MYCOLOGY
BIOL 358

Course outline

- Introduction / General features of fungi
- The thallus, ultra structure, branching, fusion and septation of hyphae
- Specialized somatic structure
- Habitats, Mode of life and nutrition
- Life cycle: Sex and sexual compatibility
- Fungal spores; shapes, ornamentation and liberation
- Principles of fungal taxonomy
- Mycotoxins
- Mushroom farming (Ghana)

- References
- Introductory Mycology: C.J. Alexopoulos and C.W. Mims
- Introduction to Mycology: John Webster

INTRODUCTION

- Mycology is the branch of biology that studies fungi.

- It started as the study of mushrooms.(reasons)

- The systematic study of fungi however started in the 17th Century with the invention of microscope.

Introduction *contd.*

- The systematic study of fungi however started in the 17th Century with the invention of microscope.

- **Pier Antonio Micheli** is the person accredited as the founder of the science of mycology

- He was an Italian botanist who published **Nova Plantarum Genera** in 1729 which included his researches on fungi.

- The term fungi covers a group of organisms of diverse forms and habitats.

Introduction *contd.*

- They were initially thought of as plants and for a very long time were grouped alongside plants.

- Presently, they are recognized as a unique group and placed in a separate Kingdom i.e. Kingdom Fungi.

- Majority are microscopic

Introduction *contd.*

- **What are fungi? (fungus)**
- **Fungi** are therefore defined as *eukaryotic*, *spore-bearing*, *achlorophyllous* organisms that generally reproduce *sexually* and *asexually,* and whose usually *filamentous branched somatic structures* are surrounded by cell wall containing *chitin* or *cellulose* or *both*, together with many other complex organic molecules.

Introduction *contd.*

- Fungi have true nuclei
- Reproduce mainly by means of spores.

- They have a sort of sexual mechanism.

- They have a thread-like body (filamentous).

- The above definition is good but not perfect.

Introduction *contd.*

- Some true fungi examples are not filamentous
- The filaments of a few others have no cell wall
- Some true algae rather fit the above definition very well
- There are some organisms mycologist have studied more or less by default but are probably not fungi.

Introduction *contd.*

- There are some organisms mycologist have studied more or less by default but are probably not fungi.
- They are the **cellular and plasmodial slime moulds**.
- In its wider sense the term fungi was used to include these organisms (slime moulds).
- The vegetative phase consist of plasmodium and it is a multi nucleate mass of protoplasm.
- **Pseudoplasmodium** is an aggregate or separate amoeboid cell.

Introduction *contd.*

- The vegetative structure of most fungi is composed of thread- like structures known as hypha(e) but these are not found at any stage of the life cycle of the slime moulds.

- Because they don't have hyphae at any stage in their life, they are not considered as fungi.

- They however share features in common with both fungi and protozoa.

- They have however been studied alongside fungi but they lack cell wall.

Introduction *contd.*

- **Ainsworth (1966)** divided fungi into ***2 categories***:
  - Myxomycota (slime moulds)
  - Eumycota (true fungi; lower and higher fungi)
- He separated the true fungi into a lower and higher fungi.
- According to him the lower fungi are the ones which are less complex in structure and lack fruit body.

Introduction *contd.*

- These fungi were initially called **phycomycete**.
- The Phycomycetes are divided into:
  - Mastigomycotina (chytrids)
  - Zygomycotina
- The higher fungi are those that are complex in structure and contain fruits bodies.
- An example of the fruit bodies is the ascocarp found in the Ascomycetes

GENERAL FEATURES OF FUNGI

- They are basically microscopic and multicellular
- The vegetative phase of the eumycota may consists of a single cell as found in yeast and chytrids.
- The vegetative phase more usually consist of branched filaments (hyphae) forming a mycelium.
- The hyphae are barely visible with the naked eye.

GENERAL FEATURES *contd.*

- The principal chemical constituents of the fungal cell wall are various polysaccharides but proteins and lipids and other substances are also included.

- The chemical composition of the cell wall vary among the members of the group.

- Substances that may be present in the young hyphae may disappear almost completely as the hyphae grow older or other material may be deposited and mask the presence of earlier constituent making their detection very difficult.

GENERAL FEATURES *contd.*

- External factors such as the composition of the media, pH values and temperature may influence the composition of fungal cell walls.

- The wall of the hyphae is generally composed of microfibrils of chitin but in some fungi the cell wall is made up of cellulose or both.

- Occasionally cellulose and chitin have been reported to occur together. However chitin is more predominant.

GENERAL FEATURES *contd.*

- This type of construction is also found in higher plants but the chemical composition of cell walls differs from those of plants and is even variable among various classes of fungi.

- The fungi constitute a group of organisms devoid of chlorophyll.

- They resembled plants in that with few exceptions have a definite cell wall and are usually non-motile; although they have motile reproductive cells and they may reproduce by the means of spores

GENERAL FEATURES *contd.*

- A spore is a minute, simple propagating unit without an embryo that serves in the reproduction of new individuals of the same species.

- Their somatic structures with few exceptions exhibit little differentiation and practically no division of labour.
- fungi do not possess stem, roots or leaves and they do not have vascular systems like plants have
- The filaments constituting the body of a fungus elongate by apical growth. However, a minute fragment from any part of the body is able to give rise to a new fungus.

GENERAL FEATURES *contd.*

- Reproductive structures are differentiated from somatic structures and exhibit a variety of forms on the basis of which their classification is done.

- Few fungi can be identified if their reproductive stage are not available.

- The somatic parts of any fungus resemble those of many other fungi.

- The characteristic feature that most distinguishes the fungi from other organisms is their mode of nutrition.

GENERAL FEATURES *contd.*

- fungi lack photosynthetic pigments and they obtain their foods by secreting enzymes on their substrate.
- Many fungal cells store glycogen, a typical animal polysaccharide.
- They also store their food in the form of oil.
- They produce bud cells in succession and these may remain attached to one another in an easily breakable chain called pseudomycelium.

GENERAL FEATURES *contd.*

- More often, more than one bud cell may form from an existing bud therefore the chains are often branched.

- The hyphae of the fungi grow through soil, wood and other substrate for many years without being noticed.

- Mycelium frequently remains out of site.

GENERAL FEATURES *contd.*

- In some higher fungi which exhibit considerable complexity of the structure, fruit bodies are formed above the substrate as manifested in mushrooms, bracket fungi or puffballs.

- Generally, the fruit body becomes the most conspicuous part of the fungus.

- Some fruit bodies form rapidly in favourable seasons but they are short lived and their main function is that they carry out or aid the of dispersal of sexually produced pores.

GENERAL FEATURES *contd.*

- Few of these fruit bodies like those that grow on wood are woody and perennials.

- The likes of powdery mildews, parasites like rust and smut are short lived
- Most fungi grow between 0 and 35˚C.

- However, the optimum temperature is between 20 and 30˚C. Some are however described as thermophilic and require maximum temperature for growth at or above 50˚C and a minimum at or above 20˚.

GENERAL FEATURES *contd.*

- Fungi have the ability to withstand extremely low temperature in a dormant state and this is utilized in a long term storage of fungal culture in liquid nitrogen at temperature of -196˚C.

- In contrast to bacteria, fungi prefer an acid medium for growth with a pH of 6 being the optimum for most species investigated.

- Light though not required for growth of fungi, some light is essential for sporulation in many fungi.

GENERAL FEATURES *contd.*

- Light plays an important role in spore dispersal and most spore bearing organs of fungi are positively phototrophic and discharge their spore towards light.

- Fungal hyphae are capable of indefinite growth under favourable conditions and some fungal colonies have been found growing for over 400 years.

- The mycelium of a fungus generally begins as a short germ tube emerging from a germinating spore.
- the mycelium has the tendency to grow more or less equally in all directions from a central point to form a spherical colony.

GENERAL FEATURES *contd.*

- This ideal situation can be observed in the lab by growing certain fungi in liquid media; a spherical fluffy colony then develops around a particle of food such as grain of wheat or portion of hemp seed placed in water or other liquids.

- An actual sphere is seldom found in nature due to the external factors or type of substrate, light and chemical to which fungus readily respond to.

- Fungal colonies tend to be circular in outline on solid surface (media) like agar.

GENERAL FEATURES *contd.*

- Fungi grow best in moist habitat but they are found universally wherever an organic material is available.
- They require moisture to grow and can obtain water from a humid atmosphere as well as the substrate on which they grow.
- Many fungi are less sensitive to high osmotic pressures than bacteria.
- As a result they grow better in concentrated salt or sugar solutions that discourage bacterial growth.

THE THALLUS (HYPHA)

Fine structure / ultra structure

- The fungal protoplast has the same general structure as the protoplast of other eukaryotes.
- Fungi posses organized demonstrable nuclei and each nucleus is bounded by a nuclear envelope consisting 2 membranes with characteristic pores.
- It contains usually one nucleolus consisting mostly RNA which sometimes disappears during nuclear divisions.
- Chromatic strands are also present and organized into chromosome during division.

THALLUS *contd.*

- The cytoplasm is bounded by a plasma membrane and contains the usual organelles and inclusions.

- These are mitochondria, vacuoles, vesicles, Endoplasmic Reticulum, crystals and glycogen

LOMASOMES

- They are membrane structures lying between the plasma membranes and the cell wall.
- They are not common in other organisms like they are in fungi.
- Golgi bodies or dictyosomes on the other hand are not always present in the fungi.
- Mitosis in fungi differs from that in other organisms

LOMASOMES *contd.*

- Centrioles are not present in some fungi.
- For these fungi, formation of microtubules is regulated by a relatively amorphous structure called plaques.
- This unique combination of features strongly suggest that fungi originated from some unknown group of single cell eukaryotes with these characteristics.

NUCLEAR COMPLIMENTS OF FUNGAL CELLS.

- **Monokaryotic** : - It is the cell containing a single nucleus with a haploid number of chromosomes.

- **Synkaryotic** : - A cell containing a single nucleus with a diploid number of chromosomes.

- **Dikaryotic** : - A cell with a pair of haploid nuclei which differ in characteristic but are genetically complementary to each other.

THE HYPHA(E)

- The fungal thallus typically consist of microscopic threads or filaments that branch in all directions over or within the substratum utilized for food.

- A hypha is made up of thin transparent tubular or cylindrical wall filled or lined with the layer of protoplasm varying in thickness.

- The actively growing hyphal tip is full of protoplasm, sap filled vacuoles appear later.

- The hyphae are plastic at the tip but it is stiffer further back.

HYPHA(E) *contd.*

- Growth of the hypha is restricted to the apical region where new material are added.
- Elongation of the hypha occurs in a zone behind the tip.
- The protoplasm in the hypha of most filamentous fungi is interrupted at regular intervals by partitions or cross walls that divide each hypha into compartments or cells.
- Some of the cells or compartment are uninucleate or binucleate but generally they are multinucleated.
- The cross walls are called septa (or septum).

BRANCHING OF HYPHA

- Branching of hyphae is common at the extensible regions near the apex.

- Branching may be dichotomous i.e. the apex of the hyphae ceases to grow or elongate and forks into two equal branching.

- More often branching is subapical in which case the leading hyphal apex continues its growth and lateral branches usually formed singly but may sometimes be paired or may arise in whorls.

BRANCHING OF HYPHA *contd.*

- More often branching is subapical .
- Dichotomous branching is rare.

- The control of branch initiation is not understood, however it is reasonable to suppose that it occurs when the production of material for wall extension exceeds the quantity that can be utilized at the apex.

- In septate fungi branches normally emerge just behind the septa and they usually grow forward.

- The only exception is found in clamp connection in the Basidiomycetes.

HYPHAL FUSION / HYPHAL ANASTOMOSIS

- Fusion between hyphae is an integral part of sexual process in most fungi.
- Vegetative hyphal fusion is more limited in its distribution.
- It occurs in a few Oomycetes and Zygomycetes notably in the vesicular – arbuscular endophytes but it is more common in the higher fungi (Ascomycota, Basidiomycota, Mitosporic/Deuteromycota).
- Hyphal fusion are formed head on or end to end.

- Neighbouring hypha may be stimulated to produce small branches which eventually fuse.

- Fusion is followed by dissolution of contact cells. This process of dissolution lasts for a very short time and results in the formation of a continuous tube which permits the transport of protoplasm to any part or point in the colony.

- There are **three(3)** main types of fusion or anastomosis traditionally

(i) Hyphal to Hyphal

- Involves the hyphae curving towards each other

(ii) Hyphal to Peg

- a hypha grows towards the subapical region of another hypha and elicits the production of a ‘peg’- a short branch*

(iii) Peg to Peg ; occurs between parallel hypha, short branches are produced at adjacent points on the two hyphae

SEPTATION OF HYPHA

- The protoplasm in the hyphae of most filamentous fungi is interrupted by partitions or cross walls that divide each hypha into compartments or cells.

- Septum is caused or formed by an inward growth of an inner wall material.

- In the simpler filamentous fungi septa are always formed at the base of the reproductive organs but are confined to those locations so that the vigorous growing hypha is coenocytic.

- Coenocytic hypha is also known as aseptate hyphae.

Septation cont'd

- When the hyphae age, septa are often formed at various places.
- As portions of the hyphae die and the protoplasm is withdrawn towards the growing tip, a septum that separates the dead from the living is formed.
- Septa formation varies in their construction.
- Some are simple whereas others are complex but all types appear to be formed by centripetal growth from hyphal wall inwards

- There are several structures associated with septal pores.
- In fungi that possess perforated septa, the protoplast on each side of the septum are connected by living strands that pass through the pore or pores.
- These pores are usually hard enough to permit the passage of nuclei and other organelles, so that nuclear migration is not necessarily inhibited in regular septated hyphae.

- **Two (2) types** of septa are recognized.

  (i) Primary septa

  (ii) Adventitious septa

- **PRIMARY SEPTA**
- They are formed is association with nuclear division (i.e. meiotic and mitotic division) and are laid down between daughter nuclei which usually separate the daughter nuclei which are formed.

- This normally takes place at the apex of the hyphae.
- Primary septa therefore appears regularly and divide the hypha into regularly equal parts.
- They are usually formed in the higher fungi.
- **ADVENTITIOUS SEPTA**
- They are formed independently of nuclear division and are especially associated with changes in the concentration of the protoplasm as it moves from one point of the hypha to another.

- They are usually formed after the protoplasm is withdrawn.
- In the lower fungi, septa are mostly adventitious and are not perforated.
- In higher fungi adventitious fungi are rarely formed (separate reproductive structures from somatic ones).

THE DOLIPORE SEPTUM

- This is associated with the most complex fungi i.e Basidiomycota.
- The septa pore in this group is more complex because of the presence of certain associated structures.
- The septa have a central apparatus in the form of a barrel shaped inflation surrounded typically by a perforated membrane.
- It is a primary septum but a thickened ring surrounds the central pore.

- The Endoplasmic Reticulum on either sides of the pore gives rise to a cap shaped structure which is perforated.

- It is an integral and functional part of the septal apparatus.

- Fluids and some smaller organelles, including nuclei pass through the perforated septa

DIAGRAM

SPECIALIZED SOAMATIC STRUCTURES (HYPHAL APPENDAGES)

- They are **two (2) types** of these structures

  (i) those that are formed by differentiation of hyphae – ***DIFFERENTIATED STRUCTURES***

  (ii) those that are formed by aggregation of hyphae – ***AGGREGATED STRUCTURES***

DIFFERENTIATED STRUCTURES

- 1. Rhizoids
- 2. Haustoria
- 3. Appresorium
- 4. Hyphal traps
- 5. Hyphopodium

RHIZOIDS (substrate hyphae)

- It s a substrate hypha.
- Hyphae in a substrate may develop root-like structures whish are filamentous and are called rhizoids.
- They are short delicate filaments that contain protoplasm but lack nuclei
- Rhizoids may function as anchoring or may also serve presumably as absorbing structures.
- Example of fungi with these structures is *Rhizopus.*
- Rhizoids are also commonly found in the Bryophytes.

APPRESORIUM (surface hyphae)

- They are modifications of surface hyphae.
- It is a flattened hyphal pressing organ from which a minute infection peg or hypha usually grows or enters the epidermis of the host.
- It may be a simple swelling or lobed swelling on a germ tube or hypha which attaches to the host surface.
- It is formed in parasitic fungi.

DIAGRAM

HAUSTORIUM (substrate hyphae)

- It is a substrate hyphae that develop in a host cell.
- Specialized absorption cells
- They are developed in parasitic fungi but may also develop in facultative parasites.
- They exhibit a determinate growth and absorb nutrients from the host cell.
- It varies in shape and size in different fungi but usually consist of a constricted region where the hypha penetrates the host cell wall and an expanded or branched region within the host cell.

HAUSTORIUM *contd.*

- They are sunk into the plant cell wall through minute pores punched in the cell wall.
- They may also enter through the stomata or by direct penetration where enzymes are secreted to dissolve the cell wall.

- Presence of haustoria provides a greater surface area for the exchange of materials between the parasite and the host cell.

HAUSTORIUM *contd.*

Diagram

- An example of a fungus that produces haustorium which enters through stomata or pore is *Cladosporium and Botrytis sp.*
- Direct penetration eg *Fusarium* spp

HYPHAL TRAPS

- They are generally produced by soil inhabiting fungi called nematophagous fungi or predacious fungi.
- Most of them belong to the Deuteromycota.
- The nematophagous fungi are being exploited in the biological control of nematodes.
- They have shown to be promising agents to combat nematode parasites of plants and animals.

HYPHAL TRAPS *contd.*

- These organisms produce special structures along the hyphae called traps which are responsible for capturing and killing of the nematodes.

HYPHAL TRAPS *contd.*

- Traps come in many forms

  (i) **Adhesive hyphae** :- Stylopage grandis

  (ii) **Networked hyphae** :- Trichotherium Cystoporium, Arthrobotrys

  (iii) **Knobs hyphae** :- Dactylella sp.

  (iv) **Ring hyphae**

  (v) **Constrictive rings** :- Dactylella bembicoides

HYPHAL TRAPS *contd.*

- Traps are initiated in response to trap inducing compounds released by the nematodes themselves.

- Some predative fungi can proliferate in the soil in the absence of nematodes while others are more dependant on nematodes as a nutrient source for growth.

HYPHOPODIUM

- It is a structure made up of one or two cells which are more or less lobed on the superficial mycelium that serves as an organ of attachment.

- It also exhibits a determinate growth.

AGGREGATION OF HYPHAE TO FORM STRUCTURES

- At certain stages of the life history of most fungi, the mycelium become organized into loosely or compactly woven tissues, distinguished from the loose hypha ordinarily composing a thallus.

- The term plectenchyma is used to designate all such organized fungal tissues.

- There are generally two types of plectenchyma.

  (i) Prosenchyma

  (ii) Pseudoparenchyma

Prosenchyma

- It literally means approaching a tissue.
- It is a rather loosely woven tissue in which the component hypha lie more or less parallel to one another.
- Their typically elongated cells are easily distinguishable.

Pseudoparenchyma

- These consist of closely packed often isodiametric or oval cells resembling parenchyma cells of vascular plants.

- In this type of fungal tissue, the hyphae have lost their individuality and are not distinguishable .

- These two types of tissues (prosenchyma and pseudoparenchyma) singly or jointly form several hyphal appendages.

- Mycelial strand
- Rhizomorph
- Stroma
- Sclerotium
- Infection cushion

Mycelial strand

- These are cord like structures composed of hyphae running parallel to one another.
- They are usually a few centimetre long and about 1 -2 mm thick
- The strand carries the mycelium to portions of the substratum where it again fans out into a more dispersed form.
- It is believed that the strands are formed where the hyphae encounter surfaces with little or no nutrients. Eg *Sclerotium rolfsii*

Rhizomorph

- This is a thick strand of somatic hyphae in which the hyphae have lost their individuality.
- It forms complex tissues that exhibit division of labour.
- The whole mass behaves as a organized unit
- It has a thick hard cortex and a growing tip whose structure resembles that of a root tip.
- They are resistant to adverse conditions and remain dormant until favorable conditions return
- Growth in Rhizomorph is termed indeterminate and they are more prominent than mycelium strands and are associated with the higher fungi ;Basidiomycetes
- They have an elaborate internal differentiation.

sclerotium

- It’s a hard or tough resting body which is resistant to unfavorable conditions.
- It may remain dormant for a long period of time but has the capacity to germinate when conditions are favorable.
- There are various forms and sizes but are commonly spherical.
- The largest known is formed underground by the *Polyporous* sp. and it can be as large as a case 5 football and may weigh up to about 15kg
- More usually it ranges from the size of a pin head to 1 cm in diameter ,however ,the size is characteristic of the species and the strain.

