South Valley University

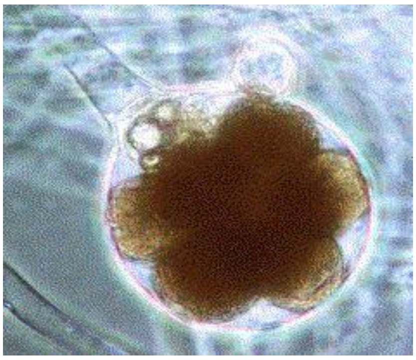
Faculty of Science

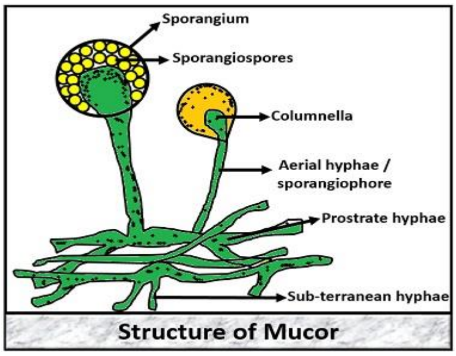
Botany & Microbiology Department

Fungi

(Aquatic &Soil)

For third year





Prepared by

Dr. Amany Atta El-Shahir

Lecturer of Mycology

Contents

ACKNOWLEDGEMENT

To my parents

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

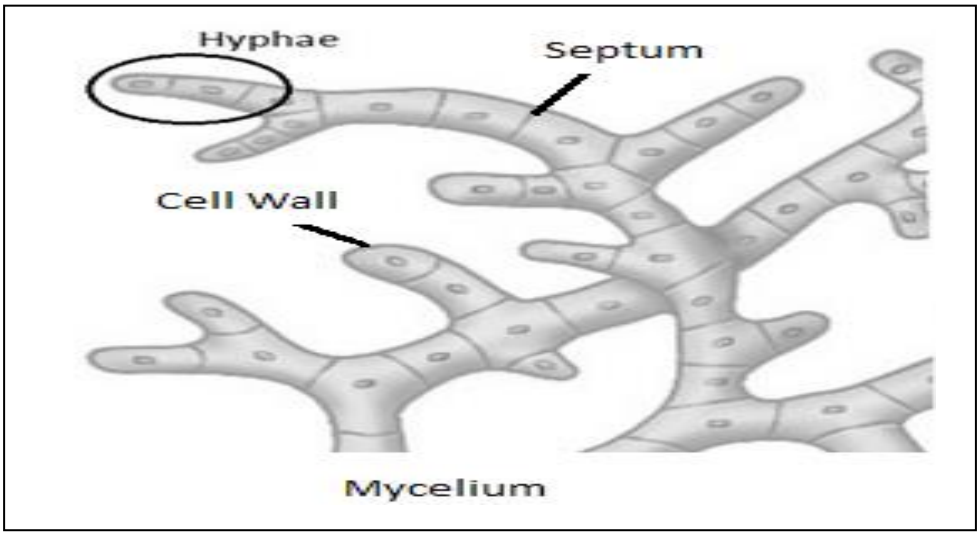


Fig. (1): Hyphae and mycelium

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*.

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).

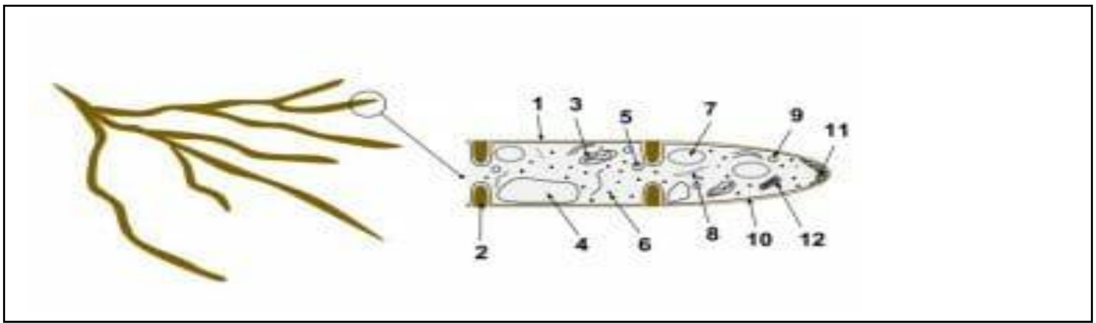


Fig. (2) 1- Hyphal wall 2- Septum 3- Mitochondrion 4- Vacuole 5- Ergosterol crystal 6- Ribosome 7- Nucleus 8- Endoplasmic reticulum 9- Lipid body 10- Plasma membrane 11- Spitzenkörper/growth tip and vesicles 12- Golgi apparatus.

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- Nutrient Absorption from a Host

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- Nutrient Absorption from Soil

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- Trapping Structures

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

4- Nutrient Transportation

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).

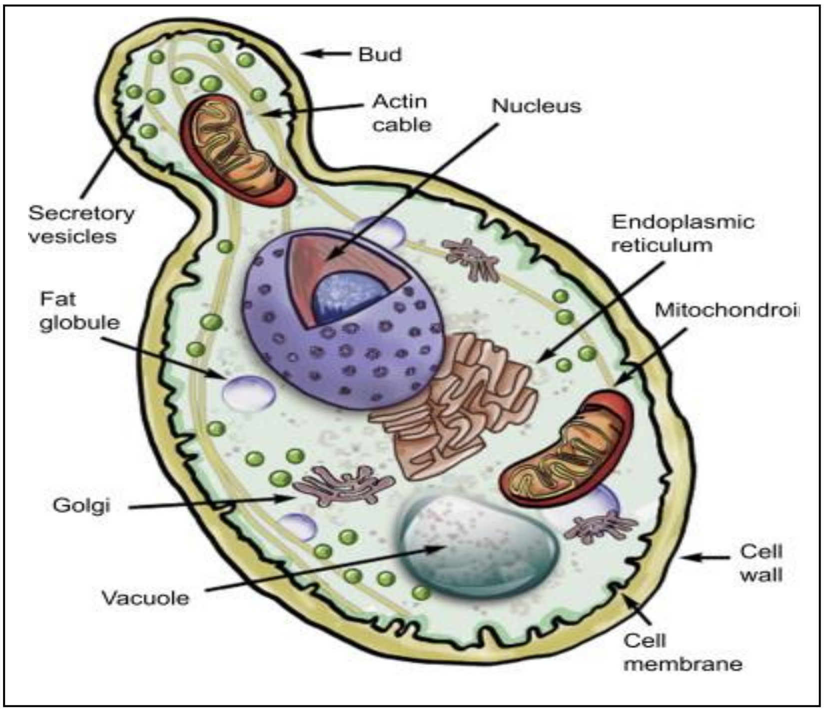


Fig. (3): *Saccharomyces cerevisiae* fine structure.

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 passag

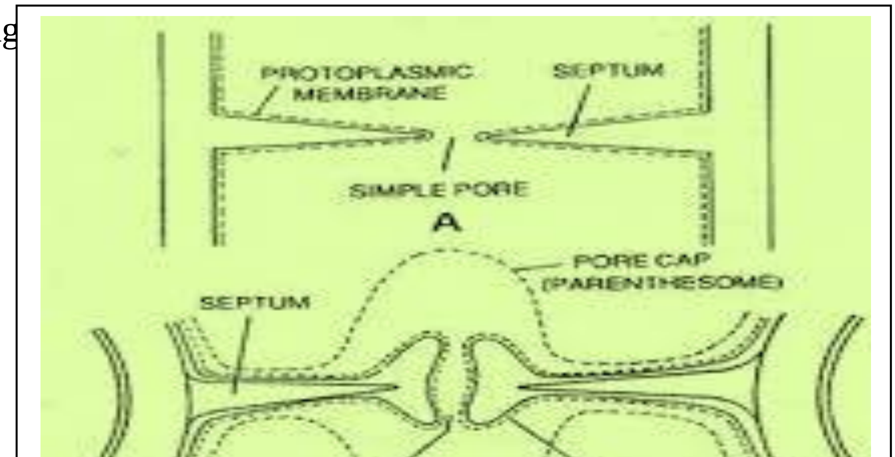


Fig. (4): A, simple pore and B, dolipore

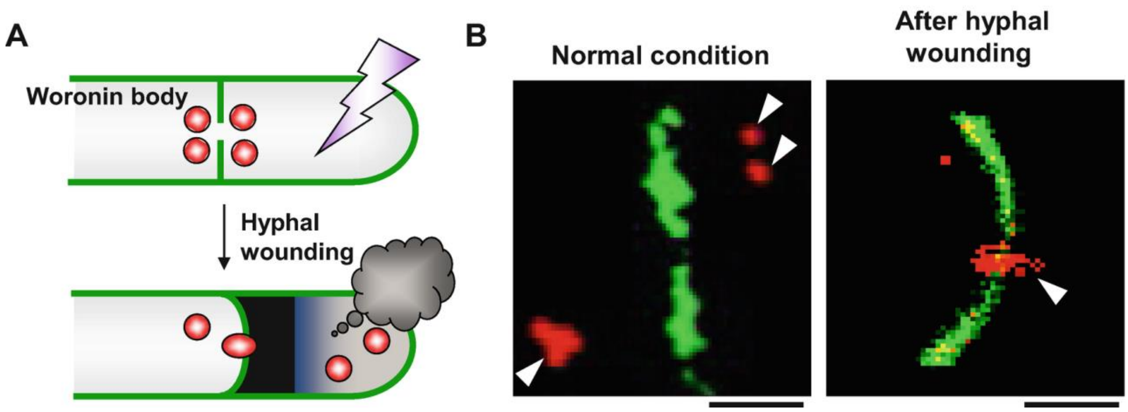


Fig. (5): Function of Woronin body

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).

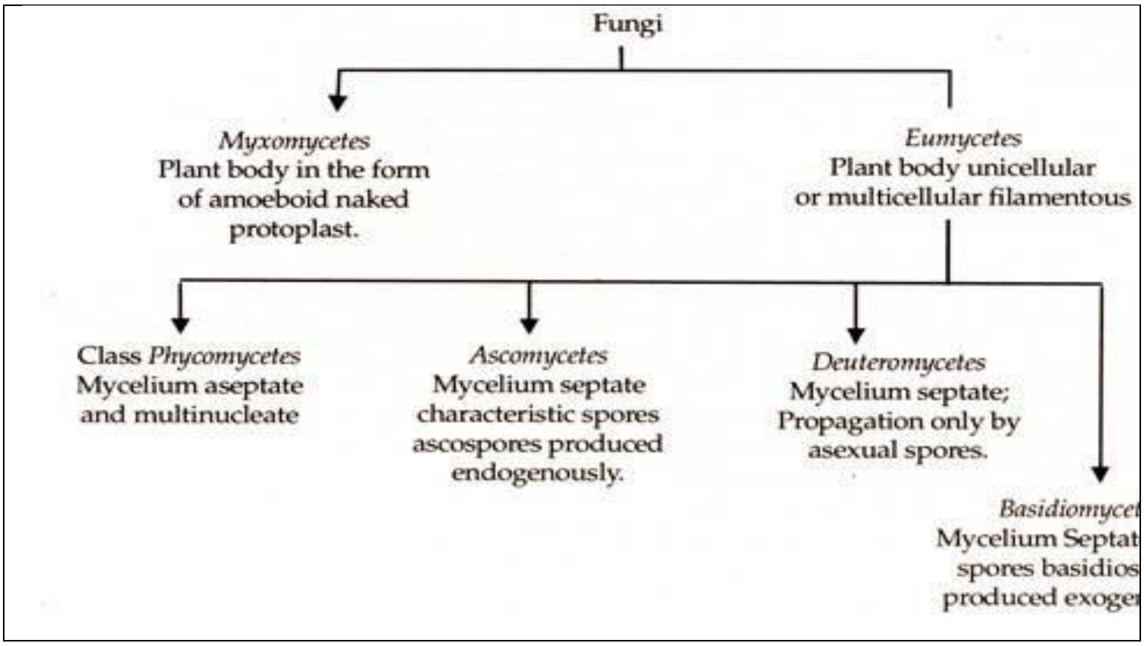
Nuclei

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.

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.

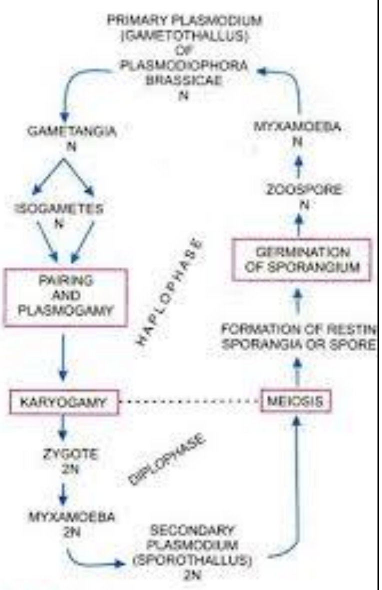
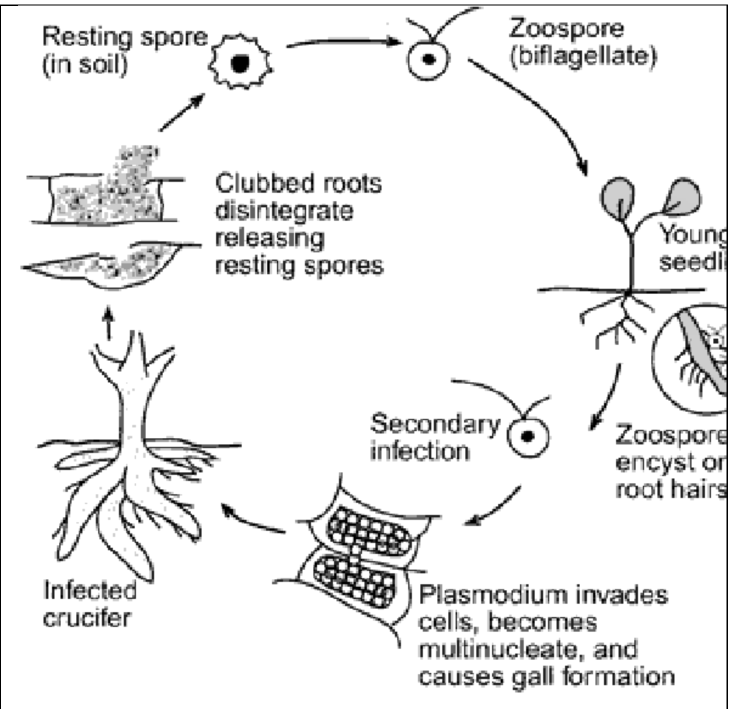


Fig. 5.7. Plasmodiophora sp. Graphic representation of the life cycle.



