COURSE GUIDE

BIO 208
SEEDLESS PLANTS

Course Team Late Professor Afolabi Adebanjo (Course Developer /Writer)-NOUN
Professor Rebeccah W. Ndana (Course Reviewer)-University of Abuja

NATIONAL OPEN UNIVERSITY OF NIGERIA

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National Open University of Nigeria
Headquarters
University Village
Plot 91, Cadastral Zone
Nnamdi Azikiwe Expressway
Jabi, Abuja

Lagos Office
14/16 Ahmadu Bello Way
Victoria Island, Lagos

e-mail: centralinfo@nou.edu.ng
URL: www.nou.edu.ng

Printed 2023

ISBN: 978-978-058-903-5

CONTENTS PAGE

BIO 208 Seedless Plants

Introduction

BIO 208: Seedless plant is a one-semester, 2 credit- hour course in the Department of Biological Sciences, Faculty of Science. It is a 200 level, second semester undergraduate course offered to students admitted in the Faculty of Science, Faculty of Education that are offering Biology or related programmes. This course is designed primarily for students in Biology disciplines to expose them to the beneficial and economic importance of seedless plants surrounding our environment and also give them a basic background on how the seedless plants evolve and interact with and within the environment. Also students should be able to get acquainted with different groups and classes that constitutes seedless plants. Seedless plants are plants that do not produce produce seeds. They include the algae, fungi, bryophyte and the ferns, pteridophytes. At the end of this course, students should be able to have a clear knowledge of seedless plants, the different types or classifications of seedless plants and also have a good knowledge of their ecological and economic importance

The course guide tells you briefly what the course is all about, what or some course materials you will be using and how you can work your way through these materials. It gives you some guidance on your Tutor- Marked Assignments.

There is/are Self-Assessment Exercise(s) within the body of a unit and/or at the end of each unit. The exercise(s) is/are an overview of the unit to help you assess yourself at the end of every unit.

Course Competencies

This course is to provide a generalized survey of the seedless plants with reference to their classifications, morphology, life cycle, ecological adaptation, ecological and economic importance.

Course Objectives

In addition to the course competencies, the course sets an overall objective which must be achieved. In addition to the course objectives, each of the units has its own specific objectives. You are advised to read properly the specific objectives for each unit at the beginning of that unit. This will help you to ensure that you achieve the objectives.

As you go through each unit, you should from time to time go back to these objectives to ascertain the level at which you have progressed.
By the time you have finished going through this course, you should be able to:

- Have a clear knowledge of what seedless plants are and their different classifications
- Have a clear understanding of the seedless plants, its classifications and characteristics
- Be clearly introduced to seedless plants, the algae, bryophytes and pteridophytes, its structures and functions.
- Have a good understanding of seedless plants of major biological significance
- Be able to differentiate between the various classifications of seedless
  plants using their morphological and life cycle characteristics
- Be able to differentiate between the various species of seedless plants within their groups.
- Know the morphological characteristics and life cycle of the different seedless plants
- Have a good knowledge of seedless plants that are considered to be primarily of economic and ecological importance

Working through this Course

In this course, you will be advised to devote your time in reading through the material. You would be required to do all that has been stipulated in the course: study the course units, read the recommended reference textbooks and do all the unit(s) self- assessment exercise (s) and at some points, you are required to submit your assignment (TMAs) for assessment purpose. You should therefore avail yourself of the opportunity of being present during the tutorial sessions so that you would be able to compare knowledge with your colleagues.

Study Units

This course is divided into 3 modules with a total of fifteen units which are divided as follows:

MODULE 1 ALGAE

References and Further Readings

You would be required to do all that has been stipulated in the course: study the course units and read the recommended reference textbooks in each unit of the course material.

Presentation Schedule

Presentation schedule for this course will be uploaded on the online course page.

Assessment

You are required to submit your assignment (TMAs) for assessment purpose.

How to get the Most from the Course

The course comes with a list of recommended textbooks. These textbooks are supplement to the course materials so that you can avail yourself of reading further. Therefore, it is advisable you acquire some of these textbooks and read them to broaden your scope of understanding. further references with web links are provided in each section/module or unit. Similarly, the course has facilitation session that will provide information on any grey areas.

Online Facilitation

Online facilitation for this course will hold at least an hour once in a week for a period of eight weeks. The duration of facilitation is usually at least one hour for the period of eight weeks

Course Information

Course Code BIO 208
Course Title Seedless Plants
Credit Unit Two (2)
Course Status Compulsory
Semester First Semester
Course Duration Eight weeks
Required Hours for Study At least One hour per week

MAIN COURSE

CONTENTS **PAGE**

MODULE 1 ALGAE

Module Structure

In this module we will discuss about the general introduction of algae with the following units:

UNIT 1 MORPHOLOGY OF ALGAE Unit Structure

1.1 Introduction

Algae are placed in the Kingdom Protista along with the protozoa. Earlier they were classified as plants since they are photosynthetic autotrophs that possess chlorophyll and chloroplasts and superficially appear like plants. Since their gametes do not have protective cells around them they are no longer classified with plants. The study of algae is called phycology, the one who specialises in the study of algae is a phycologist

In this unit, you will study the morphology of algae. Although simple in structure without any differentiation, algae exhibit a great diversity in size and appearance. Their size ranges from small microscopic to giant macroscopic thalli extending several metres meters in length as in the kelps. Algal morphology varies from simple unicellular form to complex multicellular forms as found in seaweeds.

Algae are widely distributed in nature wherever there is plenty an abundance of water and sunshine. They are also found on wet rocks and grounds, pools of water as well as some harsh habitats.

1.2 Intended Learning outcomes

By the end of this unit, students should be able to:

1. know the various habitats of algae
2. describe the basic types of thalli in algae
3. compare the various morphologies unicellular, colonial, filamentous, heterotrichous, thalloid and polysiphonoid of algae.
4. draw the morphology of. *Anacystis, Chlamydomonas, Microcystis, Volvox, Ulva,* and *Fucus* and describe their special features.

1.3 Main Contents

1.3.1 Morphology of Algae

There are basically two morphologies in algae, the unicellular and the multicellular. The body of an alga is called thallus. In unicellular algae the thallus is simple consisting of a single cell. All multicellular organisms start their life as single cells. Multicellular morphologies may be colonial, filamentous, heterotrichous, thalloid and polysiphonoid forms.

In the following account you will study the specific examples of the above basic types of_thalli in algae. It is to be noted that all the above forms may not be found in all the algal divisions but some are predominantly unicellular and others multicellular forms. A gradual complexity in form also indicates how the evolution of the thallus has taken place, in algae. The various morphological forms and their representative examples are described below.

Unicellular Forms

Anacystis

Single cells, cylindrical, short or long; sometimes very long snake forms (Fig.1.1a) Cells divide by constriction, the two daughter cells get separated, rarely they remain together to form a 2-celled filament

Individual single cells may have their own mucilagenous cover around them. Several such cells may be enclosed in common colourless mucilage giving the impression of a colony.

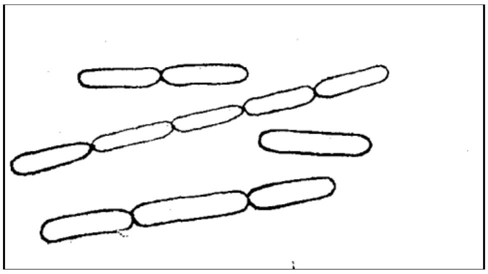
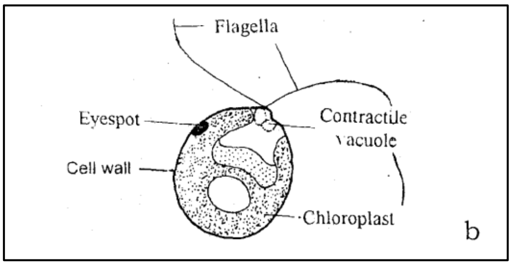


Fig. 1.1: Unicellular algae: Anacystis (Source**:** IGNOU (1991) Indira Gandhi National Open University. Plant Diversity-Algae.)

Chlamydomonas

This single celled alga contains a nucleus, a cup-shaped chloroplast in which one pyrenoid is commonly present (Fig. 1.1b) The chloroplast on the anterior side shows 2 to 3 rows of fatty red-coloured granules. This is known as eyespot or stigma which is helpful for the alga to respond to light. The cell wall is firm and distinct. A small contractile vacuole is found at the base of each flagellum. When Chlamydomonas cells divide under partially dry conditions, the daughter cells are usually without flagella, as such they remain enclosed in a common mass of mucilage, as a colony known as Palmella stage of *Chlamydomonas* (Fig.1.1c). This is only a temporary stage and on flooding with water individual cells develop flagella and escape swimming away from the colony. Thus the beginning of the colony construction found in *Volvox* can be seen in *Chlamydomonas*.



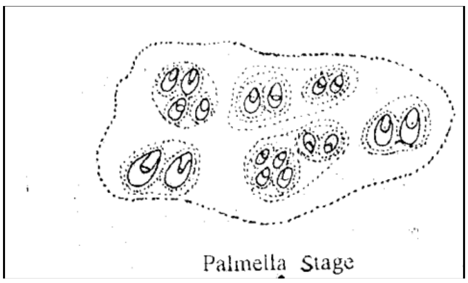


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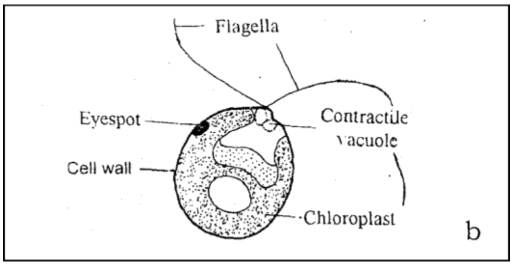
Fig. 1.2: Unicellular algae: b) *Chlamydomonas* c) *Palmella stage* **(**Source**:** IGNOU (1991) Indira Gandhi National Open University. Plant Diversity-Algae.)

The body of an alga is called the ----------------

Self-Assessment Exercise 1



The diagram above depicts which organism?

Colonial Algae

When a cell divides and the daughter cells formed remain together within a common mucilaginous mass, it is known as a colony. A colony may contain large number of cells. Sometimes it may be so big that one can see it with unaided eyes.

Microcystis

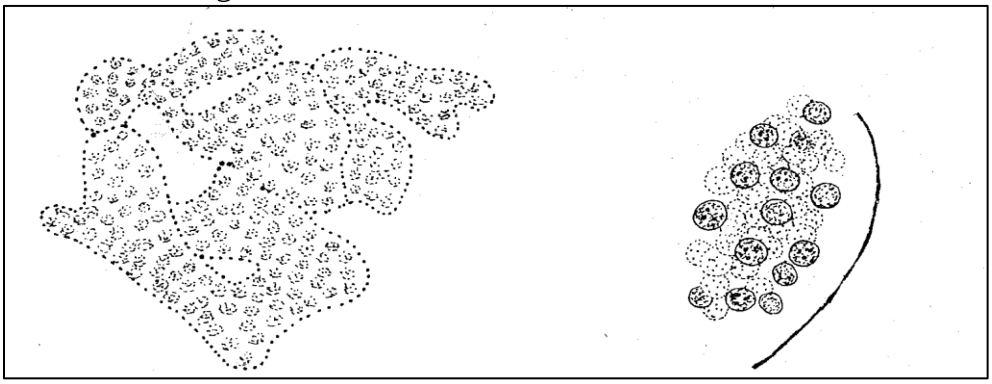
This is a colonial alga, most common in polluted ponds and lakes (Fig.1.2e) Sometimes the colonies are big and can be seen by unaided eyes. They accumulate on the surface of water forming quite a thick layer in some seasons (water blooms).

Single cells are spherical and colony is formed because of loose aggregates of several thousand cells held by mucilage (Fig. 1.2e). The colonies float on the surface of water because of the presence of elongated cylindrical gas vesicles inside the individual cells.

Volvox

The colonies of *Volvox* are spherical, ball-like and big enough to be seen with unaided eye (Fig.1.2g) Each colony contains l000-5000 cells arranged on the outside of a mucilagenous ball called coenobiuim. Coenobium is a colony in which the number of cells is fixed at the time of formation. No further addition of cells occurs. Generally the cells are also in a special arrangement. Two types of cells can be seen generally, vegetative or somatic and gonidia. In younger colonies cytoplasmic connections - plasmodesmata between individual cells can be seen under the microscope.

Vegetative cells are more or less like *ChIamydomonas* with two flagella, cell wall, single cup-shaped chloroplast, eyespot, pyrenoid, contractile vacuole and a nucleus (Fig. 1.2h). The cells on the posterior side of the colony may be larger than in the front.
In *Volvox* all the cells of a colony are derived from a single parental cell. They are arranged on the surface of mucilaginous ball, connected with other cells by cytoplasmic connections. Some cells behave as sex cells meant for reproduction whereas others remain vegetative and ultimately grow old and die. This differentiation into vegetative and reproductive cells is a very important feature in the development of multicellular organisms.



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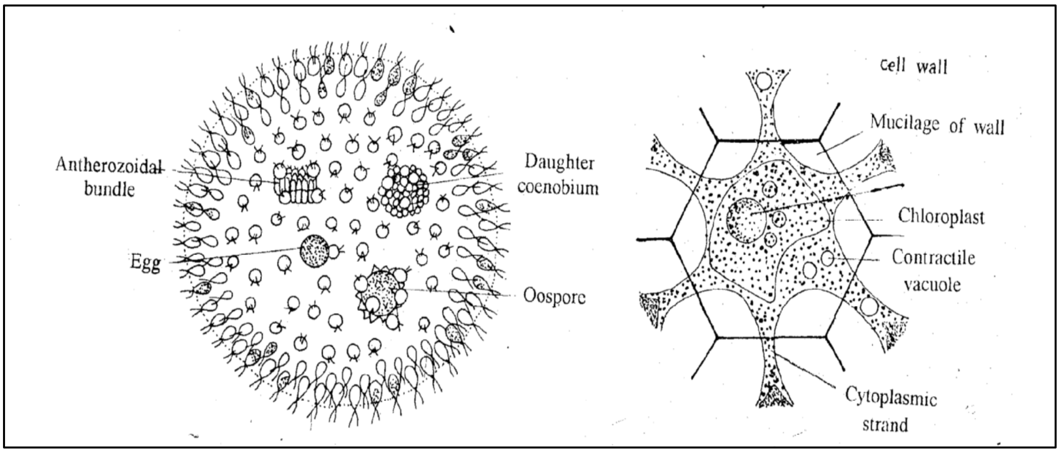

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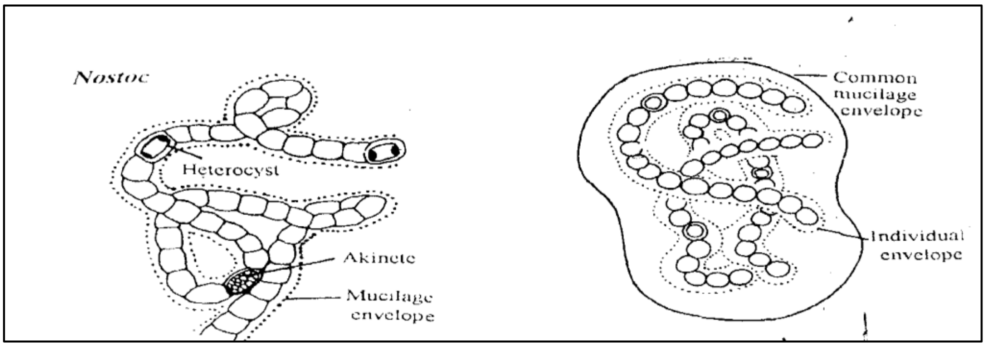
Fig. 1.3 Colonial algae; e) *Microcystis aeruginosa,* f) Portion of e magnified g) *Volvox* aureus h) Cells of in the interior polar view (Source**:** IGNOU (1991) Indira Gandhi National Open University. Plant Diversity-Algae.)

In-Text Question (ITQ)
The basic morphology in algae is ----------- and -----------

Filamentous Forms
When a cell divides always cross-wise and the daughter cells do not separate from each other, it results in a linear row of cells as in *Nostoc, Ulothrix* and *Oedogonium.* However, the three algae show different levels of differentiation.

Nostoc

This is a simple, filamentous form, a single row of cells, uniseriate (Fig.1.3a). Several filaments of *Nostoc* are generally enclosed within a common mucilage envelop to form a colony (Fig. 1.3b). Some cells in between the vegetative cells are modified into heterocysts. Heterocyst are a highly differentiated cell in some filamentaous blue-green algae that is a site of nitrogen fixation. All the vegetative cells are capable of developing into spores called akinetes. Akinete are a thick-walled, nonmotile reproductive cell found in algae.



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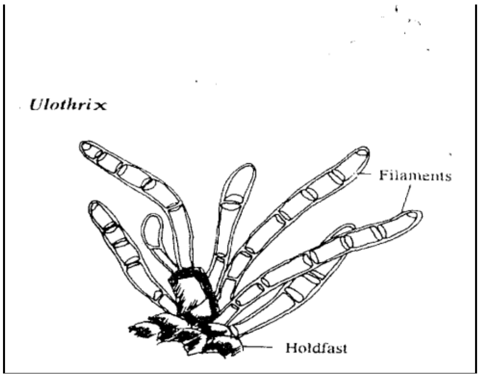

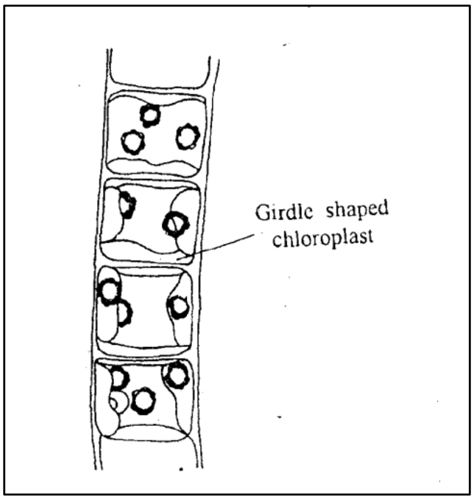

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Fig. 1.4 Filamentous algae; (a) filaments of *Nostoc* showing akinetes and (b) heterocysts and aggregate of *Nostoc* filaments forming a ball, (c) germlings of *Ulothrix and (d)* cell structure of *UIothrix* showing gridle shaped chloroplasts. **(**Source**:** IGNOU (1991) Indira Gandhi National Open University. Plant Diversity-Algae.)

Vegetative cells that can develop into spores are called -----------

Heterotrichous Forms

When some cells of a filament divide vertically it results in a branch. Many filamentous forms show extensive branching of the main filament giving it a bushy appearance.

In some algae the branches at the base remain horizontal, attached to the substratum known as prostrate system from which erect system of vertical branched filaments arise. This type of body is known as heterotrichous habit. Heterotrichous habit is the most highly developed filamentous construction in algae.

Draparnaldiopsis

It is a heterotrichous alga which shows greater differentiation in plant body. The prostate system is very much reduce The main axis contains long internodal cells alternating with short nodal cells (Fig. 1.4). The short nodal cells bear a bunch of short branches. Some of the side branches may develop into long colourless hairs or setae. The main axis produces at the base long multicellular colourless rhizoids in large number to form a kind of cortex. Their main function is to attach the alga to the substratum.

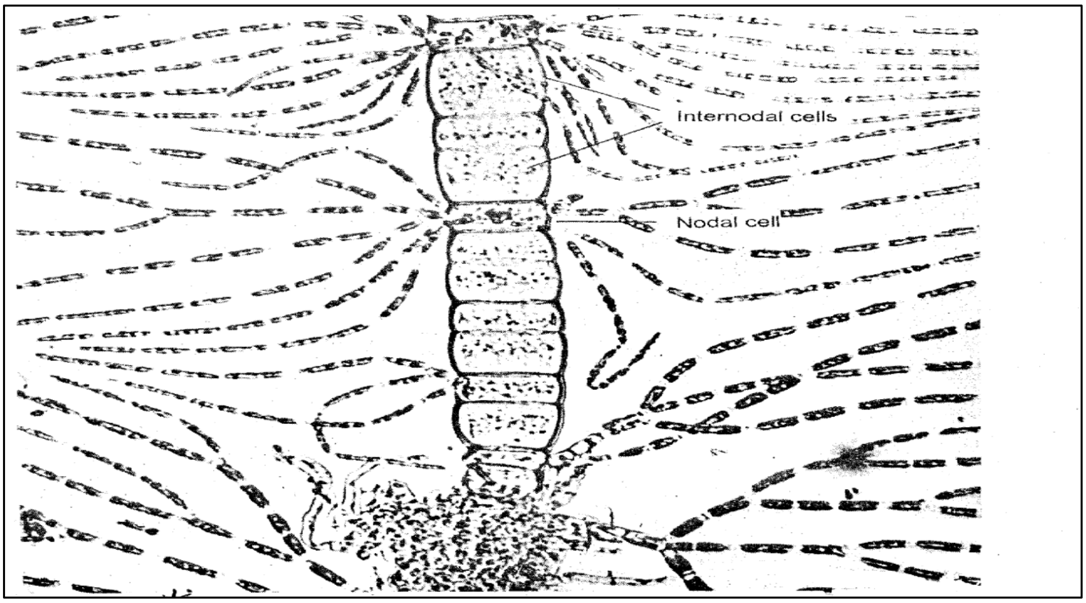


Fig. 1.5: Draparnaldiopsis indica (photograph by late Prof. Y.B.K Chowdarv).

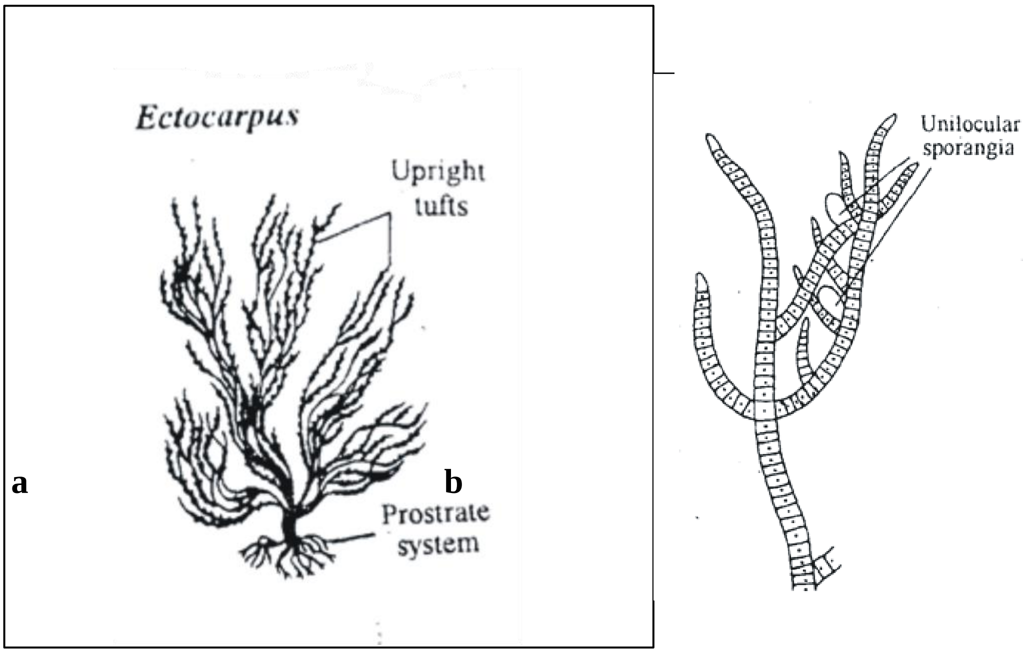


Fig. 1.6: Heterotrichous algae; a, *Ectocarpus* showing habit and b) thalli with unilocular sporangia or gametangia **(**Source**:** IGNOU (1991) Indira Gandhi National Open University. Plant Diversity-Algae.)

Ectocarpus

It is another heterotrichous alga (Fig. 1.5).The prostrate system which attaches the alga to the substratum is made of branched filaments. The erect system is in the form of uniseriate *(single row of cells)* branched filaments forming loose tufts of 1mm to 10 mm or more. The branches arise just below the cross walls of the cells of the main filament. Most of these branches terminate in elongated hairs. Heterotrichous forms are characterized by ------------

Thalloid Forms

Thalloid forms are formed when the cells of a filament divide in more than one plane, that is not only cross-wise but also lengthwise it results in a sheet of cells. The thallus may be one cell or many cells in thickness.

Ulva

Ulva is a very common alga found on rocky coasts of the sea (Fig. 1.6a). The thallus is attached to the substratum such as rocks by rhizoids at its base.

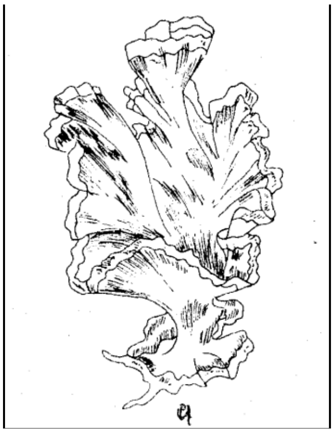
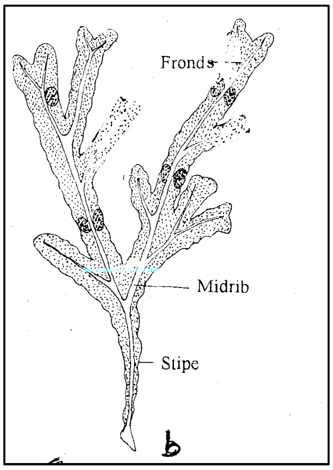



Fig. 1.7: *Ulva lactuca*; a) habit of growth b) *Fucus vesiculosus*-morphology of the thallus **(**Source**:** IGNOU (1991) Indira Gandhi National Open University. Plant Diversity-Algae.)

Fucus

Fucus is a brown algal seaweed common on the rocky coasts of the sea in temperate countries (Fig. 1.6b). The body of *Fucus* is large about half a metre or so in length. It has a basal discoid holdfast, a short stipe and long flat and dichotomously branched fronds or blades. Dichotomous branching pattern is one in which the two arms of the branch are more or less equal in length. At the tip of the blade are found air bladders which make the plant float in water.
Fucus is attached to the rocks by means of------------------------'

Polysiphonoid Forms
This form of algae is more complex than the earlier described forms. It is found in the red alga *Polysiphonia* (Fig. 1.7) which is marine in habitat.

Polysiphonia

The algae shows in general heterotrichous habit. The prostrate system is in the form of an elongated rhizoid which attaches the algae to the substratum. The erect system is highly branched. The branches are of two kinds, some are long and some short and hair-like. The main filament grows by the division of a single apical cell. The mature plant body is made up of a central row of cells - central siphon, surrounded by vertical rows of cells, 4 to 24 - pericentral siphons.

All the pericentral cells are connected with the cells of central siphon and are also connected with each other.
When the cytoplasm of one cell is connected to the cytoplasm of a neighbouring cell through a pit in their wall, it is known as pit connection. In *Polysiphonia* although all the cells are separate, their cytoplasm is connected by means of pit connections.

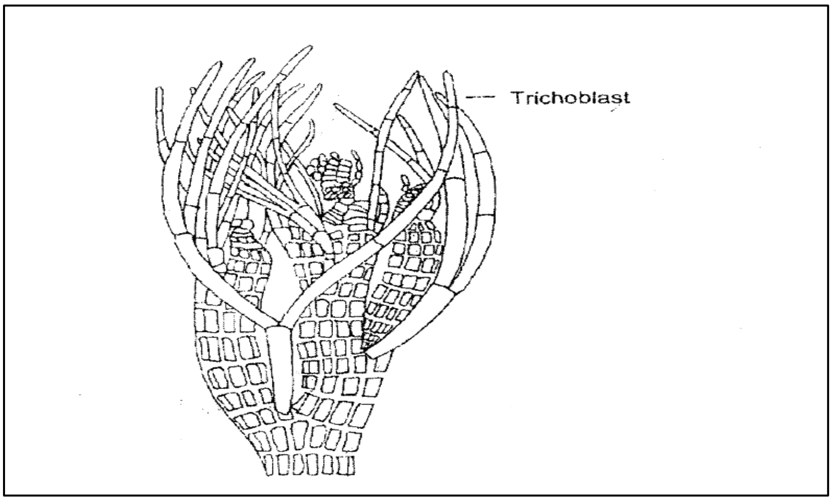


Fig.1.7: *Polysiphonia;* habit showing multicellular construction of several interconnected rows of siphons **(**Source**:** IGNOU (1991) Indira Gandhi National Open University. Plant Diversity-Algae)

New branches may develop from the cells of central siphon or from the pericentral cells.

The trichoblasts which are simple or branched hair-like lateral branches arise from the pericentral cells. Pits in the walls of cells helps to connect their ------------

Self Assessment Exercise 2

List the algal forms

1.4 SUMMARY

Algae are diverse group of organisms ranging from microscopic unicellular to giant thalloid forms anchored to rocks in the sea. Morphologically they can be distinguished as unicellular, colonial, filamentous, heterotrichous, thalloid and polysiphonoid forms.
The unicellular algae are simplest in morphology. Some advancement is observed in colonial forms. The cells of a colony may communicate

through plasmodesmata. There is division of labour between cells, some remain vegetative while others take part in reproduction.

Some algae have a prostrate system attached to the substratum and an erect system of vertical branches. This is called heterotrichous habit. Thalloid forms are sheet like polysiphonoid forms are more complex. They possess rhizoids and branched erect system. Mature thallus consists of central row of cell-central siphon surrounded by pericentral siphon.

1.5 References/Further Readings/Web Sources

Dutta, A.C. (1981). Botany for Degree Students. Oxford University Press.

IGNOU (1991) Indira Gandhi National Open University. Plant Diversity-Algae.

3-Algal Morphology_ 14_4.pdf https://pbsci.ucsc.edu
https://britannica.com science
https://en.wikipedia.org/wiki/Algae

Textbook on Algae. Authors: H. D. Kumar, H. N. Singh. DOI: https://doi.org/10.1007/978-1-349-16144-7. Publisher: Red Globe Press London.

https://youtu.be/VIS_4G3Ysyk, https://youtu.be/pguaczZXBd0, https://youtu.be/_9mpibPvf00

1.6 Possible Answers to SAEs

Answers to Self Assessment Exercises 1

Chlamydomonas

Answers to Self Assessment Exercises 2
Unicellular, colonial, filamentous, heterotrichous, thalloid and polysiphonoid

UNIT 2 CLASSIFICATION OF ALGAE Unit Structure

2.1 Introduction

From the previous unit it is evident that algae show a great diversity in structure and reproduction. In this unit you will learn classification of this diverse group. Classification means grouping of organisms according to the similarity in their characters. It is not farfetched but true that organisms showing similar morphology, life cycle, physiology and biochemistry are genetically related from the evolutionary point of view (phylogenetically related and one is justified in grouping them together.

Algae could be classified according to their common characters into 8 divisions of' the Kingdom Protista.

In this unit you are introduced to the characteristics of different divisions of algae.

2.2 Intended Learning Outcomes

By the end of this unit, students should be able to:

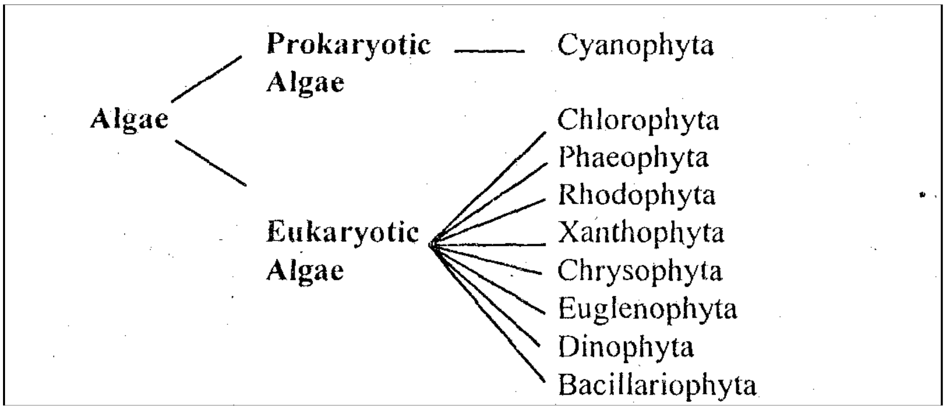
1. list the various criteria used fo2.r the classification of algae,
2. explain why algae are classified as protists instead of plants,
3. list the various divisions of algae and describe the characteristics of each
4. classify the genera of algae into division, order and family and give common examples of algae from each division.

2.3. Main Contents

2.3.1 Criteria for Classification of Algae

The criteria used by phycologists are quite varied. Generally a number of characters are used together ranging from external morphology, ultrastructure, chromosome number and their morphology, pigment composition, nature of cellular storage products, enzymes, isoenzymes, DNA homology, and DNA banding etc. As new techniques are developed they are used to decide more precisely the relatedness (or absence of it) of organisms which seem otherwise' related to each other.

Given below are the salient characters of each of the divisions of the algae. It is to be noted that each division is again divided into orders, families, genera and species. Because of the restriction of time representatives of other divisions are not included in your course, not because they are any less important in the biological world.



Prokaryotic Algae
The Prokaryotic algae has only one division, the cyanophyta

Division Cyanophyta (Cyanobacteria or Blue-green algae)

Prokaryotic algae are placed in Division Cyanophyta. Algae of this division may be unicellular, colonial and filamentous, with or without branches, branching may be 'true' or 'false' type. Most forms are embedded in mucilaginous or gelatinous sheaths.

The composition of their cell wall is similar to the bacterial cell wall which it is, made up of distinctive mucopeptides and muramic acid.

The ultrastructure of the cell shows no organised nucleus, mitochondria or chloroplasts. Photosynthetic lamellae and ribosomes of 70s type are present in the cytoplasm of the cells. Some filamentous forms possess specialised cells known as ‘heterocysts’ which are involved in nitrogen fixation.

The main photosynthetic pigments are chlorophyll a and phycobilins - (phycocyan and phycoerythrin). A number of carotenoids including β carotene are also present some of which are specific to the division. Carbon is reserved in the cells as glycogen granules and nitrogen as cyanophycean granules.

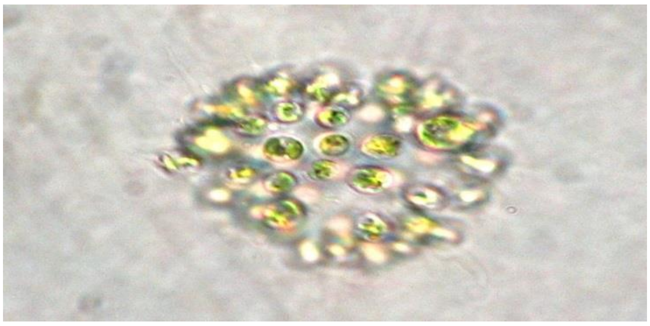
Other granules like polyphosphate granules, some enzyme aggregates Iike carboxysomes may also be present.

Reproduction occurs by simple cell division. No motile cells are found in cyanobacteria and they do not have sexual method of reproduction. Thick walled cells called ‘akinetes’ or spores are present in some forms for perennation and asexual reproduction.

Cyanobacteria are distributed all over the earth in diverse habitats, fresh water lake ponds, rivers, arctic, antarctic areas, hot water springs, brine salt pans, desert soils, subaerial surfaces like tree trunks, building terraces and rock surfaces.
Examples: *Anacystis, Microcystis, Nostoc, Anabaena, Oscillatoria, Spirulina,*

Calothrix, Gleotrichia, and Scytonema (Fig. 2.1).

Anabaena



Microcystis

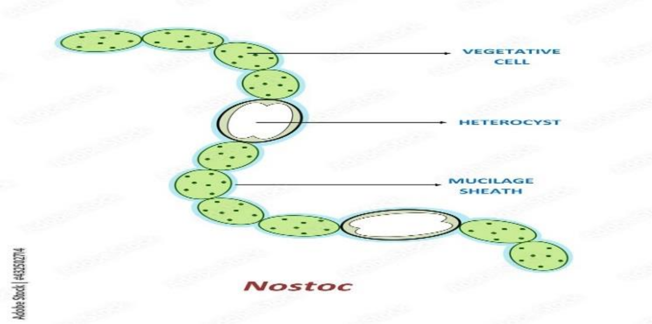


Fig. 2.1: Some examples of blue-green algae (Source: https://en.wikipedia.org/wiki/Microcystis_aeruginosa, https://en.wikipedia.org/wiki/Anabaena, https://stock.adobe.com/ng/images/diagram-showing-a-filament-of-nostoc-a-blue-green-algae/432502714)

Prokaryotic algae are the most primitive. True or False

Eukaryotic Algae

As you have learnt earlier, that Kingdom Protista includes eight divisions but some phycologists make nine divisions treating Bacillariophyta separate from Chrysophyta. You may note that we have also taken it as a separate division. They are described in detail below.

Division Chlorophyta (Green algae)

This includes unicellular to multicellular forms of green algae. The multicellular forms may be in the form of filamentous, branched or unbranched, thalloid, or sheet like arrangement of cells. Some of the green algae are colonial in form, cell structure is eukaryotic type as in higher plants with membrane bound
organised nucleus, plastids, mitochondria, and cytoplasmic ribosomes of 80s type. The cell wall is generally made up of cellulose, sometimes chitin is present

The principal photosynthetic pigments are chlorophyll a and b, carotenes and xanthophyIls located in the thylakoids.

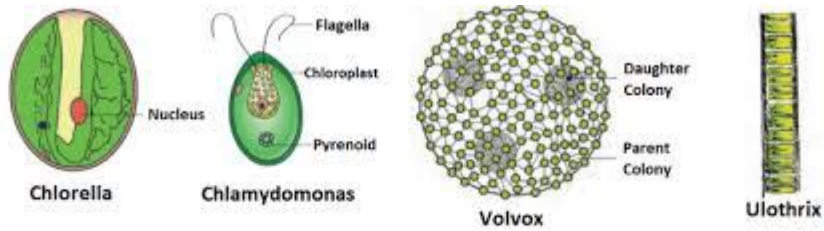


Fig. 2.2: Some members of Division Chlorophyta **(**Source: https://www.google.com/search?sa=N&sca_esv=570601344&cs=0&q= Some+members+of+Division+Chlorophyta

The storage products of the cell are mostly starch, but in some algae lipids.

Reproduction occurs by asexual and sexual methods. Asexual reproduction is by biflagellate or quadri-flagellate zoospores. whereas sexual reproduction is by biflagellate gametes The flagella are anterior and of whiplash type. Sexual reproduction includes isogamy, anisogamy, and oogamy.

Green algae are distributed in fresh water and marine habitats; some may be subaerial on wet soil or bark of trees.
ExampIes: *Chlorella, Chlamydomonas, Pediastrum, Spirogyra, Cladophora, Acelabularia, Trentephohlia, Micrasterias and Caulerpas (Fig. 2.2).* Flagella help the algae in **______________**

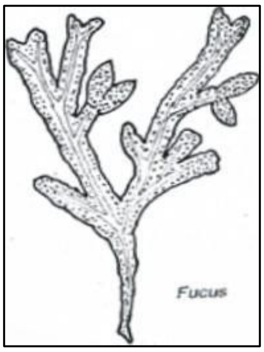
Division Phaeophyta (Brown algae)

These are the brown algae and structurally, they are most complex in morphology. They range from simple branched, filaments to massive bodies. Their Cell wall is complex. Besides cellulose, it may contain algin, fucoidin

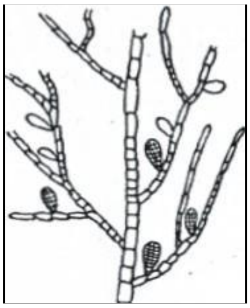
The main photosynthetic pigments are chlorophyll a and c and carotenoids. Fucoxanthin (brown in colour) is present in large amount that gives the alga its brown colour by masking the green colour of chlorophyll. Photosynthetic storage product is mannitol, sometimes laminarin. Rarely, lipid droplets may be found in the cells.

Sexual reproduction ranges from isogamy to oogamy. The motile swimmers have two unequal laterally inserted flagella, one of the flagella is larger and anterior and the other is smaller and posterior.

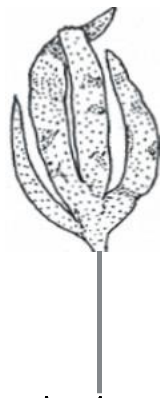
Most of the brown algae are seaweeds, very large in size, commonly known as kelps. They are the main source of iodine, agar and related products.



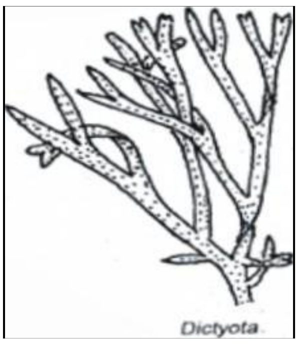
Examples: *Ectocarpus, Fucus, Laminaria, Sargassum, Dictyota, Alaria, Macrocystis, Nereocystis and Padina (Fig. 2.3)*



ectocarpus



Laminaria



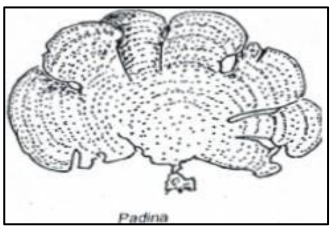


Fig. 2.3: Some common brown-algae (Source: IGNOU. (2002). Indira Gandhi National Open University. Plant Diversity-Algae.)

The brown colour is due to the pigment--------------

Division Rhodophyta (Red algae)

Most forms are multicellular and highly branched, a few are thalloid and one alga *Porphyridium* is unicellular. The body may be covered with calcium carbonate incrustations.

Besides cellulose their cell wall contains pectin, polysulphate, esters and large amounts of polysaccharides on the outside of their surface. These polysaccharides are the source of agar and carageenans. Certain red algae for example coralline algae secrete calcium carbonate around their cells and form stiff thalli.

Coralline algae are important builders of coral reefs in tropical waters, contrary to the believe that coral animals alone make up coral reefs. Fig 2.4

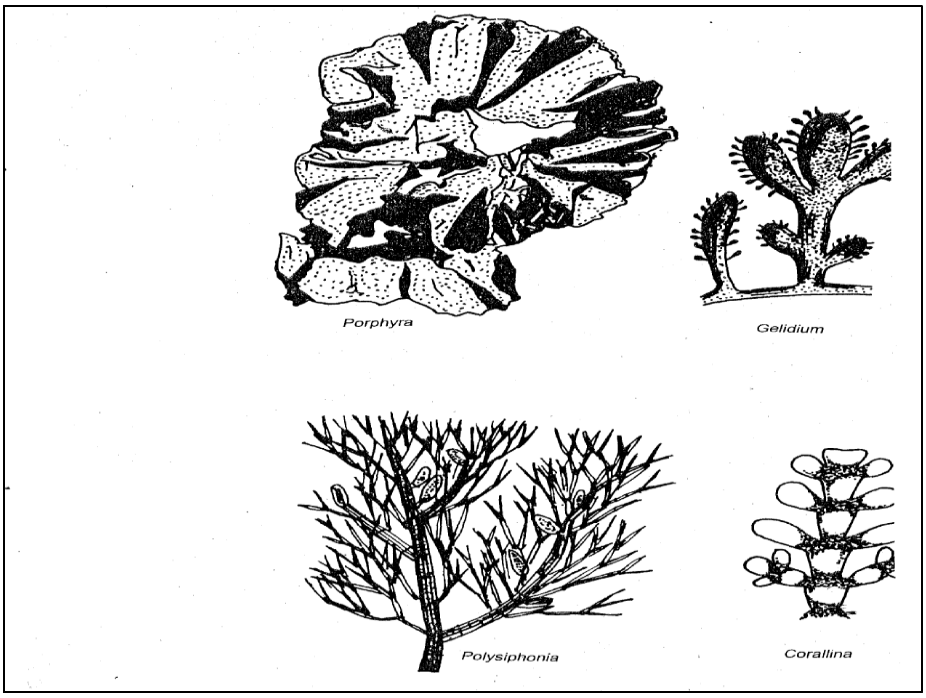


Fig. 2.4: Some common Red algae (Source: IGNOU. (2002). Indira Gandhi National Open University. Plant Diversity-Algae.)

The main photosynthetic pigments are chlorophyll a, d and phycoerythrin . Some red algae contain phycocyanin also. The red or pink colour is because of large amounts of phycoerythrin. The food reserve in the cells is floridian starch.

No motile cells are found at any stage of reproduction. Sexual reproduction is advanced oogamous type. Male gametes spermatia are passively transported by water movements to the tip of trichogyne of the female carpogonium. After fertilisation, special developmental changes occur, that are not found in any other division of the algae.

Most of the red algae are marine in habitat. A few are found in fresh water lakes, rivers, streams and ponds. Some are epiphytic or parasitic in nature.
Example: *Porphyridium (unicellular), Porphyra, Polysiplonia, Gracilaria, Gelidium and Corallina (Fig. 2.4).*
Corraline algae are found on_______________

Division Xanthophyta (Yellow-green algae)

Some forms are unicellular and motile while others are filamentous, with multinucleate cells. Photosynthetic pigments are chlorophyll a, c, β carotene which is present in large amounts, and xanthophylls giving the cells greenish- yellow colour. Food reserves include lipid and chrysolaminarin (β-1,3 - linked polymer of glucose, also known as leucosin). Cell wall frequently consists of two overlapping halves, containing pectin, silica and small amount of cellulose.

Sexual reproduction is rare. The motile cells have two unequal flagella present on the anterior end; one is tinsel and the other whiplash type (Fig. 2.5)

Yellow-green algae are widely distributed in fresh water habitats. Some are sub-aerial and a few are marine in distribution.
Examples: *Vaucheria, Botrydium (Fig.2.5)*

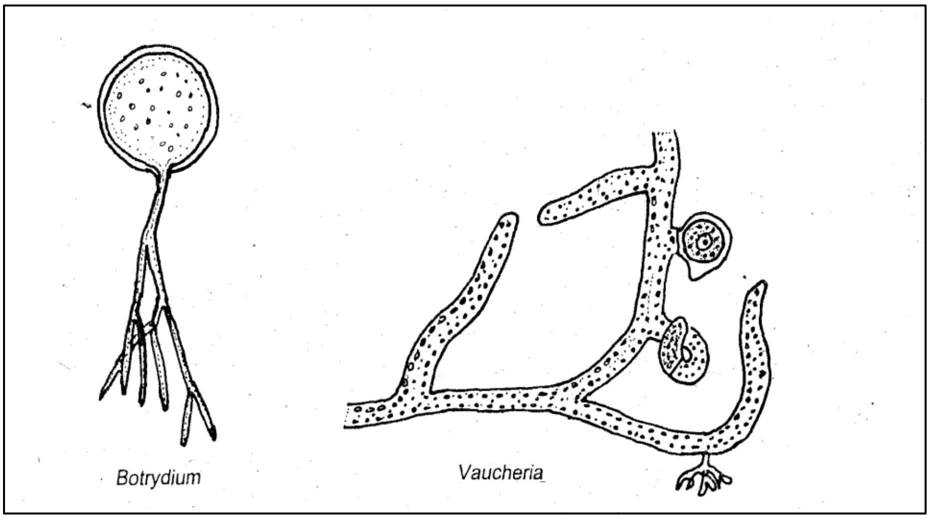


Fig. 2.5: Two members of yellow-green algae (Source: IGNOU. (2002). Indira Gandhi National Open University. Plant Diversity-Algae.)

No sexual reproduction in the Xanthophyta. True or False

Division Chrysophyta (Golden brown algae)

They occur as unicellular or colonial forms, filamentous forms are rare.

Motile cells have two equal or unequal flagella present on the anterior end. The longer one has stiff hairs while the shorter one is smooth. The cell wall is made of pectin and silica or scales of carbonate. The chloroplasts are deeply lobed.

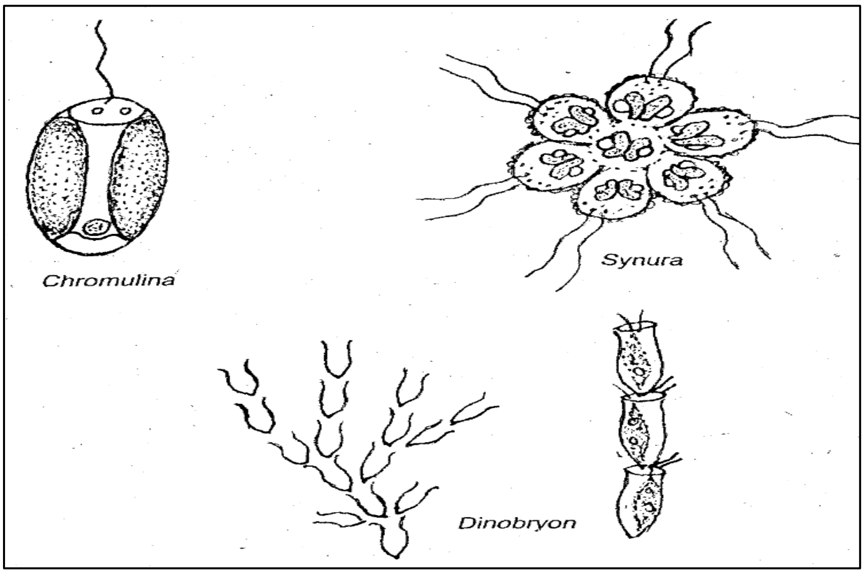


Fig. 2.6 Some members of Chrysophyta (Source: IGNOU. (2002). Indira Gandhi National Open University. Plant Diversity-Algae.)

Principal pigments are chlorophyll a, c, and carotenoids like β-carotene, fucoxanthin, diatoxanthin and neofucoxanthin.

Storage products are mostly oil droplets, true starch is absent but glucan granules or leucosin are present.

Sexual reproduction is rare. Most common features are the formation of resting cysts, resting spores (statospores), with silica walls. The cysts are formed as a result of asexual or sexual reproduction.

Golden-brown algae are distributed in marine and fresh water habitats, and in fast flowing mountain streams. Marine coccolithophorides are responsible for the formation of chalk beds on the bottom of the sea.
Examples: *Synura, Chromulina, Ochromonus, Mallomonas, and Dinobryon (Fig.*

2.6).
Chrysophytes have true starch. True or false

Self-Assessment Exercise 1

The following algae belong to which divisions?

- Brown algae
- Green algae
- Blue-green algae
- Red-algae

Division Euglenophyta (Euglenoids)

Most of the euglenoids are simple unicellular motile flagellates. They have no firm cell wall, and possess characteristics like protozoans. They have a contractile vacuole. Cell surface is pellicle (thin membrane) and has helical; knob like projections. Cell shape changes constantly (euglenoid-movements). Chloroplasts show variety of shapes such as discoid, ribbon like or stellate. Cells are biflagellate but only one flagellum emerges anteriorly (Fig. 2.7)

Members of some algal divisions such as the euglenoids euglenophytes, cryp tophytes dinolagellates, chrysophytes are predominantly unicellular. Some biologists consider these organisms to be more related to the animal kingdom and classify them under protozoa.

The photosynthetic pigments located in the plastids include chlorophyll a, b and carotenoids including β-carotene. Some euglenoids are also colourless. A form of starch-paramylon is present as distinct granules. Oil droplets and polyphosphate granules are also common in the cells.

Cells divide by binary fission. Many species produce cysts under adverse conditions. Sexual reproduction is absent.

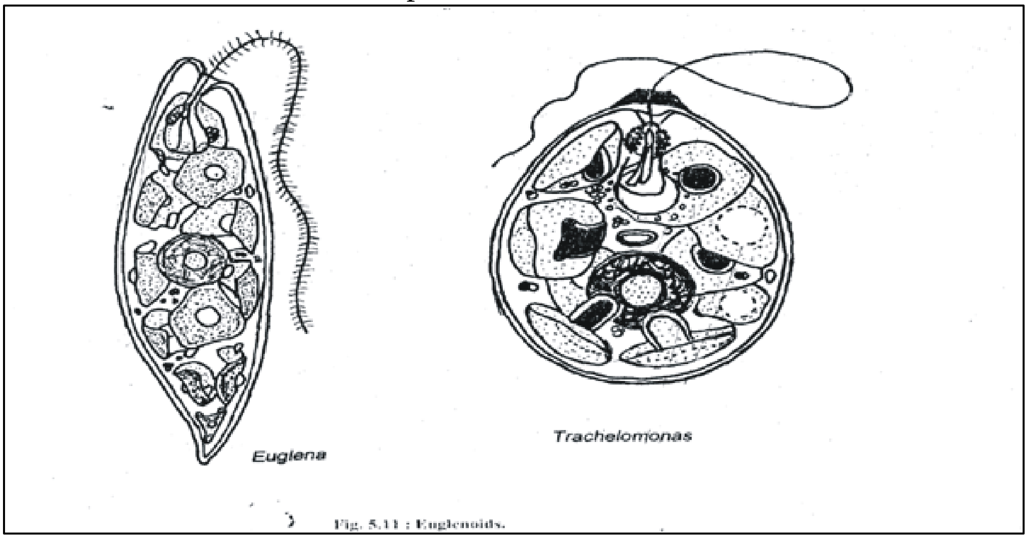


Fig. 2.7: Euglena and Trachelomonas (Source: IGNOU. (2002). Indira Gandhi National Open University. Plant Diversity-Algae)

Euglenoids occur in fresh water and brackish water and very commonly polluted ponds and temporary rain water pools.
Examples: *Euglena, Trachelomonas, Phacus.*
The euglenohytes are all unicellular,True or False

Division Dinophyta (Dinoflagellates)

Cell wall consists of cellulose plates which are inside the plasma membrane and a number of plates or body scales may be present on the cell wall. Cell structure is complex. Majority of forms are unicellular and motile. Many dinoflagellates e.g *Noctiluca*, are luminescent. They glow in the dark when they are disturbed (Fig. 2.8).

Most of these algae contain chlorophyll, a and c and distinctive carotenoid specific to dinoflagellates. Reserve foods are mostly in the form of starch and oil.
Asexual method of reproduction is by cell division. Parent cell divides into a number of aplanospores or zoospores or non-motile cells. Sexual reproduction has been recently reported, gametes are smaller than the vegetative cells and the fusion is isogamous. Formation of cysts with or without gametic fusion is found.

Dinoflagellates are mostly found as marine phytoplanktons, sometimes as redtide' blooms. Many occur as symbionts in marine animals like corals

(zooxanthellae).

Examples: *Noctiluca, Gonyaulax, Peridinium, Ceratium.*

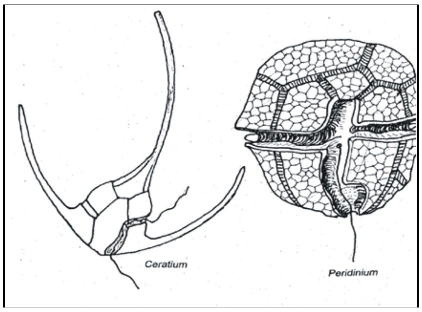


Fig. 2.8: Members of Division Dinophyta (Source: IGNOU. (2002). Indira Gandhi National Open University. Plant Diversity-Algae.)

Members of the Dinophytes are lumiscent in the dark. True/False

Division Cryptophyta (Crytomonads)

They are unicellular motile organisms,which are brown when alive. Several genera are animal like in morphology and mode of nutrition, some are colourless and saprophytic in nature. Cells are without cell walls, ovoid and dorsiventrally flattened. The two flagella are apical and unequal in length. The chloroplasts may be single or many in a cell. In some cryptomonads there are two, large parietal chloroplasts, or many disc like ones.

Pigments include chlorophyll a, c, phycocyanin, phycoerythrin, and diverse carotenoids. Reserve carbohydrate is starch.

Asexual reproduction is by longitudinal division of the cell. Palmelloid forms may produce zoospores. Sexual reproduction has not been reported so far. Examples: *Cryptomonas, Chroomonas.*

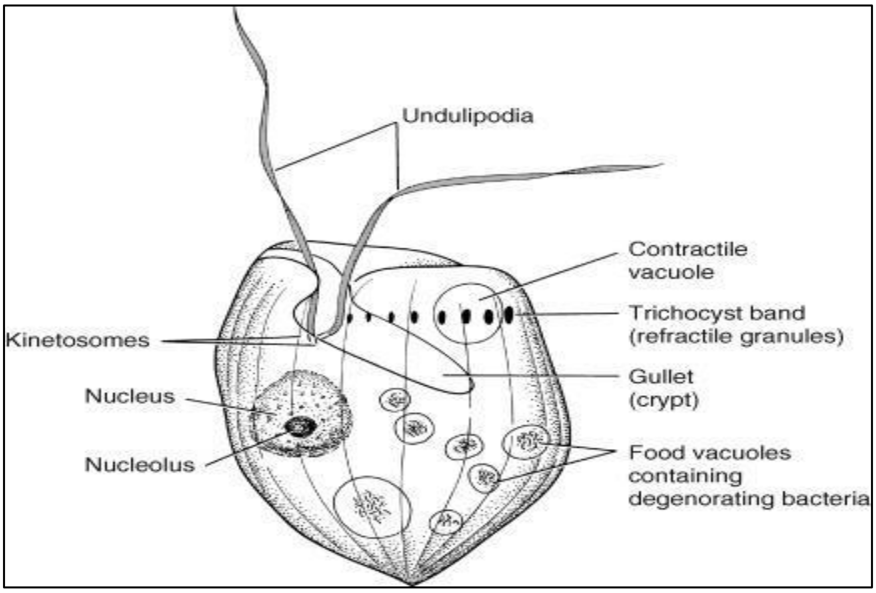


Fig 2.9 Cryptomonas Source Science Direct.Com

Some genera of cryptophytes resemble animals in ------------------- and ----------------

Division *B*acillariophyta (Diatoms)

They are mostly unicellular while some are colonial and filamentous in structure. The cell wall is silicified, consisting of two perforated overlapping plates. It is highly ornamented on the surface. Chromatophores are brownish in colour due to large amount of carotenoids. Diatoms (cut in half) each cell is made up of two parts. The larger part fitting tightly over the slightly smaller part like a petri dish (Fig. 2.10)

Photosynthetic pigments are chlorophyll a and c, fucoxanthin, diatoxanthin and diadinoxanthin. Common storage product is oil and chrysolaminarin. Reproduction occurs by vegetative and sexual methods. Diatom cells unlike other algae are diploid in nature. Sexual fusion is homothallic, within the individuals of the same clone. Two amoehoid gametes fuse to form a zygote which develops into an auxospore. Fusion may be isogamous, anisogamous or oogamous type.

Diatoms are widely distributed in fresh water and sea as planktons, on mud surfaces, moist rocks, and sand. They may even be epiphytic, epizoid or endozoid. Large deposits of fossil diatom shells known as diatomaceous earth are mined and used in various industries.
Examples: *Navicula, Cymbella, Coscinodiscus, Diatoma and Fragilaria.*

At the end it has to be pointed out that classification of algae is tentative and can be improved by using new and advanced techniques like DNA fingerprinting which can clarify the genetic relatedness of organisms.

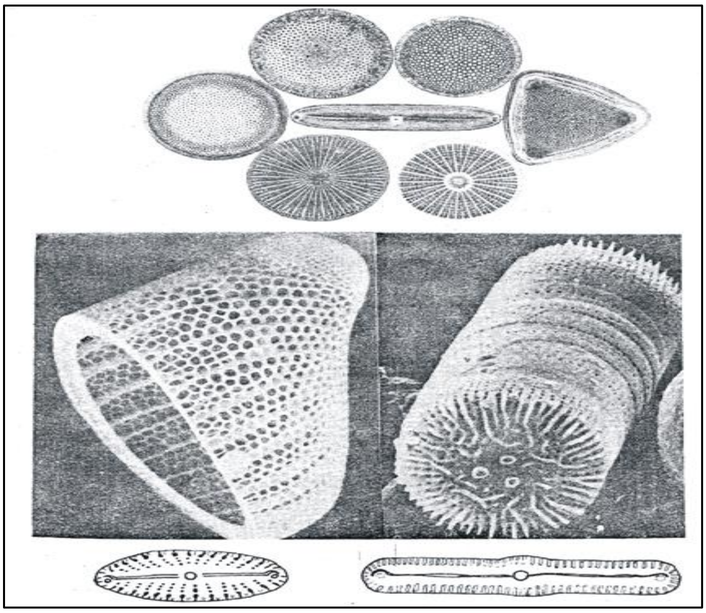


Fig. 2.10: Members of Divison Bacillariophyta. Some diatoms as seen under scanning electron microscope (Courtesy of P. D. Yanandan)

Self-Assessment Exercise 2

In the following statements fill in the blank spaces with appropriate words:
i) In cyanobacteria carbon in reserved as ………………………………. ii) The colour of red algae is due to ……………………………………….. iii) The storage material in the Division Phaeophyta is………. iv) Sexual reproduction in Xanthophyta is ………………………………

2.4 SUMMARY

In this unit you have learnt:

Algae have been grouped into two major types: prokaryotes and eukaryotes because of the basic differences in the ultrastructure of the cells.

Cyanobacteria or blue-green algae although related to bacteria, are grouped with algae because of the similarity in pigment composition and presence of oxygenic photosynthesis.

Eukaryotic algae can be classified into 9 divisions each sharing a large number of common characters. All photosynthetic algae have chlorophyll a and β-carotene, but other pigments may vary.

Three divisions Cyanophyta, Rhodophyta and Cryptophyta have similar phycobilin pigments blue phycocyanin, and red phycoerythrin, otherwise they are unrelated in any of the other characters.

Green algae (Division Chlorophyta) are unicellular, colonial and filamentous in forms, motile and free floating. The photosynthetic pigments are chlorophyll a, b, β-carotene and xanthophylls. Food is stored as starch. Though euglenoids also contain chlorophyll a and b, but they are different from green algae.

Brown algae (Division Phaeophyta) are mostly marine, large, complex usually multicellular and non-motile. The chlorophylls are masked by brown pigment fucoxanthin. Food is stored as oil and complex carbohydrate-laminarin. The zoospores and gametes are motile.
Red algae (Division Rhodophyta) are marine, multicellular and filamentous. The chlorophylls are masked by phycobilins. Food is stored as floredian starch. There are no motile cells in the life cycle of the algae

Members of Xanthophyta, Chrysophyta, Dinophyta and Cryptophyta are mostly unicellular. They contain chlorophyll a and c and are collectively called chromophytes.

In Xanthophyta, Chrysophyta, Dinophyta the cell wall is made either of cellulose or is absent. In Euglenophyta and Cryptophyta cell wall is absent.

2.5 References/Further Readings/Web Sources

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https://youtu.be/VIS_4G3Ysyk, https://youtu.be/pguaczZXBd0, https://youtu.be/_9mpibPvf00

2.6 Possible Answers to Self-Assessment Exercises

Answer to SAEs 1

1. Phaeophyta
2. Chlorophyte
3. Cyanophyta
4. Rhodophyta

Answer to SAEs 2

i) Glycogen granules
ii) Phycoerythrin
iii) Mannitol,laminarin
iv) Rare

Unit 3 REPRODUCTION IN ALGAE

Unit Structure

3.1 Introduction

In unit1, you have learnt that algae vary in size from small microscopic unicellular forms like *chlamydomonas* to large macroscopic multicellular forms like *Polysiphonia*. The multicellular forms show great diversity in their organization and this includes filamentous, heterotrichous, thalloid and polysiphonoid forms. In this unit we will discuss the types of reproduction and life cycle in algae taking suitable representative examples from various groups. Algae show all the three types of reproduction vegetative, asexual and sexual. Vegetative method solely depends on the capacity of bits of algae accidentally broken to produce a new one by simple cell division. Asexual methods on the other hand involve production of new type of cells, zoospores.
In sexual reproduction gametes are formed. They fuse in pairs to form zygote.

Zygote may divide and produce a new thallus or it may secrete a thick wall to form a zygospore.

You will see that sexual reproduction in algae has many interesting features.

3.2 Intended Learning outcomes

By the end of this unit, the students should be able to:

1. describe with suitable examples the three types of reproduction vegetative, asexual and sexual in algae.

2. distinguish the three types of union of gametes – isogamy, anisogamy and oogamy in algae.
3. illustrate diagrammatically reproduction and life cycle in *Chlamydomonas, Ulothrix,* and *Fucus* describe their special features, describe the four basic types of life cycle found in algae

3.3. Main Contents

3.3.1 Types of Reproduction

Reproductive processes found in various groups of algae can be broadly divided into three types: vegetative, asexual and sexual methods.

Vegetative Reproduction

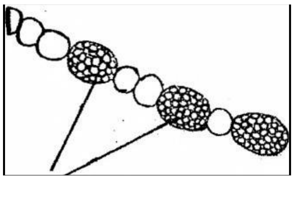
The most common type of vegetative reproduction in algae is by binary fission. In unicellular prokaryotic algae like *Anacystis* it is the only method of reproduction found in nature. Fragmentation occurs in filamentous and multicellular forms, the algae may get broken accidentally into small pieces, each developing into a new one. The above methods of propagation are known as vegetative reproduction.
Breaking into small pieces is an example of------------

Asexual Reproduction

When reproduction takes place through specialized cells (other than sex cells), it is described as asexual reproduction.

Anabaena and Nostoc

The cells accumulate food materials; develop thick walls to become spores or akinetes (Fig. 3.1). Akinetes can withstand dryness (lack of water) and high temperature for a long time, but when conditions are suitable they germinate to form new filaments.



Akinete

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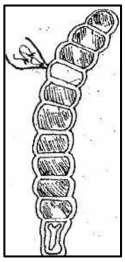
Fig. 3.1 : *Anabaena* showing akinetes (Source: IGNOU. (2002). Indira Gandhi National Open University. Plant Diversity-Algae)

Ulothrix

Filamentous algae (like *Ulothrix*) may reproduce by producing motile cells called zoospores (Fig. 3.2). The protoplast of a single cell divides many times by mitosis to produce several zoospores.



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zoospore

Fig. 3.2: Formation of zoospores in *Ulothrix* (Source: IGNOU. (2002). Indira Gandhi National Open University. Plant Diversity-Algae)

Each zoospore has 2-4 flagella with which it swims for some time and then settles by its anterior end. It subsequently divides into a lower

cell which becomes the holdfast and the upper cell which by further divisions becomes the vegetative filament. Zoospores are produced in other algae also.
Asexual reproduction in other algae is described below.

Chlamydomonas

Although this is a unicellular motile algae but it produces zoospores. The parent cell divides inside the cell envelope and each daughter cell develops two flagella each. These zoospores look exactly like the parent cell except they are smaller in size. When the zoospores are fully developed the parent cell wall dissolves, releasing them into the surrounding water (Fig.3.3)

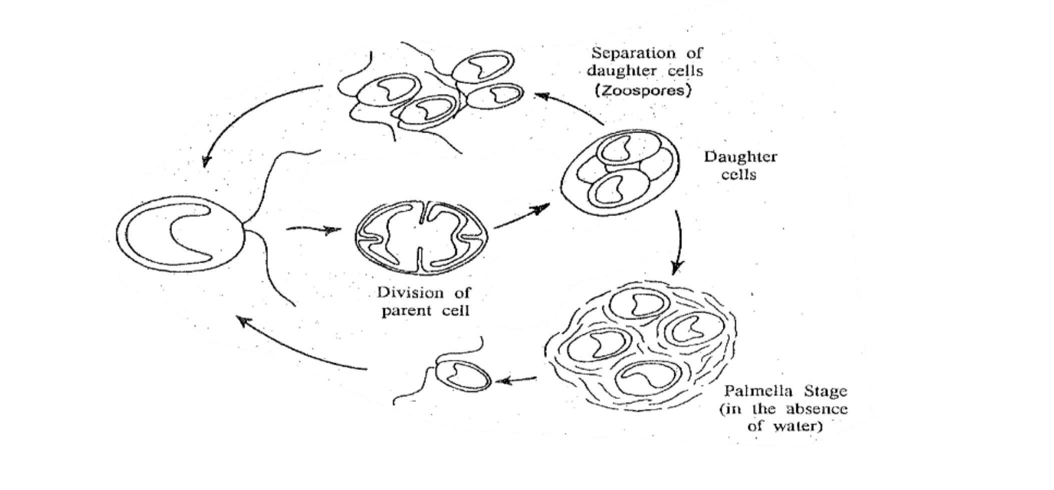

Fig. 3.3: Formation of zoospores and palmella stage in *Chlamydomonas* (Source: IGNOU. (2002). Indira Gandhi National Open University. Plant Diversity-Algae.)

Sometimes when there is less water outside, zoospores may lose flagella and round up. These non-motile spores are called **aplanospores** which develop into thick walled **hypnospores.**
On moist soil when zoospores cannot be released due to lack of water, they get embedded within a gelatinous material formed from the parent cell wall. Such cells do not have flagella but whenever they become flooded with water they develop flagella and swim away in the

water. These gelatinous masses containing thousands of non-motile cells are known as **palmella** *stage* of *Chlamydomonas.*
Oedogonium Zoospores are produced singly in a cell. Each has one nucleus and a crown of flagella at the apex.
Many zoospores are produced from a single cell, as in *Ulothrix.* They have single nucleus and 2-4 flagella.

Ectocarpus
Two types of Zoospores are produced in sporangia which are:
I **Plurilocular Sporangia**: The sporangium is made up of many cells and several biflagellate zoospores are produced (Fig. 3.4).
II **Unilocular Sporangia**: The sporangium is made up of one cell which produces single biflagellate zoospore (Fig. 3.4)

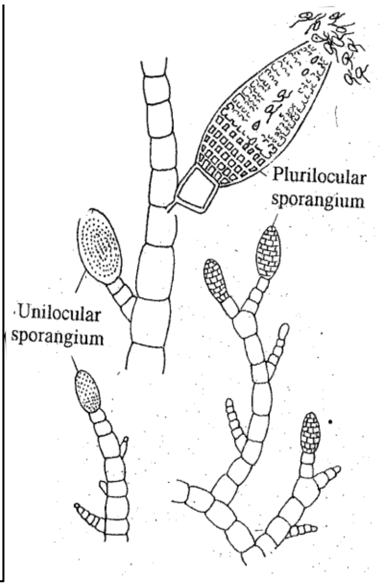

Fig. 3.4: Unilocular and Plurilocular sporangia of *Ectocarpus* (Source: IGNOU. (2002). Indira Gandhi National Open University. Plant Diversity-Algae)

Aplanospores are formed when there is a shortage of -----------

Self-Assessment Exercise 1

Define asexual reproduction

Sexual Reproduction

Sexual reproduction in algae like in other organisms involves the fusion of two cells from opposite sex called gametes, resulting in the formation of a zygote. Some basic features of this method of reproduction are as follows:

Gametes are always haploid and may or may not be different in morphology. If both the sex cells look alike, they could be male called **plus (+) or female called minus (-) mating types of strains.** Gametes can fuse only when one is plus and the other is minus.
Both of them + and – may be produced by a single parent. This is called **monoecious** or **homothallic** condition. When they come from different plus or minus thallus types it is called **dioecious** or **heterothallic** condition.

There are three types of gametic fusion (Fig. 3.5).

a. **Isogamy:** When both the gametes are of the same size and morphology.
b. **Anisogamy:** The two gametes are distinctly different in size or shape, the larger of the two is minus (female) type.
c. **Oogamy:** The female gamete, egg or ovum is big in size and has no flagella hence it is non-motile. Male gametes are flagellated and highly motile. They are also known as **antherozoids, spermatozoids** or sperms.

The male gametes are attracted by the female cells because of special hormones called gamones (a violatile hydrocarbon) produced by them. Fusion of the gametes leads to the formation of a zygote. If the conditions are unsuitable for growth, the zygote may develop a thick wall and become a resting zygospore. Gametes being haploid, are produced by mitosis in a haploid thallus. If the thallus is diploid as in *Fucus* the reproductive cells undergo meiosis or reduction division to form haploid gametes.

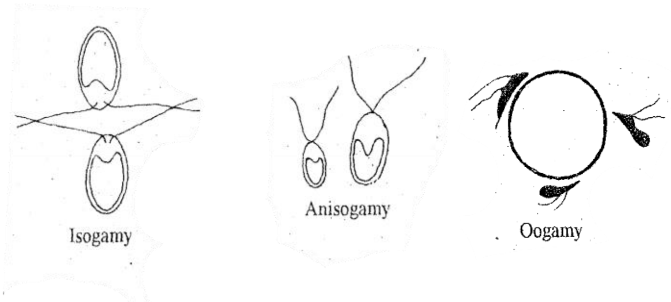

Fig. 3.5: Three types of gametic fusion-isogamy, anisogamy and oogamy.
(Source**:** IGNOU (2002) Indira Gandhi National Open University. Plant Diversity-Algae.)

In haploid thallus, after the fusion of gametes, the diploids zygote undergoes meiosis during germination. However, in diploid algae a zygote may divide mitotically and give rise to a diploid thallus (*Fucus*). Both haploid and diploid thallus are found in *Ulva*. They look very similar in size and shape. Sexual reproduction involves fusion of ---------------------

Self-Assessment Exercise 2

Define sexual reproduction in Algae

3.4 Summary

Reproduction in algae is by asexual and sexual methods. Asexual method involves fission of cells are regeneration of new ones
Sexual method involves fusion of male and female gamete resulting in the formation of a zygote.
The life cycle in algae demonstrates clearly a marked alternation of generations especially in the higher forms like *Ulva*, *Laminaria* and *Fucus*.

3.5 References/Further Readings/Web Sources

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https://youtu.be/KUL00k8xATs, https://youtu.be/qPcOsRiTKgQ, https://youtu.be/RulZjX0ZAF8

3.6 Possible Answers to Self-Assessment Excercises

Answer to SAEs 1

When reproduction takes place through specialized cells (other than sex cells), it is described as asexual reproduction.

Answer to SAEs 2

Sexual reproduction in algae involves the fusion of two cells from opposite sex called gametes, resulting in the formation of a zygote

UNIT 4 LIFE CYCLES OF ALGAE

Unit Structure

4.1 Introduction
4.2 Intended Learning Outcomes
4.3 Main Contents
  4.3.1 Life Cycles in Algae
4.4 Summary
4.5 References / Further Readings/Web Sources
4.6 Possible Answers to Self-Assessment Exercises

4.1 Introduction

In this unit we will discuss the life cycle of algae taking suitable representative examples from various groups. Algae show all the three types of reproduction vegetative, asexual and sexual. Vegetative method solely depends on the capacity of bits of algae accidentally broken to produce a new one by simple cell division. Asexual methods on the other hand involve production of new type of cells, zoospores. In sexual reproduction gametes are formed. They fuse in pairs to form zygote. Zygote may divide and produce a new thallus or it may secrete a thick wall to form a zygospore. However, we shall take up some specific algal types to illustrate their life cycle in nature

4.2 Intended Learning outcomes

By the end of this unit, the students should be able to:

1. illustrate diagrammatically life cycles in *Chlamydomonas, Ulothrix,* and *Fucus* and describe their special features,
2. describe the basic types of life cycle found in algae

4.3. Main Contents

4.3.1 Life Cycle of Algae

We have given above, in unit 3, the basic modes of reproduction in algae. Now we take up some specific algal types to illustrate their life cycle in nature. It is to be noted that the life cycle of an alga is very much controlled by environmental factors like temperature, light, seasons, and availability of nutrient, and also salinity, wave action and periodicity of tides in the case of marine forms. Observations made by people during different times from various geographical locations and sometimes experimentally studied under controlled conditions, give us fairly comprehensive if not a complete picture of the life cycle of an alga.

Chlamydomonas

Sexual reproduction in this alga shows all the three different types depending on the species (Fig. 4.1). Isogamy is found in *C. reinhardii, C. gynogama* and *C. media.*

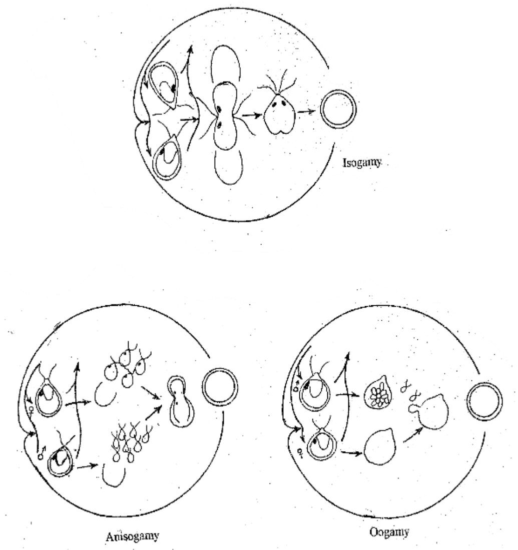

Fig. 4.1: Sexual reproduction in *Chlamydomonas:* Isogamy, anisogamy and oogamy **(**Source**:** IGNOU (1991) Indira Gandhi National Open University. Plant Diversity-Algae.)

Isogamy is of two types:

In **clonal population** (cells obtained by the repeated divisions of a single parent cell) fusion may take place between gametes which are homothallic or in self compatible strains. For example, fusion occurs between any two cells of *C. gynogama and C. media.*

In *C. moewusii and C. reinhardii* fusion of gametes can take place only when they come from two different unrelated (heterothallic, self incompatible) strains.

In many isogamous species the parent cell may divide to produce 16 to

64 biflagellate gametes while in some the adult cells themselves may directly behave as gametes and fuse. Which of these species of Chlamydomonas exhibits isogamy?
a. *C. reinhardi* b. *C. gynogama* c. *C. media* d. all of the options

Anisogamous form of gametic fusion is found in *C. braunii.* A female cell divides and produces four large cells. Each of these cells have two flagella but are less active. The male cells are about 8 in number but smaller in size.

Oogamy is the advanced type of sexual reproduction found in *C. coccifera.* A parent cell discards its flagella and directly becomes a non-motile egg or ovum. While male parent cell by repeated divisions produces sixteen male gametes. These are biflagellate and highly motile.

The process of gametic attraction, fusion and related phenomena have been studied in some detail in the laboratory. Under proper light condition and carbon dioxide concentration, production of gametes can be initiated by nitrogen starvation. The formation of male or female gametes (even in the case of isogamy) is attributed to the varying concentration of gamones produced by them. The attraction between gametes is due to the presence of glycosidic mannose at the tips of the flagella of one strain which in a complementary way binds with the substance present in the flagella of the gamete of the opposite stain. Once this sticking of the flagella of plus and minus gametes takes place, flagella twist about each other bringing the anterior ends of the gametes close. This is followed by cellular and nuclear fusion.

The zygote secrets a thick wall and accumulates large amount of food materials like starch , lipids and orange – red pigments. It is now known as **zygospore** which remains dormant till the environmental conditions are favourable for its germination

It has been shown that during germination of zygospore meiosis takes place followed by mitosis resulting in haploid *Chlamydomonas* cells.

Life Cycle

Chlamydomonas is unicellular, haploid and reproduces asexually many times by forming zoospores. Under unfavourable environmental conditions it produces gametes which fuse to form diploid zygospore.

During germination, reduction division takes place and haploid cells are formed (Fig. 3.7).

Chlamydomonas is of great interest to biologists. Its study has brought to light several interesting features of biological importance, some of which are listed below.

i Presence of DNA in the chloroplasts of the alga
ii Presence of cytoplasmic genes
iii Production of genetic mutations – affecting nutrition, photosynthesis and production of mutants without flagella or cell wall.
iv Discovery of gamones and their role in sexual reproduction.
v Presence of isogamy, anisogamy and oogamy in a single genus

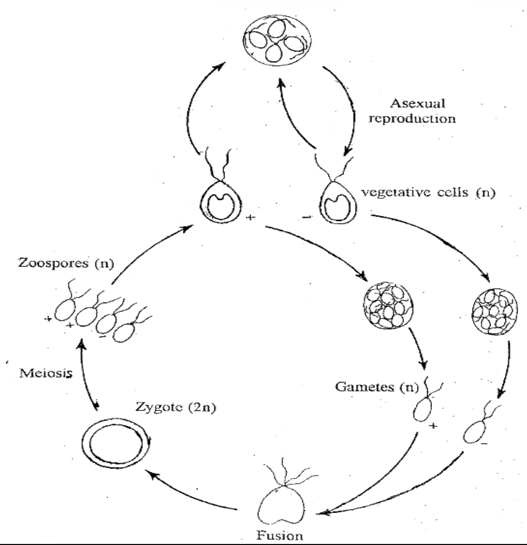

Fig. 4.2: Life cycle of *Chlamydomonas* **(**Source**:** IGNOU (1991) Indira Gandhi National Open University. Plant Diversity-Algae.)

Under unfavourable environmental conditions, chlamydomonas produces gametes which fuse to form diploid zoospore. True/False

Alternation of Generations

The type of life cycle of an organism in which reproduction alternates with each generation between sexual reproduction an asexual reproduction is called alternation of generations. The two generations are termed as **gametophytic** and **sporophytic** generations. The gametophytic generation is haploid (n) and the sporophytic generation is diploid (2n)

The fusion of two gametes(n) results in zygote(2n) which on germination forms the plant / thallus called sporophyte. The sporophyte in turn produces haploid spores by meiosis. When a spore germinates it develops into gametophyte which bears male or female gametes or both on the same plant / thallus.
In some bryophytes the gametophytic generation is more conspicuous. While in ferns the sporophytic generation is more prominent. In angiosperms main plant body is sporophyte and the gametophytic generation is reduced to a few cells. You will see that all type of situations prevail in algae. In some algae gametophyte is prominent while in others sporophyte is prominent.

Self-Assessment Exercise 1

What do you understand by: Alternation of Generation?

Ulothrix

Sexual reproduction takes place by means of isogamous, biflagellate.
Fusion takes place only between plus and minus mating types. The gametes are from different filaments (heterothallic). The zygote develops a thick wall and remains dormant till the conditions are favourable for germination. When conditions become favourable meiosis takes place and 4 – 16 haploid zoospores are produced which settle down giving rise to vegetative filaments (Fig. 4.3)

It has been found that *Ulothrix* produce gametes when grown under long day conditions while short day conditions initiate the formation of zoospores.

Life Cycle

Look at Fig. 3.8: showing the life cycle of *Ulothrix*. Which is the diploid stage of the algae?
The thallus of *Ulothrix* is haploid and the diploid stage is represented by the zygote only. In some species of Ulothrix (*U. speciosa, u. flcca and U. implexa*) the zygote develops into an independent, unicellular, thallus which is diploid in nature. It produces zoospores asexually by meiosis. The zoospores develop into haploid filaments.
Thus in *Ulothrix* two types of life cycles can be distinguished:

Haplobiontic:

The thallus is haploid and only the zygote is diploid e.g. ***U. zonata***
Diplobiontic:

In diplobiontic cycle, the alga consists of a haploid thallus that produces gametes and a diploid unicellular stalked thallus which produces zoospores after meiotic division. The two generations – haploid and diploid, alternate with each other. (alternation of generations). Because the two thalli are very different in size and morphology it is known as **heteromorphic, diplobiontic** life cycle.

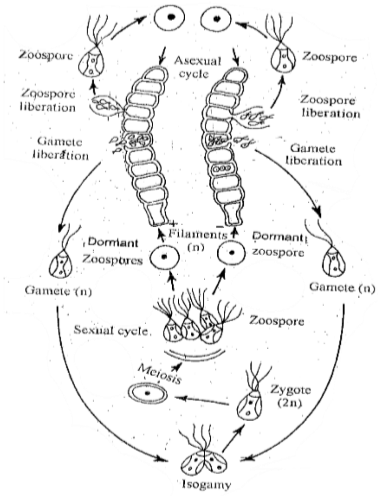

Fig. 4.3: Life cycle of *Ulothrix* **(**Source**:** IGNOU (1991) Indira Gandhi National Open University. Plant Diversity-Algae.)
The zygote of Ulothrix develops a thick wall and remains dormant till the conditions are favourable for germination. True/False

Fucus

Fucus has an advanced type of reproductive structure, known as **receptacles,** which are swollen at the tips of branches (Fig. 4.4 a) Distributed over the surface of each receptacle are small pores, known as **ostioles** which lead into the cavities, called **conceptacles** (Fig. 4.4b). Each conceptacle may produce only eggs, only sperms or as in some cases both. A thallus may be unisexual – either having male receptacle or only female ones.

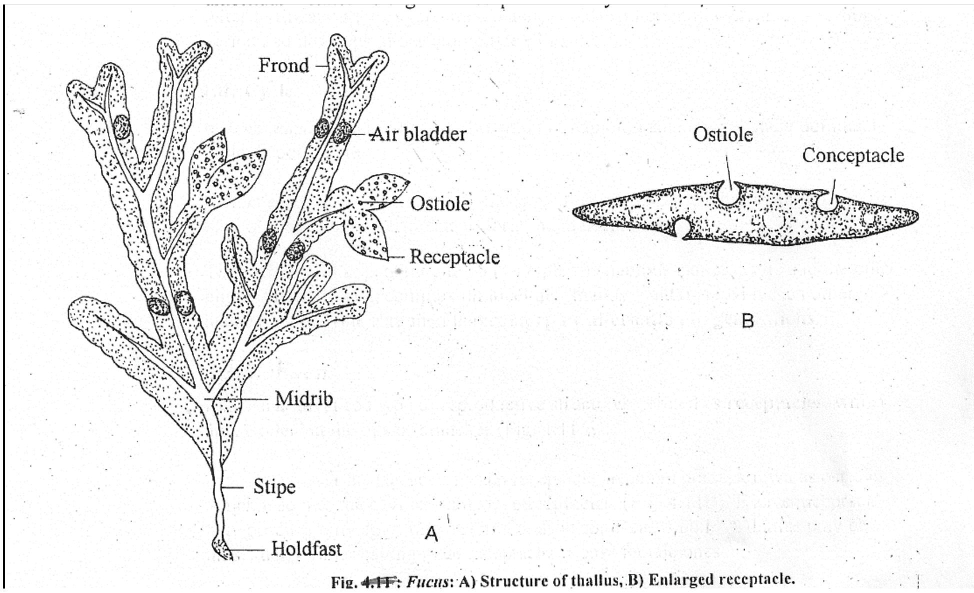

Fig. 4.4 :*Fucus* : a) Structure of thallus, b) Enlarged receptacle **(**Source**:** IGNOU (1991) Indira Gandhi National Open University. Plant Diversity-Algae.)

At the base, inside the conceptacle is a fertile layer of cells which develops into oogonia (Fig. 4.5). Each oogonium has a basal stalk cell and an upper cell which undergoes reduction division and produces eight haploid eggs (Fig. 4.5C and D). These are liberated in the conceptacle (Fig. 4.5E). Some of the cells inside the conceptacle produce unbranched multicellular hairs called **paraphyses** which emerge out of the ostiole as tufts.

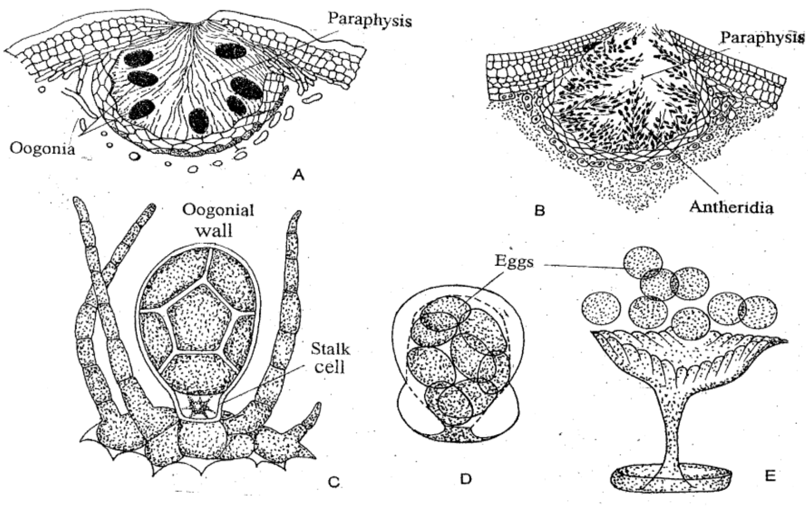

Fig. 4.5: *Fucus* A) T. S. through female conceptacle showing oogonia, B) T. S. through male conceptacles showing antheridia, C) structure of an oogonium, D and E) formation and liberation of eggs **(**Source**:** IGNOU (1991) Indira Gandhi National Open University. Plant Diversity-Algae.)

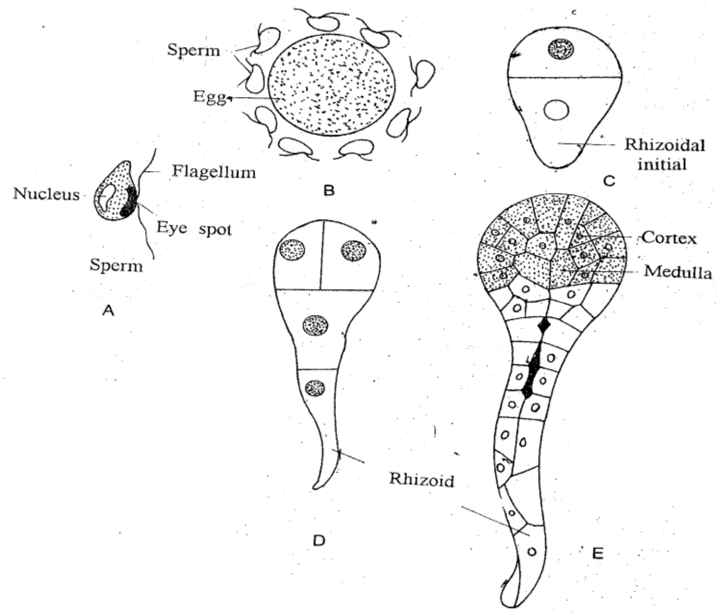

Fig 4.6: Formation and developmental stages of a **(**Source**:** IGNOU (1991) Indira Gandhi National Open University. Plant Diversity-Algae.)
Antheridia are produced on branched paraphyses inside the conceptacle (Fig. 4.5B). Each antheridium is like a unicellular sporangium which divides meiotically and then by further divisions produced 64 haploid sperms. The biflagellate sperm has a longer flagellum pointing backwards and a shorter one projecting towards the front. It has a single chloroplast and a prominent orange eye spot

The release of the gametes is connected with the sea tides. At low tide, *Fucus* fronds shrink due to loss of water, and when such fronds are exposed to an on coming tide, the eggs and sperms are released into the surrounding sea water.

The eggs of *Fucus* are known to attract sperms (Fig. 4.6 A and B) by secreting a gamone. Immediately after fertilization a wall is secreted around the zygote. It has been shown that unfertilized eggs can develop into germlings parthenogenetically if treated with dilute acetic acid.
The diploid zygote germinates by producing a rhizoidal outgrowth on one side. It is later cut by wall formation to form a lower rhizoidal cell and apical cell (Fig. 4.6 C) which by further divisions (Fig. 4.6 D and E) gives rise to the *Fucus* fronds.

Fucus has an advanced type of reproductive structure, known as Ostioles. True/False

Self-Assessment Exercise 2

What is a Conceptacle?

4.4 Summary

The life cycle in algae demonstrates clearly a marked alternation of generations especially in the higher forms like *Ulva, Laminaria* and *Fucus.*

4.5 References/Further Readings/Web Sources

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4.6 Possible Answers to Self-Assessment Excercises

Answer to SAEs 1

Alternation of Generation is the type of life cycle of an organism in which reproduction alternates with each generation between sexual reproduction and asexual reproduction is called. The two generations are termed as gametophytic and sporophytic generations. The gametophytic generation is haploid (n) and the sporophytic generation is diploid (2n

Answer to SAEs 2

Conceptacles are cavities in Fucus resulting from Ostioles which are small pores distributed overs the surface of receptacles

Glossary

(2n)……. Diploid
(n)……….Haploid
Prokaryotic….. Single celled unicellular organisms that lack nucleus and other membrane bound organelles
Eukaryotic……. Unicellular or multicellular organisms with nucleus and other membrane bound organelles
Parthenogenesis………….. Development of unfertilized eggs
Antheridia…………………. Male sex organs of algae, mosses, ferns, fungi and other non-flowering plants

End of the Module Questions

1) Which of the following algae reproduce **only** by binary fission?

. Volvox

Chlamydomonas

Anacystis

Microcystis

2) In the following statements fill in the blank spaces with appropriate words:

i ………………… is an enlarged cell in blue-green algae which accumulates food reserve, develops a thick wall and functions as a resting spore.

ii Under unfavourable conditions the zoospores lose their flagella and round up, they are called ………………

MODULE 2 FUNGI AND BRYOPHYTES

Module Structure

In this module we will discuss about the general introduction of fungi and bryophytes with the following units:

UNIT 1 FUNGI MORPHOLOGY Unit Structure

1.1 Introduction

You are probably familiar with yeast, bread mould, rust, smut and mushrooms. They are all members of the fungal Kingdom. Fungi exhibit a range of structures: unicellular, plasmodium like, filamentous and pseudo parenchymatous. However, the different forms show common cellular, physiological and biochemical characteristics. In this unit, you will study these forms in some detail.

1.2. Learning Outcomes

By the end of this unit, students should be able to:

i. distinguish fungi from other groups of organisms on the basis of morphological features.

ii. describe the range of morphological forms in fungi.

1.3 Main Contents

1.3.1 FUNGAL MORPHOLOGY

Fungi exhibit a variety of forms. Fig. 1.1 The baker's yeast is a unicellular fungus. It is very minute in size and looks like a pinhead under the light microscope. Most fungi are microscopic but several grow very large. For example, mushrooms, motels and puffballs can be seen with the unaided eyes. Under the microscope, a slime mould looks like a protozoan with a naked amoeboid mass of protoplasm. Bread mould *(Mucor),* pink mould *(Neurospora)* and green mould *(Penicillium)* show branched filaments. Whereas mushrooms, morels and puffballs are the fruiting bodies formed by close packing of several interwoven filaments. When conditions are suitable the fruiting bodies develop from the mycelium which otherwise grows beneath the surface of the ground. A mushroom consists of an umbrella-like cap and a stalk or stipe.

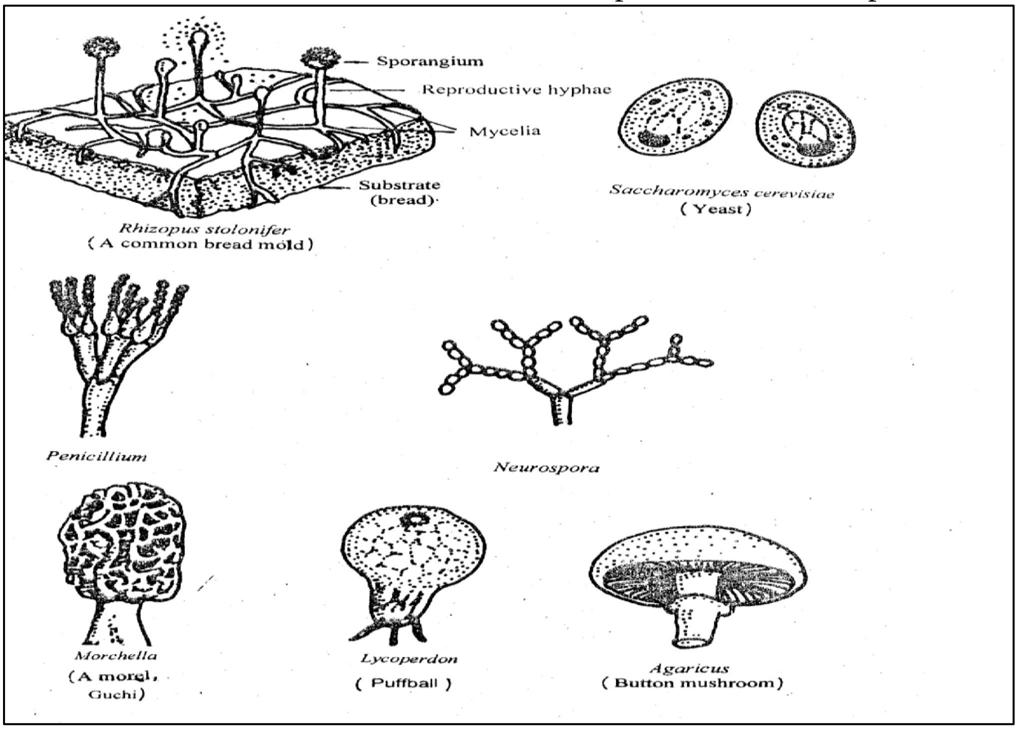


Fig. 1.1: Some common fungi (Source: IGNOU. (1991). Indira Gandhi Nationl Open University. Plant Diversity - Fungi)

The reproductive structures in fungi are formed from vegetative structures and exhibit a variety of forms on the basis of which fungi are classified. A few members of these divisions are listed below:

Unicellular Forms

a) **Yeast**

The most common unicellular fungi are yeasts. The individual cells adhere to one another forming a chain. Single Cells are hyaline but the colonies appear greenish or brownish in colour. The fine structure of a yeast cell as shown in Fig. 1.2a, is of the eukaryotic type. It has a well-defined nucleus, mitochondria, endoplasmic reticulum and other organelIes. Close to the nucleus, a large area of cytoplasm is occupied by vacuole. The cell wall of yeasts has 2-3 layers made of chitin and polysaccharides - glucan and mannans, Depending upon the stage of development variable amounts of proteins, lipids and other substances are found accumulated in the cell.

Yeasts are distributed all over the surface of earth. They are abundant on substrates that contain sugars, like the nectar of flowers and surface of fruits. They are also found in soil, animal excreta, milk and on the vegetative parts of plants

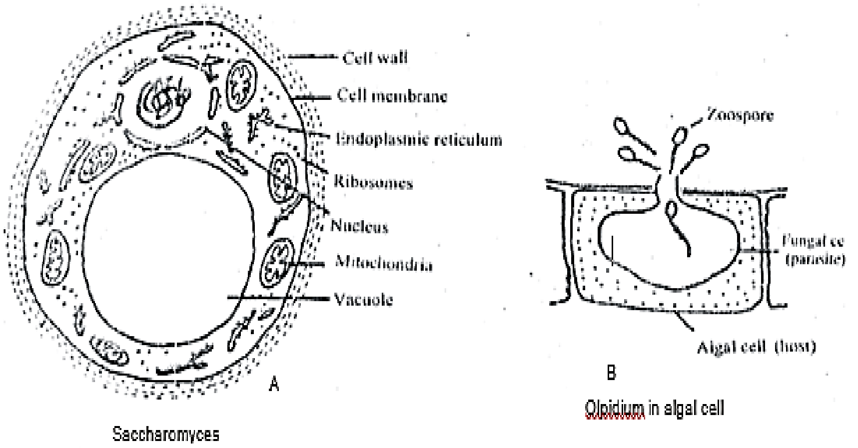


Fig.1.2 A) The fine structure of yeast *Saccharomyces* B) *Olpidium*

(Source: IGNOU. (1991). Indira Gandhi Nationl Open University. Plant Diversity - Fungi)

Yeasts are noted particularly for their ability to utilise carbohydrates, hence the name *Saccharomycetes* is applied to this group.

Another unicellular fungus is *Olpidium* (Fig. 1.2b), the simplest chytrid, which is a simple globular cell without branches. Yeast is multicellualar fungi. True/False

b) Slime Moulds

Unicellular forms are also seen in slime moulds during *a* certain stage of their life cycle (Fig.1.3). You must remember that slime moulds are not considered true fungi.

Their characteristics resemble both protozoa and fungi. That is why it has been difficult to classify them. These curious organism show unicellular (multinucleate) protozoan-like or multicellular fungus-like stages during the course of their life cycle. Slime moulds are further classified as cellular slime moulds and plasmodial slime moulds.

Cellular type

In the vegetative stage *Dictyostelium discoideum,* a cellular slime mould is small independent, uninucleate haploid cell called myxamoeba (Fig.1.3). Like amoeba, it feeds on bacterial cells by phagocytosis and multiplies by binary fission. Phagocytosis is the process in which a cell flows around particles in its surroundings and takes them into the cytoplasm. At a later stage the individual myxamoebae come together and form a single multinucleate slug but the individual myxamoebae retain their intact cell membranes (Fig. 1.3). This structure is called pseudoplasmodium.

In the reproductive stage, sporangia-bearing spores are formed like in true fungi (Fig. 1.3a to h). each spore germinates to form an amoeba like structure (Fig. 1.3f).

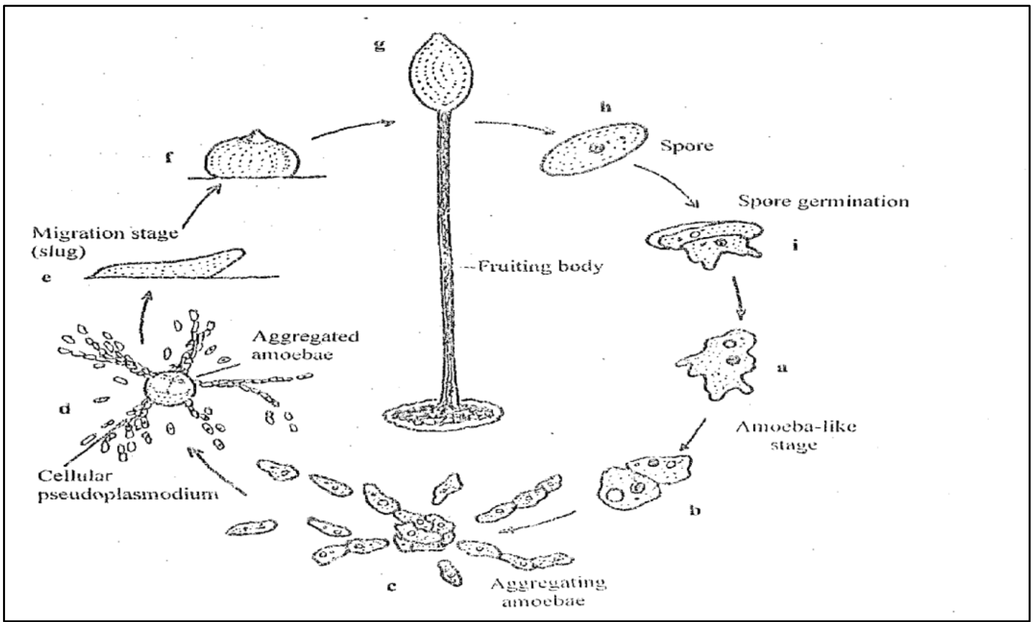


Fig. 1.3: Life Cycle of a cellular slime mould, *Dictyostelium discoideum*

(Source: IGNOU. (1991). Indira Gandhi Nationl Open University. Plant Diversity - Fungi)

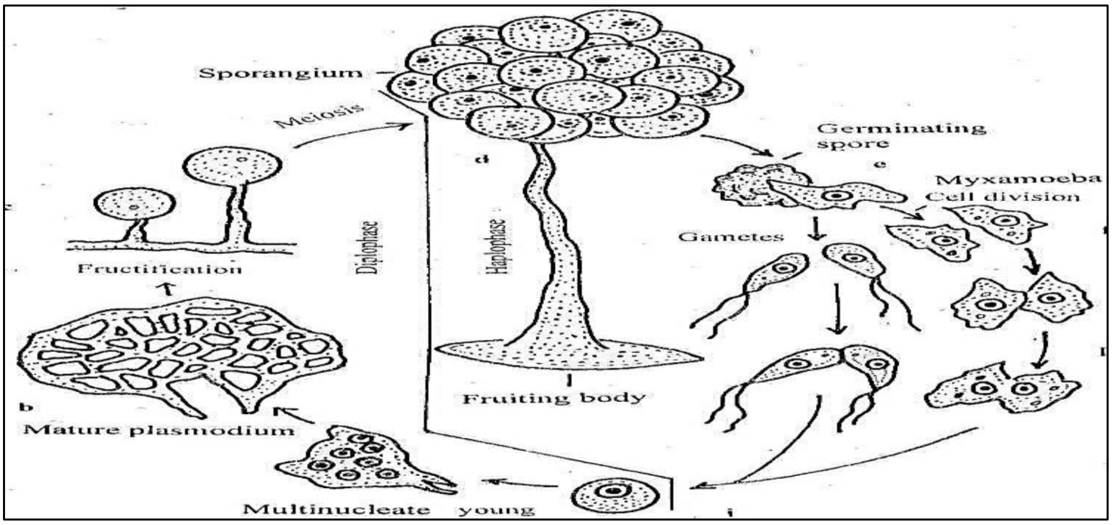
The cellular Slime mould exhibits Phagocytosis. True/False

Plasmodial Type

In plasmodial slime moulds, for example *Echinosteliurn minutum*, in the vegetative stage, a large mass of multinucleate amoeboid cytoplasm with characteristic diploid nuclei is formed (Fig. 1.4). But unlike cellular slime moulds, the individual cells are not delimited by cell membrane. The cell wall is absent. It feeds on encysted myxamoebae and bacteria and may spread over a large area. The plasmodium does not have a definite size or shape. It may be globose, flat and sheet-like spreading over a large area in the form of a very thin network (Fig. 1.4b). When the plasmodium creeps over the surface of the substratum, it changes its shape accordingly and engulfs particles of food on its way. Finally, it matures and changes into the fructification typical of the species (Fig. 1.4c and d). The entire plasmodium takes part in the formation of

fructifications, which bears spores resulting from meiosis. The spores germinate to produce flagellated cells which develop into plasmodium (myxamoeba Fig.
1.4e to i).

Plasmodial slime moulds are often brilliantly coloured ranging from colourless to shiny grey, black, violet, blue, green, yellow, orange and red. The yellow and the white plasmodia are probably the most commonly encountered. Colour changes have been observed to occur within a plasmodium under laboratory conditions. Most plasmodial slime moulds live in cool, shady, moist places in the woods, on decaying logs. Dead leaves or other organic matter which holds abundant moisture.



Zygote
(Karyogamy)
Fig.1.4: Life cycle of a plasmodial slime mould, *Echimostelium minutum.*
(Source: IGNOU. (1991). Indira Gandhi Nationl Open University. Plant Diversity - Fungi)

There are two types of slime moulds --------- and ----------------

Filamentous Forms

Most fungi are filamentous. You may have noticed on a piece of stale bread a web of very fine and delicate threads. These are formed when a fungal spore lands on the bread and germinates into a small tube-like outgrowth, which further grows as transparent, tubular filaments in all directions. Each of these filaments is called hypha, the basic unit of fungal body. The mass of interwoven hyphae constituting the body of a fungus is called mycelium (Fig.1.5) It may consist of highly dispersed hyphae, ora cottony mass of hyphae. The aerial hyphae that bear reproductive structures are called

reproductive hyphae. The fungal mycelium has an enormous surface to volume ratio and is close to the food source. This large surface-to-volume ratio is an adaptation for absorptive mode of nutrition.

The mycelium of fungi is covered with a cell wall made of chitin, a polysaccharide also found in the exoskeleton of insects and crustaceans. However, in some fungi the cell wall contains cellulose and lignin- like substances. The protoplasm of mycelium may be continuous throughout the mycelium so there will be several nuclei scattered throughout the cytoplasm. This condition is termed as coenocytic (Fig. 1.5b), Suchnon- septate hyphae are observed in the members of the Division Zygomycetes e. g. *Mucor* and *Rhizopus*.. The septa or cross walls in the non-septate mycelia are formed only to cut off reproductive structures or to seal off a damaged portion. Such septa are solid plates without any pores.
The members of other classes of fungi like ‘Ascomycetes and Basidiomycetes e.g. Asp*ergillus* and *Penicillium* develop internal cross walls i.e., septa, which divide the hyphae into segments. The septa appear at regular intervals. The segments may be uninucleate or multinucleate.

The septa, in these cases have perforations through which cytoplasmic strands including nuclei can migrate from one cell to the other (Fig. 1.5a). The presence of septa gives mechanical support to the hyphae. The reproductive structures are also separated from vegetative structures h septa but these are not perforated.

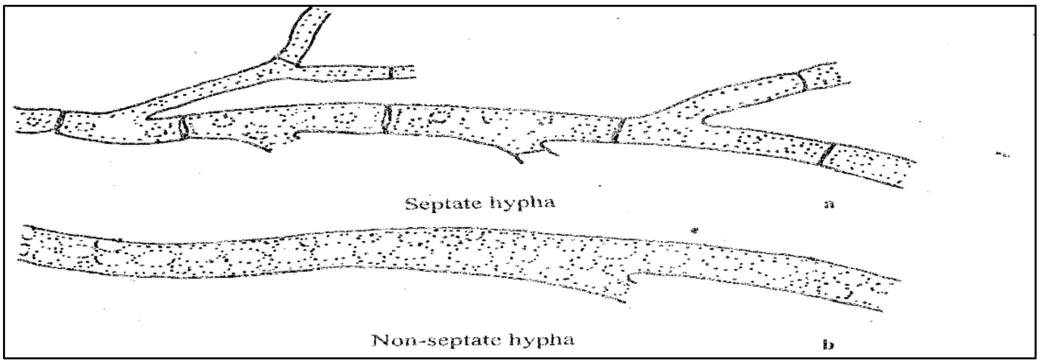


Fig. 1.5: Typical septate and non-septate hyphae of fungi.
(Source: IGNOU. (1991). Indira Gandhi Nationl Open University. Plant Diversity - Fungi)

In some groups of fungi the mycelium formed on germination of spores consists of uninucleate segments (monokaryotic) initially. This is called primary mycelium. Later when fusion occurs either between hyphal segments of the same mycelium or different mycelium, the segments contain two nuclei (dikaryotic). This conversion is called dikaryotisation and the mycelium is called secondary mycelium. This stage may last for a long period. When this mycelium gets organised into a specialized structure, it is termed tertiary mycelium.
Fungi resemble the insects and crustaceans due to the presence of-----------

Self-Assessment Exercise 1

When is a condition termed Coenocytic?

Pseudoparenchymatous Forms

The fungus mycelium normally, as mentioned above, is a mass of loosely interwoven hyphae which form a network. In some fungi the entire mycelium or its parts undergo various modifications. The walls of the hyphae in the mass get fused and they lose their individuality. As a result the hyphal mass, in cross section appears to be a continuous structure. It resembles the parenchymatous tissue of higher plants, but it is not a true parenchyna as found in higher plants. In fungi such a tissue is called plectenchyma.

There are two types of Plectenchyma. The plectenchyma with rounded fungal cells is called pseudoparenchyma and with less compacted elongated cells is called prosenchyma.

Often, the hyphae in many fungi aggregate and get organised into various structures that may be vegetative or reproductive in nature. Some examples of such structures are stroma, sclerotium and rhizomorph (Fig. 1.6).

Stroma is an indefinte body formed in Dal*dinia.* It commonly develops reproductive structures
Sclerotia are tough and resting bodies. These are formed in *Claviceps sp.* *T*he interior cells in the sclerotium are hyaline and stored with food and the outer cells are thick walled, black and crust-like. In some fungi, hyphae lose individuality and form thick, dark brown, hard strands. These are called rhizomorphs because they appear like roots.
In parasitic fungi the hyphae may enter the cell wall of the host and form haustoria for obtaining nourishment.

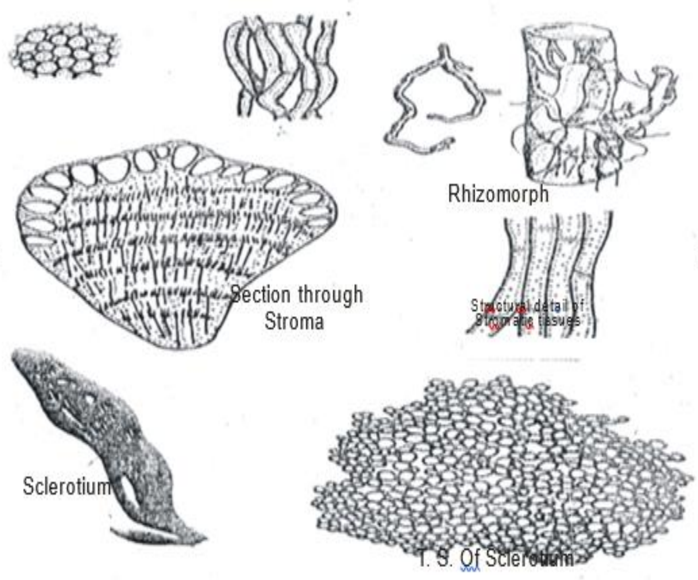


Fig. 1.6: Formation of various structures in fungi by aggregation of hyphae.

(Source: IGNOU. (1991). Indira Gandhi National Open University. Plant Diversity - Fungi)

Self-Assessment Exercise 2

Indicate which of the following statements are true or false. Write T for true or F for false;
Fungi are
achlorophyllous
organisms.
Haustoria is used by parasitic fungi to get nourishment.
iii) The cell wall of fungi is made of chitin.
iv) Fungi can utilise organic substances.
v) Yeast cell is
prokaryotic
type.
vi) Most genera in fungi are multicellular and
some are unicellular.
vii) In slime moulds the cell wall is absent.

1.4 Summary

In this unit you have learnt that:

i. Fungi show a range of morphological forms. Unicellular fungi like yeast are rare. Slime moulds are either unicellular or plasmodium like at a certain stage of the life cycle.
ii. Most fungi are multicellular, branched filaments. The mycelium is the main part of the fungal body. The reproductive structures are born on the reproductive hyphae.
iii Various kinds of structures arise when the entire mycelium or its part aggregate and give rise to special structures such as stroma, sclerotia, rhizomorphs arid others.

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https://app.box.com/s/r8up2bvx84i7lyx...

1.6 Possible Answers to Self-Assessment Exercise

Answer to SAEs 1

In some fungi the cell wall contains cellulose and lignin- like substances. The protoplasm of mycelium may be continuous throughout the mycelium so there will be several nuclei scattered throughout the cytoplasm. This condition is termed as Coenocytic

Answer to SAEs 2

i.True ii.True iii. True
iv.True v.False vi.True vii. True

UNIT 2 LIFE CYCLES OF FUNGI

Unit Structure

2.1 Introduction

In the last unit you learnt about the morphology of fungi. In this unit we shall discuss in detail reproduction and alternation of generations in fungi as shown by *Phytophthora* and *Rhizopus*.

2.2 Intended Learning Outcomes

By the end of this unit, students should be able to:

i. describe the process of reproduction in *Phytopthora* and *Rhizopus*
ii. illustrate the life cycles of *Phytopthora* and *Rhizopus showing* alternation of generations

2.3 Main Contents

2.3.1 Types of Life Cycles and Alternation of Generation

Phytophthora

This fungus, *Phytophthora* belongs to the Division Oomycota. There are about 75 species in this genus, most of which live as parasites on flowering plants. The species

Phytophthora infestans is of great economic importance. It causes a serious disease of potato called potato blight or late blight of potato.

Morphology of *Phytophthora*

The mycelium of *Phytophthora* is profusely branched and consists of aseptate, hyaline and coenocytic hyphae. The hyphae ramify in the intercellular spaces of the host tissues. The haustoria produced by the mycelium penetrates the hosts cell wall and enters the cells to draw nourishment (Fig. 2.1a). The haustoria may be simple or branched.
The fungus, *Phytophthora* belongs to the Division---------------

Reproduction
Phytophthora reproduces both asexually and sexually.
Asexua1 Reproduction

In warm and humid weather *Phytophthora* normally reproduces asexually. During this stage a tuft of slender, branched hyphae usually arise from the internal mycelium. They come out through the stomata or pierce through the epidermal cell on the lower surface of the leaf (Fig. 2.1b). In tubers they come out through the injured portions of the skin. These aerial hyphae are hyaline and branched. They bear a sporangium at their tip. You have learnt earlier that the hyphae-bearing sporangia or conidia are called sporangiophores or conidiophores respectively. The sporangia are thin-walled, hyaline and lemon- shaped and have a beak-like projection or papilla at their tips.

The mature sporangia can easily be separated from the sporangiophore. The sporangiophore is branched. It bears nodular swellings which denote the point of detachment of sporangia. Wind, rain drops or contact with neighbouring leaves detach and scatter the ripe sporangia on neighbouring potato plants. They may fall on the ground and get spread into the soil. The sporangia lose their viability if they fail to germinate within a few hours.
When the sporangia fall on the leaf of a host plant, they germinate. Moisture and temperature are the determinants for germination. In the presence of water and low temperatures (upto 12°C) the sporangiun behaves as a zoosporangium. The protoplast divides into 5-8 uninucleated daughter protoplasts which transform into zoospores.

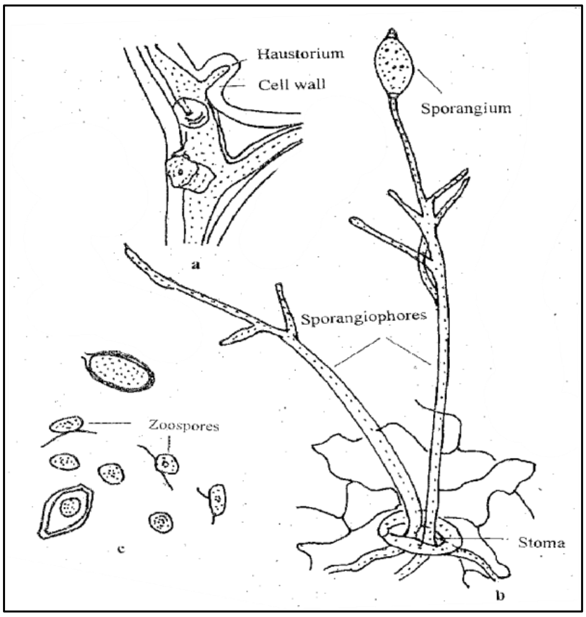

Fig. 2.1: *Phytophthora infestans;* a) Intercellular mycelium forming hapstoria, b) Soranglophores coming out of stoma bearing sporangia c) flagellared zoospores(Source: IGNOU. (2002). Indira Gandhi National Open University. Plant Diversity - Fungi)

The zoospores are uniform and biflagellate (Fig. 2.1c) of the two flagella one is of the whiplash type and the other is of the tinsel type. The zoospores are set free through the apical papilla into a vesicle in some species. The vesicle soon bursts open to liberate the zoospores. The liberated zoospores swim for some time, and later settle on a substratum losing the flagella and germinate. During germination, the zoospore puts out a short hypha called appressorium. The appressoria help to fix the fungus on the surface of the host leaf. From the appresorium, a narrow, peg- like infection hypha develops which forces its way into the host leaf.

At temperatures of up to 24°C, and low relative humidity the sporangium germinates directly behaving like a conidium. It germinates producing a germ tube or a short hypha, which enters into the host leaf.
The sporangia, which are washed into the soil, germinate and infect the tubers. As a result the tubers rot by harvest time or during storage. Under favourable conditions a number of asexual generations may be produced in one growing season. This results in rapid propagation of the fungus to spread the disease. During warm and humid weather, Phytophtora normally reproduces asexually. True/False

Self-Assessment Exercise 1

The mycelium of *Phytophthora* is profusely branched and consists of ---------, -------------- and hyphae.

Sexual Reproduction

Sexual reproduction is of the oogamous type. The male sex organs are antheridia and the female oogonia. They arise at the tips of short lateral branches as antheridial and oogonial initials respectively (Fig. 2.2a). *Phytophthora infestans* is heterothallic.

The antheridium is a club-shaped structure with one or two nuclei to begin with. Later the nuclei divide and produce about 12 nuclei (Fig.2.2b). At the time of the fertilization only one functional nucleus persists and the others degenerate. The oogonium develops on a neighbouring hypha of the antheridial branch. It grows across the antheridium and swells to form a pear-shaped or spherical structure (Fig.2.2 c), which contains dense cytoplasm and many nuclei (about 40).The protoplast of the oogonium becomes differentiated into an outer multinucleate periplasm and a central uninucleate ooplasm. The central nucleus divides into two and one of them disappears. The surviving nucleus functions as the egg nucleus. The nuclei of the periplasm later degenerate.

The oogonial wall bulges out at a certain point to make a receptive spot. The oogonial wall disintegrates at this spot. Through this opening the antheridium pushes a short fertiIization tube (Fig 2.2e). The fertilization tube penetrates the periplasm and reaches the ooplasm. Here it opens and delivers the male nucleus along with the surrounding cytoplasm. The male and female nuclei fuse, thus bringing about fertilization (Fig. 2.2f)

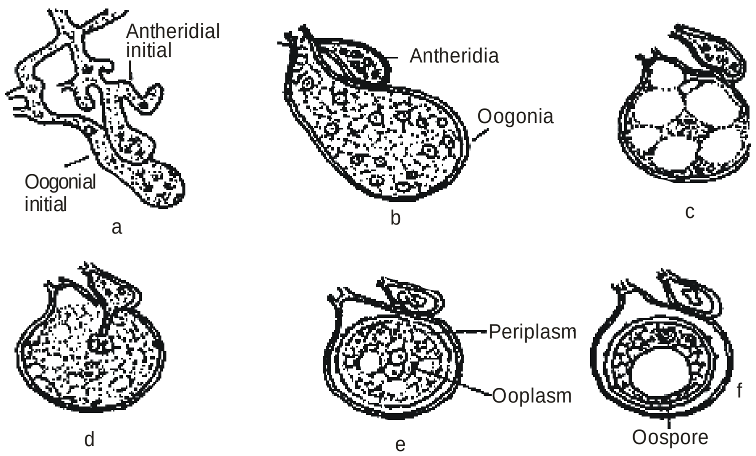

Fig. 2.2: Stages of sexual reproduction in *Phytophthora infestans.* (Source: IGNOU. (2002). Indira Gandhi Nationl Open University. Plant Diversity - Fungi)

The fertilized egg secretes a thick wall around itself and becomes the oospore. When the conditions are favourable the oospore germinates. It is believed that meiosis takes place during germination. The germination of oospore takes place after the decay of the host tissue. A germ tube develops from the oospore and may directly develop into a mycelium or oospore may bear a terminal sporangium. Inside the sporangium zoospores are produced which after liberation develop into new mycelia.

ln the life cycle of *Phytophthora* there is an asexual cycle which may repeat during favourable conditions. The sexual cycle takes place prior to the onset of unfavourable conditions forming a resting spore. These cycles normally alternate with each other.

Sexual reproduction in Phythophtora of the ------------ type

Rhizopus

Rhizopus is a saprophytic fungus in the Division Zygomycota. It is commonly called bread mould since it is frequently found growing on stale bread.. It also grows on decaying fruits, vegetables and other food materials. *Rhizopus stolonifer* sometimes grows as a facultative parasite

on strawberries causing a transit disease called ‘leak’ and also causes ‘soft rot’ disease of sweet potatoes, yam and cassava tubers.

The mycelium of rhizopus spp is a white cotton-like fluffy mass with numerous, slender, branched hyphae. The mycelium has three types of hyphae: i) rhizoidal ii) stolons and iii) sporangiophores (Fig, 2.3).
The rhizoidal hyphae are a cluster of brown, slender and branched rooting hyphae which arise from the lower surface of the stolon at certain points which are the apparent nodal points. These hyphae help in anchorage, and in the absorption of water and nourishment from the substratum.

The stolons are aerial hyphae which grow horizontally over the surface of the substratum. These hyphae are comparatively large, and slightly arched. The stolons grow rapidly in all directions, completely filling the surface of the substratum.
The sporangiophores develop during the reproductive phase. The sporangiophores arise from the apparent nodal regions, opposite to

the rhizoidal hyphae in a cluster. They grow vertically bearing sporangia at their tips.

Rhizopus is a saprophytic fungus. It is commonly called bread ------------

Reproduction

Reproduction in rhizopus is by asexual and sexual methods.

Asexual Reproduction

Rhizopus reproduces asexually by multinucleate, non-motile spores which are produced in small, round, blacksporangia. The sporangia are borne terminally, and singly on unbranched sporangiophores (Fig 2.3b). A mature sporangium is differentiated into two regions, a central less dense, vacuolated region with fewer' nuclei called columella and a peripheral dense region with many nuclei called sporoferous region. The protoplast in the columella is continuous with that of the sporangiophore.

The sporeoferous region undergoes cleavage to form a number of muItinucleate segment. These segments round off and secrete walls around them to become sporangiospores. These are

unicellular, multinucleate, non-motile aplanospores, which are usually globose or oval in shape (Fig. 2.3c). As the spores mature the sporangium bursts open liberating the spore mass (Fig. 2.3d and e). A part of the wall remains as a collar-like fringe at the base of the sporangium.

The spores are dispersed away by the wind. Falling on a suitable substratum, under suitable conditions a spore germinates producing a short germ tube
which grows further and branches profusely to produce three types of hypae.

Sporangiosphores

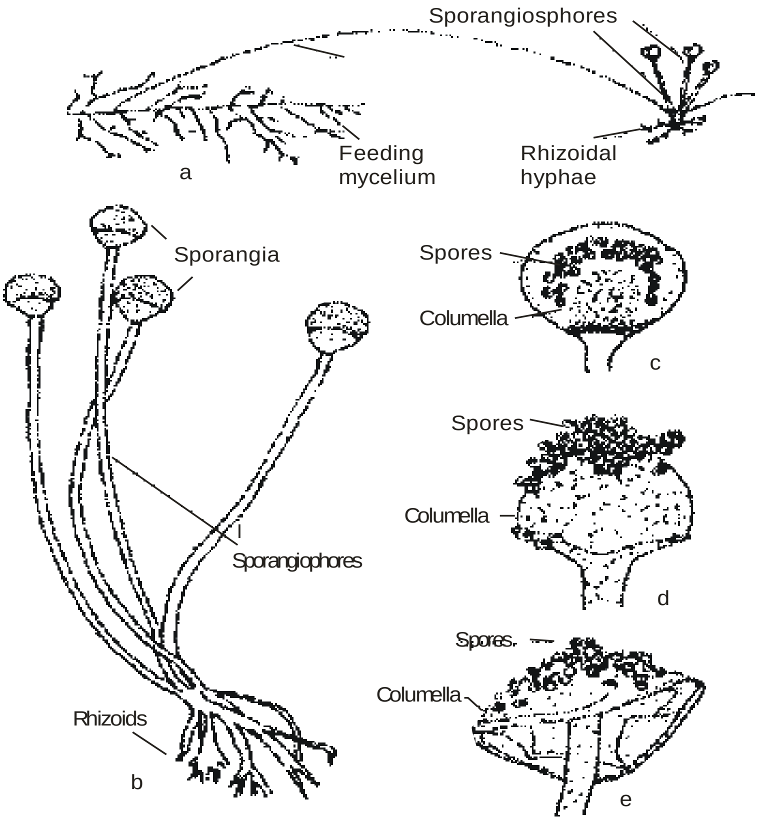

Fig.2.3: *Rhizopus stolonifer* a) three kinds of hyhae of the mycelium, b) sporangiophores developing at the point of rhizoidal hyphae, c) structure of the sporangium in detail, d) invaginated columella, e) dehiscence of the spores. (Source: IGNOU. (2002). Indira Gandhi Nationl Open University. Plant Diversity - Fungi)

Under unfavourable conditions *Rhizopus* produces chlamydiospores. As you learnt they are thick-walled spores with accumulated reserve food. They are produced intercalarily. They help the fungus to survive over unfavourable conditions during which time the mycelium perishes. With the return of favourable conditions they germinate and produce normal mycelia.

The sporangia are borne basally. True/False.

Sexual Reproduction

Towards the end of the growing season *Rhizopus* reproduces sexually. Sexual reproduction is of the conjugation type. Here the two gametangia fuse. You learnt earlier that such a union of protoplasts is called gametangial copulation. Some species of *Rhizopus* are homothallic while others are h eterothallic. In heterothallic species the mycelia belong to two mating types or strains one plus and the other minus.

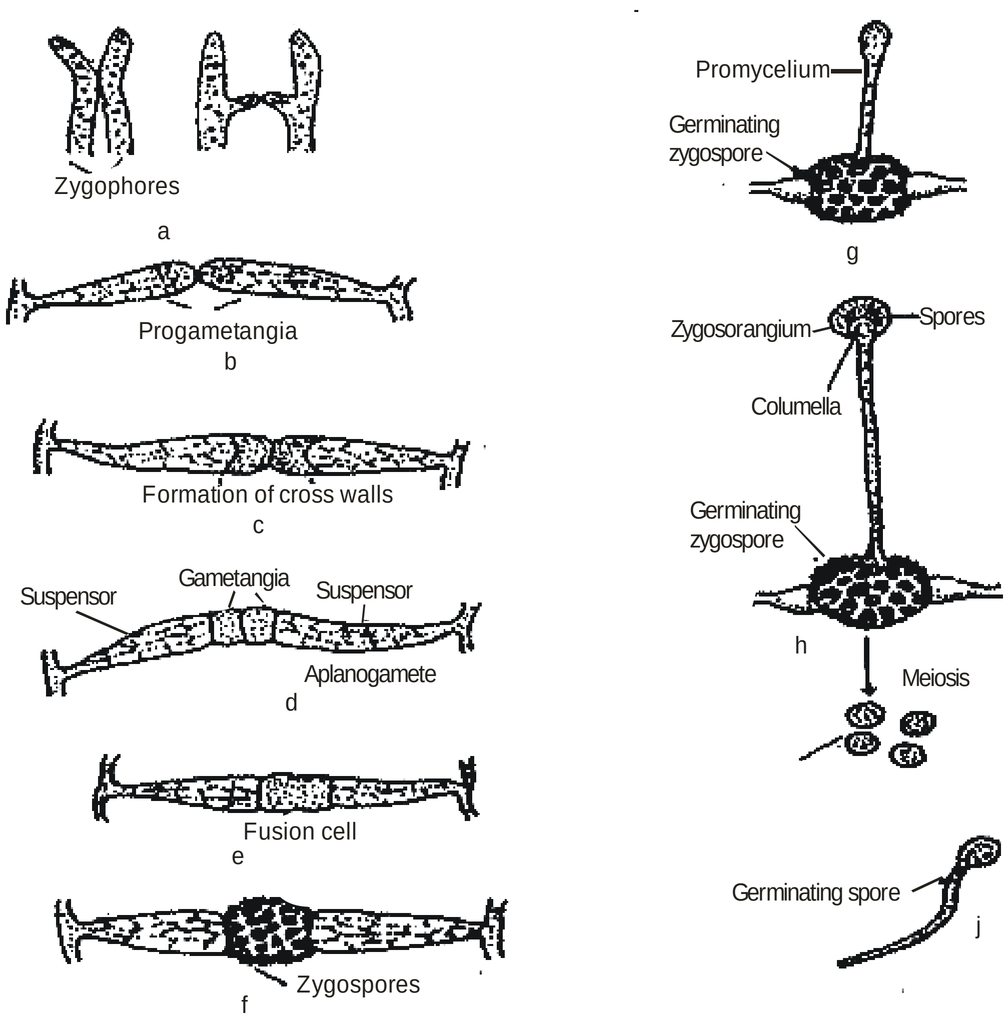

Fig. 2.4: Stages of sexual reproduction in *Rhizopus stolonifera* (Source: IGNOU. (2002). Indira Gandhi Nationl Open University. Plant Diversity - Fungi)

During sexual reproduction the hyphae of the two mating types (+ and—) called zygophores are attracted towards each other (Fig.2.4a). They produce copulating branches called progametangia which meet at their tips (Fig. 2.4b). The tips of the progametangia enlarge due to accumulation of cytoplasm and nuclei, and are cut off from the basal portion by cross walls (fig 2.4c). The terminal portion is call suspensor. The entire gametangium transforms into an aplanogamete (Fig. 2.4d). The two gametangia may be of the same size or one of them slightly smaller than the other.

When the gametangia mature the intervening, waIls dissolve and the two gametes and their nuclei fuse producing a zygospore (fig. 2.4e and f). The zygospore increases in size and secretes a thick two layered wall around it. The outer layer is dark and warty. It is called exine or exospore. The inner layer is thick and is called intine or endospore. As the zygospore increases in size, the wall of the fusion cell containing the zygospore ruptures and it is set free.

Prior to germination of the zygospore, the diploid nuclei divide meiotically producing numerous haploid nuclei. During meiosis segregation of strains takes place. The zygospore during germination absorbs water and swells. As a result the outer wall extine breaks open. The inner wall intine with the inner contents grows out as a germ tube or promycelium (Fig 2.4g). The promycelium is of limited growth and produces a terminal sporangium. It is called zygosporangium or germ sporangium (Fig 2.4h). Inside the sporangium numerous, non-motile germ spores called meiospores are produced. They are liberated at maturity which develop into new mycelia (Fig 2.4i and j).

The life cycle of *Rhizopus* consists of two phases, asexual and sexual. The asexual phase consists of mycelium, sporangiophores, sporangia and the sporangiospores. This phase in the life cycle serves to propagate the haploid phase of the fungus during favourable conditions. The sexual phase, consists of mycelia of the plus and minus strains, the progametangia, gametangia, aplanogametes, zygospore, promycelium, germ sporangium and the germ spores. Among these, the zygospore is the only diploid structure. All others are haploid. Such a sexual cycle is called haplontic characterized by zygotic meiosis and haploid mycelium as the only adult fungi

Rhizopus exhibits heterothallism wherein the mycelia of a single species are morphologically similar but physiologically different. There is no apparent distinction between male and female mycelia except in their sexual behaviour. Such a distinction is designated by the terms plus and minus. This was first discovered by Blakeslee in 1904. This is the first indication of the origin of dioecious condition of sexual phase in an organism.
Sexual reproduction in rhizopus of the ---------- type

Self-Assessment Exercise 2

a.	List the types of sexual reproduction in fungi.
b.	What are Sclerotia?

2.4 Summary

In this unit you have learnt that;

i. Asexual reproduction takes place by the formation of sporangia. Depending upon the temperature and humidity the sporangia may produce zoospores or germinate directly. Sexual reproduction is of oogamous type.
ii. In *Rhizopus* the mycelium produces rhizoidal hyphae, stolons and the hyphae- bearing sporangiophores. The sporangiophores bear non-motile aplanospores, the asexual reproductive bodies.
iii Sexual reproduction occurs by the fusion of gametangia of opposite strains forming zygosporangia which bear numerous non-motile zygospores.

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2.6 Possible Answers to Self-Assessment Exercises

Answers to SAEs 1
aseptate, hyaline and coenocytic

Answers to SAEs 2
a. oogamous, conjugation(gametangial)
b. tough resting bodies.

UNIT 3 REPRODUCTION IN FUNGI

Unit Structure

3.1 Introduction

In the previous unit you learnt about life cycles in fungi. In this unit we will discuss the process of reproduction in fungi. Like algae, reproduction in fungi occurs by vegetative, asexual and sexual methods. In the following account we will describe the various types of reproduction in fungi with suitable examples.

3.2 Intended Learning outcomes

By the end of this unit, students should be able to:

i. describe the types of reproduction in fungi.
ii. distinguish between vegetative and asexual methods of reproduction,
iii. describe plasmogamy in details.
iv. describe the phases of sexual reproduction in fungi.

3.3 Main Contents

3.3.1 Types of Reproduction

When the mycelium of a fungus reaches a certain stage of maturity and accumulates reserve food, it starts reproducing. As in algae, reproduction in fungi is of three kinds:
i) vegetative,
ii) asexual and iii) sexual

Vegetative Reproduction this is a type of reproduction, that involves new plants arising from a part of the mother plant that is used for vegetative purposes not the sexual structures. Common methods of vegetative reproduction in the fungi includes fragmentation in filamentous fungi, budding and fission in yeasts. The sclerotia,chlamydiospores and rhizomorphs are also used to reproduce vegetatively and survive adverse conditions.

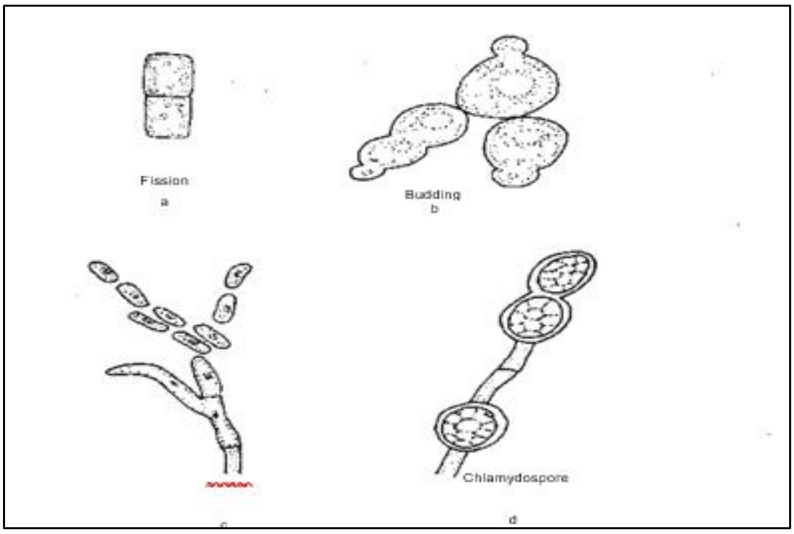


Fig. 3.1 Vegetative reproduction in Fungi **(Source:** IGNOU (1991) Indira Gandhi National Open University. Plant Diversity)

A type of reproduction that involves new plants arising from a part of the mother plant used for vegetative purposes is called ------------

Asexual Reproduction

In fungi, asexual reproduction is a more common method than sexual reproduction. It is usually repeated several times in a season. It takes place by the formation of special reproductive cells called spores. The formation of spores in fungi is called sporulation. Each spore develops into a new mycelium. These spores are produced as a result of mitosis in the parent cell and hence

they are also called mitospores. The spores vary in colour, shape and size, number, arrangement on hyphae and in the way in which they are borne. They may be hyaline, green, yellow, orange, red, brown to black in colour and are minute to large in size. In shape they vary from globose to oval, oblong, needle-shaped to helical. Thus an infinite variety of spores can be observed in fungi (Fig.3.2) and you will find them very fascinating under the microscope.

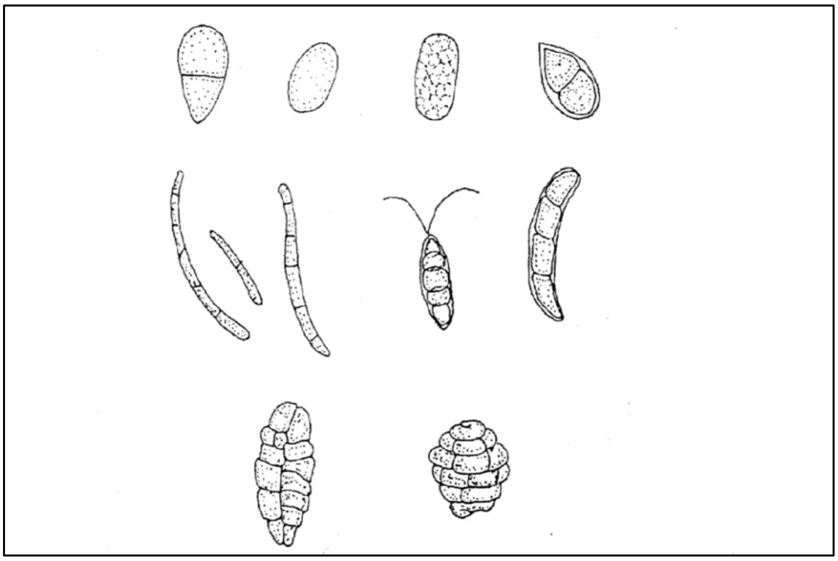


Fig. 3.2 Variety of spores in fungi (Source: IGNOU (1991) Indira Gandhi National Open University. Plant Diversity)

Usually the spores are unicellular,and they may be uninucleate or multinucleate. In some fungi like *Alternaria* and *Curvularia* they are multicellular. The mitospores produced in fungi are of two types, sporangiospores and conidia.

The sporangiospores are produced inside a sac-like structure called **sporangium.** The hypha bearing a sporangium is called **sporangiophore** (Fig.3.3a). They are characteristically branched. The sporangiospores may be motile or non-motile. The non-motile sporangiospores are called **aplanospores-** from Greek a, not + planets wanderer + spores seed, spore **(**Fig. 3.3a). These are characteristic of terrestrial species like *Mucor* and *Rhizopus.* In aquatic fungi like *Pythium* of' the Division Oomycota, motile biflagellate sporangiospores are produced, called **zoospores** and the sporangium bearing them is called **zoosporangium** (Fig.3.3b and c). A zoospore is a motile spore lacking a cell wall. After a swarming period it secretes a wall and germinates to form a germ tube. In contrast to zoospores, the aplanospores have a definite spore wall and are dispersed by wind and insects.

The conidia are non-motile, deciduous mitospores formed externally as single separate cells. They develop either directly on the mycelium or on morphologically differentiated hyphae called **conidiophores** (Fig.3.3d). The conidiophores may be simple or branched, septate or aseptate. The conidia are produced singly e.g., *Phytophthora* or in chains at the tips of the conidiophores e.g. *Aspergillus* (Fig.3.3d) or at the tips of their branches as found in *Penicillium* (Fig.3.3e).

Often the conidiophores arise singly and are scattered in the mycelium. Sometimes they arise in specialised structures called fruiting bodies. According to their appearance they are termed as synnema, sporodochia, acervuli (saucer-shaped), pycnidia (flask-shaped, globular) or pustules. These are shown in Fig.3.4

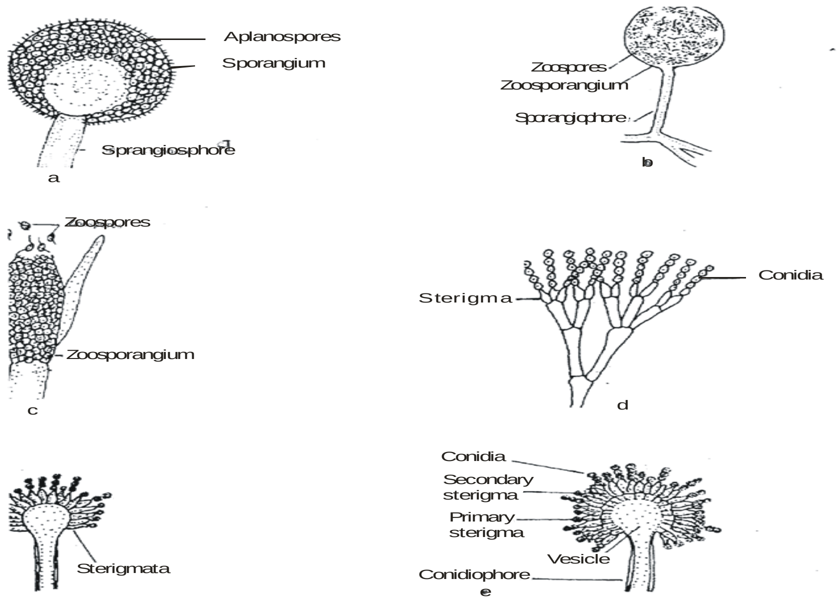


Fig.3.3: Formation of sporangiospores and conidia in fungi: sporangia containing (a) aplanospores, (b) and (c) zoospores (d) conidiophores showing conidia on branches and (e) conidophores bearing conidial chains on branches **(Source:** IGNOU (1991) Indira Gandhi National Open University. Plant Diversity)

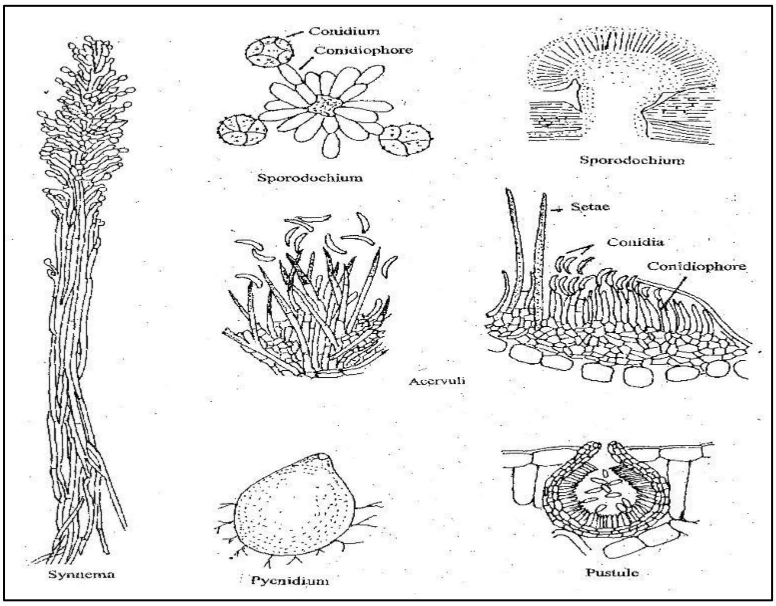


Fig. 3.4: Various types of fruiting bodies in fungi. (Source: IGNOU (1991) Indira Gandhi National Open University. Plant Diversity)

A type of reproduction that involves the formation of spore is referred to as --------------

Self-Assessment Exercise 1

Define sporulation in fungi

Sexual Reproduction

The sexual stage in fungi is called the perfect state in contrast to the **imperfect state** which is the asexual stage. Sexual reproduction involves the fusion of two compatible sex cells or gametes of opposite strains. Fungal sex organs are called gametangia. They may be equal in size. In many higher ascomycetes morphologically different gametangia are formed. The male gametangia are called antheridia and the female gametangia is called ascogonia.

The fungus may be homothallic, that is, the fusing gametes come from the same mycelium or may be heterothallic, that is, the fusing gametes come from different strains of mycelia.

In fungi, sexuaI reproduction is in three phases: plasmogamy, karyogamy and meiosis (Fig.3.5). These three processes occur in a regular sequence and at a specific time, during the sexual stage of each species.

i. Plasmogamy: Is the union of protoplasts of reproductive hyphae or cells, one from the male and the other from the female to bring about the nuclei of the two parents close together as a pair. However, the two nuclei do not fuse with each other. Such a cell is called a **dikaryon.** The dikaryotic condition is unique to fungi and may continue for several generations as the two nuclei (dikaryons) divide simultaneously during cell division. These are passed on to the daughter hyphae.

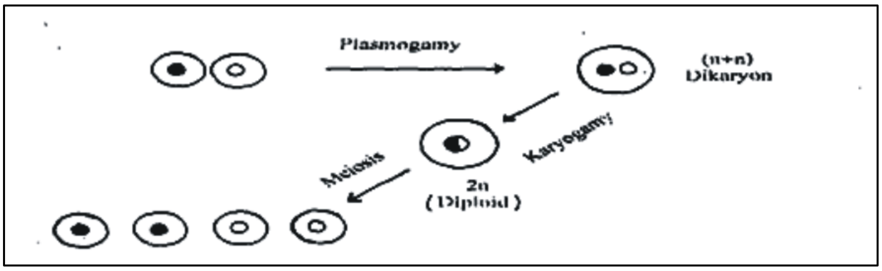
ii. Karyogamy: The fusion of the two nuclei which takes place in the next phase is called karyogamy. It may immediately follow plasmogamy as in lower fungi, or it may be delayed for a long time as in higher fungi.

iii. Meiosis: Karyogamy which eventually occurs in all sexually reproducing fungi is sooner or later followed by meiosis producing four genetically different spores.

We will now discuss plasmogamy in detail.

Plasmogamy occurs in different ways in fungi.

Haploids



Haploid spores

Fig.3.5: Three phases of sexual cycle in fungi

i) Planogametic copulation: It involves fusion of two gametes. Like in algae sexual union in fungi may be **isogamous, anisogamous or oogamous** (Fig.3.6a). Anisogamy and oogamy are together called **heterogamous sexual** reproduction. Isogamy is the simplest type of sexual reproduction, where the fusing gametes are morphologically similar e.g. *Olpidium* **and** *Catenaria.* Anisogamy, where the fusing gametes are dissimilar is found in one genus, *Allomyces*, a chitrid. In oogamy as you may recall the motile antherozoid enters oogonium and unites with egg or oosphere forming a zygote. Oogamy is seen in fungi like *Pythium* and *Albugo.*

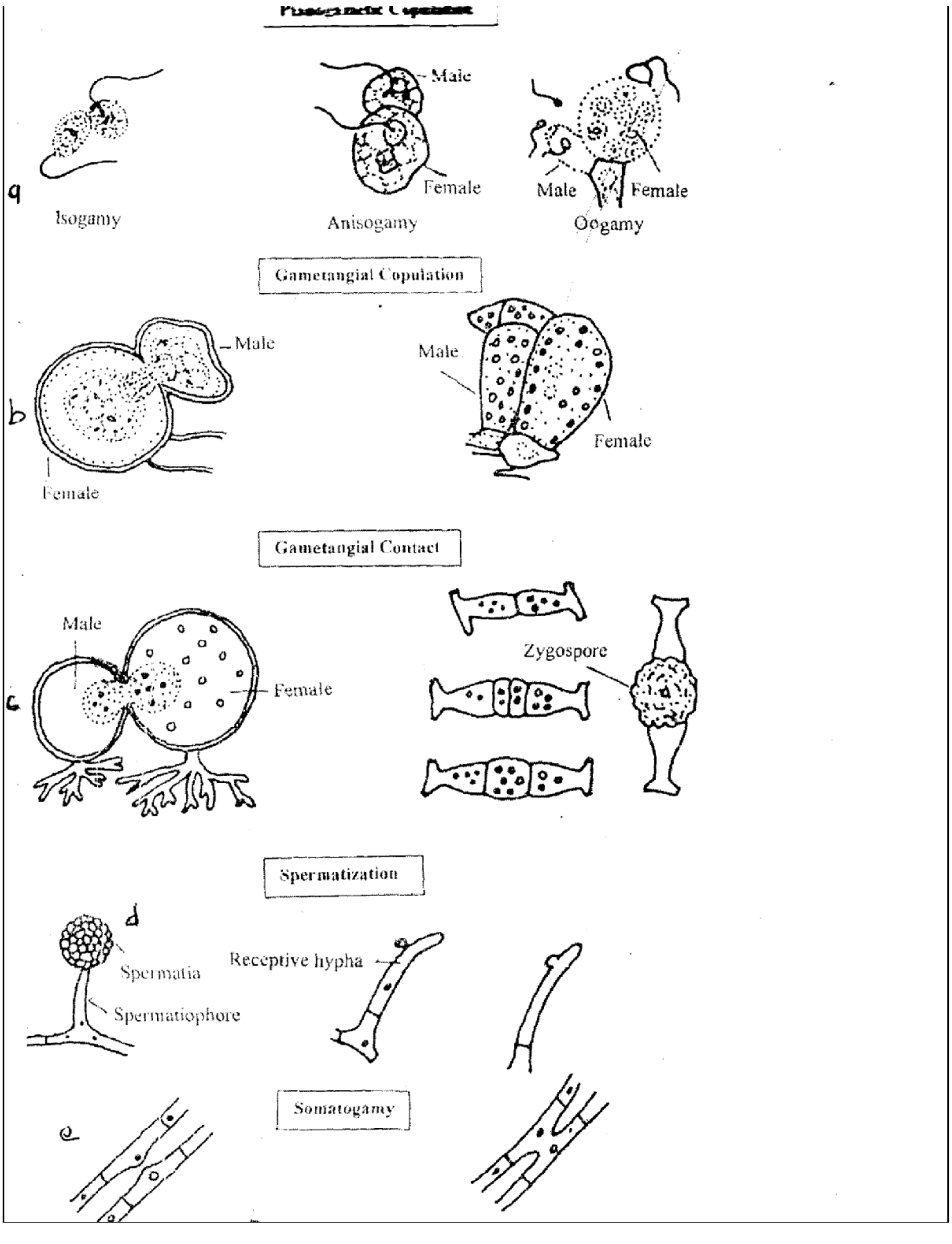


Fig. 3.6: Different ways of plasmogamy in fungi (Source: IGNOU. (1991). Indira Gandhi National Open University . Plant Diversity .)

ii) Gametangial copulation : The two gametangia make contact and the entire contents of the two fuse together and become one e. g., *Mucor* and *Rhizopus.* In some fungi the entire protoplast of one gametangia flows into the other through a pore (Fig. 3.6b). The recipient is the female and the donor is the male.

iii) Gametangial contact The male gamete is not a separate entity but the nucleus in the antheridium represents the gamete. As you can see in the Fig. the oogonium and antherididm form a contact through a tube and one or more nuclei inside the antheridium migrate into the oogonium. You may note that in this case the two gametangia do not fuse. It is observed in *Penicillium* (Fig.3.6c).

iv) Spermatization This mode is quite remarkable as the minute conidia like gametes called spermatia are produced externally on special hyphae called spermatiophore (Fig. 3.6d). Spermatia may develop inside the cavities called spermatogonia. The female cell may be a gametangium, a specialised receptive hypha or even a vegetative hypha.
v) Somatogamy: In higher fungi like Ascomycetes and Basidiomycetes there is a progressive degeneration of sexuality. The entire process is very much simplified by the fusion of two mycelia which belong to opposite strains (Fig. 3.6e). The post-fertlization changes result in the production of a fruiting body which is called **ascocarp** in Ascomycetes and basidiocarp in Basidiomycetes.

The gametangial fusion followed by the fusion of male and female nuclei results in diploid nuclei. Subsequently, reduction division occurs and haploid spores are formed. In fungi, the spores may be formed in specialised structures characteristic of a division. In Ascornycetes the spores called ascospores are formed within the ascus (plur. Asci, Fig.3.7). The asci reside enclosed within the fruiting body- the ascocarp. According to the characteristics, the ascocarps are distinguished as cleistothecium (indehiscent) apothecium, (cup or saucer shaped), perithecium (flask-shaped) and pseudo-perithecium.

In basidiomycetes, sexual spores are termed basidiospores which develop on club- shaped structures, called basidia.

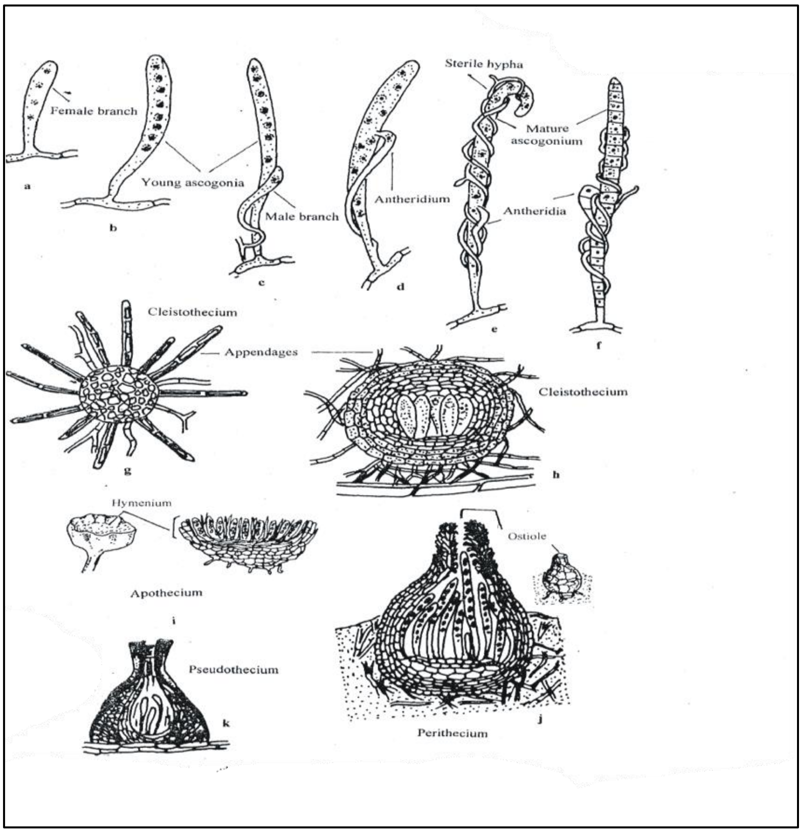


Fig. 3.7: a to f Stages of sexual reproduction in Penicillium; a to c) development of sex organs, antheridia and ascogonia, c and f) stages in plasmogamy, g and h) ascocarp-cleistothecium formed when surrounding hyphae enclose a number of asci, i) apothecium of Ascobolus sp j) perithecium, k) an immature pseudothecium of Leptosphaera. (Source: IGNOU. (1991). Indira Gandhi National Open University . Plant Diversity.)

Self-Assessment Exercise 2

a. List the main types of reproduction in fungi.

b. List the types of plasmogamy in fungi.

c. The sexual stage in fungi is known as the-----------------

3.4 Summary

In this unit you have learnt that;

i. Fungi reproduce by vegetative, asexual and sexual methods.
ii. Vegetative reproduction takes place by fission, budding, fragmentation.
iii. Asexual reproduction occurs more frequently than sexual method. The sporangiophores or conidiophores formed bear spores and conidia respectively.
iv. In sexual reproduction, depending upon the species the entire thallus or a portion of it may take part in the formation of reproductive bodies.

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3.6 Possible Answers to Self-Assessment Exercise

Answer to SAEs 1
The formation of spores in fungi is called sporulation
Answer SAEs 2
a.vegetative, asexual and sexual.
Planogametc copulation, Gametangial copulation, Gametangial contact, Spermatization, somatogamy
c.Perfect State

UNIT 4 GENERAL CHARACTERISTICS OF BRYOPHYTES

Unit Structure

4.1 Introduction
4.2 Intended Learning Outcomes
4.3 Main Contents
4.3.1 General Characteristics of Bryophytes
4.4 Summary
4.5 References/Further Readings/Web Sources
4.6 Answers to Self-Assessment Exercises

4.1 Introduction

In the previous units, you have studied about algae and fungi in general. In this unit, you will learn about the Bryophytes.

Bryophytes are considered to be the first land plants among embryophytes. Exactly how this happened is not clear because the fossil records are not complete. When there was a shift from aquatic mode of life to land habit the species had to face many challenges. How could water and minerals be taken from the soil and transported to parts that are not in contact with soil? How could the soft bodies keep from drying out? To overcome these challenges there was a need to develop certain structural modifications evolved. The land plants belonging to various groups have continued to exist approximately from the Devonian period. This demonstrates that they are well adapted to their particular niche on land. It is the nature of these adaptations that is of interest to us in this unit.

In this unit we will deal with the characteristic features of each group and describe a few genera belonging to these groups. You will study how these genera differ from each other from that of flowering plants

4.2 Intended Learning Outcomes

At the end of this unit, students should be able to:

1. describe the general characteristics of bryophytes,
2. give reasons why algae are considered to be ancestors of the first land plants,

3. classify the bryophytes

4.3 Main Contents

4.3.1 General Characteristics of Bryophytes

The Division Bryophyta includes the simplest and the most primitive members of land plants that lack roots, and do not have a vascular system. There are some mosses that have a primitive system of tubes that conduct-water and food. The water-conducting tubes are called hydroids. They have elongated, thick, dead cells that are not lignified like tracheids and vessels. The food- conducting tubes are called leptoids, and they are connected through plasmodesmata.

A single plant is very small, hardly a few cm in size. It seldom grows large because of lack of supporting tissues. Thousands of tiny moss plants often grow together, giving a thick, green carpet-like appearance. The morphology of some common bryophytes is given in (Fig.4.1). Have a good look at them. Can you recall seeing any in their natural habitats?

Bryophytes show two distinct and well defined phases of life cycle, sexual and asexual, which follows each other. The gametophyte is haploid and produces gametes. The sporophyte is diploid and produces spores. The haploid generation alternates with diploid generation (recall alternation of generations in algae). Both the gametophyte and sporophyte may be several centimetres in length but the gametophyte is the long-lived phase of life cycle. You may note that in other land plants the sporophyte is the dominant generation.

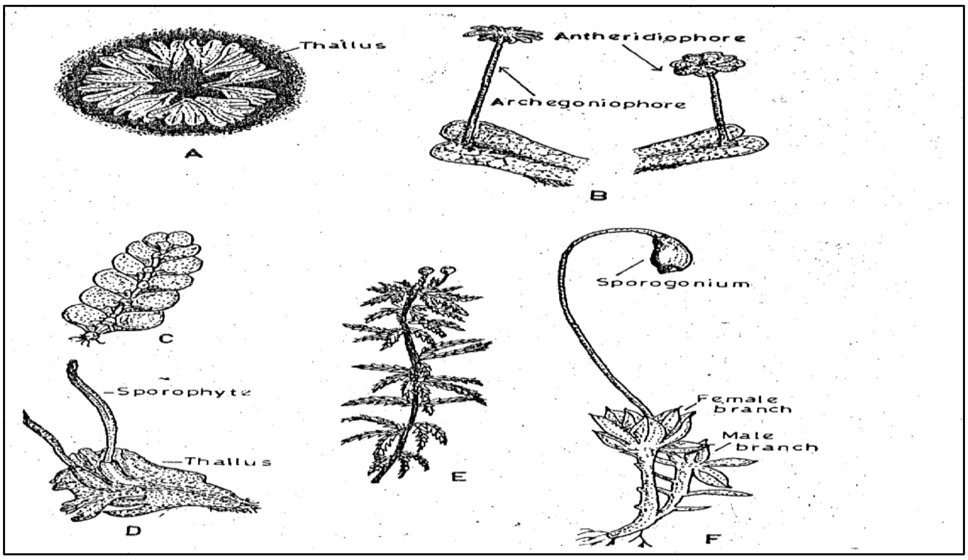

Fig.:4.1: Morphology of bryophytes: **A and B) thalloid liverworts -** *Riccia and Marchanlia,* **C) a leafy Liverwort -** *Porella,,* **D) a hornwort -** *Anthoceros,* **E and F) mosses -** *Sphagnum* **and** *Funaria.* (Source: IGNOU. (1991). Indira Gandhi National Open University. Plant Diversity)

The gametophyte may be thalloid (Fig. 4.1 A, B and D) or have an axis differentiated into stem-like and leaf-like structures (Fig. 4.1 C, E and F which lack xylem and phloem. You may note that these leaf-like structures are part of gametophyte, whereas in vascular plants the leaves strictly develop on sporophyte. The gametophyte is green, photosynthetic and nutritionally independent, and anchors to the soil by unicellular or multicellular filaments called rhizoids. Rhizoids appear like roots but unlike roots they lack vascular tissues and are much simpler in structure.

Bryophytes are most abundant in moist tropical areas. But they also grow in deserts, mountains and are observed in parts of Antarctica. In dry areas their growth and activity is restricted to wet seasons only. Some mosses grow in fresh water streams but they are not found in sea flora.

The simplest and the most primitive members of land plants belongs to the division --------------

Self-Assessment Exercise 1

1. The water-conducting tubes of bryophytes are called ---
2. The food- conducting tubes of brophytes are called ----

4.4 Summary

In this unit you have learnt that:

Bryophytes are the simplest, primitive non-vascular land plants among embryophytes. Because of several common characteristics, it is believed that they evolved from green algae

4.5 References and Further Readings/Web sources

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https://youtu.be/nw9mJu_14lk, https://youtu.be/OTRFJP4fMgs,

4.6 Answers to Self-Assessment Exercises

Answers to SAEs 1

1. **hydroids**
2. **leptoid**

UNIT 5 CLASSIFICATION AND MORPHOLOGY OF BRYOPHYTES

Unit Structure

5.1 Introduction

So far you have studied the general characteristics of bryophytes. In this unit, it is good to understand that the Division Bryophyta is divided into three classes (a) Hepaticopsida (liverworts) (b) Anthocerotopsida (hornworts) and (c) Bryopsida (mosses). Let us now study the representative genera from each class.

5.2 Intended Learning Outcomes

At the end of this unit, students should be able to:

1. Outline the classsifications of bryophytes
2. Describe the morphology of bryophytes

5.3 Main Contents

5.3.1 Classifications and Morphology of Bryophytes

Hepaticopsida (liverworts)

The gametophyte of liverworts usually lies close to the ground. There are two forms of liverworts. In some, the gametophyte is dorsi-ventral, thalloid in form with obvious upper and lower surfaces. These are thalloid liverworts. While in others it is differentiated into leaf-like and stem-like structures like those of mosses. The latter are known as leafy liverworts. The leaves of leafy liverworts are without midrib, whereas midrib is present in the leaves of mosses. Internally, the gametophytes of liverworts may be homogenous or composed of different types of tissues. Liverworts grow on moist ground or rocks that are always wet. They can be found in muddy areas near streams. In greenhouses you may find them growing in flower pots.

The gametophyte of liverworts usually lies close to the ground. True/False

In this course you will study two representatives of the order Marchantiales

(*Riccia* and *Marchantia*) and one of the order Jungermanniales (*Pellia*).

Take a look at this classification: Division - Bryophyta
Class - Hepaticopsida Order - Marchantiales Family - Ricciaceae

The gametophytes of Marchantiales are exclusively thalloid. The order Marchantiales consists of about 35 genera and approximately 420 species. We will first study in detail the genus *Riccia* and then *Marchantia.*

Riccia

Riccia belongs to the family Ricciaceae which is the most primitive and the smallest family of the order Marchantiales. *Riccia* has more than 130 species and is very widely distributed. Most of the species are terrestrial and grow mainly on moist soil and rocks. *Riccia fluitans* is an aquatic species.

In structure, *Riccia* represents the simplest of the bryophytes. Its gametophyte is small green fleshy, thalloid. It grows prostrate on the ground and branches freely by dichotomy. Several *Riccia* plants grow together and take the form of circular patches, which are typically resette-like (Fig. 5.2A). The thallus bearing female and male sex organs are shown in (Fig. 5.2B and 5.2C.)

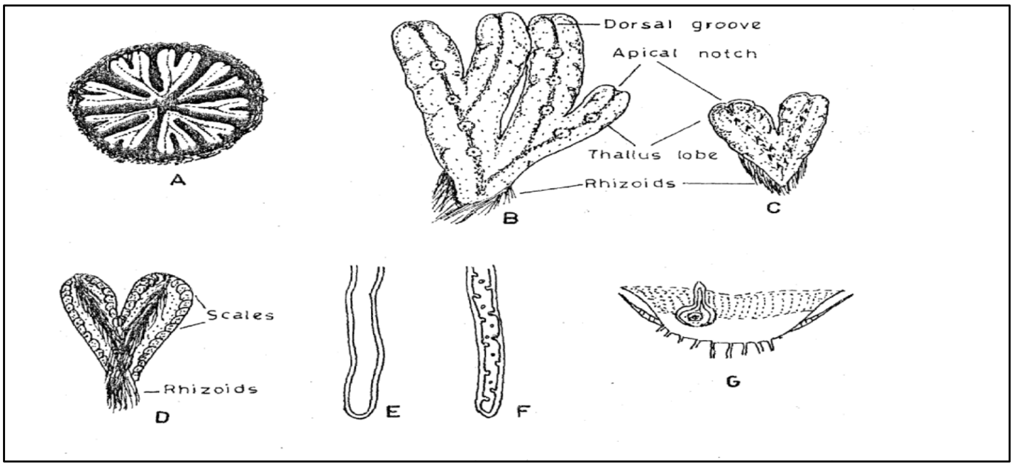

Fig. 5.2: Morphology and internal structure of *Riccia* A) a rosette of *Riccia trichocarpa,* B) a female thallus of *R. discolor,* C) a male thahlus of *R. discolor,* D)ventral surface of the thallus, E) a smooth walled rhizoid, F) a tuberculate rhizold,) transverse vertical section of female thallus. (Source: IGNOU. (1991). Indira Gandhi National Open University. Plant Diversity)

The branches of the thallus are called thallus-lobes. According to the species, thallus lobes are linear to wedge-shaped. The dorsal surface of the thallus has a prominent midrib, represented by a shallow groove called the dorsal groove. At its apex there is a depression termed as apical-notch. The sporophytes are sunk deeply, in the dorsal groove, each in a separate cavity. Both male and female sex organs may develop on the same tha]lus (monoecious) or on different thalli (dioecious) (Fig.5.2B and C). On its ventral surface (Fig.5.2D) There are a number of slender, colourless, unicellular. unbranched processes called rhizoids that help to attach the thallus to the substratum. The rhizoids are of two types: (a) smooth walled - these have smooth walls (Fig5.2E) and (b) tuberculate - these have peg-like ingrowths of wall projecting into the lumen (Fig.5.2F). On the ventral surface towards the apex and along the margins of thallus small plate like structures are also present (Fig.5.2D). These are scales which are arranged in a single row and are single cell in thickness. These scales project forward and overlap the growing point to protect it from desiccation. The growing point is located in the notch and consists of a transverse row of 3 to 5 cells. The growth of the thallus occurs in length as well as in width by the divisions of these cells. Each thallus branches

dichotomously and several dichotomies lie close to one another forming a typical rosette.

The most primitive and the smallest family of the order Marchantiales is ------

Again take a look at this simple classification of the bryophyte

Division -Bryophyta CIass -Hepaticopsida Order -Marchantiales Family -Marchantiaceae

Marchantia

The family Marchantiaceae, to which *Marchantia* belongs, includes about 23 genera and approximately 200 species. The special feature of this family is that in all the genera the gametophyte bears archegonia on vertical stalked receptacles called archegoniophores (carpocephalia). In *Marchantia* anthoridia are also produced in stalked receptacles known as antheridiophores. The type- genus *Marchantia* is placed among the most advanced members with about 65 species, of which *Marchantia polymorpha* is the most widely distributed.

Marchantia usually grows in cool moist places along with mosses and in areas of burnt ground. It is deep green in colour. Like *Riccia* it's gametophyte is flat, prostrate, dorsi-ventral and dichotomously branched thallus (Fig.5.3A). There is a prominent midrib low ridge covered with rhizoids (Fig.5.3B). Along the midrib there are a number of cuplike structures with frilled margins. These are called gemma cups (Fig. 5.3 C) which contain numerous vegetative reproductive bodies called gemmae (sing. gemma). In mature thalli antheridiophores and archegoniophores, which bear antheridia and archegonia (Fig.5.3 D and E) respectively, are also present at the growing apices of certain branches. *Marchantia* is dioecious. Like *Riccia* the apex of each branch is notched and a growing point is situated in it. You will note tha on dorsal surface the thallus is marked into hexagonal areas which are visible to the naked eye (Fig. 5.3C). If we examine with a hand lens we can see a pore at the centre of each hexagon.

Like *Riccia* the thallus of *Marchantia* is anchored to the surface by rhizoids which are of smooth walled as well as tuberculate type (Fig. 5.3F and G). Scales are also present on the ventral surface, but in *Marchantia* they are arranged on both sides of the midrib (Fig.5.3B).

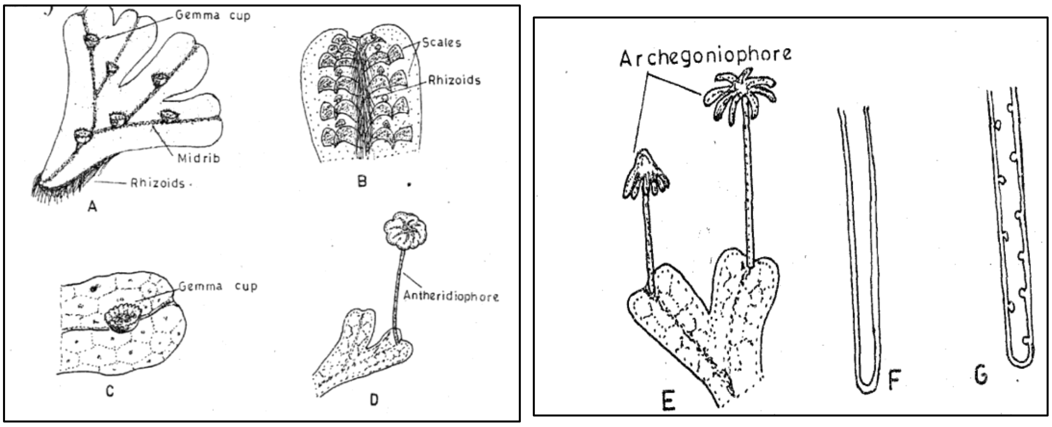

Fig.5.3:A) Morphology of *Marchantia polymorpha*: A) thallus with gema cups, B) ventral surface of the thallus, C) a portion of A enlarged, (note the hexagonal markings wth a pore in the centre of each on the surface of the thallus), D) thallus with antheridiophore, E) thallus with archegoniophores, F) smooth walled rhizoids, G) tuberculate rhizoids. (Source: IGNOU. (1991). Indira Gandhi National Open University. Plant Diversity)

The gametophyte of Marchantia is a spherical branched thallus. True/False

In the following statements choose the alternative correct word given in the parentheses. In bryophytes.

i. The dominant phase of life cycle is (gametophyte/sporophyte)

ii. (Roots/Rhizoids) anchor the plant to the soil.

iii. The protonema is (haploid/diploid)

iv. The sporophyte is (dependent/not dependent) on gametophyte

Bryopsida

Classification:
Division - Bryophyta
Class - Bryopisida
Order - Sphagnales
Family - Sphagnaceae

This is the largest class of bryophytes and includes about 600 genera and 14,500 species. Bryopsida is divided into three subclasses: Sphagnidae (peat mosses), Andreaeidae (rock mosses) and Bryidae (true mosses). Bryidae include about 14,000 species. You will study the genus *Funaria* as a representative of this order. Order Spahgnales is represented by a single genus *Sphagnum* which includes about 300 species. Let us first study *Sphagnum.*

Sphagnum

Sphagnum forms peat bogs in northern parts of the world. In some countries peat is burnt as fuel. *Sphagnum* is also used in plant nurseries as packing material. Mats of this moss hold moisture and help the seeds of other plants to germinate and grow.

*Sphagnum i*s confined to acidic, water-logged habitat. It is the principal component of peat bogs where it forms a more or less continuous spongy layer. The adult gametophyte develops as an upright leafy-shoot, called **gametophores** from a simple thallose, one cell thick protonema. The gametophore is differentiated into stem and leaves. The terminal growth of the stem is due to an apical cell. The axis is attached to the soil by means of multicellular, branched rhizoids with oblique cross walls. Rhizoids are present only in young gametophores and disappear when it matures. Afterwards, the gametophore absorbs water directly.

Look at Fig.5.4A, the mature gametophores consists of an upright stem bearing leaves. Every fourth leaf of the stem bears a group of three to eight lateral branches in its axis. These branches are of two types: (i) divergent and (ii) lying next to the stem (Fig.5.4B). Sometimes, one of the branches in a tuft continues upward growth to the same height as the main axis and resembles it in structure. These strongly developed branches are called **innovations** and they ultimately get detached and become independent plants. The branches near the apex of a stem are short and densely crowded in a compact head called **coma.**

The leaves lack midrib (Fig.5.4C and D). They are small and arranged in three vertical rows on the stem. In the surface view of a leaf one can observe two types of cells: (i) narrow, living, chlorophyll containing cells and (ii) large dead, empty, rhomboidal, hyaline (glass-like, transparent) cells with pores and spiral as well as annular wall thickenings (Fig.5.4E). In transverse section, leaf shows beaded appearance, with large, dead hyaline cells regularly alternating with the small, green, chlorophyllous cells (Fig.5.4F). The spiral thickenings provide mechanical support and keep the hyaline cells from collapsing when they are empty.

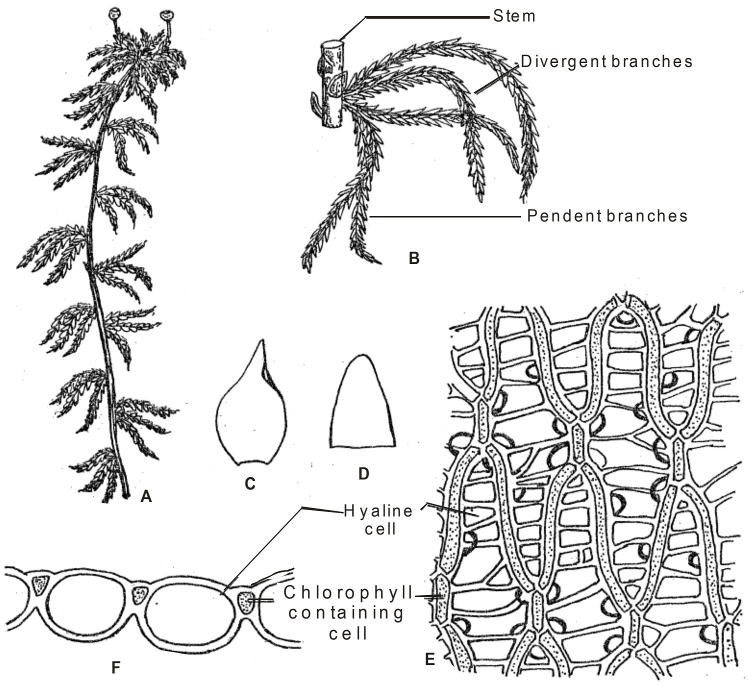

Fig. 5.4: Structure and morphology of *Sphagnum*: A) a mature gametophyte with attached sporophyte at the apex, B) portion of a shoot showing divergent and drooping (pendent) branches, C) leaf of a divergent branch enlarged. Note the apex. The midrib is absent, D) leaf of the main stem without midrib, E) leaf cells in surface. Note the network of chlorophyllous cells, surrounding porous hyaline cells; also, the fibrillar thickenings of walls of hyaline cells. F) T. S. of a leaf. (Source: IGNOU. (1991). Indira Gandhi National Open University. Plant Diversity)

The pores help in rapid intake of water and also in exchange of cations for H^+ions which are the metabolic products of *Sphagnum*. Hence, they create acidic environment in their immediate surrounding. The hyaline cells take and hold large quantities of water, sometimes as much as twenty times the weight of the plant. The narrow chloroplast containing cells carry on photosynthesis. In a mature leaf these two types of cells are arranged in a reticulate manner. This peculiar leaf structure accounts for the ability of the *Sphagnum* plant to absorb and retain large quantities of water and consequently for its outstanding bog-building properties. This water absorbing ability makes it useful in gardening.

1. Bryosipda is the largest class of bryophytes. True/False
2. Bryosipda is divided into two subclasses

Funaria

Classification:
Division - Bryophyta
Class - Bryopsida
Sub-class - Bryidae
Order - Funariales
Family - Funariacea

Funaria is a very common moss. It is very widely distributed throughout the world. One species, *Funaria hygrometrica* is cosmopolitan and is the best known of all the mosses.

Like other bryophytes that you have studied, the most conspicuous form of the moss plant is the adult gametophyte. This consists of a main erect axis bearing leaves which are arranged spirally (Fig. 5.5A). This adult gametophyte is called gametophores. It is small, about 1-3 cm high. The leaves do not have a stalk but show a distinct midrib. The gametophore is attached to the substratum by means of rhizoids which are multicellular, branched and have oblique septae. The gametophyte bears sporophyte which has foot, seta and capsule (Fig.5.5A).

The gametophores develops from a filamentous, green short-lived protonema. The protonema produces buds at certain stage of development, which initiate the development of upright leafy green axis the gametophore.

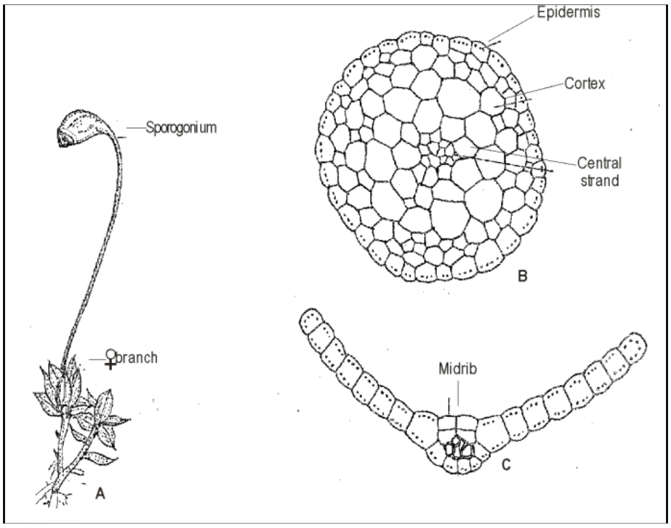

Fig. 5.5: *Funaria*: A) mature gametophores with male and female branches and also a mature sporophyte (sporogonium), B) T. S. of stem C) T. S. of leaf (Source: IGNOU. (1991). Indira Gandhi National Open University. Plant Diversity)

Funaria is an example of liverwort. True/False

Self-Assessment Exercise 2

Which of the following statements are true/false about bryophyt

i. Some mosses have hydroids and leptoids for the condu water and food, respectively.

ii. The gametophyte is an independent plant. iii. They produ types of spores

iv. TheProtonema gives rise to the gametophores

5.4 Summary

In this unit you have learnt that bryophytes are the simplest, primitive non-vascular land plants among embryophytes. Because of several common characteristics, it is believed that they evolved from green algae

The challenges of land environment for a plant are fixation to the ground, desiccation, conduction of water and dispersal of sperms and spores. These are taken care of by developing land adaptations such as epidermis, cuticle, stomata, air pores, rhizoids, multicellular jacket of cells for the protection of developing gametes, and retention of zygote in the archegonium. In some bryophytes the primitive conducting tissues - hydroids and leptoids have also developed.

The gametophyte of liverworts -*Riccia* and *Marchantia* is dorsi-ventral, thalloid structure and is internally differentiated. The pores on the dorsal surface allow exchange of gases and are much advanced in *Marchantia.* The leafy liverworts have leaf-like and stem-like appendages. The gametophyte of *Anthoceros,* is also dorsiventral, but not differentiated internally. Blue green algae *Nostoc* live in mucilage cavities of the thallus. Bryophytes are classified into

Hepaticosida(Liverworts), Anthocerotopsida(Hornworts) and Bryopsida(Mosses)
Mosses – *Sphagnum* and *Funaria* have erect axis and bear leaf-like structures.

5.5 References/Further Readings/Web Sources

Dutta A.C. (1981). Botany for degree students. Oxford University Press.

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5.6 Possible Answers to Self-Assessment Exercises

Answers to SAE1

a) i.gametophyte ii.rhizoids iii.haploid iv.dependent

b) Answers to SAE2

c) i. T ii. T iii. F iv.

UNIT 6 REPRODUCTION AND LIFE CYCLE OF BRYOPHYTE

Unit Structure

6.1 Introduction

In this unit, we will be illustrating the reproduction and life cycle of bryophytes taking *Funaria* as an example.

6.2 Intended Learning Outcomes

At the end of this unit, students should be able to:

1. Explain reproduction in bryophytes
2. Describe the life cycle of bryophytes

6.3 Main Contents

6.3.1 Reproduction and Life cycle of Bryophytes

The gametophyte of *Funaria* (Fig. 6.2A) bears two types of specialised multicellular reproductive organs (Fig.6.2B and C) called the gametangia (gamete holders) which protect egg and sperm during the development.

The male gametangia, called antheridia (sing, antheridium, Fig.6.2B), produce sperms. The female gametangia, called archegonia (sing, archegonium, Fig.6.2C), produce eggs. The gametangiá have outer sterile layer of cells forming protective jacket.
Bryophytes are oogamous i.e. the egg is larger, non-flagellated and non-motile, and the sperm is smaller and motile

After fertilisation (Fig.6.2D), the sporophyte starts developing inside the archegonium (Fig.6.2E). It may grow several centimetres in length, become photosynthetically sufficient but it draws minerals and water from gametophyte. However, in contrast to the sporophyte of all other land plants it never becomes independent of gametophyte. It remains permanently attached to it, until maturity and senescence. It is wholly or partially dependent on it for nutrition. Mature sporophyte is differentiated into a haustorial foot, a stem- like seta and a terminal spore producing capsule (Fig. 6.2F). In *Riccia* both foot and seta are absent. While in others like *Sphagnum* seta is absent. Within the capsule spores are produced by reduction division of spore mother cells.

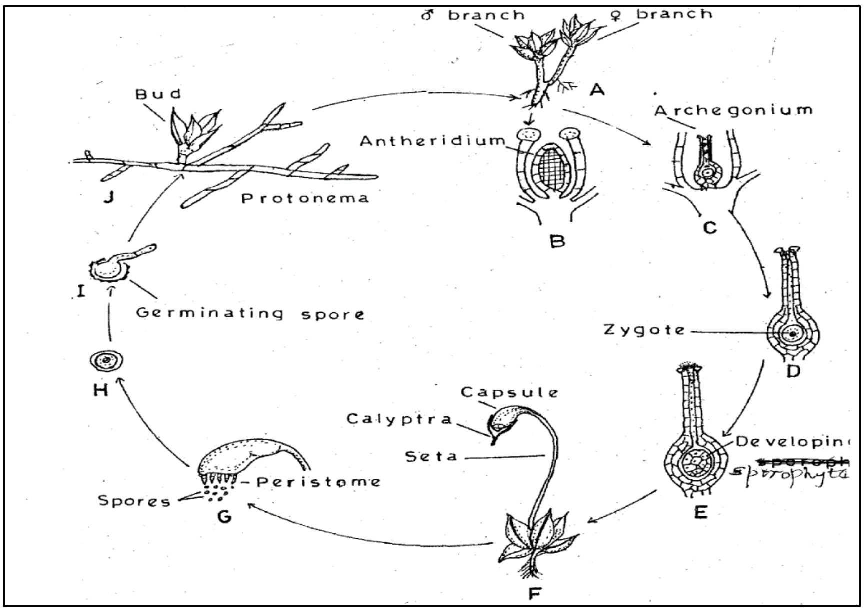

Fig. 6.2: Lifecycle of bryophytes: A) a moss plant, B) enlarged antherdiurn, C) enlarged archegonium D) formation of zygote in the archegonium, E) developing sporophyte, F) sporophyte growing on gametophyte, G) a capsule, H) a spore, I) germinating spore, J) growing protonema (Source: IGNOU. (1991). Indira Gandhi National Open University. Plant Diversity)

The gametophyte of *Funaria* bears one type of specialised multicellular reproductive organ. True/False

Self-Assessment Exercise 1

In bryophytes, after fertilisation the sporophyte starts developing inside the ---------------

The bryophytes are homosporous i.e. spores of any given species are all alike.

A spore represents the first stage of gametophytic generation (Fig. 6.2H). It is unicellular haploid and germinates (Fig.6.2H,I) to produce a short-lived green protonema (Fig.6.2j)

The adult gametophore develops on this protonema. Protonema may be thalloid, globular or filamentous. The protonema and the adult gametophore are strikingly different from each other.

An adult gametophyte bears gametangia which produce haploid male and female gametes. The gametes represent the last stage of gametophytic generation and the zygote represents the first stage of sporophytic generation, whereas the spore mother cells (diploid) represent the last stage of the sporophytic generation. The spore mother cells undergo reduction division to form haploid spores. So, any stage in the life cycle which is haploid, belongs to gametophytic generation, whereas the diploid stage belongs to the sporophytic generation.

Now let us sum up the distinguishing features of bryophytes.

1. They lack vascular system. In some of the mosses a primitive conducting system is present that transports food and water.
2. The gametophyte is dominant generation and sporophyte remains attached to it. In other land plants the sporophyte is dominant and independent

There are strong reasons to believe that green algae served as ancestors of bryophytes.
The move from water to land offers an organism some distinct competitive advantages as well as challenges. What could be the advantages of the terrestrial habitat over the aquatic? Some of the advantages are as follows:
i) greater availability of sunlight for photosynthesis, ii) increased level of carbon dioxide, and

iii) decreased vulnerability to predation.

If some more points cross your mind, add to this list.
Can you now think what are the challenges of land environment? Try to list them below.
Compare your points with the following:

1. Plants on land are exposed to direct sunlight and air. Hence there is danger of drying out or desiccation because of evaporation. Gametes and zygotes are also susceptible to desiccation.

2. The aquatic plants are supported by the buoyancy of water, but on land, plants need some anchor to fix to the ground and also require support to stand erect.
3. Absorption of minerals and water, and their transportation to the parts which are not in contact with soil. In other words, land plants need supply lines for the distribution of water and nutrients.
4. Effective dispersal of spores at right time and at right place for the survival of progeny, with the help of hygroscopic structures like elaters and peristome teeth.

All bryophytes are homosporous i.e. spores of any given species are all alike.

True/False

Self-Assessment Exercise 2

In bryophytes, the gametophyte is --------- generation and sporophyte remains attached to it

6.4 Summary

In this unit you have learnt that there is alternation of generations between green independent gametophyte and sporophyte which is wholly or partially dependent on it. Sporophyte is generally a small capsule with or without foot and seta. The gametophyte develops from protonema and bears sex organs - archegonia and antheridia. Bryophytes are homosporous.

6.5 References/Further Readings/Web Sources

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https://youtu.be/nw9mJu_14lk, https://youtu.be/OTRFJP4fMgs,

6.6 Possible Answers to Self-Assessment Exercises

Answers to SAE 1
Dominant
Answers to SAE 2
Archegonium

End of module Questions

1. Describe three different ways of Plasmogamy in fungi
2. With the aid of annontated diagram, explain the stages of sexual reproduction in *Rhizopus stolonifera*
3. Outline the general morphological characteristics of bryophytes

Glossary
Perfect state……..Sexual stage in fungi
Imperfect state…… Asexual stage in fungi
Bread mould……… Rhizopus
+ and − ………….. Mating types

MODULE 3 PTERIDOPHYTES AND FOSSILIZATION

In this module we will discuss about the general introduction of some pteridophytes and fossils with the following units

Unit1 General Characteristics Pteridophytes
Unit 2 Classification and Morphology of Pteridophytes
Unit 3 Life Cycles of Pteridophytes
Unit 4 Relationship of Pteridophytes with other Groups
Unit 5 Formation of Fossils and Their Types

Glossary
End of the module Questions

UNIT 1 GENERAL CHARACTERISTICS OF PTERIDOPHYTES.

Unit Structure

1.1 Introduction
1.2 Intended Learning Outcomes
1.3 Main Contents
 1.3.1General Characteristics
1.4 Summary
1.5 Reference / Further Readings/Web Sources
1.6 Answers to Self-Assessment Exercises

1.1 Introduction

Now we come to the last group and most advanced of the non-flowering plants, the pteridophytes. The most familiar plants of this group are ferns which we commonly see as houseplants, in parks and in house landscapes along with other ornamental plants. Ferns are rather small plants with graceful, often delicate compound leaves. Because of their beauty and difficulty in propagation, they are considered very precious plants.

In this unit you will study the general characteristics of pteridophytes

Scientists got the idea about the early vascular land plants from fossils of the extinct members. *Rhynia* and *Cooksonia* were the simple and most primitive pteridophytes. One of the simplest living members of this group is *Psilotum.*

You know, pteridophytes are vascular plants and they possess roots, stem and leaves. All vascular plants possess water and food conducting pipelines made up of xylem and phloem tissues, respectively. In different groups of plants, a great variation is found in the relative position and arrangement of xylem and phloem, other associated tissues and in the presence or absence of pit. In pteridophytes a natural gradation in vascular tissues from simple (primitive) to complex forms is observed.

1.2 Intended Learning Outcomes

At the end of this unit, students should be able to:

Outline the general the characteristics of Pteridophytes

1.3. Main Contents

1.3.1 General Characteristics

In the pteridophyte the sporophyte is the dominant phase. It possesses a vascular system and is differentiated into true root, stem and leaves. Pteridophytes exhibit a great variation in form, size and structure.

Most of the pteridophytes are herbaceous except a few woody tree ferns. They may be dorsi-ventral or radial in symmetry and have dichotomously or laterally branched stems that bear microphyllous or megaphyllous leaves

The organization of vascular cylinder (also called stele) in the sporophyte varies from simple primitive type to more complex forms. Besides, vessels are also present in some members.

The roots are generally adventitious, the primary embryonic root being short-lived.

The spores are produced in special structures called the sporangia that are invariably subtended by leaf-like appendages known as sporophylls (Fig.1.1).

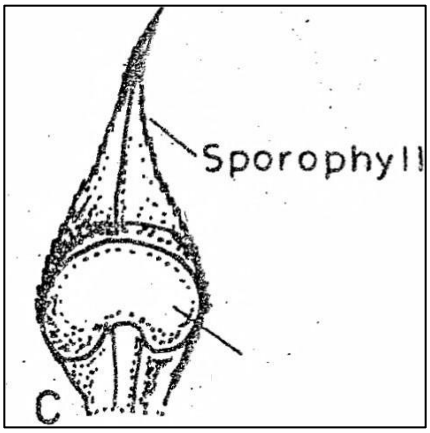

Fig. 1.1 : *Lycopiodium* showing a sporophyll (Source: IGNOU. (1991). Indira Gandhi National Open University. Plant Diversity)

Gametophyte is the dominant phase in Pteridophyte. True/False

Self-Assessment Exercise 1

The roots of pteridophytes are generally ------------

The sporangia may be scattered throughout the vegetative axis or may be restricted to a particular area. They are in many cases compacted to form distinct spore producing regions called the cones or the strobilli (sing, strobuilus). The sporangia in some cases, may be produced within specialized structures called the sporocarp. Distinct segregation of vegetative and reproductive shoots and leaves has also been observed in some other species. Have you ever noticed brown-black dots on the underside of a fern leaf? Each dot is a reproductive structure called sorus (plura, sori, Fig.1.2). It is a cluster of sponrangia that contain spores

S o r i

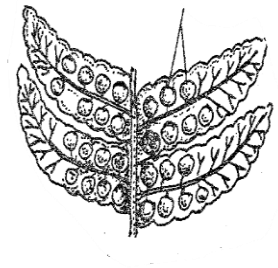

Fig. 1.2: Plant of *Cyathea.* A portion of leaf showing sori (Source: IGNOU. (1991). Indira Gandhi National Open University. Plant Diversity)

Pteridophytes, in general, are homosporous i.e. they produce only one type of spores. However, a few species are heterosporous i.e. they produce two types of spores, microspores and megaspores (Fig.1.3). A spore on germination produces gametophyte.
Heterosporous species produce microgametophyte as well as megagametophyte.

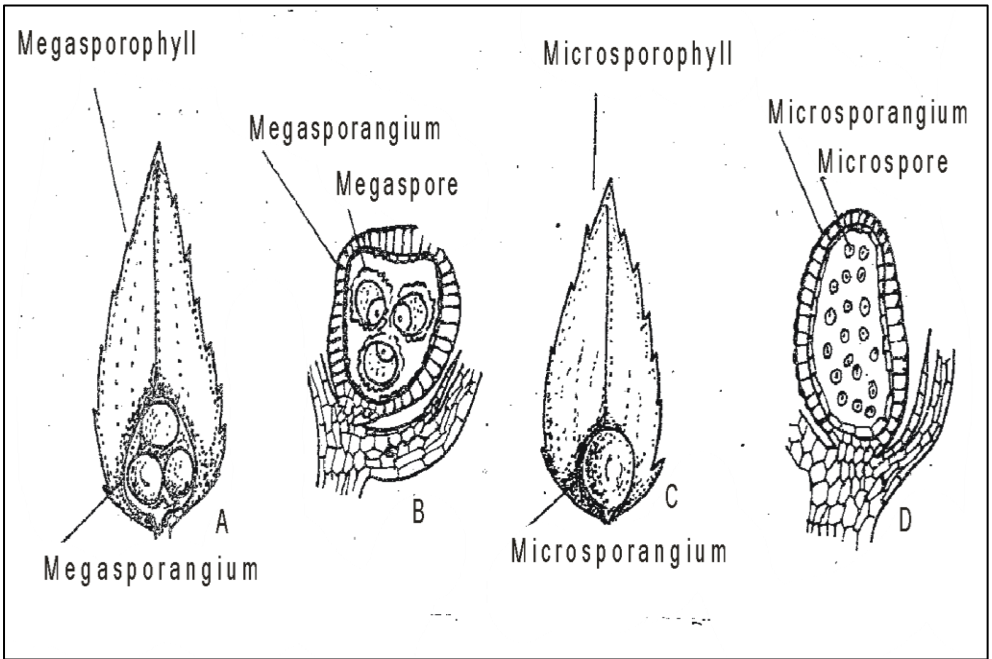

Fig. 1.3: *Selaginella*: A) A megasporophyll. B) V.S. of A. C) Microsporophyll. D) V. S of microsporophyll. (Source: IGNOU. (1991). Indira Gandhi National Open University. Plant Diversity)

In general, pteridophytes form green, dorsiventrally differentiated, thallose gametophytes with sex organs restricted to the ventral surface. The sex organs may be embedded or projecting. They resemble those of bryophytes in general plan. The female reproductive structure is archegonium and the male reproductive structure is an antheridium.

The archegonium has invariably four longitudinal rows of neck cells whose height varies in different genera. The antheridium consists of a single layer of sterile jacket of cells enclosing a mass of androcytes or antherozoid mother cells. Each androcyte gives rise to a single ciliated, motile antherozoid. The opening of the mature sex organs and the subsequent fertilization is still conditioned by the presence of water. Hence like bryophytes, they could also be called amphibians of plant kingdom.
Heterosporous species of pteridophytes produces ------------- and ------------

Self-Assessment Exercise 2

The antheridium consists of a single layer of ------ jacket of cells

1.4 Summary

So far, so good, you have learnt about the general characteristics of the pteridophytes, I hope students will be able to start identifying some common pteridophytes they come across. However, the next unit will throw more light on pteridophytes as it will highlight some morphological features and classifications.

1.5 References/Further Readings/Web Sources

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1.6 Possible Answers to Self-Assessment Exercises

Answers to SAE1

Adventitious

Answers to SAE2

Sterile

UNIT 2 CLASSIFICATION AND MORPHOLOGY OF PTERIDOPHYTES.

Unit Structure

2.1 Introduction

As you have noticed in the earlier units on Algae, Fungi and Bryophytes, each of these major plant groups are classified into smaller groups on the basis of distinguishable characteristics. Some members of the pteridophytes no longer have any living representaives they are extinct, while some have living representatives.You may recall the following major divisions of extant and extinct pteridophytes:

Extinct Pteridophytes (known only from fossil records):

Rhyniophta Zosterophyllophyta Tremerophyta

The Living Pteridophytes includes:
Psilotophyta, Lycopodiophyta, Equisetophyta
Pterophyta (= polypodiophyta, Filicopsida)

In this unit we will learn in detail about representative types of some of these classes. As you know that during evolution, advanced, complex forms evolved from primitive simpler forms. So we will first study simple, primitive forms and subsequently the advanced, complex forms.

2.2 Intended Learning Outcomes (ILOs)

By the end of this lecture unit, students should be able to:
1. Outline the classification Pteridophytes
2. Describe the morphology of some Pteridophytes

2.3 Main Contents

2.3.1 Classification and Morphology of Pteridophytes

Lycopodium

Classification:

Division - Lycopodiophyta
Class - Lycopsida
Order - Lycopodiales

Lycopodium, popularly known as club moss, is a large genus with about 180 species of which approximately 33 species are found in India. They are distributed world –wide in tropical, sub-tropical forests and in temperate regions. Some species are abundant in hills at comparatively high altitude They grow in cool climate on moist humus-rich soil.

The adult sporophyte is herbaceous and with a wide range of habits. In the tropics, they are pendulous epiphytes, whereas in temperate regions they are prostrate or erect (Fig.2.1A, B, C). They usually grow to about 30 to 60 cm in length. The stem may be unbranched or dichotomously branched which later becomes monopodial. It is covered with microphylls which in most species are spirally arranged. However, in some species leaves are arranged in whorled or decussate manner (Fig. 2.1D-G) decussate x-shaped, with pair of opposite leaves each at right angles to the pair below:

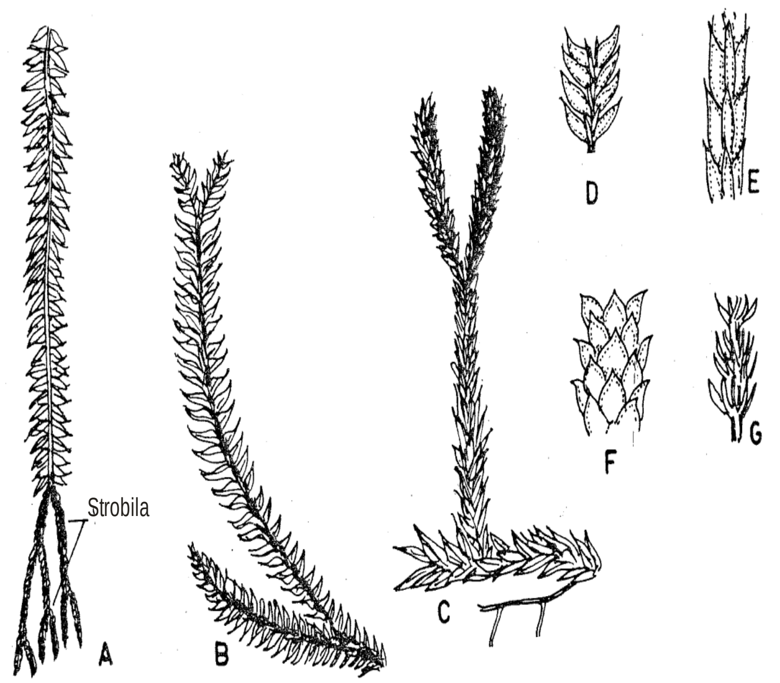

Fig.2.1: *Lycopodium*: A-C) Portion of plant of *Lycopodium phlegmaria*, L. *volubile* and *L. clavatum* respectively. D-G) Leaf form and arranged in different species (Source: IGNOU. (1997). Indira Gandhi National Open University. Plant Diversity)

Club moss is also known as ------------

Selaginella

Classification;

Division - Lycopodiophyta
Class - Isoetatae
Order - Selaginellales.

Most of the species of *Selaginella* are restricted to damp areas of the tropical and subtropical regions of the world. A few species are markedly xerophytic and inhabit desert regions. These are sometimes called "resurrection plants" because of their extra-ordinary power of recovery after prolonged drought. The plant may be prostrate, erect or sub-erect. Only a few are epiphytic. Some form delicate green mossy cushions, others are vine-like, with stems growing to a height of several metres, while many have creeping axes, from which arise leafy branch systems that bear a striking superficial resemblance to a frond of fern.

In *Selaginella* the leaves are sessile with a single unbranched vein (Fig.2.2A). Leaves of *Selaginella* are ligulate. The ligule is present in or near the axil of each leaf as a laminate outgrowth (Fig. 2.2B). It differentiates and matures very early in the ontogeny of leaf. A mature ligule is tongue-to fan-shaped. Its basal region is made up of tubular, hyaline cells forming the sheath is a hemispherical region of thin and greatly vacuolated cells referred to as glossopodium. The remaining cells are isodiametric. The apical region is one cell thick and is made up of elongated cells with scanty contents.

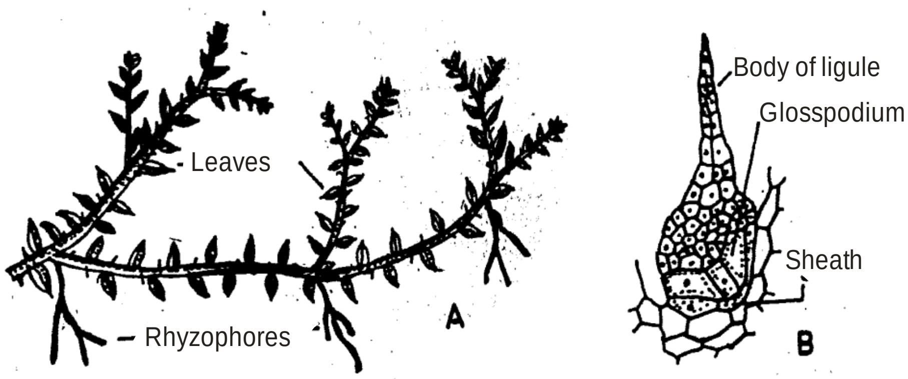

Fig. 2.2 *Selaginella* A) Portion of a plant B) T. S. of a part of leaf (Source: IGNOU. (1997). Indira Gandhi National Open University. Plant Diversity)

Most of the species of *Selaginella* are restricted to ------ areas of the tropical and subtropical regions of the world.

Classification;

Division - Pterophyta (= Filicophyta)

Class - Polypodiatae

Order - Filicales

Pteris is a widely distributed genus with about 250 species. It grows abundantly in cool, damp and shady places in tropical and subtropical regions of the world. In all there are 19 species recorded from Ind. *Pteris vitata* is a low level fern which brings out new leaves throughout the year. Its is very common along mountain walls and grows up to 1200 metres above sea level. *Pteris quadriauriata* grows abundantly along roadsides and in the valley throughout North-Western Himalayas. Another species, *Pteris cretica* grows well from 1200 to 2400 metres above sea level. Some species are also found in the rainforest but of South-West South-East and South-South parts of Nigeria.

All the species of *Pteris* are terrestrial, perennial herbs with either creeping or semi-erect rhizome covered by scales. Roots arise either from the lower surface or all over the surface of rhizome. You may have noticed that the most conspicuous part of a fern plant is its leaves which are called fronds. The leaves are compound in most species but a few have simple leaves, for example *Pteris cretica*. Look at (Fig. 2.3A), the stalk of leaf continues as rachis and bears leaflets called pinnae.

In *Pteris vittata* the pinnae present near the base and tip are smaller than those in the middle. The leaf apex is occupied by an odd pinna. Every pinna is transverse by a central midrib which gives off lateral veins that bifurcate. The pinnae are sessile and broader at the base gradually decreasing in width towards the apex (Fig. 2.3B). The leaves are bipinnate in *P. biauriata*. The pinnules are rough in texture. The young leaves show typical incurving known as circinate vernation. The leaves bear spore producing structures on the underside of the leaflets. They appear as rows of brown dots (sori, sing, sorus). Each sorus is a cluster of sporangia.
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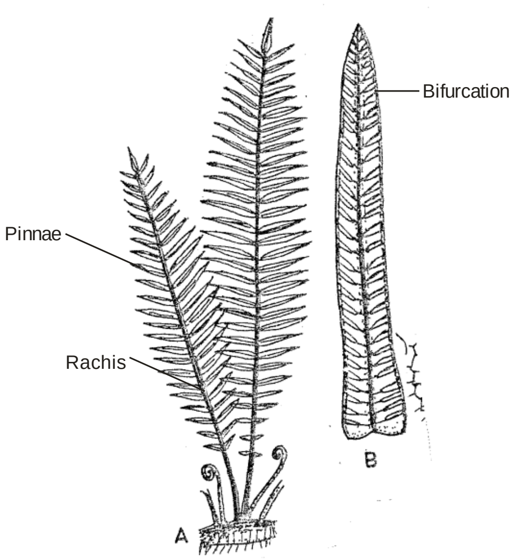

Fig. 2.3:*Pteris* A) A plant of *Pteris vittata*. B) A leaf showing mid-rib and dichotomous vein (Source: IGNOU. (1997). Indira Gandhi National Open University. Plant Diversity)

Some of the species of *Pteris* are terrestrial. True/False

Self-Assessment Exercise 1

Classify the following pteridophytes according to division, class and order: Selaginalla, Pteris

2.4 Summary

In these units you have learnt that Pteridophytes are primitive, vascular, non-flowering land plants. Like bryophytes, they show distinct alternation of generations, but instead of gametophyte, sporophyte is the dominant phase of life cycle. *Lycopodium* stem is densely covered with microphylls. It is also protostellic. Roots are from pericycle and are diarchy. In *Selaginella* the main stem may be prostrate, semi-erect or erect, branched or unbranched. It possess microphylls which are spirally arranged on the stem and are ligulate. *Pteris* has a creeping rhizome which bears scales or branched hairs. The plant is characterized by prominent pinnately compound or digitate leaves. The sporangia are generally grouped together in sori. Pteridophytes are found abundantly in wet and hilly wet areas in Nigeria

2.5 References/Further Readings/Web Sources

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2.6 Possible Answers to Self-Assessment Exercises

Answer to SAE

Selaginella

Classification:

Division - Lycopodiophyta

Class - Isoetatae

Order - Selaginellales.

Pteris
Classification;
Division - Pterophyta (= Filicophyta)
Class - Polypodiatae
Order - Filicales

UNIT 3 LIFE CYCLE OF PTERIDOPHYTES.

Unit Structure

3.1 Introduction

In this unit, we will take a look at the life cycle of pteridophytes. The life cycle of pteridophytes involves the alternation of generation as earlier discussed but which now depends on which of the phases is dominant

3.2 Intended Learning Outcomes

At the end of this unit, students should be able to:

Describe the life cycle of Pteridophytes

3.3. Main Contents

3.3.1 Life Cycle of Pteridophytes

Have a good look at the pictures of a pteridophyte. What you see are the sporophytes of these plants. Their gametophytes are very small only a few millimeters in size, and are short-lived. Like bryophytes, pteridophytes also have two distinct phases in the life cycle: gametophyte and sporophyte (Fig. 3.1) that follow each other in regular succession. Since the two generations look different, they are termed heteromorphic. Under normal circumstances, gametophyte produces motile male gametes (sperms) and non-motile female gametes (eggs). Fusion between an egg cell and male gamete results in the formation of a diploid zygote which is diploid. The zygote divides by mitotic divisions and forms the sporophyte. On the sporophyte a number of haploid, non-motile spores are produced by meiosis. The life cycle is then completed when a spore germinates and produces a haploid gametophytes by mitotic divisions (Fig.3.1).

You have studied that in bryophytes, the dominant phase in the life cycle is the gametophyte, and the sporophyte is either partially or completely dependent on it for nutrition. But in pteridophytes the sporophyte very soon becomes independent of the gametophyte and is the dominant generation.

The sporophyte shows greater degree of complexity in structural organization. It is organized into stem, root and leaves, except in the most ancient fossil pteridophytes and in the most primitive living member. The vascular tissues (xylem and phloem) are developed only in the sporophyte

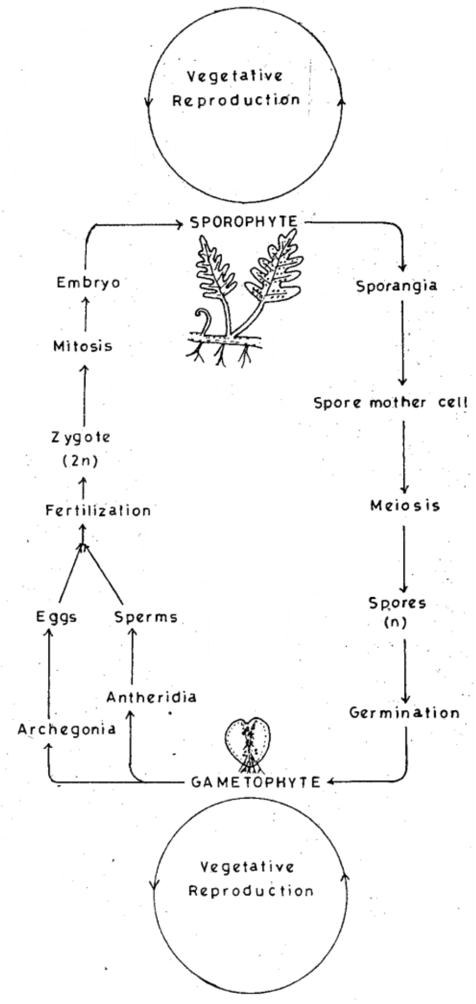

Fig. 3.1: Potential typical life cycle of *pteridophytes*

(Source: IGNOU. (1997). Indira Gandhi National Open University. Plant Diversity)
Furthermore, the aerial parts are covered with a layer of cuticle. On the epidermis there are stomata for the exchange of gases. These anatomical complexities of the sporophyte helped them adapt to a much wider environment in inhabiting a much wider range of environmental conditions than the gametophyte could. The two generations of pteridophytes looks different hence they are termed ------------

Self-Assessment Exercise 1

In pteridophytes, the vascular tissues are developed both in the gametophyte and sporophyte. True/False

The life cycle of a typical fern e.g. ***Dryopteris felixma*** is as shown in (Fig. 3.2). It is annotated and self-explanatory

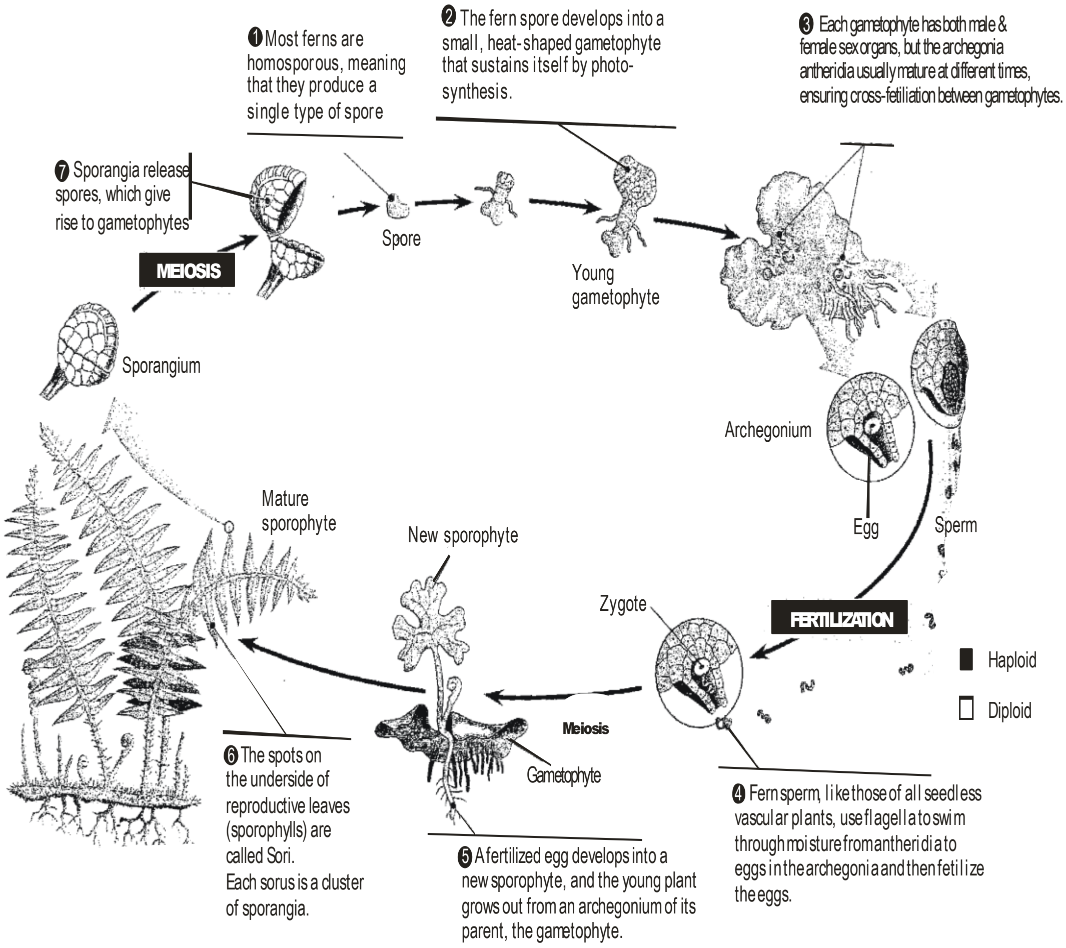

Fig. 3.2: The life cycle of a fern. After Campbell and Reece (1997)

3.4 Summary

In these units you have learnt that Pteridophytes are primitive, vascular, non-flowering land plants. Like bryophytes, they show distinct alternation of generations, but instead of gametophyte, sporophyte is the dominant phase of life cycle.

3.5 References/Further Reading/Web Sources

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3.6 Possible Answers to Self-Assessment Exercises

Answer to SAE

False (It's only the sporophyte)

UNIT 4 RELATIONSHIP OF PTERIDOPHYTES WITH OTHER GROUPS.

Unit Structure

4.1 Introduction

You have studied the general characteristics, morphology and life cycle of pteridophytes. In this unit, we will compare the pteridophytes with other groups such as bryophytes and seed plants

4.2 Intended Learning Outcomes

At the end of this unit, students should be able to:

1. Compare and contrast between pteridophytes and bryophytes
2. Itemize the differences and similarities between pteridophytes and seed plants

4.3. Main Contents

4.3.1 Relationship of Pteridophytes with bryophytes

Bryophytes resemble pteridophytes in the following features:

1. Thalloseoid liverworts and pteridophyte show similarity in vegetative structure of their gametophytes.
2. Their female and male reproductive structures are archegonium and antheridium, respectively.
3. The opening of the mature sexual reproductive organs and the subsequent fertilization are conditioned by the presence of water in liquid state, i.e., both require water for fertilization.

4. They usually show a distinct and clearly defined heteromorphic alternation of generations and the two generations follow each other in regular succession.
5. The spores arise in the same manner in both the groups. The spore mother cells are produced by the last division of the sporogenous tissues. Each of the spore mother cells undergoes meiotic division resulting in a tetrad of spores.
6. Development of embryo occurs in the archegonium
7. The young sporophyte or embryo is partially parasitic upon the gametophyte.

In-Text Question (ITQ)
Pteridophytes has no relationship with bryophytes. **True/False**
Answer: False

Differences between pteridophytes and bryophytes

1. Unlike bryophytes in which sporophyte is dependent upon gametophyte physically and physiologically, the sporophyte is independent at maturity in pteridophytes, and is the dominant phase of life cycle instead of gametophyte.
2. In pteridophytes the sporophyte has true roots, stem and leaves and well developed conducting tissues of xylem and phloem, which are absent in bryophytes.
3. Some of the pteridophytes are heterosporous but all the bryophytes are homosporous.

4.3.2 Relationship of Pteridophytes with Seed plants

As mentioned earlier, pteridophytes form an important link between bryophytes and seed plants. This suggests that they also resemble in some respects with spermatophytes.

Pteridophytes resemble seed plants in the following respects:

1. The sporophytes is the dominant, typically photosynthentic phase of life cycle.
2. It is organized into stem, root and leaves.
3. The roots and the leafy shoots are provided with a conducting system made of specialized cells.
4. Some pteridophytes do approach seed-habit and some fossil pteridophytes had seed-like structure.

   Pteridophytes form an important link between bryophytes and seed plants. True/False

Self-Assessment Exercise 1

Why are pteridophytes also known as "Vascular Cryptogams?

4.4 Summary

Due to their affinities with bryophytes as well as with higher vascular, plants, pteridophytes are also known as "Vascular Cryptogams" (non-seed producing plants).

In the above account you have learnt about their relation to other plant groups. Now we will describe the formation of various types of fossils and how they reveal life forms that occurred millions of years ago in the next unit

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4.6 Possible Answers to Self-Assessment Exercises

Answer to SAE

- Due to their affinities with bryophytes as well as with higher vascular, plants,
- Due to their affinities with bryophytes as well as with higher vascular, plants, pteridophytes are also known as "Vascular Cryptogams"
- Due to their affinities with bryophytes as well as with higher vascular, plants,
- Due to their affinities with bryophytes as well as with higher vascular, plants,

UNIT 5 FORMATION OF FOSSILS AND THEIR TYPES

Unit Structure

5.1 Introduction

You may raise a question as to how can one know “Where, when and from what ancestral group did the first vascular land plants and seed-like structure evolve?” To find the answer to these questions we have to depend on fossils. Let us first try to define a fossil and the ways in which fossils came to be formed. We will also try to know the extent to which they may be expected to provide information useful to the morphologist.

5.2 Intended Learning Outcomes

At the end of this unit, students should be able to:

1. Define fossils
2. Explain the formation of fossils
3. Explain the evolvement of vascular plants

5.3. Main Contents

5.3.1 Formation of Fossils and Their Types

What are Fossils?

Fossils are the remains and / or impressions of organisms that lived in the past. In its correct sense fossils include the remains of organisms or their parts and also anything connected with an organism proving its existence, i.e., anything which gives evidence that an organism once lived.

How are fossils formed?

The actual nature of fossilization depends on the environmental conditions in which it takes place. Dead plant remains are liable to get disintegrated and it is only rarely that they get fossilized. Chances of fossilization are better for organisms having stiff tissues / skeletons. The details of fossilization process are discussed below.

Fossilization Process

The process of formation of fossils is going on ever since the sedimentary rocks began to deposit and it is going on in nature even now.

In some cases plants may be deposited on the site where they grow (*in situ*), such as swamps and small inland lakes. Due to low oxygen content and presence of toxic substance in the water, microbial growth is inhibited, so the plants do not decay. This results in the preservation of the plant remains until they were covered by layers of sediments. European and Enugun coal forests are the example of this type of fossilization.
In other cases plant parts are carried down by flowing water and finally sink to the bottom of a lake or estuarine water where they are less susceptible to decay by microbes.

During fossilizations the protoplasmic contents and softer parenchymatous cells disappear first, while the harder wood and other sclerenchymatous or cutinized tissues resist to the last. The growing pressure of the heavy sedimentary rocks above, first reduces the vacant spaces inside the cells and forces the liquids substances out. Some organic substances may also escape as marsh gas. Naturally, all fossils get highly compressed and the final result depends on how far the conditions were favourable for good fossilization. In spite of all hazards sometimes fossils are formed, which retain their cellular structure beautifully and sometimes even some of the cell contents. The remains and / or impressions of organisms that lived in the past is called --------

Types of fossils

According to the nature of fossilization, fossils may be of the following types:

1. Petrifaction

It is the best type of fossilization. In this type buried plant material gets decayed with the passage of time and gets replaced, molecule for molecule by mineral solutions. The impregnation of silica, calcium carbonate, magnesium carbonate and iron sulphide takes place within the tissues. Most of the plant material may get decayed but at least some original cell wall components remain. After fossilization the whole structure becomes stone-like and it can be cut into fine sections. The structure of the tissues may be observed by examining the section under the microscope. Anatomical structures of ancient plants are beautifully obtained from such petrifactions. Silicified and calcified pieces of wood are quite common.

II. Cast or incrustation

This type of fossilization is also quite common. The plant parts get covered up by sand or mud. After sometime the plant material inside degenerates leaving a cavity known as mold. This cavity, again gets filled up by some rock-forming material which in course of time solidifies into an exact cast of the plant material, showing all its surface features. A cast fossil does not actually contain any part of the original plant but it is of great use as the cast correctly shows the original features of plant part.

III. Impression

These are found when a leaf or any other part of the plant falls on and leaves an impression on the surface of semisolid clay. In the course of time this impression becomes permanent when the clay turns into stone. Such impressions often very clearly show details of external features and structures like stomata are clearly seen in good preparation.

IV. Compression

In a compression the organic remains of the plant part actually remain in the fossils but in a highly compressed state. During fossilization the great pressure of sediments above causes flattening of plant parts. In the fossil usually a carbonaceous film remains which represents the surface features. However, in good compressions it has been possible to swell out the organ by some chemical treatments so that plant some details become visible. A good type of compressed fossil is the “clay nodule”. In this the plant material gets encased in a ball of clay, gets compressed and the clay ball turns into stone.

Nomenclature of fossils

Mostly, fossils consist of fragments of plants. Sometimes it may take many years to find the fossil of a stem to which a particular kind of leaf belonged. Therefore, in the meantime each fragment of fossil plant is described under a separate generic name and such genera are known as

"Form genera". In naming such form genera we usually add suffixes, signifying which part of the plant it came from.

Following are a few examples:

	Plant Part	Suffix Used
a)	Leaf	-phyllum
b)	Fern-like or frond	-pteris
c)	Tree trunk	-dendron
d)	Woody part	-xylon
e)	Seed-like structure	-spermum, -carpon, -carpus, -storms
f)	Microsporangium	-theca
g)	Cone	-strobilus, - strobes

It is the work of paleobotanists to collect bits of such fossils, i.e, form general, and to reconstruct the form, structure and mode of life of the plant from which they came. Success has been achieved in reconstructing a few fossil plants. Petrifaction is not a type of fossils. True/False

Self-Assessment Exercise 1

List the different types of fossilsization

5.4 Summary

Mostly, fossils consist of fragments of plants. Sometimes it may take many years to find the fossil of a stem to which a particular kind of leaf belonged. Therefore, in the meantime each fragment of fossil plant is described under a separate generic name and such genera are known as "Form genera".

5.5 References/Further Readings/Web Sources

https://www.vedantu.com, https://en.wikipedia.org/wiki/Fossil, https://study.com/academy/lesson/fossil-definition-types-characteristics-examples.html
https://www.textbooks.com/Catalog/MA2/Paleogeology-Paleontology-and-Fossils.php, https://www.amazon.com/Science-Times-Book-Fossils-Evolution/dp/1558216529
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5.6 Possible Answers to Self-Assessment Exercises

Answer to SAEs

1. Petrifaction
2. Cast or Incrustation
3. Impression
4. Compression

End of Module Question

1. Describe the life cycle of a named Pteridophyte
2. Based on the nature of fossilization, explain the different types of fossils

Glossary

- Clay nodule……….Compressed fossils
- Form genera……….. Fossil plant described under a separate generic name
- Pteris……………… Fern-like or frond
- Theca……………… Microsporangium