Aquatic Fungi Course

for 3rd Microbiology & Chemistry

Course code: 305 B

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Contents

Microbiology

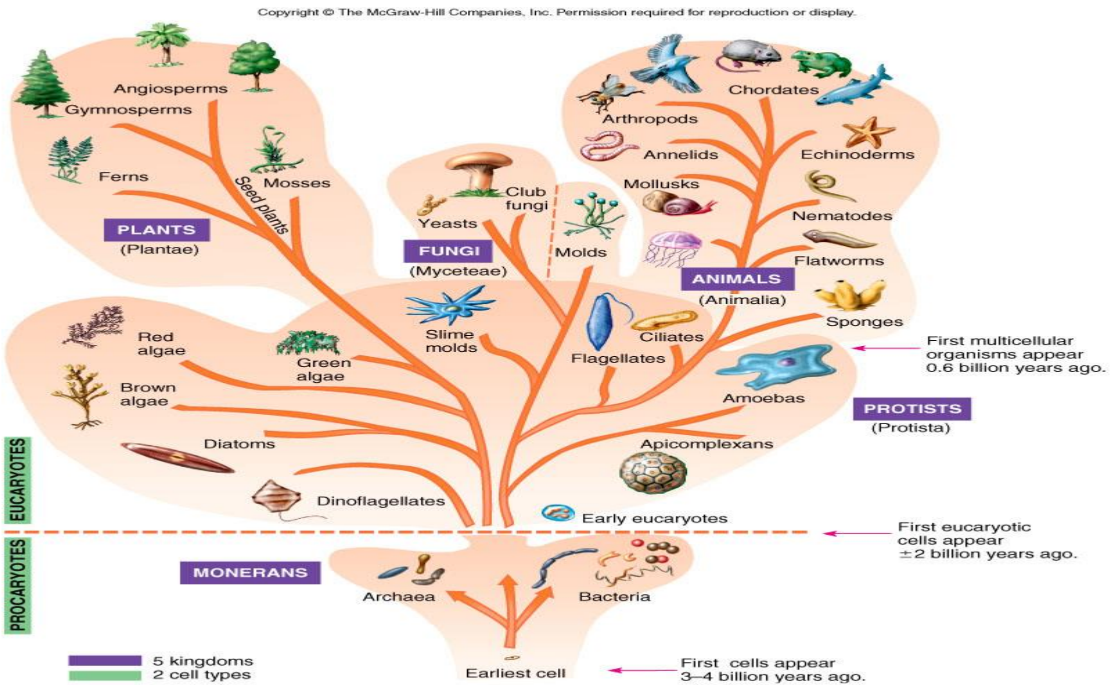
- study of organisms too small to be seen by the naked eye.

Microbes or Microorganisms

- commonly referred to as "germs" or "bugs"
- include bacteria, viruses, fungi, algae, protozoa and helminths.
- Prions ("infectious proteins") are recent addition. A protein particle that is believed to be the cause of brain diseases such as BSE, scrapie, and Creutzfeldt–Jakob disease. Prions are not visible microscopically, contain no nucleic acid, and are highly resistant to destruction.

Branches of Microbiology

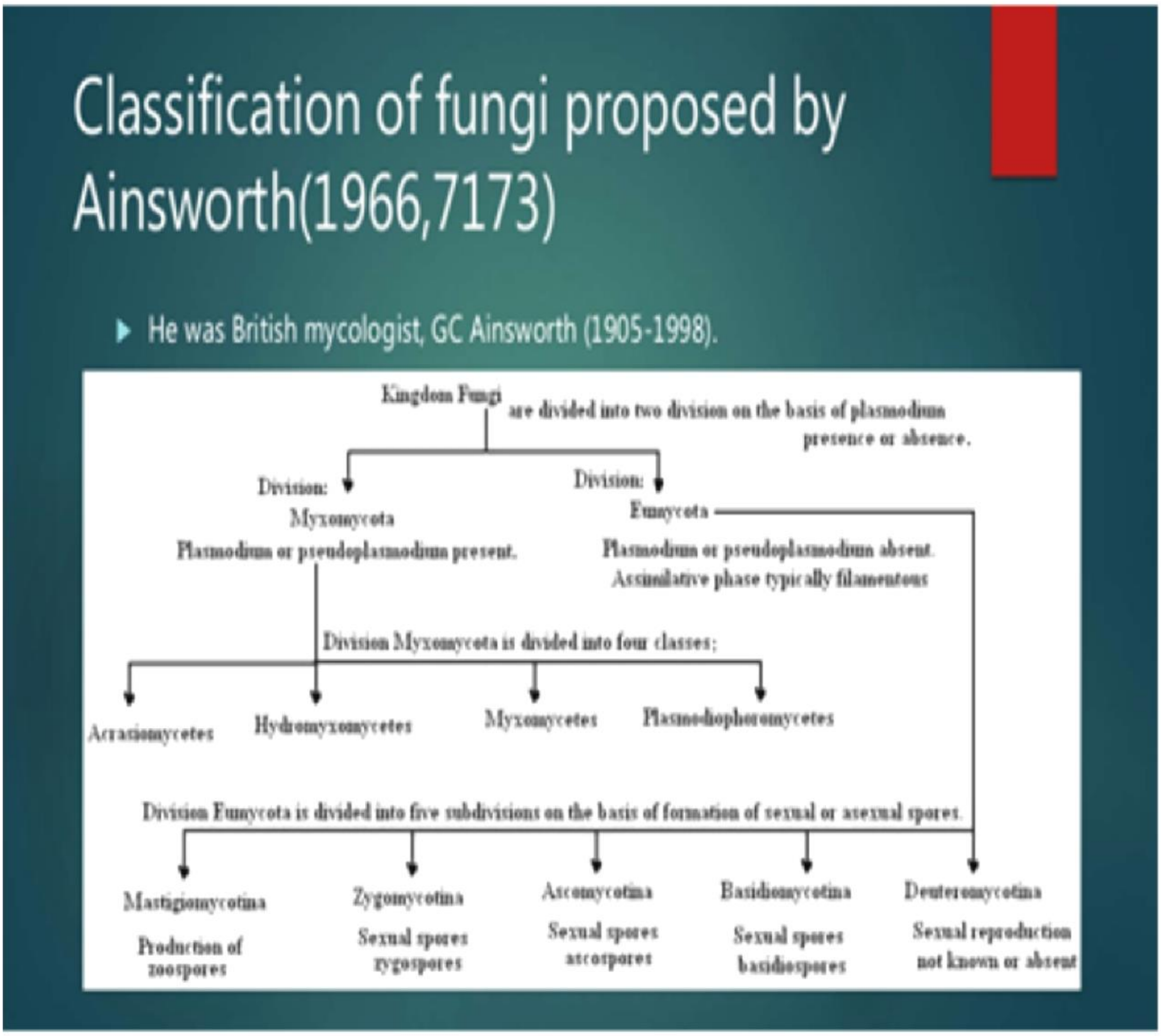
- **Bacteriology** study of bacteria
- **Mycology** study of fungi and yeast
- **Virology** study of viruses
- **Parasitology** study of parasitic protozoans and helminths
- **Immunology** study of the humoral and cellular immune response to disease agents and allergens



Classification of organisms

Fungi

It classified according to Ainsworth to the following



Eumycota

- True fungi
- Approximately 75.000 known species
- Thalli do not posses plasmodia or pseudoplasmodia

- Unicellular or filamentous
- Definite cell wall
- Growth of hyphae is apical

Mastigomycotina

- It also called zoosporic fungi
- They reproduce asexually by zoospores that formed in zoosporangium there are 3 shapes of zoospores
    1- Posteriorly uniflagellate
    2- Anteriorly uniflagellate
    3- Laterally biflagellate
- It is a sub-division of division Eumycota
- Plasmodium or pseudoplasmodium are absent
- Assimilative vegetative phase typically filamentous, coenocyte mycelium. However unicellular form are present and some genera show pseudosepta formation.
- Live either saprophytes or parasites
- Centric nuclear division, centrioles remains functional during nuclear division
- Sexual reproduction by oospore formation
- Adapted mostly in aquatic habitats

Previously it divided in to 4 classes

1- Chytridiomycetes
2- Hypochytridiomycetes
3- Plasmidiophoromycetes
4- Oomycetes

In the new classification plasmidiophoromycetes was not involved

Class: Chytridiomycetes

General Features

1- Formerly referred to as phycomycetes
2- Thought to be evolved from algae by losing chloroplast
3- The vegetative body is unicellular or chain of cells attached to substratum by rhizoids
4- Cell wall contain chitin & glucan
5- Plant body is normally haploid except Allowmycetes
6- Chytrids and rest of fungi are hypothesized to be more closely related to protozoan ancestor
7- Produces posteriorly uniflagellate zoospores
8- The class contains 18 families, 112 genera and 793 species
9- The class contains 5 orders
    - Blastocladiales
    - Chytridiales
    - Monoblepharidales
    - Neocallimasticales
    - Spizellomycetales

10- Asexual reproduction by zoospores formed in zoosporangium (Uniflagellate, whiplash type, posteriorly placed)
11- Sexual reproduction by gametangial copulation and form zygote and divided meiosisally to form haploid thallus

Ecology & Importance

1- Aquatic and terrestrial
2- Most aquatic fungi found in fresh water although, some forms found in marine water

3- Saprobes and some parasites of protists, invertebrates, fungi and plants
4- Most species complete their life cycle in a matter of just a few hours or days
5- Most saprophic species can be isolated from soil and water samples by baiting with sterile substrates such as pollens, leaves, fruits, snake skin, exoskeletons of insects
6- Barr (1990) emphasis their importance as primary invaders and decomposers of organic materials including chitin, cellulose, hemicellulose and keratin
7- Some chytrids are plant pathogens
8- Species of *Coleomomyces* parasite mosquito larvae may prove to be valuable biological control agents
9- Some species of free living saprobes have become popular experimental organisms in cellular and molecular biology
10- Currently, there is a considerable interest in the anaerobic chytrids found in the rumen of cattle and sheep

Thallus Structure

- **Holocarpic:** primitive forms in which the entire thallus may be converted into one or more reproductive structures
- **Eucarpic:** in which reproductive organs arise from only one portion of the thallus which rhizoids not incorporated
- **Endobiotic:** (Endo=within, bio=life) the most morphologically simple forms, living entirely with the cells of their hosts. The mature thallus surrounded by a cell wall, although the early stages may be naked.

- **Epibiotic:** (Epi= upon, bio=life) producing their reproductive organs on the surface of either living host or some pieces of dead organic matter with their nutrient absorbing structures sunken into the living or dead tissues on which they live
- **Monocentric:** in which the thallus give rise to only a single center for growth and reproduction
- **Polycentric:** in which thallus bear more than center for growth and reproduction

Rhizoids: short delicate filaments that contain protoplasm but not nuclei and eventually may be separated from the remainder of the thallus by septa

General characteristics of asexual reproduction in chytrids.

1) Initiates with zoosporangium filled with protoplasm and many nuclei
2) Protoplasm of zoosporangium then cleaved in to numerous sections which develop in to zoospores
3) Zoospores are released, swim, encyst by loosing their flagella and then germinate producing a thallus

Types of zoosporangia

1) Operculate zoosporangia always form well-defined circular cap (operculum) through which the zoospore emerge
2) Inoperculate zoosporangia discharge their zoospores through a pore in the wall of sporangium or discharge tube formed when the discharge papilla dissolved.

General characteristics of sexual reproduction in chytrids:

There are 3 types of sexual reproduction in chytrids

1- **Planogametic copulation:** it has 3 forms
   a) Isogamous (morphologically similar and physiologically different)
   b) Anisogamous (one is considerably larger than the other)
   c) Non-motile egg fertilized by a motile antherzoid
2- **Gametangial copulation:**
   Transfere of protoplast from one gametangium to another
3- **Somatogamy:**
   Fusion between somatic structures (e.g. rhizoidal filaments)

Order: Chytridiales

General Features

1- It is the largest and less understood order of chytridiomycetes
2- Mainly fresh water species
3- Water or soil inhabiting fungi
4- Many of fresh water forms are parasitic on algae and water molds
5- A few parasitize animal eggs and protozoa while other are saprobes on the decaying remains of dead plants
6- Some of the better known genera are: *Chytridium*, *Chytriomyces*, *Polyphagus*, *Rhizophydium*, *Endochytrium*, *Synchytrium*,…. etc.
7- Only few species of this order are economically important, *Synchytrium endobioticum* causes black wart to potato
8- Thallus types ranges from holocarpic to eucarpic, monocentric to polycentric (rhizomycelial forms).

Family: Chytriomyctaceae

e.g.: ***Chytriomyces hyalinus***

General Features:

1- The fungus is ubiquitous monocentric, eucarpic chytrid
2- Can be isolated by baiting water and soil samples
3- In nature it grows saprophytically in fresh water on skeleton of may flies and on bits of chitin
4- It can be grown in pure cultures in the laboratory on 0.5% chitin
5- It is an ideal experimental organism for demonstrating the production of extracellular chitinase

Life cycle of ***Chytriomyces hyalinus***

Chytriomyces forms a well-developed rhizoidal system in the substrate it invades

The zoosporangium which develop form encysted zoospores has an apical or sub-apical shallow from which zoospores escape in to discharge net which they soon escape.

When released to the water and after swimming for periods of time, the zoospores encyst and germinate either forming new sporangia and rhizoids (a sexual thalli) or producing thalli that functioning as (sexual thalli).

Family: Rhizidaceae

e.g.: ***Rhizophydium couchi***

*********General features*************

1- Thallus is eucarpic, monocentric and may be epibiotic, endobiotic or both.
2- The zoospore body encysts and wholly or partly enlarge to form zoosporangium or gametangium.
3- In epibiotic genera thallus is attached to substrate by rhizoids.
4- Sexual reproduction occur by gametangial copulation.
5- There are 18 genera and about 100 species .
6- Rhizophydium thallus consists of an epibiotic zoosporangium.
7- Grow on a variety of living or dead plant and animal substrata.

*****Life Cycle*****

R. couchi parasites on *Spirogyra* spp.

Asexual reproduction:

1- The zoospore settle on the spirogyra filament, lose the flagellum, encyst and develop germ tube which penetrate the algal cell and forms a tuft of fine branched rhizoids.

2- The rhizoids anchor the host and also derive nutrition for the cyst

3- The zoospore enlarges and transforms into zoosporangium

4- When the sporangium mature rhizoids degenerate and some weak spots appear on the sporangial wall which bulge out as papillae and later dissolve to form pores through which zoospores are liberated.

Sexual reproduction:

Sexual reproduction takes place by gametangial copulation

1- When two thalli grow together, one of them grow bigger than the other and acts as the female gametangium (oogonium); the smaller acts as male gametangium (antheridium).
2- The entire content (protoplast) of antheridium migrates into the oogonium through a pore formed at the point of contact between the two gametangia.
3- After fertilization oogonium form a thick wall and becomes a resting spore (= resting sporangium).
4- Karyogamy is delayed at the time of germination of the resting spore.
5- A pore is formed on the thick wall of resting spore through which the protoplast moves out surrounded by a thin wall to form a zoosporangium.
6- Zoospores liberated through an apical exist papilla.

Family: Phlyctidiaceae

e.g.: *Polyphagus euglena*.

*********General features*************:

1- The thallus is eucarpic, monocentric and interbiotic with a richly-branched rhizoidal system.
2- Sporangium, pro-sporangium or resting spores are formed wholly or in part from the enlarged body of encysted zoospore.
3- The family includes both parasitic and saprophytic genera
4- The parasites usually attack fresh water algae.

*****Life Cycle*****

Polyphagus euglena (parasite on encysted *Euglena*, a protozoan and *chlamydomonas*).

Asexual reproduction:

The posteriorly uniflagellate zoospores settle down in still waters and secrets a wall and form richly-branched rhizoids. On coming in contact with encysted euglena, the rhizoid tips penetrate and parasite on them. The enlarged body of the encysted zoospore (the cyst) is the core of the thallus. After a certain period of growth, asexual reproduction starts.

1- The cyst functions as a prosporangium and gives rise to a lateral outgrowth which develops into the sporangium.

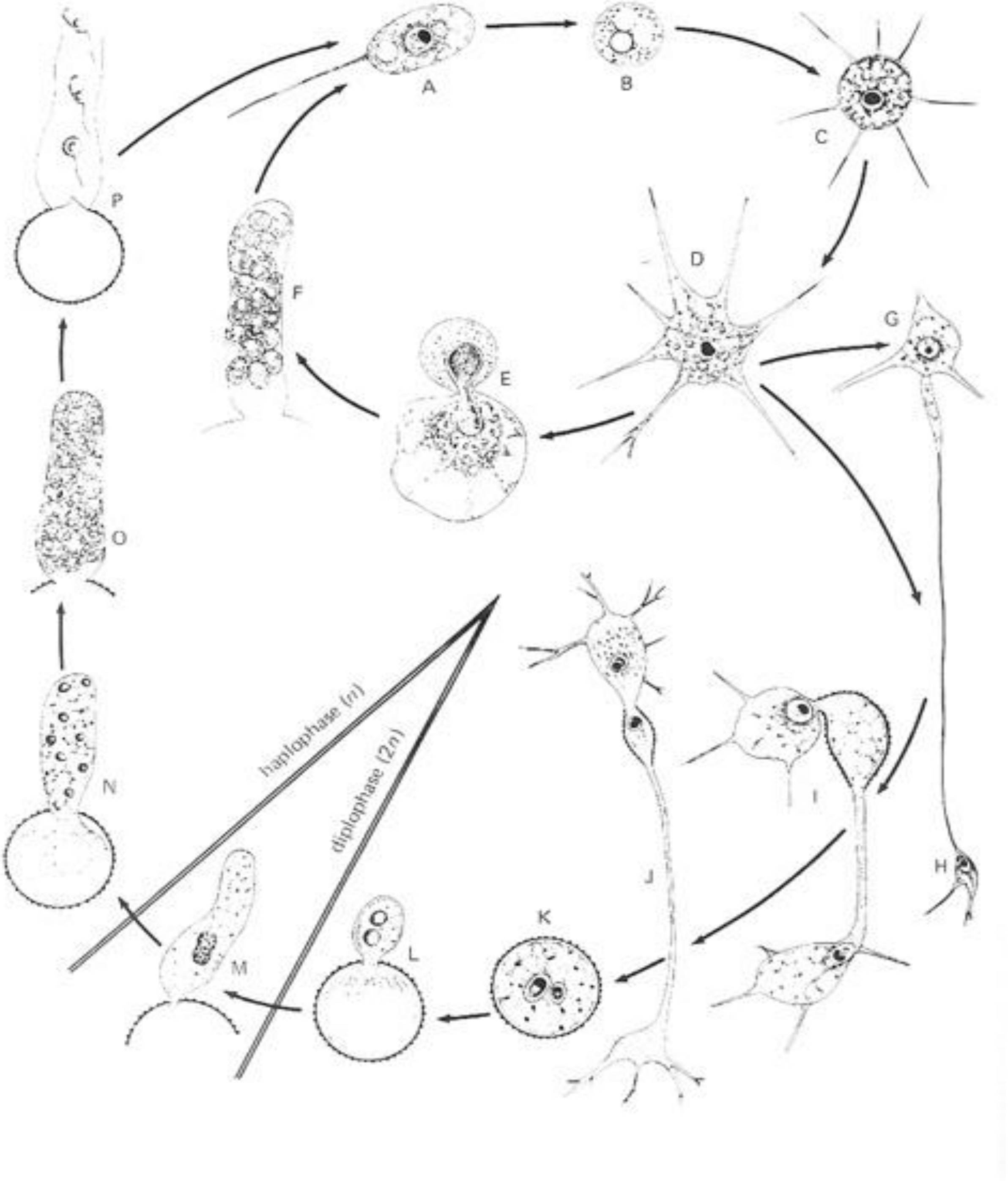
2- The contents of the prosporangium are emptied into the outgrowth.
3- The empty prosporangium is cut off from the sporangium by a septum.
4- After many nuclear divisions, the cytoplasm cleaved into hundreds of uninucleate portions which develop into posteriorly uniflagellate zoospores.
5- A pore is dissolved at the apex of the sporangium through which the zoospores escape and swim.

Sexual reproduction:

Takes place by gametangial copulation. When conditions become unfavorable for growth. The enlarged bodies (cysts) acts as gametangia. The smaller cyst acts as the male gametangium and the bigger acts as the female one.

1- The male gametangium puts out a slender lateral filament, the conjugation tube, which comes in contact with the female gametangium.
2- The contents of the male gametangium migrate into the enlarged tip of the conjugation tube to connect with the female gametangium to form zygote.
3- The wall becomes thick and the zygote transforms into a resting spore.
4- Resting spore lies dormant until the environment conducive for growth returns.

5- During germination the two nuclei undergo fusion and diploid nucleus formed
6- Meiosis takes place and haploid nuclei and multiplied by repeated mitotic divisions.
7- Zoospores are formed and liberated through an apical pore on the sporangium.



Life cycle of *Polyphagus euglena*

Family: Physodermataceae

e.g.: ***Physoderma maydis***

*********General features*************:

1- Life cycle of fungi belonging to this family involves two independent phases: 1- a monocentric, epibiotic, or zoosporangial phase. 2- a polycentric, endobiotic phase.
2- The family comprises two genera, *Urophlyctis* and *Physoderma*, both parasites on vascular plants.

Differences between *Urophlyctis* and *Physoderma* genera:

1- *Physoderma* does not induce hypertrophy while *Urophlyctis* induces strong gall formation.
2- Resting spores of *Urophlyctis* are confined within a lysiogenous cavity in the host; *Physoderma* does not form its resting spores in any such cavity.
3- Rhizoids in the epibiotic stage are dense and bushy in *Urophlyctis* but scant and stubby in *Physoderma*.

*****Life Cycle*****

Physoderma maydis causes corn pox or brown spot disease of maize. The resting spores perennating in the soil or plant debris germinate when the host crop is available. They absorb water and swell. The thin inner wall protrudes out as finger-like structure called (endosporangium) the contents divide and form 20-25 uniflagellate zoospores called (resting spore zoospore) escape through discharge papilla formed at the tip of the endosporangium.

The epibiotic phase (monocentric, epibiotic or zoosporangial phase)

1- The (resting spore zoospores) settle down on the leaf epidermis and rhizoids are sent into the epidermal cell and the cyst develops into sporangium.
2- Its contents split and form zoospores.
3- After discharge of zoospores, a basal sterile portion in the sporangium (at the point of origin of the rhizoids) enlarges and forms a new sporangium within the old one and this called sporangial proliferation which may occur at least 3 times.

The endobiotic phase: Some of resting spore zoospores that settle down on the host epidermis after retracting the flagellum dissolve a pore and enter the epidermal cell as an amoeboid body first called primary turbinate cell. Its broadly ovate to spindle-shaped cell which by repeated transverse divisions become many-celled. Secondary turbinate cells are formed by swelling of the rhizoids. A short lateral outgrowth develops into a thin-walled spherical body. It absorbs nutritive through haustoria-like processes, and finally develop into resting spore. Germination of the resting spore occur and zoospores released

Family: Megachytriaceae.

e.g.: ***Nowakowskiella***

General features:

1- This genus first reported in india by Karling 1907 and now is known to be widely distributed
2- It grows saprophytically on plant debris and can be isolated by baiting technique
3- Most of these genus are polycentric, operculate (exo- or endo-operculum) chytrids
4- Thallus may be epibiotic or endobiotic
5- The optimum temperature for growth is 16-18°C

******Life cycle******

1-The posteriorly uniflagellate zoospores settles down at plant remains, encyst and germinates by forming germ tube.