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.

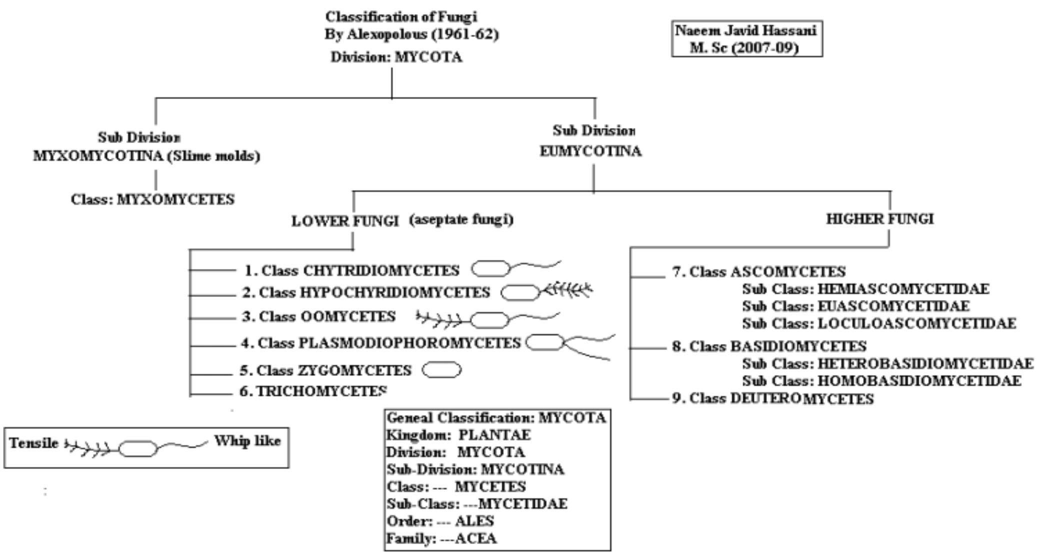
(2) Zygomycetes: reproduction is isogamous.

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.

(1) Oomycota (common name: water molds)

Oomycetes (a term used to refer to organisms in the phylum Oomycota) are a group of fungus-like organisms that rely on water for completion of their life cycle. The members are either free-living or parasitic. As they live in water they are called as “water molds”.



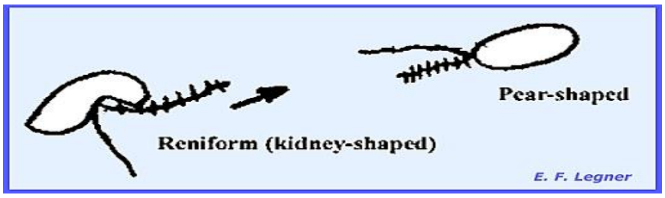
General characteristics

1. The Oomycota have long been considered fungi because they obtain their nutrients via absorption and many of them produce the filamentous threads known as mycelium characteristic of many fungi. The Oomycota now are classified as a distinct group based on a number of unique characteristics.

2. All members of the Oomycota undergo oogamous reproduction, meaning that diploid oospores are produced as zygotes following fertilization of haploid gametes. These oospores may be large and solitary or smaller and numerous inside the oogonium.

3. When Oomycetes produce swimming stages, they usually have two flagella of different types — a whiplash flagellum and a tinsel flagellum, the latter of which is decorated with small hairs. These hairs give the tinsel flagellum greater and reverse thrust, dragging spores through the water.

4. They produce bi-flagellate zoospores and are of two kinds- Pear shaped or pyriform and Reniform or kidney shaped



5. The vegetative stages of Oomycetes are generally either diploid or polyploid, including the egg-like resting spores, oospores, from which the name oomycetes is derived.

6. An advanced type of oogamous reproduction takes place by the passage of gametic nuclei.

7. Meiosis is gametangial rather than zygotic and the vegetative thallus is diploid.

8. In addition, oomycetes differ in various physiological and chemical characteristics from fungi; for example, by having a cell wall containing glucan and cellulose, producing a different storage polysaccharide, and by utilizing different pathways to synthesise lysine and sterols.

MAJOR DIFFERNECE OF OOMYCOTA AND TRUE FUNGI

Table 1. Major distinctions between the Oomycota and the true Fungi

Character	Oomycota	True Fungi
Sexual reproduction	Heterogametangia. Fertilization of oospheres by nuclei of oospores.	Oospores not produced; sexual reproduction results in zygospores, ascospores or basidiospores
Nuclear state of vegetative mycelium	Diploid	Haploid
Type of flagella on zoospores, if produced	Heterokont, of two types, one whiplash, directed posteriorly, the other fibrous, ciliated, directed anteriorly	If flagellum produced, usually of only one type: posterior, whiplash
Mitochondria	With tubular cristae	With flattened cristae
Cell wall	composed of beta glucans and cellulose	composed of chitin.

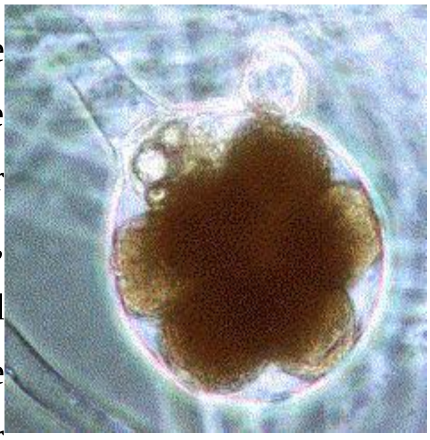
ECOLOGY OF OOMYCOTA

There are more than 500 species in the Oomycota these include the so-called water molds and downy mildews. They are filamentous protista which must absorb their food from the surrounding water or soil, or may invade the body of another organism to feed. As such, oomycetes play an important role in the decomposition and recycling of decaying matter.

Other parasitic species have caused much human suffering through destruction of crops and fish.

Oomycetes live literally everywhere. They are among the most widespread eukaryotic life forms and thrive on all continents, including Antarctica, and can be found in ecosystems as diverse as tundra, rainforests, oceans and deserts.

Saprotrophic oomycetes remains of other organisms for their nutrition. They are often the first settlers on remains of other organisms in water and play an important role in the decomposition cycle, making organic material accessible for secondary colonisers. However, most known oomycete species are pathogens of eukaryotes, affecting animals, diatoms, dinoflagellates, fungi, plants, seaweeds, and even other oomycetes. The poorly studied oomycete parasites of diatoms and other planktonic organisms might be important in the breakdown of algal blooms. The majority of known oomycete species depend on living cells of flowering plants from which they absorb nutrients through specialised structures called haustoria. Some oomycetes cause only weak symptoms, if any, but are transmitted to the next generation of their hosts by entering the seeds. Other oomycetes kill their host in order to degrade and feed on it, either after a biotrophic phase or immediately.



"Oomycota" means "egg fungi," and refers to the large round oogonia, or structures containing the female gametes, as shown in this picture of the common "water mold" Saprolegnia. Oomycetes are oogamous, producing large non-motile gametes called eggs, and smaller gametes called sperm. They may grow on the scales or eggs of fish, or on amphibians. The water mold Saprolegnia causes lesions on fish which cause problems when the water is rather stagnant, as in aquaria or fish farms, or at high population densities, such as when salmon swim upstream to spawn. Other species of Saprolegnia are parasitic on aquatic invertebrates such as rotifers, nematodes, and arthropods and on diatoms. Their greatest impact on humans, however, comes from the many species of water mold which are parasites on flowering plants. These include root rotting fungi, seedling dampening mold, blister rusts, white rusts (Albugo), and the downy mildews that affect grapes, lettuce, corn, cabbage, and many other crop plants. Two of these disease-causing Chromists have had a major impact on world history--- Plasmopara viticola, the downy mildew of grapes and Phytophthora infestans, the late blight of potato.

CLASSIFICATION

kingdom: Heterokonta

Phylum: Oomycota

Arx, 1967[1]

Class: Oomycetes

G. Winter, 1880

Orders and families

• Lagenidiales

o Lagenidiaceae

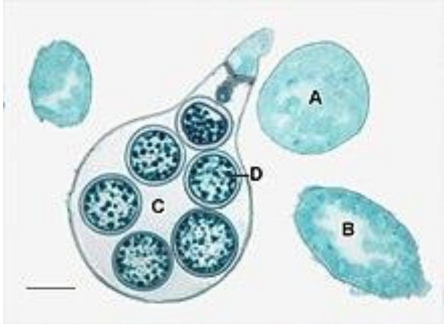
o Olpidiosidaceae

o Sirolpidiaceae

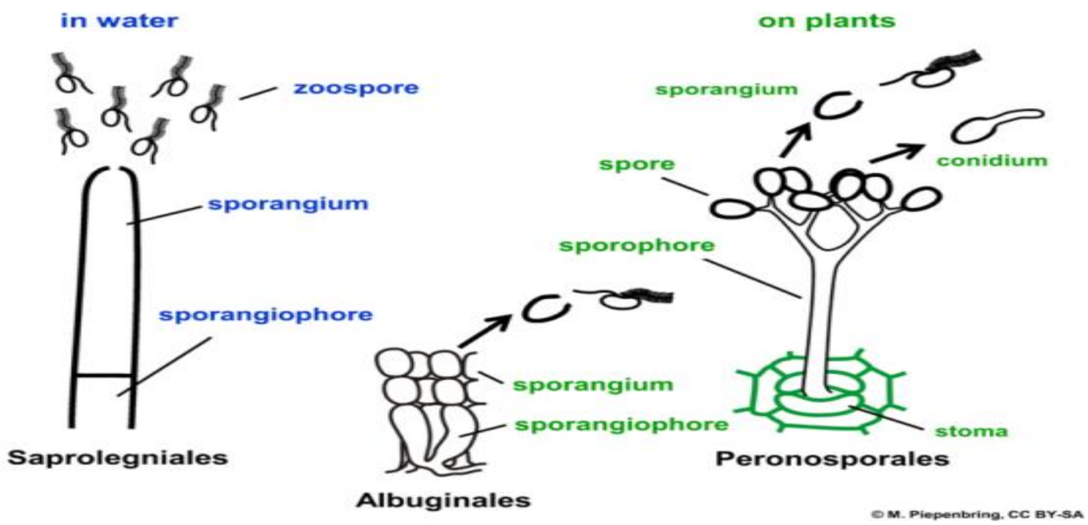
- Leptomitales
  - o Leptomitaceae
- Peronosporales
  - o Albuginaceae
  - o Peronosporaceae
  - o Pythiaceae
- Rhipidiales
  - o Rhipidaceae
- Saprolegniales
  - o Ectrogellaceae
  - o Haliphthoraceae
  - o Leptolegniellaceae
  - o Saprolegniaceae

Classification

Asexual structures (sporangia) in Saprolegniales, Albuginales and Peronosporales



Sexual structures (only oogonia, antheridia not shown) of Saprolegnia



Previously the group was arranged into six orders.

- The Saprolegniales are the most widespread. Many break down decaying matter; others are parasites.
- The Leptomitales have wall thickenings that give their continuous cell body the appearance of septation. They bear chitin and often reproduce asexually.
- The Rhipidiales use rhizoids to attach their thallus to the bed of stagnant or polluted water bodies.
- The Albuginales are considered by some authors to be a family (Albuginaceae) within the Peronosporales, although it has been shown that they are phylogenetically distinct from this order.
- The Peronosporales are mainly saprophytic or parasitic on plants, and have an aseptate, branching form. Many of the most damaging agricultural parasites belong to this order.
- The Lagenidiales are the most primitive; some are filamentous, others unicellular; they are generally parasitic.

However more recently this has been expanded considerably.

