Chapter 5

Fungi, Lichen and Mycorrhiza

FUNGI

- The **fungi** (*singular*, fungus) are a group of eukaryotic micro-organisms that lack chlorophyll, are unable to synthesize their own food and are therefore, heterotrophic. They live either as saprophytes, obtaining their food from the dead organic matter, or parasites, obtaining food from the bodies of living plants and animals.
- The term fungus is a latin word meaning **mushroom**.
- The branch of science that deals with the study of fungi is called **mycology** (Greek word *mykos* = mushroom and *logos* = discourse), and the branch that deals with the study of fungal disease is called **fungal pathology.**
- **Clausius** (1601) is regarded as the earliest writers who described fungi.
- The founder of mycology is **Antonio Micheli**. He **gave the first systematic account of fungi** in his book *Nova Plantarum Genera.*

General characters of fungi

- Fungi is very large group of over 100,000 species.
- Fungi are **ubiquitous** *i.e* occurs in a variety of habitats.
- Most of them are **moisture loving and terrestrial**, but a few are **aquatic**, *e.g., Monoblepharis* and *Saprolegnia* and these are commonly known as '**water moulds**'.
- A few fungi are **epiphytic**, live on trees, *e.g., Armillaria* on apple tree and causes red rot of apple.
- It is usually defined as a group of those organisms which form the thallus (*i.e.*, not differentiated into root, stem and leaves), built up of single cell or cells (unicellular or multicellular).
- Fungi **lack chlorophyll** and are unable to synthesize their own food by the process of photosynthesis.
- Fungi **obtain their nutrition from the external source by the process of extracellular digestion** and **absorption of the digested material**.
  Such **mode of nutrition** is called **heterotrophic** and the organisms are called **heterotrophs**.
- Heterotrophic organisms either live on dead decaying organic matter or on living organisms.
- **According to their mode of nutrition**, fungi are of **two types – parasites** and **saprophytes**.
- **Parasite** may be defined as "an organism existing in an intimate association with another living organism from which it derives an essential part of the materials for its existence". Thus, these organisms grow on living organisms and obtain their food from it.
- **Parasitic fungi** obtain their food from living hosts.
- These may be :
  - **Ectophytic :** These are externally on the host, e.g., *Erysiphe* (Powdery mildew).
  - **Endophytic :** These are inside the tissue of plants, e.g., *Albugo*, *Phytophthora*, *Alternaria*.
- **Saprotrophs** obtain their food from non-living decaying organic matter (such as bread, meat, fruit, vegetables, animal dung etc.). Such mode of nutrition is called saprophytic.
- Some fungi grow in **symbiotic association with algae to form lichens**. Some other grow in close association with the **roots of higher plants and form mycorrhiza**.
- Fungi posses definite cell wall (containing cellulose or chitin or both *i.e.*, fungus cellulose) and true nucleus (eukaryotic) but lack chlorophyll (achlorophyllous) and differentiation of vascular tissue (*i.e.* non-vascular).
- They are spore forming and **reproduce by vegetative**, **asexual** and **sexual methods**.

