DEPARTMENT OF BIOLOGICAL SCIENCES

(MICROBIOLOGY OPTION)

FACULTY OF SCIENCE

BENSON IDAHOSA UNIVERSITY

BENIN CITY

MODULE FOR BOT 211 LOWER PLANTS

PREPARED BY

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UNIT 1

GENERAL INTRODUCTION

1.1 COURSE INFORMATION

Course Description

This course is made up of three sections. The module consists of; introduction to Lower plants; their Morphology, Physiology (body function and reproduction), Ecology, Classification and Economic Importance of Algae, Fungi, Bryophytes and Ferns. Similarities and differences of the 4 groups and also economic importance of each group are to be emphasized.

Course Objectives

At the end of this course students will be able to:

- Identify the major groups of lower plants or cryptogams
- Characterize each group of cryptogams
- Appreciate the diversity of non-seed producing plants
- Explain the inter- and intra- group features of cryptogams (compare and contrast).
- Describe the relationship between seedless and seed producing vascular plants.
- Recognize the contribution of lower plants to ecosystem in general and to our economy in particular.
- Appreciate the diversity of plants

General Course Information

We aim to provide background information and practical oriented training that should serve the need of microbiologists and biologist. The two most important actors in this course would be the facilitators and the students. All major learning modes: **visual** (books, slides, and live specimens), **auditory** (lectures and class interactions), and **manipulative** (“hand on” exercises) would be followed in the process. **The active learning methods that would be employed are group discussion, brainstorming, presentation by students, report of practical activities, and interaction with facilitators during feedback presentation**.

The lecturer would be a facilitator or a guide of the class activity. The students will be the key players in this respect. The laboratory assistants and the instructors will be there throughout the laboratory sessions. Please be friendly, co-operative and avoid shyness so that the teaching and learning process could be smooth.

General Laboratory Information

Always check the lab board for instructions on the activities for each day. The list of samples to study, class exercises and demonstrations will generally be given. A short field trip around the campus to study the ecology of each group of cryptogams would possibly be scheduled. All these would be facilitated by the duo of the instructor and laboratory assistant.

1.2. COURSE CONTENT

1. **Fungi (10 sessions including laboratory)**

    a) General characteristics
    b) Nutrition and Ecology of Fungi
    c) Reproduction in fungi
    d) Classification
    e) Economic importance of Fungi

Note: Specific characteristics of each class such as occurrence, plant body (anatomy), reproduction and life history are discussed.

2. **Algae (8 sessions including laboratory)**
    a) General characteristics
    b) Range of structure
    c) Reproduction and life history
    d) General classification of Algae
    e) Major Divisions of Algae
    f) Economic importance of Alga

3. **Bryophytes (5 sessions including laboratory)**

    a) General characteristics
    b) Habitat
    c) Structure
    d) Reproduction and life history
    e) Classification of Bryophytes

        - Class Hepaticae
        - Class Anthocerotae
        - Class Musci

    f) Economic Importance of Bryophytes
4. **Vascular Crypyogams (5 Sessions including laboratory)**
    a) General Characteristics
    b) Classification

        - Psilopsida – *Psilotum*
        - Lycopsida – *Selaginella*
        - Sphenopsida – *Equisetum*
        - Pteropsida – Ferns

Note: The following features of each group should be discussed

- General Characteristics
- Anatomy
- Reproduction and life history

References

Moore, R., Clark, W.D. and Stern, K.R. (1995). Botany. Wm. C. Brown Publishers.

Mauseth, J.D.(1975). Botany: an introduction to plant biology. 2nd ed. Saunders College publishing.

Haynes, J.D.(1975). Botany: an introductory survey of the plant kingdom. John Wiley & sons Inc. New York.

1.3. INTRODUCTION

The course Lower Plants covers four major groups of organisms namely; fungi, algae, bryophytes and pteridophytes. They are spore-producing plants (non-seed bearing). They are collectively categorized as Cryptogams. The word *Cryptogam* is derived from the Greek words *kryptos* meaning ‘hidden’ and *gamos* meaning ‘marriage’ and ‘hidden marriage’ referring to the minute (microscopic) form of reproduction in these spore-producing organisms. The ‘Cryptogams’ are an artificial group, that is, a group of organisms that share a common trait but not necessarily close relatives of each other. When Carlos Linnaeus propounded the basic system of classifying organisms in the mid-18th century, he used the term *Cryptogamia* to refer to all ‘plants’ with hidden reproductive organs. The organisms he included in this group were the mosses and other bryophytes, ferns, macroalgae and fungi; basically all the non-animal macroscopic organisms that lack flowers or seed-bearing cones. Although the term *cryptogamc botany* is still in use, modern taxonomy does not include fungi as one of the groups because it is already a non-plant group. In this course fungi are treated as cryptogams because we simply want to introduce it to our students, which otherwise is not a plant therefore not studied under the field of botany but mycology.

1.3.1. Activity

1) The following organisms belong to the Plant and Fungi Kingdoms. Identify those that reproduce by spores and those that reproduce by seed. Fern, Juniper, Moss, Spirogyra, Pythium, bread mold, Mango, Cycad, Fig, Sargassum.
2) Categorize the above listed plants/organisms into the groups below.

Algae.. Pteridophytes..

Fungi .... Gymnosperm..

Bryophytes .... Angiosperms...

3) Which group of organisms from the list in no. 2 does not belong to the plant kingdom? What distinguishes this group from the others?

UNIT 2

FUNGI

2.1 General Features of Fungi — Session 1

- The fungi constitute a large and diverse group of non chlorophyll – containing simple organisms.
- They are usually filamentous, although some unicellular forms are present. The major component of the cell wall is cellulose or chitin. The cell walls of all fungi contain a mixture of fibrillar chitin for rigidity and amorphous components which include proteins, mannans and glucans.
- A single thread (filament), or a branch is termed a hypha and a mass of hyphae that constitute the thallus or vegetative plant body is termed a mycelium.
- It is usually colorless, although some do produce non photosynthetic pigments. Some have pigmented asexual spores.
- Their food storage is glycogen.
- The hypha is a tubular structure containing protoplasm which is bound by cell wall.
- The hypha is delimited by cross walls known as septa. The perforations in the septa or septal pores facilitate the free movement of protoplasm from one fungal cell to another and throughout the hyphal strand.
- Fungal cells have cross walls called septa and a hypha containing septa is referred to as **septate**.
- Hyphae without cross walls are referred to as **non-septate**.
- Hyphal cells may contain one, two or many nuclei, and are referred to as being **uninucleate**, **binucleate** or **multinucleate**, respectively.
- Hyphae without septa are referred to as **coenocytic**.
- Hyphal filaments elongate by **apical growth**, but most parts or fragments of hypha are capable of growth.
- Fungi often secrete hydrolytic enzymes which break down organic polymers like polysaccharides and proteins into organic monomers like monosaccharides and amino acids and they are easily absorbed through their cell walls.

2.2 Nutrition and Ecology of Fungi — Session 2

Objectives

At the end this session, each student will be able to;

- Explain fungal ecology and their mode of nutrition
- Describe the difference between fungal parasites, saprophytes and symbionts
- Discuss the different nutritional associations between fungi and other organisms

* Discuss the ecological role of fungi in the terrestrial ecosystem

All fungi are chemoheterotrophic. They obtain their energy and carbon compounds from the metabolism of organic nutrients. There are no photosynthetic fungi, a key difference fungi and plants. Although some fungi are parasites, most are saprophytic heterotrophs. They are major decomposers of dead organic material. They release carbon and nitrogen back into the environment, playing an essential in both the carbon and nitrogen cycles. Fungi lack chlorophyll, the green pigment that enables plants to make their own food. Consequently, fungi cannot synthesize their own food the way plants do.

Fungi grow on diverse habitats. They are found in almost every available habitat on earth where organic material is present. They are thus universal in their distribution and majority of them are terrestrial. Terrestrial fungi thrive best in humus soil and are considered more advanced. They produce non-motile reproductive cells (spores) which are dispersed passively by wind, water or animals. Aquatic fungi are considered primitive. They live on decaying matter and living organisms found in fresh water and produce flagellated (motile) reproductive cells.

a. Saprophytic fungi produce enzymes and acids that break down cellulose, starches, sugars, proteins, fats and other constituents of the substrate which in turn diffuse into the fungal cells where they are utilized for food and energy for more growth.
b. Parasitic fungi produce external or internal mycelia with reference to the host.
   i. External mycelia are usually whitish or dark brown in color and cob-web like, forming dense threads on the surface of leaves, stems, or fruits.
   ii. Internal mycelia either penetrate between the host cells, a condition termed **intercellular,** or penetrate into the host, a condition termed **intracellular.** Since they come in contact with host protoplasm, intracellular hyphae absorb food directly. Intercellular hyphae absorb food as it diffuses out through the host cell wall, or send special absorbing organs called **haustoria**, into the host cells.
   iii. The haustoria enter the host cell through a minute puncture in the cell wall. Haustoria may be a simple knob, long tube, or variously branched.

2. 2.1 Mycorrhizae

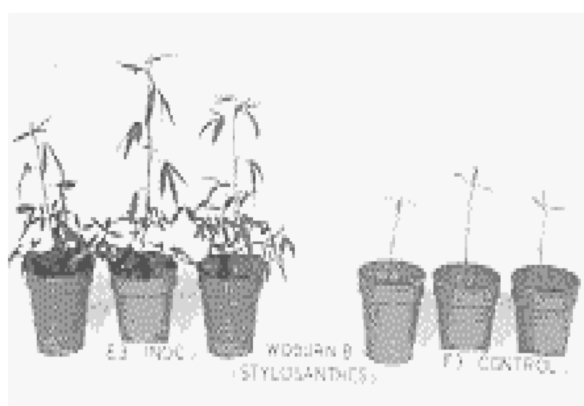
Many fungi grow in association with plant roots. The fine, highly branched fungal hyphae extend throughout a relatively large volume of soil. As a result of their superior absorptive capability, the fungi take up mineral nutrients. The fungi pass on some nutrients to the plant roots and receive sugar and other nutrients from the plant. In many forests, a lot of carbon fixed by photosynthesis ends up in fungal mycelium because of the mycorrhizal symbiotic association in which the fungus assists the growth of forest trees. What is important is that the mycelial sink keeps the nutrients on site preventing loss of nutrient from the soil by leaching.

The benefits of mycorrhizas to plants include efficient nutrient uptake, especially phosphorus; enhanced resistance to drought stress; and direct or indirect protection against some pathogens. Mycorrhizal fungi also link plants together into communities that are more resilient to stress and disturbance than single plants. When plants are connected by a common fungus, the products of photosynthesis can move through the fungus from a well-placed donor plant to a shaded recipient plant. In nutrient-poor soils, mycorrhizal fungi can provide nitrogen to their host plant that their mycelia have obtained by saprotrophic digestion of nutrients in the soil.

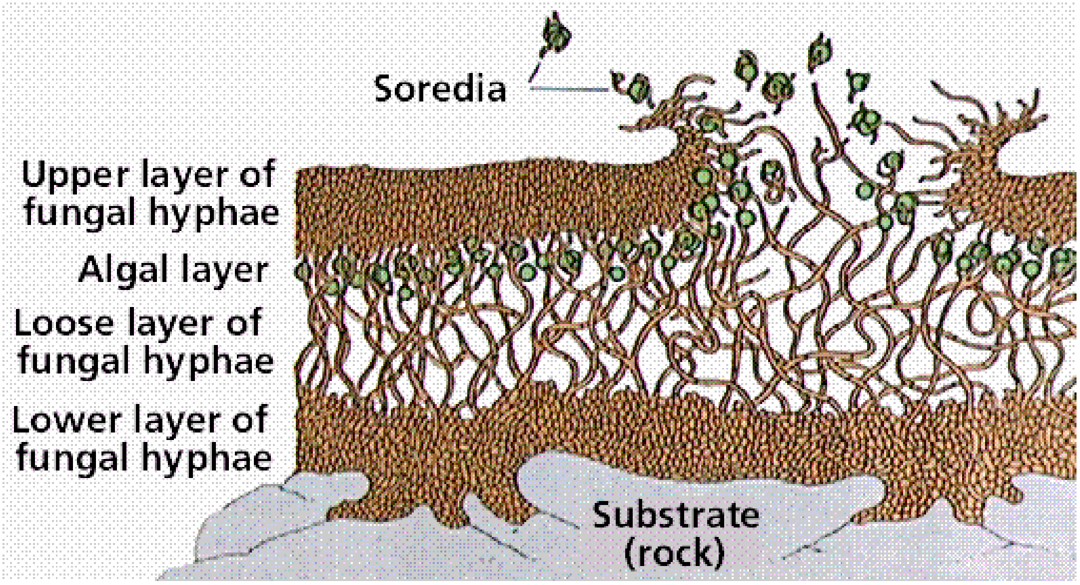
2.2.2 Lichen

Lichen is a plant-like structure composed of two kinds of organisms living symbiotically; fungi and photosynthetic cells (either blue green algae sometimes called cyanobacteria or green algae). The fungus in lichen obtains organic compounds from the photosynthetic partner and the photosynthetic partner.

This picture shows the mycorrhizal network of the roots of a small seedling



Plants on the left have mycorrhizas, plants on the right don't.



2.3 Reproduction in Fungi **Session 3**

Objectives

At the end of the session every student will be able to;

* Characterize reproduction in fungi
* Discuss the advantages and disadvantages of reproduction by spores
* Explain the different modes of sexual reproduction in fungi

Reproduction is the formation of new individuals having all the characteristics typical of the species (Alexopoulos and Mims (1982). Reproduction in fungi can be broadly categorized into types; sexual and asexual.

2.4 Asexual reproduction

This mode of reproduction occurs by physical break up of parts of the filament or modification of vegetative parts to give rise to new individuals. Asexual reproduction takes place under favorable conditions and most fungi use this method to propagate themselves several times during the season. Spores vary in shape and size, colored or hyaline, moistly unicellular.

2.4.1 Types of asexual reproduction

1) Fragmentation: the fungal hypha breaks into smaller pieces and each may later grow into new mycelium. This is a common laboratory technique where a piece of fungal segment is transferred into fresh medium which afterwards develops into a fungal colony
2) Fission: this is a common method in unicellular fungi and some lower fungi. A single cell divides on a lateral plane to give rise to two daughter cells.

3) Budding: this is common in yeasts. A small outgrowth emerges on the parent cell. The nucleus divides into two. One of the daughter nuclei passes into the bud. The bud increases in size while it is still attached to the parent cell but soon breaks off. Sometimes the daughter bud is not separated and produces another bud in the same manner. This process is repeated forming a chain of buds appearing like a mycelium called pseudomycelium.
4) Oidia: sometimes hyphae break up into small components called oidia or arthospores. They are one celled and on germination form a new plant. These are usually formed in *Eryshiphe* and Basidiomycetes.
5) Chlamydospores: in some fungi like *Fusarium* and *Mucor*, cells of hypha become thick walled either singly or in chains after accumulation of food material in them. They may be terminal or intercalary in position and are capable of forming a new plant on return of favorable condition.
6) Gemmae: are chlamydospores like in structure but not so durable and thick walled. They are formed in S*aprolegnia* and others.
7) Zoospores: these are naked, motile and flagellated spores.
8) Sporangiospores: spores produced in special structures called sporangia (singular; sporangium)
9) Conidia: asexual spores borne in chains on the tip of specialized structures called conidiophores.
10) Urediospores and pycniospore

Reproduction by spores provides the fungus advantages as follows;

a) A crop of spores provide the individual in a large number and repetition of the same many times under favorable conditions increases chances of survival.
b) The methods of dissemination through air, water, animals etc. affords the fungus of fresh supply of food.
c) Comparatively spores are more resistant than vegetative hyphae and can tolerate/withstand unfavorable conditions.

2.5 Sexual Reproduction **Session 4**

Sexual reproduction in fungi takes place by the fusion of compatible parent nuclei. It begins with the coming together of two sex cells or reproductive structures or mating types. Enzymes are produced to digest the walls of the cells and fusion of cytoplasm of the two cells takes place. This is known as plasmogamy. The two haploid (n) nuclei of the two mating types fuse together. This is called karyogamy. Karyogamy results in the formation of a diploid (2n) nucleus (zygote). Immediately after karyogamy, meiosis takes place reducing the chromosome number to haploid state. These sexually produced spores divide mitotically to produce multicellular individuals.

The fungal structure that produces gametes is known as gametangium (plural gametangia) and two compatible gametangia are morphologically identical. In some species, the male and female gametangia are morphologically different. In such cases the male gametangium is termed antheridium (pl. antheridia) and female is known as archogonium or ascogonuim (pl. archegonia, ascogonia).

2.5.1 Types of Sexual Reproduction in Fungi

A. **Planogametic Copulation**

This involves fusion of two naked gametes of opposite (+ and -) mating strains. One or both gametes could be motile. This is characteristic of lower fungi.

B. **Gametangial Contact**

The two gametangia grow parallel and close to each other, form a bridge known as fertilization tube. The male gamete migrates through the tube to the female gametangium and fertilizes the female gamete.

C. **Gametangial Copulation**

Here the entire contents of the two contacting gametangia fuse. This takes place by the dissolution of the contacting walls of the two gametangia, resulting in a common cell in which the two protoplasts mix. This method is also called conjugation or gametangiogamy. Example is zygospore formation.

D. **Spermatization**

Some fungi bear numerous, minute multinucleate, spore-like male structures termed spermatia (singular; spermatium). The spermatia are usually carried by wind and deposited on female gametangial hyphae, to which they become attached. A pore develops at the point of contact, and the contents of the spermatium pass into the particular receptive structure that serves as the female organ.

E. **Somatogamy (Somatic Copulation)**

The vegetative cells, not gametes or gametangia are involved in this type of sexual reproduction. Two hyphae meet and fuse, growing dikaryotically (n + n). The two nuclei fuse to form a diploid nucleus and further meiosis gives rise to spores.

2.5.2 Activity

1) Discuss the advantages and disadvantages of reproducing by spores
2) Following release of spores, what mechanisms disperse them?
3) Enumerate and explain asexual reproduction in fungi
4) Compare the types of sexual reproduction in fungi

UNIT 3 CLASSIFICATION OF FUNGI **Session 5**

Objectives

By the end of this session, each student will be able to;

* Discuss the criteria for fungal classification
* State the specific suffices in fungal taxonomic hierarchy
* List and distinguish between the different groups of fungi
* Characterize the major groups of fungi

3.1 Criteria for Fungal Classification

Taxonomy is the branch of science that deals with identification, description and classification of living organisms thereby differentiating between various groups of organisms based on sets of data on structure, development and physiology. It is a dynamic area of study and classification of fungi in particular is in a state of flux and different classification schemes will continue to be espoused by different researchers and differences will continue to exist until the gaps of knowledge among mycologists are filled.

In this course the classification scheme adopted are based on the following criteria;

1) Nature of somatic phase whether unicellular or a mycelium, if the latter, septate or non septate
2) Kinds of asexual spores, sporangiospores or conidia; motile or non motile
3) Number, form and arrangement of flagella in the motile spores
4) Nature of the life cycle (sexual cycle), haplontic or diplontic)
5) Presence or absence of the perfect or sexual stage

3.2 Taxonomic Hierarchies

The following are the suffices for the various ranks/hierarchies in fungal classification as recommended by the International Code of Fungal Nomenclature (ICFN)

- The name of Division of fungi ends in - mycota
- The Sub-divisions - mycotina
- Classes - mycetes
- Sub-classes - mycetidae
- Orders - ales
- Families - aceae
- Genera and species - no specific suffices

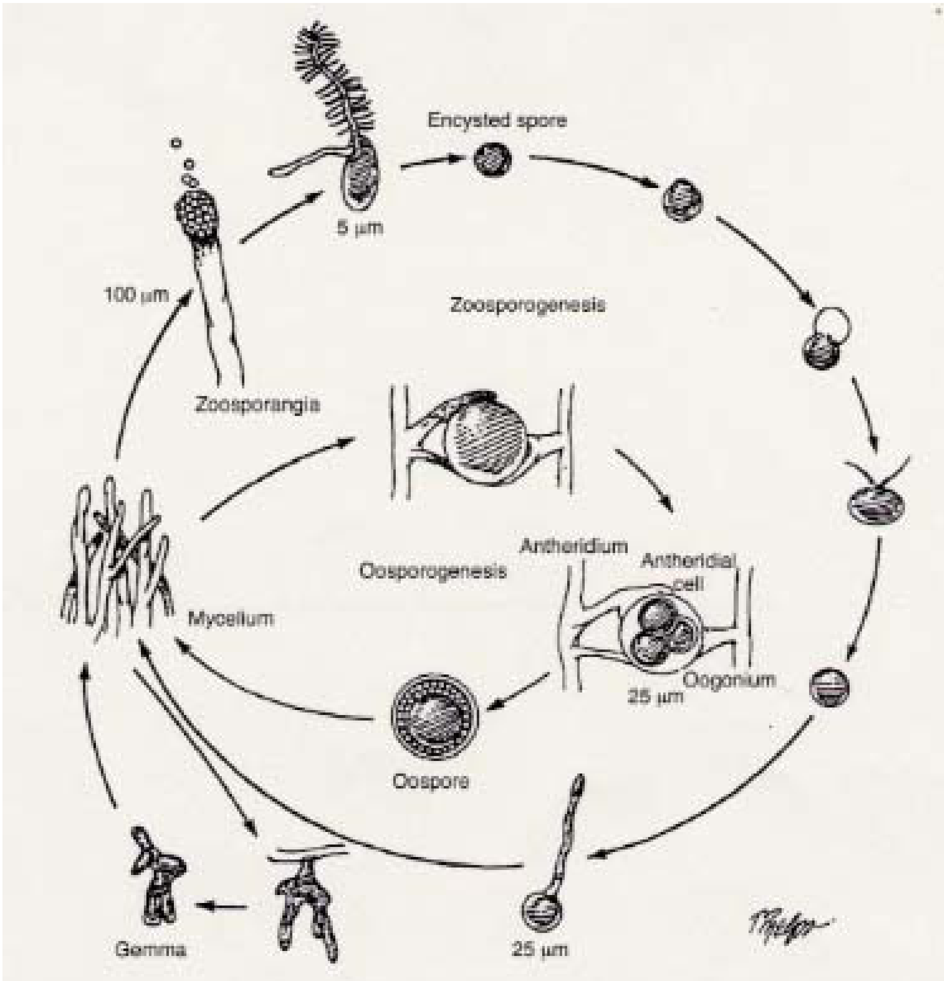
3.3 Class Chytridiomycetes

- Members of this class are commonly called Chytrids and include approximately 800 species that are found in aquatic (freshwater and marine) or moist habitats.

- They have coenocytic hyphae. The unique characteristic of members of this class is the production of motile zoospores, each with a single, posterior, whiplash flagellum.
- They bear intercellular rhizoids used in absorbing food from their substrates.
- They are generally found in damp soils, aquatic habitat, or as parasites of a wide variety of plants animals, algae, protista and other fungi. Few are found in the marine habitat.
- Examples are *Synchytrium brownii, Polycephagus euglenae* and *Synchytrium endobioticum* (causes black wart disease of potato tuber).

3.4 Class Oomycetes

- They are mostly saprophytic or weak parasites.
- Asexual spores are borne on vessels called sporangia and such spores are called sporangiospores.
- When the spores are flagellated they are known as zoospores while the non-motile forms are known as aplanospores and they germinate by germ tube formation.
- They form conidia on specialized hypha called conidiophore.
- Sexual reproduction in Oomycetes takes place by means of specialized organs – the antheridium and oogonium. The oogonia are spherical cells formed at the tip of short branches. When mature they are twice or thrice larger and denser than ordinary hyphae. The antheridia are also formed at the tips of branches and in some species near to the oogonia- each separated by a cross wall.
- The antheridia contain several non-flagellated male gametes.
- The fertilized egg or zygote develops a heavy wall becoming an oospore. It usually will not germinate immediately, even under favorable condition, hence it is well adapted to survive unfavorable conditions.
- Examples of fungi in this class are *Saprolegnia, Pythium, Albugo, Phytophthora infestans* (causes potato blight) etc.

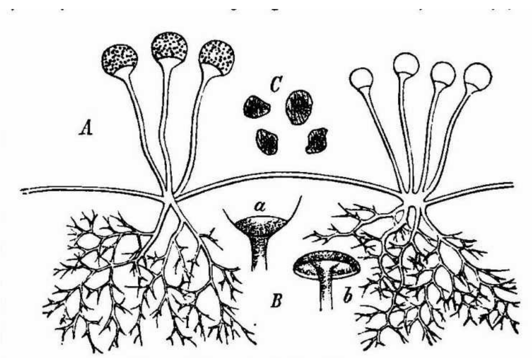


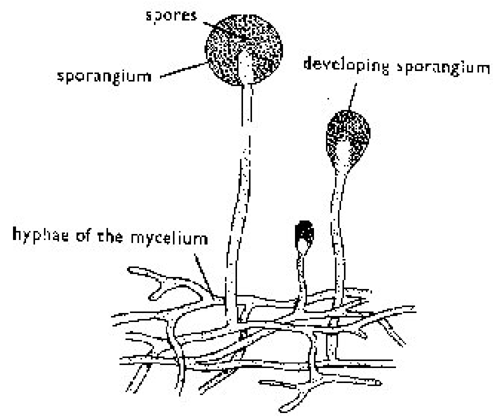
Life Cycle of *Saprolegnia parasitica*

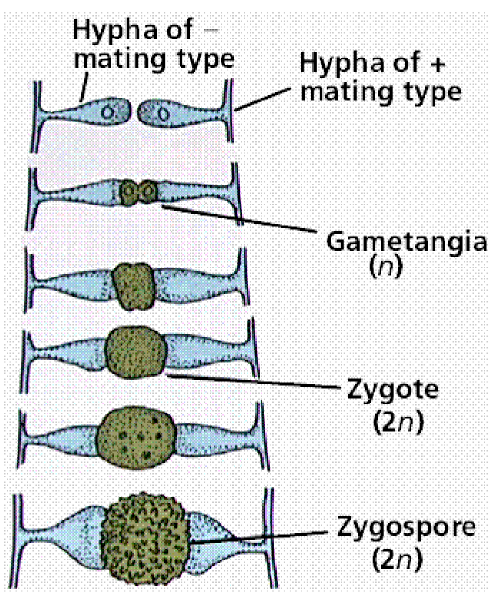
3.5 Class Zygomycetes **Session 6**

- The Class Zygomycetes consists of fewer than 1000 species. The zygomycete hyphae do not have one nucleus per cell, but rather have long multinucleate, haploid hyphae that comprise their mycelia. Asexual reproduction is by spores produced in stalked sporangia.
- They are also known as zygote fungi and the name refers to the production of sexual resting spore which typically results from the fusion of two gametangia.
- No motile cells of any form are found in members of this class.
- All produce typical aerial sporangia or conidia with coenocytic hyphae.
- They produce septa at the base of reproductive organs and at aged parts of the mycelia.
- The mycelia of some species produce rhizoids which adhere them to the substratum.
- Sporangiospores are borne on sporangia while conidia are borne on conidiophores.

- Both Sporangiospores and conidia are asexual spores.
- The gametangia grow together until they touch. Protoplasmic fusion occurs and a zygote is formed. There are three orders in the class zygomycetes; Mucorales, Entomorphthorales and Zoopagales.
- Examples of Zygomycetes are *Pilobolus* (hat throwing fungi), which grows on dung, *Entomorphthora* (fly fungi) and *Rhizopus stolonifera* bread mold.







3.5.1 Activity

1) Explain why the Zygomycetes are considered to be an intermediary group between the lower fungi previously considered and Ascomycetes, Basidiomycetes and Deuteromycetes
2) Indicate the ploidy of the following;

   a. mycelium of *Rhizopus* b. zygospore of *Rhizopus*

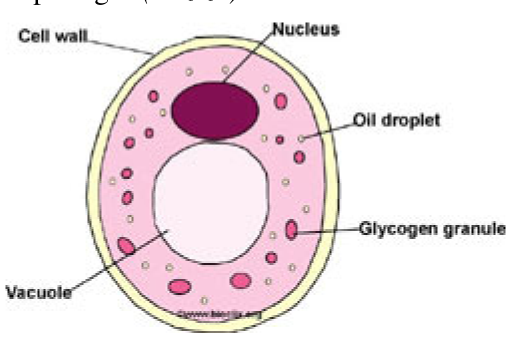
3.6 Class Ascomycetes (Sac-fungi)

- Members include yeasts, powdery mildew, blue green molds, morels and truffles.
- Some are obligate parasites, but most are facultative parasites.
- They have well developed mycelia that are septate and multinucleate (except yeasts).
- Ascomycetes differ from other groups of fungi by their ascus or sac-like structure containing usually definite number of ascospores.
- Eight ascospores are typically formed within the ascus, but this number may vary from species to species.
- Asexual reproduction is by budding, fission, fragmentation, arthrospores, chlamydospores or according to species and the prevailing environmental conditions.
- Sexual reproduction is achieved by gametangial contact, gametangial copulation, spermatization and somatogamy depending on the species. Sclerotia are formed by many species. All fruiting bodies, both sexual and asexual, arise from a stroma (plural stromata) which is a tissue-like mass of hyphae in or from which the fructifications are produced.

The following types of sexual fruiting bodies or ascocarps are recognized;

- Perithecium (plural perithecia), a hollow, flask shaped, or globular ascocarp with a pore (ostiole) at the top and a wall of its own.
- Cleistothecium (plural cleistothecia), a hollow, completely closed, spherical ascocarp.
- Apothecium (plural apothecia), an open ascocarp that is generally disk-like or cup-shaped. It may or may not be stalked. The asci are borne in a palisade layer within the cup.

- Examples of ascomycetes include yeasts *Saccharomyces,* leaf curl fungus (*Taphrina), Aspergillus*, *Penicillium,* powdery mildew (*Erysiphe),* Ergot *(Claviceps),* brown rot *(Monilinia)* and cup fungus *(Peziza).*



3.7 Class Basidiomycetes Session 7

- Members of this class include mushrooms, toadstools, bracket fungi, puffballs and species causing such diseases as wheat rust and corn smut.
- They are the most advanced group of fungi and differ from other groups in that they produce their spores called basidiospores on the outside of specialized structures called basidia.
- Many are saprophytes, being particularly important in the decay of dead forest trees. Others are parasitic and cause considerable damage to forest and orchard trees, wheat, corn onions, roses and many other plants.

Somatic structure

- The mycelium of basidiomycetes is made up of well developed septate hyphae, which penetrate the substratum and absorb nutrients.
- They have dolipore type of septa characterized with swollen, barrel-shaped, perforation and covered by a membranous pore cap.
- The mycelia pass through three distinct stages of development. The first is the primary mycelium, which results from a germinating basidiospore. The cells of the primary mycelium are haploid like the basidiospore, septate and uninucleate.
- The secondary mycelium originates from the primary mycelium. The cells are typically binucleate. The binucleate condition begins with the fusion of the protoplasts of two uninucleate cells without karyogamy taking place after plasmogamy. This is made possible through special structures called clamp connections.
- This is a special feature of Basidiomycetes and the function is to allow the passage of one of the two nuclei into a new daughter cell as the septum is formed. Since this process is unique to this class, it serves a diagnostic function as any mycelium found with clamp connection may be said to belong to this class.
- The secondary mycelium is dikaryotic (n + n) being a product of cellular fusion of primary mycelia from two compatible mating strains. It has two nuclei per cell.
- The third type is the tertiary mycelium composed of complex tissues that form various shapes of basidiocarps and therefore is limited to higher Basidiomycetes that form such fruiting bodies.
- Nearly all Basidiomycetes reproduce sexually and no specialized sex organs (like antheridia and archegonia) are formed. It is usually by conjugation and this can occur;

a) between ordinary hyphal cells
b) between two special cells or
c) between special sperm-like bodies and receptive hyphae.

Some species are heterothallic, i.e. only (+) and (-) strains conjugate.

- Fusion of the two nuclei and subsequent meiosis take place in special cells known as basidia.
- The meiospores formed by these basidia are called basidiospores.

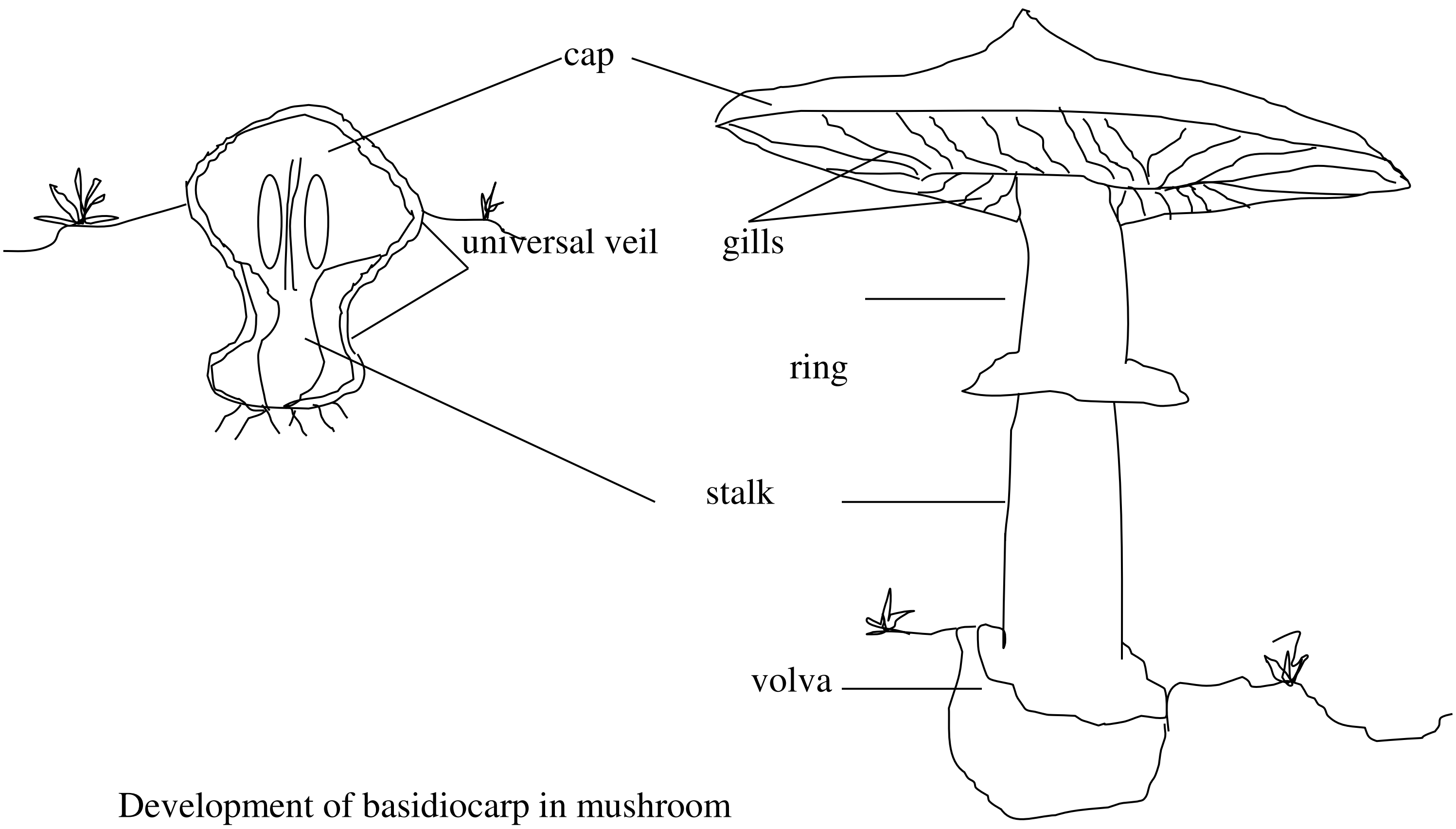
In both types, prior to conjugation the cells of the vegetative mycelium contain a single nucleus, after conjugation the resulting cell contains two haploid nuclei (n + n). The two nuclei in each cell do not fuse until just before meiosis. Fusion of the two nuclei and subsequent meiosis take place in special cells known as BASIDIA.

The common asexual spores found among the smut fungi are the dikaryotic teliospores. They are generally dark colored with thick walls and are produced in large dusty masses called SORI. Other dikaryotic spores are AECIOSPORES and UREDIOSPORES.

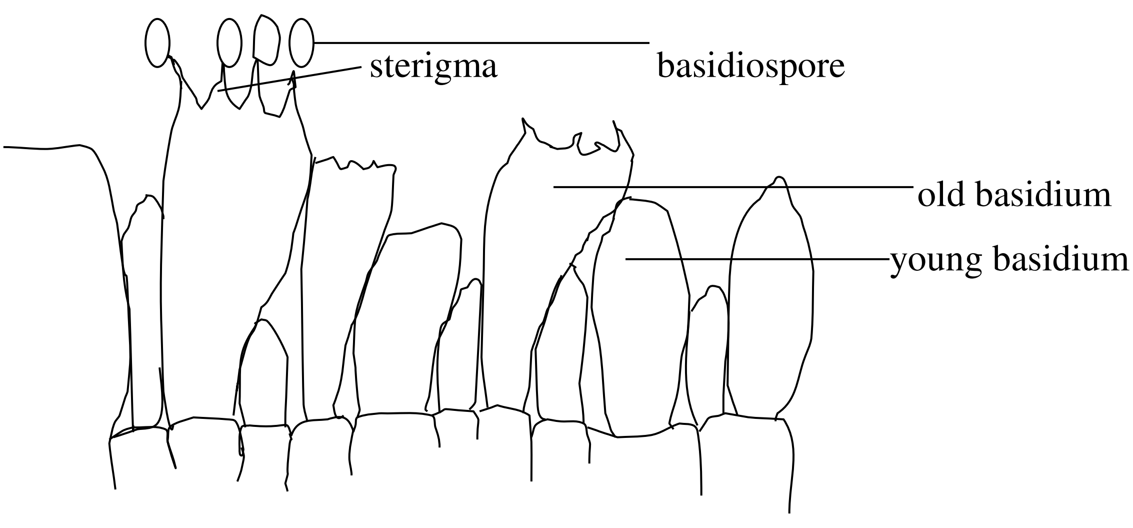
Although both n + n mycelia develop extensively, the n + n phase is of special interest because it gives rise to the spore bearing body or basidiocarp in which the basidia are developed. The hyphae form a tangled mass in the substrate or host and emerge to form a basidiocarp – the mushroom, puffball or bracket fungus. As the basidiocarp grows, the ends of certain hyphae generally become aligned in a layer that will bear spores when mature, known as hymenium.

The basidiocarp of a typical mushroom consists of a short upright stalk or stipe, attached at its base to a mass of mycelium and expanding on top into a broad cap or pileus. Many mushrooms have a ring of tissue around the stipe rather close to the pileus. This ring occurs because when it is young, the pileus was attached to the stipe at this point. The underside of the pileus is formed by thin gills radiating outwards from the stipe. These gills are lined with a hymenium or spore bearing layer. A section of the gill reveals majority of basidiospores attached to the basidia. Four basisiospores are attached to each basidium by short stalks called sterigmata.

When the basidiocarp is in the button stage, it is completely surrounded by a thin tissue known as the universal veil. As the basidiocarp expands, this veil is torn. Part of it remains attached to the cap, where ruptured fragments of it may be seen in the mature mushrooms; the remaining part stays underground forming a cup-shaped structure out of which the stalk grows. The enlarged basal structure is referred to as the volva.



Development of basidiocarp in mushroom



HYMENIUM LAYER

3.8 Class Deuteromycetes (fungi imperfecti)

About 24,000 species of fungi in some 1,200 genera are known only by their asexual stages. The class name fungi imperfecti arises from the custom of calling the sexual stages of fungi perfect stages and the asexual stages imperfect stages. Since only the imperfect stages of this large group of fungi are known, they are called fungi imperfecti.

In general, the structure of the hyphae, which are septate and of spores, suggest that many imperfect fungi may be Ascomycetes; others may be Basidiomycetes. The fungi imperfecti may be considered to be ascomycetes or Basidiomycetes whose sexual stages have not been observed or no longer exist. Their classification is not easy and mycologists face a lot of difficulties, largely because a natural classification is based upon sexual stages and the morphology of sexual and asexual stages is by no means co-coordinated. For instance two forms may have very similar conidial stages but different sexual stages. The various categories of classification in this class are designated as form genera or form families to show that the members of the genera or families do not necessarily have a natural or family relationship.

3.9 Economic Importance of Fungi **Session 8**

1) Decomposers. Many fungi are important in the decomposition of plant debris because of their ability to utilize cellulose. Together with bacteria (as saprobes), they are responsible for recycling many important chemical elements
2) Due to their ubiquitous occurrence and large number, they are the agents responsible for disintegration and deterioration of food, fabrics, leather and other consumer goods manufactured for raw materials.
3) They cause the majority of plant diseases and many diseases of animals and humans.
4) They used in various industrial processes involving fermentation such as bread, wines, beer, and fermentation of cocoa beans and the preparation of cheese.
5) They are employed in the commercial production of organic acids, drugs such as ergometrine, cortisone and of vitamin preparations.
6) They are also important in the production of a number of antibiotics eg. Penicillin and Griseofulvina.
7) They are important research tools for cytologists, geneticists and biochemists. This is due to the rapidity with which some of them grow and reproduce; a much shorter time is required to obtain a number of generations of fungi than of plants or animals.

8) Mycorrhiza. This is a fungal association with the root of higher plants. In some cases, the fungi are unicellular and live without individual root cells, but in many cases, the fungi have typical hyphae that cover the root tips in a thick mat and penetrate between cortical cells. These hyphae do not have haustoria, but contact with the root cells is very close and food is transferred in both directions. Fungi of all types are involved in this association but Basidiomycetes are by far the most common.

PRACTICALS

Two fungal specimens are provided; baker's yeast – *Saccharomyces cervisae* and common bread mold – *Rhizopus stlonifer*.

1. Make a mount of the yeast culture, observe, draw and label.
2. Can you identify the budding yeast cells?
3. Give three important uses of *Saccharomyces cerevisae* and classify it.
4. For the *Rhizopus stolonifer*, describe the hyphae.
5. Examine the sample carefully and note the shape, color and function of the spores.
6. Note the sporangium, sporangiophore, horizontal stolons and the rhizoids.
7. Draw and label the various parts of the fungus.
8. Classify *Rhizopus stolonifer*.

QUESTIONS

1. What are the food storage reserve and cell wall component of fungi
2. In which Class of fungi do Mucorales, Entomorphthorales and Zoopagales belong?
3. Sac fungi belong to which Class.
4. Presence of dolipore septa is a diagnostic feature of members of this Class of fungi.
5. Which fungus causes Ergot disease of rye and what are the benefits derivable from it.
6. Why are Deuteromycetes termed "imperfect"?
7. Name one antibiotic produced from fungi
8. What is the mutualistic relationship between some fungi and higher plant roots?
9. Type of vegetative reproduction whereby small outgrowth emerges from parent cell.
10. Sexual reproduction in Oomycetes is by............................

UNIT 4 ALGAE **Session 9**

Objectives

At the end of this session each student will be able to;

* Identify structures of some algae that help them adapt to specific habitats
* Appreciate the diversity of algae with respect to habitat
* Recognize the ecological role of algae in the aquatic food chain

4.1 Algae – What are they?

The term algae is applied to a large number of organisms, which are highly diverse with respect to habitat, size, organization, physiology, biochemistry and reproduction. Phycology is the study of algae. Ecologically algae are ubiquitous but usually are overlooked unless they are abundant as the sea weeds, pond scum or as water blooms. Based on habitat algae can be categorized into Hydrophytes, Edaphophytes, Aerophytes, Cryophytes and Endophytes. They can also exist in symbiotic relationship with other groups of organisms. Some also grow on fur of animals, on tree barks and damp soils and concrete.

4.2 General Characteristics of Algae

- Algae are autotrophic, non-vascular aquatic or semi aquatic plants.
- They are commonly found in pools, ponds and temporary waters, in lakes, streams, along ocean shores and in surface waters of oceans; on moist surfaces, including the surface of, or in the top few inches of most soil.
- They range from unicellular microscopic forms to multi cellular macroscopic plants many meters in length.
- They all contain chlorophyll a, yet they are so distinctly colored by other pigments, that the type and nature of pigmentation play an important role in their identification and classification.
- Microscopic forms occur in most natural waters including the top 75meters o the ocean. In the ocean they constitute primary food source for the marine animals of the atmosphere through photosynthesis.
- With the giant kelps as exceptions, all the cells of an alga can carry on photosynthesis or are close to cells that can.
- Algae lack roots, stems and leaves, and their plant body is therefore referred to as thallus.

Meaning of ecological terms

Define the following terms and explain how algae survive in each given habitat

Hydrophytes

Edaphophytes

Aerophytes

Cryophytes

Symbionts

4.3 Classification of Algae and their Characteristics **Session 10**

Separation of algae into divisions is based largely upon differences in pigments, food reserves, the ultra structure of the chloroplast, type of flagellation, and the chemical constitution of the cell walls. Thus the algal divisions are largely set up on biochemical and structural differences associated with the biochemical differences, are of secondary importance in determining algal classification. The algae are classified into the following divisions and the comparison of their main features is given below;

Division Chlorophyta

These are the green algae which are common freshwater algae found in streams, lakes, ponds and semi permanent pools. Some inhabit tropical oceans, and other marine habitats. They are grass-green because of chlorophyll a & b. They show great morphological diversity, both in vegetative and reproductive structures. Some genera lack flagella while others produce flagellated gametes. They exist as single cells, filaments or delicate flattened blades. The protoplast in all green is well organized with a definite nucleus and one or more distinct chloroplasts. The chloroplasts vary in shape and size in the various genera and give rise to different arrangements like disc or cup shaped, stellate, reticulate or spiral.

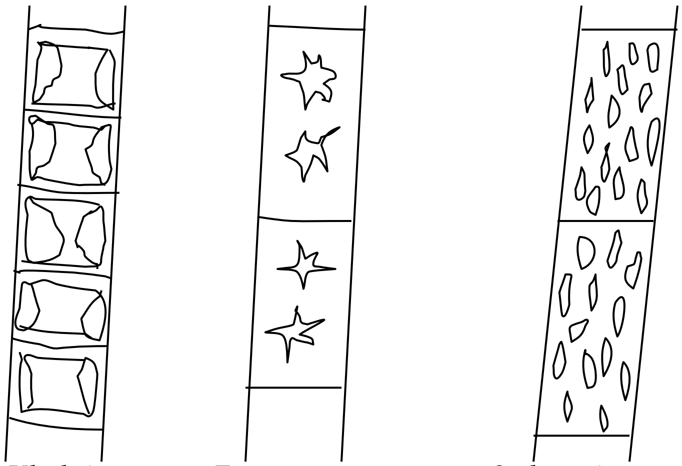
Types of chloroplast and vegetative structures of chlorophyta include;

a) Disc or cup shaped, *Chlamydomonas*.

b) Girdle shaped, *Ulothrix*.

c) Star shaped (stellate), *Zygnema*.

d) Reticulate, *Oedogonium*.



Ulothrix *Zygnema* *Oedogonium*

Examples of filamentous chlorophyta include; *Spirogyra, Ulothrix, Oedogonium, Cladophora.* Colonial forms include, *Volvox, Pandorina, Eudorina*. Flat blade-like thallus is found in Sea lettuce – *Ulva*.

Sexual reproduction occurs by the fusion of two similar or dissimilar gametes by the processes of isogamy, anisogamy, or oogamy.

Asexual reproduction takes place by spores which are of varying type; ciliate spore is called zoospore; a non-motile, non-ciliate spore with a distinct wall of its own but produced within a mother cell is called aplanospore.

Division Phaeophyta

The brown algae are nearly all found in marine habitat and they vary in size from small filamentous forms to huge complex kelps. No unicellular or colonial forms have been identified. They are a very interesting group of sea weeds with variety of peculiar forms and sizes, and comprise about 1,000 species. They are widely distributed along sea coasts between tidal levels on rocky shores. A holdfast attaches the plant to the rocky ocean floor. Photosynthesis occurs in a leaf-like blade or lamina, and a stipe connects the lamina with the holdfast. Bladders are present in some species and aid in buoyancy of the laminae. The food reserves are typically sugar, laminarin (a complex soluble carbohydrate), oils and complex alcohols; no insoluble carbohydrates are formed. The inner layer consists of a slimy, gelatinous material called algin. Members of the phaeophyta include; *Fucus, Laminaria, Ectocarpus*.

Asexual reproduction is occasionally by fragmentation, or by zoospores. Sexual reproduction is various; both isogamous and anisogamous forms are found. An alternation of phases occurs, with a strong tendency towards a reduction of the gametophyte, the large kelps are sporophytes, and in *Fucus* the gametophyte phase is present only as gamete (no multicellular gametophyte). The motile cells, either zoospores or gametes, are pear-shaped with two unequal flagella attached at the side. The brown algae are complex and well developed giving rise to definite gametophytes and sporophytes. Plants that produce gametes are known as gametophytes, and those that produce meiospores are known as sporophytes. It follows that gametophytic plants are haploid and sporophytic plants are diploid.

Division Rhodophyta

The red algae form a big group of highly specialized marine algae comprising about 3,000 species. Many species form a characteristic belt of vegetation along the sea coast between the high tide and low tide levels. They mostly grow attached to rocks. There are however, some epiphytic and parasitic forms. Red algae are characterized by red or purple color due to the presence of a red pigment called phycoerythrin in addition to chlorophyll which is often masked by the other pigments. They show a variety of vegetative forms; filamentous, ribbon-shaped, and distinctly leaf-like with veins. Gelatinous material is abundant in red algae, either occurring within the thallus or forming a sheath in the filamentous forms. Some of them are heavily encrusted with lime. The cells may be uninucleate or multinucleate. There is total absence of motile ciliate cells in this division, zoospores are altogether absent, and gametes are never ciliate. Examples are *Polyphyridium, Polysiphonia* and *Batrachospermum.*

Division Chrysophyta **Session 11**

This group includes the golden brown or yellow brown algae and diatoms. They are commonly found in both freshwater and marine habitats. Diatoms may be unicellular, sometimes forming colonies, each cell containing a nucleus and two or more chloroplasts in which are found chlorophylls a and c; plus various yellow and brown pigments. Food reserves are in form of chrysolaminarin (a complex carbohydrate) and oils, no starch is formed. The wall of each diatom cell consists of two overlapping halves composed of pectic substance, impregnated with silica (one of the chief constituents of glass). The walls do not decay. Exceedingly beautiful and delicate markings are found on the walls. Many diatoms move about slowly through a long, narrow opening or cleft that runs down the center of the top half.

Diatoms may be boat-shaped, rod-shaped, discoid, wedge-shaped, spindly, circular, oval, rectangular, etc. The wall of diatoms is made of 2 halves, one the older, bigger epitheca that fits over the younger, smaller hypotheca giving rise to a pill-box or soap case structure. The ornamentation which is a special feature of diatom valves, and it is radially symmetrical in the round or centric diatoms in the order CENTRALES and bilaterally symmetrical (in two series, one on each side of the valve) in the elongated or pinnate diatoms belonging to the order PENNALES.

Asexual reproduction is by cell division (mitosis), during which the overlapping walls come apart, each partially enclosing one of the new protoplasts. A new half wall is secreted inside the old one and is always smaller than the older half. This mode of asexual reproduction leads to formation of successive smaller cells. The original size is restored by formation of AUXOSPORES. Here, the protoplasts of two diatoms fuse to form an enlarged auxospore, which is really a zygote in this case and the protoplasts the gametes.

The zygote increases several times in size to the maximum size of the species and then secretes new siliceous walls. The vegetative stage of the diatom is diploid, meiosis occurs with the formation of gametes during auxospore stage. Examples are *Pinnularia, Nitzchia, Coscinodiscus, Navicula, Surirella* etc.

Division Euglenophyta

The euglenoids are simple, unicellular organisms. They are flagellated and are difficult to refer to them as belonging to the plants or animals kingdom. Mostly freshwater, naked, single cell, free-swimming organisms and elongated in shape with one end blunt and the other end tapering. Usually have single, long, slender whip-like flagellum which aids locomotion. Protoplast contains a central nucleus, several green plastids, a contractile vacuole, a red spot near the blunt end, called the eye spot. It feeds itself by photosynthesis and also by ingesting solid particle as food from the surrounding water.

Euglenoids are not known to reproduce sexually. They multiply by dividing longitudinally into two, starting with the nucleus. Under favorable condition, the protoplasmic contents contract and become surrounded by resistant thick wall. This is known as CYST – a resting spore. The cyst germinates under favorable conditions when the wall becomes mucilaginous and the protoplast divides into 2, 4, or more cells. Members of the euglenophyta include *Euglena* and *Phacus*.

Division Pyrrhophyta

These are the dinofagellates and they are mostly marine although a few fresh water species abound. They contain chlorophyll a and c, peridin and other carotenoids. Cell wall components are absent but most species have cellulose plates interior to the plasma membrane, and the plates are grouped into armor like arrangements that are important for identifying the various genera in this group. The dinoflagellates have the most distinctive arrangements of flagella among the unicellular algae; the rhythmic beating of these flagella propels the diniflagellates through water. Examples are *Peridium* and *Protoperidium*.

DIVISION	HABITAT	PHOTOSYNTH. PIGMENT	CELL WALL COMPONENT	CARBOHYDRATE STORAGE	FLAGELLA
Chlorophyta (green algae)	Mostly freshwater, some marine, terrestrial or airborne.	Chlorophylls a & b, carotenoids	Polysaccharides including cellulose	Starch	None, 1-8 or dozens; whiplash
Phaeophyta (brown algae)	Almost all marine, rarely freshwater	Chlorophylls a & c, fucoxanthin and other carotenoids	Cellulose, alginic acid & sulfated polysaccharides	Laminarin, Mannitol	2 lateral, forward tinsel, behind whiplash
Rhodophyta (red algae)	Mostly marine, some fresh water	Chlorophyll a, carotenoid, phycobilins	Cellulose, pectin, calcium salts	Floridean starch	None
Chrysophyta (diatoms, yellow green, golden brown algae)	Marine & freshwater, some terrestrial or airborne	Chlorophylls a & c, fucoxanthin & other carotenoids	Cellulose or silica shell, sometimes absent	Chrysolaminarin	1 or 2 whiplash or tinsel
Euglenophyta (euglenoids)	Marine or freshwater, some airborne	Chlorophylls a & b, carotenoids	Absent	Paramylon	1 – 3, tinsel
Pyrrhophyta (dinoflagellates)	Marine and freshwater, some airborne	Chlorophylls a & c, peridin and other carotenoids	Armor-like plates that may be cellulosic	Starch	None, or 2 tinsel

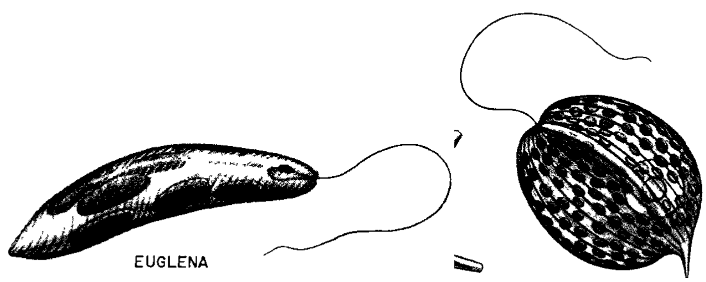
4.4 Range of Structures (Morphology) of Algae **Session 12**

Algae range in forms from simple unicellular, through colonial, filamentous, siphonous to the complex parenchymatous thalli of the large sea weeds. Algae plant body is not differentiated into true roots, stem and leaves thus they are referred to as thallophytes. They do not also have conductive vessels (except probably in some kelps). Generally they have simple structural organization and their sex organs are usually unicellular, if multicellular (in few exceptions) they are never surrounded by sterile layer of cells (usually for protection).

Unicellular forms

Simple isolated cells are found in all groups except the Phaeophyta (brown algae) while in some groups they are the only forms represented eg Bacillariophyta (diatoms). Unicellular algae may be of three types;

a) Rhizopodial eg *Chrysoamoeba* and *Ochromonas* (both Chrysophyta)
b) Protococcoidal (non-motile) eg. *Chlorella*
c) Flagellated (motile) eg. *Chlamydomonas, Euglena*



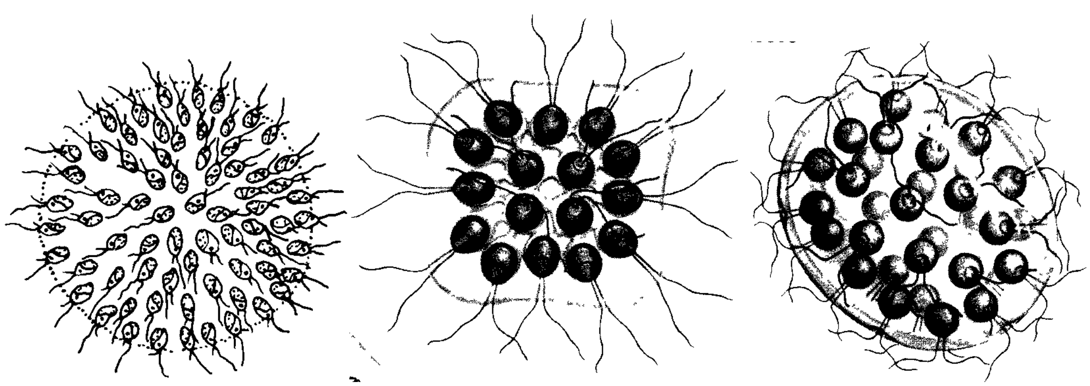
Multicellular thallus organization

Colonial

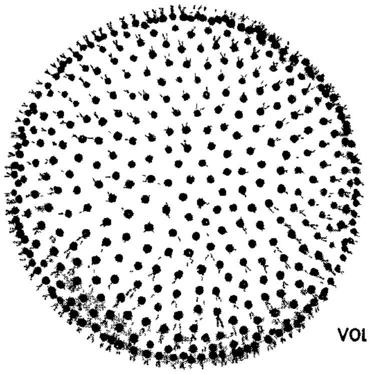
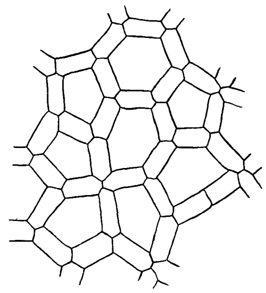
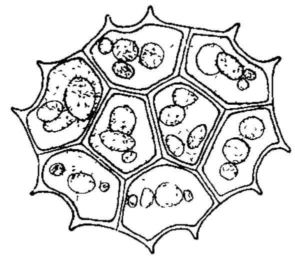
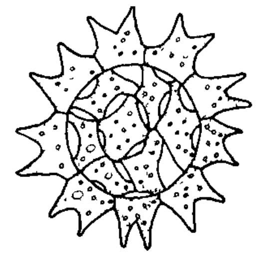
A colony is formed when several unicells come together and by so doing lose their individuality. Algal colonies may be motile or non-motle.

Motile colonies are *Uroglenopsis*, *Pandorina*, *Eudorina* and *Volvox*

Non-motile colonies include *Hydrodictyon reticulatum* and *Pediastrum boryanum*



Uroglenopsis *Gonium* *Eudorina*

Volvox aureus *Hydrodictyon reticulatum* *Pediastrum boryanum* *Pediastrum duplex*

4.4.1 Activity

1. Discuss the differences between the three groups of unicellular thallus organization
2. Study the organisms indicated as representative examples of motile and non-motile colonial structure

Aggregation

Under unfavorable conditions some single cells may fuse together to form a single unit. This is facilitated by the secretion of mucilage by the component cells or a situation whereby the cells are embedded in a gelatinous matrix. These cells resume their normal life cycle under favorable conditions as the mucilage dissolves and they become single cells. There are two types of aggregate thallus arrangement;

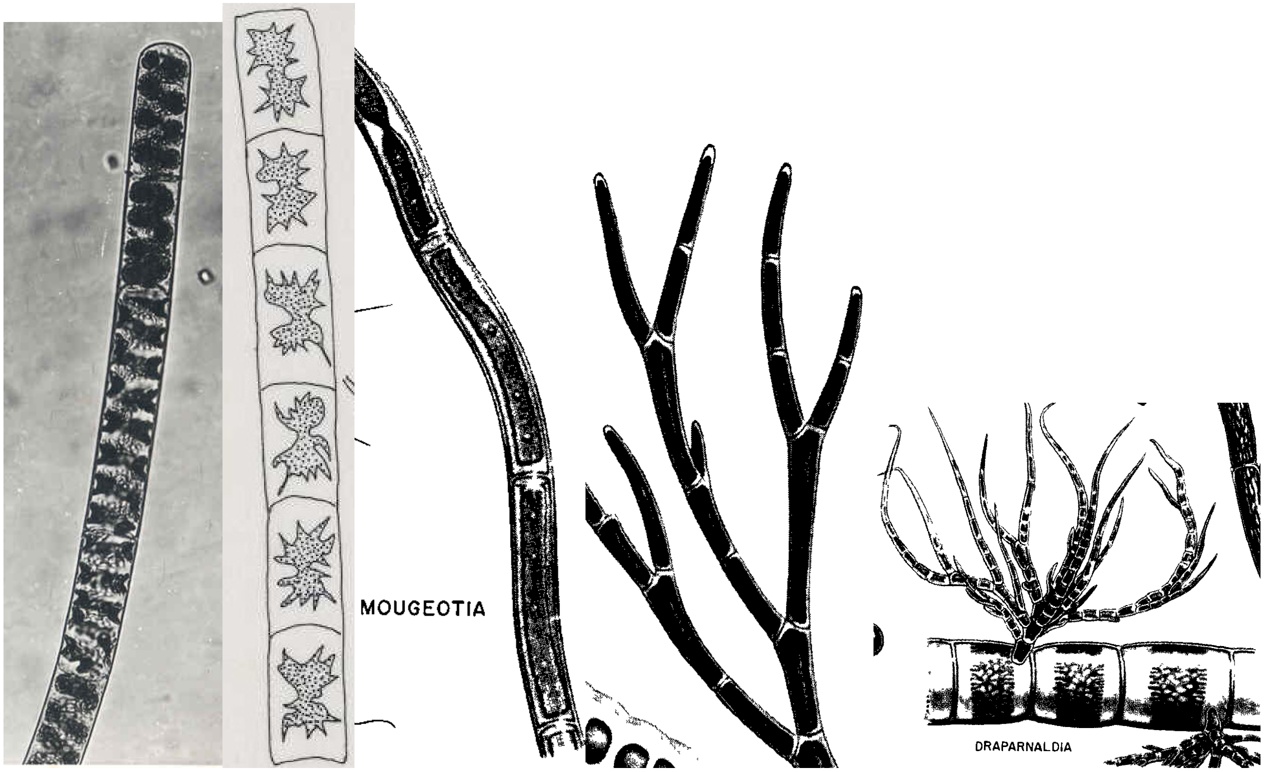
a) **Palmelloid** eg. *Tetraspora*
b) **Dendroid** eg. *Parasincladus*

Note: The mucilage which holds the cells in aggregation is either produced by the protoplast of the cells or arises by the gelatinization of their cell membranes.

Filamentous

These are characterized by vegetative cell division but the cells after division do not separate and are arranged in a linear row. These filaments or threads are of the following types;

a) Simple or unbranched filaments. There are few algae with this structure and they are usually free-living or sometimes attached. Examples *Spirogyra*, *Oedogonium*, *Ulothrix* and *Zygnema*
b) Branched filaments. There are three types of branching in algae
    i. A simple branching system attached to the substratum by a basal disc secreted by the lower cells
    ii. The heterotrichous type with a basal attachment and upright branches referred to as the erect portion and a prostrate portion which may be poorly developed in some species.



Spirogyra *Zygnema* *Cladophora*

Siphonous

This type of thallus is confined to a few genera in the Xanthophyta and Chlorophyta. The thallus is multinucleate but not divided into cells (except during formation of reproductive structures) in many forms the thallus can be elaborate and big in size. This thallus structure is referred to as acellular

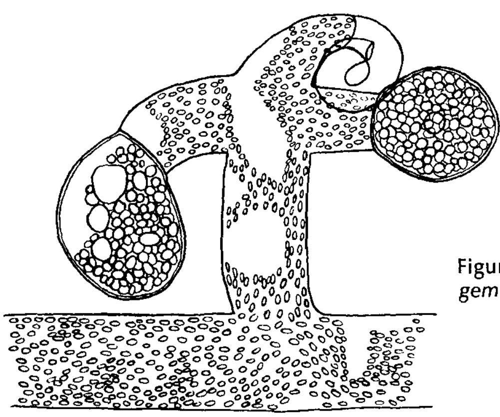


Figure 38.—*Vaucheria geminata.*

Parenchymatous

When vegetative cells division takes place in more than one plane the structure so formed is termed parenchymatous. This is the most advanced type of thallus structure in algae and its maximum development is found among the sea weeds especially the Laminariales and Fucales. The thalli of some brown algae show marked anatomical differentiation to the extent of developing sieve like members for conducting manufactured food.

4.4.2 Activity

1. Compare colonial and aggregate thallus organizations
2. Compare all the thallus organizations and decide which type is more advanced and comparatively closely related to the tissue organization in higher plants
3. Which multicellular thallus structure is unique?
4. Draw a representative for each (unicellular and multicellular) thalli organization

4.5 Reproduction and Alternation of Generations in Algae **Session 13**

Reproduction involves replication or increase in the number of individuals in a population. There are three modes of reproduction in algae; vegetative, asexual and sexual.

Vegetative Reproduction: all those processes of propagation in which portions of the plant body becomes separated from the parent plant and give rise to new individuals without any obvious change in the protoplast. Common examples are fragmentation or breaking off of parts of filamentous algae and fission in unicellular forms. The blue green algae have special vegetative reproduction called hormogones.

Asexual Reproduction: this involves the rejuvenation of the protoplast of certain cells of the algae giving rise to numerous spores both motile and non-motile.

Sexual Reproduction: this involves the fusion of two cells, gametes or gametangia and proceeds in three stages; plasmogamy or cytoplasmic fusion, karyogamy or nuclear fusion and genetic recombination. There are two types of sexual reproduction in algae;

1. Isogamy: the pairing or fusion of similar gametes is known as isogamy. Usually the gametes come from two different individual filaments or sometime from two different cells of the same parent plant.
2. Heterogamy: the fusion of two dissimilar gametes is known as heterogamy and it has two main variations
   a) Anisogamy; the two motile gametes involved may differ in size (morphological anisogamy) orr physiological behavior (physiological anisogamy)
   b) Oogamy; here male gametes (antherizoids) are flagellated whereas the female gamete (egg) is larget and non-flagellated. The gametangia producing the two types of gametes are distinct in shape from the rest of the vegetative cells and are called antheridia and oogonia respectively

4.6 Life History

This is the process which begins with one individual and continues till a new generation of similar individual is produced. During development an alga passes through a number of distinct phases, the sequence of which s called life history. The life history of algae includes two alternating generations, the gametophyte and sporophyte.