Another classification of oomycetes

- Anisolpidiales Dick 2001
  - Anisolpidiaceae Karling 1943
- Lagenismatales Dick 2001
  - Lagenismataceae Dick 1995
- Salilagenidiales Dick 2001
  - Salilagenidiaceae Dick 1995
- Rozellopsidales Dick 2001
  - Rozellopsidaceae Dick 1995
  - Pseudosphaeritaceae Dick 1995
- Ectrogellales
  - Ectrogellaceae
- Haptoglossales
  - Haptoglossaceae
- Eurychasmales
  - Eurychasmataceae Petersen 1905
- Haliphthorales
  - Haliphthoraceae Vishniac 1958
- Olpidiopsidales
  - Sirolpidiaceae Cejp 1959

o Pontismataceae Petersen 1909

o Olpidiopsidaceae Cejp 1959

• Atkinsiellales

o Atkinisellaceae

o Crypticolaceae Dick 1995

• Saprolegniales

o Achlyaceae

o Verrucalvaceae Dick 1984

o Saprolegniaceae Warm. 1884 [Leptolegniaceae]

• Leptomitales

o Leptomitaceae Kuetz. 1843 [Apodachlyellaceae Dick 1986]

o Leptolegniellaceae Dick 1971 [Ducellieriaceae Dick 1995]

• Rhipidiales

o Rhipidiaceae Cejp 1959

• Albuginales

o Albuginaceae Schroet. 1893

• Peronosporales [Pythiales; Sclerosporales; Lagenidiales]

o Salisapiliaceae

o Pythiaceae Schroet. 1893 [Pythiogetonaceae; Lagenaceae Dick 1994; Lagenidiaceae; Peronophythoraceae; Myzocytiopsidaceae Dick 1995]

- o Peronosporaceae Warm. 1884 [Sclerosporaceae Dick 1984]

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.

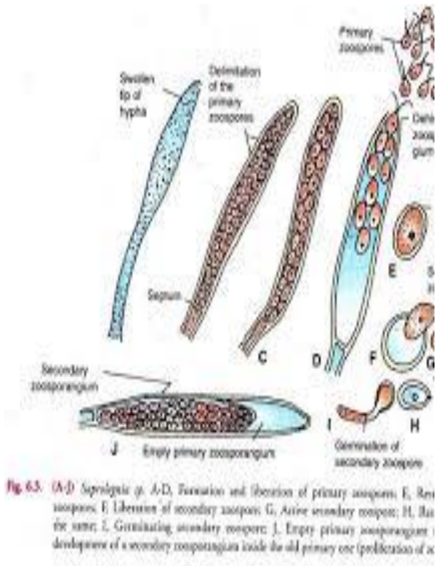
Development of zoosporangium:

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

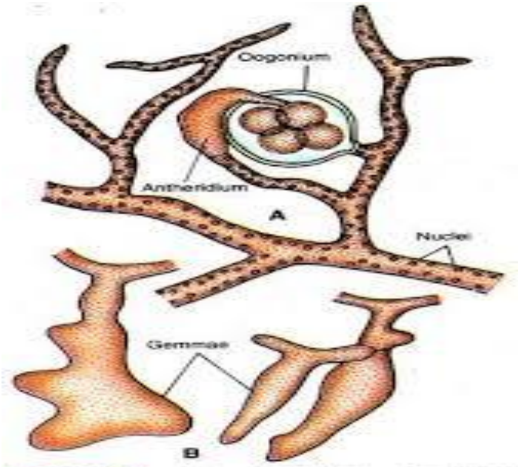


Fig. 6.2 (A-B). *Saprolegnia sp.* A. Hyphae showing structure as seen under the light microscope and bearing sex organs;

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 type 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).

Systematic position of *Albugo candida*

Class: *Oomycetes*

Order: *Peronosporales*

Family: *Albuginaceae*

Genus: *Albugo*

Species: *Albugo candida*

Characteristic feature

1. The family has a genus *Albugo*, which is pathogenic in mature.

2. *Albugo candida* cause white rust on cruciferous plants (Brassicaceae).

3. White dust like powder on the leaves is the identifying character of this genus, so they are called white rust.

4. The mycelium is intercellular forming small knob-like haustoria which penetrates the host cells.

5. The mycelium grows and ramifies in the host tissues and produce short, club-shaped sporangiophores from the tips of many hyphal branches when a certain stage of maturity is reached.

6. The sporangia are formed below epidermis in chains

7. The pressure of the developing chains of sporangia raises the host epidermis and finally rupture it.

8. The sporangia are then exposed to the outside environment and appear as a white powdery mass.

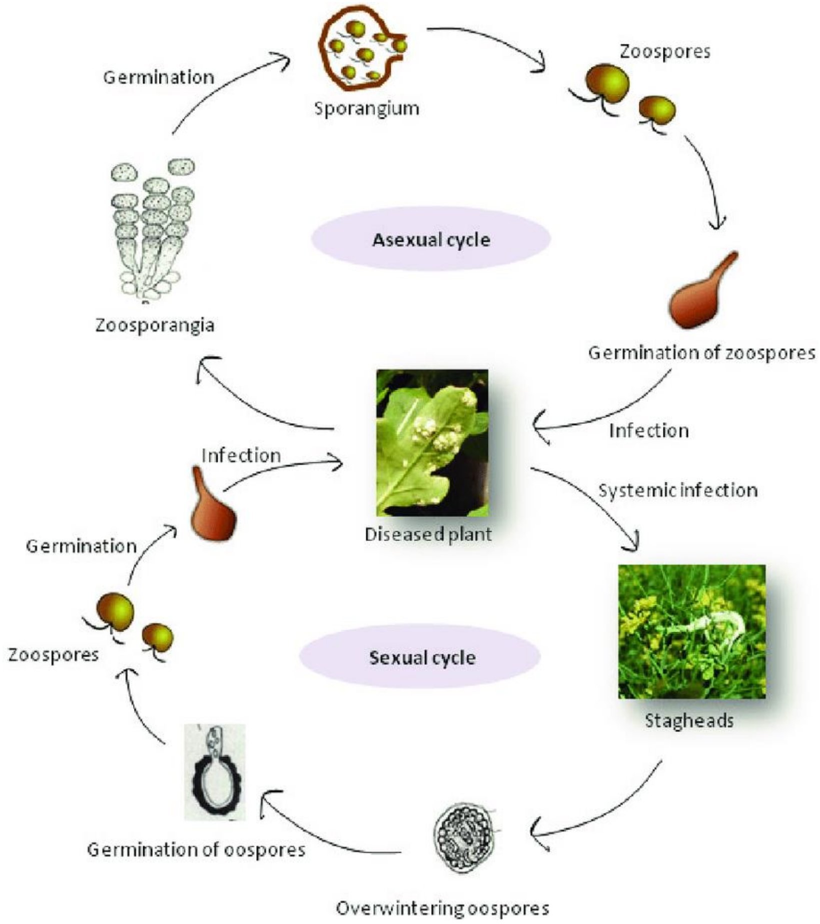
9. The sporangia germinate by germ tube or by producing biflagellate zoospore

10. The zoospore are produced in sessile vesicle.

11. After a period of motility the biflagellate zoospore become spherical, encyst and then form germ-tube which enter the host.

12. Sexual reproduction may follow the asexual reproduction.

13. Sex organ are produced from the tips of the hyphae in the intercellular spaces of the infected tissues.



LIFE CYCLE OF *Albugo candida*

Class: Oomycetes
Order: Peronosporales
Family: Peronosporaceae
Genus: Phytophthora
Species: *Phytophthora infestans*

Phytophthora infestans is an oomycete or water mold, a fungus-like microorganism that causes the serious potato and tomato disease known as late blight or potato blight.

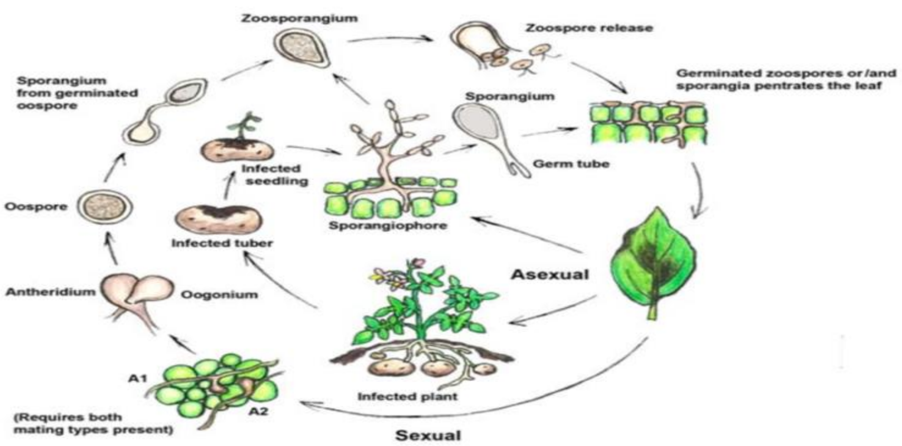
The first of these is *Phytophthora infestans*, the organism which causes late blight of potato. The potato is native to North America, but once it was introduced to Europe, it quickly became an important food crop. Late blight did not follow its host plant across the Atlantic until much later; the disease organism grows into the stem and leaf tissues, causing death, and may also infest the **tubers**, which are the part of the plant that is eaten.

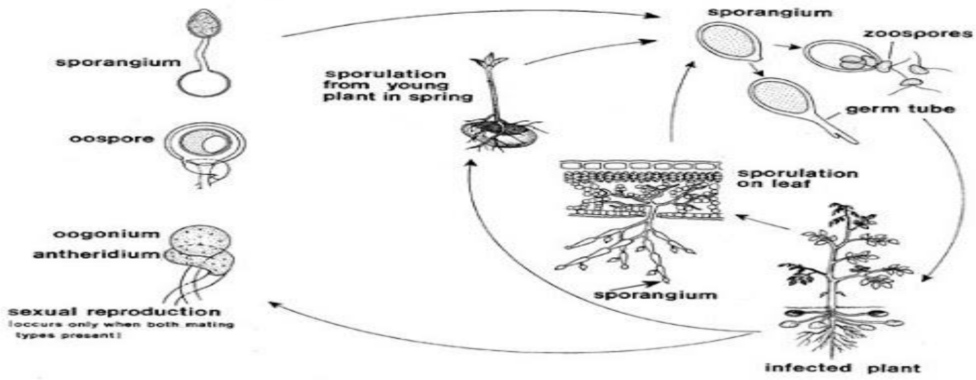
The disease spreads rapidly under cool and damp conditions, which are common in western Europe. In one week during the summer of 1846, this diease wiped out almost the entire potato crop of Ireland, a crop which was the primary food of the poor at that time. Nearly a million Irish died in the Great Famine, and an additional one-and-a-half million emigrated to other countries, including America. Thus, if you are an American with Irish ancestry, it was probably the oomycetes that brought your family here. Other species of *Phytophthora* destroy eucalyptus, avocado, pineapples, and other tropical crop plants.

1. Phytophthora cause late blight of potato.
2. The mycelium is coenocytic, intercellular with haustoria.
3. The zoospores are produced within the vesicle.
4. The protoplasm moves towards the vesicle and then zoospore are produced
5. The zoospore are released from the sporangium through the exit at the point of Papilla
6. The zoospores are laterally biflagellate and uninucleate
7. Zoospore swims, come to rest, encyst and germinate by means of germ tube.
8. The term tube produces an appresorium, at its point of contact with the host tissue.
9. Sexual reproduction by means of antheridia and oogonia of opposite mating type

Biology and ecology

p. Infestans exists as an asexual organism it is essentially an obligate parasite. It requires a living host (crop debris or solanaceous weeds) for long-term survival. Whereas sporangia may survive days or weeks in soil, they cannot overwinter or overseason. Mycelium of the fungus cannot survive in the absence of a living host cell. However, in locations where sexual reproduction occurs, the resulting oospore can survive for months or years in the absence of living hosts (drenth et al., 1995).





This is a simplified disease cycle for late blight of potato.

(2) Chytridiomycetes and Hyphochytriomycetes

The Chytridiomycetes, which are true Fungi and the Hyphochytriomycetes, are treated together because species from both groups are outwardly similar, occupy the same habitats, and are studied with the same techniques. The hyphochytrids consist of a single order with three families and four genera. Members characteristically produce zoospores with a single, anterior, tinsellated flagellum. The five orders that comprise the class Chytridiomycetes are defined on the basis of differences in ultrastructural characters of zoospores. Members of all orders except some species in the specialized Neocallimastigales have zoospores with a single, posteriorly directed flagellum. The Chytridiales, Monoblepharidales, and Blastocladiales are found in water and in soils. The Spizellomycetales primarily inhabit soils but may be found at the margins of lentic and lotic aquatic habitats. Representatives of the Neocallimastigales are obligate anaerobes and, thus far, have been isolated only from the digestive systems and feces of herbivorous animals, with the exception of a single isolation from a farm pond .

The Blastocladiales contains five families and 13 genera. Some taxa, including the well-known, experimental organisms, *Allomyces* and *Blastocladiella*, are saprotrophic, but many others are specialized parasites of invertebrates (e.g., *Coelomomyces* species in mosquito larvae). *Physoderma*, a genus whose members parasitize aquatic and semiaquatic plants, also belongs to this order. Monoblepharidales contains four families and six genera, all saprotrophic. Members of the Chytridiales first were described in the 1850s; currently four families and about 80 genera containing more than 500 species are recognized. In 1980, Spizellomycetales, which contains four families and 10 genera, was separated from Chytridiales on the basis of ultrastructural characters of zoospores.