- The **reserve food material** is in the form of **glycogen** and **oil globules**.
- Fungi grow well at **20-30ºC** and at **acidic pH** (6.0).
- Fungi may be unicellular (yeast), much branch filamentous (*Rhizopus*) type.
- The filamentous thread like structures that make up the fungal body is called **mycelium**.
- **Hyphae** is the **unit structure that make up** the **mycelium** (gk word *hypha* - web).
- Hyphae are of **two types** – **aseptate** or **coenocytic** (multinucleate) and **septate** (number of partitions or septa).
- Aseptate hyphae may form septa during reproduction, eg *Rhizopus*, *Albugo*, *Phytophthora* etc.
- In septate form cell may be **monokaryotic** (uninucleate) or **dikaryotic** (two nuclei) or **multinucleate**.
- Septa are of **3 types** – **complete septum**, **septum with simple pore** and **septum with dolipore**.
- In **complete septum** the cross wall is complete without distinct pores, e.g., *Geotrichum*.
- In most ascomycetes and deuteromycetes, the **septum possesses simple central pore**. Simple central pore may get plugged by crystalline structure called **woronin body**, e.g., trichomycetes. Woronin body is secreted by microbody and covered by membrane.
- In basidiomycetes, the septum becomes barrel-shaped around a central pore called **dolipore septum**, it may be surrounded by pore cap.
- Septal pores **allow quick transport of nutrients from the region of absorption to all parts of the mycelium**.
- The reproductive hyphae are supplied with the nourishment from the vegetative hyphae throughout the septal pores.
- When mycelium is interwoven to form web like structure it is called **plectenchyma**.
- It is of two types – **prosenchyma** and **pseudoparenchyma**.
- **Prosenchyma** is the mycelium in which hyphae are loosely interwoven and lie more or less parallel to each other.
- **Pseudoparenchyma** is the mycelium in which the hyphae are very loosely packed, so individual hypha cannot be identified and appear as isodiametric cells giving the appearance of parenchyma cells in higher plants.
- When mycelium by interweaving forms compact resting structure it is called **sclerotium**.
- When fungal mycelia are interwoven to form thick cord-like structures like roots, that help in absorption, it is called **rhizomorphs**.
- When the plant body is unicelled at one stage and mycelial at the other end then the organisation is described as **dimorphic**.
- When the entire mycelium is converted into reproductive structure, the thallus is called **holocarpic**.
- In **eucarpic forms** only a part of thallus become reproductive. This can be **monocentric** (have single sporangium) or **polycentric** (have many sporangia).
- The hyphal wall is a made up of **fungal cellulose** in which **cellulose is impregnated with chitin and contains nitrogen in addition to carbon and hydrogen**. **Chitin is a polymer of N-acetyl glucosamine**.
- The protoplast is covered by a thin semipermeable plasma membrane.
- The cytoplasm appear granular and contains many minute nuclei scattered in the peripheral layer.
- The nuclei are very small and inconspicious.
- The cytoplasm contains many small vacuoles filled with cell-sap or a number of small gas filled vacuoles.
- The vacuoles are small, few or absent in the actively growing tips of the mycelium.
- The hypha also may be seen to have mitochondria, dictyosomes (golgi bodies), ribosomes, endoplasmic reticulum, oil drops and glycogen, granules etc. under electron microscope.

Reproduction

- The fungi **reproduce by all the three methods** – **vegetative**, **asexual** and **sexual**.
- **Vegetative reproduction** takes place by various methods as fragmentation, fission, budding, sclerotia, oidia and chlamydospores.
- In **fragmentation**, the hyphae of fungus break into small pieces and each piece may later grow into new mycelium.
- **Fission** is common in yeast. The cell divides into daughter cells which separate by constriction or transverse walls.
- In **budding** daughter bud appears from parent cell. After getting the normal size bud break off. When the buds fail to separate, after repeated budding from pseudomycelium.
- **Oidia** are rounded or oval structure having thin

walls. The hyphae undergo segmentation and produce yeast like cells called oidia. Each oidium on germination produces new mycelium.