2-The germ tube grows and branches dichotomously

3- Swelling appears on one of the filaments.
4- The nucleus of the spore body (cyst) divides and daughter nucleus migrates into the swelling.
5- More nucleated swellings of various shapes (globular, spindle-shaped or irregular) are formed with the growth of the rhizomycelium.

6- The thallus consists of swollen areas connected by thinner tubes called isthumus and the nuclei occur in the swellings and not in the isthumuses or rhizoids
7- Fine rhizoids enter the substratum and derive nutrition
8- Filaments arise from the swellings or the isthumses and branch dichotomously called **flexuous hyphae**. In favourable conditions intercalary or terminal swellings appear on the flexuous hyphae which develop into zoosporangia. Asub-sporangial vesicle, also called **apophysis**, subtends the sporangium about 40 zoospores are liberated from each zoosporangium through an operculum.
9- In unfavorable conditions pseudo-parenchymatous cells is formed at certain places on the thallus when the temperature is lowered below the optimum and the resting spores originate from these cells. On germination the resting sporangium may behave as sporangium or as prosorus bearing the sporangium as an outgrowth. That finally, gives rise to zoospores.

Family: Synchytriaceae

e.g.: ***Synchytrium endobioticum***

*********__General Features__ *********

1- Members are microscopic, unicellular, holocarpic and lack a true mycelium.

2- Unicellular thallus divides in to many compartments at the time of reproduction. These compartments function as sporangia or gametangia.

3- The sporangia are inoperculate.

4- Many sporangia or gametangia remain enveloped in a membrane to form a structure called sorus.

5- Asexual reproduction takes place by uniflagellated zoospores and sexual reproduction takes place with the help of uniflagellated gametes.

Occurrence:

S. endobioticum is the casual agent of the most serious disease of potato, called black wart disease or wart disease. It occurs in almost all potato growing regions of the world. It occurs as an obligate parasite in the epidermal cells of many angiospermic plants like potato, tomato, cucurbits.

Start of infection

S. endobioticum is unicellular, endobiotic, holocarpic fungus found in the epidermal cells of the host.

In the spring season large number of uniflagellated zoospores are released from the infected parts. Such zoospores keep on swimming in the soil water for about 2 hr. They come to rest either on the surface of potato (eye) or the stolon of the plant or even on the young tubers. These zoospores dissolve a very small pore in the epidermal wall and penetrate the host and retracts its flagellum and it takes amoeboid shape. It absorbs the food from the surrounding protoplast and increase in size. Simultaneously its nucleus also increases in size, as well as the entire structure gets surrounded by a golden brown thick wall and now it called prosorus.

The fungus shows following drastic changes in its ultrastructural organization

1- Single centrally located lipid body gets divided into many smaller lipid bodies.
2- Nucleolus gets enlarged and becomes very prominent.
3- Nucleus also becomes enlarges and located centrally.
4- Mitochondria become peripheral in position.
5- Endoplasmic reticulum becomes quite extensive.
6- Just near the plasma membrane are seen many electron opaque spherical bodies.

Changes in host cell:

1- Host cell bearing the fungus becomes greatly enlarged.
2- Surrounding epidermal and cortical cells of host also divided irregularly.
3- The formation of tumor like or wart-like bodies.
4- The infected host cell dies ultimately.

Prosorus germination and zoosporangium development:

After maturation the zoospore inside the host cell changes into a thick-walled structure, called prosorus. However, some mycologists preferred to name it as zoosporangium. Prosorus starts germinating within the dead host cell at this time the fungal protoplast ruptures the wall and migrates into the upper half of the host cell and it remains surrounded by a thin hyaline membrane. It nucleus undergoes repeated mitotic divisions to form 32 nuclei. The entire multinucleate prosorus gets divided into 4-9 multinucleate chambers with the help of thin hyaline walls. The nuclei keep on dividing repeatedly to form as many as 200-300 nuclei. Each of such multinucleate chamber represents a sporangium. The group of sporangia called a sorus.

Ultrastructure of zoospore:

1- It is uniflagellate, spherical to elongate in shape and attain a diameter of approximately 3µm.
2- Ribosomes are evenly distributed.
3- An anteriorly located, large, lipid globule is present.
4- Mitochondria surrounded the nucleus from all sides.
5- Cytoplasmic microtubules remain associated with the functional kinetosome.
6- Most of the cell organelles are partially encapsulated by an extensive system of endoplasmic reticulum.
7- A contractile vacuole like structure is also present.

Gametangium:

Multinucleate chambers of prosorus function as gametangia if conditions of drought are persisting. Instead of zoospores, motile uninucleate cells of gametangium behave as planogametes these gametes are slightly smaller than zoospores. Two planogametes coming from different gametangia copulate in the water film present either on the host surface or in the soil. The copulation is isogamous. Two gametes belonging to two gametangia of the same sorus may fuse. Plasmogamy and karyogamy takes place and biflagellate zygote is formed.

Zygote and resting sporangium:

Zygote keeps on swimming on the host surface or in the soil water for some time. Finally it settels on host surface and penetrates an epidermal cell like zoospore penetration. It migrates to the bottom of infected epidermal cell of the host. As a result host epidermal cells become hypertrophied and divide repeatedly (hyperplasia). In this position zygote enlarges in size, gets enclosed by a thick ornamented bilayered wall and called resting sporangium also its preferred to call it resting spore as it remains in the resting stage throughout the winter season.

Germination of resting sporangium:

The resting sporangia are released and keep on moving in the soil water for 2 months. Many granules develop in the cytoplasm of the released sporangium these granules are the primordial of the future zoospores. The diploid nucleus of resting sporangium divides repeatedly but its first division is a reduction division. Many haploid nuclei are formed which metamorphoses to uninucleate and uniflagellate haploid zoospore.

The haploid zoospores are liberated by the rupturing of sporangial wall and again infect the host.

Order: Blastocladiales.

**********General features**********

1- Mostly saprobic in soil and water
2- Thallus varies among taxa from thin-walled and thick-walled (resting) sporangia
3- Resting sporangia are thick-walled and often pitted
4- Characterized by a distinctive zoospore
5- All members of this order have zoospores with a distinct nuclear cap surrounds the nucleus
6- This ribosome-filled cap is easily observed with an oil immersion lens

Light micrograph of resting sporangia in *Allomyces macrogynus*

This order shows advancement over chytridiales in the following respects:

1- **Development of true hyphae in some genera**. The hyphae of the genus *Coelomomyces* lack cell wall which is a feature of great mycological importance not found elsewhere in true fungi.
2- **Differentiation of male and female gametes and gametangia**. Male gamete is smaller than female in size. Gametangia are also distinguishable into male and female.
3- **Presence of alternation of generations in life cycle of some genera**.

Family: Blastocladiaceae.

Genus: ***Allomyces***

General features:

1- First reported in India (1911) by Butler
2- Species exist in soil and water as saprobes
3- Can be isolated by using semsame and hemp seeds as baits
4- The genus exhibits filamentous, polycentric development
5- Thallus consists of well developed, branched rhizoids
6- Species of this genus exhibit a distinctive alternation of generation, in which haploid gametothalli alternate with diploid sporothalli and the two types of thalli are indistinguishable until they begin to form reproductive organs
7- When they reach the certain stage of maturity, the gametothalli produce colorless female gametangia and orange male gametangia in ratio 1:1. The orange color is in the cytoplasm due to γ- carotene synthesized by the fungus.
8- The male gametangium is smaller than the female and may be borne on the latter or below them.

**********Life cycle**********

Both types of gametangia release motile gametes (planogametes) in the water. The gametes are posteriorly uniflagellated and of the same general structure as zoospores. The orange male gametes about half the size of the female gametes.

The gametangia are cut off the tips of the somatic hyphae by the successive formation of two septa. The septum nearer to the tip develops first, delimiting the male gametangium, followed by the formation of second septum that delimits the female gametangium immediately below the male. Eventually, the flagella develop and the gametes are cleaved and exit papillae have been formed on the gametangia and the gametes discharged into water.

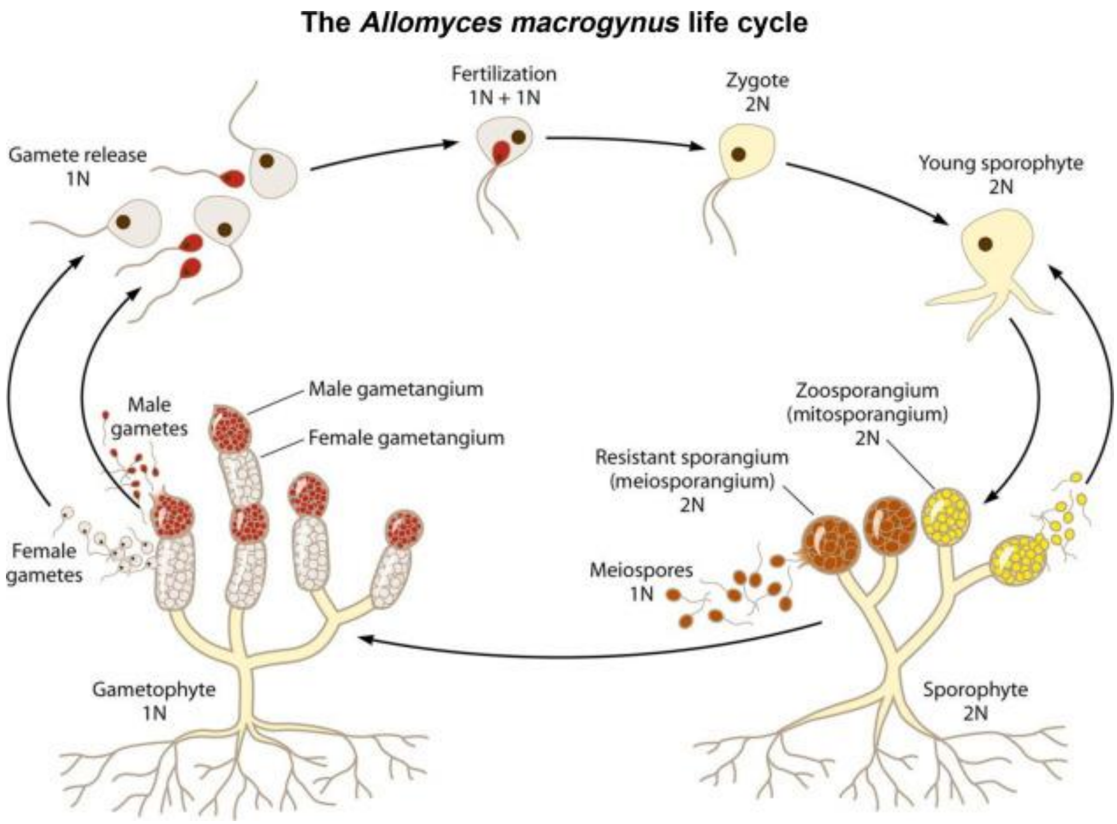
The female gametangia and gametes of *Allomyces* produce a pheromone called Sirenin to which male gametes are attracted. Male gametes also produce a female attracting pheromone called Parisin.

After release from the gametangia, the gametes fuse in pairs. Their cell membranes fuse very quickly to form binucleate fusion cell. Nuclear fusion and karyogamy is accomplished.

The formed zygote is initially biflagellate and eventually loses the flagella encysts and germinate to form sporothallus. At maturity, the sporothalli form two types of sporangia: Thin-walled, elongate, colorless zoosporangia (**mitosporangia**) and oval, thick-walled resistant sporangia (**meiosporangia**) that contain melanin pigments.

The thin-walled zoosporangia germinate after their formation, releasing diploid zoospores (mitospores) swim, encyst, and give rise to sporothalli, thus repeating the diploid generation.

The resistant sporangia require a rest period of 2-8 weeks or more before germination. Meiosis takes place at the germination to form haploid zoospores (meiospores) that gives gametothalli which produce gametangia.



Family: Coelomomycetaceae.

e.g.: *Coelomomyces psorophorae*

General features:

1- The family consists of a single genus *Coelomomyces* which is an obligate parasite inhabiting the coelome (body cavity) of mosquito larvae so it has been emphasized the great potential of *Coelomomyces* in the biological control of mosquitoes.

2- There are 80 species of this genus.
3- The thallus consists of non septate irregularly branched or lobed hyphae which lacks a cell wall and it resembles the strands of myxomycete plasmodium
4- Fragmentation of the thallus results in the spread of the fungus and more thalli are formed.
5- The lobed hyphal branches transform into thick-walled resting sporangia which break off and become free. The outer wall is coloured, pitted or striate while the inner wall is thin and hyaline.
6- Thin- that seek out another mosquito host, completing the life cycle.   wall zoosporangia are not formed the resting sporangia germinate and release of zoospores through discharge papilla
7- Zoospores produced in the coelomome of mosquito larvae fail to reinfect the mosquitoses.
8- The life cycle of *C. psorophorae* (which infects Culistea, mosquitoes) requires two hosts to complete the life cycle.
9- The alternate host in this life cycle is *Cyclops vernalis*

******Life cycle*******

The genus *Coelomomyces* is composed of over 70 species another source comprises 80 species of obligately parasitic fungi that have a complex life cycle involving an alternation of sexual (gametophytic) and asexual (sporophytic) generations (Couch & Bland, 1985; Whisler, 1985). In all species studied to date, the sexual phase parasitizes a micro crustacean host, typically a copepod (*Cyclopus*), whereas the asexual generation develops, with rare exception, in mosquito larvae. In the life cycle, a biflagellate zygospore invades the hemocoel (coelomome) of a mosquito larva where it produces a sporophyte that colonizes the body and forms resistant sporangia. The larva dies and subsequently the sporangia undergo meiosis, producing uniflagellate meiospores that invade the hemocoel of a copepod host, where a gametophyte develops. At maturation, the gametophyte cleaves, forming thousands of uniflagellate gametes. Cleavage results in death of the copepod and in escape of the gametes, which fuse and form biflagellate zygospores that seek out another mosquito host, completing the life cycle. The life cycles of these fungi are highly adapted to those of their hosts. Moreover, as obligate parasites these fungi are very fastidious in their nutritional requirements, and as a result no species of *Coelomomyces* has been cultured *in vitro.*

Biological control: the discovery of heteroecisrn in *Coelomomyces* implicated for its use in biological control of mosquitoes.

Family: Blastocladiaceae.

e.g.: ***Blastocladiella emersonii***

General features:

1- The thallus is simple, consisting of a spherical sac-like structure attached to the substratum by rhizoids.
2- The thallus resembles a monocentric chytrid.
3- The spherical body either itself converted into reproductive body or bears one at its apex.
4- Species of *Blastocladiella* occur mostly in soil and saprobes growing in soil on vegetables and animal debris. A parasitic species growing on blue green algae *Anabean* has been reported.
5- The zoospores give rise to 4 kinds of thalli that depend upon environmental conditions and the thalli distinguishable by sporangia, which may be 1) ordinary colourless, thin-walled (OC) 2) Orange thin-walled (O) 3) Resistant sporangial (RS) which are brown, thick-walled, pitted 4) late colourless, thin-walled (LC).

******Life Cycle*********

The life cycle begins and ends with the posteriorly uniflagellate zoospore. After a variable period of swimming the zoospore settle down, retract the flagellum and develop a cyst by secreting a wall. The cyst sends out germ tube which forms the non-septate rhizoids. A daughter nucleus passes into the rhizoids. The cyst enlarges enormously, later a cross wall delimiting the cyst into 1) a basal cell bearing the rhizoids. 2)

An apical multinucleate fertile cell which developed into zoosporangium that gives rise to hundreds of zoospores.

Under unfavorable conditions (like crowding or high carbonate or cation concentration) the fertile cell instead of forming a thin-walled colourless zoosporangium develops into thick-walled, globular, dark brown, pitted resting sporangium. At the return of favourable conditions the resting sporangium germinates and gives rise to hundreds of posteriorly uniflagellate zoospores that repeat the life cycle.

Sexual reproduction:

Sexual reproduction is not known in this fungus. Occasional cytoplasmic exchanges through cytoplasmic bridges have been noticed between colourless and orange zoospores and the two swarms soon septate.

Family: Blastocladiaceae.

Sub-genus: *Brachy-Allomyces*

General features:

1- This sub-genus has only one species *Allomyces anomalus***.**

2- This species characterized by lack of alternation of generations

3- The gametophyte is absent.

4- The sporophyte is similar to those of the other genera.

5- The diploid sporophyte bears both thin-walled zoosporangia and thick-walled brown resting sporangia.

6- Meiosis does not occur in the resting sporangia.

7- The zoospores on germination give rise to diploid a sexual plants.

Order: Monoblepharidales

General features:

1- Include the highest evolved members of chytridiomycetes which characterized by a well-developed mycelial thallus and oogamous type of sexual reproduction involving motile antherozoids.

2- Resting sporangia are not formed

3- Zoospores posses refractile granules in the anterior region but lack the nuclear cap and the side body.

4- This order include three genera; Monoblepharis, Gonapodya and Monoblepharella.

5- Monoblepharis and Gonapodya are aquatic saprobes while Monoblepharella is found growing on organic debris in soil.

6- The three genera are placed in two families (Gonapodyaceae and Monoblepharidaceae) on the basis of motile or non-motile nature of the zygote.

7- The family Gonapodyaceae includes two genera Gonapodya and Monoblepharella and the zygotes of these genera are propelled out of the oogonium by the flagellum of the antherozoid and undergo a period of motility before encystment and transformation into the oospore

8- The family Monoblepharidaceae include one genus Monoblepharis , the zygote either remains inside or moves out of the oogonium by amoeboid movement and transformed into oospore at the tip of oogonium.

Family: Gonapodyaceae.

Zygote has a period of motility before encysting, propelled the flagellum of antherozoid, mycelium non-septate or pseudoseptate, oogonium with one or more oospheres.

Genus: Monoblepharella.

There are two species of this genus which occur in tropical soils as saprobes growing on organic debris. They can be isolated from soil by using hemp as baits.

**********life cycle*********

Asexual reproduction:

The thallus consists of branched hyphae and attached to the substratum by rhizoids. The hyphae are non-septate and highly vacuolated giving a foamy appearance to the cytoplasm.

The tips of the hyphae develop into zoosporangia or gametangia depending on the favourable or unfavourable conditions, respectively.

The zoosporangia, which are narrow and ovate borne on sympodially branched hyphae, the posteriorly uniflagellate zoospores are released through an apical pore.

After the end of swimming period they settle down and germinate to give rise the thallus.

Sexual reproduction:

It takes place in the unfavourable conditions. Gametangia (antheridia and oogonia) are formed on sympodially branched hyphae. The antheridia are cylindrical while the oogonia are globular or obovate. Antherozoid, which smaller than zoospores liberated through apical pore. They swim and reach to the adjacent oogonium usually contains a single oosphere (non-motile, naked, female gamete). A receptive spot develops at the apex of the oogonium which dissolves to form a pore. The antherozoid enters the oogonium and fuses with the oosphere. The flagellum of the antherozoid remains functional and propels the zygote out of the oogonium and the karyogamy does not occur immediately. The zygote lose the flagellum and secret a thick wall and transformed into oospore and karyogamy occur at the time of wall formation. When the favourable conditions return it germinates and gives rise to thallus after meiosis division.

Family: Monoblepharidaceae.

Zygote (usually one) remaining in oogonium or merely oozing to gametangial orifice where it encysts and remains attached mycelium never pseudoseptate.

Genus: Monoblepharis.

General features:

1- It grows on still water and attached to the substratum by means of rhizoids

2- Low temperature ($3^{o}C$) favours the development of Monoblepharis.

3- The thallus is hypha-like resembling Allomyces but there are no pseudosepta and the cytoplasm is highly vacuolated and has foamy appearance.

*******Life cycle*****

Asexual reproduction:

Zoosporangia are formed at the tips of hyphal branches. Zoospores are released from the zoosporangium through an apical pore and after swimming encyst and germinate to give rise to the thallus. After the sporangium is emptied another sporangium may be formed on a branch at the base of old sporangium.

Sexual reproduction:

In the unfavourable conditions, zoosporangia are not formed but gametangia are formed. Antheridium is initiated from a terminal cell cut off by a septum and the second segment, oogonial is formed below the antheridial cell. Antheridia are narrow and elongated while the oogonia are globular and much bigger. At maturity antheridia appears as inserted in the oogonia, which appear in chains. Posteriorly uniflagellate antherozoids (4-8 in number) which smaller than zoospores are released from the antheridium through apical pore. The protoplast of oogonium form a single, uninucleate, naked, non-motile female gamete called the egg or oosphere. At maturity an apical papilla is formed on the oogonium which dissolves to form a pore. Antherozoid enters the oogonium and retracts the flagellum and fuse with the oosphere to form zygote. Zygote encystment may occur inside the oogonium (endogenous), where it lies as an oosphere. In *M. polymorpha* oospore formation is exogenous; the zygote oozos out and encyst at the oogonial orifice. Karyogamy occur during encystment. The oospore may be smooth or thick-walled with warts and undergo resting period. At the return of cooler temperature it germinates and gives rise to haploid thallus after meiosis division during germination.

Class: Hypochytridiomycetes (Anteriorly uniflagellate fungi)

General features:

1- Anteriorly uniflagellate zoospores and gametes.
2- The flagellum of tinsel type
3- Presence of cellulose along within chitin in the cell wall of some species.
4- The fungi show great resemblance to chytridiomycetes in thallus organization and life cycle pattern.
5- Most of these fungi once included under chytridiales.
6- This class is very small compared to chytridiomycetes and includes only 6 genera.
7- They are found as endoparasites of fresh water and marine algae, aquatic fungi or saprobes growing on a variety of organic remains of plant and animal origin.
8- The thallus is holocarpic or eucarpic, monocentric or polycentric.
9- In holocarpic species the thallus, which may is always endobiotic, transforms into zoosporangium.
10- The eucarpic species may be epibiotic and monocentric having a single reproductive organ anchored to the substratum by rhizoids. Or polycentric and endobiotic having many reproductive organs connected by branched hyphae with occasional septa.

11- Zoosporangia are inoperculate and the zoospores are released through discharge tubes.

12- Sexual reproduction is generally unknown in this group.

13- Resting sporangia have been found in a few genera.

14- There is one order Hypochytridiales with 3 families in this class.

The families:

1- Anisolpidiaceae

Thallus holocarpic and endobiotic (*Anisolpidium canteriomyces*)

2- Rhizidomycetaceae

Thallus eucarpic, monocentric and epibiotic (Rhizidomyces, Rhizidomycopsis)

3- Hypochytriaceae

Thallus eucarpic, polycentric, intrarnatrical (Hypochytrium).

Family: Rhizidomycetaceae.

Genus: Rhizidomyces.

General features:

1- Rhizidomyces is the biggest genus of this family and has 5 species.

2- *R. apophysatus* is a parasite growing on the oogonia and oosphere of water molds like *Saprolegnia* and on the algae like *Vaucheria*. It is also reported growing saprophytically in soil.

********Life cycle*******

Asexual reproduction:

Uniflagellate zoospores swim for some times and settle down the host or substratum lose the flagellum and encyst then germinate by forming germ tube which penetrates the host and gives rise to branched rhizoids. The germ tube which lies at the top of rhizoids swells and form the apophysis and the rhizoids seem to be originate from the swelling and hence the name apophysis (apo=from and physis=growth). The cyst develops into zoosporangium. A discharge tube emerges from the sporangium the protoplast which by divisions give multinucleate flows out through the discharge tube and lie in a vesicle. The protoplast then cleaved into uninucleate segements which form the zoospores that released by dissolution of the vesicle they swim and repeat the life cycle.

Sexual reproduction: is un-known.

Family: **Hypochytriaceae**

Genus: **Hypochytrium**

General features:

1- *Hypochytrium* is the sole genus of this family.
2- The species of this genus occur as parasites of algae and fungi or as saprophytes on plant debris ex. *H.*

hydrodicytii grows on green algae hydrodicyton and *H. catenoides* is saprophytic on vegetables debris.

******* **Life cycle of *H. catenoides*** *********

Asexual reproduction:

H. catenoides grows inside the substratum e.g. decaying maize, forming branched tubular thallus, which enlarges here to form sporangia. The zoospores are partly formed inside the sporangium. A discharge tube emerges whose tip develops a pore. The uninucleate cytoplasmic segements (incipient zoospores) move out to lie the orifice where they develop the flagella and mature zoospores.

Sexual reproduction: is not reported.

*********life cycle of *H. hydrodicytii**********

It differs from other species by the formation of resting spores.

The zoospores settle down on the algae and develop a wall and push in a germ tube which grows into swollen spindle-shaped structure called the primary swelling hyphae originated from this and form secondary swelling this swelling developed into sporangia and form zoospores which released through discharge tubes. Spindle shaped resting spores whose origin and function is not known are frequently formed.

Class: Plasmodiophoromycetes.

Resemble both myxomycetes and mastigomycotina and therefore they placed in both Myxomycota and Eumycota.

General features:

1- There are obligate parasites in plants. Some attack crop plants and cause economically important diseases while others attack algae and fungi or economically unimportant plants.
2- The thallus is plasmodium (a naked mass of nucleated cytoplasm with amoeboid movement).
3- The life cycle is completed entirely within the plant host.
4- The plasmodium which may be haploid or diploid, is holocarpic and develops into thin-walled sporangia, (aggregated in sori) or into resting spores (cysts).
5- The plasmodium is designated as zoosporogenous or cytogenous depending on whether it produces zoospores or cysts.
6- The zoospores are anteriorly biflagellate, heterokont (unequal in size) and uninucleate; both flagella are of whiplash type. During movement the flagella take opposite directions.
7- Nuclear divisions called cruciform division or promtosis.
8- The resting spores or cysts, which are formed by all the genera, are surrounded by smooth two-layered

wall made of chitin. The spores can survive in soil, in absence of the host plants, for many years.

e.g.: *Plasmodiophora brassicae*

General features:

1- *P. brassicae* causes the club root disease of crucifers, especially the mustard.
2- The roots become hypertrophied and club-shaped.
3- The disease occurs in areas where the soil is poorly drained and has acidic pH.

General features of *Saprolegnia:*

1- Species of *saprolegnia* are common in soil and well-aerated, fresh water ponds.
2- Most of these species colonize dead plant and animal remains, a few like *S. ferax* and *S. parasitica* parasitize fishes and cause their death and death occurs within 24 hours.
3- These fungi are primary sugar fungi they fail to decompose and utilize polysaccharides like cellulose**.**
4- Oospore with ooplast, thallus extensive and mycelial hyphae non-septate, normally eucarpic morophologically-distinct gametangia formed, zoospores showed dimorphism.

Taxonomic criteria:

The following morophological features may be profitably used for the separation and identification of taxa:

1- Shape of zoosporangia
2- Variations in the discharge and behavior of the spores
3- Oospore type
4- Oogonial wall ornamentations and pitting
5- Shape and position of the oogonium

General features of *Pythium*:

1- Having 92 species and this largest genus of the family.
2- Majority of species are soil-inhabitants which mainly cause root-rot (particularly of Graminae) and damping off disease of seedlings. A few are mycorrhizal, while some others are aquatic.
3- The characters used in speciation are: 1- the morphology and dimensions of sporangium. 2- Sporangial proliferation. 3- oogonial dimensions and morphology of spines. 4- The point of origin of antheridium in relation to oogonium and their number. 5- plerotic or aplerotic nature of oospore 6- the maximum temperature for growth.

General features of *Albugo*:

1- The genus has 25 species, all obligate parasites of higher plants causing white blisters (areas of raised host epidermis) on the foliage.

2- In addition to blisters, the fungus causes hypertrophy of different floral parts and forms tumors of varying sizes on all parts; stems, leaves, veins, petioles etc.

A. candida causes white blisters on members of cruciferae like Brassica, cabbage, Raphanus etc.

Class: Oomycetes

General features:

1- laterally-biflagellate, reniform zoospores.

2- Presence of cellulose in the cell wall.

3- The thick-walled oospore formed as a result of sexual reproduction.

4- The two flagella, which are laterally attached (occasionally anterior), are dissimiliar in structure and size. One is tinsel and other of whiplash type.

5- When movement the tinsel flagellum takes forward or anterior direction while the whiplash flagellum lies in the backward or posterior position.

6- The oogamous type of sexual reproduction usually involves a club-shaped antheridium and more or less globose oogonium, containing one or more non-motile female gametes called oosphere or egg. However, in some primitive members of oomycetes (order Lagenidiales), the gametangia are not differentiated into male and female. The holocarpic thalli of different sizes act as gametangia and fuse to form zygote.

Note: In these fungi, since the vegetative thallus is diploid, meiosis occurs before the gametes are formed, so that oospheres and the antheridial nuclei that fuse with them are only haploid structures in the life cycle of these organisms.

6- The oomycetes range from unicellular, holocarpic, endobiotic parasites of aquatic algae and fungi to forms having well-developed mycelium.

Pythium

Class: Oomycetes

Order: Peronosporales

Family: Pythiaceae

e.g. : *Pythium*

Occurrence: It is the largest genus of this family, it represented by 92 species. Many species occur only in aquatic situations as saprophytes, whereas some may be weak parasites on aquatic plants and animals. A majority of species are soil inhibitants and a few occur in mycorrhizal association. *Pythium* species are rarely host specific.

Some serious diseases of seedlings, such as damping-off, pre-emergence killing, foot-rot and root-rot are caused by species of *pythium*.

Life cycle of *P. debaryanum*

Somatic structure:

The mycelium is well-developed and consists of fine, well-branched, hyaline, intercellular or intracellular hyphae giving the appearance of a white fluffy mass. The lateral branch contains a slight constriction at its base. The hyphae do not produce haustoria. The wall consists of cellulose impregnated with chitin and the cytoplasmic contents are granular and contain oil droplets and glycogen. The older parts of the mycelium contain vacuolated cytoplasm. The young hyphae are coenocytic but cross-walls develop in the mature hyphae.

Asexual reproduction:

The asexual stage is constituted by sporangia that may be intercalary or terminal, and are of variable shapes (globose, filaments or with inflated lobes). A sporangium contain hyaline papilla. At the time of sporangial development, the terminal or intercalary portion of the hyphae become enlarges, becomes spherical and starts to function as sporangial initial in later on gets cut off by a cross-well, thus enclosing several nuclei.

In *P. debaryanum* a short tube develop from the sporangium. A bubble-like vesicle is formed at the tip of this tube. At this stage the sporangial protoplast cleavage takes place. It flows rapidly to the vesicle through the tube and zoospores differentiated in the vesicle within 15-20 minutes. Zoospores keep on moving in the vesicle very rapidly for few minutes. The wall of the vesicle bursts suddenly like soap bubbles and the zoospores are liberated in all directions. The zoospores are reniform or kidney shaped and biflagellate having their both flagella attached to the lateral side. After some times the zoospores become deflagellate, get encysted and each of them germinates by germ tube into a new somatic hypha. This young hypha infects fresh seedling.

Note: In some species of Pythium there is no zoospores formation and such cases sporangia germinate directly by forming germ tube and such sporangia have been called conidia or conidiosporangia and this formed in high temperature and dry conditions.

Evolution of conidium

Pythium contain both sporangia-producing and conidia – producing species *P. monospermum* contain elongate or filamentous sporangia producing only zoospores but in *P. debaryanum* and *P. proliferum* the sporangia produce zoospores in damp or humid conditions, whereas they behave as conidia in dry conditions specially when the temperature is above optimum. In *P. intermedium* the sporangia function as zoosporangia and conidia in normal conditions and in *P.vexans* the sporangia generally behave as conidia and very rarely as zoosporangia. On the contrary, *P. ultimum* var. *ultimum* the sporangia is always function as conidia and do not produce zoospores at all.

Sexual reproduction:

It is oogamous type occur when moisture is not sufficient for growth. The two sex organs are called antheridia and oogonia, and generally develop in close proximity on the same hypha. A majority of the species are homothallic. The antheridia develop generally below the oogonia. However, some species are certain heterothallic.

In *P.debaryanum* oogonia may be terminal or intercalary . it is spherical or globose and smooth walled and separted from the parent hypha by cross septum. At first the swollen portion of the young oogonium remains filled with hyaline contents containing ribosomes, endoplasmic reticulum, dictyosomes, mitochondria, several vacuoles and nuclei. But later its contents get differentiated in to a central multinucleate ooplasm and peripheral multinucleate periplasm. The ooplasm give rise to egg and periplasm do not take part in egg formation. Ooplasm becomes uninucleate due to the disintegration of all nuclei except the one functional female nucleus.

The antheridia develop near the oogonia, generally on the same hypha, they are smaller than oogonia and club-shaped or elongate. One to six antheridia may remain attached to the same oogonium.

Fertilization:

Pythium exhibits an example of gametangial copulation. The antheridia are applied to the wall of the oogonium and become flattened. From each antheridium develops a fine fertilization tube penetrates the oogonial wall and periplasm, reaches up to the egg. Meiosis takes place in antheridium as well as in oogonium in the meantime and all haploid nuceli except one degenerate in both the gametangia. Through the fertilization tube the functional male nucleus passes into the oosphere, reach up to the functional female nucleus, fuses with it, and form a diploid zygotic nucleus. The haploid oosphere thus turns to diploid oospore and after fertilization the antheridium becomes empty.

Germination of oospore:

In *P.debaryanum* and many other species the oospores require a resting period of several weeks before germination. At relatively high temperature of about 28°C the oospore germinates by putting out a germ tube, which soon develops into well-developed mycelium. But at lower temperature 10-17°C, a short germ tube is given out at the tip which develops a vesicle and in *P.ultimum* the contents pass into the vesicle through a small tube and get differentiated into many zoospores and in some species develops a germ tube containing sporangium at its tip.

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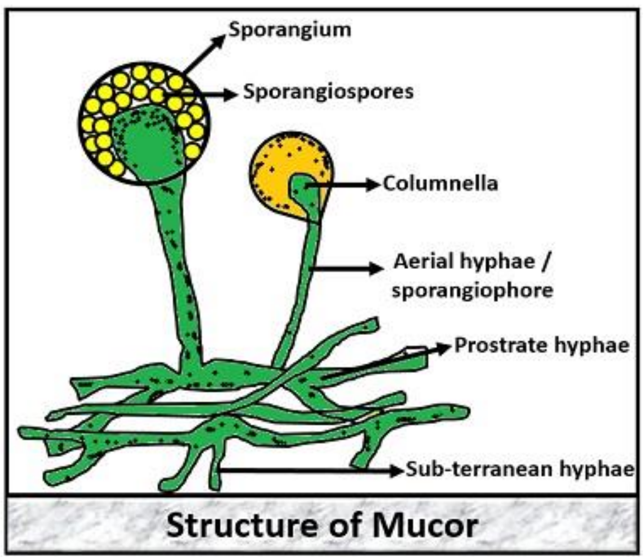
Soil Fungi

For third year



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Contents

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To my parents

1 Introduction

The word *fungus* comes from the Latin word for mushrooms. Indeed, the familiar mushroom is a reproductive structure used by many types of fungi. However, there are also many fungi species that don't produce mushrooms at all. Being eukaryotes, a typical fungal cell contains a true nucleus and many membrane-bound organelles. The kingdom Fungi includes an enormous variety of living organisms collectively referred to as Eumycota, or true Fungi. While scientists have identified about 100,000 species of fungi, this is only a fraction of the 1.5 million species of fungus likely present on Earth. Edible mushrooms, yeasts, black mold, and the producer of the antibiotic penicillin, *Penicillium notatum*, are all members of the kingdom Fungi, which belongs to the domain Eukarya.

The Fungi: Towards a Definition

It is difficult to define the fungi in simple terms because several unusual organisms as well as the typical fungi are often included in this blanket term. Nevertheless, the typical fungi have a range of features (general characteristics) that separate them from other organisms and which can be outlined here:

1- The fungi are typically filamentous. The individual filaments are called **hyphae** (sing. Hypha) and are surrounded by a wall which often, not always, contains **chitin** as a major component. The hyphae grow only at their tips, so fungi exhibit **apical growth**, and they branch periodically behind the tips, the resulting network of hyphae being termed **the mycelium** (Fig. 1).

2- All fungi are **heterotrophs** (chemo-organotrophs): they require performed organic materials which serve as both the energy source and as carbon

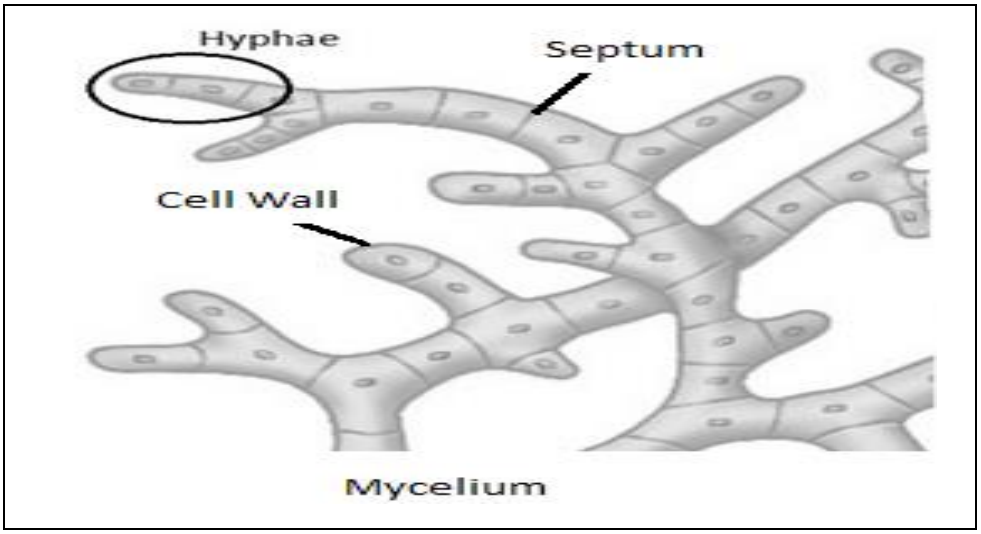


Fig. (1): Hyphae and mycelium

skeletons for cellular synthesis. Because of the rigid cell wall they cannot engulf food, rather they absorb simple soluble nutrients, which may be obtained from complex polymers by releasing extracellular enzymes (**depolymerase**) into the environment.

3- Fungi are **eukaryotic**, they have membrane bound **nuclei**, a range of membrane bound **organelles** and **ribosomes**.
4- Fungi reproduce by both sexual and asexual means, but in either case they usually produce **spores** as the end product. Spores differ greatly in size and shape.

Now we can define the fungi as, *eukaryotic characteristically mycelia, heterotrophs with absorptive nutrition*.

2 Structure and fine structure

General Structure: The hyphae structure

The hypha is essentially a tube, consisting of a rigid wall and containing a moving slug of protoplasm. It is tapered at the tip, the tapered region being termed the extension zone, this represents the region of most active wall growth. The higher fungi have cross walls or septa at intervals, but these are absent in lower fungi except where they occur as complete cross walls to isolate old or reproductive parts from the hyphae (Fig. 2).

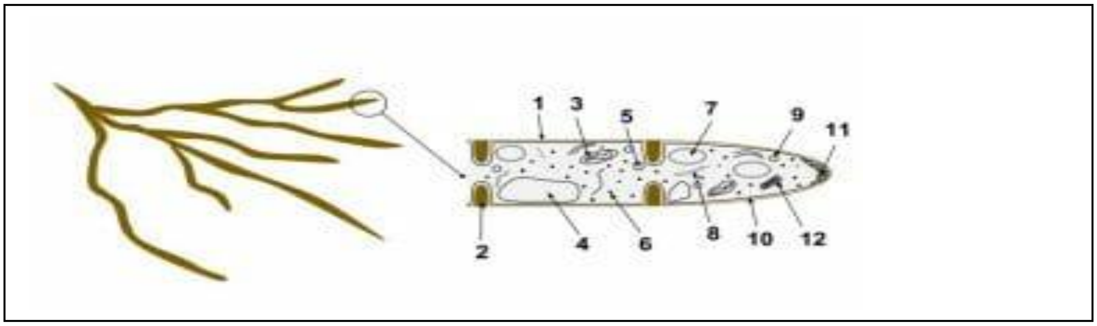


Fig. (2) 1- Hyphal wall 2- Septum 3- Mitochondrion 4- Vacuole 5- Ergosterol crystal 6- Ribosome 7- Nucleus 8- Endoplasmic reticulum 9- Lipid body 10- Plasma membrane 11- Spitzenkörper/growth tip and vesicles 12- Golgi apparatus.

Hyphae Function

Hyphae are associated with multiple different functions, depending on the specific requirements of each fungal species. The following are a list of the most commonly known hyphae functions:

1- <u>Nutrient Absorption from a Host</u>

Some hyphae of parasitic fungi are specialized for nutrient absorption within a specific host. These hyphae have specialized tips called haustoria, which penetrate the cell walls of plants or tissues of other organisms in order to obtain nutrients.

2- <u>Nutrient Absorption from Soil</u>

Some fungal species (e.g., *mycorrihizae*) have developed a symbiotic relationship with vascular plant species. The fungi forms specialized hyphae called arbuscules, which can be found in the roots or phylum of vascular plants, and function to absorb nutrients and water from the soil. In this manner, the hyphae aid the plants by increasing its access to nutrients in the soil while facilitating its own growth.

3- <u>Trapping Structures</u>

In some fungal species, hyphae have evolved into specialized nematode-trapping structures, using nets and ring structures to trap nematode species.

4- <u>Nutrient Transportation</u>

Several fungal species exhibit hyphae composed of chord-like structures, termed mycelial chords, which are used by fungi (e.g., lichens and mushrooms) to transport nutrients across great distances.

Hyphae Classification

In general, hyphae can be classified based on the following traits:

Hyphae Characteristics

Hyphae characteristics are an important method of classifying various fungal species. There are three main hyphae characteristics:

- **Binding**: Binding hyphae have a thick cell wall and are highly branched.
- **Generative**: Generative hyphae have a thin cell wall, a large number of septa, and are typically less differentiated. Generative hyphae may also be contained within other materials (e.g., gelatin or mucilage) and can also develop structures used in reproduction. All fungal species typically contain generative hyphae.
- **Skeletal**: Skeletal hyphae contain a long and thick cell wall with few septa. Skeletal hyphae can also be of a fusiform subtype, with a swollen midsection surrounded by tapered ends.

Hyphae Composition

Fungal species are also further classified based on the hyphal systems they contain. There are four general subtypes:

- **Monomitic**: While virtually all fungal species contain generative hyphae, those with only exhibit this type are referred to as monomitic (e.g., agaric mushrooms).

- **Dimitic**: A species that contains generative hyphae in addition to one other type of hyphae. The most common combination of dimitic fungi is generative and skeletal.
- **Trimitic**: Species which contain all three types of hyphae (generative, binding, and skeletal).
- **Sarcodimitic and sarcotrimitic**: Sarcodimitic hyphae are fusiform skeletal hyphae bound to generative hyphae. Sarcotrimitic species contain fusiform skeletal hyphae, as well as binding and generative hyphae.

General structure: Yeast

In *Saccharomyces cerevisiae* there is a single nucleus, a large central vacuole and the normal range of cytoplasmic organelles (Fig. 3).

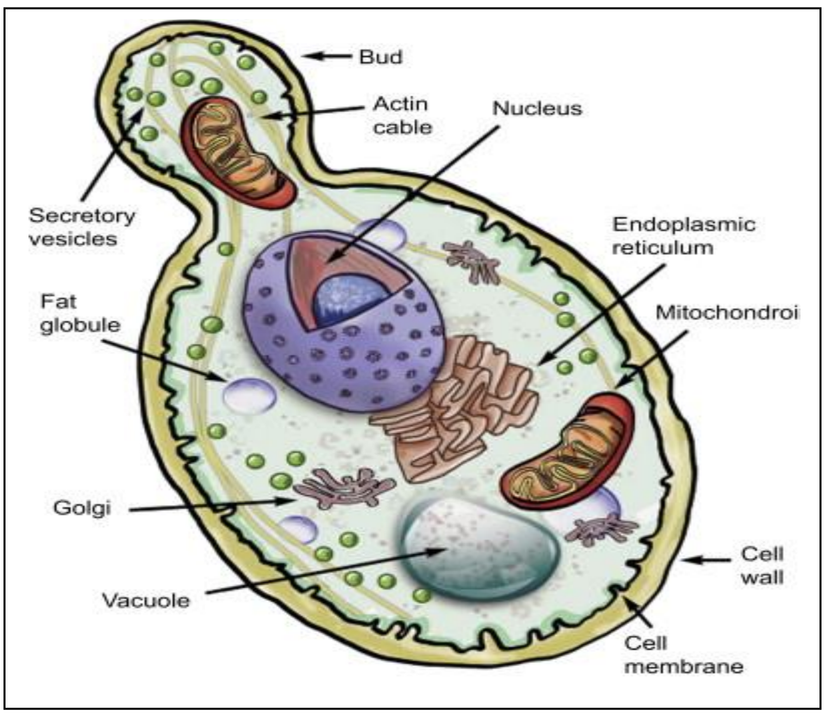


Fig. (3): *Saccharomyces cerevisiae* fine structure.

The cell reproduces by budding, and at maturity the bud separate from parent cell by the formation of the septum. This process leaves a birth scar on the daughter cell and a bud scar on the parent cell.

The bud arises from different point on the parent cell each time so, *S. cerevisiae* is said to exhibit **multipolar** budding. In other yeasts *S.ludwigii* the buds always develop from the same points on the cell, usually at one of the poles termed **bipolar budding**.

Fungal wall

Function of fungal wall:

1- It determines the shape of the cells, because if it is removed by enzymatic treatments the resulting protoplasts are always spherical.
2- Wall acts as interface between the fungus and its environment, it protect the cell from osmotic lysis and perhaps from the metabolites of other organisms.
3- It is a binding site for some enzymes.
4- It can have antigenic properties which mediate the interactions of fungi with other organisms.

Composition:

Gross chemical analysis of fungal walls reveals a predominant of polysaccharides but also significant amounts of protein and lipids. Nevertheless, the wall composition of a fungus should not be fixed because even within a single species the ratio can differ at different stages of the life cycle.

The walls of fungi contain a mixture of

a- Fibrillar components: include chitin and cellulose (Oomycetes). These are straight chain of N-acetylglucosamine and glucose, respectively.

b- Amorphous or matrix: include glucans (polymers or glucose, proteins, polymers of galctosamine and polymers of mannans).

Septa

Septa are found in all filamentous fungi except most members of Oomyctes and Zygomycetes .

Function

1- They acts as structural support of the hyphae.
2- They act as the first line of defense against damage, the septal pores plugged by Woronin bodies as hyphae age or damaged(Fig. 5).
3- Septa have a role in differentiation of fungal groups.

Types

a- Simple septum: found in most of Ascomycotina and Deuteromycotina, in which there is a large central pore 0.05- 0.5 μm diameter.
b- Dolipore septum: in some stages in the life cycles of Basidiomycotina. There is a very narrow central pore bounded by two flanges of amorphous wall material. On either sides of this central pore there are perforated, bracket-shaped membranes, termed parenthosomes, which seem to be a special modifications of endoplasmic reticulum. This type of septa enables cytoplasm to pass from one compartment to another but it usually restricts the passage of nuclei (Fig. 4).

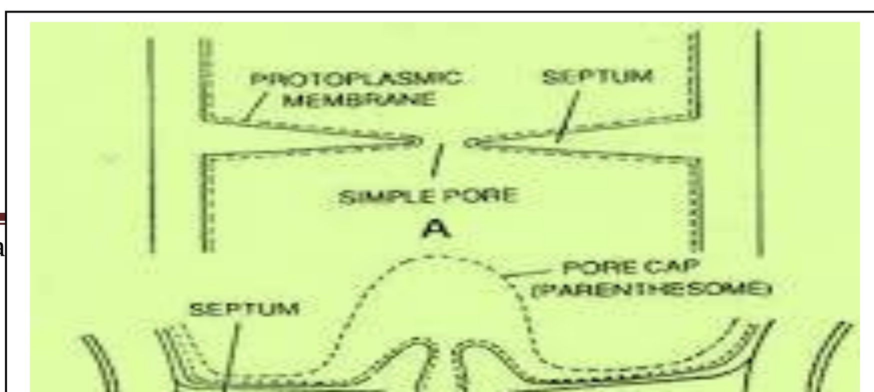


Fig. (4): A, simple pore and B, dolipore

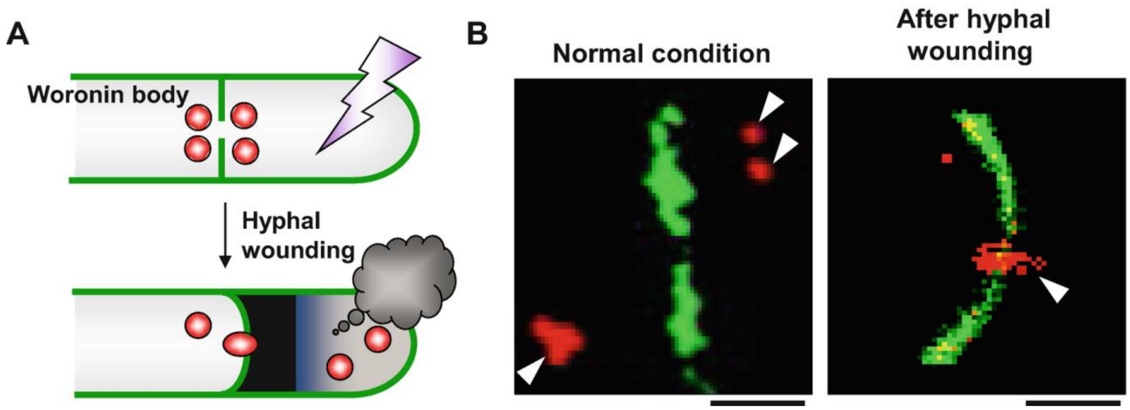


Fig. (5): Function of Woronin body

Membrane and membrane bound organelles

The fungal plasma membrane has a typical tripartite appearance in electron micrographs, (double layer of phospholipids, amounts of protein and sterols).

Permease: govern uptake and release of materials by the cells.

Sterols: help to order the phospholipids and enabling membrane to fuse with another. The main sterol in fungi is ergotsterol.

The endomembrane system

The small membrane-bound vesicles are present in large numbers in the hyphal apex. In higher plants and some algae the vesicles involved in wall growth have been shown to originate from a Golgi body and are thought to move from this to their sites of fusion with the cell membrane, releasing materials into the wall. In most fungi the Golgi body consisting of only a single cistern or a ring-like arrangement of cisternae which are thought to have the same role. The vesicles themselves are thought to be budded off the Golgi cisternae, and their contents are carbohydrate, cellulase, alkaline, phosphatase, glucanase and mannan synthase(i.e enzymes for degradation and synthesis of the wall).

Nuclei

Fungal nuclei are usually small 2-3µm diameter. They are bounded by a double nuclear membrane with conspicuous pores. Most fungi are haploid, although there are some exceptions to these rules. For example *S. cerevisiae* and *Allomyces* can alternate between haploid and diploid generation.

3 Growth

Mechanism of apical growth

We have said that fungal hyphae grow only at their apices. Hyphal apex is surrounded by a wall. Even though it may be thinner and more plastic than the mature hyphal wall. Growth at the apex must involve both a degree of wall lysis and degree of wall synthesis, these processes being so balnced to ensure that the wall becomes neither too weak nor too rigid for further growth.

Spitzenkorper is a body observed in the tips of growing hyphae and disappeared when growth stopped.

The vesicles include some wall precursors, wall synthases and wall lytic enzymes. The functions of the vesicles in apical growth:

1- To transport enzymes that break the bonds between the existing wall components so that the wall stretches as a result of turgor pressure.
2- To transport new wall materials, (precursors) for incorporation into the wall.
3- To increase the surface area of the plasmalemma during growth.

Hypothetical representation of the events in a unit of cell wall growth (Fig. 6):

A- Vesicles containing wall lytic enzymes fuse with plasmalemma.

B- Bonds between existing wall components are broken.

C- Wall stretches as a result of internal pressure vesicles containing wall synthesizing enzymes fuse with plasmalemma.

D- New wall components arise in vesicles or are synthesized from precursors that cross the plasmalemma.

E- A new unit of cell wall has been synthesized.

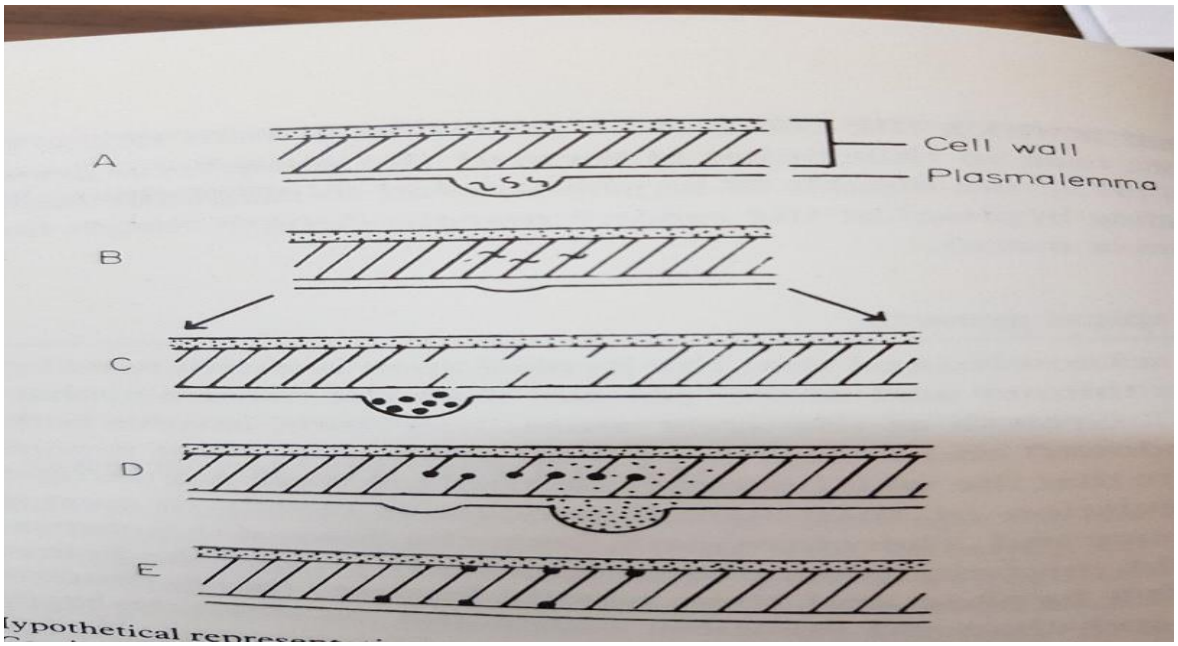


Fig. (6): Hypothetical representation of the events in a unit of cell wall growth.

How does an apex form?

In several fungi such as *Mucor* and *Aspergillus*, spore germination involves an initial phase of swelling as a result of hydration followed by a further phase of swelling that depends on metabolic activity.

Stages in the germination of spores of *Aspergillus niger* (Fig. 7):

a- In normal conditions the spores swells and incorporates a new wall materials uniformly over its surface, later a germ tube emerges and a new wall materials are incorporated at the tip of the germ tube.

b- At 44^{o}C the spore continues to swell and incorporate wall material uniformly, lowering of the temperature to 30^{o}C leads to germ tube outgrowth but the germ tube immediately forms a sporing head.

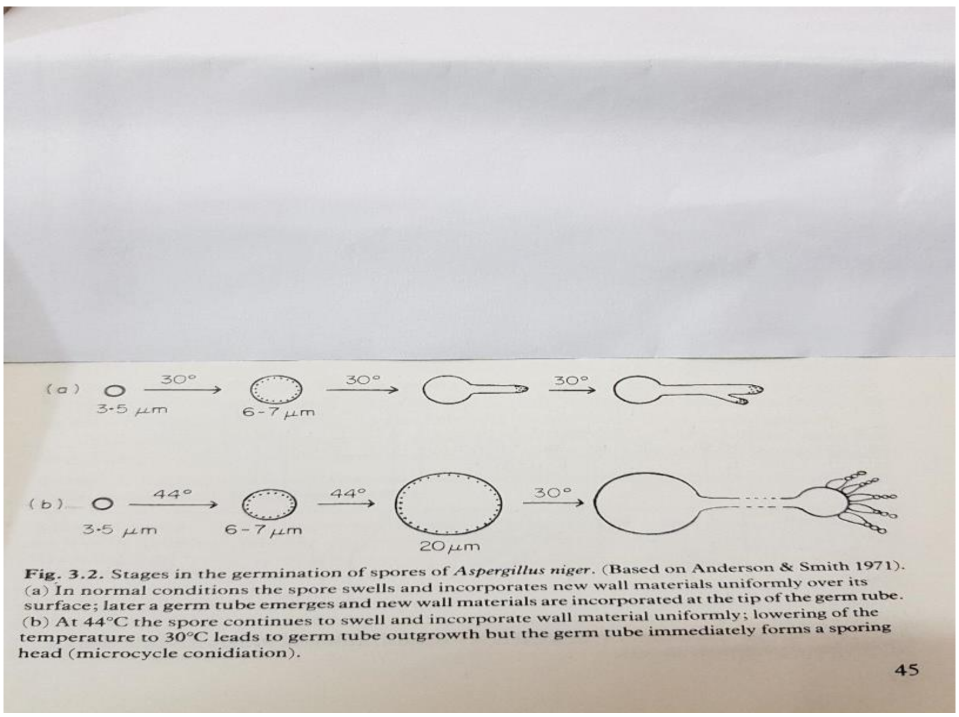


Fig. (7): Stages in the germination of spores of *Aspergillus niger*.

3 Reproductions

I- Asexual Reproduction

Fungi reproduce asexually by fragmentation, budding, or producing spores. Fragments of hyphae can grow new colonies. Mycelial fragmentation occurs when a fungal mycelium separates into pieces with each component growing into a separate mycelium. Somatic cells in yeast form buds, the nucleus divides mitotically, and the bud ultimately detaches itself from the mother cell.

The most common mode of asexual reproduction is through the formation of asexual spores, which are produced by one parent only (through mitosis) and are genetically identical to that parent. Spores allow fungi to expand their distribution and colonize new environments. They may be released from the parent thallus, either outside or within a special reproductive sac called a sporangium

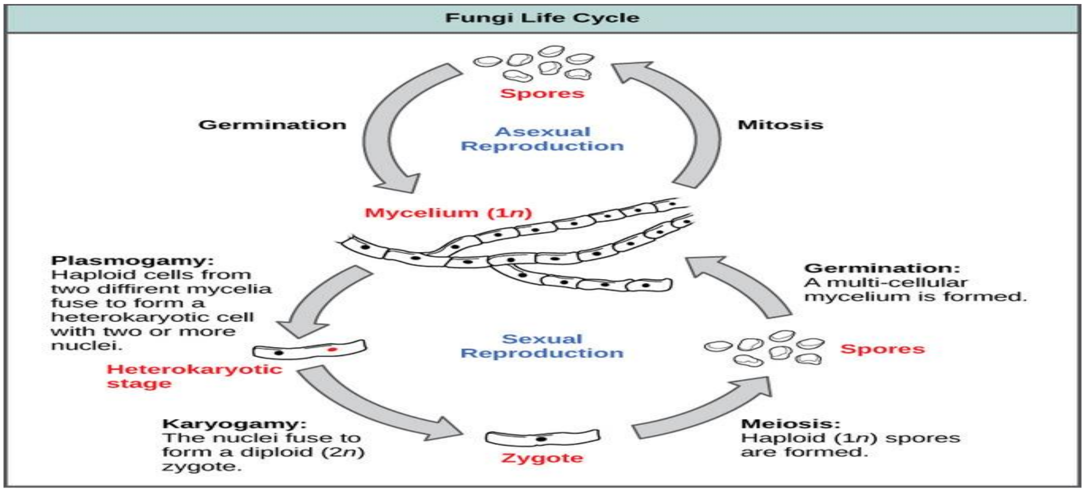


Fig. (8): Fungi Life cycle.

Conidia:

a- Blastic conidia: arise by budding or swelling process and then separated from the supporting structure by a septum.

-Proconidia as this bud enlarges it forms a further bud at its tip and so on until a chain of conidia is formed.

-Phialide another type of plastic conidia formed by a flask shape cell, the phialide. In *Aspergillus* and *Penicillium* after the first conidium has been formed from the phialide all subsequent conidia are extruded from the phialide tip and cut off by a septum. They accumulate one after another in chains (Fig. 9).

b- Thallic conidia: arise by fragmentation or septation of hypha but may be subsequently swell.

In extreme cases of thallic conidia represent little more than hyphal fragments, formed by multible septation of a hypha and separation of the cells by breakdown of the middle region of each septum this type called arthrospore.

The thallic conidia differ from blastic conidia because the former is cut off by a septum at an early stage, before any swelling takes place (Fig. 10).

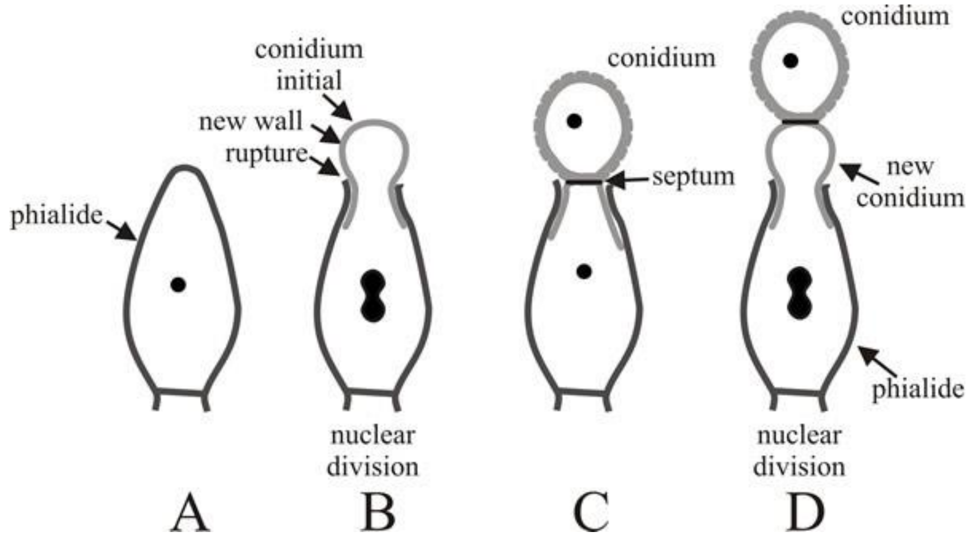


Fig. (9): Phialide

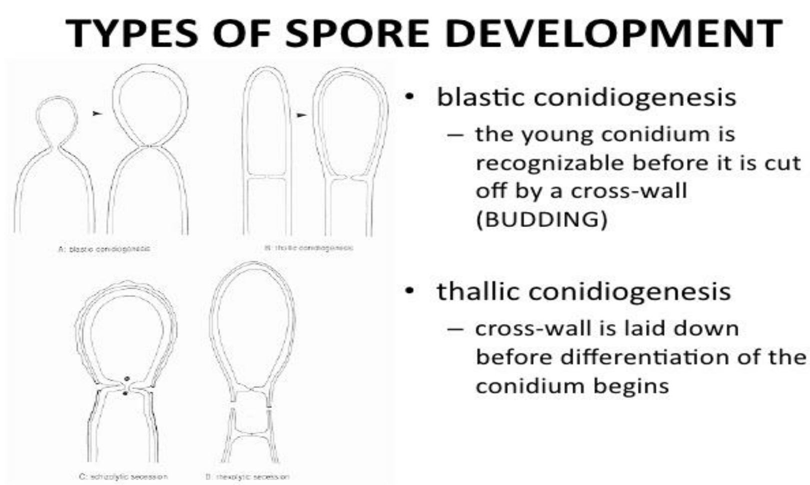


Fig. (10): Types of spores development

Sporangiospores

Sporangiospores develop by cleavage of the cytoplasm around individual nuclei in a multinucleate sporangium (Fig. 11). Cleavage occurs in several ways. In *Saprolegnia* the central vacuole of the sporangium enlarges between the nuclei and its membrane fuses with the plasmalemma, the resulting spores consist of a nucleus, a portion of the cytoplasm and spore membrane derived in part from the vacuole membrane and in part from the sporangium plasmalemma.

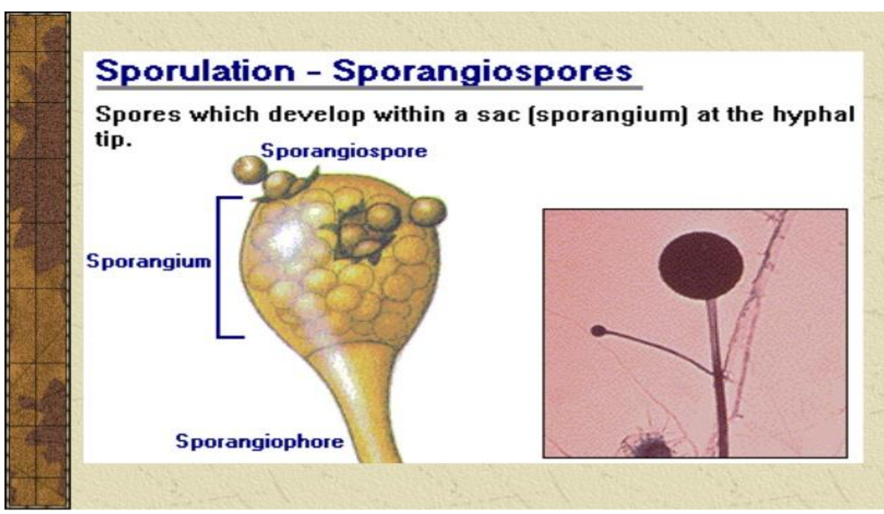


Fig. (11): Development of sporangiospore

II- Sexual Reproduction

Sexual reproduction must be regarded as a whole series of events:

1- Production of sex organs and gametes.

2- Fusion of gametes or sex organs (plasmogamy) followed sooner or later by nuclear fusion (karyogamy).

3- Meiosis in haploid fungi.

4- Development of fruiting bodies to enclose and disperse the spores.

5- Development of sexual spores.

Hormonal systems are known to occur in several fungi (four hormones):

a- Sirenin: is produced by female gametes of *Allomyces* to attract male gametes.

b- Anthreidiol: is produced by female branches of *Achyla* and it initiates the development of antheridia on male hyphal branches.

c- Oogoniol: produced by male branches, which diffuses towards the female hyphae and causes them to develop oognia.

In the Zygomycotina it is common to find different mating types, which are termed + and – because they do not differ in morphology. Species exhibiting this behaviour are termed **hetrothallic** because two different thalli are needed for sexual reproduction, whereas self fertile species are termed **homothallic**.

d- Trisporic acid: the + and – strains of heterothallic species produce different hormone precursors which diffuse in the air towards the opposite mating type and are then converted to active hormone.

Specialized vegetative structure:

Fungi produce a range of structures during penetration of plant surfaces

1- Appressoria: simple swollen cells.
2- Hyphopdia: loped structures.
3- Sclerotia: massive vegetative structures produced by some fungi for dormant survival. They are range from simple of pigmented hyphae as in *Rhizocotina solani* to more complex structures a darkly pigmented ring *(Sclerotinia* spp.)

Fungal growth phases

From the time a spore or a hyphal fragment germinates to form a colony to the time the fungus dies, there are a number of growth phases. Although these phases have been determined under laboratory conditions, it is possible that the same occur in nature. In nature the duration of each phase would be determined by the environmental conditions including other competing micro-organisms.

- **Lag phase**

  Once the growth conditions become favorable for the fungal propagules (i.e., viable spores or mycelial fragments) to germinate, new transport systems must be induced before growth commences. Thus growth starts slowly and accelerates gradually. This phase is referred to as the lag phase.

- **Exponential or log phase**

  Exponential growth occurs only for a brief period as hyphae branches are initiated, and then the new hypha extends at a linear rate into un-colonized regions of substrate. The biomass of the growing fungus doubles per unit time. As long as the nutrients are in excess growth remains constant during the exponential phase.

- **Stationary phase**

  As soon as the nutrients are depleted or toxic metabolites are produced growth slows down or is completely stopped. The biomass increases gradually or remains constant. During the stationary phase, hyphal growth stops and, in some molds, cell differentiation occurs, resulting in spore formation. During this process nutrients are transferred from the vegetative mycelium to the developing spores. The spores are dispersed by air movement to other areas of the building where they can start new mold growth once the conditions for growth are favorable.

- **The death phase**

  During the death phase, the mycelium eventually dies off. The death phase is usually accompanied by breakdown of the mycelia through self-digestion. Some fungi form spores by fragmentation of the hyphae.