Most of the diversity of the Chytridiomycetes lies within the Chytridiales, but unfortunately, studies of that group are severely limited by the lack of adequate species descriptions, mentors who can help with identifications, and recent identification guides. The most recent monograph that includes Chytridiomycetes and Hyphochytriomycetes is Sparrow's *Aquatic Phycomycetes* (1960), which he later followed with a key to genera (Sparrow 1973). More than 23 genera and 300 species have been described since Sparrow's monograph and are listed along with other changes in taxonomy in a bibliography by Longcore (1996). Taxa described since 1960, however, have not been incorporated into taxonomic keys. *Zarys hydromikologii* (Batko 1975) is dedicated exclusively to aquatic fungi, but its usefulness is limited in many countries because the keys are written in Polish and are not comprehensive in their coverage of species. *Chytridiomycetarum Iconographica* (Karling 1977) contains commentaries on genera of chytrids and hyphochytrids and many drawings. Because it is tempting to use Karling's drawings to “picture-key” aquatic fungi, we emphasize that his book portrays only a fraction of the described species. Investigators who wish to identify chytrids and hyphochytrids, particularly those described since 1960, need to refer to original descriptions.

Reviews of the ecology of freshwater fungi (Sparrow 1968; Dick 1976; Powell 1993) provide an overview of what is known about the diversity of zoosporic fungi. Knowledge of the diversity of zoosporic fungi in several geographic areas has accrued as a consequence of the career research of mycologists who specialize in those groups. Notable in this regard with respect to aquatic habitats are the papers of H. M. Canter and colleagues, which document chytrids associated with algae in the Lake District of England (see references in Karling 1977). Knowledge of the aquatic mycota of the

Lake District was broadened further by L. G. Willoughby's studies of the saprotrophic chytrids of the margins and muds of several lakes in that area (see references in Karling 1977).

Similarly, a general knowledge of the diversity of chytrids and other aquatic fungi found in northern Michigan, in the United States, exists as a result of the research of F. K. Sparrow and colleagues. Over a span of about 20 years, those researchers published papers on zoosporic fungi from aquatic sites and soils throughout the northern counties of the lower peninsula of Michigan. Their studies emphasized the fungi, not the habitat.

The Chytridiomycetes and Hyphochytriomycetes are denoted as “aquatic” fungi because they disperse through water with motile spores. After rain or snow melt, most soils are transformed into an “aquatic” habitat in which chytrids and hyphochytrids are widespread. Consequently, many aquatic fungi have been studied from soil samples, which contain resting spores of zoosporic fungi, because they are relatively easy to collect and transport. For example, Karling based his reports of zoosporic fungi from India, Africa, New Zealand, Oceania, and various South American countries mostly on his studies of soil samples, although some of the soil samples came from dried aquatic habitats. Willoughby (1962a, 1962b) reported differences between the species found in lakes and those usually found in soils, but many species have been reported from both aquatic habitats and soils.

Chytrids associated with discrete, countable substrata such as algae have been quantified; for reviews see Masters (1976) and Powell (1993). In northern North America, conifers produce an annual shower of pollen, which falls in such abundance that yellow pollen lines surround lake shores. Ulken and Sparrow (1968) used a modification of the most probable number (MPN) method used by bacteriologists and found that the number of chytrid zoospores that attack pollen grains per liter of lake water peaked during the 2 weeks following the height of the pollen shower.

Endemism has not been known among chytrids and hyphochytrids; however, recent molecular evidence (Morehouse et al. 2000) suggests that *Batrachochytrium dendrobatidis*, a chytridialean pathogen of amphibians, may have recently spread to several continents. Sparrow's experience with Michigan fungi allowed him to observe that several of the fungi he found in a bog in the Hawaiian Islands belong to the same species that occur in bogs in northern Michigan (Sparrow 1965). Chytrid species with morphologies so distinctive as to preclude misidentification have been reported from different continents. The prevailing hypothesis is that chytrid species are distributed worldwide, with occurrence determined by local conditions rather than geography (Sparrow 1968).

Structure and Thallus Organization

Chytrids are monocentric (with one reproductive body, either a sporangium or resting spore) or polycentric (with more than one reproductive body). Monocentric species are either holocarpic (having alI the thallus used for the reproductive body) or eucarpic (having only part used for the reproductive body). It is the presence or absence of rhizoids that determines whether a monocentric species is holocarpic or eucarpic, but often the rhizoids are difficult to see inside a host cell, and may be evanescent. Sporangium development is said to be endogenous if the nucleus remains in the zoospore cyst, where it multiplies. The sporangium develops from expansion of the cyst, or a lateral expansion where the cyst wall remains as an ornament on the sporangium wall. The nucleus migrates into the germ tube and rhizoid, where the sporangium develops following nuclear division, sporangium development is said to be exogenous (i.e., outside the zoospore cyst). Exogenous-endogenous development occurs in *Catenochytridium* (Barr et al. 1987). The nucleus migrates into the germ tube, where a prosporangium is formed, and the zoospore cyst is left empty. The contents of the prosporangium then move back into the zoospore cyst, which usually ruptures, and the sporangium is formed outside the germ tube. A unique form of development is found in *Caulochytrium*. It produces either sessile sporangia or stalked, aerial sporangiocarps

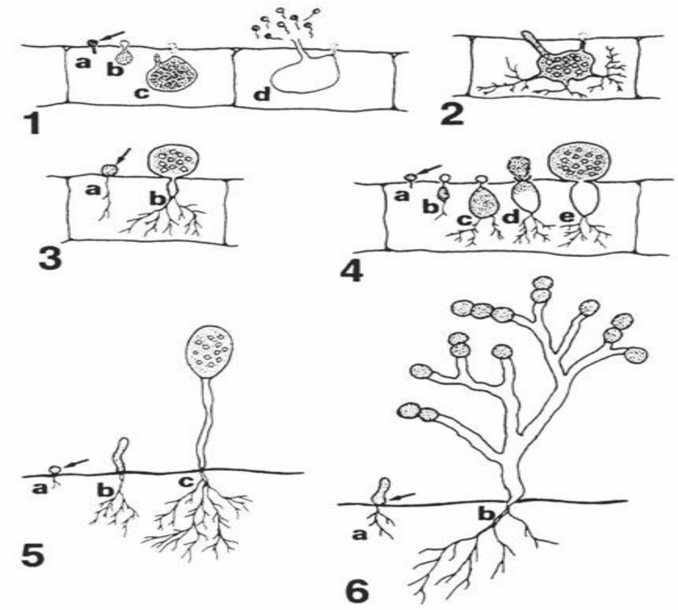


Fig. 1-6. Morphological forms. Fig. 1. Monocentric, holocapric thallus with exogenous sporangium formation: a zoospore cyst (arrow) with a short germ tube; b movement of nucleus into the swollen germ tube; c an endobiotic sporangium with a developing discharge tube, and empty zoospore cyst; and d an empty sporangium following release of zoospores. Fig. 2. Monocentric, eucarpic thallus with exogenous sporangium formation; a mature sporangium with rhizoids arising from three axes, a discharge tube, and empty zoospore cyst. Fig. 3. Monocentric, eucarpic thallus with endogenous sporangium formation: a germling following enlargement of the zoospore cyst (arrow); and b enlargement of the zoospore cyst into a mature epibiotic sporangium with an endobiotic rhizoid system. Fig. 4. Exo-endogenous sporangium development: a germinating zoospore cyst (arrow); b movement of the nucleus into thc germ tubc lcaving the cyst empty, and early formation of rhizoids; c an endobiotic, exogenously formed prosporangium; d movement of the contents of the prosporangium back into the zoospore cyst; and e a mature, epibiotic sporangium. Fig. 5. Monocentric thallus with bipolar germination: a zoospore cyst (arrow); b developmcnt of a sporangiophore and rhizoid system; and c sporangium on the end of a sporangiophore. Fig. 6. Polycentric thallus: a bipolar germination of a zoospore cyst (arrow); and b development of a branched thallus with numerous reproductive bodies

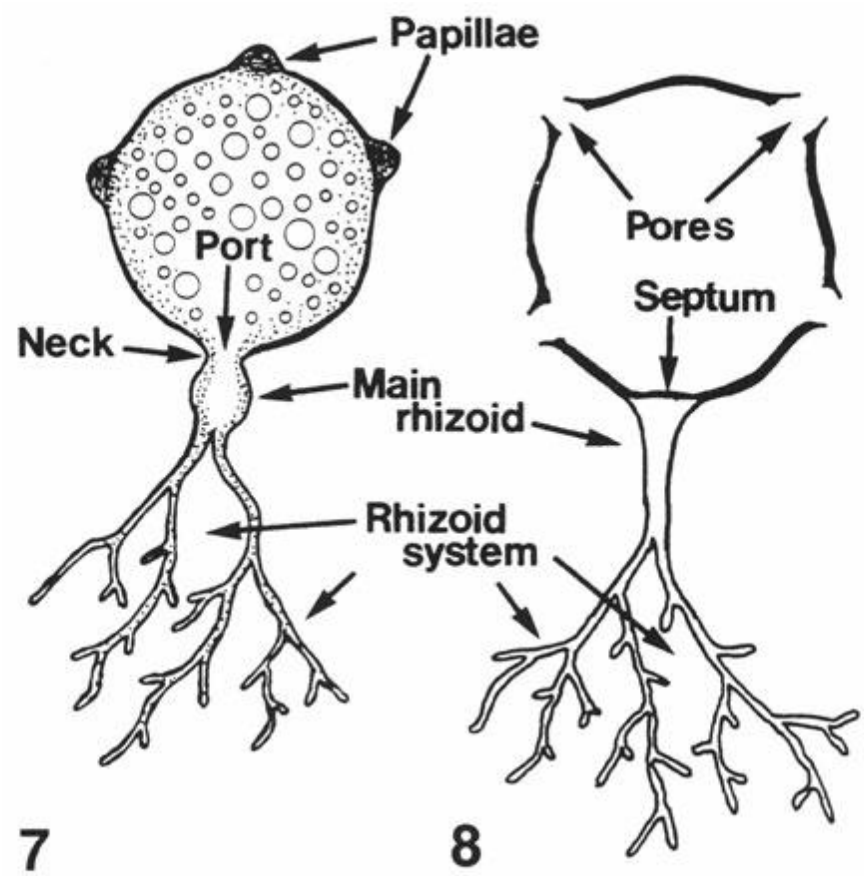


Fig. 7, 8. Thallus terminology. Fig. 7. A mature, endobiotically formed sporangium with a single rhizoid axis. Fig. 8. An empty sporangium

(Olive 1980). The terms epibiotic, endobiotic and interbiotic are used to describe the reproductive parts of the thallus relative to the substrate. Epibiotic refers to a reproductive body on the surface, endobiotic for inside the host cell, and interbiotic where the reproductive body is not immediately related to the substrate, and is connected, of ten to two or more cells, by rhizoids. Certain taxa such as Chytridium have endo-exogenous sporangium development. In these taxa there is an endobiotic resting spore and an epibiotic sporangium. Unfortunately, the position of the reproductive body can be affected by the growing conditions.

Classification

1. Chytridiales

All species have unifiagellated zoospores, although the occasional zoospore may be biflagellated or rarely multiflagellated. Zoospores tend to be globose to subglobose, in some species elongated when actively swimming, and ameoboid only before encystment.

2. Spizellomycetales

All species have unifiagellated zoospores but the occasional zoospore may be bifiagellated or rarely multifiagellated. Zoospores are mainly irregular and undergo ameboid movement while actively swimming.

3. Blastocladiales

Zoospores are elongate and distinguishable even in the light microscope. The nucleus is cone-shaped.

4. Monoblepharidales

The zoospore is uniflagellated and elongate. The nucleus is centrally located in the zoospore.

5. Neocallimastigales

Zoospores of some species are uniflagellated but often have up to four flagella, and zoospores of other species are always polyflagellated.

The following examples are discussed here;

1. Blastocladiales ex. *Allomyces*
2. Mucorales ex. *Mucor*

Division: Mastigomycota

Subdivision: Haplomastigomycotina

Class: Chytridiomycetes

Order: Blastocladiales

Family: Blastocladiaceae

Genus: Allomyces sp.

The genus of *Allomyces* was frist discovered in India at 1911. Subsequently it was found to be worldwide in tropical or warm country. It is saprophyte fungus found in soil, plant remains and decaying animals. The genus comprises 5 species.

Thallus structure: It is filamentous and attached to the substratum by delicate but well formed, branched rhizoidal hyphae constituting the rhizoidal system. From the latter arises a single slender hypha forming the lower trunk-like portion which subsequently undergoes several dichotomous branching to form dichotomously branched part of the mycelium on which the reproductive organs are borne terminally. The hyphae are thus multinucleate and coenocytic.

The vegetative thalli in *Allomyces* are two types, gametophyte (haploid) and sporophyte (diploid). In the vegetative phase the two are indistinguishable.