- Some fungi produce **chlamydospores** which are thick walled resting cells. They are intercalary in position. They are capable of forming a new plant on approach of favourable conditions.
- **Gemmae** resemble chlamydospores in structure but are not very durable and thick walled.
- Many true fungi produce **sclerotia** which are hardened, resistant bodies. Sclerotia are capable of surviving unfavourable periods and as soon the conditions are favourable, they germinate to produce vegetative hyphae.
- Asexual reproduction takes place by means of **spores**.
- The spores in fungi vary in shape. Spores are usually unicellular, thin walled, spherical and diameter ranging from 5-50 m.
- Several types of spores are reported in fungi, eg. zoospores, sporangiospores, uredospores, teleutospores, pycniospores etc.
- Sometimes the spores are produced endogenously in special sac- like asexual reproductive bodies called **sporangia**.
- Spores in such cases are called **sporangiospores**.
- **Zoospores** are uninucleate, thin walled, formed in zoosporangia. They may be **uniflagellate**, *e.g.*, *Synchytrium* or **biflagellate**, *e.g.*, *Saprolegnia*, *Pythium*.
- Biflagellate zoospores are of **two types** –
  - **Pear-shaped** or pyriform, with 2 flagella placed at anterior end, are known as primary zoospores.
  - **Kidney-shaped** or bean-shaped, bearing two oppositely directed flagella inserted laterally in a furrow or concave side (secondary zoospores).
- **Aplanospores** are **thin walled**, **non-motile** spores formed inside sporangium, which **give rise to new mycelium**, *e.g.*, *Rhizopus*, *Mucor*.
- **Conidia** are non-motile, thin walled **exogenously** produced spores on a condiophore and sometimes they are arranged in chains upon the conidiophore, *e.g.*, *Aspergillus* and *Penicillium* or singly in *Pythium*, *Phytophthora*.
- Hyphae bearing conidia are called **conidiophores**.
- The conidiophores in groups may form structures like acervuli, synnemata etc.
- **Pycniospores** are small conidia-like bodies produced in flask-shaped cavities called the pycnia, *e.g.*, *Puccinia*.
- **Ascospores** are uninucleate, unicellular non-motile, usually eight in number produced in sac-like structures called ascus, characteristic of ascomycetes.
- **Basidiospores** are characteristic of basidiomycetes, produced exogenously by club-shaped basidium or sterigma. Usually four basidiospores are produced.
- **Uredospores and teleutospores** are binucleate spores produced in clusters called **uredosori**.
- **Sexual reproduction** in fungi **involves three process – plasmogamy** (fusion of protoplast), **karyogamy** (fusion of two haploid nuclei) and **meiosis**.
- Fungi may be dioecious or unisexual some are monoecious or bisexual. Former are heterothallic and latter are homothallic.
- Fungi generally possess **unicellular sex organs** and show **gradual degeneration of sexes**.
- **Male gametangia** is called **antheridium.** It is s**maller in size**.
- **Female gametangia** is called **oogonium** which are comparatively **larger in size**.
- The gametes are formed within gametangium.
- All three types of sexual reproduction is present in fungi as isogamy, anisogamy, oogamy.
- In **isogamy** fusing gametes are exactly alike in appearance and functions.
- Fusion of dissimilar gametes is called **anisogamy**. In anisogamous forms both fusing male and female gametes are usually motile.
- Fusion of male gamete with female gamete is called **oogamy**.
- In **gametangial contact** the two gametangia come close to each other, but do not fuse. The male gametangium sends a tubular outgrowth, called fertilization tube, through which the non-motile male gamete or male nucleus migrates into the female gametangium. Eg. *Phytophthora, Albugo*.
- In **gametangial copulation** two gametangia fuse with each other and lose their identity in the sexual act resulting in the formation of zygospore. Eg. *Mucor, Rhizopus*.
- In **spermatization** some fungi produce numerous, minute, uninucleate, spore-like

bodies called **spermatia**. These are transferred through various agencies to **receptive hyphae** or **trichogyne** of female gametangium. Finally the contents of spermatium is transferred into receptive hypha through a pore. Eg- *Puccinia graminis*.

- In **somatogamy**, the sex organs are not formed and the fusion occurs between two vegetative or somatic cells resulting **dikaryotization**. Eg. *Agaricus*.
- **Homothallism** is the condition whereby thalli are morphologically and physiologically identical. So that fusion can occur between gametes produce on the same thallus.
- **Heterothallism** is the phenomenon in which the fusing gametes belong to two genetically distinct strains of the some species though there may not be any morphological distinction between the gametes or structures bearing them. It was first **discovered by Blakeslee** in 1904.

Blakeslee found that in *Mucor* and *Rhizopus*, certain strains formed zygospores even in pure cultures where different mycelia belongs to the same genetic strain, eg. *Rhizopus sexualis*.

Heterothallism is a mechanism to perform outbreeding and prevent inbreeding. As it involves sexual reproduction between genetically different strains, the product of sexual reproduction comes to have different alleles and different genes linkages. It introduces variations that are helpful in adapting to diverse habitats, unfavourable environments and toxic chemicals.

Classification of fungi

- Fungi are divided into **4-classes**, according to the septation of the mycelium and on the basis of characteristic features of reproduction – **phycomycetes**, **ascomycetes**, **basidiomycetes**, **deuteromycetes** (*Refer table given below*).

Phycomycetes

- **Phycomycetes** are algae like fungi.
- Hyphae of phycomycetes are **coenocytic** and **non septate**.
- Phycomycetes are **entirely aquatic** and **known as water moulds**.
- Phycomycetes are the **most primitive true fungi**.
- In phycomycetes, reproduction takes place by both **sexual** and **asexual methods**.
- Asexual reproduction **takes place by spores**.
- Motile spores are called **zoospores** and non-motile spores are called **aplanospores**.
- **Chlamydospores** are those thick walled resting spores which are formed on the hyphae of some lower fungi.
- Two types of flagella are present in phycomycetes, these are **whiplash** and **tinsel type**.
- Sexual reproduction in phycomycetes takes place by **planogametic copulation**, **gametangial contact** (or **gametangial copulation**.)
- The **most common examples of phycomycetes** are *Saprolenia, Rhizopus, Mucor* etc.