Stroma

- A stroma is compact somatic structure much like a mattress within which fruit bodies or frutifications are formed

Infection cushion

- They are discrete aggregate vegetative hyphae of parasites formed on host surfaces which serve as an attachment organ from which infection hyphae grow into the host

HABITAT, MODE OF LIFE, NUTRITION

HABITAT, MODE OF LIFE, NUTRITION CON'T

- FUNGI are found everywhere in the soil ,water bodies; atmosphere
- The atmosphere is the harshest environment for most fungi.
- Many are saprophyte and gain their food by decomposing dead organic matter.
- Many attack and degrade raw or manufactured material e.g. timber, leather.
- Optical glasses can be ruined by fungi growing on dust particles on the glass

- Some are obligate parasites
- many can be saprophytes depending on the circumstance and are called facultative parasite.
- An example is Cladosporium. It can live as a parasite and can grow on a nutrient medium. It attacks tomato.
- Any fungus which cannot be cultured on a nutrient medium is an obligate parasite. Obligate parasites require living protoplasm to thrive on.

SYMBIOTIC ASSOCIATION - MYCORRHIZA

- A large number of fungi enter into a special symbiotic association with the roots of green plants both wild and cultivated plants.

- The hyphae of these fungi and the roots of a plant form a joint structure known as MYCORRHIZA.

Mycorrhiza con’td

Mycorrhiza con’td

- Mycorrhiza is a symbiotic association between hyphae of certain fungi and absorbing structures especially roots.

- The term absorbing structure is used here because it is also found in Bryophytes which do not really have roots but have rhizoids.

Mycorrhiza con’td

- Almost all forest trees under normal conditions have mycorrhiza.
- The fungus infects roots from spores or hyphae present in the soil near root.
- The fungi involved are described as highly specialized parasites .
- The root tip and vascular tissues are not affected. Mycorrhiza improves the uptake of nitrogen, potassium and Phosphorus. They also improve water uptake.

Mycorrhiza con’td

Mycorrhiza con’td

- They protect the host roots against pathogens and from certain diseases.
- They produce plant growth hormones and improve the solubility of minerals within the soil.
- There are two types based on the relationship of the fungi hyphae and the roots.

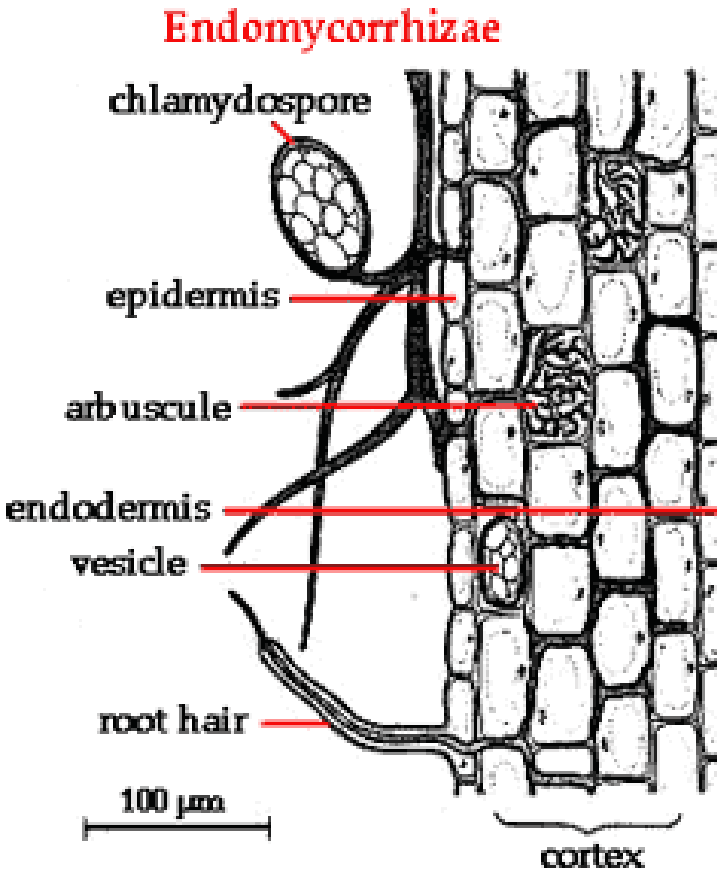
Types of mycorrhizae

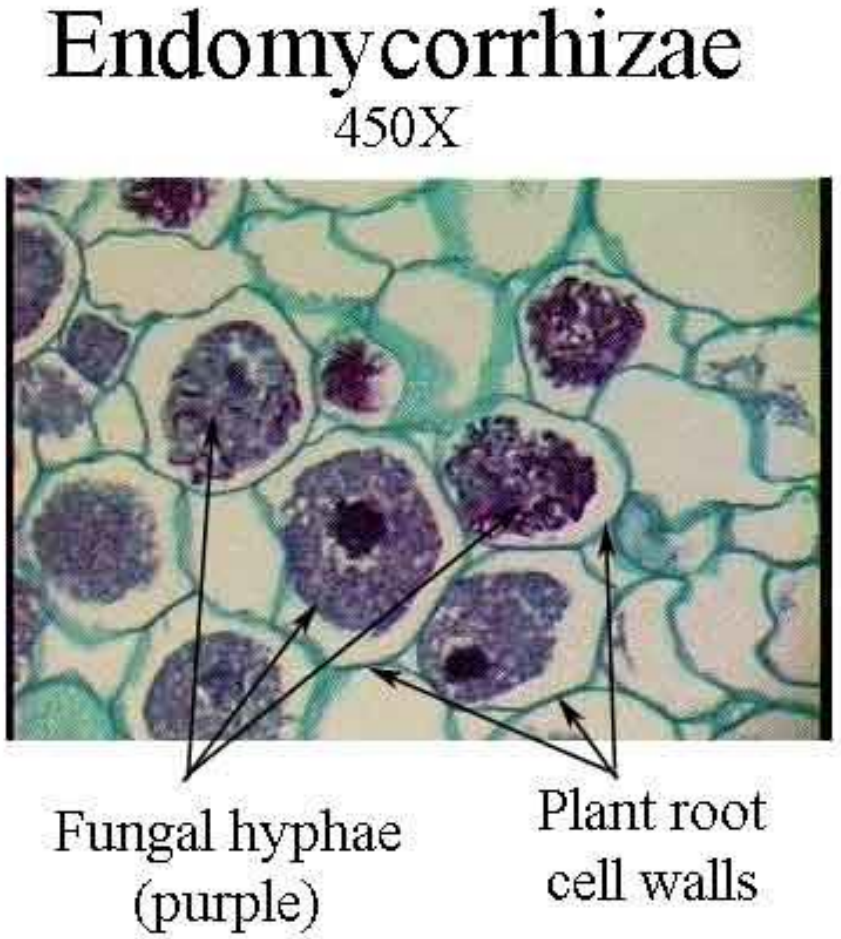
- (I) ENDOMYCORRHIZA:
- These are distinguished based on the relationship of the fungus hyphae to the cells of the absorbing structure (roots).

- They are characterized by the growth of the hyphae in an intracellular fashion .

- They thus penetrate the root hairs and other epidermal cells as well as cortical cells.

Endomycorrhiza cont'd





Endomycorrhiza con’td

- Endomycorrhizas are more variable and may form association with shrubs, herbs as well as other green plants under appropriate conditions
- Usually no dense hyphal growth of any sort is visible on the surface of the root.
- The hyphae are mainly intracellular (ie penetrating the root cells).

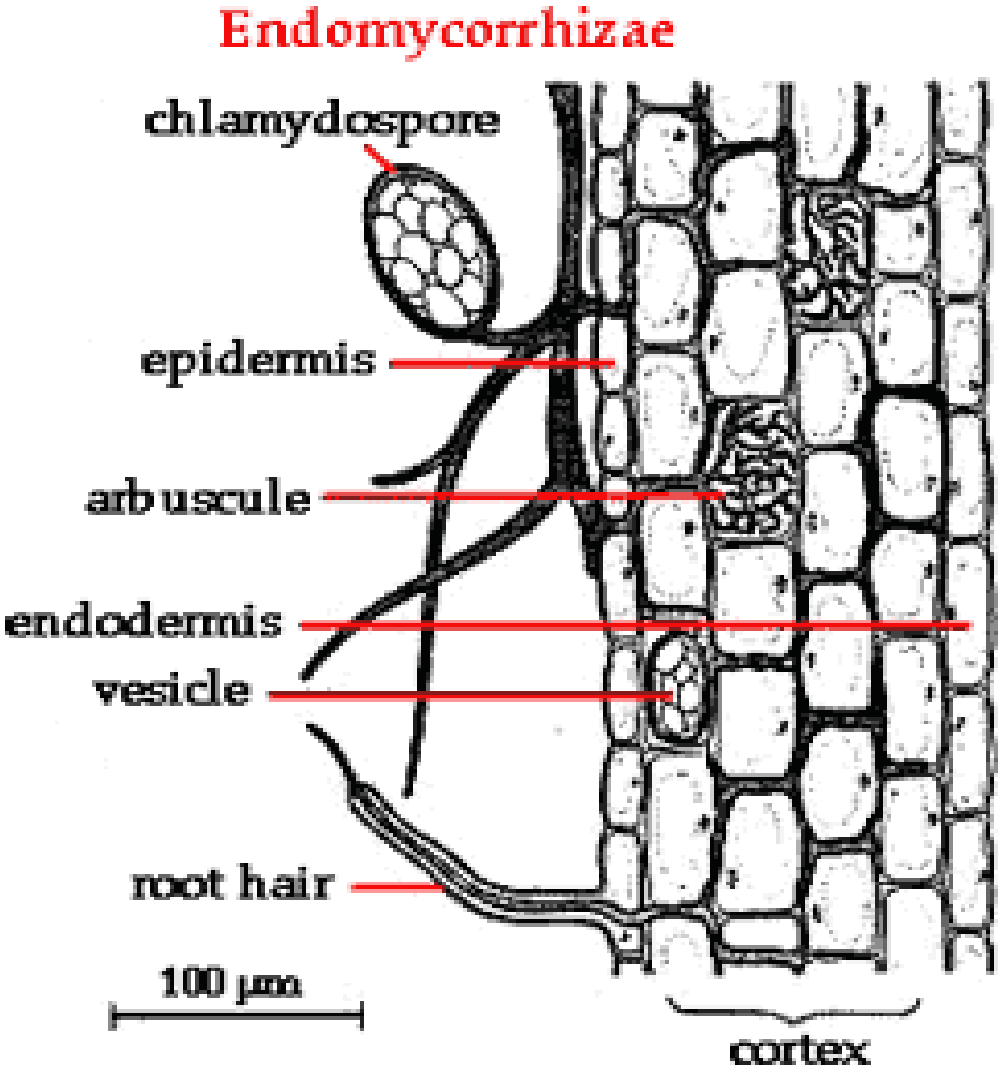
Endomycorrhiza con’td

- The hyphae may form swellings (vesicles) and minute branches (haustoria, elsewhere) called arbuscules within the cells of the host.

- This is thus described as vesicular – arbuscular.

- Intracellular hyphae are often digested by the root cells and apparently provide nutrients for the host plants.

Endomycorrhiza con’td



Endomycorrhiza con’td

- The fungi that form endomycorrhizae are usually the lower fungi, generally belonging to the Endogonales.

- The endogonales belong to class Zygomycetes e.g. *Pythium;* a few higher fungi are involved and these include the orchid endophyte and Rhizoctonia.

- Most of the few higher fungi involved in endomycorrhiza are Basidiomycetes.

Endomycorrhiza con’td

- Finally unlike the ectomycorrhiza, the endomycorrhiza are not restricted in their nutritional requirement.

- They utilize polysaccharides both cellulose and starch and many of them are capable of breaking down lignin.

Types of Mycorrhiza

- Ectomycorrhiza

- This type is characterized by hyphae that grow in an intercellular fashion.

- Typically an infected root tip is covered by a mantle of hyphae varying from a loose weft to a parenchyma- like layer.

Ectomycorrhiza con’td

Ectomycorrhiza con’td

- Hyphae frequently cover the root tip and suppress growth of hairs.

- A hyphal-network (Hartig net) extends from the mantle into the first few layers of the cortex or rarely deeper and reaches the endodermis.

- Strands extending out from the mantle obtain nutrients from the soil and conduct them to the plant roots through a network of hyphae that penetrates the cortex.

Ectomycorrhiza con’td

- The root hairs do not develop in the infected roots and the root is morphologically distinct being short and branched.
- Most often it appears swollen.

- The net takes over the function of the root hairs and they appear to be more efficient.

- Ectomycorrhiza are widespread in nature, occurring in most important woody plants.

Ectomycorrhiza con’td

- Most of the ectomycorrhiza fungi are Basidiomycetes .
- A few Ascomycetes eg. Truffles however exist
- Most of the ectomycorrhiza Basidiomycetes are in the order Agaricales (Agarics) E.g of better known Agaricales are Amanita, Leccinum, Russula, Suillus, Cortinarius, Lactarius.

Importance of Mycorrhiza

- Ectomycocorrhiza are important in the nutrition of forest trees, some of which die young if appropriate mycorrhizal fungi are not present.

- There is a clear evidence that healthy forest trees have well formed mycorrhiza particularly when found on poor soil.

- Works have shown that fungi are very efficient at absorbing salts which are passed on to the roots of the trees.

Importance of Mycorrhiza con’td

- Factors that determine exactly what mycorrhizal fungi are associated with what host plant are not fully understood.

- However, it is generally known that an excess of carbohydrate in the root of the host plant is important factor in the establishment of the relationship and that they are also abundant in nutrient deficient soils.

Importance of Mycorrhiza con’td

- Much knowledge of mycorrhizal relationship has been put to practical use in a number of areas including:

- (i) Establishment of high yield planted forest.

- (ii)Introduction of exotic plants

- (iii) Reclamation of strip- mined land

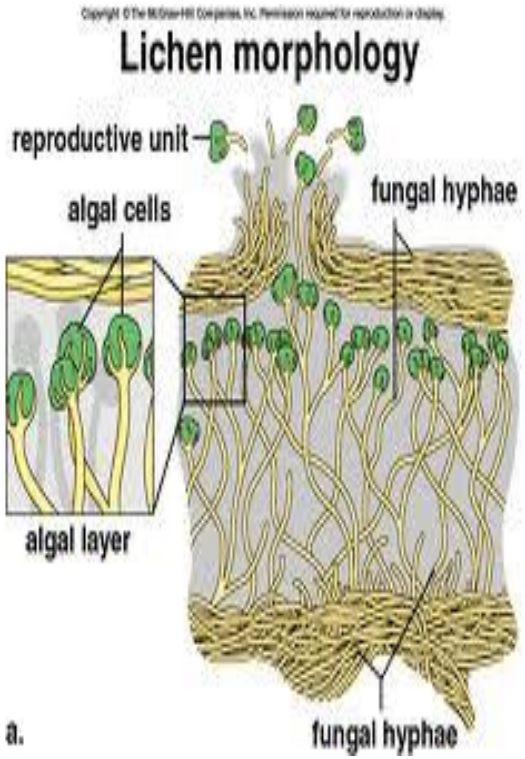
SYMBIOTIC ASSOCIATION - LICHENS

- LICHENS
- This is an association between a fungus and an algae in which the two are so intertwined that they form a single thallus.

- The fungal component is called the mycobiont and the algae the phycobiont.

- For a long time, lichens were thought of as **any other plants.** However, their nature was only recently explained.

Lichens con’td



Lichens con’td

- However the consensus is that the lichen thallus represents a mutualistic symbiosis from which both organisms benefit.
- The algae cells are protected from high light intensity and the fungus may also provide water and some nutrients that the algae needs.
- The fungus lives saprophytically on the dead algae cells.
- There are no lichenized Phycomycetes.

Lichens con’td

- A vast majority of the mycobionts are Ascomycetes.
- However there are a few Basidiomycetes as well as Deuteromycetes.
- Of the Ascomycetous lichens the majority are Discomycetes e.g Loculoascomycetidae and Pyrenoascomycetidae.
- However, there are no lichenized Hemiascomycetidae.
- There are more species that are lichenized than those that are not of the Ascomycetes and the ratio of the lichenized to non-lichenized is 18000: 15000

Occurrence and Importance of Lichens

- Lichens are ubiquitous.
- They can occur in a variety of habitats from the Arctic to Antarctic and regions between them.
- They are found on exposed rocks in the desert. They are also found on solidified larval flows and also on frozen substratum in the Polar Regions.
- They are also found on the bark of trees, leaves, flowers of plants particularly in the tropics.

Importance of lichens

Saxicolous lichens ; lichens growing on rocks.

They are very instrumental in the initiation of soil formation either chemically by secreting lichen compounds that weather the rocks on which they live or mechanically by the destruction of the rock directly by a physical action of the lichen thallus.

Importance of lichens con't

- Cyanophycophyllous are very important in certain ecosystems where they provide the bulk of fixed nitrogen.

- A number of commercial products such a dyes , litmus ,essential oils for perfume manufacture were formally obtained from lichens but have now been replace by synthetic compounds.

Importance of lichens con't

- Usnic acid produced by a number of lichens is an antibacterial substance.
- introduced into a number of ointments but has never found a place in medicine as an antibiotic.
- Tropical lichens like Strigula possibly affect plants adversely by shading leaf surfaces.
- Cladonia rangifera and similar sp. are important winter foods for the reindeer in the North America and Northern Europe.

Cladonia rangifera

Importance of lichens con't

- Presently, as far as humans are concerned, the most important role of lichens is that they serve as indicators of air pollution.
- In centres of heavy pollution no lichens can be found. The lichen population increases gradually with distance from these centres and is thus something of a measure of pollution intensity.
- The lichens do not have excretory mechanism or an efficient excretory mechanism.

Anatomy and Morphology of Lichens

- There are two general types of the lichen thalli based on the distribution of the algal cells among the fungal tissues. These are the (i) homoiomerous and (ii) heteremerous
- In the hemoiomerous the algae cells are more or less evenly distributed throughout the thallus whereas in the heteromerous, the algal cells form a distinct layer within the thallus.

Anatomy and Morphology con't

- The vast majority of known lichens are in the second form which the thallus exhibits stratification
- Three layers are generally distinguishable in the heteromerous thallus (i) algal (ii) medulla , (iii) cortex.
- These layers occur in all the three major recognized growth forms which are foliose, crustose, and fructicose (squamulose, a modification of fructicose),

Classification of Lichens

- Classification of lichens is based on the fungal component.
- If the fungal component is an Ascomycetes the lichen becomes an Ascolichens.
- They reproduce by means of spores and there are two kinds of spores:
- Soredia are microscopic, non- corticated powdery masses of algal cells enveloped by fungal hyphae.
- Insidia are minute, corticated more or less columnar structures consisting of both fungal hyphae and algal cells that break off and are distributed by wind, rain and animals

NUTRITION

- They are basically heterotrophs
- Some are restricted to only one substrate like specialized parasites which grows on only one particular species.
- However Penicillium or Aspergillus will grow on anything that contains organic matter.
- Their nutrition is absorptive , ingestion is very rear and is restricted to the slime moulds.
- The hyphae lie in direct contact with nutrients and absorb dissolved smaller molecules such as amino acids and sugars.

Nutrition con’td

- They affect the physical and chemical nature of the substratum as they absorb
- Fungi are extremely versatile in their nutrition except for plastics, fluorine and a few detergents, There is nothing that fungi can not degrade to obtain or derive nutrient.
- Naturally, the numerous digestive enzymes needed to breakdown the various organic compounds cannot be present at all time. ?
- They are produce only when they are needed.?

Nutrition con’td

- They fall into two categories.
- They are either adaptive or inducible.
- In studying the nutrition of fungi, they are normally grown under sterile conditions in sterile medium. Agar is often used and it is mucilage . It is a complex carbohydrate which most fungi can’t use as a source of food.
- Agar retains its physical texture and appropriate substances are incorporated into this jelly.

Nutrition con’td

- Studies have shown that the nutritional requirements of fungi are not different if not the same as other organisms.
- They require about 17 elements ,some of which are required in extremely small or trace amounts and the range is o.oo17 – 0.05 ppm and these are the trace elements or micro elements.

Nutrition con’td

- Others are required in high amounts and are called macro elements.
- All are essential in fungal growth.
- The macro elements in fungal nutrition include the non-metallic C,N,O,S,P,H and the metallic elements include K and Mg.
- Ca is either not needed at all by fungi or taken in some trace amounts by certain fungi

Nutrition con’td

- The non –metallic macro elements in general serve as structural elements in the protoplasm and for cell wall synthesis.
- The metallic elements are functional elements active in metabolism.
- All the elements participate in metabolic events of life processes.

Nutrition con’td

- Hydrogen is obtained from water and oxygen from the air.
- Other elements are taken in the forms of compounds or ions.
- The trace elements are generally metallic and these include Fe, Zn, Cu, Mn, and Mo.

Nutrition con’td

- They require vitamins
- Fungi show extreme to intermediate behavior with respect to vitamin synthesis and based on this they are put into two groups:
- (i). Auxoautotrophic
- (ii) Auxoheterotrophic

Nutrition con’td

- The auxoautotrophs are able to synthesize all vitamins they require and sometimes produce them in excess.
- For example Ermothecium ashbyii and Ashbya gossypii are therefore used for the commercial production of B12.
- Auxoheterotrophs lack biosynthesis partially or completely.

Nutrition con’td

- Partially deficient species make only limited growth in the absence of vitamin and show marked increase in growth if the deficient vitamin is supplied.
- Deficiency may be genetic or due to environmental factors. E.g. Phythium butleri require higher amounts of thiamine when salt concentration exceeds certain levels.
- As a rule, fungi have no requirements for fat soluble vitamins and these are vitamins A,D,E,K.

Nutrition con’td

- Only water soluble vitamins are required and these are the vitamin B group in addition to vitamin H.
- Phycomyces show no growth in the absence of thiamine. However, with the increase of concentration of thiamine in a nutrient medium from zero to a few mg.,
- Growth of the phycomyces then becomes proportional to the thiamine concentration.
- Phycomyces then can be used to determine the concentration of thiamine in an unknown concentration.

Nutrition con’td

- Each medium for fungal growth must have the following constituents.
- (i). A suitable organic substance as a source of carbon. A few fungi are capable of fixing atmospheric CO2. The best carbon source is glucose.
- 50% of the dry weight of fungi is contributed by carbon compounds.
- Practically, all the cell wall components such as chitin and cellulose and others are synthesized from carbon.
- Carbon is the major structural element of the fungal thallus.
- (ii). A source of Nitrogen, and this comes from nitrites and nitrates, peptones and asparagines.
- (iii). A source of Inorganic Ions.
- (iv). A source of vitamins

Nutrition con’td

- PDA is a very simple medium.
- Yeast extract may be added to PDA and yeast extract may contain most of the vitamins required by fungi.
- The yeast extract also contains all the microelements in addition to other growth factors

SEX AND SEXUAL COMPATIBILITY

- Compatibility is closely related to sex because it governs sexual reproduction in a way.

- There are a great number of fungi that produce clearly distinguishable male and female organs on the same thallus but nevertheless, the single individuals are sexually self sterile
- the male organs are therefore incompatible with the female organs and plasmogamy cannot take place.

SEX AND SEXUAL COMPATIBILITY CON'TD

- Fungi can be classified into 3 categories on the basis of sex;
- **i. Hermaphroditic/Monoecious**; in this category each thallus bears both male and female organs that may or may not be compatible.
- **ii. Dioecious**; some of the thalli bear only male and some only female organs. Very few dioecious family have been discovered.

SEX AND SEXUAL COMPATIBILITY CON'TD

- **iii. Sexually undifferentiated**; sexually functional structures are produced; however, these are morphologically indistinguishable as male/female organs.
- Fungi in the above mentioned categories may be homo or heterothallic on the basis of compatibility

HOMOTHALISM

- i. HOMOTHALISM: In those that exhibit homothallism, every thallus is sexually self fertile and therefore produce sexually without the aid of another thallus.
- It means therefore that no dioecious fungus can be homothallic.
- *Rhizopus sexualis;* a single spore can germinate to form mycelium. The mycelia can fuse and fertilization may take place.
- In this case, the thallus or species is only one strain and is self fertile or self-compatible and therefore would be referred to as homothallic species.

HETEROTHALLIC

- ii. HETEROTHALLIC: Those in which every thallus is sexually self sterile regardless of whether or not it is hermaphroditic.
- They require the aid of another thallus of different mating type for sexual reproduction.
- Those who require another mating type of a thallus are called heterothallic species and the concept is heterothallism.

REPRODUCTION

- It is the formation of new individuals having all the characteristics of the species.
- Most fungi reproduce sexually and asexually.
- In general, asexual reproduction also called somatic or vegetative is more important for the propagation of the species.
- asexual cycle is repeated several times during the season whereas sexual stage of a fungus is produced only once or few in a season or a year.

REPRODUCTION CON'T

- In the formation of reproductive organs, be it sexual or asexual, the entire thallus may be converted into one or more reproductive structures so that the somatic and reproductive phases do not both occur together in the individual.
- The fungi that exhibit this are described as **holocarpic**.

REPRODUCTION CON'T

- Asexual reproduction doesn't involve the union of nuclei and is sometimes defined as the nonsexual production of specialized reproductive structures such as spores.
- They may also be defined as any method of propagation of new individuals such as occurs in simple division of unicellular organisms into daughter cells or of a multicellular thallus into a number of thalli each of which grows into new individuals.

REPRODUCTION CON'T

- In accordance to the definition above, asexual method of reproduction commonly found in fungi are;
- i. Fragmentation of somatic bodies
- ii. Fission of somatic bodies
- iii. Budding
- iv. Production of spores

FRAGMENTATION OF SOMATIC BODIES

- Some fungi explore fragmentation as a normal means of propagation.
- The hyphae may breakup into their component cells that behave as spores. These spores are called arthrospores.
- If the cells become enveloped in a thick wall before they become separated from each other or from the hyphal joining them, then they are called Chlamydospores.

FRAGMENTATION CON'TD

- Fragmentation may also occur accidentally by tearing of portions of mycelium through external forces.
- Such bits of mycelium under favourable conditions will start a new individual.
- Often in the lab, mycelium fragmentation is important to keep fungal culture growing on artificial media by transferring a bit of mycelium to a new or fresh media and thus starting a new colony.

FISSION OF SOMATIC CELLS

- This usually involves unicellular thalli. It is the simple splitting of cells into two daughter cells by constriction and subsequent formation of cell wall. The nucleus of somatic cells divides by mitosis. It is the characteristic of a number of simple organisms including some yeast.

BUDDING

- It is the production of small outgrowth (bud) from a parent cell.
- As the bud is formed, the nucleus of the cell divides and one daughter nucleus migrates into the bud.
- The bud increases in size while still attached to the parent cell but eventually breaks off to form new individuals.
- Chains of bud forming a short mycelium are sometimes produced and are called pseudomycelium.
- Budding takes place in a majority of yeasts but it also occurs in many other fungi at certain stages of their life history or under certain conditions of growth.

SPORES

- The most common method of asexual reproduction in fungi is by means of spores.
- Spores vary in colour from transparent through blue, green and others.
- They also vary in shape; could be oval, oblong and the spores also vary in number of cells from one to many and they also vary in the arrangement of cells.
- Some fungi produce only one type of spores whereas others produce as many as four.

SPORES CON'TD

- Fungal spores produced asexually are either borne in sporangia and are called sporangiospores or they may be produced at the tips or sides of hyphae in various ways and are called conidia.
- A sporangium is a sac-like structure where the entire content (protoplasm) is converted through cleavage into one or more spores but usually the spores are many
- Sporangiospores may be motile or non-motile. In the simple fungi the sporangiophores are usually motile and are called zoospores and the sporangium in which they are contained are called zoo-sporangium.
- The non-motile spores are called aplanospores.

SEXUAL REPRODUCTION

- Sexual Reproduction in fungi as in other organisms involves a union of two compatible nuclei. The process of sexual reproduction in fungi consists of 3 distinct phases:
- (i) PLASMOGAMY: it is the union of two protoplast and this brings the nuclei close together within the same cell. The fusion of two nuclei brought together by plasmogamy is called karyogamy

SEXUAL REPRODUCTION CON'TD

- (ii) KARYOGAMY: it follows plasmogamy almost immediately in many of the fungi. In the more complex fungi however, these 2 processes are separated in time and space with plasmogamy resulting in a binucleate cell containing one nucleus from each parent. Such a paired nucleus is referred to as dikaryons.
- (iii) NUCLEAR FUSION in all sexually reproducing fungi is followed by meiosis which reduces the number of chromosomes to a haploid condition and it is the 3rd phase of sexual reproduction

SEXUAL REPRODUCTION CON'TD

- In summary plasmogamy brings 2 haploid nuclei together in one cell.
- Karyogamy unites them into one diploid zygote nucleus and meiosis restores the haploid condition.
- If there is only one free living thallus, with no alternation between the two, haploid or diploid, that life cycle is called haplobiontic.
- However if the haploid condition alternates with the diploid condition,it is called diplobiontic.

SEXUAL REPRODUCTION CON'TD

- The sex organs of fungi are called gametangia. They form differentiated sex cells called gametes or gamete nuclei.
- isogametangium and isogametes are terms used to designate gametangia and gametes that are morphologically indistinguishable but physiologically distinct.
- Heterogametangia and heterogametes are used to designate male and female gametangia and gametes that are morphologically different.
- The male gametangium is the antheridium and the female is oogonium.

METHODS OF SEXUAL REPRODUCTION

- There are different methods of sexual reproduction;
- i. Somatogamy
- ii. Spermatization
- iii. Gametangial copulation
- iv. Gametangial contact
- v. Planogametic copulation

SPERMATIZATION

- When a spermatium unites with an oogonium the process is called spermatization.
- Spermatia are minute conidia-like male gametes attached or born externally on specialized hyphae called spermatiophores or inside cavities called spermogonia.
- They are uninucleate and differ from conidia in that they aren't capable of germinating and are smaller than conidia.

SPERMATIZATION CON'T

- The spermatia may empty their content through a pore upon contact with a female organ, either female gametangia or a specialized receptive hypha or even a somatic hypha.
- The nucleus of the spermatium eventually becomes very close to the gametangium and fusion occurs. Spermatia are carried by wind, water, and insects.
- These are very common in the Ascomycota(Neurospora) and Basidiomycota(eg. Puccinia sp.)

GAMETANGIAL COPULATION

- It is a method of plasmogamy in which the entire content of 2 gametangia or their protoplast fuse and give rise to a zygote that develops into a resting spore. It occurs in 2 ways:
- i. direct fusion of gametangia as exemplified by Mucor, Dipodascus and Eremascus
- ii.migration of the entire protoplast of one of the gametangia to the other through a pore. The entire gametangia acts as a gamete.

GAMETANGIAL COPULATION CON'TD

- The recipient gametangium is called the female while the gametangium that empties its content is called the antheridium.
- It occurs in rhizophidium. No dikaryotic phase is developed in such species as karyogamy takes place immediately after plasmogamy.
- In the yeast cells which also undergo this, because they are unicellular, the somatic cells themselves act as gametangia.

GAMETANGIAL CONTACT

- Under these methods, 2 gametangia come into contact but do not fuse.
- The male gamete is usually represented by the nucleus contained inside the antheridium while the female is represented by the egg contained in the oogonium.
- When two gametangia come into contact the male gametic nucleus migrates into the oogonia through a pore dissolved at the point of contact or through a fertilization tube specially developed for the purpose by the male gametangium.

GAMETANGIAL CONTACT CON'TD

- The 2 gametangium do not fuse, thus their identity is preserved.
- The oogonium undergoes post copulation transformation while the antheridium usually dissolves or disintegrates.
- In the Ascomycetes, the nucleus passes through the antheridium into the ascogonium.

PLANOGAMETIC COPULATION

- This involves the fusion of 2 naked free gametes, one of which may be motile.
- There are 3 types of planogametic copulation based on the size and motility of the fusing gametes
- i. isogamy: the conjugation of isogamous planogametes
- ii. anisogamy: conjugation of anisogamous plano gametes.
- iii. heterogamy: fertilization of a non-motile female gamete by a motile gamete (antherizoid)

ISOGAMY

- When the 2 fusing gametes are morphologically similar (ie same size and shape) but physiologically different, the fusion is isogamy and are called isogametes.
- In some species, gametes originating in the same gametangium will not fuse. Eg *Olpidium viciae* and *Synchytrium endobioticum* .
- The fusion results in motile gametes.

ANISOGAMY

- The union of morphologically similar gametes which differ in size.
- One plano gamete is considerably larger than the other.
- Fusion takes place in water and a motile zygote is formed, commonly found in the order Blastocladiales.

HETEROGAMY

- This entails heterogametes and they are gametes that are morphologically distinguishable.
- It involves the fusion of a motile male gamete with a non-motile female gamete (oospore contained in an oogonium).
- The motile male gametes (antherizoid) enter the oogonium and fertilize the egg (oospore) and this is found in the order Monoblepharidales.

SOMATOGAMY

- It is the fusion of somatic hyphae and it is more common in the higher fungi than in the lower fungi or it is the fusion between udifferentiated vegetative cells or spores.
- It has a special significance only if it brings compatible nuclei of opposite mating types into one cell.
- This cell gives rise to dikaryotic tissues.

FUNGAL SPORES

- Fungal spores are microscopic and may be either unicellular or multicellular.
- In simpler fungi, spores are generally motile and are called zoospores.
- Fungal zoospores are equipped with one or two flagella. There are 2 types of flagella:
- i. whiplash
- ii. tinsel.

FUNGAL SPORES CON'TD

- The whiplash is divided into 2 parts. It has a lower or a basal portion which Is usually longer but more rigid than the upper or terminal end (portion) which is usually shorter but flexible.
- The tinsel flagellumis feathery in structure consisting of a long rib with lateral hair-like projections which are termed flimmers or fibrils or mastigomeres.

FUNGAL SPORES CON'TD

- In some multicellular spores both longitudinal and transverse septa are present eg. *Alternaria* sp.
- Spores of aquatic fungi show some adaptive features to their habitat.
- Some spores have radiating arms that help them to remain afloat or hold on to leaves or twigs.

FUNGAL SPORES CON'TD

- Fungal spores have various ornamentations and this include the following:
- i. some spores are very smooth and have holes in them. These spores are called pitted or **alveolate**.
- ii. Reticulate type: has a network of raised ridges represented by lines
- iii. Spiny type: Have spines that are very sharp
- iv. verrucose type: have spines but not as sharp as those of the spiny type

GERMINATION OF FUNGAL SPORES

- Majority of fungal spores germinate by a germ tube which is a juvenile filament.
- A germ tube by its elongation and branching establishes the mycelium.
- In most spores investigated by electron microscopy, the walls have been found to be at least 2 layered.
- During germination the inner wall protrudes through a weakened portion of the outer wall of a germ tube.
- The spores of fungi commonly swell in the cause of germination.
- Where the spore is multicellular, each cell is capable of germinating eg. *Cercospora arachidicola.*

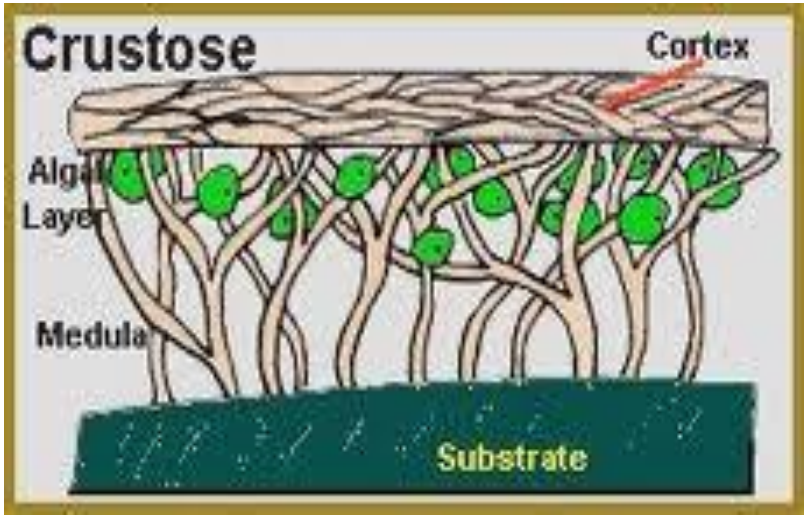
GERMINATION CONT'D

- Factors that affect spore germination include moisture.
- Most spores will not germinate below 95% relative humidity.
- There are some which will germinate only in liquid water.
- The powdery mildew *Leveillula taurica* is however an exception. It can even germinate at 0% relative humidity but does better in moisture.
- Other factors that affect spore germination include temperature, wind, light and nutrients.

NOTES ON GROWTH FORMS OF THALLUS - CRUSTOSE LICHENS.

- CRUSTOSE LICHENS
- The simplest crustose lichens lack an organized thallus.
- They consist of an intermediate hyphal material which entraps and encloses algal colonies .e.g. in powdery crust Leprarie.
- On rocks, a hyphal material and associated algae may grow among rock crystals just under the rock surface; these are endolithic lichens.
- Comparable species on bark where the hyphae grow between cork cells are called hyphophlodeal.
- The ascocarps form on the surface of the substrate.

Crustose lichens con’td



Crustose lichens con’td

- The vast majority of crustose lichens grow on surface of rocks and trees and have a distinct thallus.
- There is an upper cortex and an algal layer with a medulla of variable thickness which penetrates between rock or periderm layers, firmly attaching lichen to the substrate.
- The margin of the thallus may be clearly delimited or distinct.

Crustose lichens con’td

- A few groups have an alga-free usually blackened margin called a prothallus around the thallus.
- This material; is eventually lichenized in the older parts. The follicolous lichens occur on leaves of evergreen tropical trees and ferns but do not penetrate the epidermis.
- With increasing specialization, crustose lichens become centrally fissured or areolite, as in Acarospora and Rhizocarpon.

Crustose lichens con’td

- In a more advanced stage the margins become divided into tightly appressed lobes as in Dimelaena nad Diploicia. These lobate genera are differentiated from closely attached foliose lichens by the lack of a lower cortex.
- Highest stage in development of crustose lichens is the squamulose thallus. The individual lobes, still lacking a lower cortex become partially free of the substrate e.g in soil lichens such as Catapyerium, Cladonia and Psora.

Foliose lichens

- FOLIOSE LICHENS
- Differs from crustose in being dorseventral with distinct upper and lower surfaces. It is free of the substrate but usually attached to it by rhizines.
- Thallus is typically divided into branching lobes, as in our commonest lichens, Anaptychia, Cetraria, Hertedermia and Parmelias, Physcia and Xanthoria. This highly developed form has given rise to a great range of thallus size and diversity

FUNGAL TAXONOMY

- Like other organisms, taxonomic categories can be created.
- Each category is referred to as a **TAXON.**
- A Taxon is a general term for any taxonomic group; whatever the rank.
- The various taxa are the:
  - Kingdom - Family
  - Division - Genus
  - Class - Species
  - Order
- The various categories may have subtaxon eg. Division has subdivision and Class – subclass.

FUNGAL TAXONOMY *contd*

- Species may have varieties, strains.
- The various categories have standard endings provided by ***International Code of Nomenclature***:
  - Division ends with –***mycota***
  - Subdivision ends with –***mycotina***
  - Class ends with –***mycetes***
  - Subclass ends with –***mycetidae***
  - Order ends with –***ales***
  - Family end with –***aceae***
- Genus and Species don't have any specialized endings.

DIVISIONS

- There are **five (5) divisions**:
  i. Mastigomycota
  ii. Zygomycota
  iii. Ascomycota
  iv. Basidiomycota
  v. Deuteromycota
- The **MASTIGOMYCOTA** and **ZYGOMYCOTA** are either unicellular as well as filamentous forms.
- *However, there are more filamentous forms*.
- Their cells are always almost multinucleated and septation is predominantly adventitious.

DIVISION *contd.*

- The soma is generally coenocytic and the two divisions are referred to as the ***Lower fungi***.
- Asexual reproduction is by means of motile and non-motile cells (spores).
- Spermatization and gametagia contact generally don't occur in this divisions.
- The difference between the two is that the Mastigomycota have aquatic membership and produce motile cells.

MASTIGOMYCOTA

- They are fungi with centrioles which function during nuclear division.
- The zoospores are flagellated in various ways and form the basis for their classification..
- Nutrition is typically absorptive .
- Sexual reproduction within the group is by various means whereas asexual reproduction is by zoospores.

Mastigomycota *contd.*

- There are two (2) subdivisions:
  a) **Haplomastigomycotina**:
- Under this subdivision are 3 class:-
  i. Chytridiomycetes
  ii. Hyphochytridiomycetes
  iii. Plasmodiophoromycetes

  b) The second subdivision is **Diplomastigomycotina** and the only Class is **Oomycetes**.

CLASS CHYTRIDIOMYCESTES

- One distinguishing characteristic of this group is the production of motile cells (ie. Zoospore and Planogametes)
- Each of these is equipped with a single flagellum which is posteriorly located and is whip-lash.
- The have coenocytic structure.
- They convert the zygote into a resting spore or resting sporangium.
- The general constituent of cell wall is ***chitin*** and are generally microscopic.

OCCURRENCE AND IMPORTANCE

- They are more prevalent in aquatic habitat even though some are also found in soil.
- Most Chytrids are of little economic importance.
- Some are parasitic on algae and destroy them.
- They are therefore indirectly injurious to man
- Many members of the genera **Olpidium**, **Physoderma**, **Synchytrium** are parasitic on economic plants.

OCCURRENCE AND IMPORTANCE *contd.*

- Many of the species of the **Coelomomyces** genus are parasitic on mosquito larvae. *and may be very important in the biological control of mosquito.*
- In recent years, mycologists have used various species of Allomyces, Bastocladiella as very important research tools in morphogenesis.

SOMATIC STRUCTURE

- Some are unicellular and holocarpic and others have no mycelium.
- Others don’t have cell walls in their early stages of development.
- In the more complex species, a few rhizoids are produced which serve to anchor the unicellular thallus to its substratum.
- Some species produce a network of rhizoids called ***Rhizomycelium*** which is usually not nucleated.

SOMATIC STRUCTURE *contd.*

- Rhizomycelium functions as the somatic part and bears one or more reproductive structures.
- If a thallus consists of rhizomycelium and bears only a single reproductive structure, it is referred to as ***Monocentric***, otherwise it is ***Polycentric***.
- A thallus may be **Endobiotic** which means the entire thallus grows within the entire host organism.
- It may also be **Epibiotic** which means the rhizoids grow within the host whereas the reproductive structure grow outside the host.

SOMATIC STRUCTURE *contd.*

- They are classified into **four (4) orders** on the basis of ***somatic*** and ***reproductive structures***.
- These are:
  - **i. Chytridiales**
  - **ii. Harpochytriales**
  - **iii. Blastocladiales**
  - **iv. Monoblepharidales**

- **<u>CHYTRIDIALES</u>**

- Referred to as the **Chytrids** and are regarded as the simplest of the true fungi.
- A true mycelium is lacking and generally, they are unicellular.

CHYTRIDIALES *contd.*

- They are both soil and water inhabitants.
- Many of them are parasites on algae and water moulds.
- A few economically important species are ***Synchytrium endobiotium*** – this causes the disease known as potato wart which is widely distributed in all potato growing regions of the world and is the most destructive parasite in the order.
- Another one is the ***Physoderma zeae-maydis*** which causes brown spots of maize.

CHYTRIDIALES *contd.*

- ***Urophlytis alfalfa*** causes crown wart of the alfalfa plants which often results in the serious destruction of the crop.
- ***Synchytrium*** causes hypertrophy and hyperplasia of the surface layer of the potato tubers.
- ***Olpidium brassicae*** infects the roots of cabbage and other parts.

GENERAL CHARACTERISTICS

- They generally are true mycelium aquatic/saprophytic form on debris.
- The most morphologically simple are endobiotic living entirely with cells of their host.
- The mature thallus may be surrounded by a cell wall although the early stages may be wall-less.
- Some are epibiotic-producing their reproductive organs on the surface of the host, although their nutrient-absorbing structures may be sunken into the host tissues.

GENERAL CHARACTERISTICS *contd.*

- Some are holocarpic/encarpic.

- Asexual reproduction is by means of zoospores that are borne in sporangia and emerge through one or more papillae when the sporangia discharges or a tip of a tube issuing from it.

- **Operculum**: A well defined circular cap at the tip of the discharge papillae: inoperculate.

BLASTOCLADIALES

- These are chiefly water molds or soil inhabitants.
- Characterised by the production of thick walled resistant sporangia usually with pitted walls.
- Another feature is the prominent double unit membrane bounded nuclear cap in zoospores and plenogametes.
- The zoospores also have complex structure called **side body**: located just beneath the cell membrane near the posterior end of the spore.
- It is associated with microbodies and lipids.

BLASTOCLADIALES *contd.*

- The order is divided into the families:
  i. Coelomomycetaceae
  ii. Catenariaceae
  iii. Blastocladiaceae

- **Blastocladiaceae**

- The mycelium is well developed.
- A group of well-form branched rhizoids which attaches the fungus to a substratum
- They are usually dichotomously branched on which reproductive organs are formed.
- The walls of the hyphae give a chitin reaction.
- The hyphae are non-septate: pseudosepta.

Blastocladiaceae *contd.*

- Two types of thalli – **gametothalli** and **sporotalli** are known in those that reproduce sexually
- Only distinguishable by the types of reproductive organs they bear.
- Sexual reproduction is by copulation and depending on the species it may be isogamy or anisogamy.
- The family has **five (5) genera**: **Allomyces**, **Blastocladiella**, **Blastocladiopsis, Blastocladia** and **Microallomyces**.

Blastocladiaceae *contd.*

- ***Allomyces***: subgenera, ***Euallomyces***, ***Cystogenes***, ***Brachyallomycess.***
- They exhibit a complete alternation of generation.
- At certain stage of maturity, the gametothalli produce colourless female gametangia and orange male gametangia in close proximity to one another usually in a ration 1:1.
- Male is smaller than female and may be borne on or below depending on the species.

Blastocladiaceae *contd.*

- The gametes are posteriorly uni-flagellate
- The female gametangia and gametes produce a sexual hormone- **sirenin** to which the male gametes are attracted.

DIPLOMASTIGOMYCOTINA

- This subdivision has only one class which is the oomycetes.
- Their distinguishing features include the ff:
- They produce bi-flagelate zoospore.
- Their cell wall consist mainly of glucans.
- Their sexual reproduction is oogamous by gametagial contact.
- Meiosis is gametagial.
- Their somatic nuclei being diploid.
- The oomycetes with the simplest structure are aquatic fungi either free-living or parasitic on algae, water moulds, small animals and other forms aquatic lives.

DIPLOMASTIGOMYCOTINA *contd.*

- The most complex are terrestrial parasite of plants.
- The somatic structure of these fungi ranges from a simple unicellular thallus to a profusely branched filamentous mycelium.
- Majority are eucarpic.
- Both sexual and asexual structures occur in most species.
- Zoospores are produced throughout the class.

DIPLOMASTIGOMYCOTINA *contd.*

- The shape of the nucleus is pear shaped but the zoospores are either ***kidney*** or ***pear*** shaped.
- Near the tapered end of the nucleus lies a pair of basal bodies from which arise the flagella.
- Microtubules and fibres radiate from the basal bodies into the cytoplasm.
- They are thought to anchor the flagella apparatus within the cell.
- Rumposome and side bodies present in the zoospores of chytrids are absent here.
- Oospore in characteristic in all except the simplest forms.

DIPLOMASTIGOMYCOTINA

- There are four (4) orders namely Saprolegniales, Leptomitales, Lagenidiales, Peronosporales.

- Of the four only Peronosporales affect human welfare to a greater extent.

- A few species in the species in the saprolegniales attack economically important plants and a few cause serious diseases of fish but taken as a whole they are of no great significance.

- Peronosporales on the other hand include some of the most destructive parasites known.

- At least two (2) of them have a hand in shaping the economic history of an important portion of humanity.
- ***Phytopthora infestans***, the cause of late blight of potato and ***Plasmopara viticola***, the cause of downy mildew of grape.
- **Peronosporales: -**They are the most specialized of the oomycetes.
- Some are aquatic, amphibious, terrestrial species highly specialised obligate parasite.

CLASSIFICATION OF PERONOSPORALES

- This is based mostly on the characters of the sporangia and sporangiophores.
- The latter are strikingly characteristic of many group, and the variation among them lends itself to taxonomic treatment.
- This is in contrast to the sexual (oospore) stage in which the variations are not so obvious.
- Four families are recognised.

- **PYTHIACEAE:**

- The mycelium is well developed.
- Generally bear their sporangia directly on a somatic hyphae.

PYTHIACEAE *contd.*

- In some species the fertile hyphae are no different from the somatic hyphae.
- The more complex ones produce recognizable sporangiophore which grow indefinitely.
- They include aquatic, amphibians and terrestrial.
- Many of them cause serious diseases to plants of economic value.
- In the simplest forms, the sporangia remain attached to the hyphae that bear them.
- Upon maturity, they produce and liberate zoospores.

PYTHIACEAE *contd.*

- The most specialized, sporangia is deciduous and often germinate each by germ tube instead of producing zoospores.
- This is influenced by the environment.
- The most common genera are **Pythium** and **Phytophthora**.
- Pythium includes some aquatic parasites on algae as well as many aquatic and soil inhabitants.
- The best known is ***Pythium debaryanum*** the cause of damping-off seedling (Tomatoes, corn, tobacco) .

PYTHIACEAE *contd.*

- The genus Phytophthora include many important plant pathogens of which P. infestans is the most infamous.
- Under low temperature and high humidity, the disease occurs on epiphytotic scale .
- In the past, it was responsible for the complete destruction of the entire potato crop over large areas.

PYTHIACEAE *contd.*

- Irish famine of 1845-1846 which was partially responsible for the repeal of the corn law in England.
- Migration from Ireland to America in traceable to P. infestans.

- **PHYTOPHTHORA**

- The chief distinction between the genera Pythium and Phytophthora is the method of sporangial germination.
- In general, no vesicle is formed in Phytophthora, or if one is formed, the zoospores differentiate in the sporangium proper and pass into the vesicle as mature zoospores.

PHYTOPHTHORA *contd.*

- Other important species include ***Trachysphaera fructigena*** is a serious parasite of coffee in Africa and destroys pods of cocoa as well.
- Sclerophthora is parasitic on grasses and causes downy mildew.

- **PERONOSPORACEAE**

- It is the most specialized under the peronosporales.
- All species are obligate parasites of vascular plants causing diseases called **Downy mildew**.

PHYTOPHTHORA *contd.*

- However, there are reports of lab culture of Peronospora brassicae and Sclerospora graminicola on artificial media
- They are very important economically.
- Their host include a large number of plant families, many of them widely distributed and widely cultivated commercially.
- Diseases they cause include, among many others, the downy mildews of grape caused by ***Plasmopara viticola***
- Onion – ***Peronospora destructor***
- Lettuce – ***Bremia lactucae***

PHYTOPHTHORA *contd.*

- Cucurbits – ***Pseudoperonospora cubensis***
- Various Grasses – maize inclusive – ***Peronosclerospora maydis***.

- **FAMILY ALBUGINACEAE**

- They include the fungi known as White Rust.
- They are all obligate parasite causing diseases of vascular plants.
- Several species of Albugo, the only genus of the family are known, of these, only Albugo candida, which attack crucifers, is the only one causing disease attaining economically significant proportion.

BLACK POD OF CACAO

- It is the most serious fungal disease of cacao caused by *Phytophthora spp.*
- It occurs in all cocoa growing areas and is estimated to destroy at least 10% of world cacao.
- There are about 8 known species; however, the four most important are:
  - **P. megakarya** **- P. citrophthora**
  - **P. capsici** **- P. palmivora**
- ***Phytophthora megakarya*** is a plant pathogen that causes black pod disease in cocoa trees in West and Central Africa.
- The fungus is not restricted to the pod ,it attacks all parts of the plant causing considerable damage to the roots of seedlings and it is responsible for canker of the stem.

BLACK POD OF CACAO *contd.*

- Sporangia are formed that may germinate by forming biflagellate zoospores or directly by means of germ tube.
- Also form chlamydospores which give rise to sporangia on germination.
- Though they produce oospores, they are rare in nature and they seem not to play significant role in infection.
- Disease develops in newly formed pods which may be invaded by mycelium from cankers in the bark spreading through the stalk.
- Sporangia and chlamydospores formed by hyphae in the soil constitute the other source of fresh infection (-Sporangia are lifted into the pod).

BLACK POD OF CACAO *contd.*

- Near the base of the trunk in droplets splattered by rain.
- The fungus is transported from diseased pods in the form of sporangia or zoospores by rain splash or by rain water running over diseased pods on upper branches onto small pods at lower levels on the trunk or by contact by diseased and healthy pods.
- Insects and rodents also disperse the fungus.
- The germ tube and the hypha penetrates the intact wall of the pod.

BLACK POD OF CACAO *contd.*

- Rotting proceeds quickly to affect the entire pod including the beans in 10days, the pod becoming brownish-black in colour.
- It is at this stage that the fungus travel from the pod stalk into the bark to cause canker.
- **CONTROL**:
- At present, it is controlled to some extent by **Spraying** with fungicides, by agronomic (cultural) practices and by crop sanitation.
- Copper based fungicides, especially Bordeaux mixture cuprous oxide, Cu oxychloride have so far given the best control.

BLACK POD OF CACAO *contd.*

- It is also almost the only way of combating the fungus in the soil, used in Fernando Po for a long time.
- Easiest method of control with the minimum expenses is **Crop Sanitation**.
  - Diseased pods should be promptly removed and burnt.
  - Pods left on the tree indefinitely is a danger to neighbouring healthy pods and also to the bark.
  - It is however time consuming and it often appears to be recommended more often than practiced.

BLACK POD OF CACAO *contd.*

- Husk pile should be burnt.

- **Control by Cultural Practises** is very little used at the moment.
  - The wider the cocoa trees are spaced the smaller the danger of tree to tree transfer of the fungus.
  - Excessive spacing however, is known to reduce yield and therefore this method of control unattractive.
  - Excessive shade trees generally prevent air circulation and help build up moisture level of the atmosphere and encourage fungus growth and spore formation.
  - Drier and unfavourable conditions can be created by reducing shade.

BLACK POD OF CACAO *contd.*

- There is no known cacao varieties at the moment with complete immunity against the disease.
- **Biological Control**
- ***Trichoderma viride****- this is antagonistic to the Phytophthora sp* which causes the Blackpod disease.
- ***Geniculosporium sp****.*
- ***Pseudomonas aeruginosa****.*

- The amastigomycota consist of tremendous assemblage of fungi.
- Included here are yeast, mould. Mildews, cup fungi, rust, smut, bracket fungi, puffball and mushrooms.
- All these have absorptive nutrition except for the yeast.
- Most produce a well developed mycelium consisting of septate and aseptate hyphae.
- Spindle pole bodies are present but centrioles and motile cells are completely absent in these fungi.

- Asexual reproduction is by budding, fragmentation, sporangiospores or conidia.
- Sexual reproduction where known, culminate with the production of zygospores, ascospores or basidiospores.
- The group comprise the zygo, asco, basidio and the deuteromycota.

- **ZYGOMYCOTA**

- the term refers to the production of a thick walled, resting spore called zygospore which develops within the a zygosporangium.

- Formed as a result of complete fusion of two equal and unequal gametangia.
- The gametangia may arise from the same mycelium or different mycelium.
- Most zygomycetes produce a well-developed mycelium consisting of coenocytic hyphae.
- Motile cells are absent and asexual reproduction is typically by sporangiospores though some produce chlamydospores.
- Budding may occur under certain conditions in others.

- Biologically, they range all the way from saprophyte, facultative, weak parasite of plants to specialized plants of animals and obligate parasites of various organisms.
- Many of them are of direct importance.
- Some are used in the fermentation of food items.
- Others are used commercially to produce certain enzymes as well as acids
- On the other hand, many saprophytic species attack and spoil foods and many are also human pathogens whiles others have been known to be important mycorrhizal fungi.

- There are three 3 main orders under the Zygomycetes
  - Mucorales
  - Entomophthorales and
  - Zoopagales
- There are other orders aside the above listed.

- **MUCORALES**

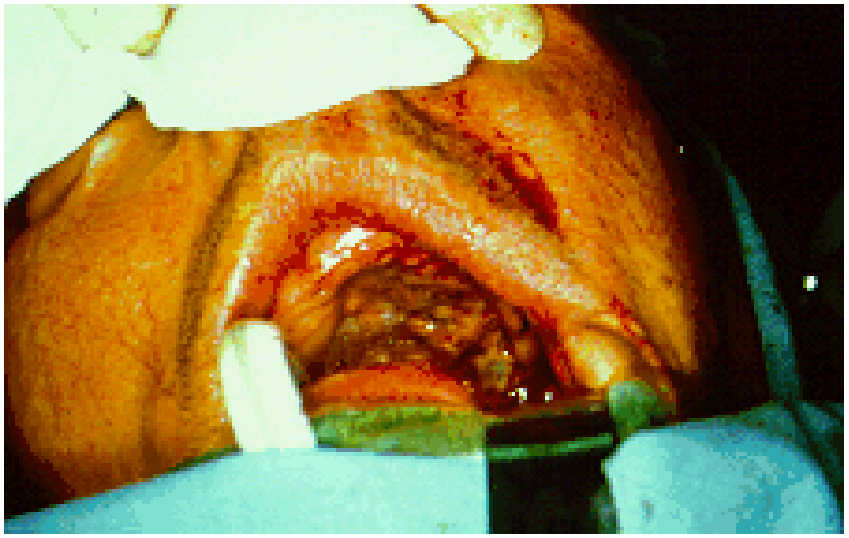
- They are by far the largest order.
- Majority are saprophytes

- Many of the saprophytes are capable of synthetizing important industrial products.
- For eg. ***Rhizopus stolonifer*** has been used commercially for the production of fumaric acid and also for some steps in the manufacture of cortisomes.
- ***Rhizopus oryzae*** for alcohol.
- various species of Rhizopus R. sinensis, stolonifer, oryzae, nodosus are also capable of forming large quantities of lactic acid.

- They also produce citric , oxalic , succinic acids and other important chemicals.
- Some species are also used in the production of orientals. Eg. Sufu and tempeh.
- A few of them are weak parasites on fruits and other detached plants parts and causing disease in transit and in storage.
- Eg. *Rhizopus stolonifer* causes a serious transit disease of strawberries and a soft rot of sweet potato in storage.

- Others are parasitic on other organism.

- Others are known to cause disease in humans.



SOMATIC STRUCTURES

- The soma is well-developed.
- They produce septa at the base of the reproductive organs.
- Plasmodesmata have been reported in the gametangial septum.
- The mycelium of some species produces rhizoids which may connected by stolon.
- In addition to possessing capacity to produce mycelia (some show dimorphism).

- Dimorphism is common in the mucor.

- Eg. Mucor, ***Mycotypha*** and ***Mucor*** rouxii used extensively as an experimental tool can be maintain exclusively as in the yeast form when grown under anaerobic condition with an atmosphere consisting of at least 30% CO_2 .
- Glucose concentration is also important factor in determining the form.
- Concentration in excess of 5% will induce yeast-like growth in some species even under aerobic condition.

- Likewise phenethyl alcohol favours the development of the yeast form.

- **<u>Asexual Reproduction</u>**

- They reproduce asexually by aplanospores that are produced in a sporangia which are borne on a simple or branched sporangiophore
- Mucor (simple)– ***Thamnidium*** *(whorled)* – Piptocephalis (profusely/highly branched)
- Sporangiola (1 or few spores)
- Merosporangia= cylindrical

SEXUAL REPRODUCTION

- Takes place by the copulation of 2 multinucleate gametangia that are mainly similar in structure but may differ in size.
- Endogonales: contain a single family: Endogonaceae
- Most species bear spores singly in soil
- Some produce sporocarps containing either **zygospores** chlamydospores or sporangia.
- **Entomophthorales**
- Interesting group of fungi parasitic on both plants and animals or saprophytic.

- Their ability to parasitize insects is particular noted.

- **Zoopagales:**

- Most fungi included in this order are either predacious on amoeba rhizopods, or nematodes or live parasitically on or in such animals.
- Found in various habitats including soil, rotting plant material water, etc.

- **Trichomycetes:**

- The class comprised forms obligately associated with living arthropods - insects, millipedes and crustaceans.

- They grow internally within the guts of their host most of which are aquatic forms.
- They attach by means of holdfast.

- **Ascomycetes:**

- Include the ascus forming yeast, some of the common black moulds, green moulds, powdery mildew, the cup fungi, morel and the truffles.

- **OCCURRENCE/IMPORTANCE**

- They occur in a variety of habitats
- Many are small and inconspicuous parasitic on plants.

- Saprophytic ones are also common.
- A few are entirely hypogean.
- A few are also coprophilous.
- They are of great importance in human affairs.
- The cellulolytic Ascomycestes, such as Chaetomium are amoung the organisms responsible for the destruction of fabrics containing cellulose.
- Destroy crops and crop plants, timber, ornamental eg. apple scab , brown rot of stone fruits, powdery mildews, foot rot cereals, ear rot of corn.

- The chestnut blight (Endothia parasitica) almost completely destroy the chestnut forest of America.
- The Dutch elm disease by ***Ceratocystis ulmi*** (the extinction of American elm).
- Histoplasmosis,(a respiratory disease,) Ringworm.
- ***Claviceps purpurea*** ergot (ovaries of rye)
- **Benefit:**
- Fermenting activities of certain yeast
- Morel and truffle as food

- **<u>Characteristics</u>:**
- One character distinguishing them from other fungi is the ***ascus***, a sac like cell containing a usually definite number of ascospores.
- Eight (8) ascopores are typically formed within the ascus
- Septate mycelium
- Complete absence of any kind of flagellate cell, fruit bodies that enclose asci.
- Two (2) distinct reproductive stages.

ASEXUAL REPRODUCTION

- Some of the hyphae inside the pod break through the epidermis and the sporangiophore among them produce sporangium terminally.
- Spore liberation is generallly by water splash.
- The rain may carry the spores down the heary pods below.
- Insects are primarily responsible for tree to tree spread of the disease.
- The soil has been identified as the main source of inoculum.

ASEXUAL REPRODUCTION *contd.*

- In some W/A countries like Nigeria and Cameroun, it has been observed that the first infection are the pods near the ground and suggests that water splash from the grounds is responsible as a means of dispersal.
- The sporan