Towards maturity: -

1- The gametophyte bear more or less globose gametangia which are orange male gametangium alternating with colourless female gametangium. and sporothallus produce sporangia.
2- The sporophyte produce two types of sporangia:

a. Colourless thin walled sporangia (Mitosporangium)
b. Thick walled reddish Brown resting or resistance sporangia (Meiosporangium)

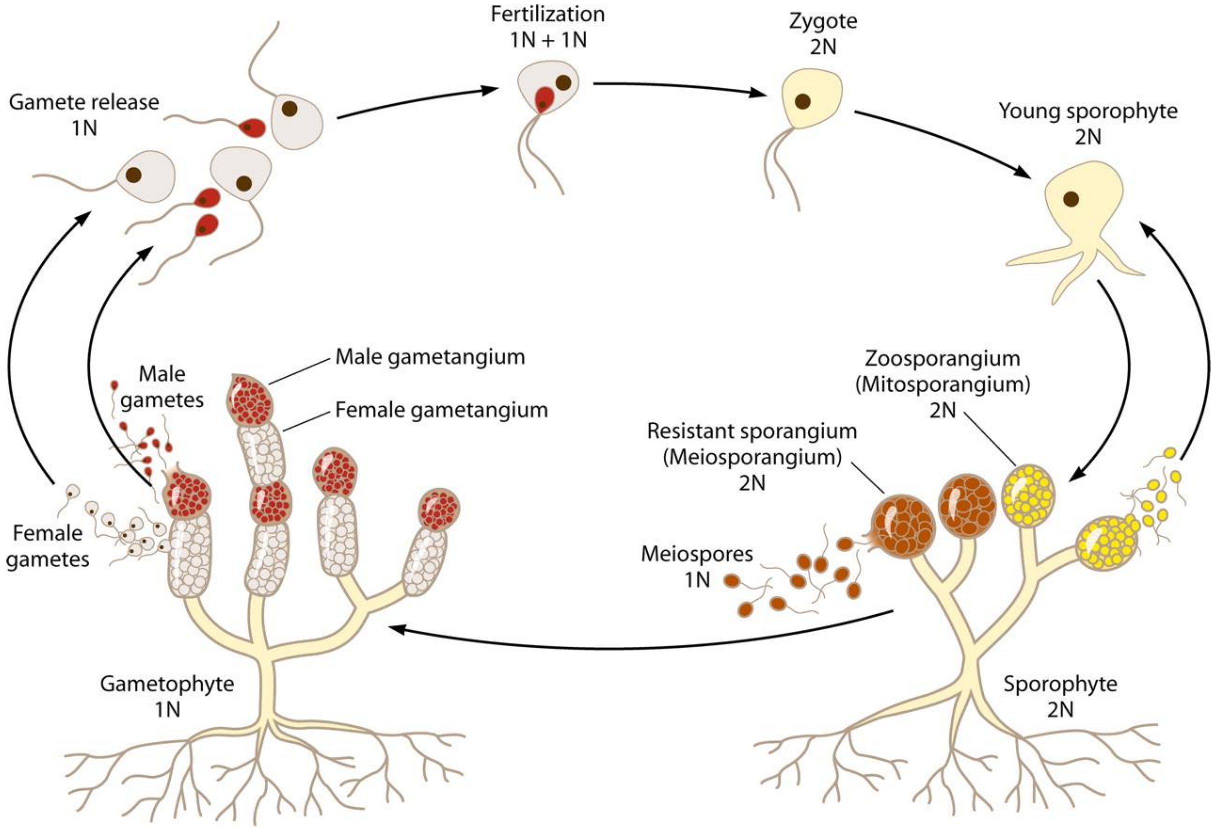
Life cycle

Allomyces in its life cycle exhibits distinct alteration of generations. One of these is the haploid (gametophyte) and other diploid (sporophyte).

At maturity the sporophyte produce two types of sporangia, thin walled mitosporangia and thick walled, pitted resting or resistant meisporangia. The mitosporangia produce diploid zoospores (mitozoospores) which after liberation grow to give diploide sporophyte (secondary sporophyte).

The meisporangium prior germination undergoes meiosis division forming meiozoospores which on germination produce an alternate plant in life cycle called gametophyte.

The gametophyte at maturity bearing orange male and colourless female gametangia which produce haploid male and female gametes. After liberation, fusion take place between male and female gamete forming zygote (2N) which germinate to form new sporophyte (2N).



Life cycle of *Allomyces*

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

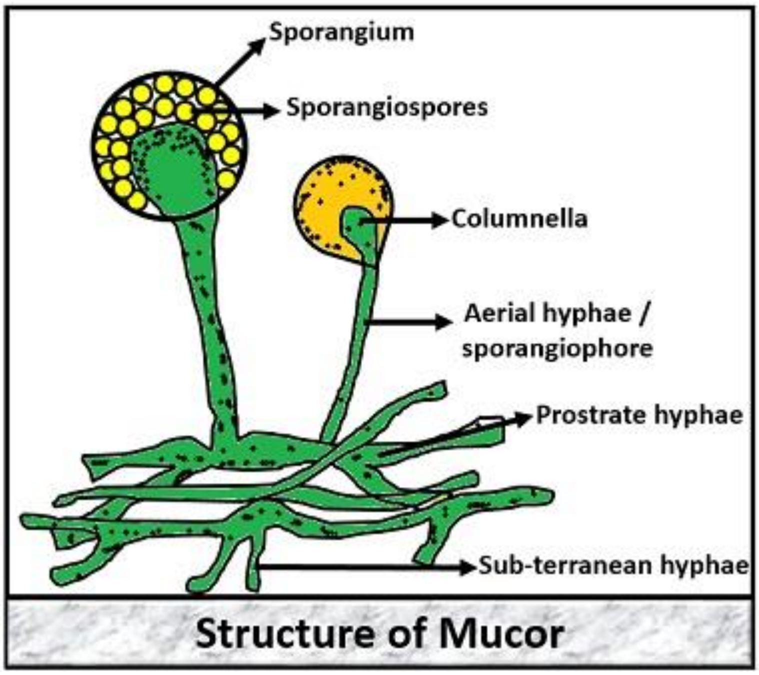
It is the round and thick outer covering which carries numerous spores inside it. It can be globose to spherical.

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.

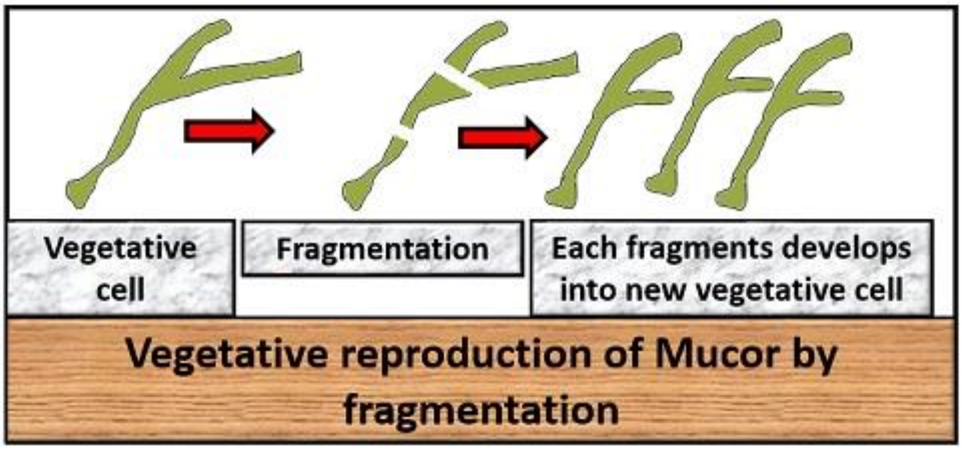
Life cycle of *Mucor*

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.



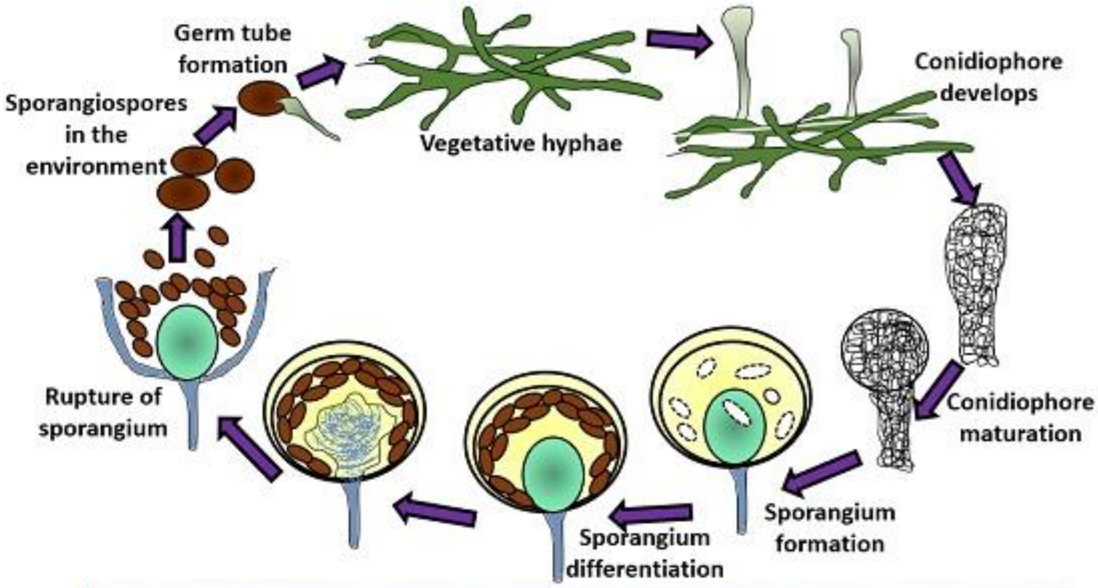
Asexual Reproduction

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:



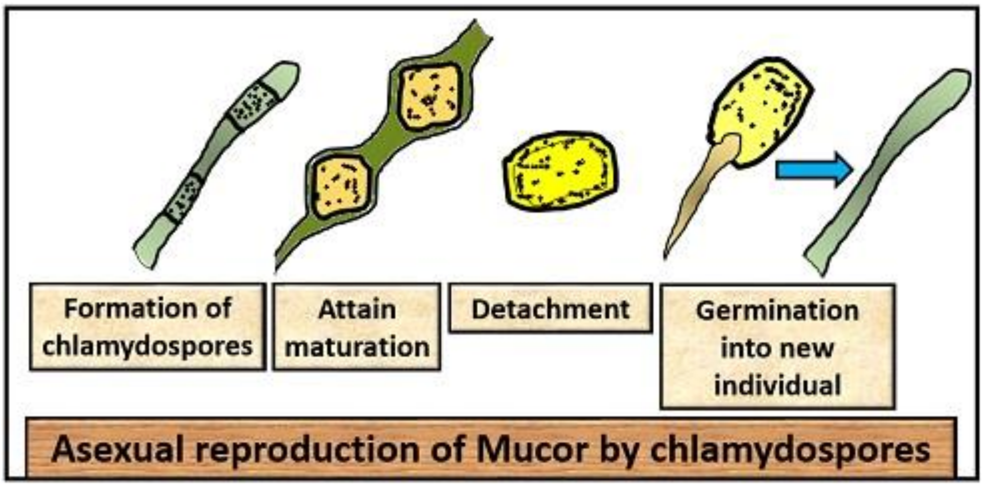
Asexual reproduction of Mucor by sporangiospores

- 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.

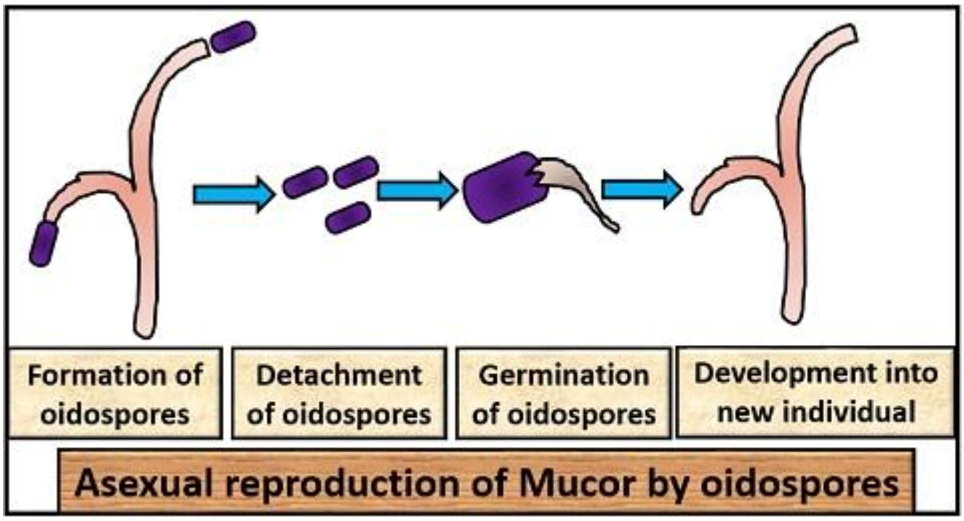
Chlamydospores

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.



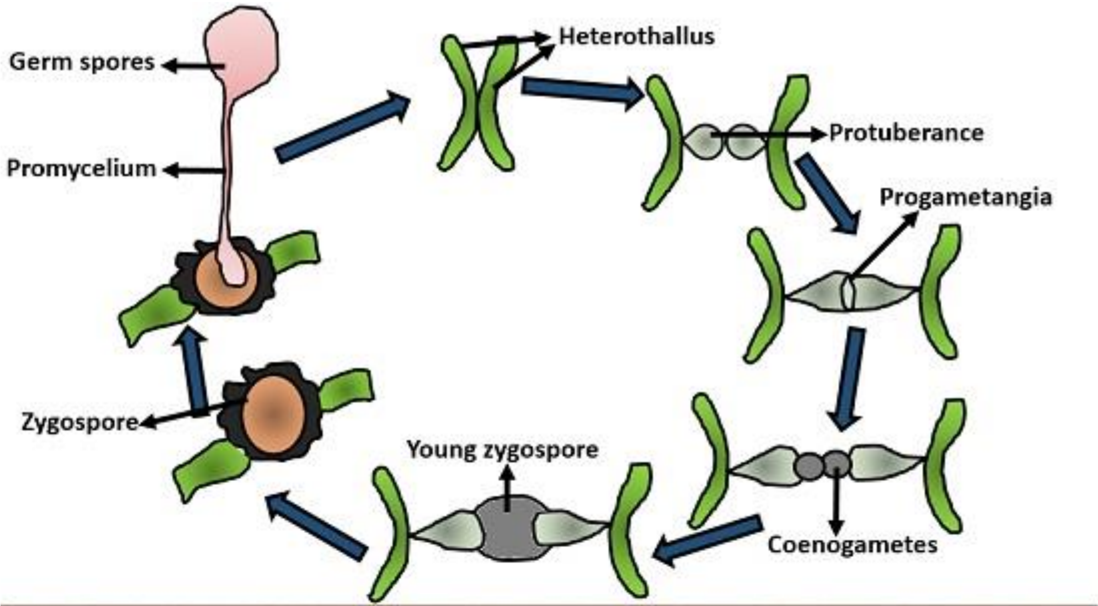
Oidiospores

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.