Table : Classification of fungi

Features	Phycomycetes	Ascomycetes	Basidiomycetes	Deuteromycetes
Common name	Algae like fungi	Sac fungi	Club fungi	Fungi imperfecti
Mycelium	Aseptate, coenocytic	Septate, branched unicellular	Secondary, mycelium, dikaryotic	Branched, septate mycelium
Asexual reproduction	Zoospores, aplanospores, chlamydospores, sporangiospore	Conidia, budding	Oidia, basidiospores	Conidia
Sexual reproduction	Isogamy, oogamy	Fusion of compatible nuclei. Ascospores formed in ascus	Somatogamy, Basidiospores formed on sterigmata	Absent or not known
Fruiting body	Zygospore	Ascocarp (cleistothecium, perithecium, apothecium)	Basidiocarp	Absent

Ascomycetes

- Ascomycetes are commonly called as **sac fungi**.
- Ascomycetes are characterised by **well developed thallus** and **production of ascospores**.
- Cell in ascomycetes are **uninucleate** or **multinucleate**.
- Mycelium of ascomycetes are **branched and septate except in** Yeast.
- Yeast is **unicellular** ascomycetes.
- **Ascospores** are formed inside the ascus during sexual reproduction.
- The typical number of ascospores in an ascus is **eight**.
- **No flagellated cells** are found in ascomycetes.
- Asexual reproduction may take place by **budding**, **fission**, **fragmentation**, **oidia**, **conidia formation** etc.
- Sexual reproduction takes place by **plasmogamy** which may be **isogamous** or **heterogamous**.
- Fruiting body of ascomycetes is **ascocarp**.
- Ascocarp may be **cleistothecium** (globose having no natural opening), **perithecium** (globose having one apical opening) or **apothecium** (saucer shaped).
- The **most common examples** of ascomycetes are *Penicillium, Neurospora, Yeast* etc.

Basidiomycetes

- Basidiomycetes are **commonly called as club fungi**.
- Basidiomycetes resembles the ascomycetes in having a **septate mycelium** and **production of non-motile spores**.
- **Dikaryotization** or **diplodization** is the process by which binucleated condition is attained from uninucleated conditions.
- Basidiomycetes have a **short lived uninucleate stage** and a **dominant binucleate stage**.
- Cells of basidiomycetes are made up of **chitin-mannan**.
- Basidiomycetes are characterised by the **dolipore septa and clamp connections** (a hook like clamp is formed which help in passage of nuclei) in the mycelium.
- Basidiospores are **formed over the basidium during sexual reproduction**.
- Fruiting body of basidiomycetes is known as **basidiocarp**.
- **Asexual reproduction** occurs by **fragmentation**, by means of spores such as **conidia**, **oidia**, **arthrospores etc.**
- **No specialised sex organs** are present in basidiomycetes.
- The **life cycle** of basidiomycetes **consists of** three clear and distinguishable phase. These are **plasmogamy, karyogamy** and **meiosis**.
- Common basidiomycetes are *Ustilago, Puccinia Agaricus, Polyporus* etc.

Deuteromycetes

- Deuteromycetes is an **artificial group without any common relationship**.
- Deuteromycetes are commonly called as **fungi imperfecti** due to the absence of perfect sexual stage.
- Deuteromycetes have **septate hyphae** and **reproduce asexually by means of conidia**.
- Beside conidia **thallospores** are – also found in some fungi imperfecti.
- Two types of thallospores are – **chlamydospores** and **arthrospores**.
- Common deuteromycetes are *Cercospora, Collectotrichum, Pyricularia, Fusarium*.

Harmful and beneficial aspects of fungi

- Some fungi are **used as delicious food**. The fructifications of certain fungi are used as nutritious and delicious foods, *e.g.*, *Agaricus bisporus* and *A. campestris* (mushrooms). *Morchella* and *Lycoperdon*, *Clavatia*, *Pleurotus*, *Volvaria*, *Volvariella*, etc., are also edible fungi.
- Yeast is an **important source of vitamin B and D**. *Saccharomyces*, *Endomyces*, *Rhodotorula*, *Torulopsis* are **rich in proteins**.
- A food called '**Sufu**' is produced from *Mucor* and antimucor.
- Fungi are used in the **production of different antibiotics** (substances of microbial origin and having antimicrobial activites).
- In **alcoholic industry** yeast (*Saccharomyces*) is used for **fermentation**.
- In **baking industry** CO_2 evolved raises '**dough**'.
- **Enzymes** like **taka diastase**, **digestin** and **polyzime** are produced from *Aspergillus flavus-oryzae* series.
- **Invertase** is prepared from *Saccharomyces cerevisiae*, **amylase** from *Aspergillus oryzae*, **zymase** from yeast (*Saccharomyces cerevisiae*)
- *Penicillium camemberti* and *P. roqueforti* are **used for flavouring cheese**.

