Semester	Course	Hours	Credit	Sub. Code	Marks		
					Internal	External	Total
I	CC 1	6	5	18KP1B01	25	75	100

PLANT DIVERSITY I (ALGAE, FUNGI AND BRYOPHYTES)

UNIT I: ALGAE

Introduction– Classification (F. E. Fritsch 1935-1948). Phylogeny of Algae- Thallus organization – Ultra structure of Prokaryotic and Eukaryotic Algae. Reproduction and Life cycle of Algae. Ecology of Algae, Freshwater and Marine Algae, Terrestrial Algae, Phytoplankton, Epiphytic, Parasitic and Symbiotic algae. Fossil Algae.

UNIT II:

Salient features of Protochlorophyceae, Cyanophyceae, Chlorophyceae, Charophyceae, Xanthophyceae, Bacillariophyceae, Phaeophyceae, Rhodophyceae, Economic importance of Algae.

UNIT III: FUNGI

Introduction, Classification (Alexopoulos and Mims 1979) Phylogeny of Fungi. General characters of Fungi, Ultra structure, Mode of nutrition- Reproduction – Life cycle, Culture of fungi, Heterothallism, Parasexuality and Fossil Fungi.

UNIT IV:

General characters and reproduction of Myxomycotina, Mastigomycotina, Zygomycotina, Ascomycotina, Basidiomycotina and Deuteromycotina, Economic importance of Fungi.6

LICHEN: General characters, Classification (Miller -1984), Distribution, Thallus organization and Reproduction of Lichens. Ecological and Economic importance of Lichens.

UNIT V: BRYOPHYTES

General characters, Classifications (Rothmaler-1959), Structure and Reproduction of Hepaticopsida - (Marchantiales, Jungermanniales) Anthoceroptopsida (Anthocerotales) Bryopsida (Funariales and Polytrichales), Economic importance of Bryophytes, Evolution of Sporophytes, Fossil Bryophytes.

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Unit – I & II

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Source of Study Material

1. Pandey.S.N., S.P.Misra and P.S. Trivedi. 2002. A Textbook of Botany Volume II. Vikas Publishing House Pvt Ltd, New Delhi
2. Alexopoulos, C.J., C.W. Mims and M. Blackwell. 2007. Introductory Mycology. IV Edition. Wiley India (P) Ltd., Daryaganj, New Delhi.
3. Rashid.A. 2007. An Introduction to Bryophyta – Vikas publications, New Delhi.

UNIT I - ALGAE

Introduction To Algae

Algae (singular **alga**) is an informal term for a large and diverse group of photosynthetic eukaryotic organisms. It is a polyphyletic grouping, including species from multiple distinct clades. Included organisms range from unicellular microalgae, such as *Chlorella* and the diatoms, to multicellular forms, such as the giant kelp, a large brown alga which may grow up to 50 m in length. Most are aquatic and autotrophic and lack many of the distinct cell and tissue types, such as stomata, xylem and phloem, which are found in land plants. The largest and most complex marine algae are called seaweeds, while the most complex freshwater forms are the Charophyta, a division of green algae which includes, for example, *Spirogyra* and stoneworts.

Classification of Algae - F. E. Fritsch (1935-1948)

Algae are simple autotrophic plants showing following diagnostic characters - • Thalloid plant body. • Autotrophic mode of nutrition with few exceptions. • No vascular tissue. • Sex organs, whether unicellular or multicellular, are without a layer of jacket. • Zygote never develops into an embryo. • Life cycles of various types. The primary classification of algae is based on certain morphological and physiological features . These are… • Pigment composition • Chemical nature of reserve food • Kind, no., point of insertion and relative length of flagella • Presence or absence of a definite nucleus Many algologists gave classification of algae but most authentic and comprehensive classification was proposed by F. E. Fritsch (1935) who published his voluminous work in the form of a book entitled “Structure and Reproduction of Algae” in two volumes. He classified algae into 11 classes.

These are 1. Chlorophyceae (green algae) 2. Xanthophyceae (Yellow-green algae) 3. Chrysophyceae 4. Bacillariophyceae (Diatoms) 5. Cryptophyceae 6. Dinophyceae (Dinoflagellates) 7. Chloromonadineae 8. Euglenophyceae 9. Phaeophyceae (Brown algae) 10. Rhodophyceae (Red algae) 11. Myxophyceae (blue green algae).

1. Chlorophyceae – Fresh water, marine and terrestrial - unicellular motile forms,colonial,nonmotila thalli as well as filamentous thallus. -Dominant pigment chl a and b alogwith carotenoids - Reserve food starch but oil in perennating structures. -Motile cells with equal flagella of same length -Sexual rep iso to oogamous. -Meiosis usually zygotic -Life cycle usually haplontic.

2. Xanthophyceae - Freshwater or terrestrial -Dominant pigments chl a and e and βcarotene and a special xanthophyll -Reserve food oil and leucosin -Motile cells with unequal flag. of diff types -Sex rep predominantly iso rarely oogamous -L.C. haplontic with zygotic meiosis

3. Chrysophyceae - Mostly freshwater sometimes marine . - Chl a and c and an excess of phycochrysin (yellow orange) pigments)Reserve food oil and leucosin -Sex rep rare, when present isogamous -Motile cells have 1 or2 flagella of equal or rarely unequal length.

4. Bacillariophyceae – Freshwater as well as marine -Cell wall silicaceous with two halves - Chl a and c, β- carotene ,and xanthophylls (lutein and fucoxathin) - -Reserve food oil, chrysolaminarin and a prot. reserve food- volutin -Motile stages with 1 or 2 tinsel flagella - Meiosis gametogenic -Sex rep isogamous with the formation of special spores- auxospores. - Life cycle monogenic and diplontic

5. Cryptophyceae – Found in cold and subsurface of freshwater as well as marine habitat - Pigment chl a,c, β - carotene, xanthophyll, phycocyanin and phycoerythrin but these are different from those of cyanophyceae -Reserve food starch ,pyrenoid present - Mostly motile with unequal flagella - Sexual reproduction isogamous..

6. Dinophyceae - Freshwater as well as marine and unicellular, motile biflagellate forms. - Pigments chlorophyll a and c, βcarotene, phycoerythrin, red peridinin -Reserve food starch and fat. - Sexual rep rare, when presentisogamous.

7. Chloromonadineae - Simple freshwater forms -Bright green due to an excess of chlorophylls and xanthophylls. - Reserve food fat -Rep by longitudinal div

8. Euglenineae - Found in freshwater as well saline habitat - Unicellular motile forms with one or two flagella -Cell wall absent , pellicle present. -Pigments chl a and b -Rep by fission.

9. Phaeophyceae – Mostly marine. Simplest thallus organization is heterotrichous filamantous thallus. Higher forms are large bulky parenchymatous thalli which may attain a length of several meters. - Chromatophores have chl a and c, β-carotene, fucoxanthin. - Reserve food laminarin and mannitol - Motile rep structures with two laterally inserted flag. of unequal length and type - Sexual rep. - isogamy to oogamy . - L.C. digenic with isomorphic or hetermorphic alternation of generations. or monogenic(diplontic) eg members of order fucales

10. Rhodophyceae – Majority are marine with a few exceptions. -Pigments are chl a, d, β-carotene, rPhycocyanin and r-phycoerythrin. -Reserve food is floridean starch. -Presence of pit connections common. Motile stages completely absent in the life cycle and the male gamete is known as spermatium. -Sexual rep oogamous, female sex organ – carpogonium and male sex organ spermatangium.The zygote never released from carpogonium. -Formation of a fruiting body – the carposporophyte ,as a result of postfertilisation changes. - Meiosis sporogenic and zygotic - L.C. trigenic.

11. Myxophyceae – Freshwater, terrestrial , epiphytic, endophytic and symbiotic. -Main pigments chl a, β-carotene, xanthophylls, c-phycocyanin and cphycoerythrin, allophycocyanin. - Reserve food glycogen, cyanophycean starch, metachromatin granules . -Conventional sexual rep absent.

Thallus Organization

1. Unicellular - Motile and non-motile
2. Aggregates - Palmelloid and Dendroid
3. Colonial - (a) Colony motile, (b) Colony non-motile
4. Filamentous - (a) Un-branched (b) Branched - (i) Simple (ii) Heterotrichous, (iii) Pseudoparenchymatous.
5. Siphonaceous
6. Parenchymatous

Ultra structure of Prokaryotic Algae

Prokaryotic cells lack membrane-bounded organelles (plastids, mitochondria, nuclei, Golgi bodies, and flagella) and occur in the cyanobacteria. The remainder of the **algae** are eukaryotic and have organelles. ... The nucleus, which contains the genetic material of the **cell**, is surrounded by a double membrane with pores in it.

Ultrastructure of Eukaryotic Algal Cell:

Chlamydomonas, a member of green algae (chlorophyceae) is found almost in all places. It is simple, motile, unicellular, fresh water alga. Its ultrastructure can be divided into following parts

Cell Wall of Eukaryotic Algal Cell:

The cell is bounded by a thin, cellulose cell wall. Cellulose layer is finely striated with parallel cellulose fibrils (Fig. 1). In many species there is a pectose layer external to it which dissolves in water and forms a mucilaginous pectin layer.

Plasma Lemma of Eukaryotic Algal Cell:

It is present just below the cell wall and consists of two opaque layers which remain separated by less opaque zone

Protoplast of Eukaryotic Algal Cell:

It is bounded by plasma lemma. It is differentiated into cytoplasm, nucleus, chloroplast with one or more pyrenoids, mitochondria, Golgi bodies, two contractile vacuoles, a red eye spot and two flagella.

Chloroplast of Eukaryotic Algal Cell:

In majority of the species of Chlamydomonas, cytoplasm contains of a single, massive cup shaped chloroplast which almost fills the oral or pear shaped body of the cell. It is surrounded by a double-layered unit membrane. It bears number of photosynthetic lamellae (disc or thylakoids). The lamellae are lippo-proteinaceous in nature and remain dispersed in a homogeneous granular matrix (stroma). About 3-7 thylakoids bodies fuse to form grana like bodies. Matrix also contains ribosomes, plastoglobuli, microtubules and many crystals like bodies.

Flagella of Eukaryotic Algal Cell:

The anterior part of thallus bears two flagella. Both the flagella are whiplash or acronematic type, equal in size. Each flagellum originates from a basal granule or blepharoplast and comes out through a fine canal in cell wall. It shows a typical 9+ 2 arrangement. Fibrils remain surrounded by a peripheral fibril. According to Ringo (1907), 2 central ones are singlet fibrils and 9 peripheral ones are doublet fibrils

Stigma or Eyespot of Eukaryotic Algal Cell:

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

The eye spot is made of curved pigmented plate. The plate contains 2-3 parallel rows of droplets or granules containing Carotenoids.

The other structures such as mitochondria, Golgi bodies, endoplasmic reticulum and nucleus are also bounded by double-layered unit membrane.

Life Cycle in Algae

The following points highlight the four main patterns of life cycle in algae. The patterns are: **1. Haplontic Life Cycle 2. Diplontic Life Cycle 3. Diplohaplontic Life Cycle 4. Triphasic Life Cycle.**

1. Haplontic Life Cycle:

The plant body is gametophyte (haploid) and sporophyte (diploid) stage is represented only by zygote. The gametophytic plant develops haploid gametes in the gametangium. The fusion between gametes results the formation of zygote, the only diploid stage i.e., sporophytic phase of the life cycle. The zygote undergoes meiotic division and forms four meiospores. These meiospores develop into haploid plants. The alternation of generations can be interpreted by chromosome number. This life cycle is also known as monogenic life cycle. This type of life cycle is found in majority of Chlorophyceae like Chlamydomonas, Ulothrix, Oedogonium, Spirogyra, Chara etc. and all members of Xanthophyceae.