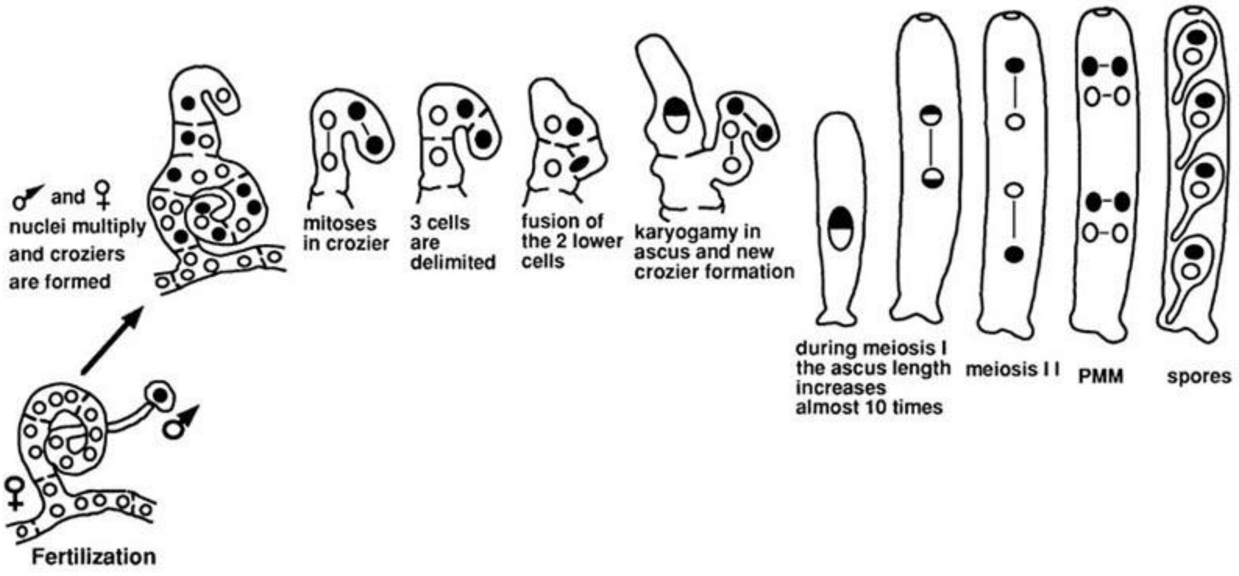
Structure : except for members such as yeast the plant body of ascomycetes is

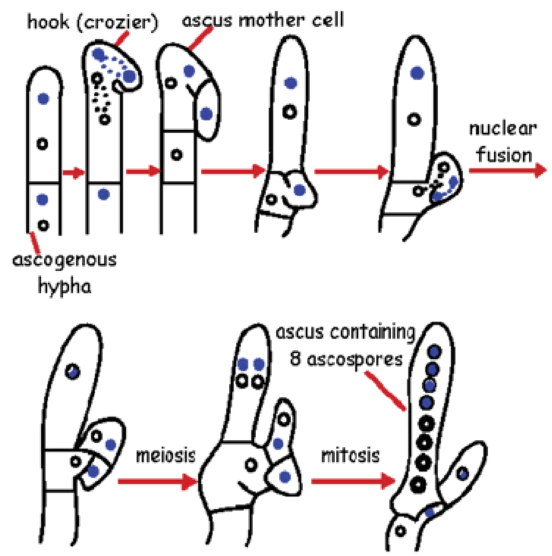
- A septate much branched mycelium.
- Cell wall contains a large portion of chitin.
- The cells of the hyphae may be uninucleate, binucleate or multinucleate.

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.





<u>Ascospore formation</u>

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:

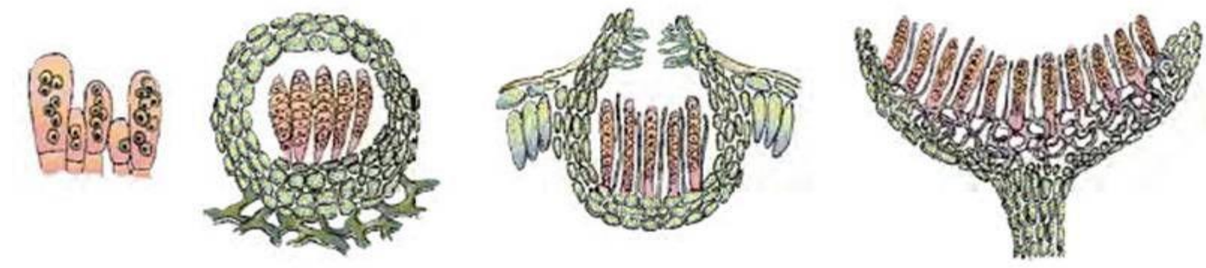
In great majority of ascomycetes the asci are enclosed in compact protective structure called the fruiting body or frutification or Ascocarp. Ascocarps vary in structure and composition, they may be classified into four categories:

(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)

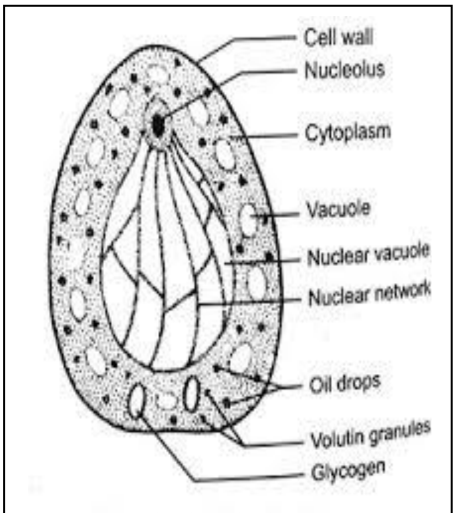
Pyrenomycetes (perithecium)

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 are saprophytes, and are 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.

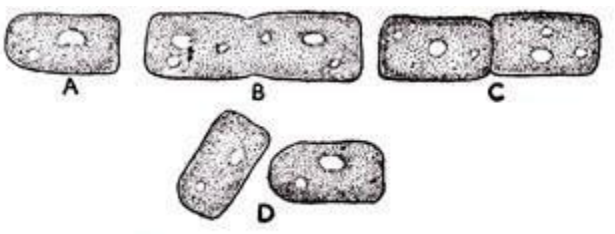


Fig. 217. *Schizosaccharomyces octosporus*. Stages in cell multiplication by fission.

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).

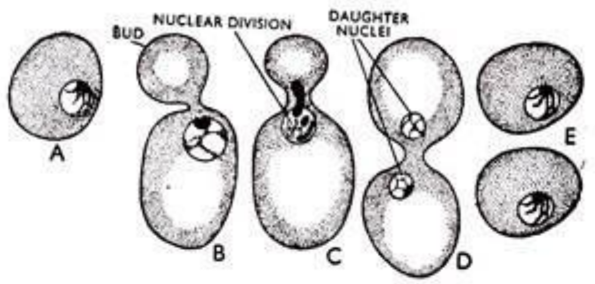


Fig. 218. *Saccharomyces cerevisiae*. Stages in cell multiplication by budding.

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.

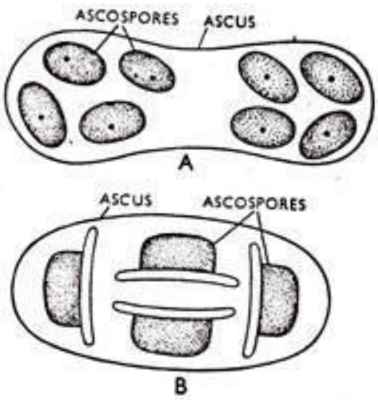


Fig. 219. Various types of yeast ascospores. A. *Schizosaccharomyces octosporus*. B. *Hansenula* sp.

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.

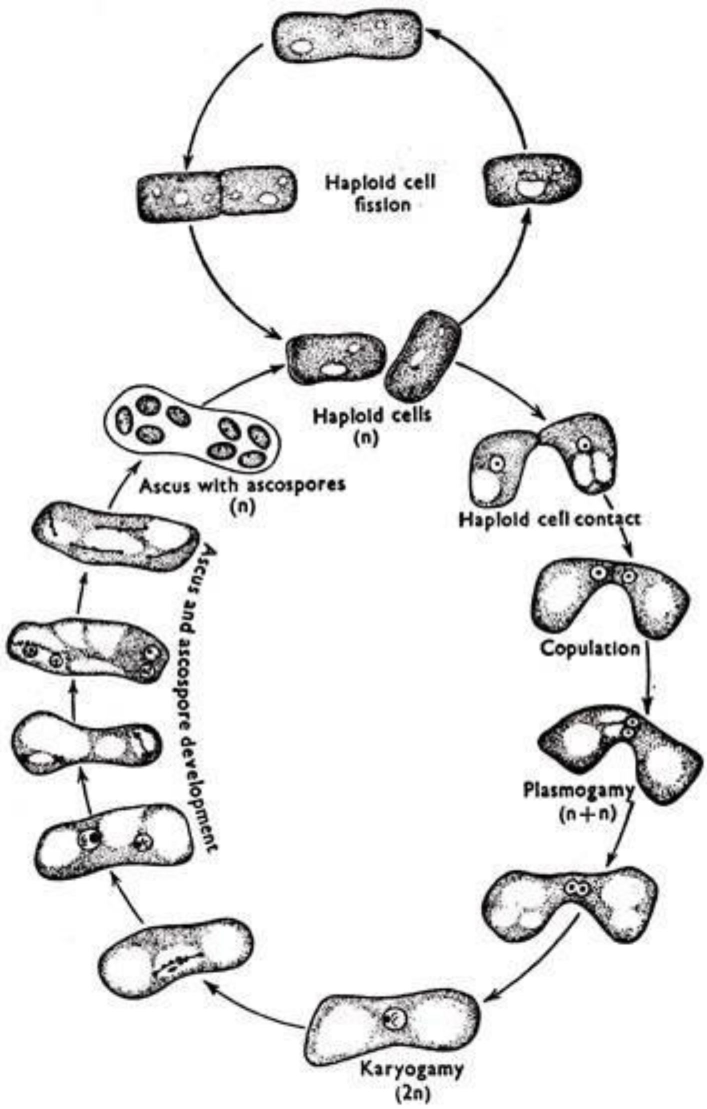


Fig. 220. Haplobiontic life cycle of *Schizosaccharomyces octosporus*.

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.

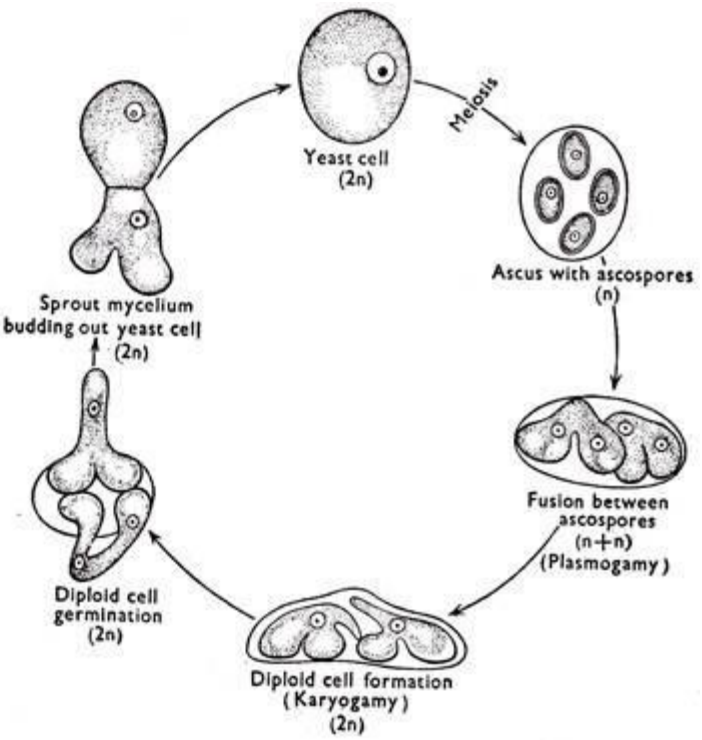


Fig. 221. Diplobiontic life cycle of *Saccharamycodes ludwigii*.

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.