- **Various organic acids** are obtained from fungi, ***e.g.*****, citric acid** by *Aspergillus niger* and *A. wentii*, *Mucor*, etc, **gluconic acid** by *Aspergillus niger* and *Penicillium purpurogenum*; **gallic acid** by *P. glaucum* and *A. gallomyces*; **kojic acid** by *A. oryzae*; **fumaric acid** by *Rhizopus stolonifer*.
- **Gibberellic acid** is obtained from a fungus *Fusarium moniliforme* (*Gibberella fujikuroi*).
- **Fungus** widely **used in genetic engineering** is *Neurospora crassa*. While working on *Neurospora crassa***,** Beadle and Tatum (1941) proposed **one gene one enzyme hypothesis** and received Nobel prize in 1958.
- *Aspergillus niger* is widely used to **determine available copper, magnesium, potassium and molybdenum in the soil**.
- Saprophytic fungi live upon dead organic matter and thus break down complex substances into simple ones, which are again absorbed by plants has increasing soil fertility.
- Soil inhabiting fungus *Trichoderma* kills *Pythium* fungus (root rot fungus). Similarly *Penicillium vermiculatum* checks *Rhizoctonia solani*.
- **Predacious fungi** like *Dactyllela, Dactylaria, Zoophagus* and *Arthrobotrys*, etc.,destroy certain nematodes, eelworms, etc., causing plant diseases.
- They help in absorption of **water and nutrients** and in turn get ready-made food (symbiosis).
- *Absidia*, *Aspergillus*, *Cladosporium*, *Mucor*, *Penicillium* and *Rhizopus* have soil binding property (by mucilage) and they make the soil good.
- Many **insect pests** can be controlled by use of fungi like *Aschersonia aleyroides*, *Isoria ferinosa*, *Empusa*, etc.
- Few fungi like *Saccharomyces, Rhodotorula* **fix-atmospheric nitrogen in soil**.
- Fungi is the **causative organism** of many diseases in plants, animals as well as in **humans**.
- *Claviceps purpurea* causes **ergotism** and also yield a hallucinogenic drug called **LSD**.
- The potato crop was destroyed in Ireland in the middle of 19th century due to infection of *Phytophthora*.

Diseases associated with fungi

Plant diseases:

- Black wart disease of potato– *Synchytrium endobioticum*.
- White rust of crucifers– *Albugo candida or Cystopus candidus*.
- Late blight of potato– *Phytophthora infestans*. (Famous famine of Ireland (1845) is associated with this disease which caused death of lakhs of people).
- Early blight of potato– *Alternaria solani*.
- Powdery mildews– *Erysiphe* sps.
- Damping of seedling– *Pythium* sps.
- Loose smut of wheat– *Ustilago tritici.*
- Black rust of wheat– *Puccinia graminis-tritici*.
- Apple scab– *Venturia inaequalis*.
- Downy mildews– *Peronospora* sps.
- Red rot of sugar cane– *Colletotrichum falcatum*
- Tikka disease of groundnut– *Cercospora* sps.
- Stem gall of coriander– *Protomyces* sps.
- Wilt of arhar– *Fusarium* sps..
- Leaf rust of coffee– *Haemelia vastatrix*.
- Blast disease of rice– *Pyricularia oryzae*.
- Green ear disease of bajra– *Sclerospora graminicola*.
- Flag smut of wheat– *Urocystis tritici*.
- Maize smut– *Ustilago maydis*.
- Loose smut of oat– *Ustilago avenae*.
- Covered smut of oat– *Ustilago kolleri*.
- Covered smut of jowar (*Sorghum*)– *Sphacelotheca sorghii*.
  (Severe famine of Bengal (1943) which caused death of a large number of people was due to this disease).

Human diseases:

- Aspergillosis (lung disease)– *Aspergillus niger*, *A. flavus, A. fumigatus*.
- Ring worm– *Trichophyton*, *Microsporum*.
- Neuritis (Infection of nervous system)– *Mucor pusillus*.
- Mental disorder (Cryptococcosis)– *Lipomyces neoformans*.
- Ear infection (Automycosis)– *Aspergillus flavus, A. nidulans*.
- Thrush disease of throat– *Monilia*

Animal diseases:

- Athlete foot– *Tinea rubrum*.
- Ringworm– *Trichophyton, Microsporum, Epidermophyton*.
- Mucomycosis– *Mucor, Rhizopus*.
- Aspergillosis– *Aspergillus*.
- Penicillosis– *Penicillium*.