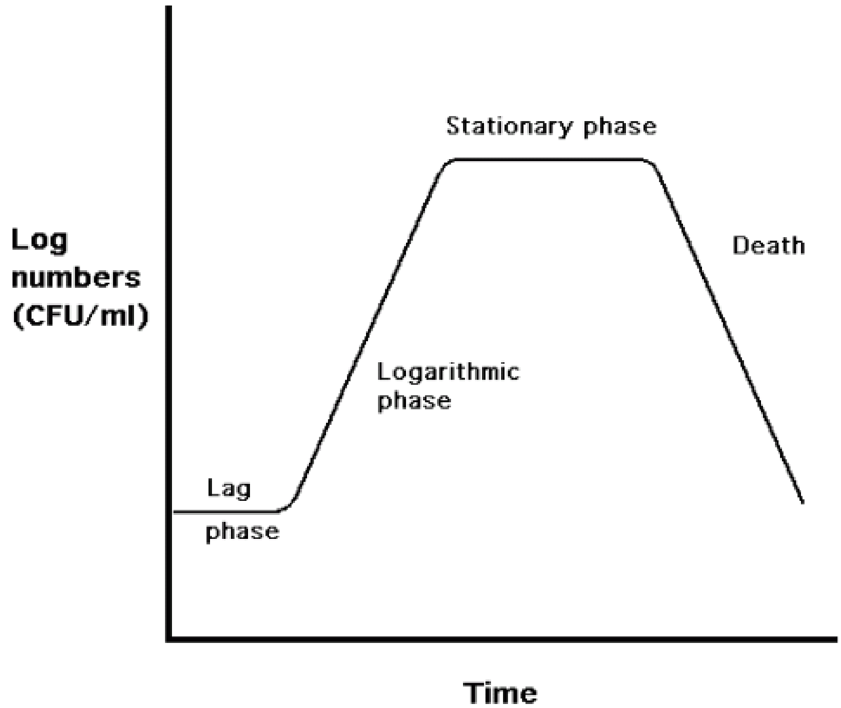


Fig.(12) **Hypothetical bacterial growth curve.**

4 Nutrition

Important classes in which the nutrition of fungi may be classified are as follows:

The fungi are chlorophyll less plants and cannot synthesize their own food unlike green plants from carbon dioxide and water in the presence of sunlight. They are so simple in structure that they cannot obtain inorganic food directly from the soil, and therefore they are always dependent for their food on some dead organic material or living beings.

(a) Saprophytes:

The saprophytic fungi live on dead organic materials produced by the decay of animal and plant tissues. They grow upon dead organic matters such as rotten fruits, rotten vegetables, moist wood, moist leather, jams, jellies, pickles, cheese, rotting leaves, plant debris, manures, horse dung, vinegar, moist bread and many other possible dead organic materials. *Saprolegnia, Mucor, Rhizopus, Penicillium, Morchella, Aspergillus, Agaricus* and many others are good examples of saprophytic fungi.

The saprophytic fungi absorb their food from the substratum by ordinary vegetative hyphae which penetrate the substratum, e.g., *Mucor mucedo*. In other cases of the saprophytic fungi such as *Rhizopus* the rhizoids develop which penetrate the substratum and absorb the food material. In the case of saprophytic fungi the mycelium may be ectophytic or endophytic. In the case of *Rhizopus* the mycelium is ectophytic whereas the rhizoids remain embedded in the substratum and said to be endophytic.

(b) Parasites:

The parasitic fungi absorb their food material from the living tissues of the hosts on which they parasitize. Such parasitic fungi are quite harmful to their hosts and cause many serious diseases. These fungi cause the great losses to the human beings or indirectly. Many diseases of the important crops are caused by parasitic fungi. The rusts, smuts, mildews and many other plant diseases are important examples of fungal diseases of crops. Their mode of life is parasitic and the relation of host and parasite is called the parasitism.

The parasites which survive on living hosts and only on living hosts are called the **obligate parasites**. Such parasites cannot be grown upon dead organic culture media, e.g., *Puccini*, *Peronospora, Melampsora*, etc. The parasitic fungi which usually live on living hosts and according to their need they adopt saprophytic mode of life for some time are called the facultative saprophytes, e.g., *Taphrina deformans* and some smuts.

Some parasitic fungi usually pass saprophytic mode of life, but under certain conditions they parasitize some suitable host and are called the facultative parasites, e.g., *Fusarium, Pythium*, etc.

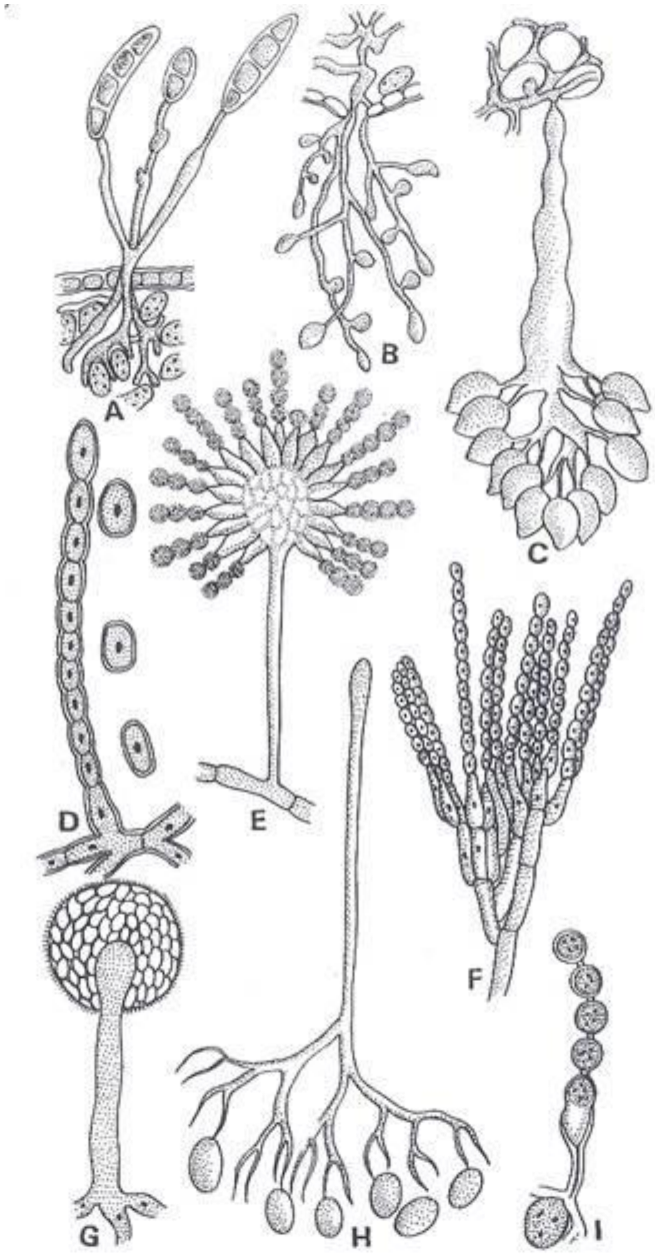


Fig 8.8. *The Fungi.* Various types of sporophores. A, conidiophores and conidia of *Helminthosporium*; B, sporangiophore and sporangia of *Phytophthora*; C, sporophore and sporangia of *Sclerospora*; D, conidiophore and conidia of *Erysiphe*; E, conidiophore and conidia of *Aspergillus*; F, conidiophore and conidia of *Penicillium*; G, sporangiophore and

The parasitic fungi absorb their food from the hosts in different ways. The fungus having the mycelium outside the host is called the **ectoparasite,** e.g., *Erysiphe*, whereas the fungus having the mycelium embedded in the host tissue is called the **endoparasite**. In the former type certain cushion-like appressoria develop on the surface of the host and from each appressorium a peg-like structure develops which penetrates the host epidermal cell giving rise to a branched or unbranched absorbing organ called the haustorium.

The haustoria may also develop from the mycelium of endoparasites. The haustoria vary in their shapes. They may be small, rounded, and button-like as in *Albugo*, branched and convolute as in *Peronospora* and highly branched as in *Erysiphe*.

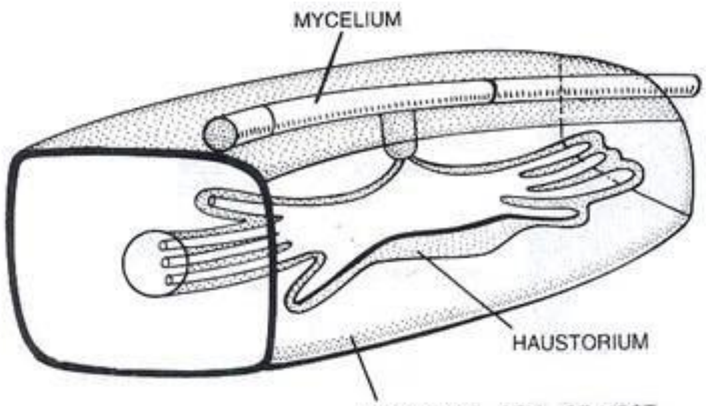


Fig. 8.9. Haustorium. Three-dimensional diagram of an infected epidermal cell with a branched haustorium of *Erysiphe* sp. (powdery mildew).

In the case of rusts and mildews the mycelium remains confined in the pustules and not in the whole body of the plant. This type of fungus is called the **localized** fungus. When the mycelium prevails in the whole of the plant it is said to be **systemic fungus**, e.g., smuts. When the mycelium is confined to the intercellular spaces it is called **intercellular** mycelium and in other cases the mycelium penetrates the host tissue and said to be **intracellular**. Usually the former bears haustoria and the latter does not.

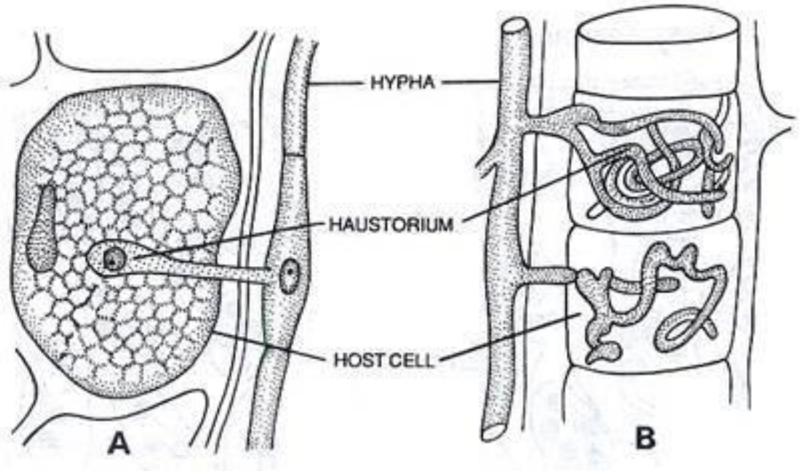


Fig. 8.10. Haustoria. A, elongated capitate haustorium; B, branched or digitate haustorium.

(c) Symbionts:

Some fungi live in close association of other higher plants where they are mutually beneficial to each other. Such relationship is called the ‘symbiosis’ and the participants are the ‘symbionts’. The most striking examples are the lichens and mycorrhiza. The lichens are the resultants of the symbiotic association of algae and fungi.

Here, both live together and are beneficial to each other. The algal partner synthesizes the organic food and the fungal partner is responsible for the absorption of inorganic nutrients and water.

Certain fungi develop in the roots of higher plants and the mycorrhiza are developed. Here the fungi absorb their food from the roots and in response are beneficial to the plants. The mycorrhiza may be external or internal. The **external** mycorrhiza also called the **ectophytic** mycorrhiza are confined to the outer region of the roots whereas the internal mycorrhiza are found deeply in the root cells.

It is to be remembered that in all the cases whether they may be saprophytes, parasites or symbionts, the food is absorbed in the form of solution by cell walls, rhizoids and haustoria.

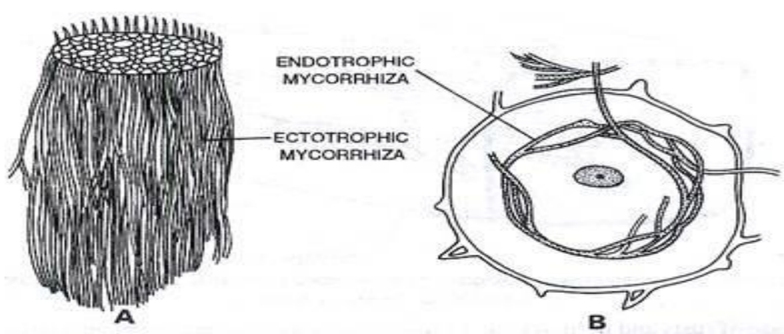


Fig. 8.11. Mycorrhiza. A, ectophytic mycorrhiza, B, endophytic mycorrhiza.

When fungi are cultured in the laboratory on synthetic media, the necessary elements may be supplied in the following way: C is usually supplied in the form of a carbohydrate, such as glucose or maltose sucrose and soluble starch are utilized by many fungi also. N may be supplied in the form of NH_4 salt or as amino acids.

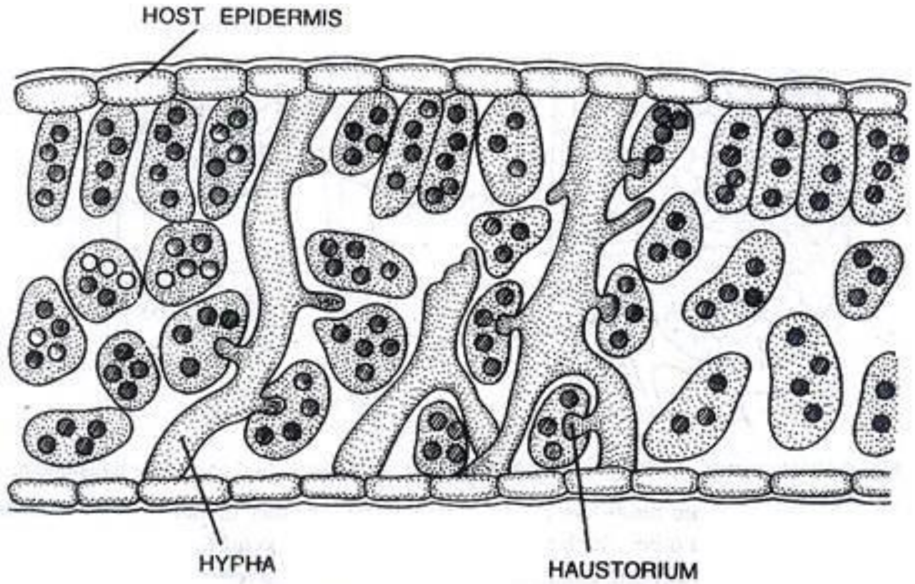


Fig. 8.12. Haustorium. Button-like or globular.

(d) Predacious fungi:

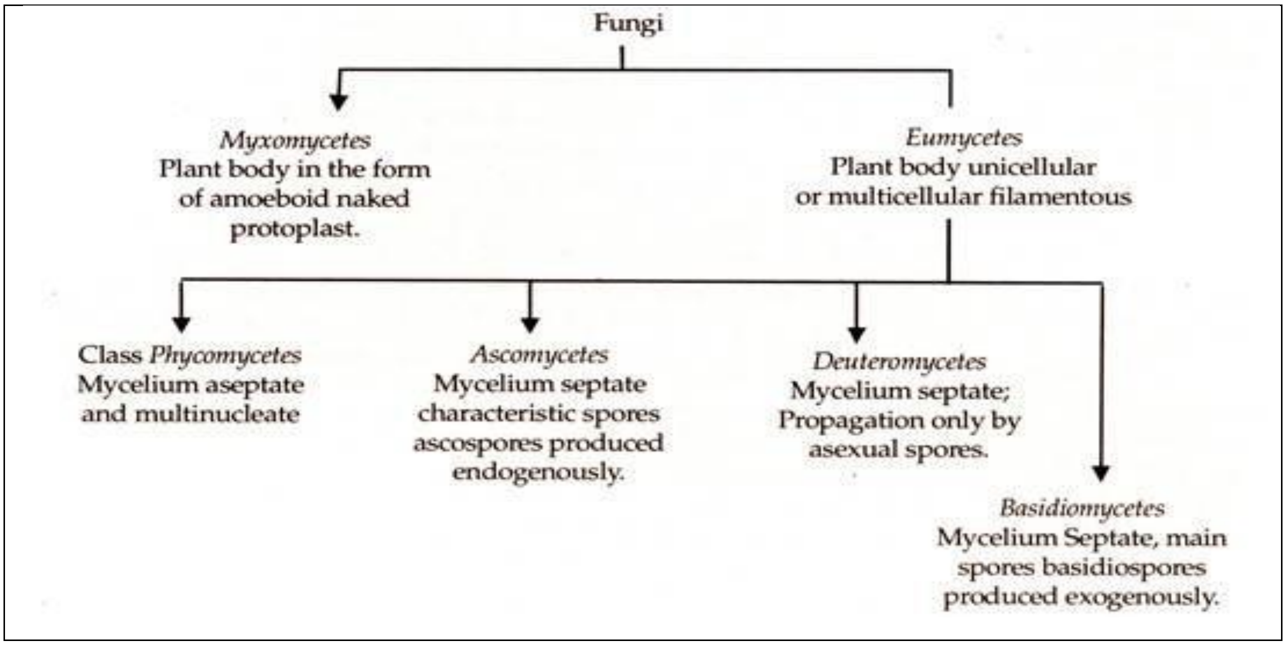
There are many animal trapping fungi which have developed ingenious mechanisms for capturing small animals such as protozoa which they use for food. The most interesting of these mechanisms is that which utilizes a rapidly constricting ring around a nematode which holds it captive while the hyphae sink haustoria into the body of the victim.

Several species of fungi in the genera *Arthrobotrys*, *Dactylella* and *Dactylaria* employ this method. In the presence of an eelworm population, the hyphae of the fungi produce loops which are stimulated to swell rapidly and close the opening when an eelworm passing through the loop rules against its inner surface.

5 Classifications

Alexopoulos (1956) places all fungi in the division Mycota. The division Mycota is divided into two subdivisions (1) Myxomycotina (2) Eumycotina (true fungi). Myxomycotina has only one class – Myxomycetes.

Eumycotina has the four classes as shown in the figure.



Subdivision (1) Myxomycotina

Class – Myxomycetes

Occurrence: Myxomycetes are found in cool places, decaying wood and humus rich soil.

Structure: The vegetative stage in Myxomycetes has no cell wall, naked and irregular mass of protoplasm called plasmodium. The plasmodium is amoeboid in shape and multinucleate and moves with the helpof pseudopodia.

Classification: the class Myxomycetes divided into three orders, namely *Plasmodiophorales*, *Stemonitales* and *Acrasiales*.

C: *Myxomycetes*

O: *Plasmodiophorales*

F: *Plasmodiophoraceae*

Ex. *Plasmodiophora brassicae*

Distribution: the fungus causes disease to cruciferous plants mainly to cabbage (club rootdisease).

Occurrence: the fungus is an obligate parasite.

Disease symptoms: irregular growth or hypertrophy in the root.

Structure of the pathogen: naked massof protoplasm called plasmodium.

Asexual reproduction:

1- The nuclei in the plasmodium are diploid.They undergo reduction division when the plasmodium are in the cells of root of host plant.

2- Spherical nonmotile spores have a chitinous wall are formed. The death and decay of the root cells of the host sets the spore free.

3- The spores metamorphose themselves into biflagellate zoospores infect the healthy plants forming myxmoeba, which repeatedly divided forming haploid plasmodium.

Sexual reproduction:

4- Each nucleus of the haploid plasmodium gets isolated surround itself by a little cytoplasm and form gametangium.

5- The nucleus of each divides mitotically to form 8-10 biflagellate isogametes.

6- Two isogametes fuse and form a diploid zygote

7- The diploid zygote divides mitotically and develops into diploid pladmodium.

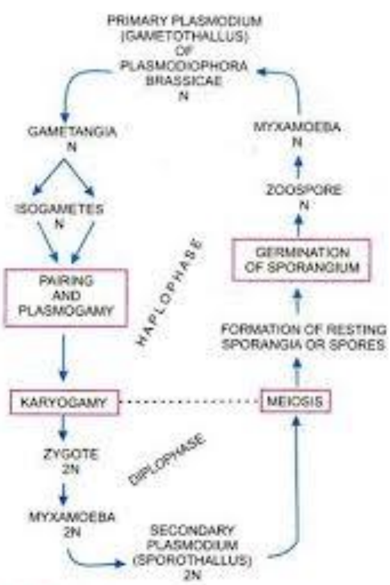
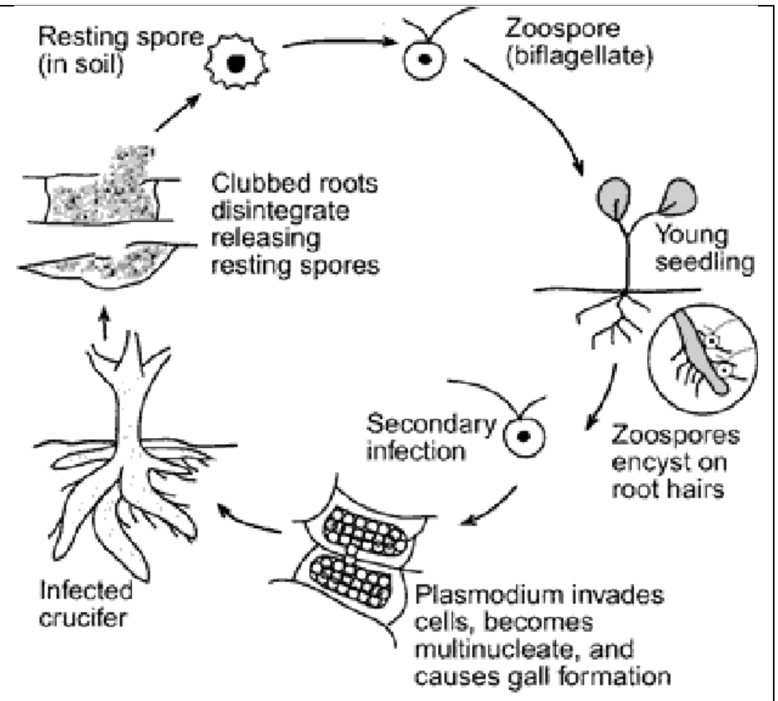


Fig. 5.7. *Plasmodiophora* sp. Graphic representation of the life cycle.



Subdivision (2): Eumycetes

Class 1: Phycomycetes

Occurrence: they are very common in occurrence. The bread mold (*Mucor*), the water mold (*Saprolegnia*), the white rust of mustard all are phycomycetes.

Structure: they are coenocytes, aseptate much branched mycelium (septa appearing to the dead portions or at the time of formation of reproductive structures. Many primitive phycomycetes are aquatic in their distribution even higher forms (except zygomycetes) show dependence on moisture. They may be parasite or saprophyte.

Reproduction:

Asexual reproduction is brought about by

1- Fragmentation 2- Spore formation

Phycomycetes produce both zoospores and conidia. *Saprolegnia* , *Phytophthora*, *Pythium* and others produce zoospores. *Albugo* produces conidia. In Mucorales, asexual reproduction is by aplanospores. Chlamydospores also found in some members.

Sexual reproduction

1-Planogametic copulation. 2- Gametangial copulation. 3- Gametangial contact.

Stages in sexual reproduction

a- Plasmogamy b- Karyogamy c- Meiosis

Classification

The filamentous phycomycetes are divided according their mode of reproduction into 2 orders namely

(1) Oomycetes: reproduction is oogamous.

(2) Zygomycetes: reproduction is isogamous.

The nonfilamentous phycomycetes having rounded lobed mycelia thallus are placed in (3) Archymycetes.

Alexopoulos (1956) divides phycomycetes into 7 orders. Chytridiales, Monoblepharidales, Plasmodiophorales, Saporolegpiales, Peronosporales, Mucorales and Entomophthorales.

The following examples are discussed here;

1- Saprolegniales ex. *Saprolegina*.
2- Mucorales ex. *Mucor*.

C: Phycomycetes

O: Saprolegniales

F: Saprolegniaceae

Ex.: *Saprolegnia* sp.

Occurrence: *Saprolegnia* sp. is commonly called water mold, because of their frequent occurrence in water. Often they grow on dead insects, fishes etc. Most of them are saprophytic the only exception is *S. parasitica* which infects fishes causes salmon disease.

Mycelium: is coenocytic and branched forming white mold. Hyphae are aseptate and septa are formed only when it enters the reproductive phase. Cytoplasm contains several nuclei. Food is stored in the form of globules or glycogen.

Asexual Reproduction: takes place by the formation of pear shaped biflagellate zoospores produced in club shaped zoosporangia. These are usually produced at the terminal regions of somatic hyphae.

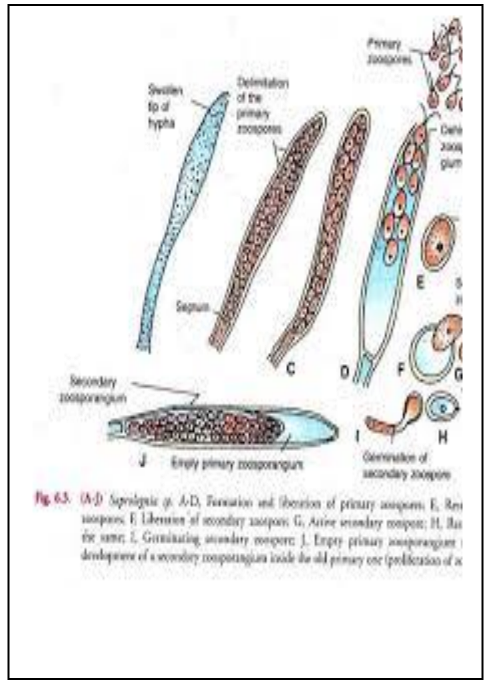
Development of zoosporangium:

1- The apical portions of certain of the hyphae enlarge into swelling.
2- This show dense cytoplasm contents into this migrate many nuclei.
3- Later this is cut off by transverse septum at the base.
4- The young zoosporangium shows multinucleate protoplasm.

Formation of zoospores:

1- The content of the zoosporangium divide into several uninucleate portions by cleavage of the protoplast.

2- Each uninucleate daughter protoplast becomes rounded off and assumes pear shape.
3- Later two flagella develop apically (whiplash type and tinsel type).
4- At maturity the tip of the zoosporangium breaks open and zoospores emerge one after another.

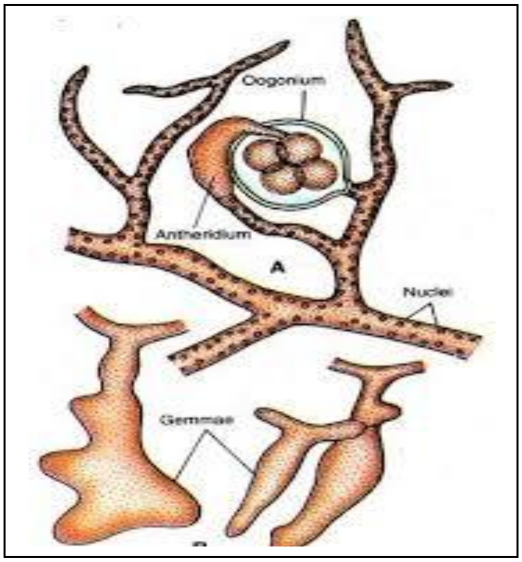


The zoospores are called **primary zoospores**. They swim for some time later they withdraw their flagella become round and enter the resting period. Then the contents of each develop into single kidney shape **secondary zoospore**. These zoospores escape through small pore formed in the cyst. They germinate on a suitable substratum by the formation of germ tube. This tube finally forms the mycelium.

Saprolegnia exhibits two very important phenomena namely:

1- **Diplanestism** : *Saprolegnia* is diplanetic because it produces two types of zoospores, primary and secondary, separated by resting period.
2- **Sporangial proliferation**: after the production and liberation of primary zoospores from the zoosporangium, it becomes empty. Later the basal septum of the emptied zoosporangium enlarges and grows into new secondary zoosporangium inside the old one (produces primary zoospore). This process may be continue.

Sexual reproduction



Sexual reproduction is of typical oogamous type male sex organ is called antheridium and female sex organ is called oogonium. Species of *Saprolegnia* may be homothallic or heterothallic. Sex organs are formed at the tips of the somatic hyphae.

Fertilization:

1- The antheridium becomes closely applied to the oogonium.
2- At the point of contact a fertilization tube is formed.
3- Each branch of fertilization tybe approaches oospheres witin oogonium.
4- On coming into contact with an ooshpere fertilization tube discharge one male nucleus into it.
5- The male nucleus fuses with female nucleus. The fertilized egg secretes a thick wall around it and is now known as oospore.
6- During favorable conditions oospores start germination by a germ tube, it may grow directly into mycelium or into zoosporangium (meiosis occur during germination of zygote).

C: *Phycomycetes*

O: *Mucorales*

F: *Mucoraceae*

Ex. *Mucor*

Occurrence and habitat: *Mucor* lives in a habitat like organic soil, a dead decaying matter of fruits, vegetables and plants, it is essentially saprophyte.

Structure of *Mucor*

Morphological features

Mycelium

The mycelium of *Mucor* is highly branched forms a fine network of hyphae. A mycelium is simply a cluster of hyphae.

Hyphae

These are the thread like and very fine structures that form a "Mycelial network". Hyphae of Mucor is filamentous, aseptate or coenocytic. In *Mucor*, the hyphae categorize into three types:

1. Sub-terranean hyphae
2. Prostrate hyphae
3. Aerial hyphae

Sub-terranean hyphae are the type which is highly branched, more penetrating and is present horizontally to the substratum.

Prostrate hyphae are the type which is also present horizontally between or under the substratum. These two hyphae i.e. sub-terranean and prostrate hyphae help in absorption of water and nutrition.

Aerial hyphae are the type, which originates vertically out from the prostrate hyphae.

Sporangiophore

It is elongated, slightly narrow in shape.

Columella

Sporangiophore swells up to form a dome-like structure called "Columella" which can vary in both shape and size.

Sporangium

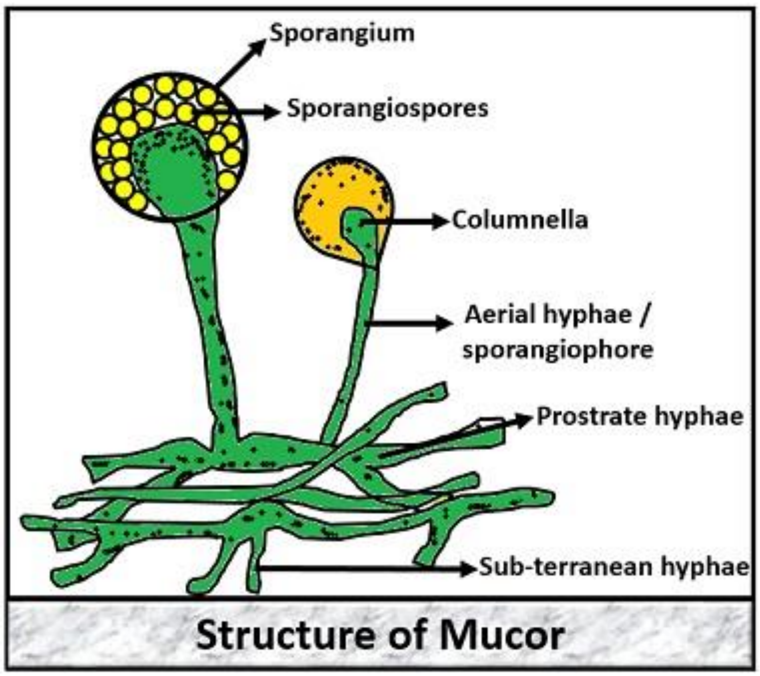
It is the round and thick outer covering which carries numerous spores inside it. It can be globose to spherical.

Spores

These are the reproductive structures forms within the sporangium which are simple, flattened and variable in shape and size.

Nucleus

Multinucleate nuclei present in *Mucor*.



Macroscopic features

- The colony of *Mucor* shows rapid growth.
- The colour of the colony is usually white to grey and turns to brown when the culture becomes old.

Microscopic features

- Hypha: Coenocytic and branched

- Spores: Generally black in colour but can vary with different species. The spores can be motile or non-motile and can exist in variable shapes.

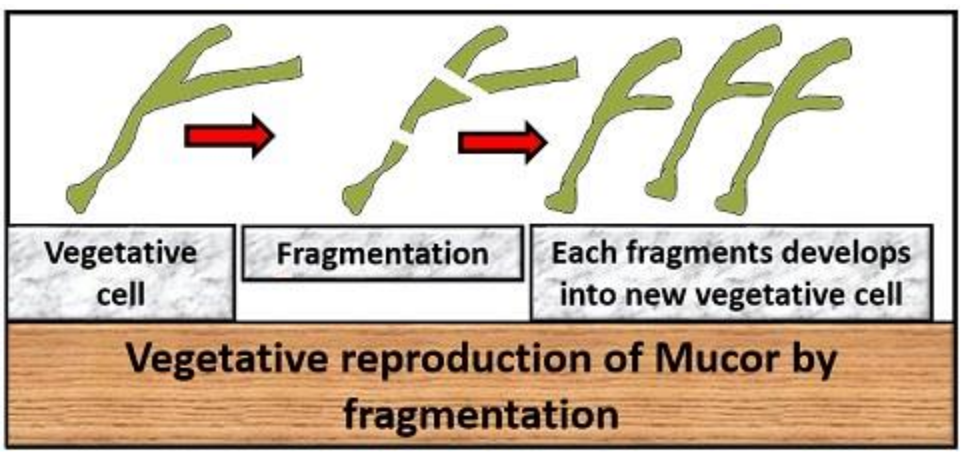
Life cycle of *Mucor*

There are three types of reproduction methods in its life cycle:

1. Vegetative reproduction
2. Asexual reproduction
3. Sexual reproduction

Vegetative Reproduction

It occurs by the fragmentation method, where a vegetative cell breaks into several fragments during some unfavorable conditions. After which, each fragment then develops into a new vegetative body.



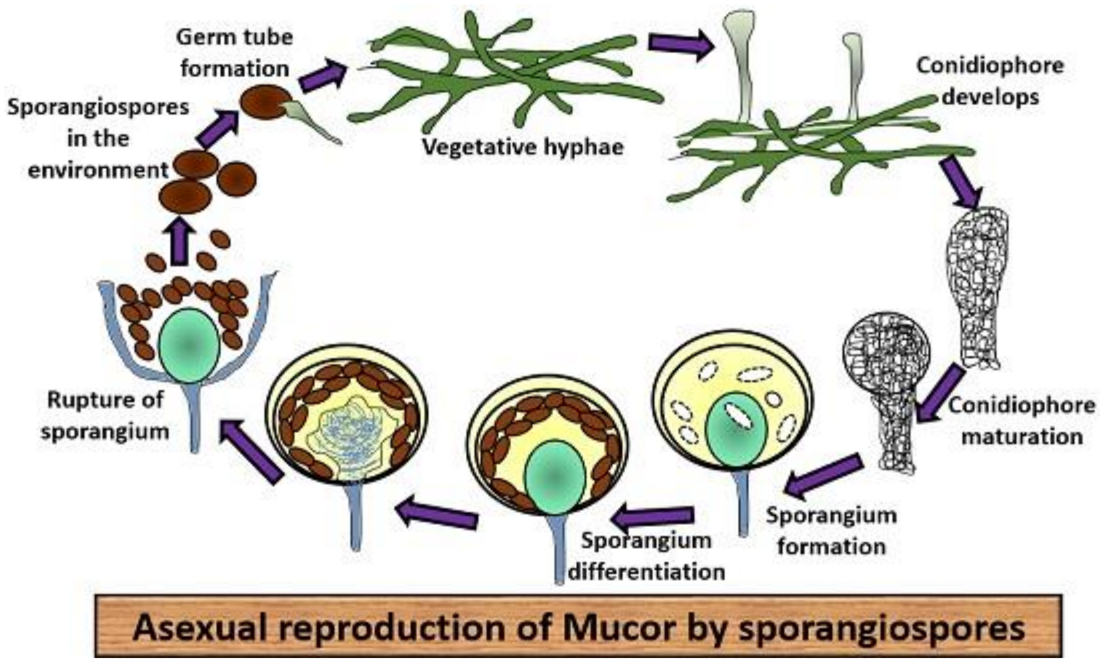
Asexual Reproduction

It occurs through the asexual and non-motile spores like:

- Sporangiospores
- chlamydospores
- Oidiospores

Sporangiospores

These are the spores form within the cell or sporangium and are non-motile. There are following steps involved in asexual reproduction of *Mucor* through sporangiophores:

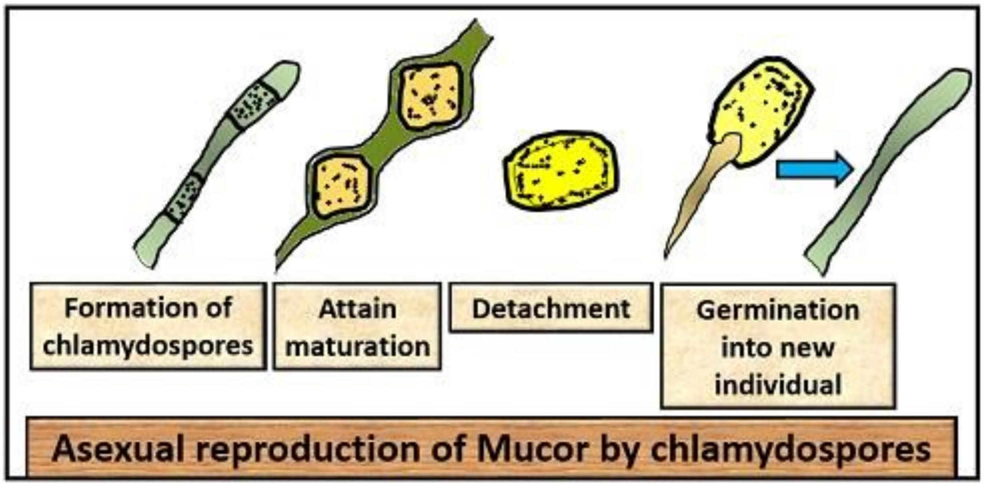


- From the hyphae, first **sporangiophores** arise singly and are erect in position and unbranched.
- Then, maturation of sporangiophore occurs where the cytoplasm and nuclei push upwards by making the aerial hyphae swollen from the apical end.
- After that, it develops a large round **sporangium**.
- During this, maturation phase, sporangium differentiates into:

  - **Sporoplasm**: It is thick, dense, multinucleate and present inside the sporangial wall.
  - **Columellaplasm**: It is vacuolated and nucleated towards the centre.
- After this, a number of small vacuoles appear between these differentiated portions. The space between the vacuoles forms cleavage furrows (cavity for cleavage).
- Then, to the inner side of cavity septum forms that further divides the **inner columella** and **upper sporoplasm**. This septum then grows to form a dome shape and push itself into the sporangium.
- Cleavage occurs in the sporoplasm between the nucleus and the cytoplasm. This division forms a wall around many thin-walled, multinucleate spores called "**Sporangiospores**".
- The sporangiospores then releases out of the sporangia when columnella swells up which creates pressure on the sporangial wall cause **cell lysis**.
- The spores remain dormant for some time and when they obtain suitable substratum they germinate to a new vegetative body through germ tube.

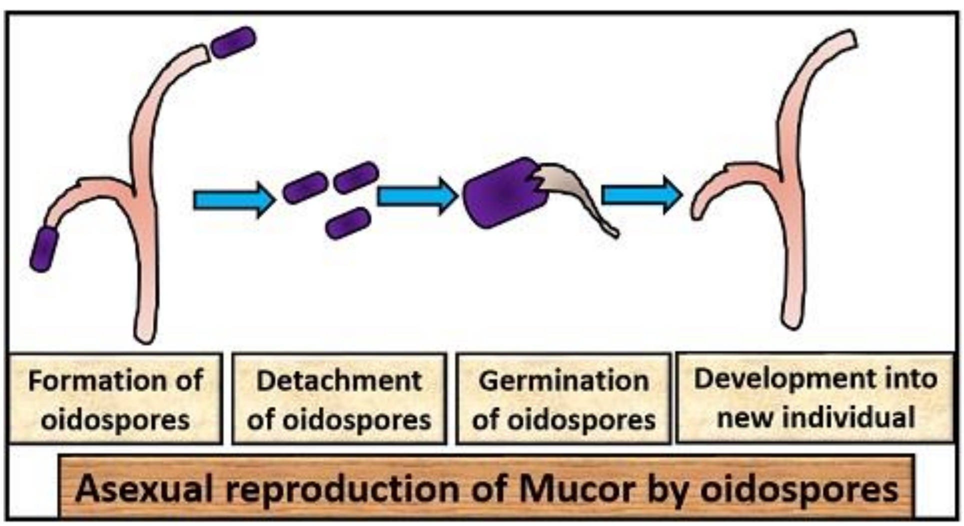
Chlamydospores

These spores are covered by a hard wall, which forms inside the vegetative cell during unfavourable conditions. In unfavourable conditions, mycelium becomes septate by the accumulation of nuclei and cytoplasm in a certain portion surrounded by a thick wall forms Chlamydospores. This spore then detaches from the mycelium and remains dormant. On favourable conditions, they form a germ tube.



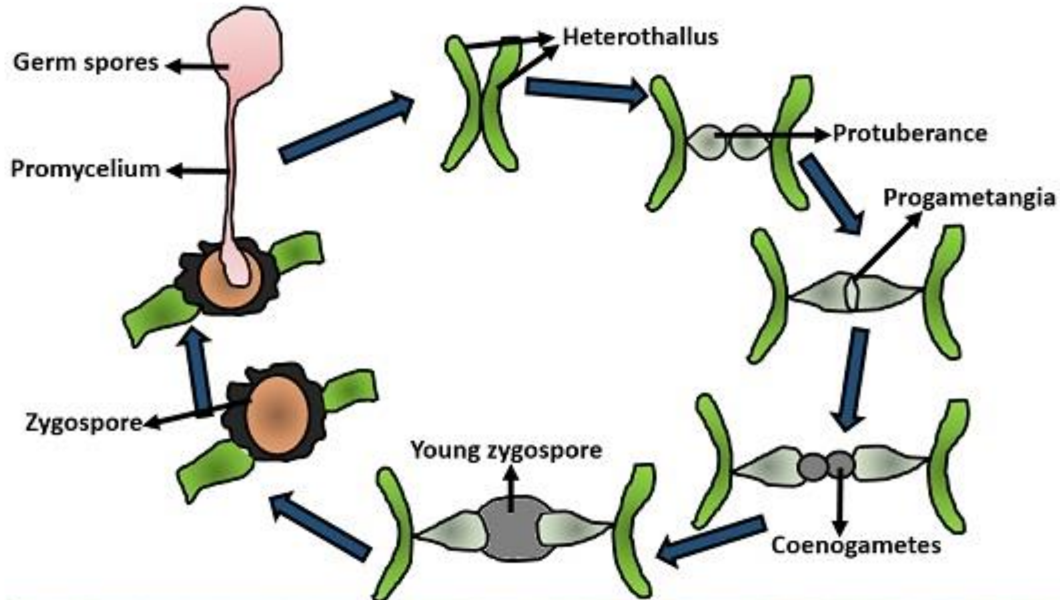
Oidiospores

When a mycelium grows in a substrate (rich in sugar), some small, thin-walled and pearl-like reproductive structure forms. It detaches out of the vegetative cell-like budding in yeast. Then oidospores remain dormant for some time and on favorable conditions it forms a germination tube to form a new vegetative body.



<u>Sexual Reproduction</u>

In *Mucor*, the sexual reproduction occurs by the method refer to "*Gametangial conjugation*" which involves the following steps:



Sexual reproduction of Mucor by Gametangial conjugation

- First, the thallus of two opposite strains i.e. one is (+) and other is (-), comes in contact with each other.
- When they come in contact, there develops a small outgrowth or protuberance from both of the thalli.
- After that, the outgrowth swells to form "**Progametangium**".
- Then septum develops between the progametangium and the fusion of progametangia occurs which results in the formation of gametes refers to "**Coenogametes**".
- Then gametes of both the strains fuse with each other to form "**Zygote**".
- The zygote then enlarges in size and get surrounded by a thick-walled structure called "**Zygospore**".

- Zygospore is dark black in colour which develops and get covered by two layers namely:
  - Outer layer: Also refers to "**Exosporium**"
  - Inner layer: Also refers to "**Endosporium**"

The zygospore remains dormant for some time and on favorable conditions, promycelium develops out from the zygospore, forming a new vegetative body.

Through these three reproductive methods, a *Mucor* completes its reproductive phase and can cause some serial infections or diseases that can affect the ecological system and human health.

Class 2: Ascomycetes

Occurrence :Ascomycetes are found in variety of habitat. The members may be parasitic or saprophytic.

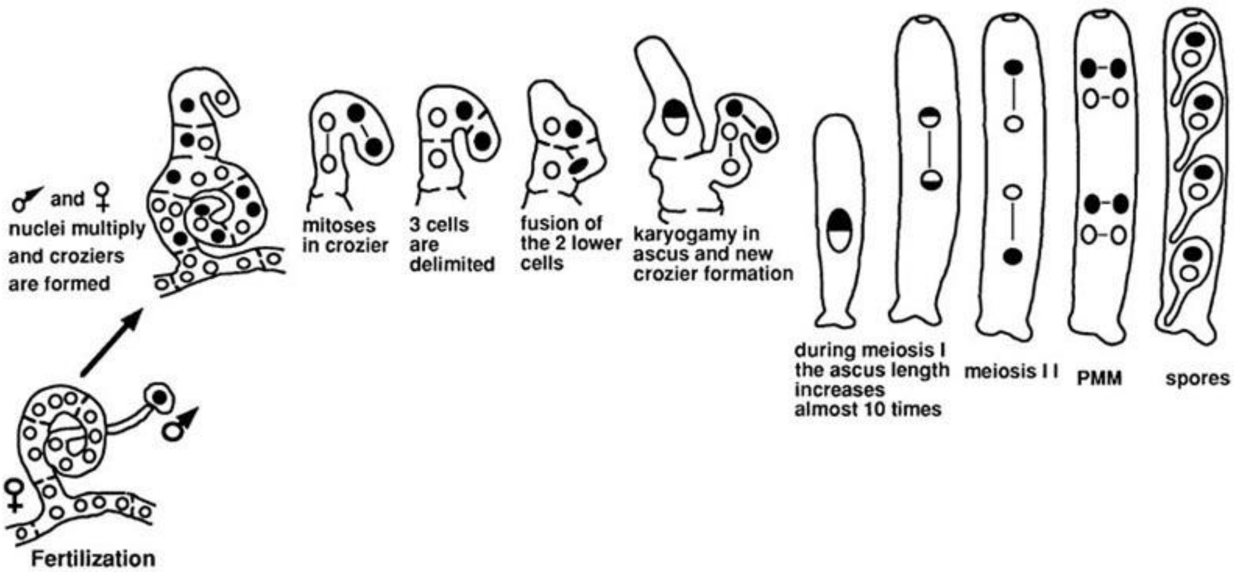
Structure : except for members such as yeast the plant body of ascomycetes is

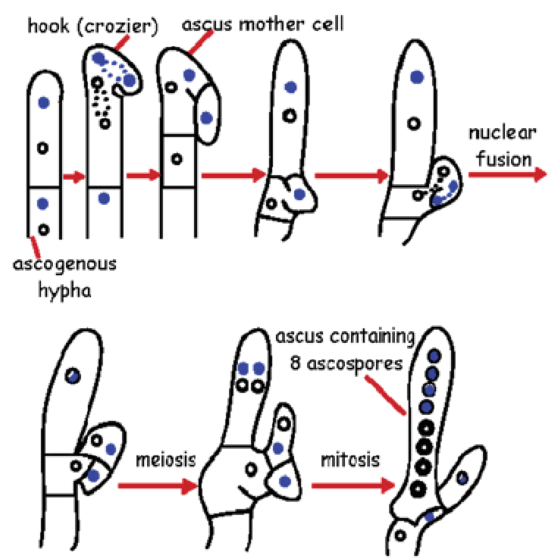
- A septate much branched mycelium.
- Cell wall contains a large portion of chitin.
- The cells of the hyphae may be uninucleate, binucleate or multinucleate.

The cross septum dividing the cell is porous permitting the streaming of cytoplasm from one cell to another.

Asexual reproduction; fragmentation, fission, budding, chlamydospore formation and conidial formation.

Sexual reproduction:The male reproductive structure is a club shaped antheridium and the female reproductive structure is flask shaped ascogonium , it has a swollen base and terminal elongated portion called trichogyne. Both the antheridium and ascogonium are multinucleate. Stages in sexual reproduction are plasmogamy, dikaryotic stage, karyogamy and reduction division.





Ascospore formation

The process of ascus formation:

1- The tip of antheridium comes into contact with the tip of trichogyne. The separating walls dissolve and plasmogamy takes place.

2- The male and female nuclei are irregularly distributed. Later they pair in ascogenous hyphae, one pair into one ascogenous hyphae.

3- Nuclei start dividing and produce many nuclei, attraction between nuclei of different genotype.

4- The ascogenous hyphae now gets divided into basal cell, ascus mother cell and apical cell (croizer).

5- Karyogamy takes place in ascus mother cell forming a diploid nucleus.

6- The diploid nucleus undergoes meiosis followed by mitosis to produce eight haploid nuclei. Each one of the nuclei forms ascospore.

7- The ascus breaks releasing the ascospores which germinate forming monokaryotic mycelium.

Structure and development of fructifications:

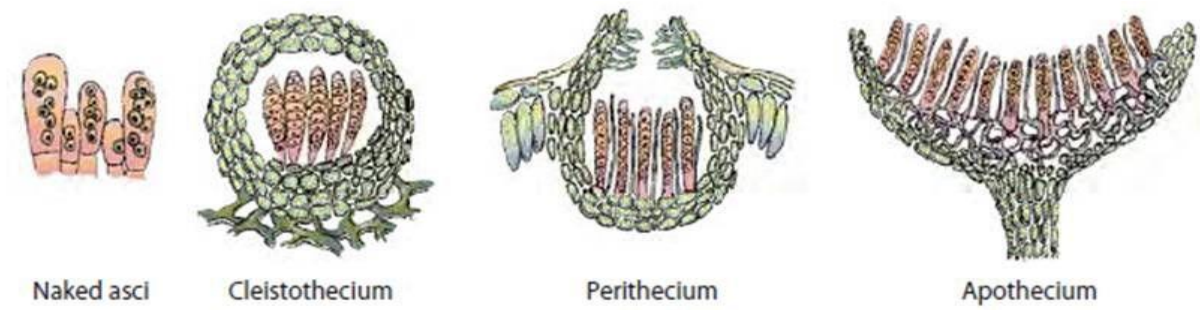
In great majority of ascomycetes the asci are enclosed in compact protective structure called the fruiting body or frutification or Ascocarp. Ascocarps vary in structure and composition, they may be classified into four categories:

(1) **Cliestothecium** is completely closed structure, may be globose or ovoid.

(2) **Perithecium** is flask shaped structures possessing small opening called ostiole .

(3) **Apothecium** is an open type of ascocarp and cup like with a board opening.

(4) **Ascostromata**: asci are formed directly in a cavity in the stroma so there is no wall surrounding the central region of ascocarp.



Classification

Many modern mycologists classify Ascomycetes as follow:

Class: Ascomycetes

Sub-class 1. **Hemiascomycetes** (no ascocarp)

Sub-class 2. **Euascomycetes** (ascocarp present)

Based on the nature of ascocarp the sub class Euascomycetes is divided into three series namely

Plectomycetes (cliestithecium)

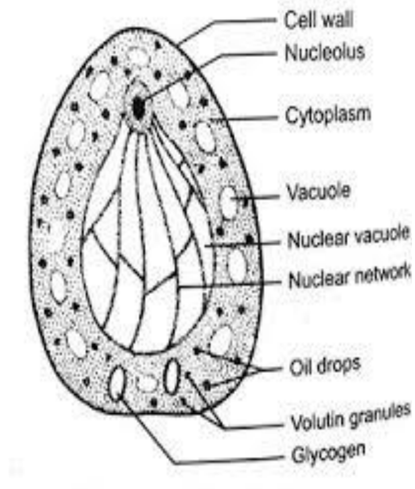
Pyrenomycetes (perithecium)

Discomycetes (apothecium)

The following examples will discussed here:

Hemiascomycetes: *Saccharomyces* (yeast)

Plectomycetes : *Penicillium*



Structure of Yeast cell

C: Ascomycetes

S.C.: Hemiascomycetes

O: Endomycetales

F: Saccharomycetaceae

Ex. *Saccharomyces*

Occurrence: yeasts are widely distributed in nature. They ... commonly found on sugar substrata like fruits.

Cell structure:

Antony Von Leeuwenhoek (1680) was the first to describe the yeast cells. Its unicellular and non-mycelial.

Generally, the shape of cells may vary from circular, spherical, oval, elliptical, elongated, rectangular, dumb-bell shaped to triangular. The cells are minute and range from 2 to 8 μ in diameter and 3 to 15 μ in length. Individually, the cells are hyaline (colorless) but its colonies appear white, cream-coloured or light brown. Each cell consists of a tiny mass of protoplast surrounded by a definite cell wall.

The Cell Wall:

The cell wall is double layered, thin, delicate and flexible. It is composed of two complex polysaccharides, mannan (30%) and glucan (30-40%) with smaller quantities of protein (6-8%), lipid (8.5 – 10.5%) and chitin (2%). Cellulose is absent.

The Protoplast:

Inner to cell wall is a cytoplasmic membrane or plasma membrane. It surrounds the cytoplasm and a nucleus. Under light microscope, a large hyaline structure, occupying a large portion of the cell and a deeply staining body associated on one side of it is seen.

Electron microscopic studies of ultra-thin sections of *S. cerevisiae* and of *S. octosporus* show that the nucleus is surrounded by a nuclear membrane and is distinct from the vacuole.

The nuclear membrane has pores. The cytoplasm in addition to the various cell organelle (mitochondria, endoplasmic reticulum, ribosomes etc.) contains glycogen, proteins, oil and refractile volutin granules (an inorganic metaphosphate polymer) as reserve food materials.

Asexual Reproduction:

Yeasts reproduce asexually either by fission or by budding. Depending on this character they are grouped as fission yeasts, Schizosaccharomyces and budding yeasts, Zygosaccharomyces.

Fission:

1- Yeasts the parent cell elongates (Fig. 217A & B), the nucleus divides into two daughter nuclei

2- Gradually a transverse partition wall dividing the mother cell into two daughter cells (Fig. 217 C & D).

3- The two daughter cells so formed may remain together for some time and begin to divide again or they may separate soon and then divide.

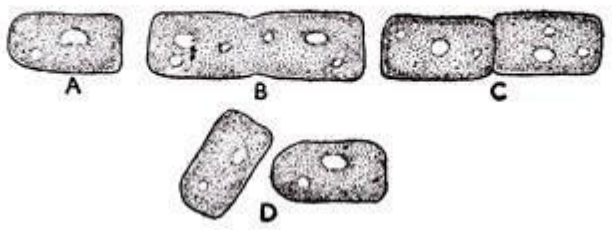


Fig. 217. *Schizosaccharomyces octosporus*. Stages in cell multiplication by fission.

Budding:

Budding yeasts are rather common than the fission yeasts.

1- A small portion of the cell wall, usually near the end, softens.

2- The nucleus of the mother, cell divides mitotically. One of the two daughter nuclei migrates into the enlarging bud (Fig. 218G & D).

3- The bud grows until it attains the size of the mother cell. The daughter cell then becomes separated from the mother cell and the process may be repeated indefinitely (Fig. 218E).

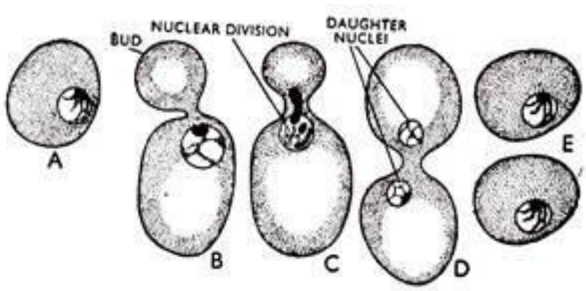


Fig. 218. *Saccharomyces cerevisiae*. Stages in cell multiplication by budding.

Eventually the bud separates from the parent cell leaving a bud scar and the process may be repeated giving rise to chains or groups of yeast cells.

In this way a large number of buds are developed without being detached from one another resulting in the formation of branched or unbranched chains of cells constituting the pseudomycelium. The cells in chains for pseudomycelium are loosely joined together. Sooner or later, however, the chains break into their constituent cells.

Sexual Reproduction:

It takes place by the union of two cells more often similar in size but sometimes they may be dissimilar in appearance, and by the development of short protuberances which unite to form a conjugation tube. This is followed by the dissolution of intervening walls and nuclear fusion which takes place in the conjugation tube.

The subsequent stages' are extremely variable and are discussed separately. The copulating pair of cells may be vegetative cells or ascospores. Often copulation occurs between a mother cell and its bud. This is known as pedogamy and is observed in *Zygosaccharomyces chevalieri*. Yeasts may be homothallic or heterothallic.

Sexual reproduction of yeasts was first clearly recognized by Guillermond (1901-1902). He demonstrated copulation of yeast nuclei and the subsequent stages leading to the ascospore formation. The number and shape of ascospores are variable (Fig. 219). In 1940 Guillermond showed that three life cycle patterns are distinguishable among yeasts.

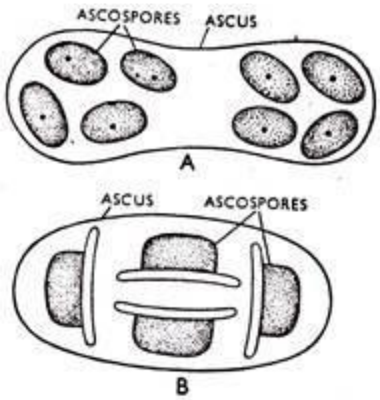


Fig. 219. Various types of yeast ascospores. A. *Schizosaccharomyces octosporus*. B. *Hansenula* sp.

They are:

I. Haplobiontic Life Cycle:

This is exhibited by *Schizosaccharomyces octosporus* which is homothallic. Here the haploid stage (haplophase) is very elaborate. Whereas, the diploid stage (diplophase) is very short being confined to the zygote cell only. Meiosis of the diploid zygotic nucleus takes place immediately after karyogamy. The somatic cells are haploid and elongated. They divide by fission forming daughter cells. Life cycle is presented in Figure 220.

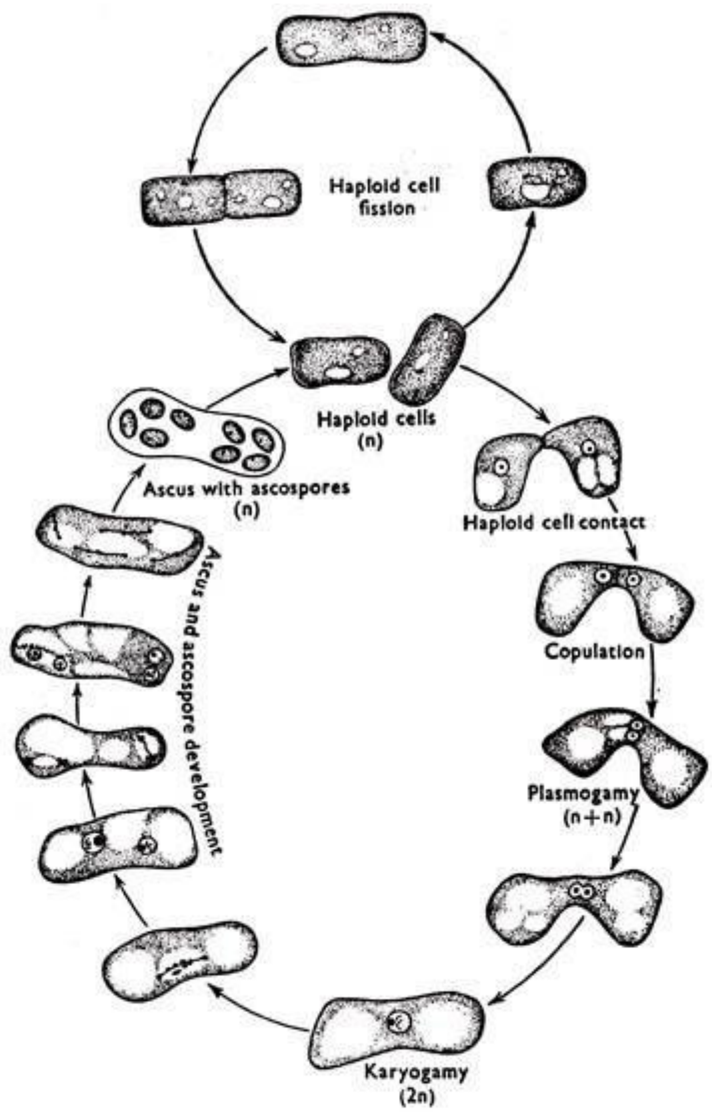


Fig. 220. Haplobiontic life cycle of *Schizosaccharomyces octosporus*.

II. Diplobiontic Life Cycle:

This is exemplified by *Saccharomycodes ludwigii*. Here the diploid somatic stage is long and the haploid stage is very short. The diploid somatic cells produce buds which eventually enlarge to function as asci. The diploid nucleus divides meiotically forming four haploid nuclei around which four ascospores are developed. Life cycle is presented in Figure 221.

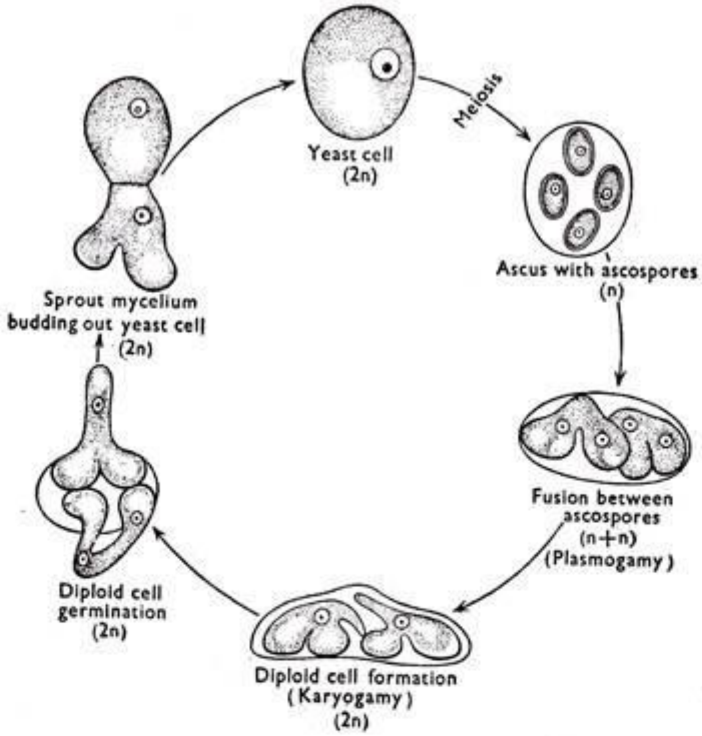


Fig. 221. Diplobiontic life cycle of *Saccharamycodes ludwigii.*

III. Haplo-Diplobiontic Life Cycle:

This is exhibited by *Saccharomyces cetevisiae*. In this type of life cycle both haploid and diploid phases are equally well represented constituting somewhat an alternation of generations. Two haploid cells copulate forming a diploid cell. The diploid cell multiplies by budding producing large number of diploid cells.

Eventually, each diploid cell behaves as an ascus bearing four ascospores and meiosis takes place during the development of ascospores. Life cycle is presented in Figure 222.

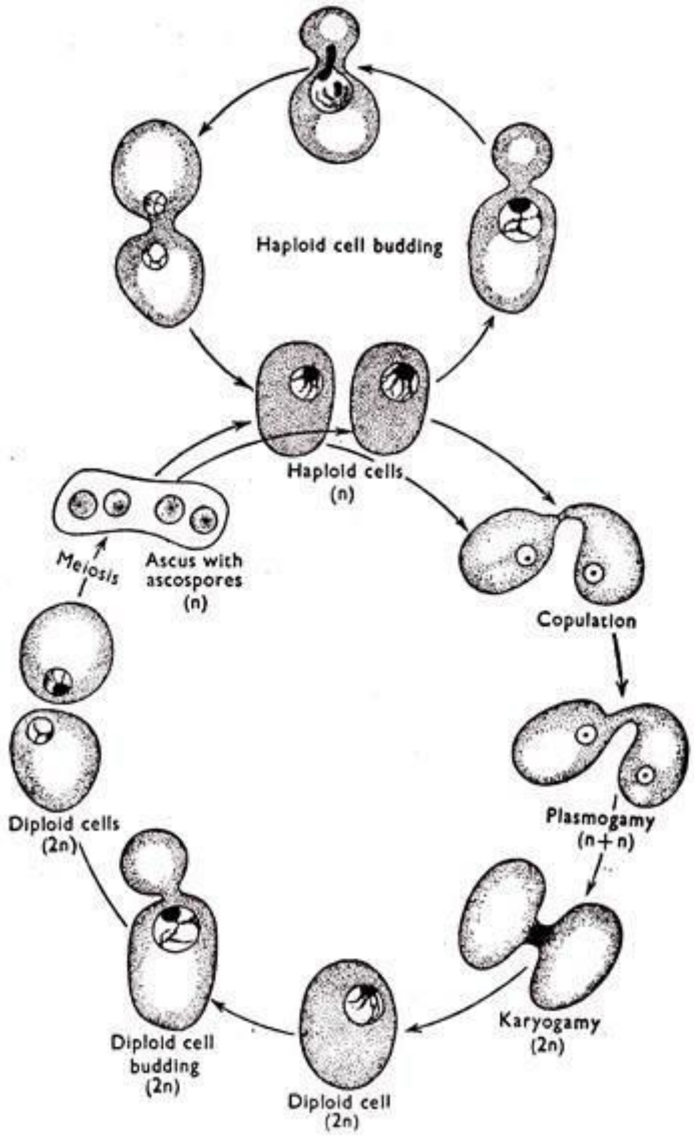


Fig. 222. Haplo-diplobiontic life cycle of *Saccharomyces cerevisiae*.

C: Ascomycetes

S.C.: Euascomycetes

S: Plectomycetes

O:Aspergillales

F: Aspergillalaceae

Ex. *Penicillium*

Occurrence :*Penicillium* is commonly called green or blue mold and is a saprophytic fungus, which grows on rotten fruits, rotten vegetables, meat etc.

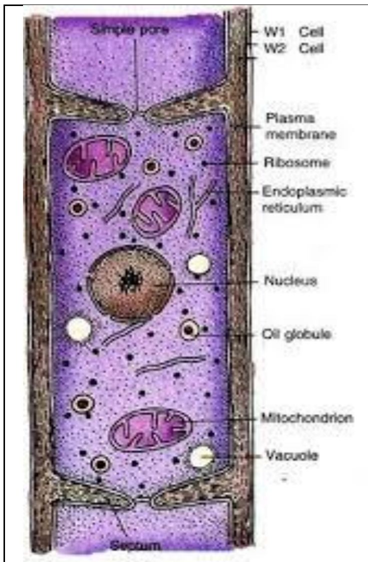
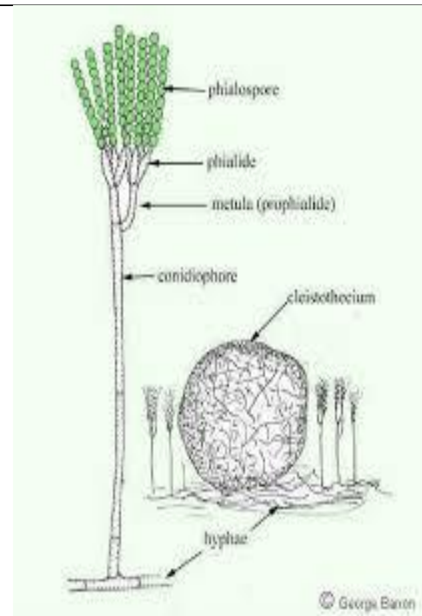


Fig. 10.9. *Penicillium sp.* Diagrammatic representation of fine structure of a cell.



Cell structure: the hyphae are septate and each cell is uninucleate. The cell wall is microfibrillar and in *Penicillium notatum* it is reported to consist of three or four layers, the outer most layer is composed of glucans, the next of proteins, the third of chitin fibrils embedded in a granular matrix, and the inner most of pectic or hemicellulosic material. The plasma membrane surrounds the cytoplasm in which mitochondria, ribosomes and endoplasmic reticulum is embedded.

Reproduction:

Vegetative Propagation: The vegetative reproduction takes place by fragmentation during which the hyphae break up into short fragments, which grow by repeated division into a new mycelium.

Asexual Reproduction: The asexual reproduction is by formation of non-motile, asexual spores, the conidia, and produce at the tip of special, erect, hyphae called conidiophores. Many crops of conidia are produce during a growing season.

Conidiophores: The mycelium produces simple, long, erect, conidiophores that branch two third of the way to the tip, in characteristic broom like fashion. The branches of conidiophores end in a group of conidiogenous cells, the phialides that produce conidia at their tips in chain.

Structure and development of conidia: The conidia are tiny, uninucleate, spore like structures which may be globose to avoid in form. The spore wall is pigmented and is differentiated into two layers, an outer thick, ornamented layer, the exine; and inner smooth and thin layer, the intine. The conidia are detached from the conidiophores and are carried by wind to a suitable substratum where they germinate by forming a germ tube. The germ tube elongates, becomes septate to form a new hyphae.

Sexual Reproduction: The perfect state of *Penicillium* is assigned to two different genera, the *Eupenicillium* and *Talaromyces.* All the species are homothallic. In *Penicilllium vermiculatum* the sexual reproduction is oogamous. The male sex organs are antheridia and female sex organ are ascogonia.

Ascogonium: A mature ascogonium is a long erect, multinucleate, tubular structure with curved upper end. It arises from uninucleate, septate hyphae as a finger like, lateral outgrowth which elongates into an ascogonium. The nucleus of the ascogonium divides many times mitotically to produce 32 or 64 nuclei.

Anteridium: while the ascogonium is developing a uninucleate branch originates from a cell of the same hyphae adjacent to the developing ascogonium, or from neighbouring hyphae. This is the antheridial branch. It grows up band coils around the ascogonium. The tip of the antheridial branch swells up and is cut off from rest of the branches to form a uninucleate antheridium.

Fertilization: The tip of the antheridium comes in contact with the walls of the ascogonium and the walls of contact between the two dissolves to form a pore. The protoplast of the gametangia comes in contact with each through this pore. The antheridial and ascogonial nuclei arrange themselves in pairs. Each pair is called a dikaryon.

Development of Ascus and Ascospores: The stimulus of plasmogamy results in septation of ascogonium into binucleate cells. Some of these segments usually those present in the middle, produce outgrowth called ascogenoum which develop into ascogenous hyphae composed of binucleate cells. The tip cells of these hyphae act as ascus mother cells which develop either simply by elongation, or by crozier formation into ascus. Karyogamy takes place in the ascus mother cell and this diploid uncleus undergoes meiosis to produce four haploid nuclei. A mitotic division results in the formation of eight haploid nuclei. These are transformed into ascospores by free cell formation. The ascus are globose or pear-shaped and the unicellular, uninucleate and lens-shaped with a groove around the edge.

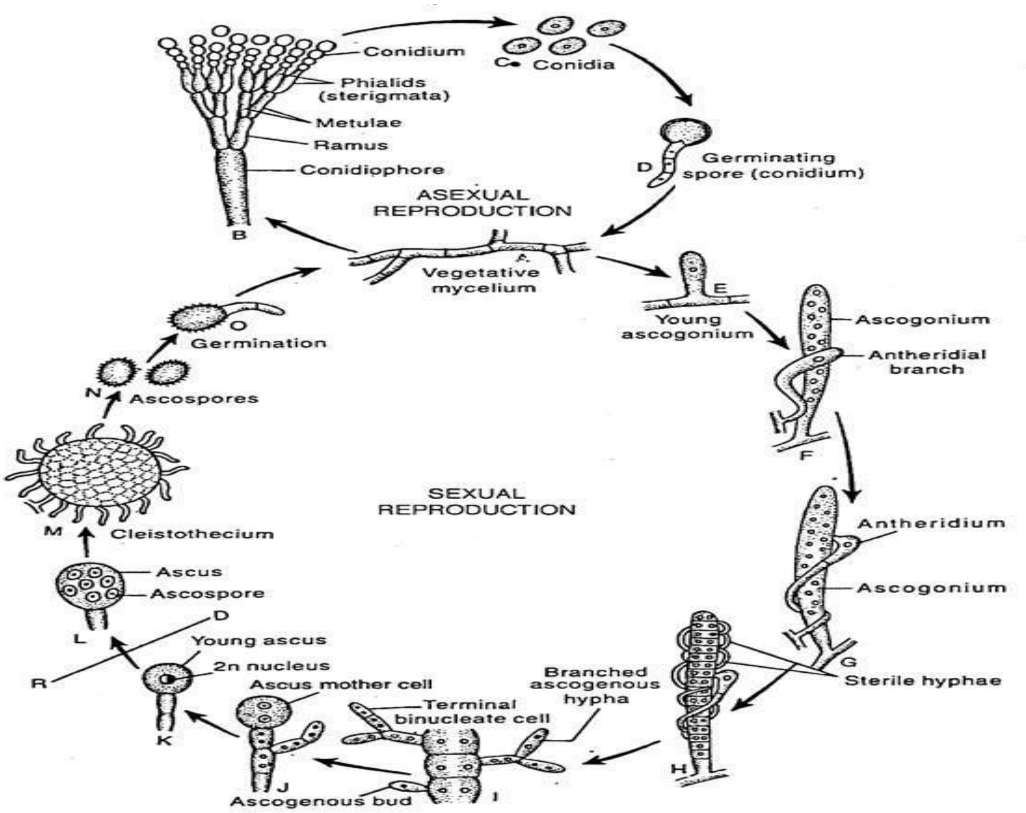


Fig. 4.44 : Life cycle of *Talaromyces vermiculatus* (*Penicillium vermiculatum*)

Class 3: Basidiomycetes

Occurrence: Basidiomycetes are both parasitic (rust and smut) and saprophytic.

Somatic structure: the plant body is a septate, much branched mycelium. The mycelium is usually white, bright yellow or orange coloured. The mycelium of basidiomycetes passes through three stages:

1- Primary mycelium: formed from the germination of haploid basidiospore and it is monokaryotic and the cells are uninucleate.
2- Secondary mycelium: originates from the primary mycelium asa result of sexual reproduction, with only plasmogamy taking place.
3- Tertiary mycelium: at the completion of the life cycle it is produced as a result of karyogamy.

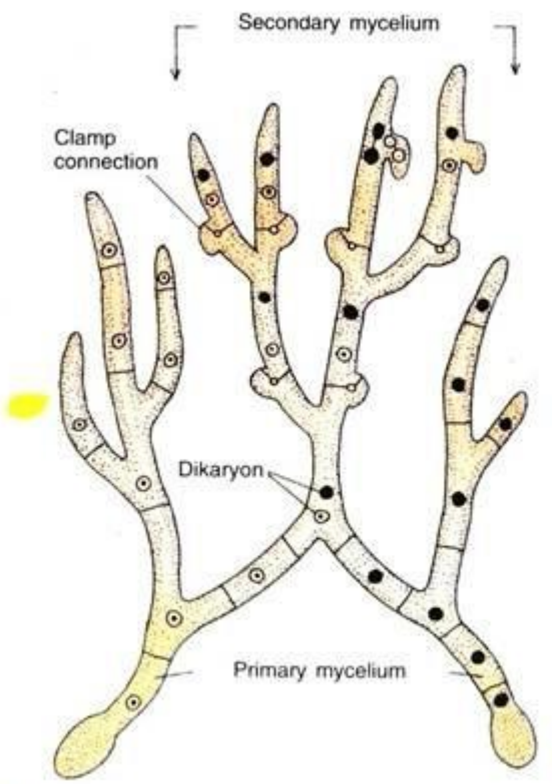


Fig. 13.2. *Basidiomycetes*. Sketch showing the formation of a secondary mycelium from a dikaryotised cell produced by somatogamous copulation between two uninucleate cells of primary mycelia of opposite strains.

The clamp connection: thus simply functions as a bypass. It ensures that the sister nuclei formed by the conjugate division of the dikaryon separate into two newly formed daughter cells. The clamp connections are usually formed on the terminal cells of the hyphae of the secondary mycelium.

Asexual reproduction: takes place by avariety of methods such as fragmentation, budding, conidia and arthrospores

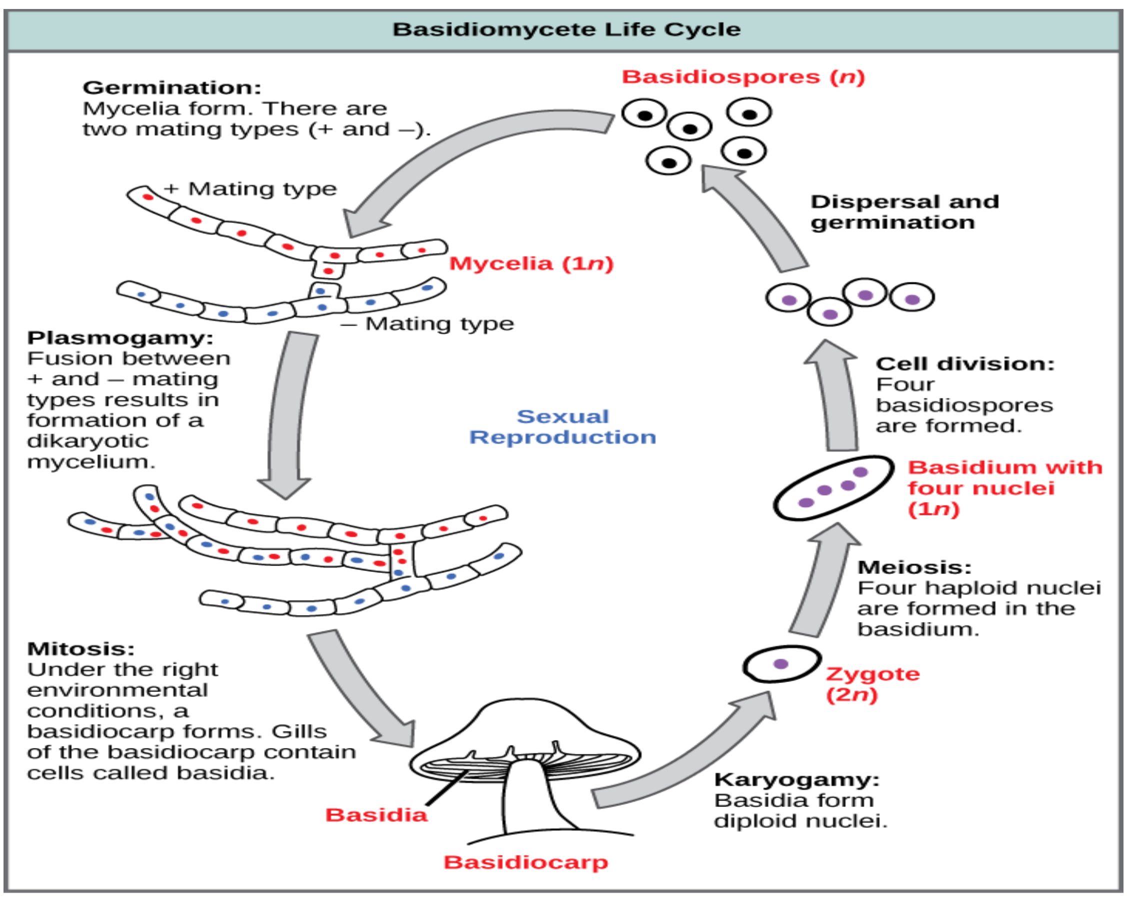
Sexual reproduction: there are four stages

(1) Plasmogamy (2) dikaryotization

(3)karyogamy (4) reduction division

The lifecycle of basidiomycetes includes alternation of generations.

1- Spores are generally produced through sexual reproduction, rather than asexual reproduction. The club-shaped basidium carries spores called basidiospores.
2- In the basidium, nuclei of two different mating strains fuse (karyogamy), giving rise to a diploid zygote that then undergoes meiosis. The haploid nuclei migrate into basidiospores, which germinate and generate monokaryotic hyphae. The mycelium that results is called a primary mycelium.
3- Mycelia of different mating strains can combine and produce a secondary mycelium that contains haploid nuclei of two different mating strains. This is the dikaryotic stage of the basidiomycetes life cyle and it is the dominant stage.
4- The secondary mycelium generates a **basidiocarp**, which is a fruiting body that protrudes from the ground—this is what we think of as a mushroom. The basidiocarp bears the developing basidia on the gills under its cap.



Classification: majority of modern mycologist classified basidiomycetes into two subclasses.

Subclass 1- Heterobasidiomycetidea: is primitive, here no basidiocarp is formed and the basidium is septate. This includes three orders *Ustilaginales*, *Uredinales* and *Tremellales*.

Subclass 2- Homobasidiomycetideae: is advanced here the basidiocarp formed and basidium is unseptate. Depending on the nature of basidiocarp, this is divided into two series:

(1) Hymenomycetes, the basidiocarp is open and the basidia are exposed from the very beginning. This includes only one order: *Agricales*.

(2) Gasteromycetes, the basidiocarp is closed structure. It breaks open only at maturity releasing the basidiospores this includes four orders *Hymenogasterales*, *Nidulariales*, *Lycoperdales* and *Sclerodermatales*.

Basidiomycetes

Agaricales

Agaricaceae

Agaricus

The basidiomycetes are commonly called the higher fungi. The genus *Agaricus* is commonly called mushroom. Agaricus campestris is one of our popular mushrooms which is cultivated for its delicous fruiting body. Not all mushrooms however are edible, some of them in fact are deadly.

Hapitate: It is a saprophytic fungus found growing on soil humus, decaying litter on forest floors, in the fields and lawns, wood logs and manure piles. It grows best in moist and shady places and is commonly seen during rainy season.

Vegetative structure: Vegetative body mycelia consists of septate much branched hyphae. Spore on germination develop into monokaryotic or primary mycelium, either + or- typ. The primary mycelium is short lived and it soon transform into

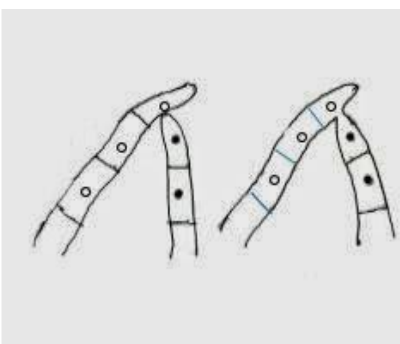
diakaryotic or secondary mycelium by the fusion of two cell of different monokaryotic mycelium following clamp connection. The hyphae of the diakaryotic mycelia interlace
twist together to form thick hyphal cord, called rhizomorph which bear the fruit bodies. Agaricus reproduces by all the three means: vegetative, asexual and sexual.

VEGETATIVE REPRODUCTION

It is mostly propagated by vegetative means where dikaryotic mycelium develops spawn, the mushroom seed. The mass spawn divides artificially into small blocks that are grown in soil supplemented with organic manure to obtain fruits bodies.

ASEXUAL REPRODUCTION

It takes place by chlamydospores that are formed rarely during unfavorable condition. Terminal or intercalary chlamydospores are developed on dikaryotic mycelium, which are on germination during favorable condition produce dikaryotic mycelium.

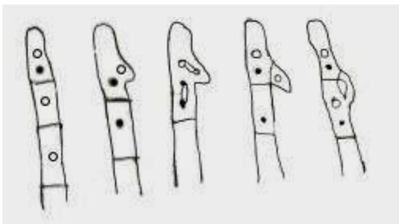


Stages of plasmogamy

SEXUAL REPRODUCTION

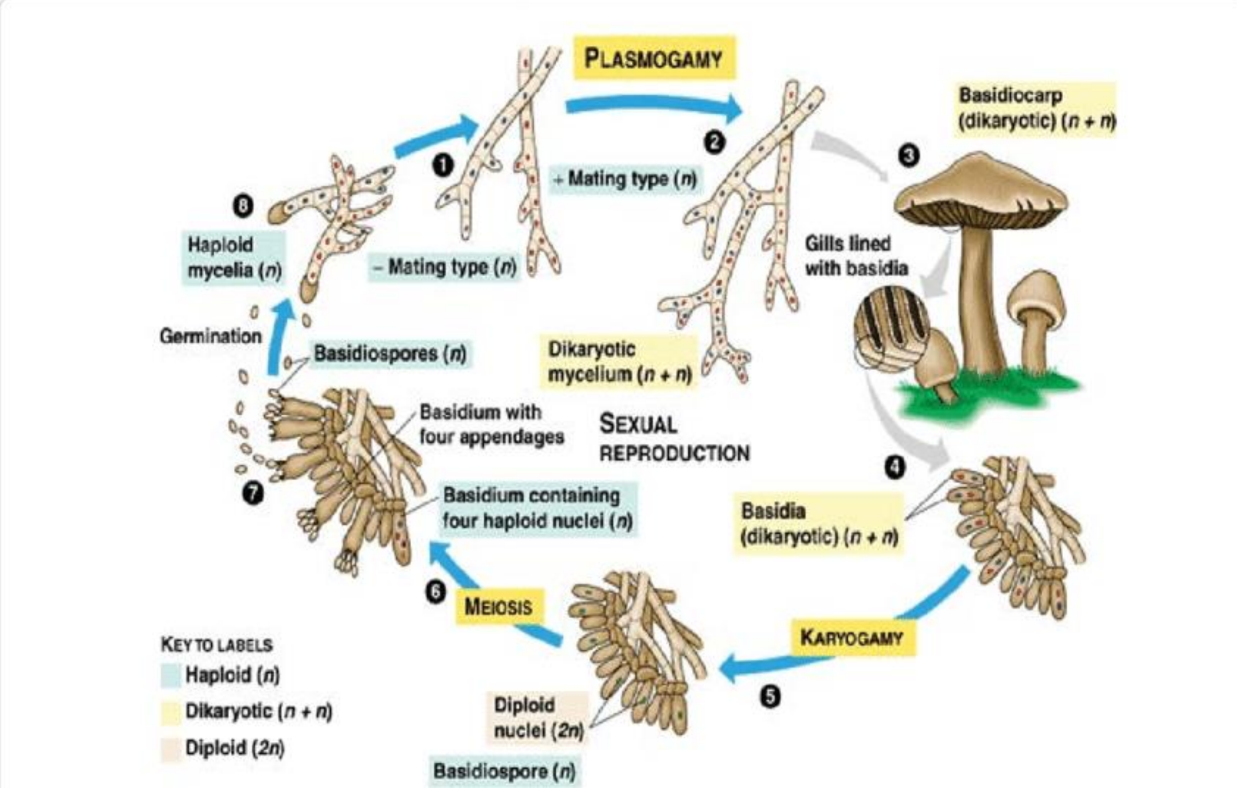
Sex organ are absent in *Agaricus* and sexual reproduction takes place by somatogamy. Most of the species including *Agaricus campestries* are heterothallic. Somatogamy includes plasmogamy, karyogamy, and meiosis. Karyogamy does not take place immediately after plasmogamy, but meiosis follows soon after karyogamy:

1. Plasmogamy: two cells of monokaryotic hyphae of opposite strains (- or +) come in contact with each other. The cell wall dissolve at the point of contact and a dikaryon (n+n) is formed this dikaryotic cell develops into dikaryotic mycelium by regular cell divisions through clamp connection. The dikaryotic mycelia are subterranean and after aggregation at some points they form button which remains dormant before the rain comes during late summer. After rain, the soil become soft and the button develops into fruit body.
2. Karyogamy: it takes place in the young basidium which develops in on gills in the fruit body. Both the nuclei fuse together and form diploid nucleus.

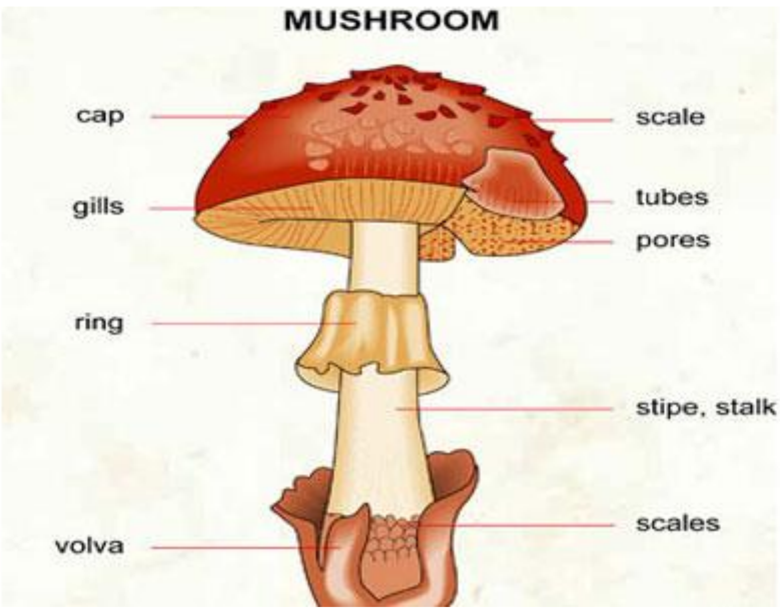


Growth of mycelium by clamp connection

3. Meiosis: it takes soon after karyogamy and forms four haploid nuclei. The basidiospore, thus formed on the sterigma of basidium are haploid and either of + or – type.



Life cycle of *Agaricus*



Class 4: Deuteromycetes (fungi imperfecti)

Deuteromycetes are also called fungi imperfecti. This is an artificial class of fungi created to include all those fungi in which the sexual stage is either absent or not known. Some of the deuteromycetes are unicellular like yeast.

Deuteromycetes have members that belong to both ascomycetes and basidiomycetes.

Reproduction in deuteromycetes is only by asexual spores i.e. conidia formation. They are parasitic or saprophytic in nutrition. Many act as decomposers of litter, thus helping in mineral cycling.

Somatic structure: the thallus of fungi imperfecti consists of a well developed septate branched mycelia. The cells are usually multinucleate. The septa are perforated permitting the streaming of cytoplasm.

Deuteromycetes asexually reproduce by conidia which are borne on conidiophores. The conidiophores may be simple structures or are produced in special structures like Acervulus, Synnema and Pycnidium. In addition to this some Deuteromycetes specially animal and human pathogens produce other types of spores called:

Microconidia are minute conidia.

Blastospores are asexual cells produced as a result of budding or directly from hypha.

Arthrospores are produced by disjoining and isolation of cells. They are otherwise called oidia.

Classification : Deuteromycetes are divided into the following orders

1- Sphaeropsidales conidia are borne in pycnidial cavities
2- Melanconiales conidia are borne in acervuli which are sub epidermal orsub cuticular in the host.
3- Moniliales conidiophores may be simple or branched.

Deuteromycetes

Moniliales

Dematiaceae

Alternaria

Diseases caused and symptoms:

1- Early blight of potato: this disease is caused by *A. solani* and is widespread in areas wherever potato cultivated.
2- Alternaria leaf spot of cabbage: cruciferous plants like cabbage, mustard, cauliflower and raddish get the attack of leaf spot. *A. brassicae*, *A. brassicola* and *A. raphani* cause the leaf spot disaes. *A. raphani* is specific to raddish only.
3- Leaf blight of wheat: the disease is caused by *A. triticola*.

Vegetative structure: the plant body is a mycelium the mycelium is much branched with septate hyphae. The hyphae are light yellow, hyaline and semitransparentin young conidia. Mature hyphae are of the colour of olive oil.

Reproduction; perfect stage of the fungus are not seen. Asexual reproduction takes place by means of conidia. Conidiophores are simples, unbranched and septate. Conidia are multicellular and have 5-10 cross walls. In some cases the end of conidia have beak like projections. They are dictyosporous, ie., have both transverse and longitudinal septa.