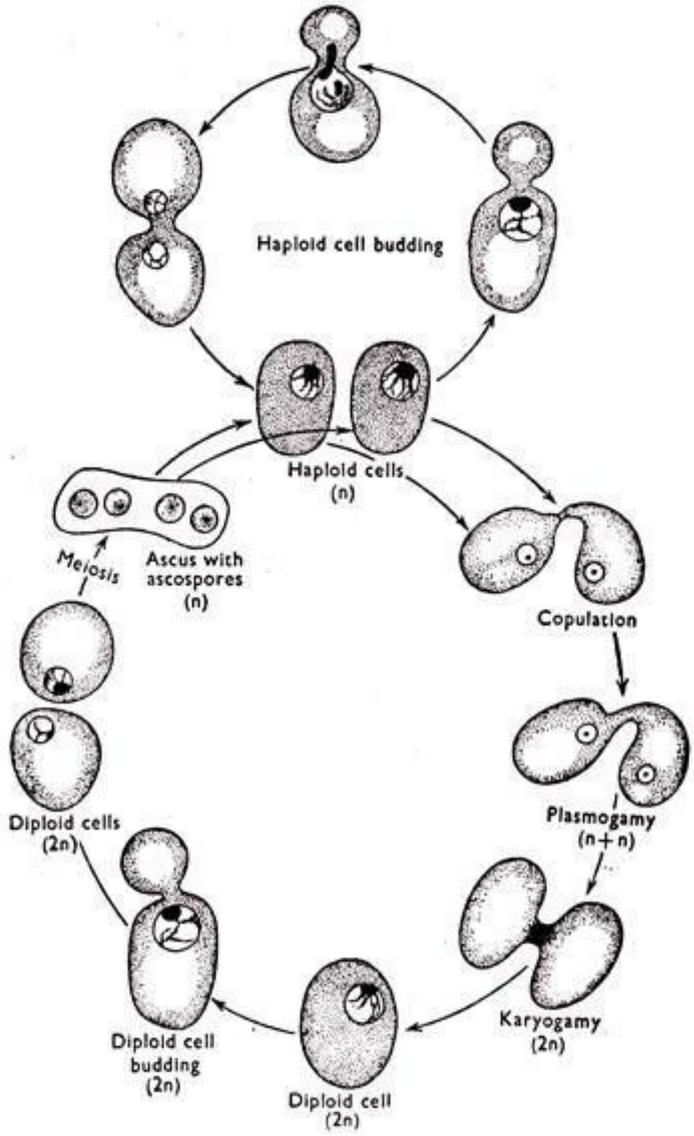


Fig. 222. Haplo-diplobiontic life cycle of *Saccharomyces cerevisiae*.

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.

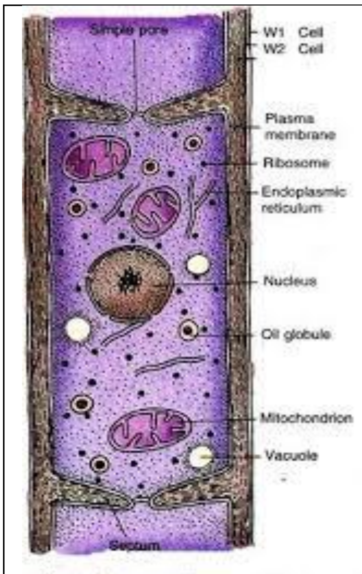
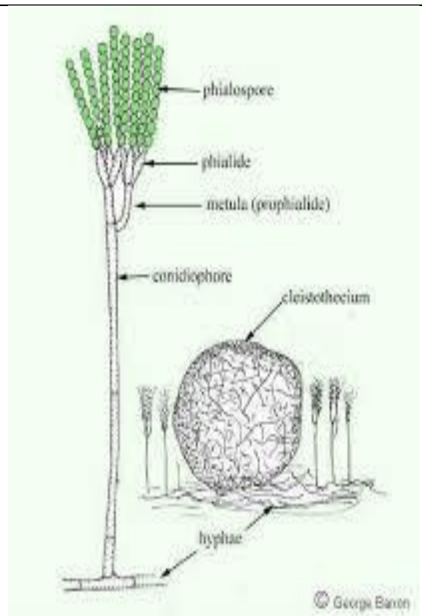


Fig. 10.9. *Penicillium sp.* Diagrammatic representation of fine structure of a cell.



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.

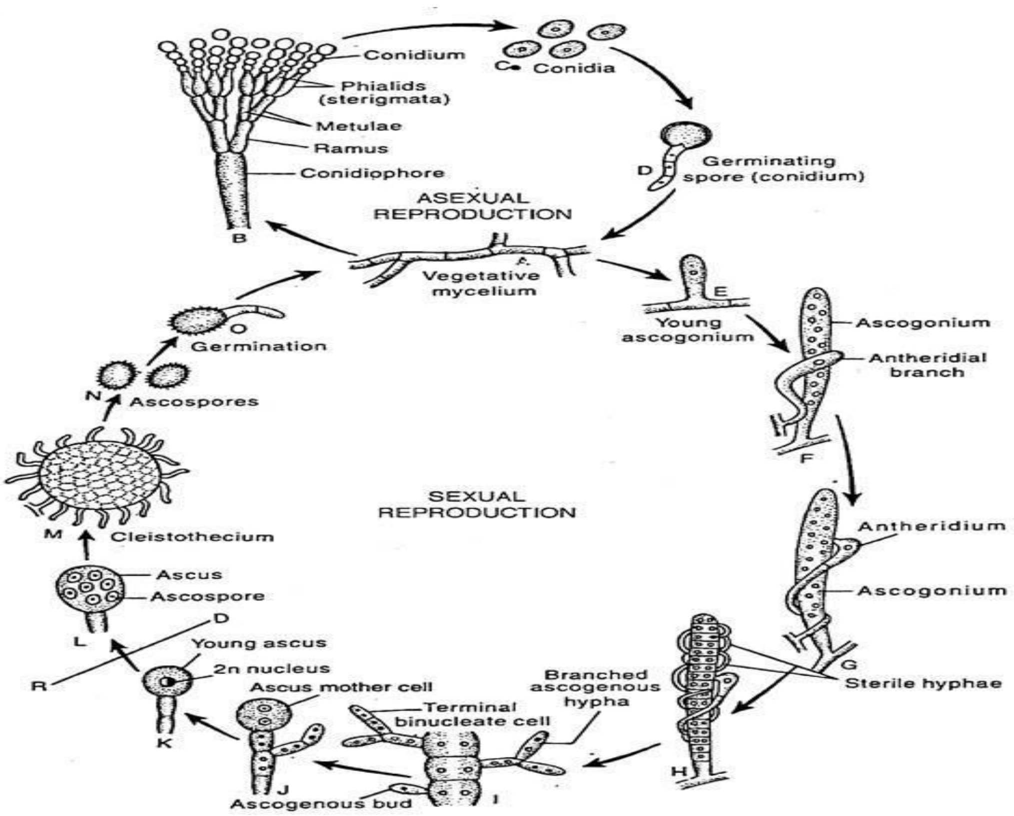


Fig. 4.44 : Life cycle of *Talaromyces vermiculatus* (*Penicillium vermiculatum*)

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.

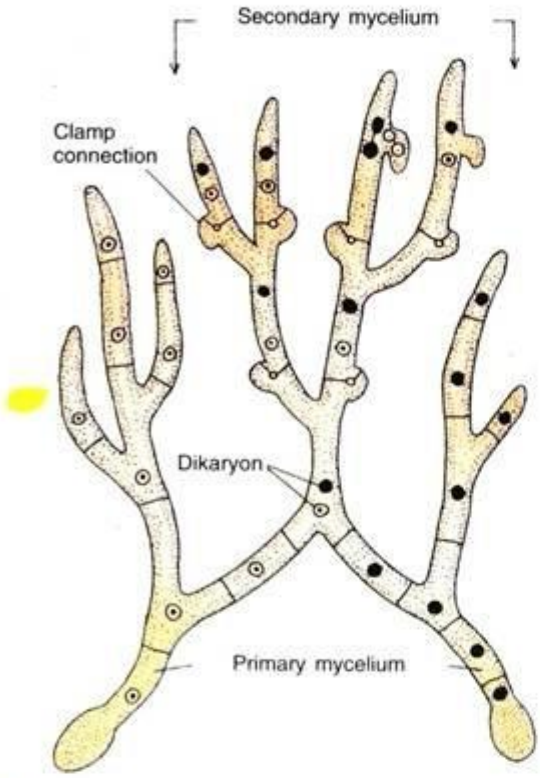


Fig. 13.2. *Basidiomycetes.* Sketch showing the formation of a secondary mycelium from a dikaryotised cell produced by somatogamous copulation between two uninucleate cells of primary mycelia of opposite strains.

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

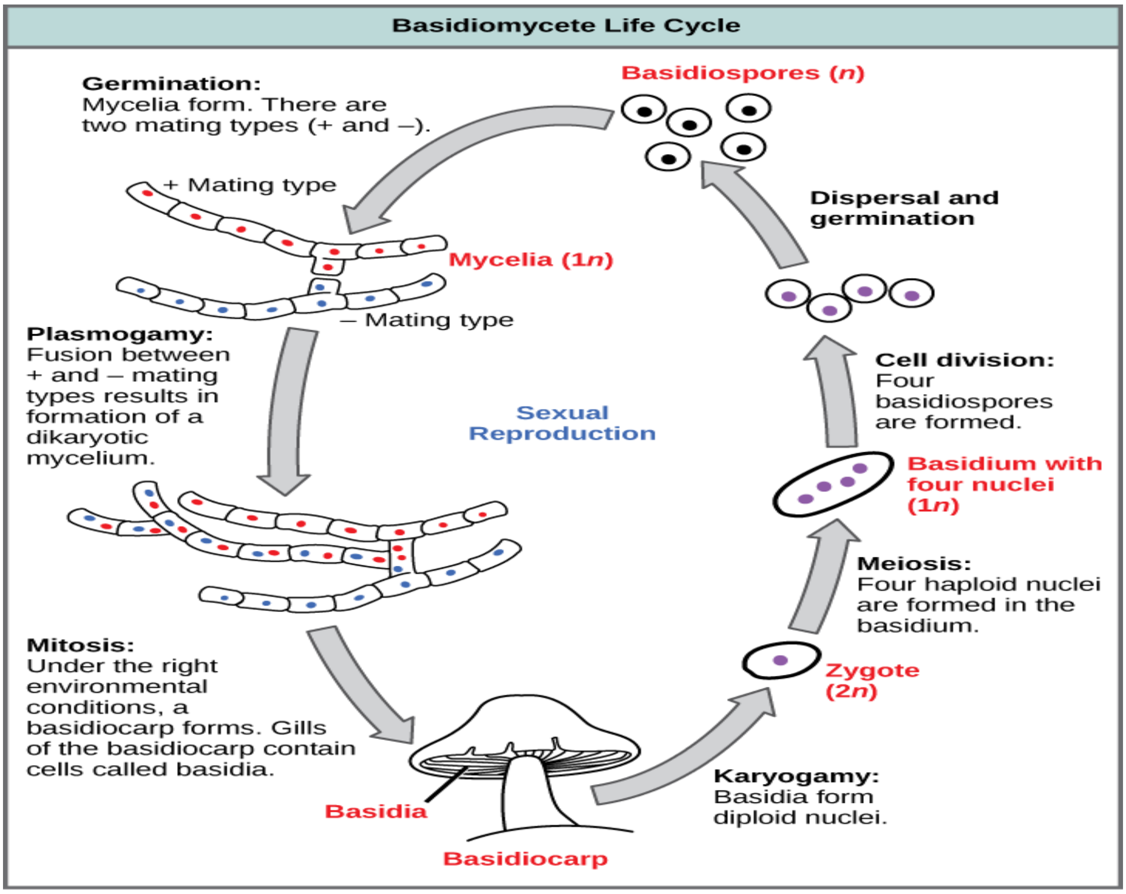
Sexual reproduction: there are four stages

(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.