- *Boletus* and *Amanita* spp.are **poisonous fungi**.
- The **fungus that produces latex** is *Mycena*.
- *Mucor*, *Rhizopus*, *Penicillium*, *Neurospora*, *Amanita*, *Polyporus* are commonly called as **pin bread mould**, **bread mould**, **green mould**, **pink bread mould**, **toad stools and brackett fungi** respectively.
- Spores of *Rhizopus*, *Mucor*, *Aspergillus* germinate on jam, jellies, pickles, bread, etc., and destroy them, *Penicillium*, *Mucor* and *Aspergillus* destroy meat.
- *Polyporus* (Pore fungi) causes **wood rot**.
- *Alternaria, Penicillium, Trichoderma, Mucor, Chaetonium, Cephalothecium* and *Fusarium* destroy leather, cloth, rubber, paper, camera lenses, etc.
- **Aflatoxins** are **mycotoxins** (harmful secretion) produced by *Aspergillus flavus, A. fumigatus*, *Penicillium islandicum*, etc.
- These **bind with DNA** and **prevent transcription**, hence protein synthesis. These **cause liver cancer in animals and men**.
- In **VAM** the hyphae develop an arbuscule (penetrate) within the cortex of root. It **helps mainly in phosphate absorption from the soil**.

LICHENS

- Lichens are formed by a **symbiotic relationship between algae** or **cyanobacteria and fungi**, in which individual photobiont cells are embedded in a complex of fungal tissue.
- The number of lichen genera is 400 and species over 15,000.
- The study of lichens is called **lichenology**.
- Body of the lichen is made of a fungus partner called **mycobiont** and a photosynthetic algal partner called **photobiont** or **phycobiont**.
- In 98% of the lichens, the mycobiont or fungal partners belong to ascomycetes. Few lichen shows basidiomycetes fungal partner also.
- Photobionts or phycobionts **either belongs to cyanobacteria or green algae**.
- **Photobiont performs** photosynthesis, nitrogen fixation and elaborates vitamins and other growth substances while **mycobiont takes part in** protective covering body, attachment, absorption and retention of moisture from dew, rain and wet air, and protection against harmful radiations.

History of Lichen

- The term lichen was first given by **Theophrastus** for superficial growth on bark of *Olea europea* (olive) tree.
- **Morisson** (1699) called lichen as musco-fungus.
- **Schwendiner** (1867) gave **dual hypothesis** and established the composite nature of lichen. He defined lichen as 'fungi parasitizing algae'.
- **Bonnier** (1886 - 89) successfully synthesized a lichen by growing fungal spores with algae.
- **Reininke** (1872) gave the term **'Consortium'** for the association of algae and fungi. The term means mutual growth and interdependence. **De Bary (1879)** termed this association as symbiosis.
- **Crombic (1885)** gave the term **helotism** *i.e.* master and slave relationship to the algal and fungal association in lichen. Helotism is the most accepted term used now a days to describe this relationship.

- Algae are present on the **upper part** of thallus and fungi are present on the **lower part** of thallus.
- Fungal partner provides **protection to algal** partner and are also **responsible for the sexual reproduction**.
- Such a mutually beneficial relationship is called symbiosis or mutualism.
- For proper diffusion of nutrients the algal cells and fungal hyphal tips become surrounded by common extracellular substance.
- At times, the mycobiont send haustoria into algal cells, prevent alga to secrete pectic substances or induces alga to secrete nutrients.
- Consequently, fungus is considered to be controlled parasite. The phenomenon of **controlled parasitism** is called **helotism**.
- As algae and fungi both contain **cell wall** which is the characteristic feature of plant cell, **so lichens are considered as plants**.
- About **12 genera** of cyanobacteria and **21 genera** of green algae are considered as lichen symbiont.
- Important **cyanobacteria** are *Nostoc*, *Gloeocapsa* and *Rivularia*.
- **Green algae** symbiont involves *Protococcus*, *Trentepohlia*, *Cladophora* and *Trebauxia.*

- Lichens generally grow on **old walls, roof of house, trunk of trees** or **exposed rocks**.
- Lichen like *Usnea* hangs from the smaller branches of trees.
- Lichen can withstand extreme of cold, heat and drought.
- They are dominant form of vegetation in alpine and arctic tundras.

Reproduction

- **Reproduction** may be vegetative, asexual or sexual.
- **Vegatative reproduction occurs** by –
  - **Fragmentation** – When thallus break into small fragments develop into new lichen thalli.
  - **Soredia** – Soredia are small masses of hyphae enclosing a few algal cells. Soredia are dispersed by air currents. Each soredium develops into a new thallus.
  - **Isidia** – They are **superficial outgrowths** from the upper surface of the thallus. Isidia consist of an external cortical layer and an internal algal layer.
- **Asexual reproduction**
  - In some lichens pycnidiospores are produced at tips of fertile hyphae inside pycnidium which is a flask shaped structure, opening through a pore called ostiole.
  - These spores germinates to produce a fungi mycelium.
  - The fungal mycelium with corresponding alga form new lichen thallus.
- **Sexual reproduction**
  - It is **performed** mainly by its **fungal component**.
  - Most of the lichens belong to the division ascolichens, in which the fungal partners belong to ascomycetes.
  - The male reproductive organ is flask shaped **spermogonium** which produces non-motile male gametes or **spermatia**.
  - The female reproductive organ is **carpogonium** which is differentiated into basal coiled **ascogonium** and upper long tube like **trichogyne**.
  - The **fruiting body ascocarp** formed after fertilization may be a **apothecium** type or **perithecium** type.
  - The bottom of ascocarp is lined by **hymenium** which consists of asci in spread with paraphysis. The wall of ascocarp (apothecium or perithecium) is composed of the vegetative part of the thallus consisting of algal and fungal layers.
  - Each ascus contains eight ascospores which germinate and form fungal mycelia.
  - The mycelium when comes in contact with a suitable alga, forms new lichen thallus.

Classification of lichens

- **On the basis of their fungal partner** the lichens are divided in **two groups** –
  - **Ascolichens** – Fungal partners belongs to ascomycetes. Gymnocarpae, fruiting body is apothecium type. Pyrenocarpae, fruiting body is perithecium type.
  - **Basidiolichens** – Fungal partners belongs to basidiomycetes.
- **On the basis of habitat** lichens are –
  - **Saxicolous** : Rock-dwellers and adapted to xerophytic adaptation, eg. *Xanthoria*.
  - **Corticolous** : Bark-dwellers and grows in adaptation of plenty of moisture, eg. *Parmelia*.
  - **Terricolous** : Terrestrial species and thus grows in soil, eg. *Cladonia floerkeana*.
  - **Lignicolous** : Lichens which grow on wood directly, eg. *Cyphelleum*.
- **On the basis of thallus** lichens may be –
  - **Leprose lichens** – The lichens are in the form of minute scales, attached superficially over the substratum, e.g. *Lepraria incana*.
  - **Crustose** – Lichens are crust-like, closely attached to substratum due to adhesion at several points, eg. *Graphis, Rhizocarpon*.
  - **Foliose** – Lichen body is like a crinkled and twisted leaf, *ie*. flat, branched or lobed. It is attached to substratum by one or a few points, eg. *Parmelia, Peltigera*.
  - **Fruticose** – The lichen shows branched, erect or pendulous with bushy appearance, An attaching disc is present at the base, eg. *Ramalina, Cladonia, Usnea*.
  - **Filamentous** – The photosynthetic partner is well developed and filamentous. It is covered by a few fungal hyphae, eg., *Racodium*.
- **On the basis of distribution of algal component in the thallus** lichens are of **two types** –
  - **Homoisomerous thalli** – Algal cells and fungal hyphae are uniformly dispersed throughout the thallus, eg. *Collema*.

– **Heteromerous thalli** – The algal cells are found in algal zone only. The bulk of lichen body is formed by fungal partner (mycobiont). It includes the surface, medulla and rhizinae. The algal constituents hardly 5% of the lichen body, eg *Parmelia*.

Economic importance of lichens

- Fresh water species of lichen is *Hymenelia lacustris* and marine water species is *Caloplaca marina*.
- *Cladonia rengiferina*, commonly called as **reindeer moss**, is an **important source of food for reindeer**.
- *Cetraria islandica*, commonly called **iceland moss** is **used as source of food of sheep, cattle as well as human**.
- *Everina* **used for making bread**, *Lecanora* is also edible.
- Lichen *Evernia prunastri* **yields an excellent perfume**.
- *Roccella, Parmelia, Evernia* etc. are **dye yielding** (**orchil**) lichen species.
- **Litmus** is **obtained from** lichen *Roccella montaignei*.
- Medicinal property of lichen is due to a substance **lichein**.
- **Usnic acid**, an important broad spectrum antibiotic, **is obtained from** *Usnea* and *Cladonia*.
- *Xanthoria parietina* is used against **jaundice**.
- *Peltigera canina* is used against **hydrophobia**.
- *Cetraria* is used as **laxative**.
- The **protolichesterinic acid**, obtained from some lichen like *Cetraria icelandica*, has anticarcinogenic properties.
- Lichens **serve as indicator of air pollution**, as they are very sensitive to air pollution, especially SO_2 pollution.
- **Crustose lichens** are pioneers in xerosere (succession beginning in dry condition).
- In **Russia** and **Sweden**, some lichens like *Cetraria* and *Lecanora* are used for **alcoholic fermentation**.
- Lichens secrete some organic acids which break down rocks and thus help in soil formation.
- Some lichens are **poisonous also due to various substance present in them** as :

Lichen	Poisonous due to
Letharia Vulpina	Vulpinic acid
Cetraria juniperina	Pinastrinic acid
Parmelia molluscula	Selenium
Xanthoria parietina	Beryllium
Everina fur furcea	Chlorine

MYCORRHIZA

- Mycorrhiza is symbiotic relationship between fungi and roots of higher plants.
- They are thick, irregular with wooly covering devoid of root hair and root cap.
- In a **mycorrhizal association**, the fungus may colonize the roots of a host plant either intracellularly or extracellularly.
- This mutualistic association provides the fungus with a renewable source of food through access to fixed carbon (sugars) from the plant photosynthate.
- These are translocated to the root tissues from their source location (usually leaves), and then to the fungal partners. In return, the plant gains the use of the mycelium's tremendous surface area to absorb mineral nutrients from the soil.
- The **mycelia of mycorrhizal networks have better mineral absorption capabilities** compared to plant roots.
- Mycorrhizal plants are often **more resistant to diseases**, such as those caused by microbial soil-borne pathogens, and are **also more resistant to the effects of drought**, perhaps due to the improved water uptake capability of the fungal hyphae.

Types of mycorhizza

- The two most common types of mycorrhizas are – the **ectomycorrhizas** and **endomycorrhizas** (more commonly known as **arbuscular mycorrhizas**).
- The **two groups are differentiated by the fact that** the **hyphae of ectomycorrhizal fungi do not penetrate the cell wall** of the plant's root cells, while the **hyphae of arbuscular mycorrhizal fungi penetrate the cell wall**.

Ectomycorrhizae

- Ectomycorrhizas, typically form between the roots of woody plants and fungi belonging to the divisions basidiomycota, ascomycota, or zygomycota.
- These are **external mycorrhizae** that form a cover on root surfaces and between the root's cortical cells.
- Besides the mantle formed by the mycorrhizae, most of the biomass of the fungus is found branching into the soil, with some extending to the apoplast, stopping short of the endodermis.

- These are found in 10% of plant families, mostly the woody species, including the Oak, Pine, *Eucalyptus*, *Dipterocarp*, and olive families.

Endomycorrhizae

- Arbuscular mycorrhizas, or VAM (formerly known as **Vesicular-Arbuscular Mycorrhizas**) involves entry of the hyphae into the plant cell walls to produce structures that are either balloon-like (vesicles) or dichotomously – branching invaginations (arbuscules).
- In VAM the hyphae develop an arbuscule (penetrate) within the cortex of root. It helps mainly in **phosphate absorption** from the soil.
- The fungus is generally a zygomycetes.
- The fungal hyphae do not in fact penetrate the protoplast (*i.e.* the interior of the cell), but invaginate the cell membrane.
- The structure of the arbuscules greatly **increases the contact surface area between the hypha and the cell cytoplasm to facilitate the transfer of nutrients between them**.
- Arbuscular mycorrhizas are **formed only by fungi** in the division glomeromycota, which are typically associated with the roots of herbaceous plants, but may also be associated with woody plants.
- Arbuscular mycorrhizas are likely to be very helpful in protecting plants from adverse conditions such as lack of water and nutrients.
- Arbuscular mycorrhizal fungi are quite extraordinary organisms. First they have been asexual for many million years and secondly, individuals can contain many genetically different nuclei (a phenomenon called **heterokaryosis**).
- This type of association is found in 85% of all plant families in the wild, including many crop species such as the grains.

[*For more on mycorrhiza refer chapter Pesticides and Biofertilizers*]

End of the Chapter