There are different types of life cycles in algae;

1. Diplontic life cycle eg. *Sargassum*

   The only haploid structures in this type of life cycle are the gametes. Upon fusion of the gametes, the diploid nature of the thallus is restored and the mature thallus is diploid.
2. Haplontic life cycle eg. *Chlamydomonas*

   In a haplont life cycle, the only diploid phase is the zygote. Meiosis follows immediately after the fusion of gametes and the resulting mature thallus will be haploid.
3. Two morphological phases; haploid gametophyte and diploid sporophyte

   Gametophyte is always haploid and saprophyte diploid. The haploid gamete producing generations alternates with a diploid spore producing generation in a complete life cycle. Both gametophyte and sporophyte may be morphologically alike (isomorphic eg. *Ectocarpus*) or look different (heteromorphic eg. *Laminaria*).
4. Three morphological phases (Red algae only) eg. *Polysiphonia*

   This comprises of three distinct individuals in one life cycle.
   a. Haploid gametophyte
   b. Diploid carposporophyte (usually develop on female gametophyte) and
   c. Independent tetrasporophyte

4.7 Economic Importance of Algae **Session 14**

1) In addition to supplying food directly for human and animal consumption, the algal photosynthetic process supplies oxygen to life in water. The diatoms and the pyrrhophyta are known as the "grass of the sea" and form the basis of the ocean food chains.

2) When abundant in water supplies (especially greens and blue-greens), they form blooms that impart obnoxious odor and flavor to water. Such large numbers may cause difficulties in the filtration processes of treatment plants. In oceans, "Red tides" occasionally occurs as a result of billions of cells of dinoflagellates usually of the species *Gymnodinium* or *Gonyaulux*. These algae produce toxins that cause high fish mortality during such red tide outbreaks. When ingested by other organisms like mussels, they may be dangerous for human consumption as a result of the accumulation of toxins (bioaccumulation).

3) Agar-agar. This is a gelatinous substance obtained from red algae *Gelidium* and *Gracilaria*. It is a good bacterial and fungal culture medium. It is used as a base substance for shoe polish, shaving cream, cosmetics etc. it is also an emulsifying agent, as a dying and printing material for textiles.

4) Since the siliceous walls of diatoms do not decay, they accumulate at the bottom of water over time forming diatomaceous earth. This is used as metal polish, in toothpaste, paints and plastics manufacture. They are also useful as filters in the filtration of liquid e.g. in sugar refining and as heat insulator in boilers and furnaces.

5) Ash obtained from burnt kelps is an excellent source of iodine and potassium. Kelps are also harvested for their algin content. Algin is a colloid used in stabilizing many dairy products. It imparts a consistency and prevents the formation of ice crystals.

EXERCISE

- **List the different groups of algae**
- **Characterize the various groups of algae**
- **Identify representative species of the major groups of algae**
- **Explain the features of major groups of algae**

ACTIVITY

Discuss the diversity of cyanophyta, chlorophyta, phaeophyta, rhodophyta and chrysophyta.

Describe the thallus organization of the brown algae and differentiate between the life cycles of *Ectocarpus* and *Fucus*.

What are the special features of the life cycle of *Polysiphonia*?

Describe the diatom frustule and what is their ecological importance in the ocean?

UNIT 5 BRYOPHYTES **Session 15**

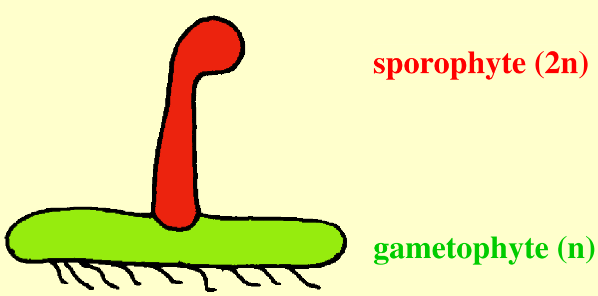
Objectives

Like the rest of land plants, the Bryophytes are Embryophytes (plants that produce an embryo) and they have traditionally been viewed as a distinct lineage from other land plants. They are not considered to have given rise to the vascular plants but they probably were the earliest land plants. Like the rest of the land plants, they evolved from green algal ancestors, closely related to the Charophytes. They are a group of simple land plants, well-adapted to moist habitats. Like other land plants, the Bryophytes:-

- have multicellular sex organs, i.e. the gametes are enclosed by a sterile jacket of cells
- are parenchymatous, not filamentous
- retain the zygote within the female sex organ and allow it to develop into an embryo there
- have cutin (a cuticle) on the plant and spores
- All bryophytes exhibit definite alternation of generations. A haploid plant producing gametes alternates with a diploid plant; gametophyte and sporophyte respectively.
- The gametophyte is nutritionally independent and structurally more complex than the sporophyte. It bears the male and female sex organs; antheridia and archegonia respectively.

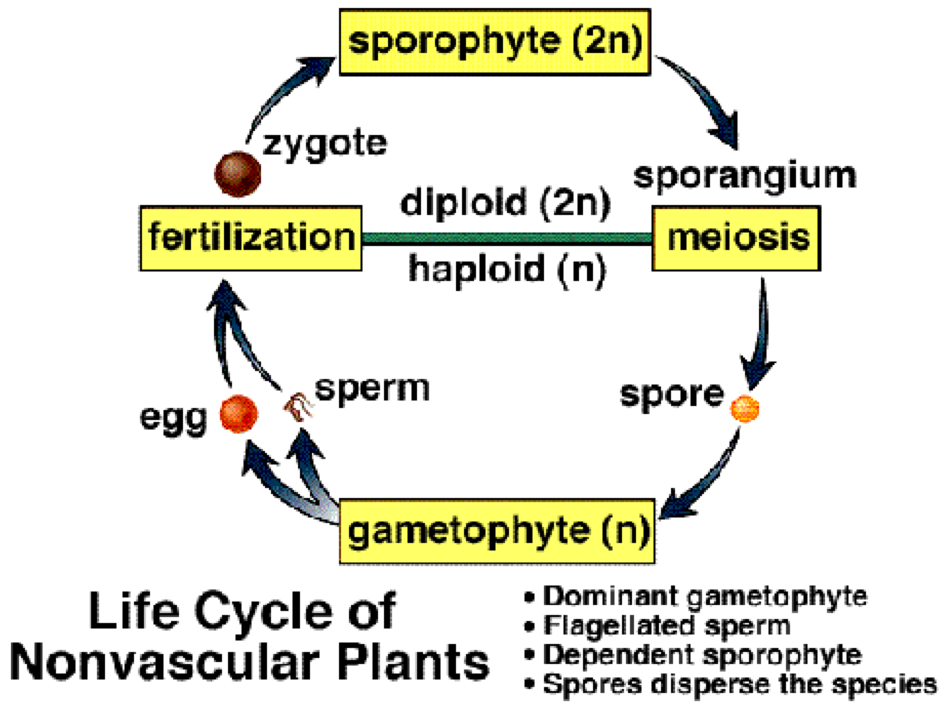
Bryophytes, in contrast,

- have no lignin usually
- are small, low-lying, (generally) moisture-loving plants
- have no roots, only filamentous rhizoids



THE ONLY LAND PLANTS WITH A DOMINANT GAMETOPHYTE!

The sporophyte is parasitic on the gametophyte. This stems from the embryo being retained in the female sex organ of the gametophyte.



Resemblances between Bryophytes and Algae **Session 16**

1. Thallus-like plant body
2. Lack of vascular tissues
3. Absence of roots
4. Conspicuous plant in the life cycle being the gametophyte
5. Autotrophic mode of nutrition
6. Retention of swimming habit of sperm which indicates algal ancestry of bryophytes
7. Early stages of gametophytic development of many bryophytes are green filaments strikingly resembling filamentous thallus of green algae
8. Identical chlorophyll compliments in the vegetative cells of bryophytes and green algae.
9. Carbohydrate food reserve in both bryophytes and green algae is true starch made up of two kinds of glucose macromolecules, amylase and amylopectin
10. The bryophytes and green algae have much in common at the level of cell structure and metabolic pathways.

Similarities between Bryophytes and Pteridophytes

The features in which bryophytes resemble pteridophytes are;

a) Terrestrial habitat
b) Development of embryo after gametic union
c) Development of embryo within the archegonium protected by multicellular maternal tissue.

d) Similar type life cycle characterized by heteromorphic alternation of generations
e) Presence of cuticle
f) Presence of stomata except the liverworts
g) Multicellular sex organs with a jacket of sterile cells
h) Presence of water essential for fertilization

5.2 Classification of Bryophytes

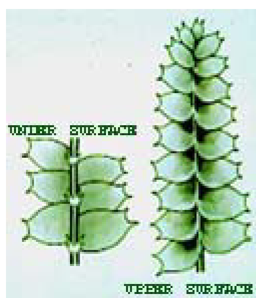
Bryophytes are divided into three main classes; Hepaticae (liverworts) Anthocerotae (hornworts) and Musci (mosses). In some texts these classes are treated as Divisions Hepaticophyta, Anthocerotophyta and Bryophyta for mosses. These are generally viewed as three monophyletic lineages emerging from the very earliest land plants.

Class Hepaticae

There are two groups of liverworts, leafy and thallose; we focus on the thallose type which is just about the most primitive true plant alive today. The leafy liverworts can easily be confused with mosses. Some are leafy (leafy liverworts) and greatly resemble mosses while others are thalloid (thalloid liverworts); and the thallose type is just about the most primitive true plant alive today.

Examples of leafy liverworts

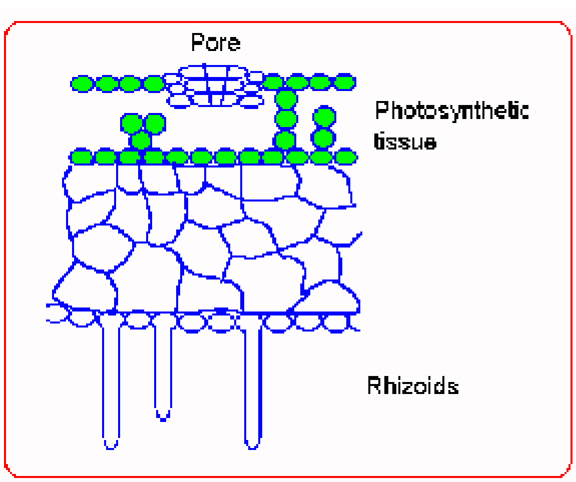
The leafy liverwort *Bazzania*



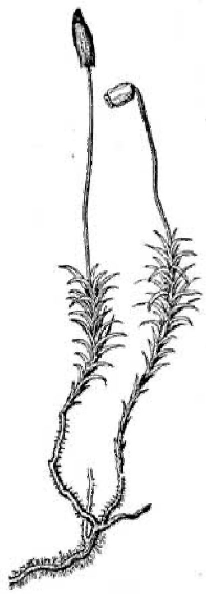
Lophocolea

Example of thallose liverworts

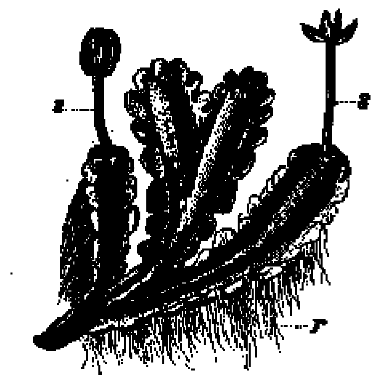

Kny's Wall Chart Showing Male Gametophyte of *Marchantia* a thallose liverwort



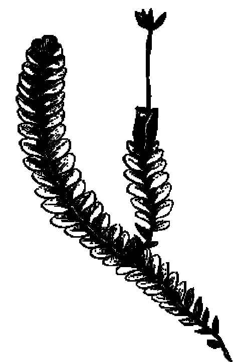
The thallus, seen here in section, shows little external differentiation (no stem or leaves) and internally there is little differentiation either.



Moss -
radially symmetrical
rhizoids multicellular
leaves with or without a midrib



Thallose liverwort -
bilaterally symmetrical
rhizoids unicellular

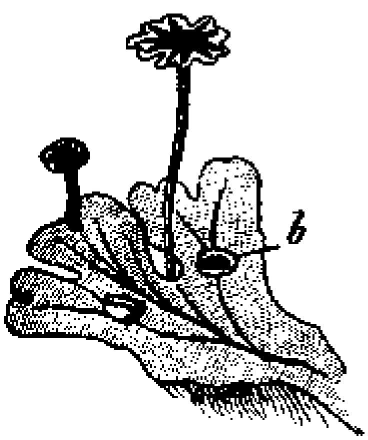


Leafy liverwort -
bilaterally symmetrical
rhizoids unicellular
leaves without a midrib

Reproduction in Liverworts **Session 17**

Liverworts have two means of vegetative reproduction;-

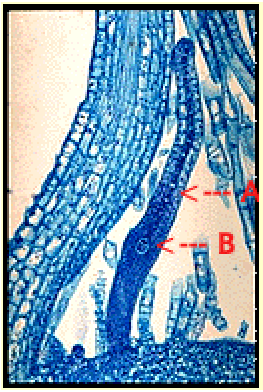
1. **fragmentation** - pieces of the gametophyte breaking off
2. **gemmae -** specialised propagules produced mitotically.



In some liverworts, gemmae are produced in cup-like structures called gemmae cups (labelled b, at left).

Sexual Reproduction

The gametophytes (which are the stage of the life cycle we recognise as the liverwort) bear male sex organs termed antheridia (antheridium *sing.*) and female sex organs termed archegonia (archegonium *sing.*).



Flask-like archegonium (A) with single egg cell (B) at base of canal.

Biodisc photomicrograph

- Archegonia form on underside of umbrella-shaped structures called archegoniophores
- Antheridia form on upper surface of disk-shaped cap called antheridiophores
- They are widely distributed in places throughout the world, but are most common in the tropics.
- A few species are found floating or submerged in water, and some others in sites that are alternatively wet and dry

Classification of Hepaticae

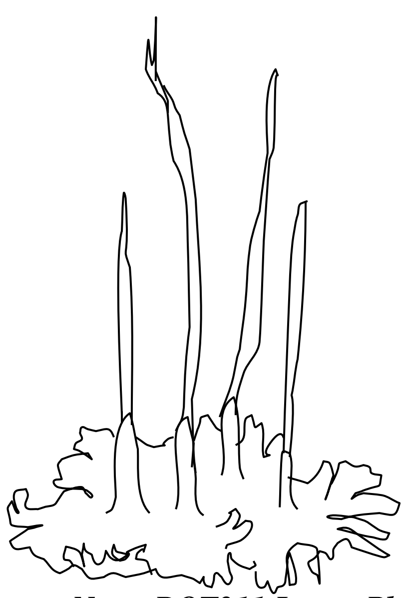
There are seven orders in the class hepaticae with several genera namely;

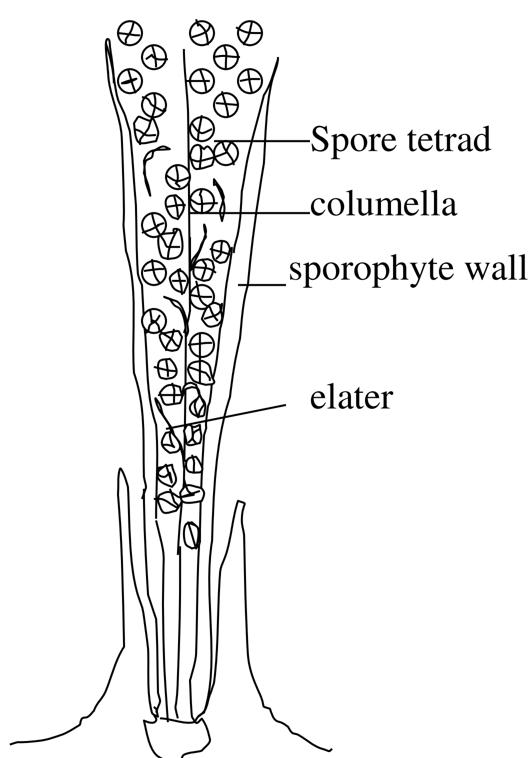
Order Marchantiales	*Conocephalum*, *Marchantia*, *Raboulia*, *Riccia*, *Ricciocarpus*.
Order Sphaerocarpales	*Riella*, *Sphaerocarpos*.
Order Monocleales	*Monoclea*.
Order Metzeriales	*Fossombronia*, *Pallavicinia*, *Pellia*.
Order Jungermanniales	*Cephaloziella*, *Frullania*, *Jungermannia*.
Order Haplomitriales	*Haplomitrium*
Order Takakiales	*Takakia*.

Class Anthocerotae **Session 18**

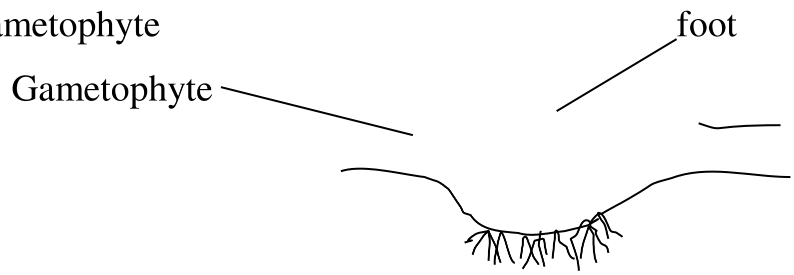
- These are also known as hornworts and always grow on moist substrates, including soil and logs.
- They rarely inhabit tree trunks or bare rocks.
- Most grow in shades, but *Notothylas* species tolerate full sunlight.

- *Anthoceros* is the most familiar species in the temperate zone, others being chiefly tropical. They have the simplest gametophytes of all bryophytes.
- The gametophytes of hornworts are flat, dark green thallus and structurally simpler. They are small green thallus plants with little internal differentiation of vegetative tissues.
- They are slightly lobed with numerous rhizoids growing from the lower surface; either annual or perennial.
- The pores and cavities are filled with mucilage rather than air and the mucilage usually contains cyanobacteria.
- Hornworts are unisexual and gametangia form on the upper part of the thallus but their development is distinctive.
- The antheridia are formed from special cells lining the inner surface of the mucilage chambers near the upper surface - roofed chambers in the upper portion of the thallus.
- The archegonia are formed from superficial cells, but the archegonia do not completely surround the egg, thus the archegonia are embedded within the thallus and in direct contact with the surrounding vegetative cells.
- The sporophyte of anthocerotae has subepidermal cells that contain chloroplasts and typical stomata are also found on the epidermis.
- A foot embedded in the thallus is the absorbing organ. The sporangium is an upright elongated structure.
- Spores mature in progression from top down.
- Hornworts sporophytes have tapering tips, distinct epidermis and stoma-like structures.
- The sporophyte remains photosynthetic and can live for several months while spores are released over time.





Hornwort gametophyte



Representative Genera and Species of Hornworts

Phaeoceros species are common in rain forests and on shaded, muddy soil beside streams, rivers and other damp places. They have short, much branched thalli which form almost circular rosettes. They lack *Nostoc* cavities. Capsules are 3 to 4cm high and they produce yellow-brown spores.

Anthoceros species look similar but have *Nostoc* cavities and black spores.

Notothylos species is very common in all parts of Africa. It forms small, dark, green rosettes on level, wet soil and sometimes in waterlogged soil during wet season. It differs from other hornworts in that the capsule stops growing when the tip has just appeared through the surface of the thallus. The structure of the sporophyte is simpler and there is no columella.

Class Musci **Session 19**

- Gametophytes are radially symmetrical and "leaves" usually with a midrib
  - Rhizoids are multicellular and most are unisexual
  - Archegonia form on end of shoot and have one egg
  - Antheridia found on terminal shoots, produce many flagellated sperm
  - Some species actually have conducting tissues
- Sporophytes
  - Begins with formation of zygote
  - Mature sporophyte has three parts

    Foot - absorbs water, minerals, and food

    Seta - raises the capsule

    Capsule - sporangium may have stomata
  - Haploid spores grow into gametophyte
- Mosses are perennial and remarkably successful plants that thrive alongside more conspicuous vascular plants.

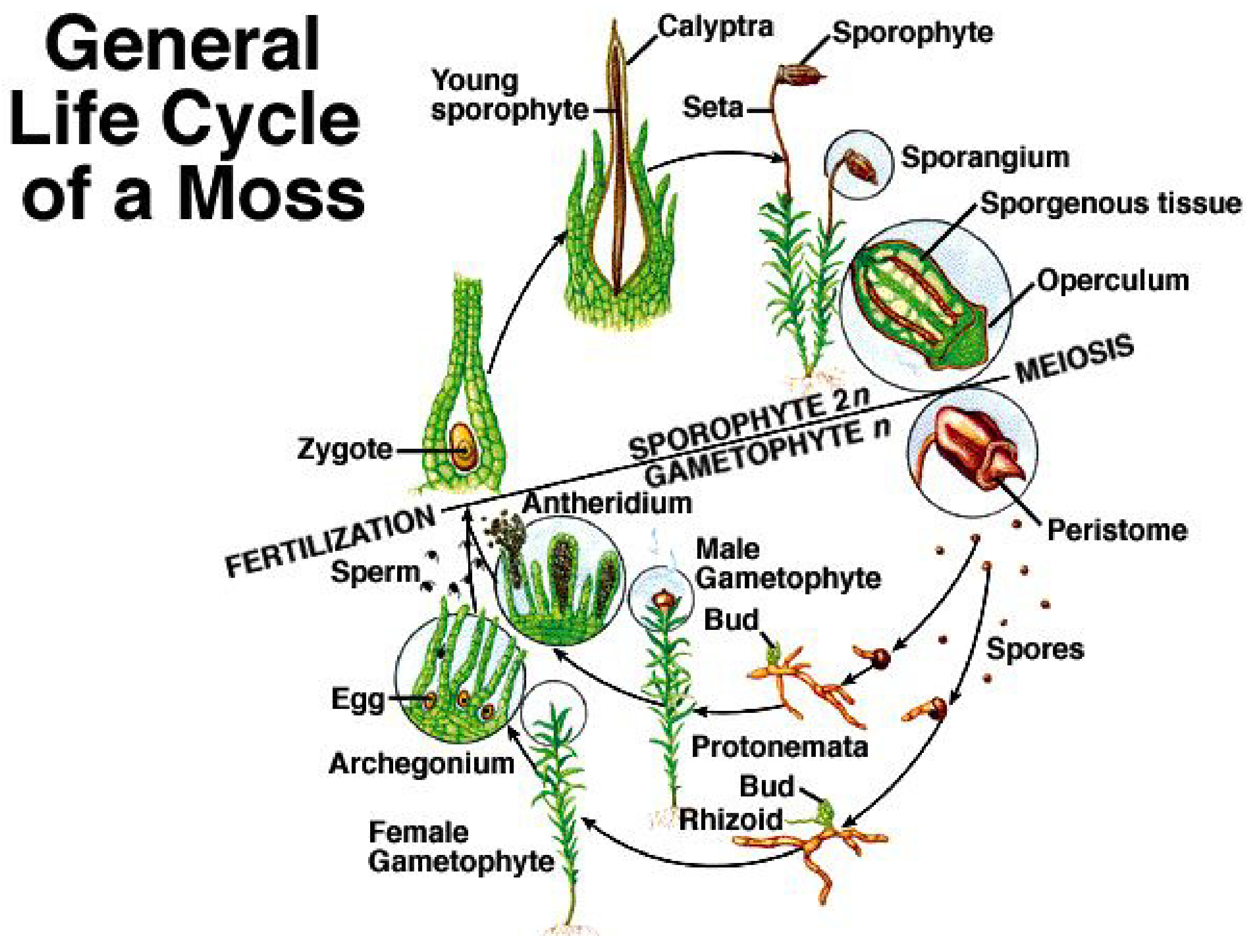
- The approximately 12,000 species of mosses make up the largest and most familiar group of bryophytes.
- Musci as a class show great structural uniformity.
- Some are prostrate while others are erect and vary in size from a few millimeters tall to half a meter in some species of *Sphagnum, Polytrichium, Dawsonia* and *Fontnalis*.
- Often desert mosses pass almost completely unnoticed until moistened by rain, and change from dull brown to bright green Gametophytes of nearly all species have two growth stages;
  a)creeping filamentous stage (protonema) from which develops
  b) the moss plant with an upright or horizontal stem bearing small, spirally arranged green leaves. Rhizoids are found at the base of the stem.

Ecological Role of Bryophytes

Many are pioneer plants, growing on bare rock and contributing to soil development. In bogs and mountain forests they form a thick carpet, reducing erosion. In forest ecosystems they act like a sponge retaining and slowly releasing water. They provide habitat for other plants and small animals as well as microorganisms like N_2-fixing blue-green bacteria. Lacking a cuticle and transport tissue they readily absorb whatever is around them and can serve as bioindicators of pollution and environmental degradation

Economic Importance of Bryophytes

Bryophytes today have limited economic importance. Some are edible although liverworts were soaked in wine and eaten in the 16th century. Mosses are used as stuffing in furniture, as soil conditioner, as fuel and absorbent in oil spills. Because of its acidity, the moss *Sphragnum* has been used by aboriginal people as disinfectant and for dressing wounds. North American Indians used *Mnium* and *Bryum* to treat burns



Representative Genera and Species

Moss taxonomy is characterized by a few genera with large number of species.

Fissidens grandifrons is a common and conspicuous moss plant found in waterfalls and rapids of small streams. The frond is flattened, with two rows of dark green leaves, superficially giving the appearance of liverworts. It is easily recognized as a moss by its relatively thick leaves, dark green color and lack of notched leaves.

Polytrichium juniperinum is a relatively common species well adapted to frequently dry habitat. Leaf structure is more complex than in other mosses. From the upper surface of the leaves there arise a number of parallel plates thin-walled photosynthetic cells separated from each other by narrow fissures. The lower part of the leaf is made up of thick, sclerotic cells, the leaves roll up longitudinally closing the air spaces and protecting the chlorenchyma layer from drying.

Tortula ruralis is a very common desert moss growing on soil.

Grimmia apocarpa is another desert moss growing on rock especially basalt.

Species of *Funaria* and *Bryum* are frequent along the edges of shrubbery or in footpaths and cracks of sidewalks.

QUESTIONS

1. Describe the distinguishing features of bryophytes. In what aspects do they differ from algae and pteridophytes?
2. Give a general account of Bryophyta with special reference to its classification
3. Define alternation of generations. Point out the differences between the alternations in algae and bryophyte
4. List the salient features in the life cycle of bryophytes
5. Describe the general features of the classes of bryophytes
6. Write an essay on general characteristics and classification of bryophytes

Objective questions

1. The spore producing organ in bryophytes is

   A. foot B. Seta C. Capsule D. Archegonium
2. The haploid or gametes producing generation is commonly known as

   A. sporophyte B. Gametophyte C. Adult D. All of the above
3. The condition of producing only one type of spore is called

   A. Heterospory B. Apospory C. Homospory D. Autospory
4. Which of the following is not a character of bryophytes

   A. presence of archegonium B. independent sporophyte

   C. motile sperm D. water is essential for fertilization
5. Gametophytic generation is dominant in

   A. Bryophyte B. Pteridophyte C. Gymnosperm D. Angiosperm
6. Which of the following statements is NOT TRUE of bryophytes?

   A. they are photosynthetic

   B. they lack tracheids and sieve and sieve tubes

   C. their zygote and the sporophyte are haploid

   D. the spores germinate and produce gametophyte
7. The female gametangium of a bryophyte differs from that of a fungus in possessing

   A. large neck B. a venter

   C. jacket of sterile cells D. a single egg cell

Vascular Cryptogams (Seedless vascular plants)

The seedless vascular plants consist of four divisions of non-seed bearing vascular plants namely; Psilotophyta (whiskferns), Lycopodiophyta (club mosses) Sphenophyta/Equisetophyta (horsetails) and Polypodiophyta (true ferns). Features that enable members of these groups to thrive on land include;

- a resistant cuticle
- complex stomata
- vascular tissue
- absorptive root hairs and
- desiccation resistant spores.

They share some features with bryophytes, including the same type of pigments, storage of starch as their primary food reserve and basic life cycle. However the evolution of functional vascular tissue among others enabled vascular plants to invade and dominate drier habitats on land and effectively than non-vascular plants.

They have chlorophyll a, b and carotenoids as photosynthetic pigments; same as found in bryophytes and green algae with starch as their food storage reserve and presence of cellulose cell wall. The sporophytes and gametophytes are nutritionally independent. The sporophyte is the dominant generation.

Reproduction

They are homosporous or heterosporous. The spores are produced in sporangia which may be borne on sporophylls, either scattered or arranged in definite organ called stribilus cone. Heterosporous species bear two types of sporophylls – microsporophyll and megasporophyll. Most ferns bear sporangia on the abaxial surface of mature leaves in structures called sori. The sporangia may be eusporangium (developed from several sporangial initials) or leptosporangium (developed from single initial). Spores produced in strobili are usually wind dispersed. A strobilus is essentially a stem tip with several closely packed sporangia. However the strobilus is one of the most significant developments in reproductive organization among plants because it is older than cones in gymnosperms and flowers in angiosperms.

Organs that produce gametes and spores in the Pteridophytes are similar in several ways to those of bryophytes. Antheridia and archegonia are multicellular and protected by a layer of sterile (non-reproductive) cells. The antheridia are spherical or ovoid and embedded partly or wholly in the gametophyte while the archegonia are flask shaped. Each antheridium produces many sperm cells but each archegonium has only one egg cell.

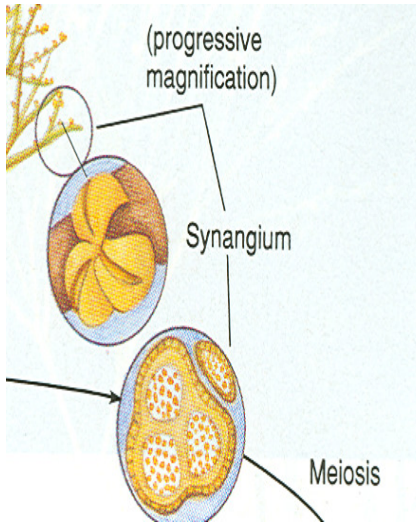
The gametophyte/prothallus is formed by the germination of the spore and it is a small and inconspicuous structure. Gametophytes from homospores are termed exosporic – they grow upon the soil and form independent plants. They have thin delicate thallus with numerous rhizoids e.g. *Psilotum*, *Lycopodium*, *Ophioglossum*. Gametophytes from heterosporous pteridophytes are termed endosporic because they are retained within the original spore case. They utilize the food reserve in the spore.

Fertilization is facilitated by water medium; the zygote gives rise to the embryo which divides repeatedly and develops into young sporophyte.

Pteridophytes are currently divided into 4 divisions.

Division Psilotophyta (whisk fern)

- Members of this division are mostly fossils except two living genera; *Psilotum* and *Tmesipteris*. They are rare plants mainly found in the tropics.
- *Psilotum* is a slender tufted perennial herb 15 – 60 cm or more in length, grows as an epiphyte on tree trunks, or on rocky slopes with little organ differentiation.
- The plant shows conspicuous dichotomous branching. It has a slender, subterranean rhizome and slender, green aerial branches.
- True leaves are absent, and sporangia developed on tips of some branches, and typical quartets of spores suggesting normal meiosis have been observed.
- Sporangia of *Psilotum* are actually considered to be three sporangia fused together in a three-lobed structure called synangium.
- Rhizoids growing from the rhizome absorb moisture and nutrients and anchor the plant to the soil.
- The gametophytes of *Psilotum* are perennial and usually grow under the soil.
- They are achlorophyllous and live saprophytically on soil rich in organic matter or in symbiosis with mycorrhizal fungi.
- Antheridia protrude slightly above the surface and produce multiflagellate sperms.
- Archegonia are slightly sunken and have necks shorter than those of bryophytes.
- Water medium is necessary for fertilization of the egg by the sperm.
- Fertilization is followed by the development of young sporophyte within the archegonium.
- The zygote forms a foot and an embryonic stem.



Division Lycopodiophyta (Club mosses)

- These are commonly known as club mosses, although they are in no way in resemblance with the mosses.
- They include about 1,100 species in 15 genera of 3 families. There is one living genus from each family in our modern flora: *Lycopodium, Selaginella* and *Isoetes*.
- They are primarily tropical but they also form a conspicuous part of the flora in temperate regions.
- Various species of *Lycopodium* and *Selaginella* have been used as ground cover and ornamentals in exterior plantings as well as in green houses and home display.
- *Lycopodium* spores have been used medicinally as a pill coating.
- The division still is of great economic significance for the production of coal. The lycopods that thrived in the past periods were responsible for many of our coal deposits.
- The short fleshy axis pf *Isoetes* has been used as food for man; it contains a lot of starch and oils.
- However the major importance of the genus is probably that it serves as food for water birds, muskrats and many aquatic wild animals.

Division Equisetophyta (Horsetails)

- Members of this division once grew very abundantly, as in evident in their good representation in fossil records. Today the division has one genus *Equisetum* with about 25 species.
- Most species are characterized by the presence of silica in the epidermis of their stems and they are commonly known as horsetails.
- The sporophyte of *Equisetum* is the dominant phase of its life cycle.
- The stem has distinct nodes and internodes. Meristematic tissue occurs above the nodes, which are sheathed by whorls of small, brownish, short-lived leaves.

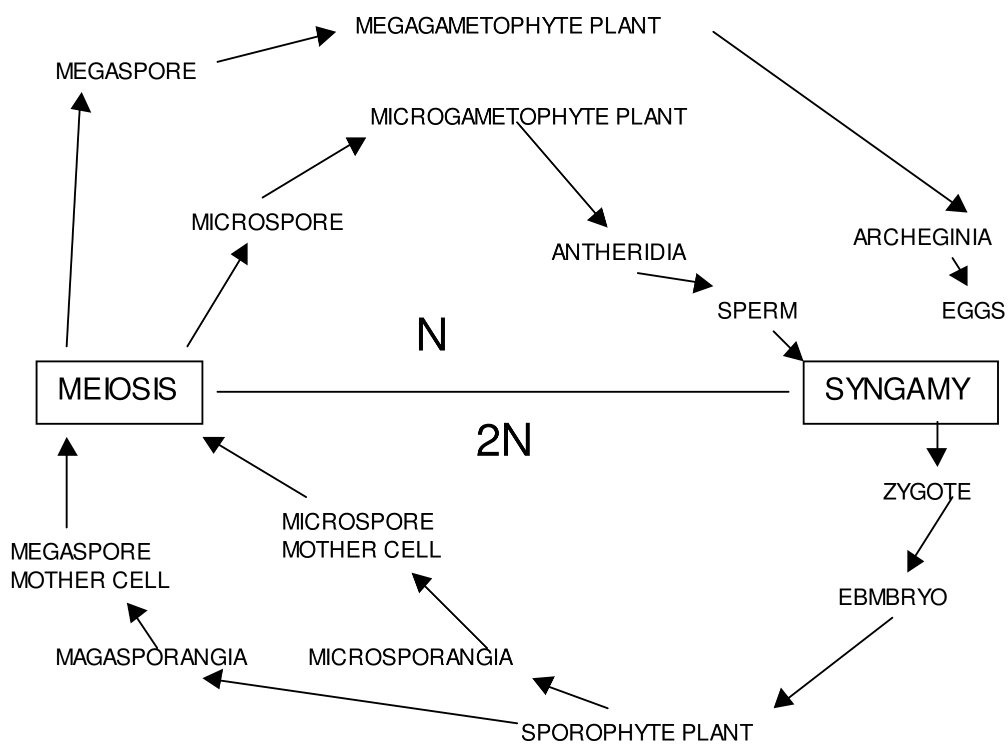
- Photosynthesis is carried out by the green stems. Roots occur only at the nodes of the rhizomes or bases of upright stems.
- The gametophytes are green bodies about the size of a pin head and consist of a cushion-like base with many erect, delicate lobes.
- The sporangia are stalked, shield-shaped structures borne at right angles to the main axis of the cone and borne on sporangiophores.
- The archegonia produce the egg and the antheridia the antherizoid mother cell which gives rise to numerous sperm cells.
- Fertilization is in water medium and results in a diploid (2n) oospore which gives rise to an embryo that develops into a branching rhizome. This subsequently produces erect aerial shoots and numerous adventitious roots.
- At the present time *Equisetum* is neither ecologically important on a world basis, nor of great economic value.
- About a century ago it was used for scrubbing and polishing floors, pots and pans.
- Their fossils contributed much to the world's coal deposits. It has often been suggested that silicon being an essential element in the plant nutrition due to *Equisetum* accumulating large amounts and therefore shows promise as a genus in which the details of silicon metabolism could be studied and elucidated.

Division Polypodiophyta (Ferns)

- This division comprises of the ferns (about 7,600 species), most of which are shade-loving plants of small size, their upright leaves or fronds generally being their most prominent feature.
- Ferns are basically terrestrial plants that grow well in moist, shady, cool places.
- They are able to grow and reproduce when there is abundance of water, either free water or very moist soil.
- All ferns are perennial and herbaceous and range in size from small aquatic to giant tree ferns that may grow to over 12 m tall.
- Ferns exhibit alternation of generations with sporophyte generation being large and long-lived (dominant phase).
- The two generations are independent at maturity.
- The sporophyte is always photosynthetic, and the gametophyte is usually so, but in some species are subterranean, colorless, saprophytic and mycorrhizal.
- The fern sporophyte is differentiated into true stems, roots and leaves with vascular supply.
- Young fronds are CIRCINATE ie. coiled inwards on the upper surface and are characterized by great apical growth and present only in the ferns.

- The young leaves are commonly called fiddleheads.
- The lateral leaflets borne by the axis or rachis are known as the pinnules. As the leaf expands, it uncoils and becomes flat. This is true not only for the rachis but of the leaflets too.
- Generally, sporangia are thick or thin walled, homosporous or heterosporous, borne on unmodified foliage or on specialized fertile leaves.
- Gametophyte or prothallus is a flat, green, heart-shaped structure with rhizoids on its lower surface.
- They may be short lived and bear both antheridia and archegonia. The antheridia are borne lower down the gametophyte, closer to the rhizoids. The archegonia are borne closer to the notched end of the gametophyte and consist of a short neck, venter that encloses the egg cell.
- Fertilization occurs when moisture is present with the sperm swimming to the neck of the archegonium.
- The resulting zygote is diploid and rapidly develops into an embryo sporophyte; comprising of foot, root, stem and leaf. The embryo develops directly into a young sporophyte.

Heterospory



ECONOMIC IMPORTANCE OF PTERIDOPHYTES

While ferns are not used in industry, they are of economic importance in some rather specialized ways especially in medicine, food and as ornamentals.the rhizomes of *Polypodium glycerrhiza* are used commercially to a limited extent in flavoring pipe tobacco. The juice extracted from rhizomes of *Ophioglossum vulgatum* and *Botrychium lunaris* were used to stop vomiting, nose bleeding and treat ulcer. The now seldom used de-worming drug – Aspidium is obtained from *Dryopteris filix-mas. Athyrium filix-fermina* and *Pteridium aquilineum* are also reported to be useful in controlling worms in both livestock and humans. The old foliage of all three species, but especially *D. filix-max,* has been reported to be poisonous when used in large quantities. An extract of *P. aquilineum* is used as an astringent (a substance that draws tissues together). *Adiantum pedatum* was used by the American Indians in making ointments for treating inflammation of the skin.

Marsilea vestita has been used in some places as horse fodder. It is also considered a weed in areas where its growth gets out of control. Some species of *Pellaea* are poisonous to livestock. *Salvinia molesta* – a native of South America has been introduced to almost all continents and has become a serious weed. It has been seriously considered as a source of livestock fodder as it is reported to produce over 100 tons of dry matter per hectare annually.

Blue green algae live symbiotically with the fern *Azolla.* It has been established that, for example in China over 3 million acres of rice fields planted with *Azolla* containing nitrogen fixing species of *Anabaena* as symbionts.

Several ferns are cultivated as ornamentals; among these are *Woodwardia fimbrianta, Polystichum lonchitis* and species of *Adiantum* and *Woodsia*.