2. Diplontic Life Cycle:

The plant body is sporophyte and develops sex organs. Sex organs produce gametes by meiosis. The gamete only represents the gametophytic stage. The gametes undergo fertilization immediately and form zygote. The zygote does not undergo meiosis and give rise to new sporophytic plant body. This type of life cycle is found in majority of the members of Bacillariophyceae, some members of Chlorophyceae like Cladophora glomerata. Fucus and Sargassum of Phaeophyceae also show this type of life cycle.

3. Diplohaplontic Life Cycle:

In this type the haploid and diploid phases are equally prominent and are represented by two distinct vegetative individuals. They differ only in chromosome number and function. The haploid gametophytic plant reproduces by sexual method, while diploid sporophytic plant by asexual process. In this life cycle alternation of two vegetative individuals occurs by sporogenic meiosis and fusion of gametes.

It is of two types:

i. Isomorphic or Homologous Diplohaplontic Type:

In this type both sporophytic and gametophytic plants are morphologically similar and free living. The gametophytic plant (haploid) produces gametes, undergo sexual reproduction and form zygote. The zygote germinates directly into a sporophytic (diploid) plant. The sporophytic plant forms haploid zoospores by meiosis. These zoospores can develop new gametophytic plant.

This type of life cycle is found in Clapdohora, Ulva, Draparnaldiopsis of Chlorophyceae and Ectocarpus of Phaeophyceae.

ii. Heteromorphic or Heterologous Diplohaplontic Type.

In this type both sporophytic (diploid) and gametophytic (haploid) plants are morphologically dissimilar. Generally the sporophyte is complicated and much elaborate, but the gametophyte is simple and small as found in Laminaria of Phaeophyceae. In some cases like Cutlaria etc. gametophyte is dominant over sporophyte. In Laminaria the gametophytic plant body is made up of minute filaments which produce gametes. The gametes undergo fusion and form zygote, which germinates directly into a sporophytic plant. The sporophytic plant body is macroscopic and several meters in length. The sporophytic plant bears zoosporangia and produce zoospores after meiotic division. The haploid zoospores on germination produce haploid gametophytic plant.

4. Triphasic Life Cycle:

In this type, there is succession of three distinct generations.

It is of two types:

i. Haplobiontic Type:

In this cycle the gametophytic (haploid) phase is elaborate, dominant and persists for long time than sporophytic (diploid) phase which is represented only by zygote i.e., haplobiontic type and two successive haploid generations are interrupted only by diploid zygote stage indicate its triphasic nature. This type of life cycle is found in the primitive members of Rhodophyceae like Batrachos-permum and Nemalion. In Batrachospermum the gametophytic plant body develops sex organs and produces male (spermatium) and female (egg) gametes. The gametes by fusion form zygote. The zygote immediately undergoes meiosis and produces another haploid gametophytic plant, the carposporophyte. The carposporophyte develops carposporangium which produces haploid carpospores. The carpospores germinate and develop new free-living gametophytic plant.

So in this cycle, three phases are :

i. Haploid carposporophyte,

ii. Haploid gametophyte, and

iii. Diploid zygote.

ii. Diplobiontic Type:

In this type there is one gametophytic phase and two sporophytic phases indicate its triphasic nature and the sporophytic phase is more elaborate and persists for long duration than the gametophyte i.e., diplobiontic type. This type of life cycle is found in Polysiphonia, a member of Rhodophyceae. In Polysiphonia, the gametophytic phase is represented by two types of gametophytic plant i.e., male and female plant, those bear spermatangium and carpogonium respectively. Later, the spermatangium and carpogonium develop sperms and egg respectively.

The male and female gamete i.e., sperm and egg undergo fusion and form zygote. The zygote (2n) develops into a diploid carpospophytic phase. The diploid carpospores are formed in the carposporophyte.

The carpospores on germination develop the diploid tetrasporophytic plants. The tetrasporophytic plant develops diploid tetrasporangia each of which produce four tetraspores (n) by meiotic division. They are liberated by splitting of sporangial wall. Out of four tetraspores two produce male gametophyte and the other two into female gametophyte.

So in this cycle, three phases are:

i. Haploid gametophyte,

ii. Diploid carposporophyte, and

iii. Diploid tetrasporophyte.

Affinity with Fungi:

The affinity between algae and fungi are given:

1. Plants are thalloid.
2. Sex organs are very simple and not protected by jacket wall.
3. No embryo formation after sexual union.

ECOLOGY OF ALGAE

Algae are prominent in bodies of water, common in terrestrial environments, and are found in unusual environments, such as on snow and ice. Seaweeds grow mostly in shallow marine waters, under 100 m (330 ft) deep; however, some such as *Navicula pennata* have been recorded to a depth of 360 m (1,180 ft). A type of algae, *Ancylonema nordenskioeldii*, was found in Greenland in areas known as the 'Dark Zone', which caused an increase in the rate of melting ice sheet. Same algae was found in the Italian Alps, after pink ice appeared on parts of the Presena glacier.

The various sorts of algae play significant roles in aquatic ecology. Microscopic forms that live suspended in the water column (phytoplankton) provide the food base for most marine food chains. In very high densities (algal blooms), these algae may discolor the water and outcompete, poison, or asphyxiate other life forms.

Algae can be used as indicator organisms to monitor pollution in various aquatic systems. In many cases, algal metabolism is sensitive to various pollutants. Due to this, the species composition of algal populations may shift in the presence of chemical pollutants. To detect these changes, algae can be sampled from the environment and maintained in laboratories with relative ease.

Freshwater Algae

Majority of the algae about 90 per cent are aquatic. They may be fresh water algae or marine algae. In the freshwater algae some are still water forms like Oedogonium, Chara, Zygnema, Rivularia etc. The running water forms among the freshwater algae include forms like Cladophora and Vaucheria. The marine algae are those which live in sea water like Sargassum, Dictyota, Ceramium, Gracilaria, Fucus, Laminaria etc

Terrestrial Algae

These forms are often found epiphytic on trees like Trentepohlia and Protococcus. Some forms are found subterranean in soil which can withstand unfavourable conditions.

Phytoplankton

The term 'planktonic algae' refers to the forms found floating or freely swimming in water. Among the freshwater planktonic algae, forms such as Chlorella, Scenedesmus, Hydrodictyon, Chlamydomonas, Volvox and Eudorina of Chlorophyceae, Euglena and Phacus of Eugleninae; Microcystis, Anabaena, Aphanotheca, Spirulina, Arthrospira, Anabaenopsis and Oscillatoria of Myxophyceae and Melosira, Cyclotella, Pinnularia, Navicula, Fragilaria and Asterionella of Bacillariophyceae are common while among marine planktonic forms Phalacroma, Dinophysis, Exuviaella and Prorocentrum of Desmophyceae; Gymnodinium, Peridinium, Gonyaulax and Ceratium of Dinophyceae; Sceletonema, Cyclotella, Planktoniella, Eucampia, Hemidiscus, Chaetoceros, Biddulphia, Fragilaria, Asterionella and Nitzschia of Bacillariophyceae; Trichodesmium, Anabaena Oscillatoria and Aphanothece of Myxophyceae and Chlamydomonas of Chlorophyceae are well-known.

Epiphytic Algae

Some algae grow attached on the other plants and are called epiphytes. Such algae do not obtain the food from the plants on which they grow rather require support only. Bulbochaete, Oedogonium, Ulothrix etc., grow on other larger algae, besides, Coleochaete in association with Chara and Nitella, Chaetophora on leaves of Vallisnaria and Nelumbo and Oedogonium on Hydrilla.

Parasitic Algae

Some algae, for their food, are dependent on other plants and are termed as parasitic forms. The common intercellular parasite Cephaleuros(Chlorophyceae) grows on the leaves of angiosperms like Magnolia, Rhododendron. Polysiphonia fastigata is a semiparasite occurring on another algae.

Symbiotic Algae

Some species of algae form symbiotic relationships with other organisms. In these symbioses, the algae supply photosynthates (organic substances) to the host organism providing protection to the algal cells. The host organism derives some or all of its energy requirements from the algae. Examples are:

Lichens

Rock lichens in Ireland

Lichens are defined by the International Association for Lichenology to be "an association of a fungus and a photosynthetic symbiont resulting in a stable vegetative body having a specific structure". The fungi, or mycobionts, are mainly from the Ascomycota with a few from the Basidiomycota. In nature they do not occur separate from lichens. It is unknown when they began to associate. One mycobiont associates with the same phycobiont species, rarely two, from the green algae, except that alternatively, the mycobiont may associate with a species of cyanobacteria (hence "photobiont" is the more accurate term). A photobiont may be associated with many different mycobionts or may live independently; accordingly, lichens are named and classified as fungal species. The association is termed a morphogenesis because the lichen has a form and capabilities not possessed by the symbiont species alone (they can be experimentally isolated). The photobiont possibly triggers otherwise latent genes in the mycobiont.

Floridian coral reef

Coral reefs are accumulated from the calcareous exoskeletons of marine invertebrates of the order Scleractinia (stony corals). These animals metabolize sugar and oxygen to obtain energy for their cell-building processes, including secretion of the exoskeleton, with water and carbon dioxide as byproducts. Dinoflagellates (algal protists) are often endosymbionts in the cells of the coral-forming marine invertebrates, where they accelerate host-cell metabolism by generating sugar and oxygen immediately available through photosynthesis using incident light and the carbon dioxide produced by the host. Reef-building stony corals (hermatypic corals) require endosymbiotic algae from the genus *Symbiodinium* to be in a healthy condition. The loss of *Symbiodinium* from the host is known as coral bleaching, a condition which leads to the deterioration of a reef.

Sea sponges

Endosymbiontic green algae live close to the surface of some sponges, for example, breadcrumb sponges (*Halichondria panicea*). The alga is thus protected from predators; the sponge is provided with oxygen and sugars which can account for 50 to 80% of sponge growth in some species.

Fossil algae

Algae are very important **fossils** in helping geologists and paleontologists to understand the ancient environments of depositions and ecosystems that existed in the geologic past. The kind of **algae** present in a rock can give the geologist some idea as to the depth of water in which the rock was deposited.

UNIT - II

Salient Features of Chlorophyta:

1. Chlorophyta is the largest of the eight divisions of algae. Members of the Chlorophyta, or grass-green algae are similar to higher plants being characterized by a well-defined nucleus, photosynthetic pigments localized in chloroplastids in which usually pyrenoids are present, the food reserve is commonly stored as starch, and the possession of cell walls in which cellulose is usually a clearly recognizable ingredient.
2. Most of the grass- green algae are fresh-water forms with a few exception of marine species. They exhibit a considerable range of variation in the form and structure of the plant body. In short, the diversity of habit and habitat is very striking and in this respect the Chlorophyta surpass any other algal taxon.
3. Motile cells both zoospores and gametes may be bi-, quadri-, or multiflagellate with the exception of forms where motility is lacking altogether. Gametic reproduction is common within the entire taxon.
4. Moreover, clear division of labour indicated by some heterotrichous forms, and special adaptations of the terrestrial species to survive against external unfavourable conditions have been quite intriguing to some phycologists to trace the algal ancestry of land plants.

Salient Features of Cyanophyceae:

1. The individual cells are prokaryotic in nature. The nucleus is incipient type and they lack membrane bound organelles.
2. Both vegetative and reproductive cells are non-flagellate.
3. Cell wall is made up of microfibrils and is differentiated into four (4) layers. The cell wall composed of mucopeptide, along with carbohydrates, amino acids and fatty acids.
4. Locomotion is generally absent, but when occurs, it is of gliding or jerky type.

5. The principal pigments are chlorophylls a (green), c-phycocyanin (blue) and c-phyco- erythrin (red). In addition, other pigments like β-carotene and different xanthophylls like myxoxanthin and myxoxanthophyll are also present.
6. Membrane bound chromatophore are absent. Pigments are found embedded in thylakoids.
7. The reserve foods are cyanophycean starch and cyanophycean granules (protein).
8. Many filamentous members possess specialized cells of disputed function (supposed to be the centre of N_2 fixation) known as heterocysts.
9. Reproduction takes place by vegetative and asexual methods. Vegetative reproduction takes place by cell division, fragmentation etc. Asexual reproduction takes place by endospores, exospores, akinetes, nannospores etc.
10. Sexual reproduction is completely absent. Genetic recombination is reported in 2 cases.