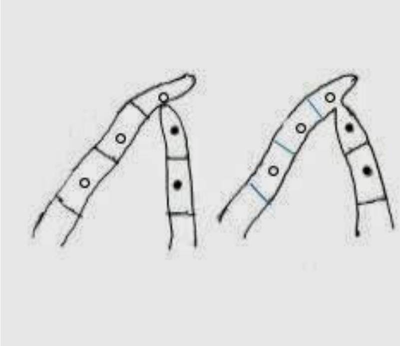
Vegetative structure: Vegetative body mycelia consists of septate much branched hyphae. Spore on germination develop into monokaryotic or primary mycelium, either + or- typ. The primary mycelium is short lived and it soon transform into diakaryotic or secondary mycelium by the fusion of two cell of different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

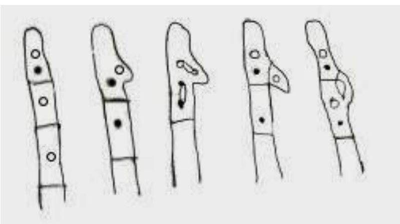


Stages of plasmogamy

SEXUAL REPRODUCTION

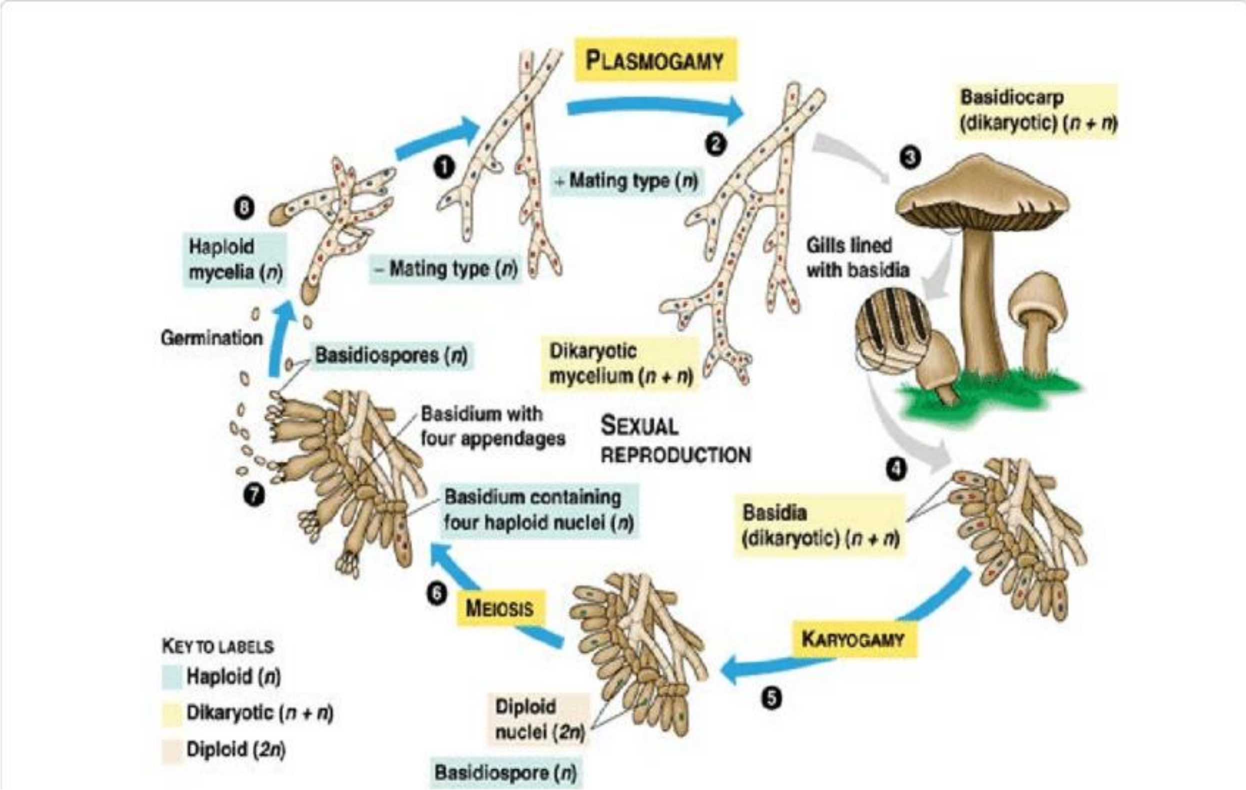
Sex organ are absent in *Agaricus* and sexual reproduction takes place by somatogamy. Most of the species including *Agaricus campestries* are heterothallic. Somatogamy includes plasmogamy, karyogamy, and meiosis. Karyogamy does not take place immediately after plasmogamy, but meiosis follows soon after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

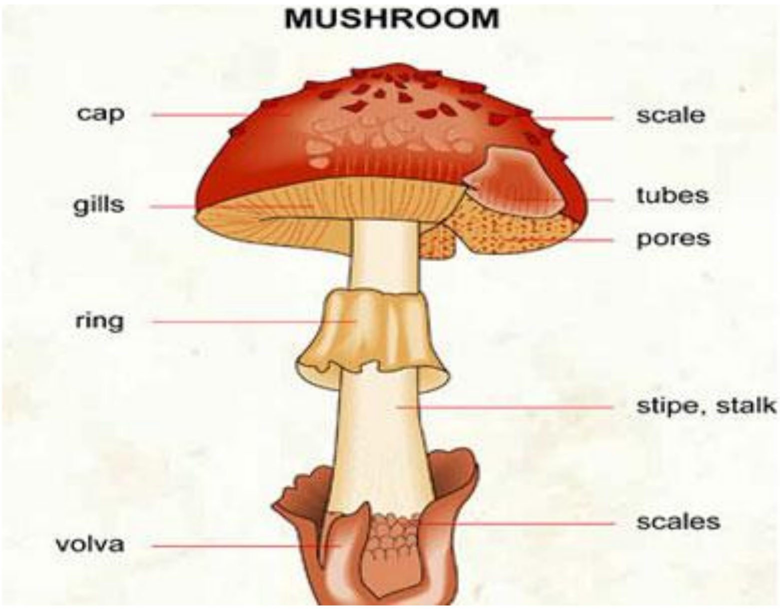


Growth of mycelium by clamp connection

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.

Role of Soil Fungi

Fungi are an important part of the microbial ecology. The majority of fungi decompose the lignin and the hard-to-digest soil organic matter, but some fungi consume simple sugars. Fungi dominate in low pH or slightly acidic soils where soils tend to be undisturbed (Lavelle & Spain, 2005). Fungi break down the organic residues so that many different types of microbes can start to decompose and process the residues into usable products.

Approximately 80 to 90 percent of all plants form symbiotic mycorrhizae fungi relationships by forming hyphae networks. The hyphae are about 1/60 the diameter of most plant root hairs and assist the plant in acquiring nitrogen, phosphorus, micronutrients and water in exchange for sugar produced by the plant. This mutually beneficial relationship is called a mycorrhizae network (Magdoff & Van Es, 2009). Figure 1 shows soil fungus forming mycorrhizae networks.

Hyphae interact with soil particles, roots, and rocks forming a filamentous body that promotes foraging for soil nutrients. These networks release enzymes into the soil and break down complex molecules that the filaments then reabsorb. Fungi act like natural recycling bins, reabsorbing and redistributing soil nutrients back to plant roots. Most hyphae are either pure white or yellow and are often misidentified as plant hair roots (Islam, 2008). Figure 2 shows mycorrhizal fungi.

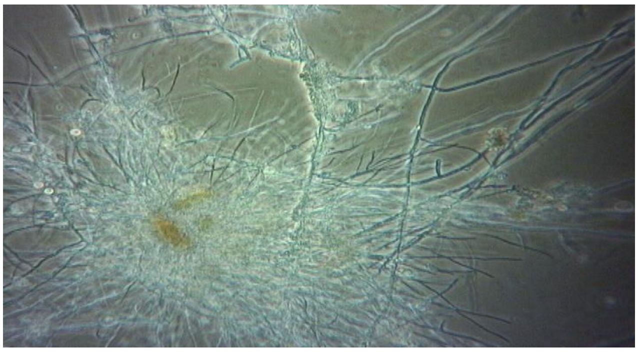


Figure 1: Soil fungus form mycorrhizae networks like a spider web to explore the soil profile for soil nutrients. *Photographed by Tim Wilson. Used with permission and all rights reserved.*

Figure 2: Mycorrhizal fungi are usually white or yellow while the root at the top is a light brown or tan color. *Photo by Randall Reeder. Used with permission and all rights reserved.*

The rhizosphere is an area next to the root dominated by soil microbes where many chemical and biochemical process occur. Soil fungi make up 10 to 30 percent of the soil rhizosphere. Generally there are fewer individual fungi than bacteria but fungi dominate the total biomass due to their larger size in a healthy soil. Fungi biomass in the soil ranges from the equivalent of two to six cows in a healthy soil or 1,100 to 11,000 pounds of biomass (Metting, 1993, Sylvia et al., 2005).

Fungi prefer slightly acidic conditions, low disturbance soils, perennial plants, internal nutrient sources directly from the plant, and highly stable forms of organic residues with high carbon to nitrogen (C:N) values and slower recycling time. Bacteria dominate in highly disturbed ecosystems with fast nutrient recycling, low C:N values, prefer annual plants, and external nutrient additions outside the plant (Lavelle & Spain, 2005). Bacteria are single-celled organisms and need a film of water to survive, while fungi are multi-celled organisms that grow rapidly and in great lengths in the soil (feet or meters). This allows fungi to bridge gaps in the soil so as to transport nutrients relatively far distances back to the plants (Lowenfels & Lewis, 2006).

References

- Introduction to Modern Mycology. Second edition. J. W. Deacon (1988).
- An Introduction to fungi. Third edition. H. C. Dube (2005).
- Introduction to Fungi. First edition. S. S. Rajan (2001).
- Role of Soil Fungus James J. Hoorman, Assistant Professor and Extension Educator, Agriculture and Natural Resources, Putnam CountyDate: Jun 7, 2016

Practical part

Fungi

Dr. Amany Atta EL-Shahir

Safety Procedures for the Microbiology Laboratory

General Laboratory Safety Practices and Procedures

1. If you are **taking immune-suppressants, are pregnant,** or have a known medical condition that would prevent full participation in the laboratory, please contact the course instructor before the first day of lab.
2. Read and understand each laboratory exercise **before** you come to class.
3. Do not eat, drink, smoke, or chew pens in the laboratory.
4. You must wear close-toed shoes while in the laboratory and long pants.
5. No hats of any kind will be allowed in lab, unless allowed by University policy and cleared with the instructor.
6. Long hair should be pulled back to keep it away from bacterial cultures, bacticinerator or open flames.
7. Follow precautionary statements given in each exercise.
8. Personal electronic devices will be turned off and stored while in this laboratory. *The unauthorized use of any electronic device (phone, tablet, computer) in lab will result in a loss of course points.
9. Know where specific safety equipment is located in the laboratory, such as the fire extinguisher, safety shower, and the eyewash station.
10. Recognize the international symbol for biohazards, and know where and how to dispose of all waste materials, particularly biohazard waste. Note that all biohazard waste must be sterilized by autoclave before it can be included in the waste stream.

Figure 1: Biohazard Symbol

11. Keep everything other than the cultures and tools you need OFF the lab bench. Only necessary work material should be at or on the laboratory bench. Coats, backpacks, and other personal belongings will not be allowed on the laboratory bench top. Store them in a place designated by your instructor. This is to prevent cluttering of the workspace and to avoid exposing them to permanent stains, caustic chemicals, and microorganisms used in the exercises.
12. Leave all laboratory facilities and equipment in good order at the end of each class. Before leaving the laboratory, check to make sure the bacticinerator heat sterilizer is turned off.
13. Never, under any circumstances, remove equipment, media, or microbial cultures from the laboratory.
14. No pets are allowed in the laboratory.

Microbiology Specific Laboratory Safety Practices

During the course of the semester in the laboratory you will be taught the methods used in the proper handling of microorganisms. Although you will not be working with any that are human pathogens, exercise caution in handling all material coming in contact with live microbial cultures. All cultures should be handled with respect and proper aseptic technique *as if they were potential pathogens.* This is called **"universal precaution"**. Specific instructions that should be followed:

1. Remember that all bacteria are potential pathogens that may cause harm under unexpected or unusual circumstances. If you as a student have a compromised immune system or a recent extended illness, you should share those personal circumstances with your lab instructor.
2. Wear gloves when working with cultures, and when your work is completed, dispose of the gloves in the biohazard garbage. Lab coats, safety glasses or goggles are also required. These will be stored in the laboratory each week in a ziplock bag.
3. Disinfect your work area both BEFORE and AFTER working with bacterial cultures.
4. Cultures of live microorganisms and any material coming in contact with live cultures must be properly sterilized after use in the laboratory. Your instructor will inform you of specific procedures. Follow the general rules outlined below.

   a. Glassware such as test tubes, bottles, and flasks may be reused and washed after sterilization. These are normally placed on a cart at the front of the laboratory after you have finished an experiment or exercise. BE SURE TO REMOVE LABELS before placing any glassware on the cart. Your instructor will sterilize and then wash these items.

   b. Some materials, such as plastic petri dishes, plastic pipettes, microscope slides, and swabs, are considered disposable. These are used once and if they become contaminated by contact with live microorganisms are sterilized and discarded. All of these disposable contaminated materials should be placed in the designated waste container containing a BIOHAZARD autoclave bag.

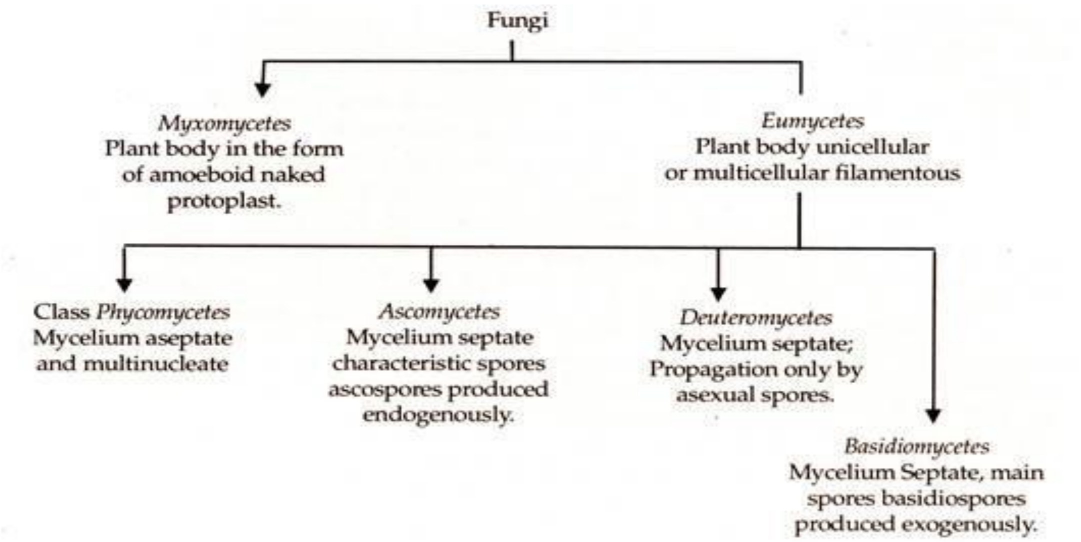
5. