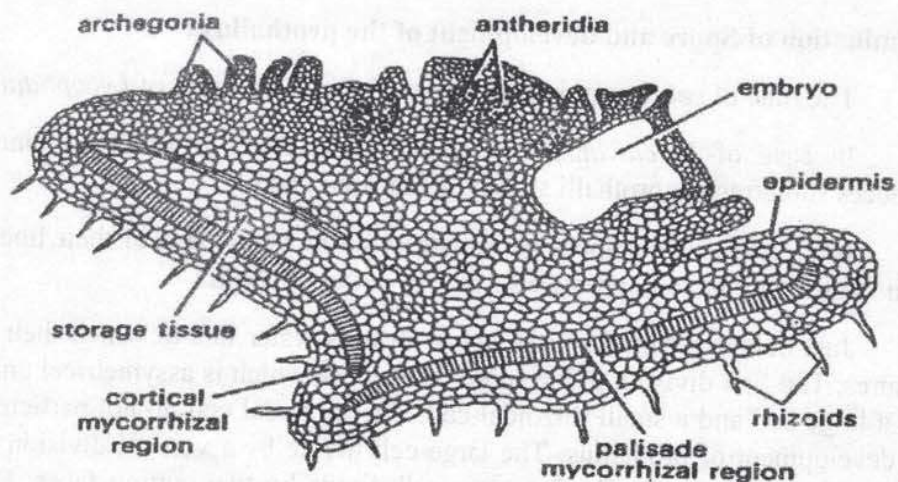


Fig. 8.10. *Lycopodium cernuum* : Prothallus.

2. **Second type Prothallus or Clavatum type :-** It germinates after 3-8 years of liberation. It is found in creeping species eg. *L. clavatum*. The prothallus is underground, yellowish brown tuberous structure of 1-3cm. top or carrot shaped. Long rhizoids arise from the lower surface of prothallus.

In a V.S. (vertical section) mature prothallus has an outer epidermis from which rhizoids arise. The outer cortex is prosenchymatous where as, the inner cortex is filled with mycorrhizal fungus. In the center is parenchymatous storage tissue. The top of the prothallus is lobed. The antheridia, archegonia and embryo are located in these lobes.

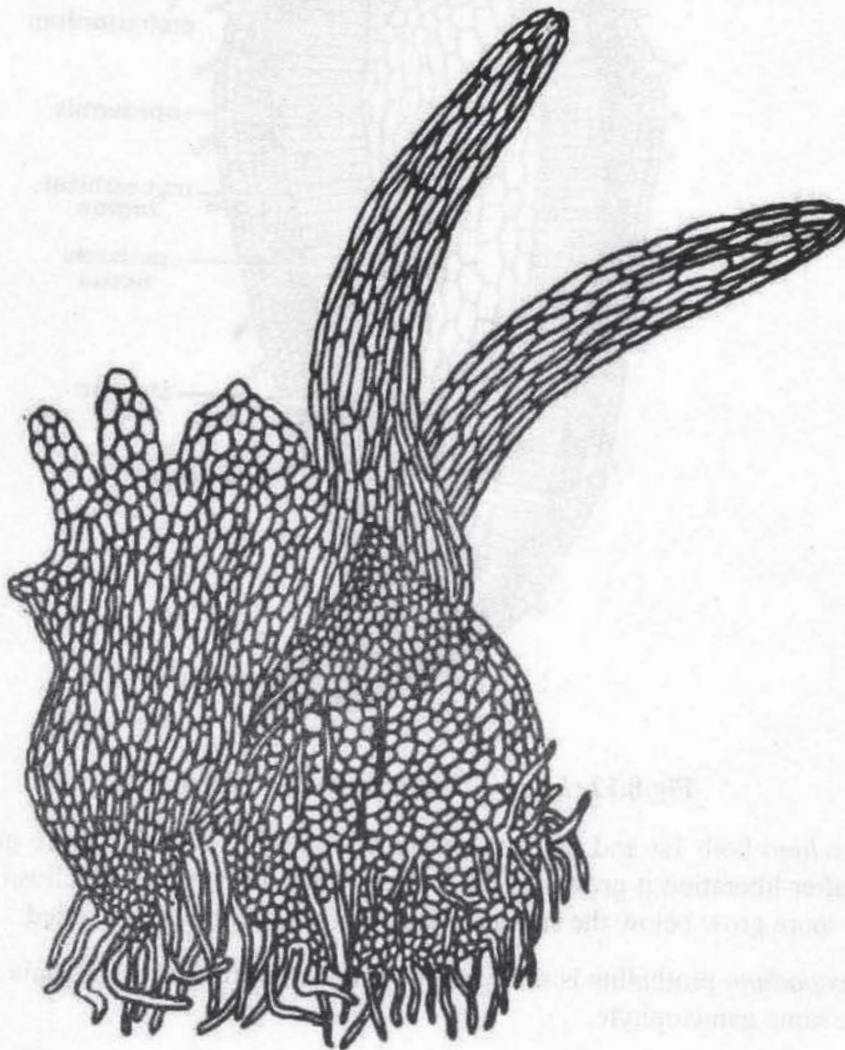


Fig.8.11. *Lycopodium clavatum* : prothallus.

3. **The third type prothallus or Phlegmaria type :-**

This type of prothallus is found in epiphytic species eg. *L. phlegmaria*. The gametophyte is saprophytic and grows on trunks just below the surface of humus. It has a small tuberous body from which a number of colourless branches extend out. These branches bears antheridia and archegonia. The central core of branch is traversed by mycorrhiza.

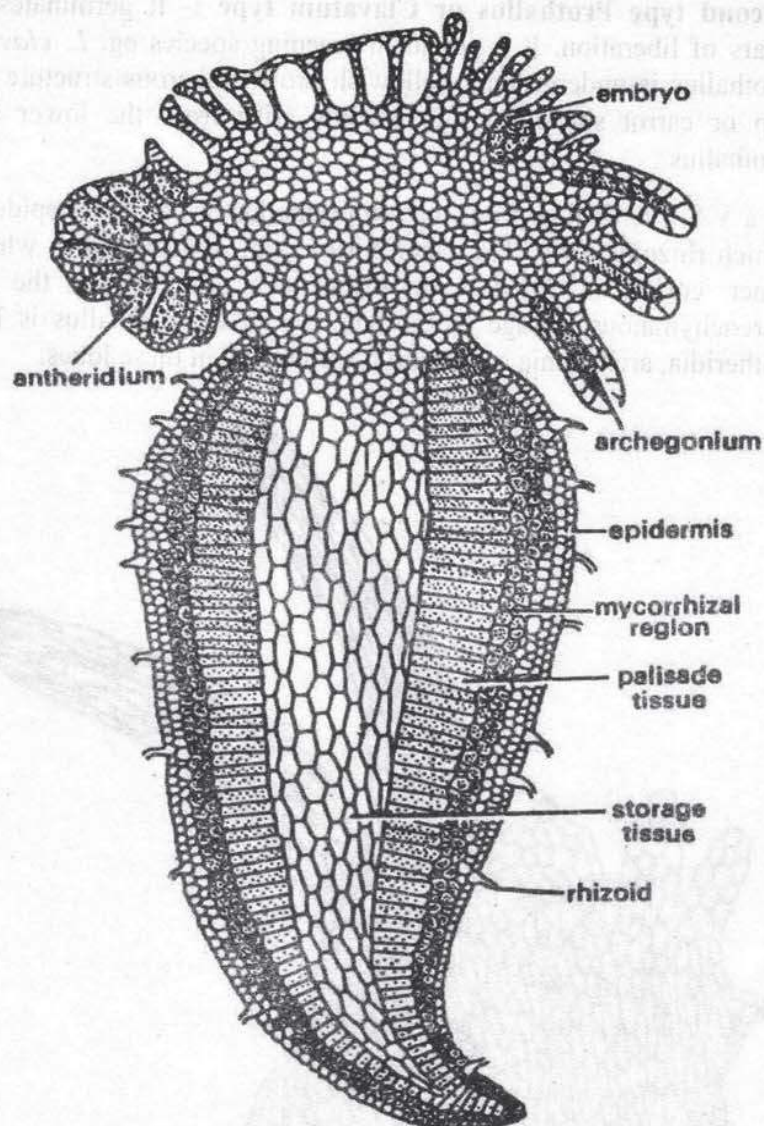


Fig.8.12. *Lycopodium phlegmaria* : Prothallus.

In *L. selago* both 1st and 2nd type of gametophyte is found. If spore germinates soon after liberation it grows on the surface. Thus, the aerial prothallus is formed. If the spore grow below the surface clavatum type prothallus is formed.

In *Lycopodium* prothallus is monoecious and antheridia and archegonia are borne on the same gametophyte.

Antheridia :- Antheridia are globose structure partly embedded in the gametophyte. It has a sterile jacket inside which are antherozoid mother cell. Which give rise oval, pointed, biflagellated antherozoids.

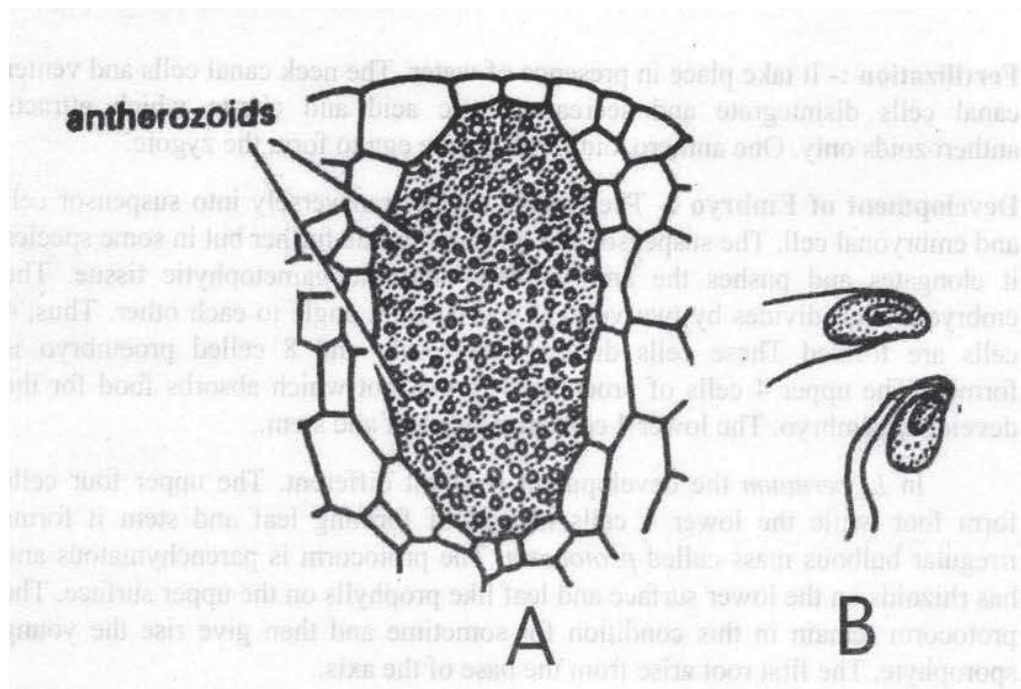


Fig.8.13. A-B. *Lycopodium* : A. Mature antheridium, B. Antherozoid.

Archegonia :- The archegonia have a neck and venter. The neck has neck canal cells which protrude out. The venter has venter canal cells and an egg. On maturity the neck canal cells and venter canal cells disintegrate and a passage is formed through which antherozid reach the egg.

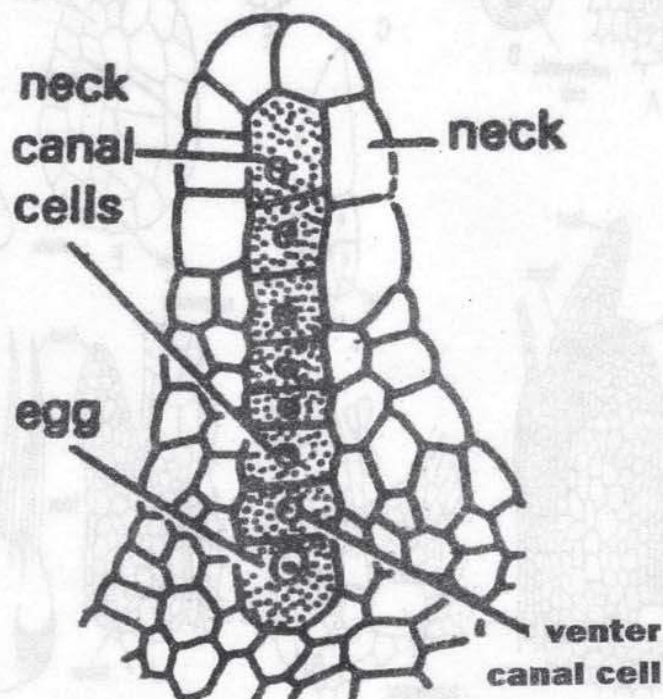


Fig.8.14. *Lycopodium* : Archegonium.

Fertilization :- It take place in presence of water. The neck canal cells and venter canal cells disintegrate and secretes citric acid and citrate which attracts antherozoids only. One antherozoid fertilizes the egg to form the zygote.

Development of Embryo :- The Zygote divide transversely into suspensor cell and embryonic cell. The suspensor cell does not divide further but in some species it elongates and pushes the embryo deep into the gametophytic tissue. The embryonic cell divides by two vertical wall at right angle to each other. Thus, 4 cells are formed These cells divide transvresely and 8 celled proembryo is formed. The upper 4 cells of proembryo forms foot which absorbs food for the developing embryo. The lower 4 cells give rise leaf and stem.

In *L. cernuum* the development is slight different. The upper four cells form foot while the lower 4 cells instead of forming leaf and stem it forms irregular bulbous mass called *protocorm*. The protocorm is parenchymatous and has rhizoids on the lower surface and leaf like prophylls on the upper surface. The protocorm remain in this condition for sometime and then give rise the young sporophyte. The first root arise from the base of the axis.

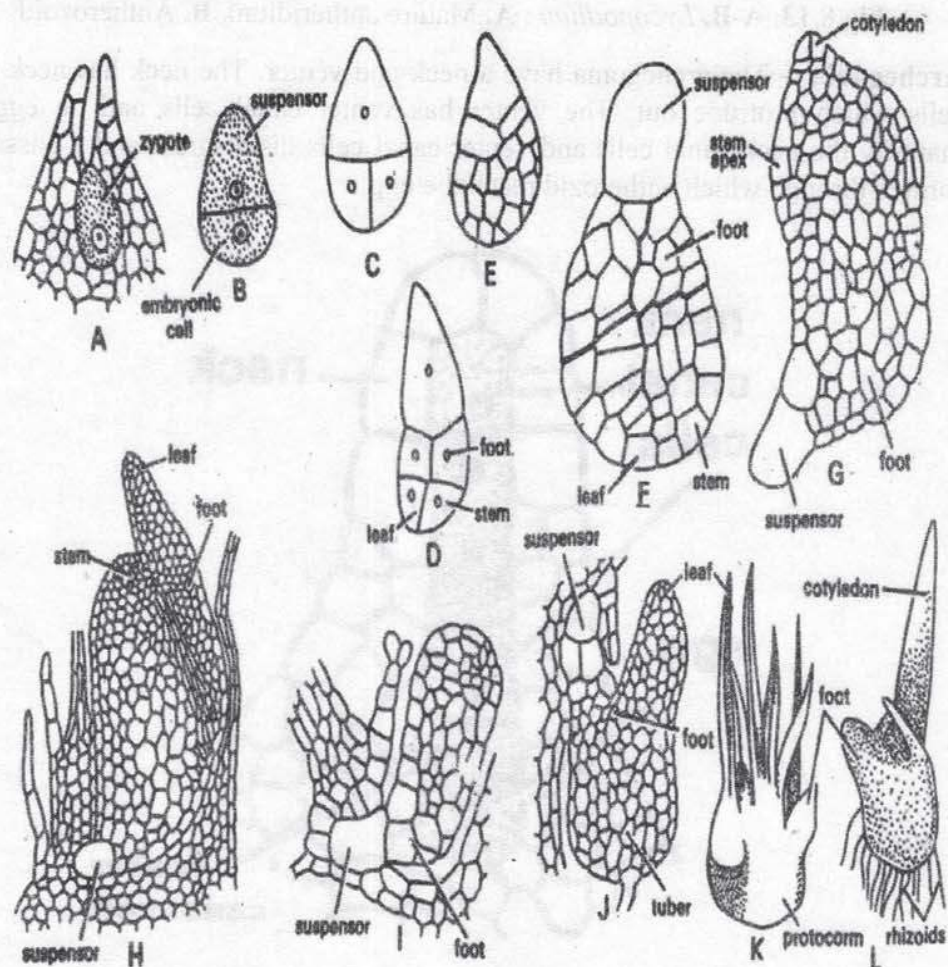


Fig.8.15. Lycopodium : Embryo development; A. Zygote, B-J. Stages in embryo development, K-L. Protocorm.

Morphological Nature of Protocorm :-

There are various views regarding morphological nature of protocorm :-

1. According to Treub it is an undifferentiated primitive stage of sporophyte which was present in all pteridophytes but has disappeared in most of the existing pteridophyte.
2. Goebel and Bower considered protocorm as an occasional adaptation to meet the strain of sporophytic development under special conditions.
3. According to Holloway protocorm is a specialized structure which helps the young sporophyte to perenate in dry season and according to Wardlaw protocorm out growth is due to high C/N ratio.

SAQ-2

- (a) *Lycopodium* is commonly known as moss.
- (b) *Lycopodium* is a pteridophyte.
- (c) The stem of *Lycopodium* has stele.

8.4 SELAGINELLA

Systematic position

Division - Lycophyta

Class- Ligulopsida

Order- Selaginellales

Family- Selaginellaceae

Genus- *Selaginella*

Selaginella is a large genus contains about 700 species which grow mostly in the damp forest of tropical countries. 70 species of *selaginella* are reported in India. Few species are xerophytic, eg. *S. lepidophylla*, *S. rupestris* and *S. pilifera*.

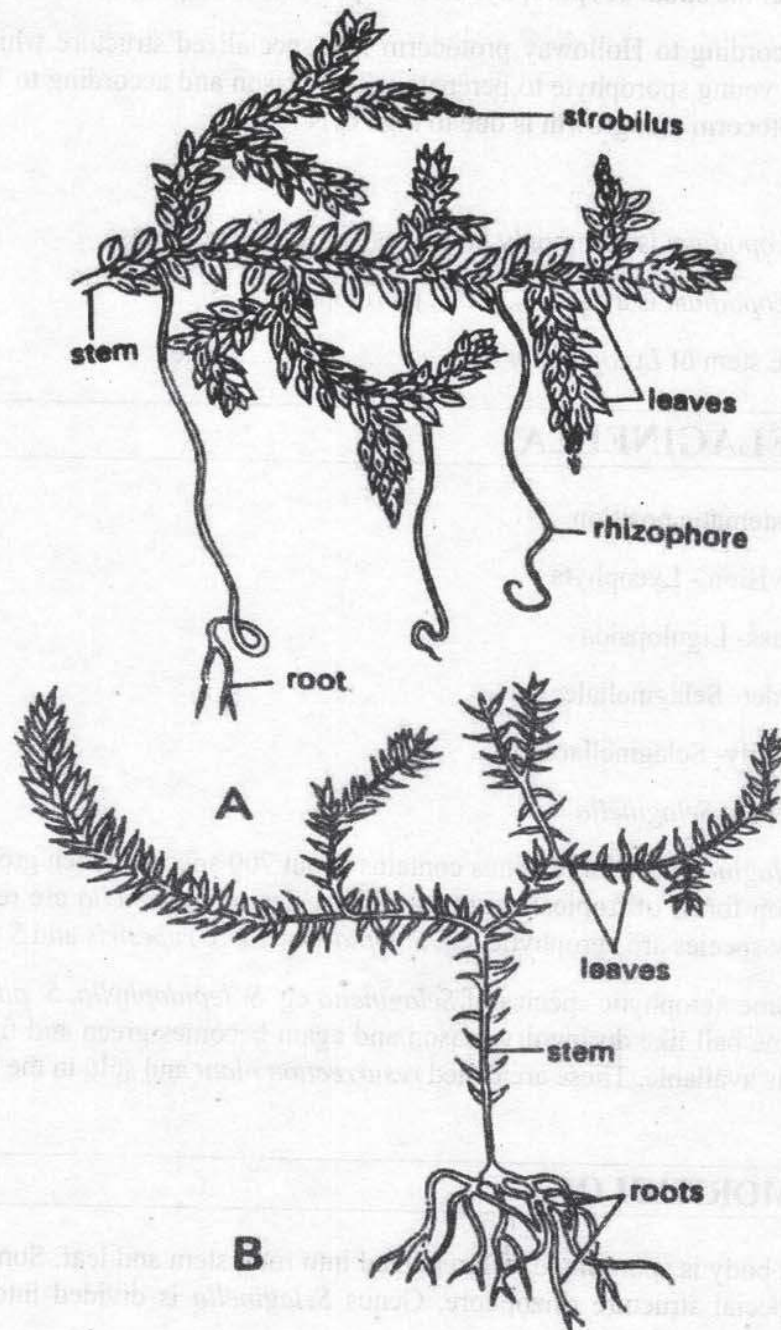
Some xerophytic species of *Selaginella* eg. *S. lepidophylla*, *S. pilifera* curl and become ball like during dry season and again becomes green and fresh when moisture is available. These are called *resurrection plant* and sold in the market as *Novelties*.

8.4.1 MORPHOLOGY

The plant body is sporophyte differentiated into root, stem and leaf. Some species have a special structure rhizophore. Genus *Selaginella* is divided into two sub genera -

- (1) Homoeophyllum
- (2) Heterophyllum

- (1) **Homoeophyllum** :- It has erect dichotomously branched stem. Leaves are spirally arranged and roots are adventitious present on the stem eg. *S. lepidophylla*.
- (2) **Heterophyllum** :- It has a prostrate stem from which arise erect stem. Leaves are arranged in 4 vertical rows. In the angle meristem are (+)vely geotropic rhizophore. At the end of which are adventitious roots. eg. *S. kraussiana*.



**Fig.8.16. A-B. Selaginella : External morphology : A. *S. kraussiana*,
B. *S. selaginoides*.**

Rhizophore :- Rhizophore is long, cylindrical, unbranched leafless structure. It's anatomy is similar to the root but morphological nature of the rhizophore has been variously interpreted by different botanists. Some consider it as a root while other as a stem and the third view regard it as an organ sui-generis.

1. Rhizophore is a root :- Rhizophore is a root because of following reasons:-

1. It is positively geotropic.
2. Anatomy is similar to root.
3. They have no leaves.
4. The Rhizophore always have monostelic stelar organization even when stem is polystelic.

2. Rhizophore is a stem :- Rhizophore is a stem due to following reasons :-

1. Root cap and root hairs are absent.
2. They are exogenous in origin.
3. They are always formed from "angle meristem" which are present between the two arms of the stem.
4. They can be developed into leafy shoot under controlled experimental conditions.

3. Organ sui-generis :-

According to Bower and Goebel rhizophore is neither a root nor a shoot but is an organ sui-generis (Independent organ).

Ligule :- On the upper surface of each leaf close to its base there is present a flap like appendage called ligule. It is prominent and functional during growth of leaf but wither away in mature leaf. Ligule is characteristic of ligulopsida.

Structure :- The basad part of ligule is hemispherical called glossopodium. It is made up of thin walled tubular cells. The glossopodium is surrounded by glossopodium sheath. It is sunken in the tissues of leaves. The projected part of ligule is tongue like and has more or less cubical cells densely filled with protoplasm.

Function : The function of ligule is not definite. It has been suggested that in some way it helps in absorption of water.

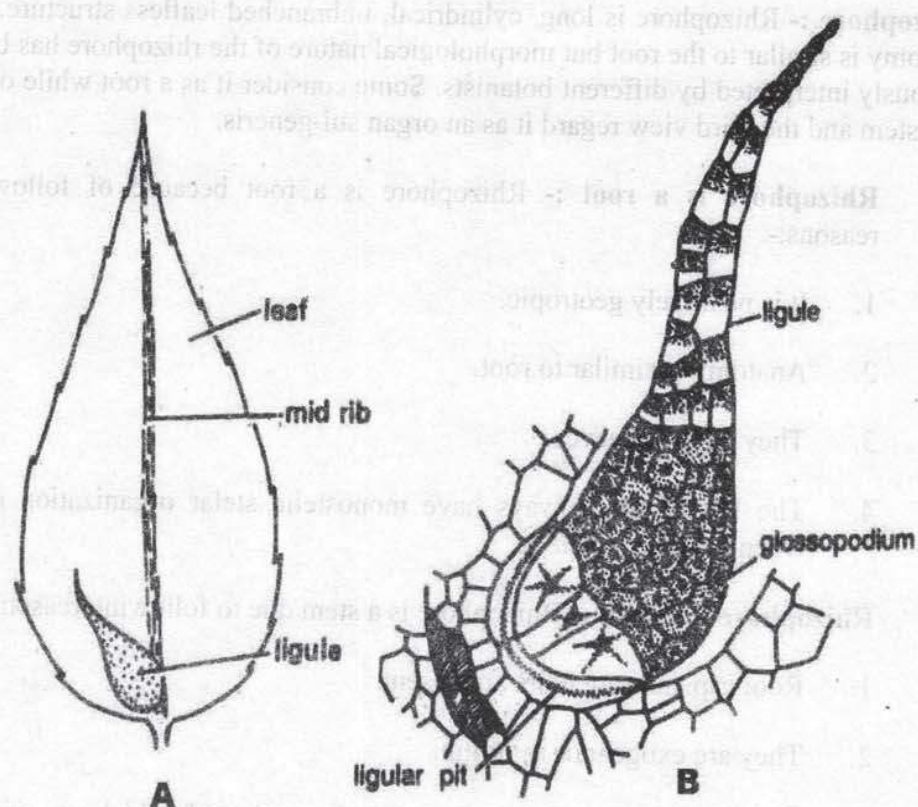


Fig.8.17. A-B. *Selaginella* : A. Leaf with ligule, B. Vertical section of ligule.

8.4.2 ANATOMY

Stem :- Outer most layer is single layered epidermis. Out side which is thick cuticle. Below it is many layered cortex which is sclerenchymatous. In xerophytic species the cortex is divided into outer few layered sclerenchymatous region and inner many layered parenchymatous region. The innermost layer of cortex is endodermis.

In the young stem the endodermis is a normal compact ring but on maturity the endodermal cells are radially elongated called trabeculae which has characteristic casparian band on lateral wall. Due to trabeculae stele is separated from the cortex by large air spaces. Stele has a single layered pericycle and protostele i.e. central core of xylem surrounded by phloem. The xylem may be circular flate ribbon like. It is monarch and exarch. (Protoxylem at the edge and metaxylem in the center). Xylem has tracheids. Protoxylem cells have annular and spiral tracheids and metaxylem tracheids have scalariform thickning.

No of stele varies in different species of *selaginella*.

S. spinulosa is monostelic, *S. kraussiana* is distelic and *S. laevigata* is Polystelic.

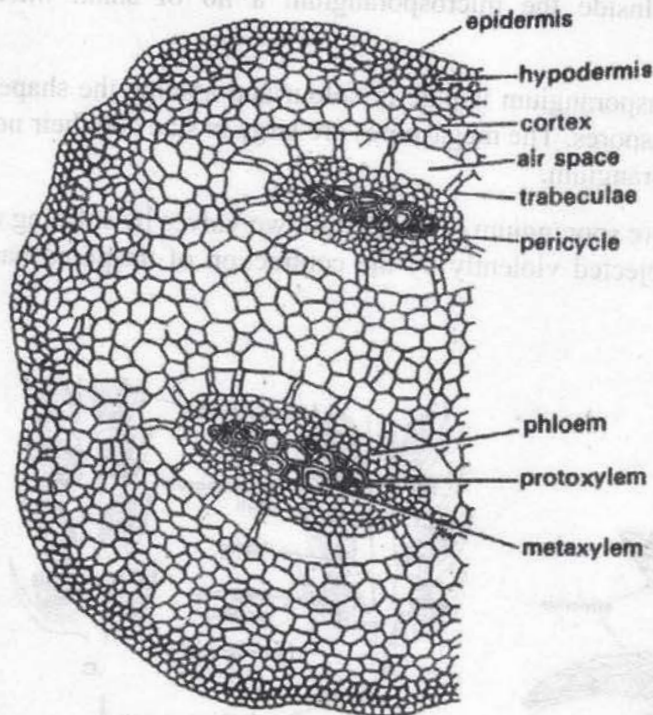


Fig.8.18. *Selaginella* : Anatomy of stem.

8.4.3 LIFE CYCLE

1. Strobilus/cone/spike

Selaginella is heterosporous pteridophyte and bears microspores and megaspores produced in microsporangium and megasporangium respectively. Microsporangium is born on microsporophyll and megasporangium on megasporophyll. The micro and mega sporophylls are spirally arranged around a central axis at the apex of main stem to form strobilus. The strobilus is often inconspicuous. Its size varies from 5mm to 6-7 cms.

The distribution of micro and megasporangium varies in different species of *Selaginella*. In *S. rupestris* the basal part of strobilus has megasporophyll having megasporangium whereas, the upper part has microsporophyll having microsporangium.

In *S. kraussiana* there is only single megasporophyll having megasporangium and rest are microsporophyll having microsporangium.

In *S. inaequalifolia* megasporophylls having megasporangia are on one side of the strobilus and microsporophylls having microsporangia are on the other side of strobilus.

The development of sporangium is eusporangiate type i.e. it develops from group of sporangium initial. The mature microsporangium is slightly elongated stalked, yellow, red or orange coloured structure. It has two

layered Jacket. Inside the microsporangium a no of small microspores are produced.

The megasporangium is pale in colour and assume the shape dectated by developing megaspores. The megaspores are large in size and their no varies from 1-4 in a megasporangium.

The mature sporangium dehisces into two volves by splitting of distal part. The spores are ejected violently by the contraction of unsplit basal part as it dries.

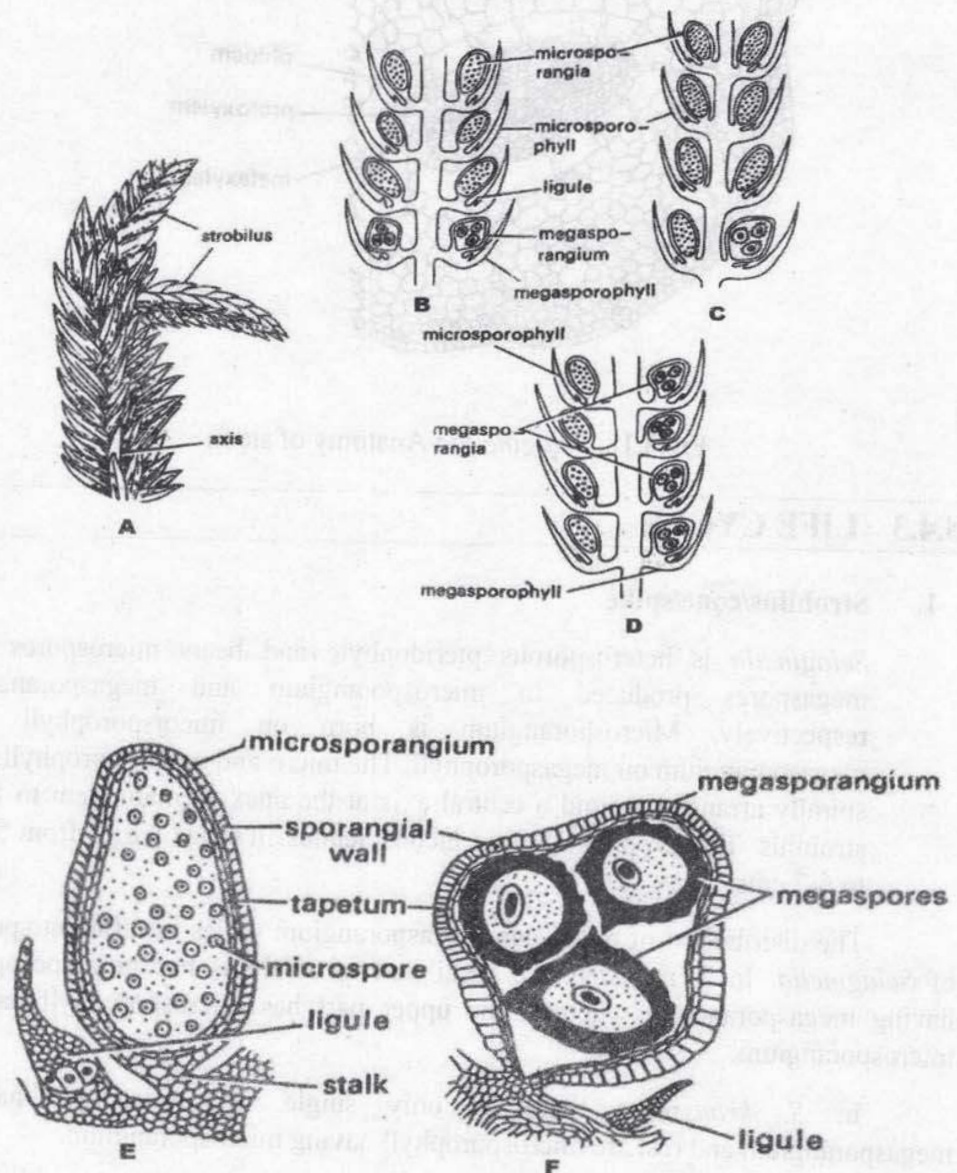


Fig.8.19. A-F. *Selaginella* : A. Branch bearing strobilus, B-D. Longitudinal sections of strobili showing distribution of micro and megasporangia, B. *S. rupestris*, C. *S. kraussiana*, D. *S. inaequalifolia*. E. Mature microsporangium, F. Mature megasporangium.

2. **Gametophyte** : Microspore and megaspore are the first cell of the gametophytic generation. Microspores on germination give rise male gametophyte where as, megaspore on germination give rise female gametophyte.

- (a) **Development of male gametophyte** :- Germination of microspore starts within the wall of microsporangium. The microspore divides into a prothallial cell and an antheridial cell. The antheridial cell further divides into 12 cells. Thus 13 cells are formed (4 androgonial cell, 8 outer cell and 1 prothallial cell).

The microspore of selaginella is shed from microsporangium at 13 celled stage. After shedding 4 androgonial cells under go a no of divisions and about 138-256 antherozoid mother cells are formed which get metamorphosed into antherozoids. Each antherozoid is an elongated structure with two flagella at one end. As antherozoid matures the wall of microspore cracks open along the triradiate ridge and antherozoids are liberated.

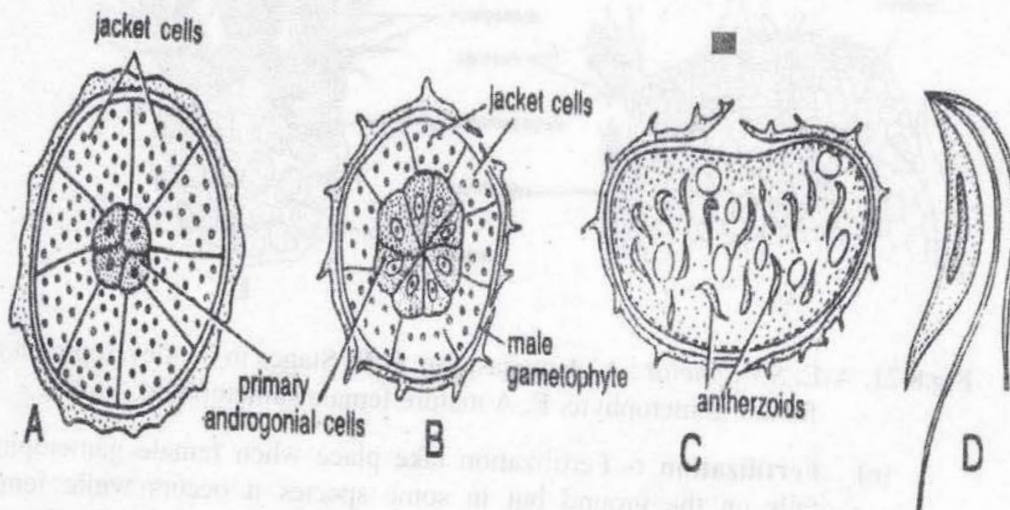


Fig.8.20. A-D. Development of male gametophyte. A and B young gametophyte, C. Mature gametophyte. D. Antherozoid.

- (b) **Development of Female gametophyte** :- Megaspore represents the first stage of female gametophyte. Usually 4 megaspores of equal size are produced in a megasporangium. The development of female gametophyte begins within the megasporangium. The female gametophyte is liberated after the formation of first archegonium in *S. kraussiana* or after the development of embryo has started in *S. rupestris*.

A large vacuole appears in the centre of the megaspore. The cytoplasm is pushed along the wall. The haploid nucleus under go mitosis followed by formation of wall. As a result a lens shaped pad of cellular cushion is formed at the apical end. The cellular cushion get separated from the rest of the female gametophyte by a diaphragm. With the increase of cytoplasm the central vacuole

disappears. At this stage the spore wall ruptures along the triradiate ridge exposing the cellular pad. The chloroplast, rhizoids and archegonia develops in the cellular pad. The mature archegonia have two celled neck, a venter and an egg.

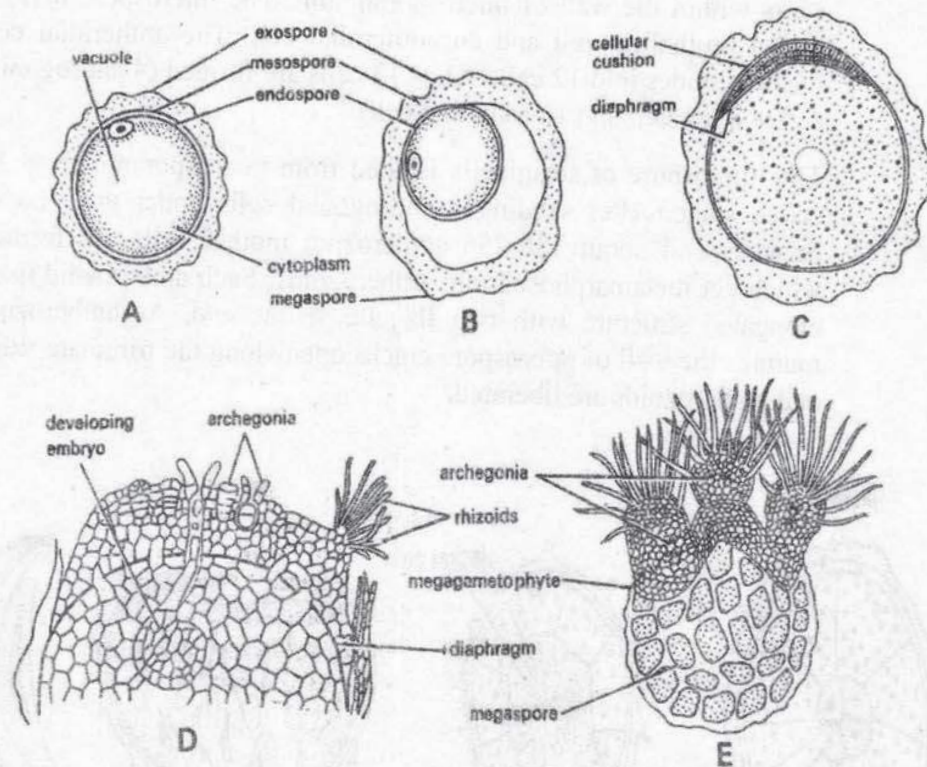


Fig.8.21. A-E. *Selaginella* : A. A megaspore, B-D. Stages in the development of female gametophyte, E. A mature female gametophyte.

(c) **Fertilization** :- Fertilization take place when female gametophyte falls on the ground but in some species it occurs while female gametophyte is still with in the megasporangium. Before fertilization the neck canal cell and venter canal cell disintegrate and a passage is formed. The antherozoids swim in rain or dew water and reach the archegonium. Usually one antherozoid enters into an archegonium and fuses with the egg to form diploid zygote.

(3) **Development of Embryo** :- The diploid zygote divide transversely and form an embryonal cell and a suspensor cell. The embryo develops from the embryonal cell.

The embryonal cell divides by two vertical walls at right angle to each other and form four celled embryo. One of the four cells of the embryo divide by an oblique wall and form an apical cell. Which give rise future stem enclosed on either side by two lateral cells. The lateral cell give rise the cotyledons. The three cells and the sister cell of the apical cell divide transversely to form two tiers of 4 cells each. One of the lower quadrant by repeated division form foot of the embryo. The foot absorbs food for

the developing embryo from the gametophytic tissue. The part of embryo posterior to cotyledons give rise hypocotyle. The foot by further growth pushes the stem apex to one side so that the axis of embryo comes to lie at right angle to the suspensor. From inner side of each cotyledon near to its base an out growth develops which forms ligule.

The apical cell of the root is differentiated from a superficial cell between foot and suspensor. It cuts off segments which produces rhizophore. The root develops on rhizophore.

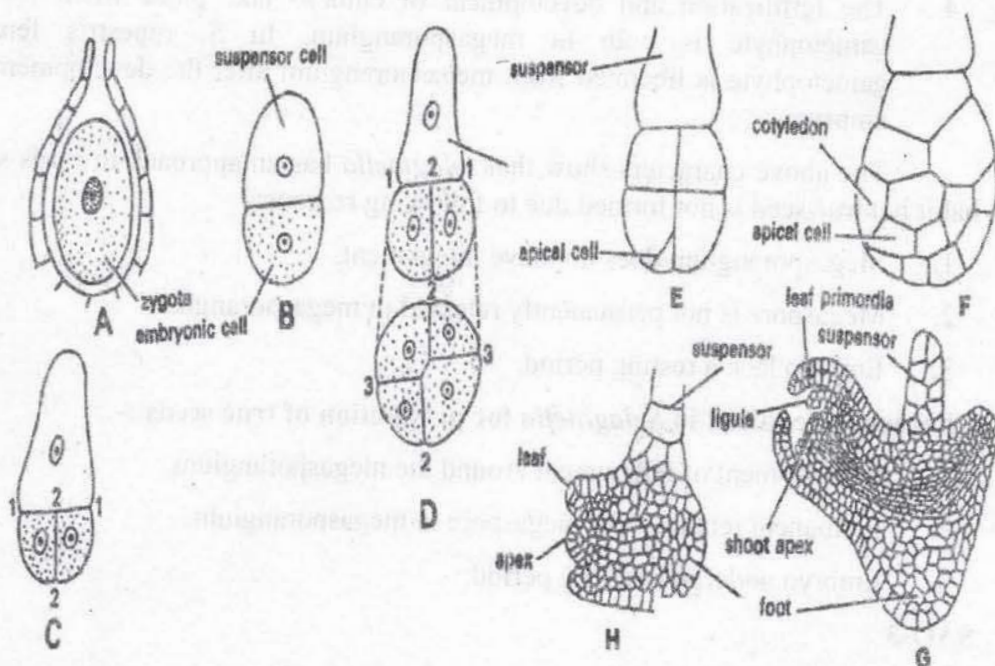


Fig.8.22. A-H. *Selaginella* : Stages in embryo development.

8.4.4 HETEROSPORY AND SEED HABIT

Heterospory :- Means production of two types of spores, microspores and megaspores. Microspores are small in size produced in large no in microsporangium. The megaspores are large in size produced in megasporangium. Their no varies from 1-4 in a megasporangium.

Genus *Selaginella* is heterosporous and produces two types of spores microspore and megaspore.

Advantage of heterospory :- In heterosporous pteridophyte the spores germinate within the sporangium. It remains dependent on the sporophyte for their nourishment. In the homosporous pteridophyte the spore germinates in soil and gametophytes are independent of the sporophyte. The gametophyte has to prepare food for themselves as well as for the developing embryo. Thus chances of survival of heterosporous pteridophytes are more as compared to homosporous pteridophyte.

Seed Habit :-

Genus *Selaginella* exhibit an approach towards seed habit due to following features :-

1. Almost all the species of *selaginella* are heterosporous.
2. In most of the species eg. *S. rupestris* and *S. apus* single functional megaspore is produced in the megasporangium.
3. The megaspore germinates within the megasporangium to form female gametophyte eg. *S. rupestris* and *S. apus*.
4. The fertilization and development of embryo take place when female gametophyte is with in megasporangium. In *S. rupestris* female gametophyte is liberated from megasporangium after the development of embryo.

The above characters show that *selaginella* has an approach towards seed habit but true seed is not formed due to following reasons:-

1. Megasporangium does not have integument.
2. Megaspore is not permanently retained in megasporangium.
3. Embryo lack a resting period.

Characters required in *Selaginella* for production of true seeds :-

1. Development of integument around the megasporangium.
2. Permanent retaintion of megaspore in megasporangium.
3. Embryo undergo a resting period.

SAQ-3

- (a) *Selaginella* is commonly known as moss.
- (b) *Selaginella* is a pteridophyte.
- (c) Which species of *selaginella* is known as resurrection plant.

8.5 EUISETUM (HORSE TAIL)

systematic position

Division- Sphenophyta

Class- Calamopsida

Order- *Equisetales*

Family- Equisetaceae

Genus- *Equisetum*

Genus *Equisetum* is distributed all over the world except Australia and Newzealand. It is commonly known as horse tail or scouring rushes. They grow in a variety of habitats. Some species eg. *E. palustre* grows in wet and swampy environment and *E. arvense* grows in xerophytic environment. Some species of *Equisetum* accumulates gold from the soil.

8.5.1 MORPHOLOGY

The plant body has an underground branched rhizome which has nodes and internodes. Scale leaves are present on the nodes. Alternating with each leaf at node is a bud. Erect aerial stem arises from the rhizome. In some species aerial stem is evergreen but, in others they are annual and appears in the spring season. Aerial stem is branched and branches arise from the node of stem. The stem is cylindrical with solid nodes and hollow long internode which has marked longitudinal ridges. The number of ridges on internode are equal to the number of leaves at node. Just above the node are meristematic tissue protected by leaves. Due to which stem becomes weak at the base and can be easily pulled a part at these points. Leaves are scale like brown in colour. It form a whorl at the node and fused laterally at the base into a sheath. The photosynthesis is carried by stem and branches. Adventitious roots arise from the nodes of rhizome. In *Equisetum* etalics the aerial stems are of two types.

- (1) The unbranched fertile shoot which is pale in colour.
- (2) Sterile, green much branched vegetative shoot.

In *Equisetum debile* aerial stems are alike chlorophyllous and some of them bears cone.

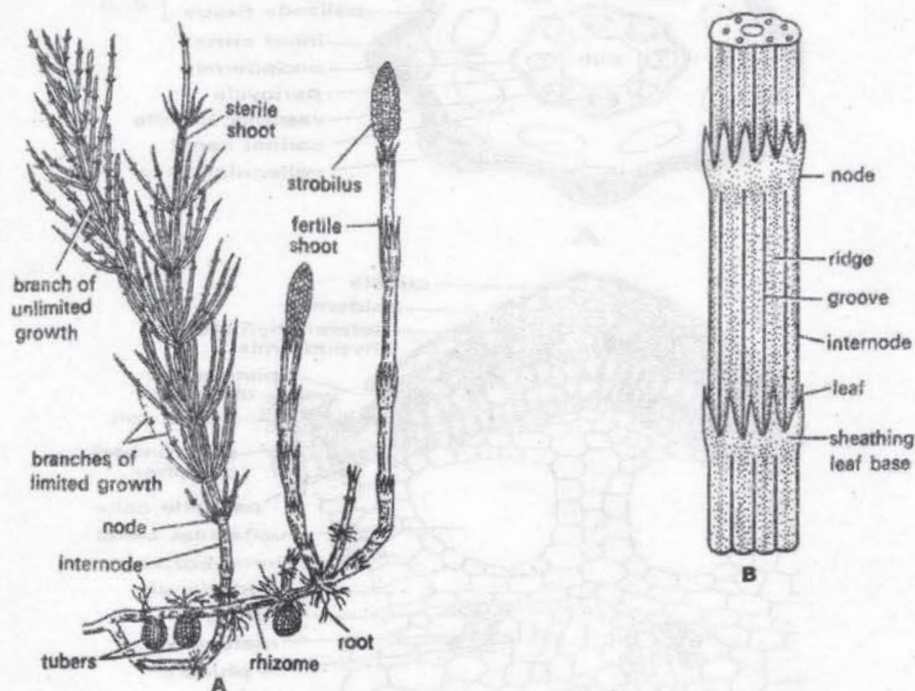


Fig.8.23. A-B. A. *Equisetum* plant, B. A part of aerial stem.

8.5.2 ANATOMY

Stem :- The out line is wavy. It has ridges and furrows. Outer most layer is single layered epidermis surrounded by thick cuticle, the epidermis is impregnated with silica. Due to which surface is very rough and harsh. Therefore, stems were formerly used to scour pots and pans and commonly called as scouringrushes. In

the ridges below the epidermis is thick walled sclerenchyma. Sunken stomata are present in the furrow. Below the sclerenchyma is chlorenchymatous cortex followed by inner parenchymatous cortex. The inner cortex has large spaces below the furrow known as *vallecular canal*. It is schizolysigenous canal extending throughout the length of the internode and forms distinct aerating system. Below the cortex is single layered endodermis followed by single layered pericycle. The position of endodermis varies in different species of *Equisetum*.

In *E. arvense* there is single layered endodermis outside the vascular bundle (Most primitive). In *E. debile* there is an outer and an inner endodermis. In *E. limnosum* there is separate endodermal layer around each vascular bundle (Most advance)

Stele has a ring of vascular bundle opposite to ridge. Each V.B. is conjoint, collateral and endarch. In the mature vascular bundle carinal canal is formed due to disintegration of protoxylem. Outside the carinal canal phloem is present on both the lateral side of xylem (Metaxylem) *Phloem is well developed and xylem poorly developed*. In the centre pith is a hollow cavity.

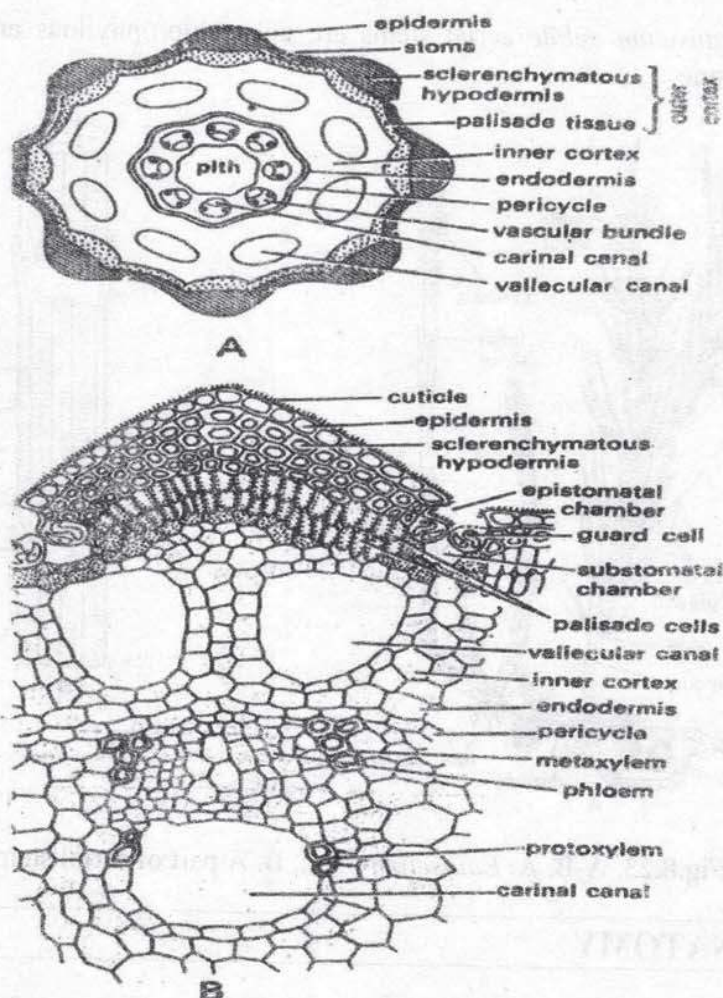


Fig. 8.24. A-B. *Equisetum* : Anatomy of aerial shoot (internode);

A. Transverse section (diagrammatic representation), B. A part cellular.

Hydrophytic and xerophytic characters of *Equisetum* :-

Hydrophytic characters :-

1. Xylem less developed.
2. Phloem well developed.
3. Vallecular canal present in the cortex of stem.
4. Carinal canal present in the vascular bundle.

Xerophytic characters :-

1. Outer and inner wall of epidermis is impregnated with silica.
2. Presence of ridges and grooves.
3. Leaves are small scaly and shed after some times.
4. Stem has chlorenchyma and photosynthetic is nature.
5. Sclerenchyma is present in the ridges of stem.
6. Sunken stomata in the furrow.

8.5.3 LIFE CYCLE

1. **Cone or strobilus :-** *Equisetum* reproduce asexually by means of spores. The alike spores are produced in sporangium born on sporangiophore. The sporangiophores are aggregated in definite cone on strobilus.

The cone is terminal present either on green aerial shoot or on non green shoot. Each cone has a central axis around which a no of stalked peltate sporangiophores are in whorl. Number of sporangiophore in each whorl various from few to many. Each sporangiophore is umbrella like in shape. It has a stalk and a hexagonal disc. On the under surface of which are elongated hanging sporangia. The number of sporangia on a sporangiophore varies from 5-10. The development of sporangium is eusporangiate type. Each sporangium is elongated cylindrical structure and has many layered jacket. Mature sporangium has only two layered jacket inside which are alike spores. (Homosporous)

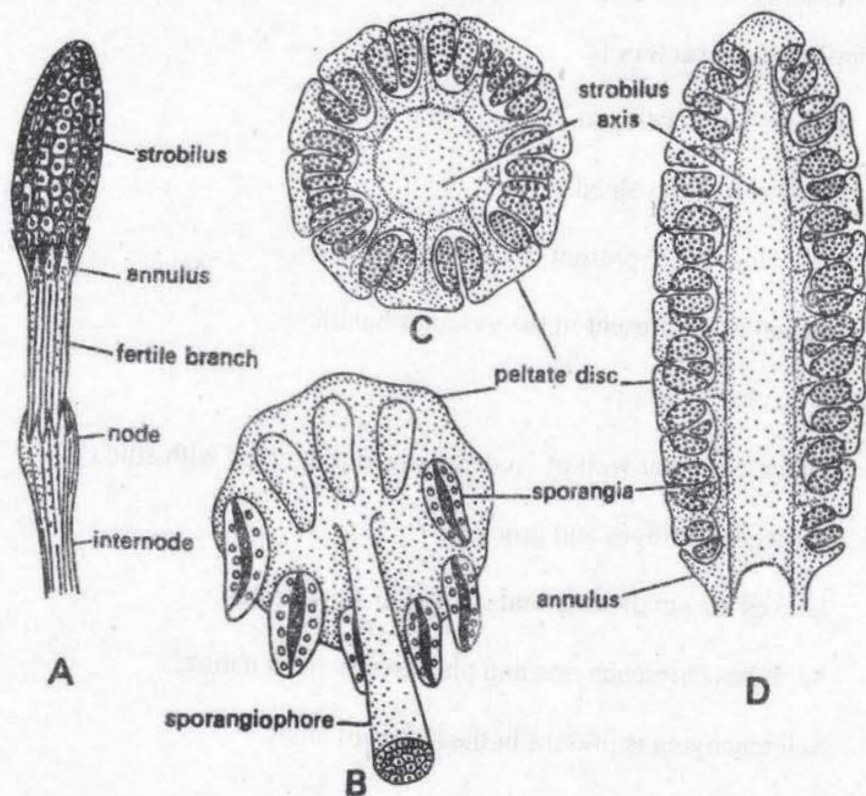


Fig. 8.25. A-D. *Equisetum* : Structure of strobilus; A. A fertile shoot, B. A sporangiophore with sporangia, C. Transverse section of strobilus, D. Longitudinal section of strobilus.

Morphological nature of strobilus :- The strobilus is made up of short end axis consisting of nodes and internodes. Sporangiophore comes out from the node.

Morphological nature of sporangiophore :- According to Milde (1876) and Tschudy (1939) the sporangiophore is a fertile leaf but according to Bower (1908) and Browne (1927), the sporangiophore is a modified branch and considered it to be axial in nature.

Dehiscence :- The axis of strobilus elongates due to which the sporangiophore get separated. The sporangium dehisces by longitudinal slit and spores are liberated.

- (2) **Gametophyte :-** Spores are haploid and represents the first stage of gametophytic generation. The spores are spherical structure which contains nucleus and chloroplast. The spore wall has 4 layers. The outer most layer is exine and inner most layer is intine. These two layers form the true wall of spores. In between exine and intine are two middle layers which splits to produce four spirally arranged ribbon like bands called elaters. The elaters are free from spore except for one common point of attachment. The elaters are hygroscopic under moist conditions. They coil

around the spore and uncoil when dries out. Mature elaters uncoil and this expansion of elaters help in dehiscence of sporangium. During shedding the uncoil elaters become elongated and entangled with the elater of other spores. Thus, the spores are shed in groups.

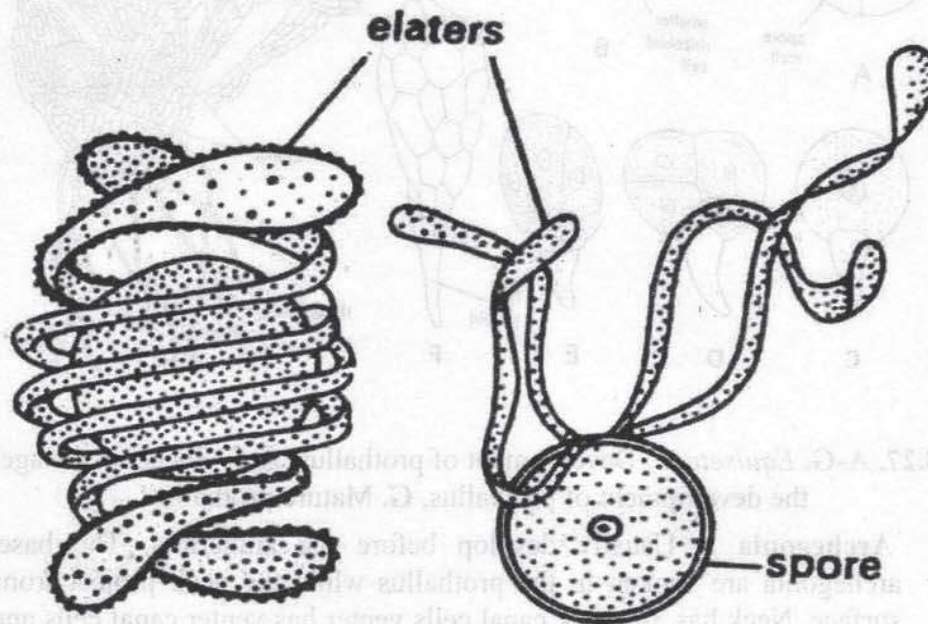


Fig. 8.26. A-B. Spores : A. Spore with coiled elater, B. Spore with uncoiled elater

Germination of Spores :- The spore germinates immediately. It divide by a transverse wall into a small cell and a large cell. The small cell give rise rhizoids and large cell divide in any plane to give rise prothallus. Under unfavourable conditions the filamentous prothallus is formed while, under favourable condition thick type prothallus is formed.

The mature prothallus is dorsiventral and grows in prostrate position on the surface. Rhizoids are present on the lower surface by means of which prothallus remain attached to the surface.

At the base prothallus is cushion like non green from which green lobes arise. The prothallus bears antheridia and archegonia. In most of the species prothallus is monoecious and sex organs are found on the basal part of prothallus. But in some species eg. *E. arvense* when prothallus is closely crowded and condition of growth are unfavourable, porothallus is small and bears only antheridia. But if conditions for growth are favourable 50% prothallus bear antheridia and remaining becomes large and develop archegonia. In *E. debile* under unfavourable conditions crowded prothalli are dioecious, while under favourable conditions prothalli are monoecious.

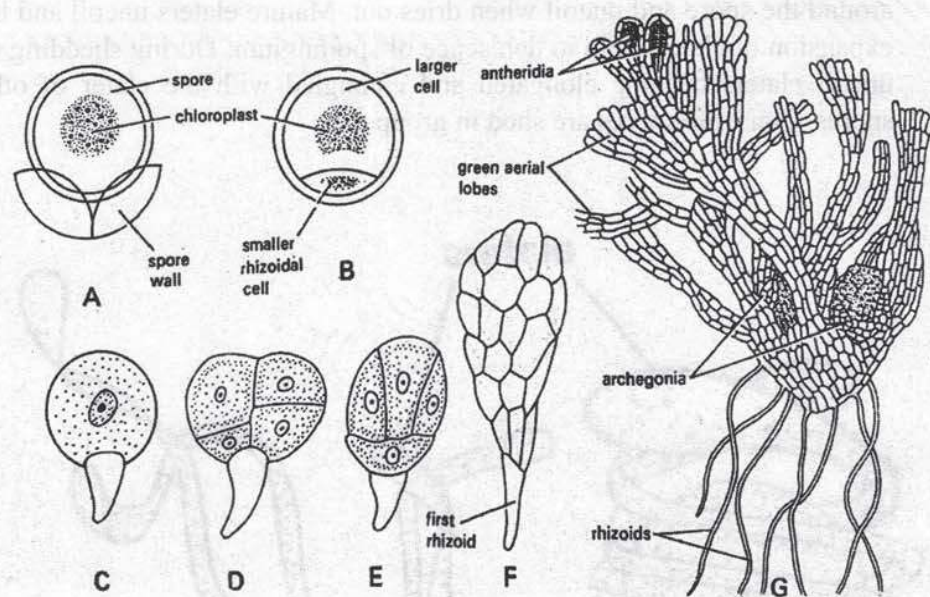


Fig.8.27. A-G. *Equisetum* : Development of prothallus; **A-F.** Successive stages in the development of prothallus, **G.** Mature prothallus.

Archegonia :- Usually develop before the antheridia. The base of archegonia are sunken in the prothallus while the neck project from its surface. Neck has 3-4 neck canal cells venter has venter canal cells and an egg.

Antheridia :- They are of two types :-

1. Projecting antheridia present on the lobes of upright branches.
2. The embedded antheridia developed in massive cushion shaped part of the prothallus.

Each Antheridium is spherical structure surrounded by single layered jacket. Inside which are about 256 antherozoids.

Each antherozoid is large spirally coiled structure with many flagella at the anterior end.

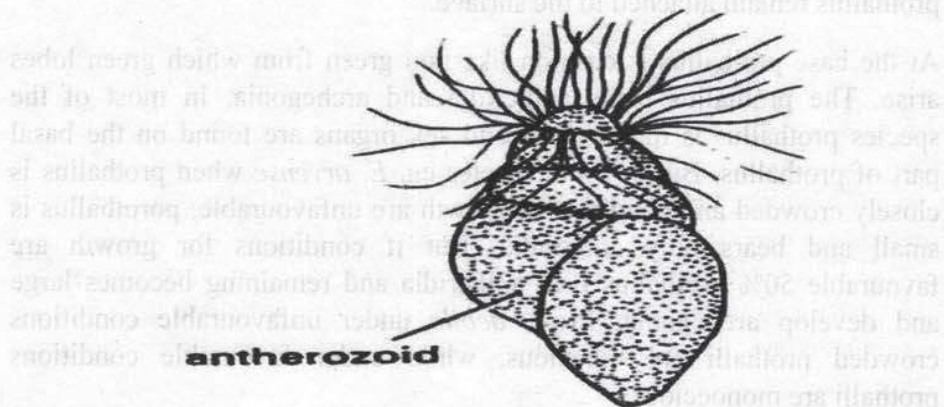


Fig.8.28. *Equisetum* : An Antherozoid.

Fertilization :- At the time of fertilization neck canal cell and venter canal cell disintegrate and secrete malic acid. Which attract antherozoids towards archegonia. Single antherozoid fuses with the egg to form diploid zygote.

3. Development of Embryo :- (Exoscopic type)

The zygote divides by a transverse wall into an epibasal cell and a hypobasal cell. Both the cell participate in the formation of embryo and divide by a vertical division. Thus a quadrant is formed. Now it again divide by another vertical division at right angle to first thus, an octant is formed. Which has four epibasal and four hypobasal cells. One of the cell of epibasal region becomes large and form apical cell of the stem and the remaining 3 cells form leaf sheath of young stem. One of the cell of hypobasal region becomes large and forms apical cell of root and the remaining three cell form foot. The stem part burst out from the neck of archegonium.

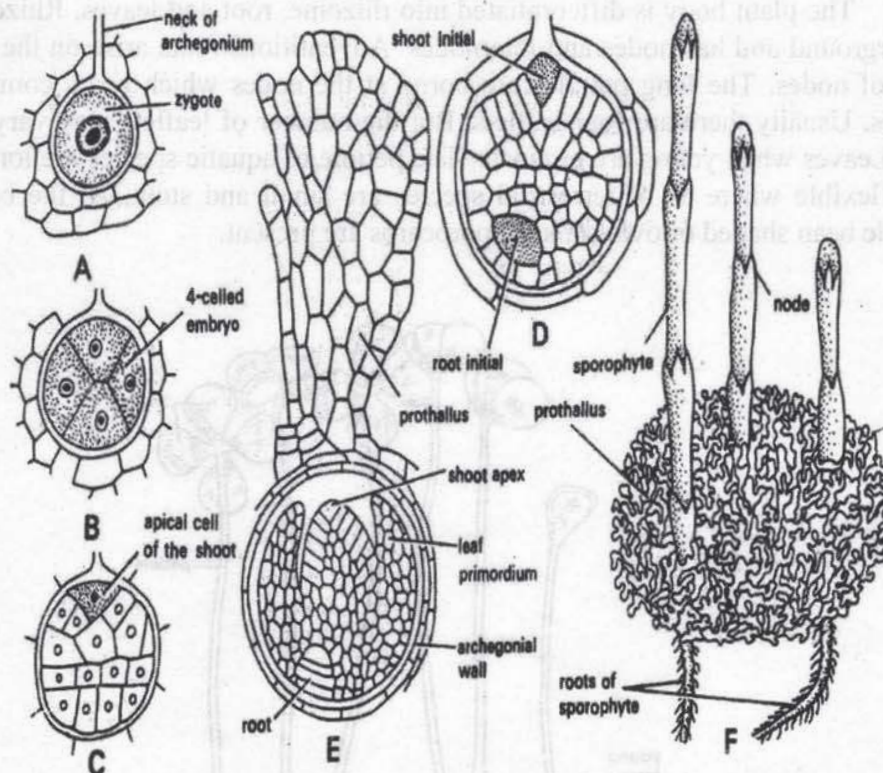


Fig.8.29. *Equisetum* : Embryo development; **A.** Longitudinal section of archegonium showing zygote, **B-E.** Stages in the embryo development, **F.** Young sporophyte.

SAQ-4

- The common name of *Equisetum* is
- Which pteridophyte accumulates gold in it
- Equisetum* has both and characters.

8.6 MARSILEA (WATER FERN)

Systematic position

Division- Filicophyta

Class- Leptosporangiopsida

Order- Marsiliales

Genus- *Marsilea*

Marsilea is commonly known as water fern. They are aquatic or amphibious. Aquatic species grow in shallow ponds and pools. In amphibian species sporocarp is formed only in terrestrial habitat. *M. quadrifolia* is aquatic species and *M. rajasthanensis* is xerophytic species.

8.6.1 MORPHOLOGY

The plant body is differentiated into rhizome, root and leaves. Rhizome is underground and has nodes and internodes. Adventitious roots arise on the under side of nodes. The long petioles are borne at the nodes which bears compound leaves. Usually there are four leaflets. But the number of leaflets may vary from 3-8. Leaves when young are circinate. The petiole of aquatic species are long soft and flexible where as of terrestrial species are small and stout. At the base of petiole bean shaped or oval stalked sporocarps are present.

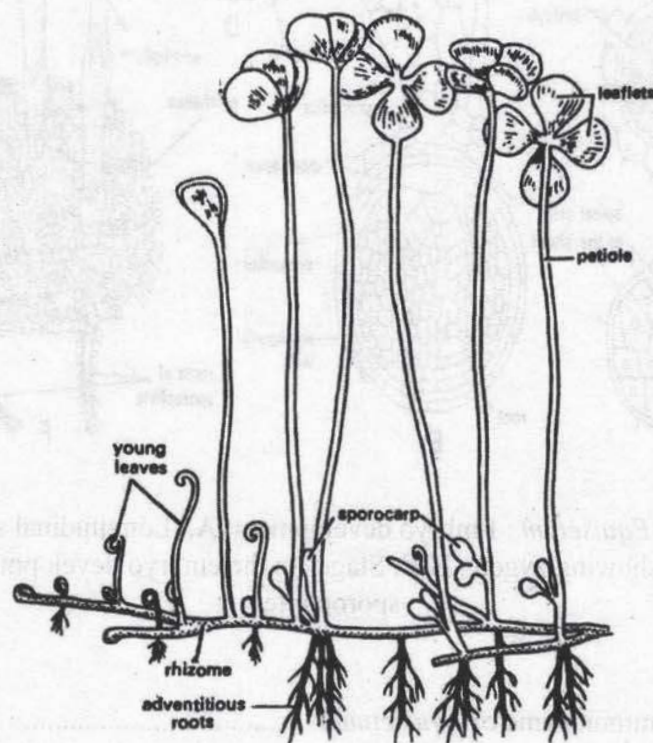


Fig.8.30. *Marsilea* Plant.

1. Rhizome :-

The outer most layer is single layered epidermis which is without stomata. Below it is outer cortex which has Air chambers separated by trabeculae. The inner cortex is parenchymatous. In between the outer and inner cortex is few layered sclerenchyma. The stele is amphiphloic siphonostele. The xylem ring has protoxylem and metaxylem cells inter mixed. On the outer surface of which is outer phloem then outer pericycle followed by outer endodermis. On the inner side of xylem ring is inner pericycle and endodermis. In the center is pith which is sclerenchymatous in xerophytic species and parenchymatous in submerged species.

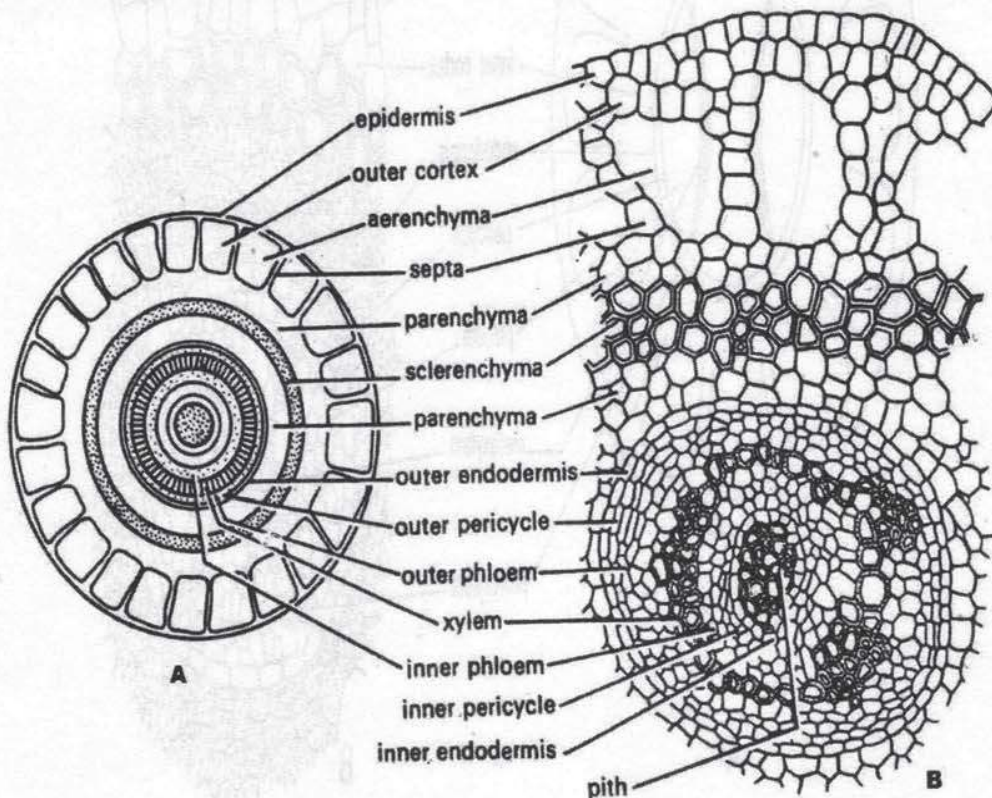


Fig.8.31. A-B. *Marsilea* : Anatomy of rhizome; A. Diagrammatic representation, B. A part cellular.

2. Petiole :-

Outer most layer is epidermis. Below it is cortex divided into outer and inner cortex. The outer cortex has air chambers separated by trabeculae. The inner cortex is parenchymatous and contains starch grain and dark brown tannin. The inner most layer of cortex is endodermis followed by pericycle. In the center is protostele which has two xylem arms forming curve. The metaxylem is present towards the base of curve and protoxylem towards tip. Xylem is surrounded by phloem. Pith absent.

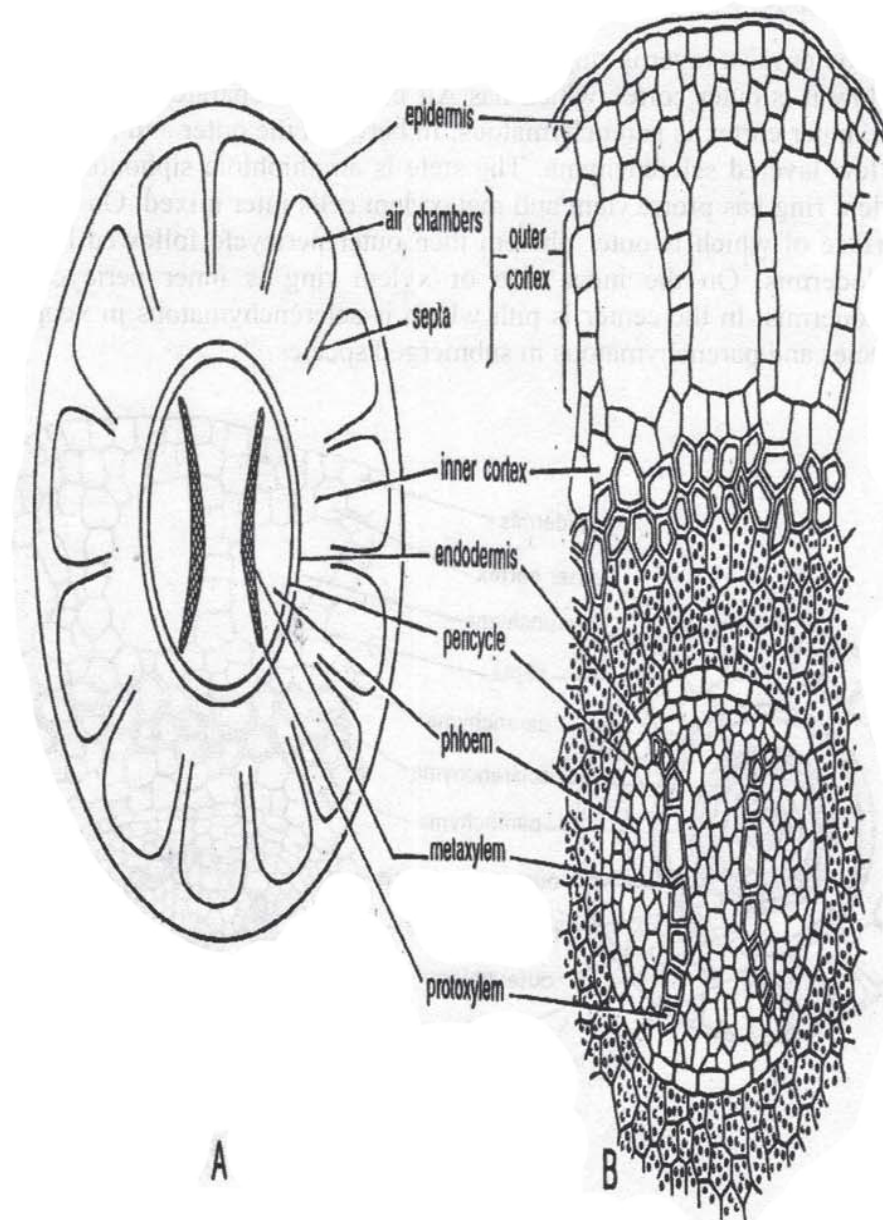


Fig.8.32. A-B. *Marsilea* : Anatomy of petiole; **A.** Diagrammatic representation, **B.** A part cellular.

Characters of water plant in *Marsilea*

1. Long internode.
2. Roots unbranched.
3. Petiole long, weak and flexible.
4. Sclerendyma absent in vegetative part.
5. Stomata present only on the upper surface.

Characters of Land Plant in *Marsilea*

1. Internode short.
2. Roots branched.
3. Petiole short and stout.
4. Sclerenchyma present in cortex and pith.
5. Few or small air spaces.
6. Stomata on both the surface of leaf.

8.6.3 LIFE CYCLE

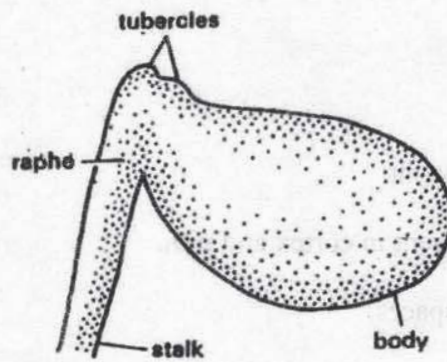
1. Sporocarp of *Marsilea*

Structure of sporocarp :- The sporocarp is bean shaped structure present at the base of petiole. When young it is green and soft but turns dark brown and hard at maturity.

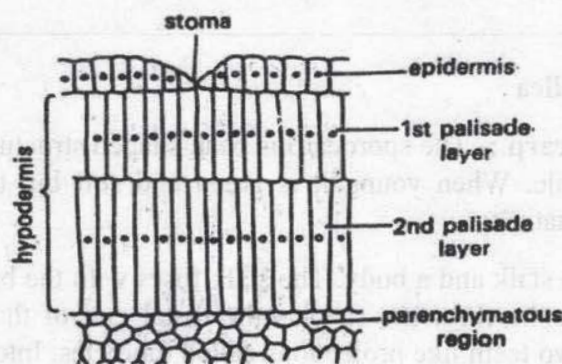
The sporocarp has a stalk and a body. The stalk fuses with the back of the body. It is called raphe. In some species the distal end of the raphe is marked by one or two teeth like projections called tubercles. Internally the wall of sporocarp is very hard and differentiated into an outer epidermis, middle hypodermis and inner parenchymatous region. Sunken stomata are present in the epidermis. The inner layer of parenchyma forms a gelatinous ring inside the sporocarp wall. From the vascular cylinder of petiole a single strand enters into the sporocarp called dorsal bundle which give out a number of ventral bundle.

Marsilea is heterosporous and produces two types of spores. The microspores and megaspores in microsporangium and megasporangium respectively. The body of sporocarp is bivalved and has group of sori arranged in two rows one in each valve. The sori of one value alternate with those of the other. The number of sori in each sporocarp ranges from 2-20. Each sorus is elongated and enclosed by a delicate sac like structure called indusium and consists of ring of receptacle. The receptacle bears terminal row of short stalked megasporangium. The stalked microsporangia are around the side of megasporangium.

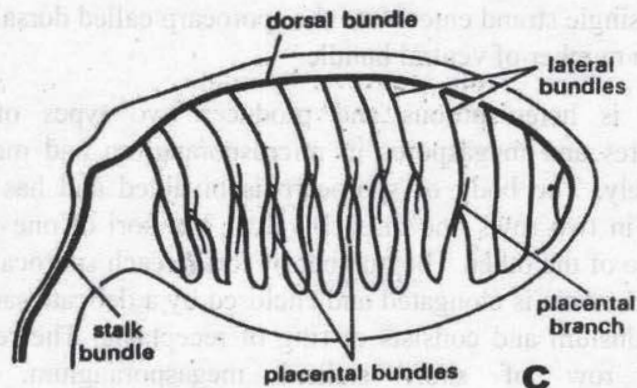
The Megasporangium is large in size and produces single megaspore where as microsporangium is small in size and produces many small microspores.



A



B



C

Fig. 8.33. A-C. *Marsilea* : A. Sporocarp, B. Wall of sporocarp, C. Vascular system of sporocarp.

Horizontal Longitudinal Section (H.L.S.) :- In H.L.S. the gelatinous ring appear in the form of a dorsal and ventral mass. Both micro spores and megaspores are seen in sori. These are in two alternate row. The megasporangium is terminal and microsporangium is lateral in position.

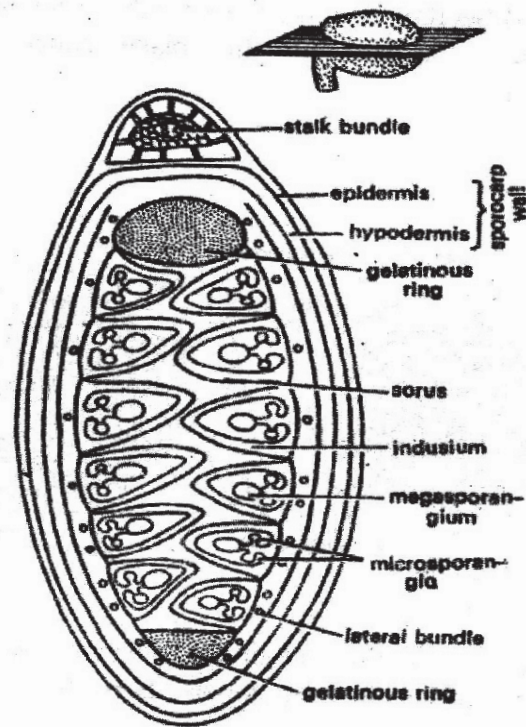


Fig.8.34. *Marsilea* : Horizontal longitudinal section (HLS) of sporocarp.

Vertical transverse section (V.T.S.) :-

In V.T.S. sorus has either microsporangia or megasporangia. The vascular bundle extending from dorsal to the lateral side of the sporocarp.

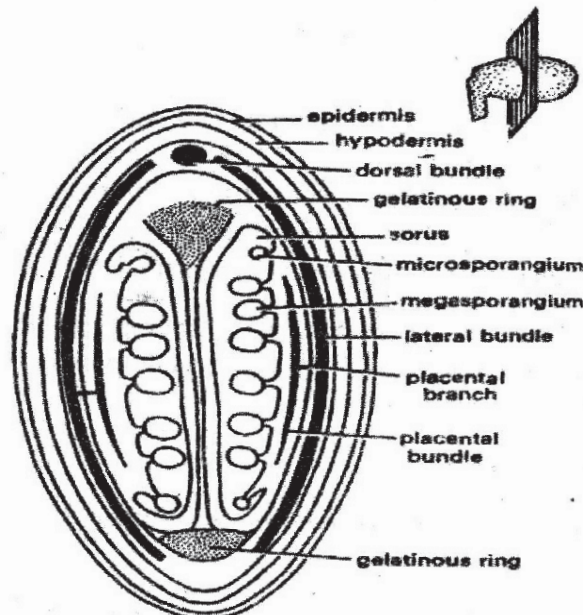


Fig.8.35. *Marsilea* : Vertical transverse section (VTS) of sporocarp.

Vertical longitudinal Section (V.L.S.) :- In V.L.S. gelatinous ring appear as a complete ring around the sori. In this plane either microsporangia or megasporangia are seen.

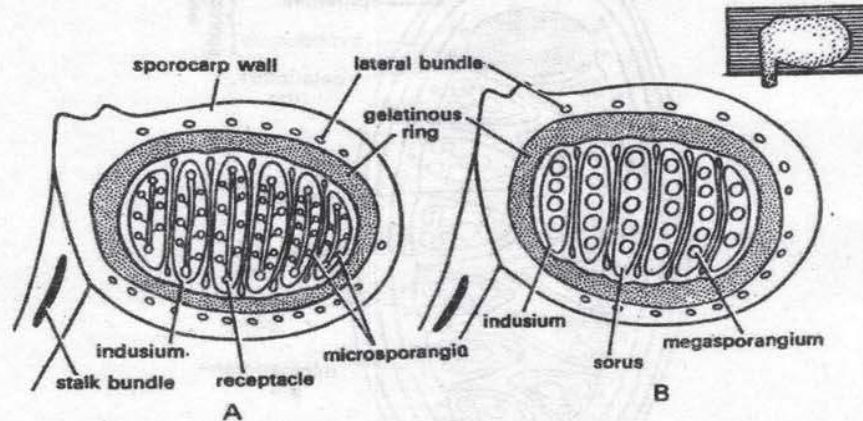


Fig.8.36. A-B. *Marsilea* : Vertical longitudinal sections (VLS) of sporocarp; **A.** Section passing through microsporangia, **B.** Section passing through megasporangia

Morphological Nature of Sporocarp :- There are three views regarding the morphological nature of sporocarp.

1. **Leaf segment or laminar hypothesis :-** According to this sporocarp is modification of pinnately compound leaf. According to Campbell sporocarp is the folded pinnately divided leaf in which the pinnule have become fused into one structure. Eames states that the two distal leaflets form the body of the sporocarp and the two proximal leaflets are represented by tubercles.

According to Smith Pinna has a midrib with lateral veins on each side in alternate position. The lateral veins are forked. At the point of forking receptacle develops on the abaxial side. The indusium projects forward in the axil of each receptacle, and thus covering the sorus. The infoldings of pinna result in the formation of sporocarps.

Vascular supply in the sporocarp and structure of abnormal leaves intermediate between normal leaves and sporocarp provide evidence in support of laminar hypothesis.

2. **Petiolar hypothesis :-**

According to this hypothesis the sporocarp is the modification of the whole leaf (Pinna + Petiole).

3. **Phylogenetically Synthesizd New organ :-** According to Bierhorst (1971) the ontogeny of sporocarp in the early stage is similar to sporangial ontogeny. Where as in the later stage it is similar to the ontogeny of pinna. Thus he stated that sporocarp has changed their morphological nature in

mid-ontogeny. He concluded that sporocarp is phylogenetically synthesized new organ.

Dehiscence of Sporocarp :-

The wall of sporocarp is very hard and take about 2-3 years for the decay. If, the sporocarp after slight rupture of wall along its ventral side is placed in water, the water enters through the slit. The gelatinous material swells resulting in splitting of sporocarp wall into two valves.

The gelatinous ring greatly expand due to swelling and is pulled out of the slit in a looped conditions. The loop begins to uncoil, becomes straight and bears two rows of sori one on either side. The sori get separated. The indusia also imbibe water and ventral end of sori gets open. As a result sporangia escape. Finally the wall of sporangia absorb water, ruptures and spores are liberated.

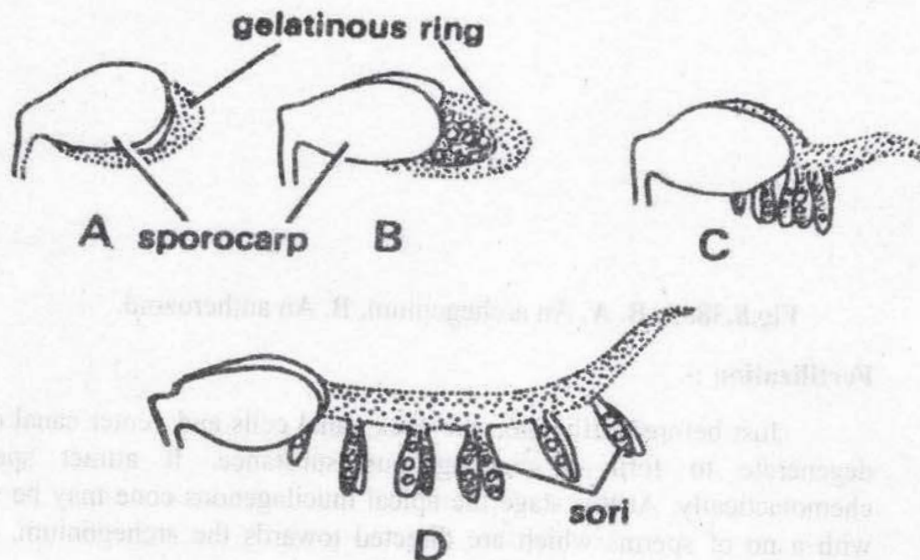


Fig. 8.37. A-D. *Marsilea* : Stages in the dehiscence of sporocarp.

2. Gametophyte :-

The megaspore on germination gives rise female gametophyte. The female gametophyte bears archegonium. The archegonium has neck and venter. Neck has neck canal cells covered by cover cell. The venter has venter canal cell and an egg. The microspore on germination give rise male gametophyte which bears antherozoids.

The antherozoid is cork screw shaped multiflagellated, structure. It has a characteristic prominent terminal vesicle.

Fig.8.38. A-B. A. An archegonium, B. An antherozoid.

Fertilization :-

Just before fertilization the neck canal cells and venter canal cells degenerate to form a mucilagenous substance. It attract sperms chemotactically. At this stage the apical mucilagenous cone may be seen with a no of sperms which are directed towards the archegonium. One sperm fuses with the egg to form zygote.

3. The Embryo :-

The Zygote develops into young sporophyte within 2 to 4 days. The first division of Zygote is longitudinal, followed by a transverse division. Thus a four celled embryo is formed. The upper two cells of the embryo give rise to the first leaf and root whereas, the lower two cells give rise to the stem and foot of the embryonic sporophyte. With the development of embryo the vegetative cells of surrounding gametophyte divide periclinally forming a calyptra around the young sporophyte. After the differentiation of first leaf the calyptra splits at the tip and young sporophyte comes out of it.

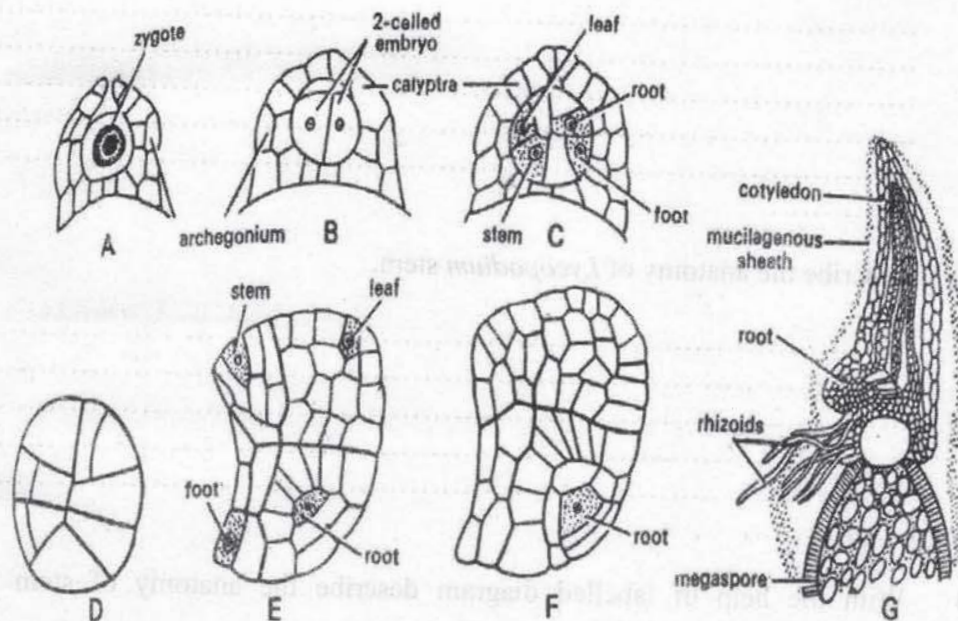


Fig.8.39. A-G. *Marsilea* : Stages in the development of embryo.

SAQ-5

- The common name of *Marsilea* is
- Sporocarp* occurs in
- Marsilea* is a pteridophyte.

8.7 SUMMARY

- *Rhynia* was rootless, leafless fossil pteridophyte. The main plant body was sporophyte but gametophyte is not known.
- *Lycopodium* is a homosporous pteridophyte and produces spores which on germination give rise gametophyte.
- *Selaginella* is a heterosporous pteridophyte and produces microspores and megaspores. Microspore and megaspore on germination give rise male and female gametophyte. This genus shows heterospory and seed habit.
- *Equisetum* is homosporous pteridophyte. It accumulates gold in it.
- *Marsilea* is heterosporous pteridophyte. The sporophytic plant body bears sporocarp which has microspores and megaspores. Microspore and megaspore on germination give rise male and female gametophyte.

8.8 TERMINAL QUESTIONS

Long Questions :-

- Describe the sporophyte and gametophyte of *Rhynia* with the help of labelled diagram.

.....
.....
.....
.....
.....
.....
.....

Q.2 Describe the anatomy of *Lycopodium* stem.

.....
.....
.....
.....
.....
.....

Q.3 With the help of labelled diagram describe the anatomy of stem of *selaginella*.

.....
.....
.....
.....
.....

Q.4 With the help of labelled diagram describe the anatomy of *Equisetum* stem.

.....
.....
.....
.....
.....

Q.5 Describe the sporocarp of *Marsilea*.

Short Questions :-

Write short notes on-

1. Stem or axis of *Rhynia*.
2. Strobilus or cone of *Lycopodium*.

3. Strobilus or cone of *Selaginella*.
4. Heterospory and seed habit.
5. Hydrophytic and xerophytic characters of *Equisetum*.
6. Dehiscence of *Marsilea* sporocarp.

8.9 ANSWERS

SAQ.1

- (a) Kidston and Lang
- (b) *Rhynia major*, *Rhynia gwynnee-vaughanii*.
- (c) Petrified
- (d) Noth Scotland

SAQ.2

- (a) Club
- (b) Homosporous
- (c) Plectostele

SAQ.3

- (a) Spike
- (b) Heterosporous
- (c) *Selaginella lepidophylla*, *Selaginella pilifera*

SAQ.4

- (a) Horse tail
- (b) *Equisetum*
- (c) Hydrophytic, xerophytic

SAQ.5

- (a) Water fern
- (b) *Marsilea*
- (c) Heterosporous

REFERENCES

1. Fungi by Dr. H.N. Srivastava
2. Botany for Degree Students Part-I Algae by B.R. Vashistha
3. A text book of botany by Singh, Pande & Jain