Salient Features of Chlorophyceae

1. Plant body may be unicellular, colonial, filamentous or multicellular.
2. They are usually green due to the presence of chlorophyll a, chlorophyll b and beta-carotene.
3. The chloroplast may be discoid, cup-shaped (e.g. *Chlamydomonas*), spiral or ribbon shaped (e.g. *Spirogyra*)
4. Most chlorophytes have one or more storage bodies called pyrenoids (central proteinaceous body covered with a starch sheath) that are localised around the chloroplast.
5. The inner cell wall is made of cellulose and the outer layer is pectose.
6. Asexual reproduction is by zoospores. They are flagellates produced from the parent cells by mitosis. Also by aplanospores, hepnospores, akinetes, Palmella stage, etc.
7. Sexual reproduction of plants is isogamous, anisogamous or oogamous.

.**Salient Features of Charaphyceae**

1. The stoneworts usually occur in still and clear waters in attached condition to the mud of the bottom of the pools. They are found in less oxygenated water and best survive in clear and hard waters. Calcium carbonate is deposited on the plant body and the surface of the plant becomes rough.

2. The thallus is attached to the mud by a rhizoidal system. The plant body is erect and possesses nodes and internodes. Secondary laterals, also called ‘leaves’ arise from the nodes which are of limited growth. The leaves may or may not be differentiated into nodes and internodes.

3. The reproduction takes place by vegetative and sexual methods. Asexual reproduction is altogether absent. Vegetative reproduction takes place by means of special vegetative bodies

such as amylum stars, bulbils, secondary protonema, etc. Sexual reproduction is oogamous and takes place by oogonia (nucule) and antheridia (globule).

4. The zygote nucleus divides reductionally producing 4 haploid nuclei. Out of these 4 haploid nuclei one is functional and rest degenerate. The functional nucleus divides into two cells, the lower cell is rhizoidal and the upper one gives rise to main thallus.

Salient Features of Xanthophyta

1. A majority of yellow-green algae are freshwater but some of the species are aerial growing on tree trunks, on damp walls or soil on drying mud. A few species are marine e.g., Halosphaera.
2. The members of the class show a wide range in thallus structure. The thalli range from unicell (Chloramoeba, Choromeson) to palmelloid state (Chlorosaccus), and also through the filamentous (Tribonerna, Heterococcus) to the siphonaceous habit (Vauchena, Botrydium).
3. The **xanthophycean** cell has a definite cell wall chiefly composed of pectic substances either pectose or pectic acid. In many genera, the cell walls are in the form of two equal or unequal overlapping halves.
4. The cells in motile genera have two unequal flagella attached to the anterior end. One flagellum is tinsel type and the other whiplash type.
5. The pigments are located in discoid chromatophores and consists of chlorophyll- a, chlorophyll-e, beta-carotene and **xanthophylls**. Chlorophyll-b is absent. The dominant pigment is a **xanthophyll** diadinoxanthin which provides the cells its characteristics yellow-green color. The pyrenoids are absent.
6. The chief reserve foods are oil, lipid and leucosin (chrysolaminarin). Many genera have uninucleate cells while others have multinucleate ones.
7. The members of the class usually reproduce vegetatively and asexually, but in few genera sexual reproduction is also found.
8. The asexual reproduction may be by zoospores, aplanospores and akinetes.

   The sexual reproduction is rare and is generally of isogamous type found among the siphonaceous genera like Vaucheria.

Salient Features of Bacillariophyceae

1. Fresh water and marine algae. Majority are unicellular and some are multicellular and colonial.
2. Cells are eukaryotic.
3. Chief pigments are chlorophyll a, beta carotene, and xanthophylls.
4. Reserve food includes fats and volutins.
5. Sexual reproduction is a special type, with the formation of auxospores.

6. Male gametes are flagellate, with 1 or 2 flagella.
7. Life cycle is diplontic.

Salient Features of Phaeophyceae:

1. Most of the marine species grow attached to rocks or similar other objects along the shores up to a depth of about 17 metres under the water. Some of the giant 'kelps' (e.g. Laminaria and others) grow along the Pacific coasts of America on rocks at a depth, even beyond 20 metres, below the surface of water. Others may grow as epiphytes in association with other algae or within their tissues as endophytes.
2. The Phaeophyceae show great diversity in form and structure of the plant body among its various members and in a great majority of cases possessing regular alternation of generations between free-living multicellular gametophytes and sporophytes. Both the generations may be identical in form and structure, and the sporophyte is larger than the gametophyte, or vice versa. Both these generations may be annual or perennial, and the gametophyte is annual and the sporophyte, perennial.
3. The range of thalli varies from genus to genus, all the way beginning from single, few-celled gametophytes or sporophytes of microscopic size to definite macroscopic forms attaining a length of 27—33 metres or more, without having any relationship between the size and longevity of the plants concerned.
4. The gametophyte or the sporophyte of a plant, possessing a definite form, is differentiated into a holdfast supporting an upright simple or branched portion, which is either solid or hollow and tubular, but may also be spherical or compressed. Great complexity in form is encountered among the 'kelps', where the thallus is differentiated into a roof-like holdfast, a simple or branched stem (stipe) and one or more leaf-like blades.
5. The cell of brown algae has a distinct cell wall, which is differentiated into an inner firm cellulose portion and an outer gelatinous portion made up of a pectic compound, known as 'algin'.The protoplast is vacuolated and generally contains a single nucleus of normal form and structure. The division of protoplast takes place by mitosis.
6. During the division, centrosomes become evident near the poles, and these appear to be a constant feature in the dividing cells of the various members of the Phaeophyceae. There is usually more than one plastids in each cell and they are always without pyrenoids. They are usually flattened or discoid in shape and may have irregular outlines.
7. The plastids, in addition to the four photo- synthetic pigments, contain a golden brown carotinoid pigment, fuco-xanthin, which is supposed to be a mixture of two pigments, fuco-

xanthin a and fuco-xanthin b. Food reserves are in the form of carbohydrates which are found in a dissolved state in the vacuoles and in the cytoplasm.

8. Of these, sugar is present in small quantity. A dextrin-like carbohydrate (polysaccharide) known as 'laminarin' is always present. Another widely distributed carbohydrate is mannitol. Fats and oils are also found in some species.

Salient features of Rhodophyceae

1. Rhodophyceae commonly called as red algae.
2. Mostly marine habitats.
3. The thallus is multicellular, macroscopic, and may be filamentous, ribbon – like etc.
4. Chlorophyll 'a' , r-phycoerythrin and rphycocyanin are photosynthetic pigments.
5. Asexual reproduction is by means of monospores, neutral spores and tetraspores.
6. Floridean starch is the storage material
7. Sexual reproduction in oogamous.
8. Male sex organ is spermatangium producing spermatium.
9. Female sex organ is carpogonium.
10. Spermatium is carried by water and fuses with egg forming zygote.
11. Zygote undergoes meiosis forming carpospores.
12. Alternation of generation is seen.

Economic importance of Algae

These eukaryotic marine organisms have no roots, flowers and stem. It plays important role in alkaline reclaiming which is used as soil binding agent. They are economically important in a variety of ways which are discussed below:

1. Food: Algae are healthy source of **carbohydrates, fats, proteins, and vitamins A, B, C, and E** as well as the minerals like **iron, potassium, magnesium, calcium, manganese, and zinc**. Hence, people of countries like Ireland, Scotland, Sweden, Norway, North and South America, France, Germany, Japan, and China uses it as the food ingredient from the centuries.

2. Fodder: Algae are also used as the fodder to feed livestock such as cattle and chickens.

3. Pisciculture: In fish farming, Algae plays very important role because it helps in the production process. Fish used plankton and zooplankton as a food. It helps in maintaining the health of the marine ecosystem because algae are naturally absorbent of carbon dioxide and also provide oxygen to the water.

4. Fertilizer: Algae are rich in minerals and vitamins. So they also used as liquid fertilizer which helps in the repairing level of nitrogen present in the soil.

5. Reclaiming Alkaline: Blue Green Algae helps in the reduction of high concentration of alkalinity in the soil.

6. Binding Agent: Algae act as the binding agents against natural processes such as erosion.

7. Biological indicator: Algae are very sensitive. If there is a slight change in the environment their pigments changes or might get died. The water pollution is checked with the help of Algae like **Euglena and Chlorella**.

Unit III: FUNGI

Introduction to Fungi

Fungi (singular: fungus) are a kingdom of usually multicellular eukaryotic organisms that are heterotrophs (cannot make their own food) and have important roles in nutrient cycling in an ecosystem. Fungi reproduce both sexually and asexually, and they also have symbiotic associations with plants and bacteria. However, they are also responsible for some diseases in plants and animals. The study of fungi is known as mycology.

Important Terms

- **Heterotroph** – An organism that cannot make its own food and must obtain nutrients from other organic sources.
- **Hyphae** – Branching filaments of a fungus.
- **Mycelium** – A network of hyphae.
- **Yeast** – Single-celled fungi.

Classification of Fungi - V. C. J. Alexopoulos and C. W. Mims (1979):

C. J. Alexopoulos and C. W. Mims (1979) placed fungi and slime molds under the kingdom of their own, called Myceteae under the superkingdom Eukaryonta. The kingdom is divided into three divisions and further the divisions are divided into sub-division, class and form-class.

The outline of the classification is given:

Kingdom. Myceteae (Fungi):

Achlorophyllous, saprobic or parasitic organisms with unicellular or more typically, filamentous soma (thallus), usually surrounded by cell walls that characteristically consists of chitin and other complex carbohydrates, nutrition absorptive, except in the slime molds (Division Gymno- mycota) where it is phagotrophic, propagation typically by means of spores produced by various types of sporophores; asexual and sexual reproduction usually present.

The kingdom is subdivided into three major divisions:

A. Division. Gymnomycota:

Phagotrophic organisms with somatic structures devoid of cell walls:

a. Subdivision. Acrasiogynomycotina:

1. Class. Acrasiomycetes

b. Subdivision. Plasmodiogymnomycotina:

1. Class. Protosteliomycetes
2. Class. Myxomycetes

B. Division. Mastigomycota:

Fungi with centrioles; flagellate cells typically produced during the life cycle; nutrition typically absorptive; varying from unicellular that becomes converted into a sporangium, to an extensive, filamentous, coenocytic mycelium, asexual reproduction typically by zoospores; sexual reproduction by various means:

a. Subdivision. Haplomastigomycotina

1. Class. Chytridiomycetes
2. Class. Hyphochytridiomycetes
3. Class. Plasmodiophoromycetes

b. Subdivision. Diplomastigomycotina

1. Class. Oomycetes

C. Division. Amastigomycota:

Fungi without centriole, no motile cells, nutrition absorptive, single-celled to mycelial with a limited or extensive, septate or aseptate mycelium, asexual reproduction by budding, fragmentation, sporangiospores or conidia; sexual reproduction, where known, by various means; haplobiontic-haploid life cycle with zygotic meiosis.

a. Subdivision. Zygomycotina

1. Class. Zygomycetes
2. Class. Trichomycetes

b. Subdivision. Ascomycotina

1. Class. Ascomycetes

c. Subdivision. Basidiomycotina

1. Class. Basidiomycetes

d. Subdivision. Deuteromycotina

1. Form class. Deuteromycetes.

Origin and Phylogeny of fungi

The origin and evolutionary relationship of fungi are not definitely known. There are two important views regarding the origin of fungi put forwarded by different mycologists. They are Polyphyletic view (algal origin) and Monophyletic view (prtozoan origin). Concerning the origin of fungi first and traditional hypothesis regards algae as the ancestral stock. Some mycologists led by Bessey (1942) advocated algal origin of fungi from the unicellular coccoid Xanthophyceae. This hypothesis is based on the similarity in structure, anterior position of flagella, presence of cellulose in cell wall, and accumulation of glycogen as reserve done in both cases. The coccoid ancestor have rise to the phycomycetes along with two divergent lines, one with anteriorlyuniflagellate.

Fischer and **Dangeard** advocate the prtozoan ancestor of phycomycetes. It is based on similar metabolism and type of flagellation in both the phycomycetes and protozoa. On the basis of this theory the phycomycetes have evolve from the flagellates tic chytrids. The uniflagellate forms arose from the uniflagellate protozoa and biflagellate from the biflagellate protozoa. There non mycelial forms in turn give rise to the more advanced mycelial forms by progressive evolution.

Hawker (1967) suggested a polyphyletic origin of the lower fungi (phycomycetes) from the aquatic flagellate along paralled lines. According to him chytridiales, hyplochytridiomycetes and plasmodiophoromycetes have originated from flagellates having appropriate type of flagella. The **oomycetes** which resemble certain filamentous algae in their composition of cell wall, forms of sex organ, life cycle and form of endosperm and mitochondria may have evolve from an click ancestor by the loss of chlorophyll. If suggests some common ancestory for the chytrides and **zygomycetes** for at the flagellate level. The floriax origin of higher fungi based on the similarities between the reproductive organ does not survive critical examination.

GENERAL CHARACTERS OF FUNGI

1. Fungi are found in all types of environments where organic materials are available. For examples, water, air, dead and decaying organic matter, living organisms.
2. Some fungi are unicellular. The thallus of the fungi is long and tubular with filamentous branches called as hyphae. Hyphae are aseptate, coenocytic, uni-, di- or multinucleate.
3. The mass of interwoven hyphae is called mycelium. Mycelium may be unicellular or multicellular.
4. The cells of fungi have definite cell wall mainly made up of chitin. Chitin is a nitrogenous material containing polysaccharide. Other components of the fungal cell

wall may be cellulose-glycogen, cellulose-glucan (found in oomycetes), Cellulose-chitin, chitin-chitosan (found in zygomycetes), Chitin-glucan (found in ascomycetes and basidiomycetes) etc.

5. Fungi are eukaryotic and they do not have plastids. As fungi do not have chlorophyll, they cannot perform photosynthesis. They obtain their nourishment from the environment by extracellular digestion and absorption of digested food material. So they are known as heterotrophs.

6. Fungi live as saprophytes on dead and decaying organic matter, as parasites on/inside living organisms. Some fungi grow in symbiotic relationship with algae and form lichens. Some of the fungi grow in close association with the roots of the vascular plants forming mycorrhizae.

7. The reserve food material of the fungi is glycogen, fats or lipid globules.

8. Fungi reproduce vegetatively by fragmentation, budding and fission.

9. During favorable conditions, they reproduce asexually by spores. The asexual spores are called sporangiospores and conidia. The sporangiospores may be zoospores or aplanospores. Zoospores are flagellated spores with one or two flagella. Aplanospores are non-flagellated spores.

10.Sexual reproduction in fungi is through gametes and is carried out with the help of planogametic copulation, gametangial contact, gametangial copulation, spermatization or somatogamy.

11.Fungi show progressive reduction of sexuality

12.Fungi exhibit asexual haplontic, haplontic-dikaryotic, haplo-diplontic or diplontic life cycle.

ULTRASTRUCTURE OF FUNGI

THE CELL WALL - The fungal cell wall is a dynamic structure that protects the cell from changes in osmotic pressure and other environmental stresses, while allowing the fungal cell to interact with its environment. Except slime molds (Myxomycetes), the fungal cell consists of a rigid cell wall and cell organelles. Chemical analysis of cell wall reveals that it contains 80-90% polysaccharides and remaining proteins and lipids. Chitin, cellulose or other glucans are present in cell walls in the form of fibrils forming layers.

2) Plasma membrane • In fungi too, cell wall is followed by plasma membrane that encloses the cytoplasm. It is semipermeable and in structure and function it is similar to that of prokaryotes. The plasmalemma invaginates and forms a pouch like structure enclosing the granular or vesicular materials.

3) Cytoplasm - The cytoplasm and most organelles and inclusions of fungal cytoplasm are typical of eukaryotic organisms. Cytoplasm is colourless in which sap-filled vacuoles are found. The cytoplasmic inclusions are dead, non-functional and unimportant for fungal survival. Cell organelles are ER, mitochondria, ribosomes, golgi bodies and vacuoles. Lomasomes are also present between plasma membrane and cell wall.

a) Mitochondria: The mitochondria of fungi are clearly recognisable. They have a double bilayer membrane and contain complex internal membranes. They differ from other eukaryotic organisms in that the mitochondria are commonly elongate, oriented along the hyphal axis. These are power house of the cell. It has machinery for transcription and translation of organelle specific DNA.

b) Endoplasmic reticulum. Presence of ER in fungal cytoplasm is observed through electron microscope. It is made up of a system of microtubules with small granules. In most of the fungi, it

b) Endoplasmic reticulum. Presence of ER in fungal cytoplasm is observed through electron microscope. It is made up of a system of microtubules with small granules. In most of the fungi, it is highly vascular. It is loose and irregular as compared with cells of green plants. In multinucleate hyphae, the nuclei may be connected by ER.

c) Vacuoles are essential for cell function in fungi. Fungi are characterised by the presence of spherical to tubular vacuoles. They are found in the old cells of hyphae. The end of hyphal tip of young hyphae lacks vacuole. They are surrounded by membrane called tonoplast. They play an important role in osmoregulation.

d) Golgi apparatus or Dictyosomes Except in Oomycetes and non-fungal eukaryotic cells, golgi apparatus is rare occurrence in fungal cells. In Oomycetes, golgi apparatus consists of stacks of folded membranes functioning in secretion. Major function is to process and package macromolecules (proteins) and transportation of lipids around the cell.

f) Cytoplasmic inclusions Cytoplasm consists of various inclusions such as lipid droplets and glycogen, carbohydrate trehalose, proteinaceous material and volutin. The vacuoles contain glycogen. Several metabolites are secreted by the cytoplasm. In matured cell, lipids and glycogen are abundantly present.

MODE OF NUTRITION

Like animals, fungi are heterotrophs: they use complex organic compounds as a source of carbon, rather than fix carbon dioxide from the atmosphere as do some bacteria and most plants. In addition, fungi do not fix nitrogen from the atmosphere. Like animals, they must obtain it from their diet. However, unlike most animals, which ingest food and then digest it internally in specialized organs, fungi perform these steps in the reverse order: digestion precedes ingestion. First, exoenzymes are transported out of the hyphae, where they process nutrients in the environment. Then, the smaller molecules produced by this external digestion are absorbed through the large surface area of the mycelium. As with animal cells, the polysaccharide of storage is glycogen rather than the starch found in plants.

Fungi are mostly saprobes (saprophyte is an equivalent term): organisms that derive nutrients from decaying organic matter. They obtain their nutrients from dead or decomposing organic matter, mainly plant material. Fungal exoenzymes are able to break down insoluble polysaccharides, such as the cellulose and lignin of dead wood, into readily-absorbable glucose molecules. The carbon, nitrogen, and other elements are thus released into the environment. Because of their varied metabolic pathways, fungi fulfill an important ecological role and are being investigated as potential tools in bioremediation.

Some fungi are parasitic, infecting either plants or animals. Smut and Dutch elm disease affect plants, whereas athlete's foot and candidiasis (thrush) are medically important fungal infections in humans.

FUNGI REPRODUCTION

Most fungi can reproduce through both sexual and asexual reproduction. Asexual reproduction occurs through the release of spores or through mycelial fragmentation, which is when the mycelium separates into multiple pieces that grow separately. In sexual reproduction, separate individuals fuse their hyphae together. The exact life cycle depends on the species, but generally multicellular fungi have a haploid stage (where they have one set of chromosomes), a diploid stage, and a dikaryotic stage where they have two sets of chromosomes but the sets remain separate.

All fungi reproduce using spores. Spores are microscopic cells or groups of cells that disperse from their parent fungus, usually through wind or water. Spores can become dormant for a long time until conditions are favorable for growth. This is an adaptation for opportunism; with a sometimes unpredictable food source availability, spores can be dormant until they are able to colonize a new food source. Fungi produce spores through sexual and asexual reproduction.

LIFE CYCLE OF FUNGI

The life cycle of fungi has many different patterns based on the species of the fungi. Not all fungi reproduce in the same way. While some fungi reproduce sexually, others reproduce asexually. Therefore, we are going to look at the life cycle of a fungi in asexual and sexual stage.

Sexual Reproduction of Fungi –

a. **Spore (Haploid):**

All fungi begin their life cycle in this stage. This is the first stage in the life cycle of a fungus. In the beginning, all spores are haploid which means that they have only a single copy of their entire genetic material. These spores migrate far distances through air by grabbing on to other organisms on the way. After locating a favourable living environment, they grow a bunch of root-like structures called mycelium. Nutrients are transferred through mycelium in order for spores to develop.

b. **Mycelium (Diploid):**

When the mycelium grows and develops, it might encounter another fungi. If the two fungi are compatible, a cell from each of the two mycelium fungi fuse together to form into another new single cell. These new fused cells are diploid as they have more than one copy of their genetic information.

c. **Meiosis:**

After the fungi has become mycelium, it enters the next process known as meiosis. During meiosis, a single cell splits into two cells and the genetic material from both parents gets mixed up. The produced two daughter cells do not have identical features to their parents and they do not look similar to each other as well.

Asexual Reproduction of Fungi:

During the mycelium stage, the fungi has the choice of reproducing sexually or asexually. The asexual life cycle in fungi produces mitospores, which are idectical to the parent.

These mitospores later grow into a new set of mycelium and the entire life cycle repeats again.

Conclusion:

The life cycle of a fungi is quite complex in nature as they do not reproduce in one way, but sexually and asexually based on the environmental conditions. Due to its distinct nature, a fungus is capable of surviving anywhere and everywhere.

CULTURE OF FUNGI

The most direct and usually conclusive means of establishing the diagnosis of a fungal infection is to grow the fungus from a patient sample. Numerous different samples can yield a fungus, including blood, cerebrospinal fluid, pus, urine, tissue, respiratory samples (sputum, bronchoscopy lavage), pleural, pericardial or peritoneal fluid, skin scraping, hair, nail clippings, oral or vaginal samples. Processing of these samples may involve centrifugation or softening/liquidisation to allow spreading of the sample onto an agar medium. A number of laboratory manuals and specific describe the methods for doing this although remarkably few comparative studies comparing one method with another have been done.

The importance of media selection

The yield of most fungi is improved by direct culture of samples on so-called 'fungal media'. For some fungi, cultures are always or almost always negative on bacterial media, examples being *Histoplasma*, Mucorales and *Coccidioides* spp. The culture of *Aspergillus* spp. on bacterial media is ~30% less effective than on fungal media.

General purpose media that are commonly used for fungal culture are Sabouraud dextrose, malt extract and less commonly brain heart infusion medium. To prevent contamination of the medium by bacteria, chloramphenicol is used, but prevents the growth of *Actinomyces*, which others grows well on Sabouraud dextrose agar. For reducing the frequency of environmental fungal growth, cycloheximide is added, but this reduces the yield of many opportunistic fungi including *Aspergillus* spp., *Cryptococcus neoformans* and Mucorales isolates. Therefore if cycloheximide is used, one agar plate not containing it should also be used in parallel.

Blood culture for fungi

Numerous blood culture systems have been used, including 'standard' bacterial cultures and more specialised systems such as the lysis centrifugation system, the Septi-Check systems, and special bottles within an automated system (sometimes of Mycobacteria and fungi). A small number of comparisons have been done of these systems, and the choice matters a great deal more when the range of potential infecting fungi includes *Cryptococcus neoformans*, *Histoplasma capsulatum* and *Penicillium marneffei*.

Incubation conditions

The standard temperature for incubation of fungi is 30ºC and cultures should be incubated in a humidified environment for 21 days. They should be inspected daily for at least a week, and at least 3 times weekly thereafter. Some fungi are very slow to grow, notably *Histoplasma* spp., and may need longer incubation times. Culture of respiratory cultures at 42ºC prevents the growth of *Candida* spp. allowing *Aspergillus* spp. to flourish without competition.

Handling growth and procedures for identification

Once colonies are visible, they should be inspected carefully for their morphology. Yeasts can be further identified by their growth pattern on specialised media such as cornmeal agar and with biochemistry testing. Some presumptive identification of yeasts can be made based on colour and colony morphology on chromogenic media. Some rapid testing systems are available which are more or less comprehensive and reliable. Published comparisons of these methodologies are available.

Filamentous fungi are harder to identify. Without spores or other sterile structures, the only real distinction that can be made is whether the hyphae are septate or not (i.e. are likely be

Mucorales, *Basidiobolus ranarum* or *Conidiobolus* spp. Media that can assist with sporulation include potato dextrose agar. If the colony will not spore, only molecular identification is possible. Once the colony has sporulated identification by microscopy using phenol cotton blue or another simple means of highlighting the distinctive structures of the fungus allows an experienced mycologist to identify to at least genus level in the vast majority of cases. Species identification of filamentous fungi can be very difficult or impossible without additional data such as colour and morphology of additional media, differential temperature growth rates and molecular information. Many cryptic (ie identical appearance) species have been described in many genera.

HETEROTHALLISM

According to Whitehouse (1949) can be caused by the absence of the morphological sex organs of the opposite type (morphological heterothallism) or by the absence of genetically-different nuclei (physiological heterothallism).

Whatever be the reason for heterothallism, the fact remains that different thalli are needed for sexual reproduction. A heterothallic species may not be of only two mating types. There can be four types of thalli and one thallus can mate with only one of the rest three. This is called tetrapolar heterothallism.

Bipolar Heterothallism:

Fungi in this category have two mating types, each containing genetically different nuclei. The sexual compatibility is controlled by a pair of genetic factors A and a located at the same locus on different chromosomes. This is, therefore, also called as 'two allele heterothallism'. During meiosis, the two chromosomes, containing the alleles A and a are separated in the haploid spores (germ spores, ascospores, or basidiospores). The spores give rise to two types of thalli, which must come together to bring together the two nuclei carrying the compatibility factors A and a. The two mating types are designated (+) and (-) strains. The two allele or bipolar heterothallism is found in Mucorales (Mucor, Rhizopus, Phycomyces), Ascomycota (Neurospora, Ascobolous), Basidiomycota (Puccinia graminis and Ustilago levis).

Tetrapolar Heterothallism:

Fungi in this group form thalli of four mating types. This type of heterothallism is governed by two pairs of compatibility factors Aa and Bb, located at different chromosomes, which segregate independently during meiosis. If crossing over occurs between the mating type loci, four types of segregations (AB, Ab, aB, ab) are possible depending on the chromosomal arrangement.

Thus four types of spores (AB, Ab, aB and ab) are formed which give rise to four types of thalli. Only those thalli that have nuclei carrying opposite genes for both the factors can mate. The resulting zygote must have the genotype Aa, Bb. Majority (63 per cent) of the heterothallic Basidiomycota are tetrapolar, forming four types of basidiospores. However, if crossing over does not take place, only two types of spores (AB and ab or Ab and aB) are formed and only two types of thalli are produced. Since it is governed by two factors it is called tetrapolar.

Secondary Homothallism:

In some bipolar species the two nuclei, which should give rise to hyphae of two mating types, are contained in the same spore. Thus, the hyphae produced behave as homothallic, though it involves genetically-different nuclei. This situation is termed secondary homothallism. Korf (1952) and Hartman (1956) recommended that the terms homothallism and heterothallism should be abandoned. Esser (1959) suggested the use of the terms monoecious and dioecious, as done in higher plants. Call by whatever 'term' you please, the function of heterothallism remains unaltered. Heterothallism is a device for achieving outbreeding, which is a genetic desirability. Homothallism brings in inbreeding and provides no chance for genetic change.

PARASEXUALITY IN FUNGI

Until 1944, the sexual cycle was the only means of exchange of genetic material. It is to the credit of microbial geneticists that a series of novel methods of genetic recombination are now known in bacteria, which do not involve karyogamy and meiosis. These are transformation, conjugation, transduction, lysogeny, and sexduction which differ from the standard sexual cycle.

A similar alternative to sexual reproduction was discovered in the imperfect fungus, Aspergillus nidulans, in 1952 by Pontecorvo and Roper of Glasgow. They called this parasexual cycle. In this, genetic recombination occurs in somatic cells by the mechanism of mitotic crossing over, which brings the same result as is achieved by the meiotic crossing over.

The parasexual cycle involves the following steps:

1. Formation of heterokaryotic mycelium.
2. Nuclear fusions and multiplication of the diploid nuclei.
3. Mitotic crossing over during division of the diploid cells.
4. Sorting out of the diploid strains.
5. Haplodization.

1. Formation of Heterokaryotic Mycelium:

The methods of formation of heterokaryotic mycelium are described earlier under 'heterokaryosis.'

2. Nuclear Fusions and Multiplication of the Diploid Nuclei:

Nuclear fusion in somatic heterokaryotic hyphae was first noted by Roper (1952) in Aspergillus nidulans. Nuclear fusion may occur between genetically similar and dissimilar nuclei, resulting in the formation of homozygous and heterozygous diploid nuclei, respectively. Diploid heterozygous nuclei are formed very rarely (at a frequency of one in a million). In such hyphae, five types of nuclei are present- 2 types of haploid nuclei, their two types of homozygous diploids, and the one type of heterozygous diploids.

3. Mitotic Crossing Over:

Crossing over is a phenomenon which occurs during meiosis and gives rise to new linkage of genes, gene recombination. However, mitotic crossing over was discovered in 1936 by Stern in Drosophila. A similar mitotic crossing over occurs during the multiplication of the diploid heterozygous nuclei, though at a low frequency of 10^{-2} per nuclear division.

4. Sorting Out of Diploid Strains:

The segregation of the diploid strains occurs when uninucleate diploid conidia are formed. The colonies that are formed by diploid conidia are recognized by various methods, e.g., higher DNA content and bigger (1.3 times) size of the conidia and certain phenotypic characters of the colony.

5. Haplodization:

The diploid colonies show appearance of sectors on the Petri plate, which produce haploid conidia. This indicates that some diploid nuclei must have undergone haplodization, forming haploid nuclei, which later get sorted out in haploid conidia. Some of these haploids are genetically different from the original haploid parental nuclei. This is because of the recombination that occurred during the mitotic crossing over.

FOSSIL FUNGI

At left are **fossil** hyphae from the Cretaceous of northern France. The filaments resemble those of the living genus Candida. At right is a Miocene perithecium from Nevada. ... Their **fossils** tend to be microscopic; very few large **fungal** bodies, such as mushrooms, have ever been found as **fossils**. While fungi are not uncommon fossils, their fossils have not received a great deal of attention compared to other groups of fossils. Their fossils tend to be microscopic; very few large fungal bodies, such as mushrooms, have ever been found as fossils. Fossil fungi are often difficult or impossible to identify. The fungal filaments shown above at left are a case in point; found in Cretaceous amber from north France, they resemble living filaments of the common ascomycete *Candida*; however, since there is little information on how this fossil organism lived or how it reproduced (both important in recognizing modern taxa), its true affinities may never be known. By contrast, the Miocene fossil at right above has preserved the **perithecium**, an enclosed reproductive structure. Features of the spores and the perithecium in which they occur suggest that this may be a fossil species of *Savoryella*.

Recent careful studies of some well-preserved material have contributed much to our knowledge of fossil fungi. In particular, microscopic examination of fossil fungi from the Devonian-age Rhynie Chert in Aberdeenshire, Scotland, has shown that fungi and land plants were forming symbiotic relationships even at that very early stage in terrestrial evolution. In fact, all four major groups of modern fungi have now been found in Devonian strata, showing that the fungi had successfully invaded the land and begun to diversify before the first vertebrates crawled out of the sea!

UNIT IV

General Characters of Myxomycotina

The class Myxomycetes, known as the acellular slime molds. There are commonly occur in damp places especially on decaying wood, all of which are terrestrial (found on land). The organisms included in this division are commonly known as the plasmodial or acellular slime molds. Vegetative phase is unicellular, without a cell wall, a multinucleate mass of protoplasm called a plasmodium. The vegetative stage in slime molds is morphologically similar to that of an amoeba, because of that known as myxamoeba. Plasmodium produces one or more sporangia where meiosis takes place.

Reproduction :-

Asexual reproduction occurs by binary fission of myxamoeba or fragmentation of the plasmodium. Sexual reproduction takes place by the plasmogamy (fusion of compatible gametes) occurs between myxamoebae or swarm cells (some species are heterothallic).Karyogamy (fusion of nucleus) occurs shortly after plasmogamy to form zygote (2n). Zygote forms plasmodium – longest lived vegetative stage.

General characteristics of Mastigomycotina :-

- Most of them are filamentous and have coenocytic mycelium. However, unicellular form are present, and some genera show the pseudosepta (false cross wall) formation.
- Rhizoids are present in some of unicellular forms.
- They show centric nuclear division. Their centrioles remain functional during nuclear division.
- Live either as saprophytes or parasites.Due to presence of haustoria in a majority of Mastigomycotina , the mode of nutrition is typically absorptive.

Reproduction

Asexual reproduction

Asexual reproduction is by biflagellate heterokont (different) and anisokont (unequal) zoospores that are produced in zoosporangia.

Sexual reproduction:-

Sexual reproduction is heterogamous (oogamous) by oogonia (female) and antheridia (male). Female gamete (oosphere) produced by an oogonium. Male gamete is produced by antheridium and transferred to the oogonium by gametangial contact and migration of male nuclei into oogonia and fertilize. The eggs and sperms are products of meiosis and the only parts of the life cycle that are haploid. Diploid zygote develops into thick-walled resistant oospore that germinates and give rise to vegatative diploid hyphae that reproduce asexually by production of zoospores.

Zygomycotina – General Characters

- Most of the Zygomycotina are present in soil and dung, occurring mostly as saprophytes; few are parasitic on plants and animals. About 1000 fungal species belong to Zygomycotina.
- Vegetative (somatic) body is Haploid .
- Thallus is usually mycelial, hyphae coenocytic.
- Cell wall is made up of chitin and chitosan.

Reproduction

Asexual reproduction takes place by the formation of sporangiophores with terminal uni-to-multispored sporangia. Sporangiophores arise from mycelium. Each sporangium begins as a swelling into which a number of nuclei flow, and it is eventually cut off from the sporangiophores (Aplanospores) by the formation of a septum. The protoplasts of the sporiferous zone cleave mitotically to form dark-coloured multinucleate spores. In this process, nonmotile, single-celled, haploid sporangiospores are formed. The sporangium becomes black as it matures, giving the mold its characteristic colour. Each spore, when liberated, can germinate to produce a new mycelium.

Sexual reproduction

Sexual reproduction occurs only between different mating strains such fungi are known as heterothallic. Two hyphae of opposite strains come closer, hormones cause their hyphal tips to come together.These hyphae are called zygophores. The tip of zygophores develop into gametangia, which become separated from the rest of the fungal body by the formation of septa. The walls between the two touching gametangia dissolve, and the two multinucleate protoplasts come together. The + and - nuclei fuse in pairs to form a young zygospore with several diploid nuclei. The zygospore which can become dormant for several months. Meiosis occurs in the diploid nuclei of zygospore.It results in the segregation of separate '+' and '-' nuclei all the nuclei so formed disintegrate except one. After a long period of rest, the wall of the zygosporangium cracks. And produces a sporangium that produces spores same as the asexually produced sporangium, and the life cycle begins again.

Ascomycotina (sac fungi) – General Characters

- Hyphae with regular cross-walls called septa and haploid.Which are centrally perforated to allow movement of cytoplasm, and sometimes nuclei, between compartments.
- The hyphal cells of the vegetative mycelium may be either uninucleate or multinucleate.
- Cell walls are composed mostly of chitin.

Reproduction and life cycle

Asexual reproduction

Asexual reproduction in the majority of the Ascomycetes occurs by the formation of specialized spores, known as conidia. Which are formed on tips of modified hyphae called conidiophores. Conidia are formed in longitudinal chains on the conidiophores. Each conidium contains one or more nuclei. Conidia form on the surface of conidiophores in contrast to spores that form within sporangia in Rhizopus. When mature, conidia are released in large numbers and germinate to produce new organisms.

Sexual reproduction

In these fungi sexual reproduction occurs by the formation of multinucleate gametangia. Male gametangia may be an antheridium or conidium-like structure – spermatium. Female gametangium - ascogonium, may have a long projection, the trichogyne. Asci formation occur on the same mycelia that produce conidia.

Basidiomycotina - General characters

The mycelium of the Basidiomycotina in most species have three distinct phases during the life cycle of the fungus:-

i) Primary mycelium :- When it germinates, a basidiospore produces haploid primary mycelium . Initially the mycelium may be multinucleate, but septa soon form and the mycelium is divided into monokaryotic (uninucleate) cells. This septate mycelium grows by division of the terminal cell.

ii) Dolipore septa with parenthesome are present in most of the genera.

iii) Allows cytoplasmic movement but prevents nuclear migration from one compartment to the next.

iv) Secondary mycelium :-Commonly a secondary mycelium forms upon conjugation of two sexually compatible hyphae (heterokaryotic).

Reproduction of Basidiomycotina :-

Asexual Reproduction :-

Basidiomycotina reproduce asexually by either budding or asexual spore formation. Budding occurs when an outgrowth of the parent cell is separated into a new cell. Any cell in the organism can bud. The usual asexual spores formed by these fungi are arthrospores, sometimes called oidia. Few species form blastic conidia.

Sexual reproduction :-

The specialized nature of sex organs is lost and the whole process is ultimately confined to copulation between vegetative mycelia (somatogamy). The tertiary mycelium, which is also dikaryotic, arises directly from the secondary mycelium, and forms the basidiocarp. The spore forming basidia(basidia are not produced by asexual Basidiomycota) are produced by the terminal cell on millions of dikaryotic hyphae. Basidiocarps vary greatly in appearance in different genera, but all bear basidia which are usually arranged in a layer of hymenium. The basidia and basidiospores are produced on even sufaces or on hymenophores in form of teeth, tubes or leaf-like structures (gills) at the inferior side of caps or consoles (crustothecium, pileothecium).

Deuteromycotina – General Characters

(i) Deuteromycetes occur mostly as saprophytes on a wide range of substrates, but a large number of them are parasites on plants and animals (including humans) and cause a variety of diseases.

(ii) The mycelium is made up of well-developed, profusely branched and septate hypha that possess multinucleate cells and simple pore septa.

(iii) The hyphae may be inter- or intracellular, and their cell wall chiefly contains chitin-glucan.

Reproduction of Deuteromycotina

Reproduction of Deuteromycota is strictly asexual, occuring mainly by production of asexual conidiospores. Some hyphae may recombine and form heterokaryotic hyphae.

Most Deuteromycetes are conidial forms, i.e., produce conidia. Besides conidia, some of the Deuteromycetes may produce different other spores. But there are also numerous forms which are known to produce merely sterile mycelia and no conidia at all. The sterile mycelia may or may not make sclerotia. The conidial forms produce conidia on conidiophores arising directly from the somatic hyphae which may be hyaline or bright-coloured. The somatic hyphae may be loose; separate; innate or not; or closely aggregated to form sporogenous structures, such as, acervulus, sporodochium and synnema. Besides these, conidia may also be produced in complex structures like, pycnidia.

ECONOMIC IMPORTANCE OF FUNGI:-

Fungi include hundreds of species which are of tremendous economic importance to man.

1. Role of Fungi in Medicine:

Some fungi produce substances which help to cure diseases caused by the pathogenic microorganisms. These substances are called the antibiotics. The term antibiotic, therefore, denotes an organic substance, produced by a microorganism, which inhibits the growth of certain other microorganisms. The most important antibiotics are produced by the moulds, actinomycetes or bacteria.

2. Role of Fungi in Industry:

The industrial uses of fungi are many and varied. In fact the fungi form the basis of many important industries. There are a number of industrial processes in which the biochemical activities of certain fungi are harnessed to good account.

3. Role of Fungi in Agriculture:

The fungi play both a negative and a positive role in agriculture.

A. Negative Role:

They have a negative value because they are the causative agents of different diseases of our crop, fruit and other economic plants. These fungal diseases take a heavy toll and cause tremendous economic losses.

B. Positive Role of Fungi:

Some soil fungi are beneficial to agriculture because they maintain the fertility of the soil. Some saprophytic fungi particularly in acid soils where bacterial activity is at its minimum cause decay and decomposition of dead bodies of plants and their wastes taking up the complex organic compounds (cellulose and lignin) by secreting enzymes.

4. Role of Fungi as Food and as Food Producers:

Many edible fungi are of great economic value as food. They are regarded as delicacies of the table. There are said to be over 200 species of edible fungi. The fructifications of some fungi such as the field mushroom Agaricus campestris (dhingri), Podaxon podaxis (Khumb), the honey coloured mushrooms, the fairy ring mushrooms, the puff balls (Lycoperdon and Clavatia), morels (Morchella, guchhi), and truffles are edible.

The content of available food in them is not high but they supply vitamins and are valuable as appetisers. Yeasts and some filamentous fungi are valuable sources of vitamins of the B-complex. A few of the mushrooms are fatally poisonous, some cause only discomfort. To the former category belong Amanita.

LICHEN

Introduction

Lichens are a small group of curious plants of composite nature made up of two different organisms, an alga (phycobiont: in Latin phycos-alga; bios-life) and a fungus (mycobiont: in Greek mycos-fungus; bios-life). Algal and fungal components live in a truly intimate symbiotic relationship. This true nature of lichens was first identified by Simon Schwendener. He named the algal component as Phycobiont and the fungal component as Mycobiont.

General characters of Lichens

1. In general, the major portion of the thallus is occupied by the fungal component. The fungal component produces its own reproductive structures.
2. The algal partner makes the food by the process of photosynthesis. The food diffuses out and is absorbed by the fungal partner.
3. Owing to their symbiotic relationship, lichens can live in variety of habitats and climatic conditions including extreme environments.
4. Based on the substrate of growing, the lichens can be of following types

- Corticolous (grows on tree barks),
- Follicolous (grows on leaves surfaces),
- Saxicolous (grows on rock surfaces),
- Terricolous (grows on soil)
- Musicolous (grows on mosses)

5. Lichen growth forms are generally visible on surfaces forming grayish, greenish or orange areas. They are classified mainly based on their morphology and size into three major types namely,

- Crustose (crust like)
- Foliose (leaf like)
- Fruticose (shrubby)

6. Crustose lichens are called microlichens whereas foliose and fruticose lichens are called as macrolichens.
7. The main plant body of the lichen is called as thallus. Thallus is the vegetative portion and is similar to the vegetative portions of mosses and liverworts.
8. Mycobiont (Ascomycete or Basidiomycete) establishes an intimate symbiotic relationship with phycobiont (green algae or blue green algae). After association,

both phycobiont and mycobiont lose tsheir uniqueness and they are known as lichens. Now the lichens act as a single organism, both morphologically and physiologically.

9. The method of reproduction in lichens is completely different from that of fungi and algae. Vegetative reproduction in lichens is through the development of special propagules called as diaspores. The most common diaspores of lichens are soredia and isidia.
10. The fungal partner of the lichens reproduces sexually. Sexual reproduction in the lichens is initiated by the production of fruiting bodies followed by formation of spores called as ascospores. Ascospores are resting spores which have the ability to tolerate adverse conditions.

Classification (Miller, 1984)

According to Miller (1984) lichens are assigned subdivision status in true fungi (Eumycophyta), and are divided into two classes:

1. Class Ascolichens: Fungal partner is an Ascomycotina

   Ascolichens are subdivided into two sub-groups

   a. Gymnocarpae in which the ascocarp is of an apothesium type.
   b. Pyrenocarpae in which the ascocarp is perithesium type.
2. Class Basidiolichens: Fungal partner is an Basidiomycotina

Distribution

There is about 400 genera and 15,000 species of lichens, widely found in different regions of the world. The plant body is thalloid; generally grows on bark of trees, leaves, dead logs, bare rocks etc., in different habitat. They grow luxuriantly in the forest areas with free or less pollution and with abundant moisture.

Some species like *Cladonia rangiferina* (reindeer moss) grows in the extremely cold condition of Arctic tundras and Antarctic regions. In India, they grow abundantly in Eastern Himalayan regions. They do not grow in the highly polluted regions like Industrial areas. The growth of lichen is very slow.

Structure of Thallus in Lichens:

The plant body of lichen is thalloid with different shapes. They are usually grey or greyish green in colour, but some are red, yellow, orange or brown in colour.

A. External Structure of Thallus:

Based on the external morphology, general growth and nature of attachment, three main types or forms of lichens (crustose, foliose and fruticose) have been recognised. Later, based on detailed structures,

Hawksworth and Hill (1984) categorised the lichens into five main types or forms:

1. Leprose:

This is the simplest type, where the fungal mycelium envelops either single or small cluster of algal cells. The algal cell does not envelop all over by fungal hyphae. The lichen appears as powdery mass on the substratum, called leprose, e.g., Lepraria incana.

2. Crustose:

These are encrushing lichens where thallus is inconspicuous, flat and appears as a thin layer or crust on substratum like barks, stones, rocks etc. They are either wholly or partially embedded in the substratum, e.g., Graphis, Lecanora, Ochrolechia, Strigula, Rhizocarpon, Verrucaria, Lecidia etc.

3. Foliose:

These are leaf-like lichens, where thallus is flat, horizontally spreading and with lobes. Some parts of the thallus are attached with the substratum by means of hyphal outgrowth, the rhizines, developed from the lower surface, e.g., Parmelia, Physcia, Peltigera, Anaptychia, Hypogymnia, Xanthoria, Gyrophora, Collema, Chauduria etc.

4. Fruticose (Frutex, Shrub):

These are shrubby lichens, where thalli are well developed, cylindrical branched, shrub-like, either grow erect (Cladonia) or hang from the substratum (Usnea). They are attached to the substratum by a basal disc e.g., Cladonla, Usnea, Letharia, Alectonia etc.

5. Filamentous:

In this type, algal members are filamentous and well-developed. The algal filaments remain ensheathed or covered by only a few fungal hyphae. Here algal member remains as dominant partner, called filamentous type, e.g., Racodium, Ephebe, Cystocoleus etc.).

B. Internal Structure of Thallus:

Based on the distribution of algal member inside the thallus, the lichens are divided into two types. Homoisomerous or Homomerous and Heteromerous.

1. Homoisomerous:

Here the fungal hyphae and the algal cells are more or less uniformly distributed throughout the thallus. The algal members belong to Cyanophyta..

2. Heteromerous:

Here the thallus is differentiated into four distinct layers upper cortex, algal zone, medulla, and lower cortex. The algal members are restricted in the algal zone only. This type of orientation is found in foliose and fruticose lichens e.g., Physcia, Parmelia etc.

C. Specialised Structures of Thallus:

1. Breathing Pore:

In some foliose lichen (e.g., Parmelia), the upper cortex is interrupted by some opening, called breathing pores, which help in gaseous exchange.

2. Cyphellae:

On the lower cortex of some foliose lichen (e.g., Sticta) small depressions develop, which appears as cup-like white spots, known as Cyphellae. Sometimes the pits that formed without any definite border are called Pseudocyphellae. Both the structures help in aeration.

3. Cephalodium:

These are small warty outgrowths on the upper surface of the thallus. They contain fungal hyphae of the same type as the mother thallus, but the algal elements are always different. They probably help in retaining the moisture.

Reproduction in Lichens:

I. Vegetative Reproduction:

(a) Fragmentation:

It takes place by accidental injury where the thallus may be broken into fragments and each part is capable of growing normally into a thallus.

(b) By Death of Older Parts:

The older region of the basal part of the thallus dies, causing separation of some lobes or branches and each one grows normally into new thallus.

II. Asexual Reproduction:

1. Soredium (pi. Soredia):

These are small grayish white, bud-like outgrowths developed on the upper cortex of the thallus. They are composed of one.or few algal cells loosely enveloped by fungal hyphae. They are detached from the thallus by rain or wind and on germination they develop new thalli.

2. Isidium (pi. Isidia):

These are small stalked simple or branched, grayish- black, coral-like outgrowths, developed on the upper surface of the thallus.

3. Pycniospore:

Some lichen develops pycniospore or spermatium inside the flask-shaped pycnidium. They usually behave as gametes, but in certain condition they germinate and develop fungal hyphae.

III. Sexual Reproduction:

Only fungal partner of the lichen reproduces sexually and forms fruit bodies on the thallus. The nature of sexual reproduction in ascolichen is like that of the members of Ascomycotina, whereas in Basidiolichen is like that of Basidiomycotina members.

In Ascolichen, the female sex organ is the carpogonium and the male sex organ is called spermogonium (= pycnidium). The spermogonium mostly develops close to carpogonium.

The spermogonium is flask-shaped and develop spermatia from the inner layer. The spermatia behave as male gametes. The spermatium, after liberating from the spermogonium, gets attached with the trichogyne at the sticky projected part. On dissolution of the common wall, the nucleus of spermatium migrates into the carpogonium and fuses with the egg.

Many ascogenous hyphae develop from the basal region of the fertilised ascogonium. The binucleate penultimate cell of the ascogenous hyphae develops into an ascus.
Both the nuclei of penultimate cell fuse and form diploid nucleus (2n), which undergoes first meiotic and then mitotic division — results in eight haploid daughter nuclei. Each haploid nucleus with some cytoplasm metamorphoses into an ascospore.

The asci remain intermingled with some sterile hyphae — the paraphyses. With further development, asci and paraphyses become surrounded by vegetative mycelium and form fruit body.

The ascospores may be unicellular or multicellular, uninucleate or multinucleate, and are of various shapes and sizes. After liberating from the ascus, the ascospore germinates in suitable medium and produces new hypha. The new hypha, after coming in contact with proper algal partner, develops into a new thallus.

In Basidiolichen , the result of sexual reproduction is the formation of basidiospores that developed on basidium as in typical basidiomycotina. The fungal member (belongs to Thelephoraceae) along with blue green alga, as algal partner forms the thalloid plant body. The thallus grown over soil produces hypothallus without rhizines, but on tree trunk it grows like bracket fungi and differentiates internally into upper cortex, algal layer, medulla and lower fertile region with basidium bearing basidiospores.

ECONOMIC IMPORTANCE OF LICHENS

1. As Food and Fodder:

Lichens are used as food by human being in many parts of the world and also by different animals like snail, catterpiliars, slugs, termites etc. They contain polysaccharide, lichenin; cellulose, vitamin and certain enzymes.

2. As Medicine:

Lichens are medicinally important due to the presence of lichenin and some bitter or astringent substances. They have been used in the treatment of jaundice, diarrhoea, fevers, epilepsy, hydrophobia and skin diseases. Cetraria islandica and Lobaria pulmonaria are used for tuberculosis and other lung diseases;

3. Industrial Uses:

Lichens of various types are used in different kinds of industries.

(i) Tanning Industry:

Some lichens like Lobaria pulmonaria and Cetraria islandica are used in tanning leather.

(ii) Brewery and Distillation:

Lichens like Lobaria pulmonaria are used in brewing of beer. In Russia and Sweden, Usneaflorida, Cladonia rangiferina and Ramalina fraxinea are used in production of alcohol due to rich content of "lichenin", a carbohydrate.

(iii) Preparation of Dye:

Dyes obtained from some lichens have been used since pre- Christian times for colouring fabrics etc. Dyes may be of different colours like brown, red, purple, blue etc. The brown dye obtained from Parmelia omphalodes is used for dyeing of wool and silk fabrics.

(iv) Cosmetics and Perfumery:

The aromatic compounds available in lichen thallus are extracted and used in the preparation of cosmetic articles and perfumes. Essential oils extracted from species of Ramalina and Evernia are used in the manufacture of cosmetic soap.

Harmful Activities of Lichens:

1. Some lichens like Amphiloma and Cladonia parasitise on mosses and cause total destruction of moss colonies.
2. Lichen like Usnea, with its holdfast hyphae, can penetrate deep into the cortex or deeper, and destroy the middle lamella and inner content of the cell causing total destruction.
3. Different lichens, mainly crustose type, cause serious damage to window glasses and marble stones of old buildings.

ECOLOGICAL IMPORTANCE OF LICHENS

Lichens have some ecological importance.

1. Pioneer of Rock Vegetation:

Lichens are pioneer colonisers on dry rocks. Due to their ability to grow with minimum nutrients and water, the crustose lichens colonise with luxuriant growth. The lichens secrete some acids which disintegrate the rocks.

After the death of the lichen, it mixes with the rock particles and forms thin layer of soil. The soil provides the plants like mosses to grow on it as the first successor, but, later, vascular plants begin to grow in the soil. In plant succession, Lecanora saxicola, a lichen, grows first; then the moss Crtmmia pulvinata, after its death, forms a compact cushion on which Poa compressor grows later.

2. Accumulation of Radioactive Substance:

Lichens are efficient for absorption of different substances. The Cladonia rangiferina, the 'reindeer moss', and Cetraria islandica, the 'Iceland moss' are the commonly available lichens in Tundra region. The fallout of radioactive strontium (^{90}Sr) and caesium ($^{137}C_S$) from the atomic research centres are absorbed by lichen. Thus, lichen can purify the atmosphere from radioactive substances.

The lichens are eaten by caribou and reindeer and pass on into the food-chain, especially to the Lapps and Eskimos. Thus, the radioactive substances are accumulated by the human beings.

3. Sensitivity to Air Pollutants:

Lichens are very much sensitive to air pollutants like SO_2, CO, CO_2 etc.; thereby the number of lichen thalli in the polluted area is gradually reduced and, ultimately, comes down to nil. The crustose lichens can tolerate much more in polluted area than the other two types. For the above facts, the lichens are markedly absent in cities and industrial areas. Thus, lichens are used as "pollution indicators".

UNIT – V : BRYOPHYTES

General Characteristics of Bryophytes:

- Plants occur in damp and shaded areas
- The plant body is thallus like, i.e. prostrate or erect
- It is attached to the substratum by rhizoids, which are unicellular or multicellular
- They lack true vegetative structure and have a root-like, stem-like and leaf-like structure
- Plants lack the vascular system (xylem, phloem)
- Bryophytes show **alternation of generation** between independent gametophyte with sex organs, which produces sperm and eggs and dependent sporophyte which contains spores
- The dominant part of the plant body is gametophyte which is haploid
- The thalloid gametophyte is differentiated into rhizoids, axis and leaves
- The gametophyte bears multicellular sex organs and is photosynthetic
- The antheridium produces antherozoids, which are biflagellated
- The shape of an archegonium is like a flask and produces one egg
- The antherozoids fuse with egg to form a zygote
- The zygote develops into a multicellular sporophyte
- The sporophyte is semi-parasitic and dependent on the gametophyte for its nutrition
- Cells of sporophyte undergo meiosis to form haploid gametes which form a gametophyte
- The sporophyte is differentiated into foot, seta and capsule

Classification of Bryophytes

According to the latest classification, Bryophyta is divided into three classes:

A. **Hepaticopsida (Liverworts)**
B. **Anthocerotopsida (Hornworts)**
C. **Bryopsida (Mosses)**

A. Hepaticopsida (Liverworts): The name hepaticopsida comes from the word “hepatic” meaning liver. Liverworts come under this class.

Hepaticopsida is further divided into 4 orders:

1. **Marchantiales** (e.g. Riccia, Marchantia)
2. **Sphaerocarpales** (e.g. Sphaerocarpos)
3. **Calobryales** (e.g. Calobryum)
4. **Jungermanniales** (e.g. Pellia)

B. Anthocerotopsida (Hornworts): There are around 300 species present in this class. They are commonly known as hornworts. It has only one order i.e. Anthocerotales. Examples: Anthoceros, Megaceros, Notothylas.

C. Bryopsida (Mosses): It is the largest class of Bryophyta with around 1400 species. They are commonly called mosses. Examples: Funaria, Polytrichum, Sphagnum.

Bryopsida is further divided into 5 orders:

1. Bryales
2. Andreales
3. Sphagnales
4. Polytrichales
5. Buxbaumiales

Structure and Reproduction of Hepaticopsida

- Gametophyte plant is either thalloid or foliose
- In foliose forms, leaves are without midrib and dorsiventral
- Thalloid is dorsiventral, lobed and dichotomously branched
- Each cell of thallus contains many chloroplasts without pyrenoids
- Rhizoids are unicellular, branched and aseptate
- Sex organs are borne dorsally embedded in gametophytic tissues
- The sporophyte is made up of only capsule (in Riccia) or foot, seta and capsule (in Marchantia)

Reproduction:

Asexual reproduction:

It takes place by fragmentation or by the formation of gemmae. Gemmae are produced inside gemma cups. Gemmae are asexual buds, which are green and multicellular. The gemma cup develops into a new plant after detaching from the parent plant

Sexual reproduction: Antheridium (male organ) and archegonium (female organ) may be present on the same thalli or different thalli. They produce sperm and egg respectively. After fertilisation, zygote is formed. The zygote develops into a diploid sporophyte, a few cells of the sporophyte undergo meiosis to form haploid spores. These spores develop into haploid gametophytes, which are free-living and photosynthetic

Structure and Reproduction of Anthocerotopsida (Hornworts):

- The gametophytic body is flat, dorsiventral, simple thalloid without internal differentiation
- Rhizoids are smooth-walled
- Each cell has one chloroplast with a pyrenoid
- Sex organs are present dorsally embedded in the thallus
- The sporophyte is differentiated into foot, meristematic zone and capsule
- Sporogenous tissues develop from amphithecium

- Pseudoelaters are present in the capsule
- The columella is present in the capsule, which originates from endothecium

Reproduction:

Asexual reproduction:

Vegetative propagation is by fragmentation of thallus and by tubers, which are formed under unfavourable conditions

Sexual reproduction:

They reproduce sexually by waterborne sperm, which travel from antheridium to archegonium. A fertilised egg develops into the sporophyte. Sporophyte splits lengthwise to release spores which develop into a gametophyte.

Structure and Reproduction of Bryopsida (Mosses):

The gametophyte is differentiated into protonema and foliose gametophore

- Foliose is made up of stem as an axis and leaves without midrib
- Rhizoids are multicellular with oblique septa
- Sex organs are borne apically on stem
- Elaters are absent
- The sporophyte is differentiated into foot, seta and capsule
- Sporogenous tissues develop from endothecium
- Columella is present
- Dehiscence of the capsule takes place by separation of the lid

Reproduction:

Asexual reproduction:

Asexual reproduction is by budding and fragmentation of secondary protonema

Sexual reproduction:

Antheridia and archegonia are present at the apical part of leafy shoots. After fertilization sporophyte is produced, which is more differentiated than liverworts. The gametophyte develops from the spores

Economic Importance of Bryophytes

1. **Medicinal uses:**
    - Sphagnum is used in surgical dressing due to its high absorptive power and some antiseptic property for filling absorptive bandages in place of cotton for the treatment of boils and discharging wounds
    - Marchantia has been used to cure pulmonary tuberculosis and affliction of liver
    - The decoction of dried sphagnum is used in the treatment of acute haemorrhage and eye infections
    - Peat-tar is antiseptic and used as a preservative. Sphagnol, which is a distillate of peat-tar is used to treat skin disease
    - Polytrichium species has shown to dissolve stone in kidney and gall bladder
    - Antibiotic substances can be extracted from certain bryophytes having antibiotic properties

Food: Some mosses provide food for herbaceous mammals, birds and other mammals

As Indicator plants: Some bryophytes grow in a specialised area and can be used as an indicator for acidity and basicity of the soil. E.g. Polytrichum indicated the acidity of the soil, Tortella species grow well in the soil rich in lime or other bases and occur as calcicoles

In seedbeds: Because of its water retention capacity, it is used in seedbeds, greenhouses, nurseries to root cuttings. Sphagnum is also used to maintain high soil acidity required by certain plants

Peat formation: Sphagnum is also known as peat moss. Peat is formed by slowing down the decaying process. The gradual compression and carbonisation of partially decomposed vegetative matter in bogs give rise to a dark-coloured substance called Peat.

- It is used as a fuel
- Lower layers of peat form coal
- Peat is also used in the production of ethyl alcohol, ammonium sulphate, ammonia, dye, paraffin, tannins etc.
- It improves soil texture in horticulture

Formation of stone: The travertine rock deposits are extensively used as a building stone

Evolution of Sporophyte in Bryophytes:

The sporophyte of bryophytes is called sporogonium which generally consists of a single, terminal sporangium (monosporangiate) with a bulbous foot and with or without an unbranched stalk or seta. The sporogonium is very delicate, short-lived and nutritionally dependent on its gametophyte.

The sporophytic phase begins with the formation of a diploid zygote within the venter of the archegonium. In the simplest form of sporophyte (e.g., Riccia) the entire zygote is taking part in the formation of stelile capsule wall and the central sporogenous cells. In complex forms, zygote differentiates and sporogenous cells form more sterile tissues.

There are two opposing theories regarding the evolution of sporophyte in bryophytes:

(i) Theory of Progressive evolution i.e., Evolution of sporophytes by the progressive sterilisation of potentially sporogenous tissue:

This theory was advocated by Bower (1908- 35) and supported by Cavers (1910) and Campbell (1940). According to this theory, the primitive sporophyte of bryophytes was simple and most of the sporogenous tissue was fertile (e.g., Riccia) and from such a sporophyte, the more complex sporophytes (e.g., mosses) have been evolved by the progressive sterilisation of potential sporogenous tissue. This theory is also known as “theory of sterilisation”.

The increasing sterilisation of sporogenous tissue from simple sporophyte of Riccia to the most complex type of Funaria can be arranged through the following stages:

First stage:

The simple sporophyte of Riccia consists of a single-layered sterile jacket enclosing sporogenous cells with a very few absorptive nutritive cells (nurse cells). The zygote divides by a transverse wall, followed* by a vertical wall to form a four-celled embryo. Subsequently 20-30 celled embryo is formed by further divisions, in which periclinal divisions differentiate a single layered outer amphithecium and the inner multicellular mass, the endothecium.

Second stage:

In this stage, the zygote divides transversely to form a hypobasal and an epibasal cells. A small foot is formed from the hypobasal cell. The epibasal cells differentiates into an outer amphithecium and inner endothecium.

The amphithecium forms a single-layered sterile jacket of the capsule, while the endothecium differentiates into fertile sporocytes and long sterile elater-like nurse cells without the thickening bands. Thus, the zygote has polarity showing more sterilisation of sporogenous cells like nurse cells and sterile foot. This stage has been noted in Corsinia.

Third stage:

The development of sporophyte is like that of Corsinia, but there is more sterilisation of sporogenous tissue. This condition is noted in Sphaerocarpus sporophyte which consists of a sterile bulbous foot, a narrow sterile seta developed from hypobasal cell and a fertile capsule developed from endothecium containing sporocytes and sterile nurse cells.

Fourth stage:

This stage is represented by Targionia, where the sporophyte consists of a sterile bulbous foot, a sterile narrow seta and a fertile capsule. Here about half of the endothecial cells produce fertile sporogenous tissue, while the remaining half gives rise to sterile elaters with 2-3 spiral thickening. Hence, in Targionia, more sterilisation of sporogenous tissue has been observed.

Fifth stage:

This stage is illustrated by Marchantia, where further sterilisation of sporogenous tissue has been noted in comparison with Targionia. In Marchantia, the sterile tissue consists of a broad foot, a massive seta, a single-layered jacket of capsule, sterile apical cap at the apex of capsule and a large number of long elaters with spiral thickening.

Sixth stage:

This stage is represented by some members of Jungermanniales like Pellia, Riccarclia, etc. Here more sterilisation of sporogenous tissue has been observed. Sporophyte is differentiated into foot, seta and capsule having multilayered jacket. The sporogenous tissues produce mass of sterile elatophores and diffuse elaters.

Seventh stage:

This stage is illustrated by members of Anthocerotophyta like Anthoceros. Here marked reduction in the sporogenous tissue has been noted. The multilayered capsule differentiates into epidermis with stomata and chlorophyllous cells.

Eighth stage (Final stage):

The members of Bryopsida like Funaria, Polytrichum, Pogonatum etc., show the highest degree of sterilisation. The sporophyte is differentiated into a foot, a long seta and a capsule. The sterile tissue of capsule consists of the apophysis, operculum, many- layered jacket, the columella, trabeculae, the wall of spore sac and the peristome. The sporogenous tissue is restricted to the spore sacs only, hence it forms a negligible portion in the sporophyte.

(ii) Theory of Regressive evolution i.e., evolution of sporophytes due to the progressive reduction or simplification:

This theory is known as regressive or retrogressive theory, and supported by several scientists like Church (1919), Kashyap (1919), Goebel (1930) and Evans- (19391 According to this theory, the most simple sporophyte of Riccia (comprised of a simple capsule) is the most advanced type which has been evolved by the simplification or progressive reduction of the complex sporophytes (foliose with complex assimilatory tissue and functional stomata) of mosses (e.g. Funaria, Pogonatum, Polytrichum etc.)

The stages of progressive reduction of the foliose sporophyte (primitive type) to the simpler sporophyte (advanced type) have been enumerated:

(a) The semiparasitic foliose sporophyte gradually lost its leaves and became embedded within the gametophyte.

(b) There is a gradual reduction of the assimilatory (photosynthetic) tissue in the sporophytes and subsequently this tissue is confined only to the jacket of capsule (e.g., Funaria, Anthoceros).

(c) Stomata are restricted in the apophysis region (e.g. Funaria, Polytrichum) that communicate with the intercellular spaces. In Sphagnum, the stomata of apophysis are non-functional and become rudimentary. In all liverwort members stomata are completely absent in sporophytes.

(d) The capsules of most mosses (Funaria, Polytrichum, Sphagnum, etc.), hornwort (Anthoceros) and some jungermanniales (Pellla, Porella) are multilayered which subsequently became single-layered (Marchantia, Plagiochas- ma, Riccia) by reduction.

(e) The foot and seta are well-developed in mosses (Pogonatum, Funaria, etc.) and some liverworts (Pellia, Marchantia, etc.). The seta became much reduced and form a narrow sterile part of the sporophyte (Corsinia, Targionia).

(f) The sporophytes of mosses show the highest degree of sterilisation with a negligible amount of sporogenous tissue. There has been gradual reduction in the sterile tissue of the capsule, with simultaneous increase in the amount of sporogenous tissue.

In hornworts, a good amount of sporogenous tissue is formed from the inner layer of amphithecium. In liverworts (Riccia, Marchantia) the entire endothecium gives rise to sporogenous cells.

Fossil Bryoohytes

1. Fossil Hepatophyta
2. Fossil Anthocerotophyta
3. Fossil Bryophyta
4. Problematic Fossil Bryophytes.

1. Fossil Hepatophyta (Marchantiophyta):

The earliest record of vegetative fossil bryophyte remains is the liverwort from the Upper Devonian of New York which has been assigned to the form-genus Pallavicinites, (= Hepaticites) devonicus.

The reproductive structures are not found with any of the species of Pallavicinites. The vegetative features suggested that the species of Pallavicinites may be more closely related to the anacrogynous Jungermanniales.

Various species of Pallavicinites have been described from the Carboniferous to the Pleistocene deposits and can easily be compared with living bryophyte genera like Pallavicinia, Metzgeria, Treuba and Fossombronia.

Diettertia, an interesting hepatic, has been identified from Cretaceous era which may be more closely compared with the Jungermanniales.

The best known bryophyte fossil is Naiadita lanceolata that has been described by Harris (1938) from the Rhaetic (Upper Triassic) of England. The spores of Naiadita show the closest resemblance to the member of the Marchantiales and Sphaerocarpales.

The type of spores, unicellular rhizoids, the nature of archegonia and capsules suggested that Naiadita represents a liverwort similar to the living genus Riella of Sphaerocarpales. However, Schuster (1966) argued that the vegetative features of Naiadita showing closer proximity to the Calobryales.

A fossil bryophyte, Marchantiolites, has been described from the Lower Cretaceous rock of central Montana. M. porosus has been identified from the Jurassic deposit of Sweden. Marchantiolites has been placed in the Marchantiales due to the similarity in the airpores.

A thalloid bryophyte identified from the Upper Triassic of South America has been placed in the genus Marchantites. Ricciopsis, a rosette- shaped bryophytic thallus has been identified from the Jurassic of Sweden.

The similar rosette-shaped thallus has been identified from Deccan Intertrappean beds of India and has been placed in the modern genus Riccia.

2. Fossil Anthocerotophyta (Hornworts):

There are no reports of fossil Anthocerotophyta thalli, although some reliable reports of hornwort spores are available from the Cretaceous (Maastrichtian) rocks of North America. The spores are trilete, circular and possess a distinct cingulum with variable ornamentations which are comparable with the modern hornwort genus Phaeoceros.

3. Fossil Bryophyta (Mosses):

The fossil record of the mosses is much less complete as compared to the fossil hepatics, though they are recorded as early as the Permian. An impression of a leafy shoot of Muscites plumatus has been described from the rocks of Lower Carboniferous age.

This plant shows an axis, covered with helically arranged leaves. Sex organs, sporophyte capsules or rhizoids were not associated with the gametophytic plant. Several species of Muscites have been reported from the Upper Carboniferous of France and the Triassic of Africa.

An extensive moss flora has been identified by Neuberg (1960) from the Permian rocks of Siberia, of which six identified genera (Intia, Salairia, Uskatia, Polyssaiuria, Bajdaieira and Buchtia) were placed under the Bryales and three (Protosphagnum, Vorentannularia and Jungajia) to a new order, the Protosphagnales.

The genus Protosphagnum has leaves comparable to the modern genus Sphagnum, except for the presence of a midrib.

Several compression fossils of true mosses have been described from the Mesozoic, of which Tricostium and Yorekiella from the Jurassic of the Bureja Basin, Russia and Aulacomnium heterostichoides from deep water varved clays (Eocene) of a fresh water lake in British Columbia.

The well-preserved Aulacomnium heterostichoides has been extensively studied which is very closely related to the present day living species, Aulacomnium heterostichum found in eastern North America and eastern Asia.

4. Problematic Fossil Bryophytes:

The Lower Devonian compression fossil Sporogonites is one of the oldest plants that resembles a bryophyte. The plant consists of many parallel-oriented sporangial stalks that terminate in elongate capsules, developed from a common thallus.

The sporangium is multilayered and possibly contains a central columella. Numerous trilete spores are present in the sporangium. Sporogonites has been considered to be an early hornwort or gametophyte-bearing sporophyte of a moss.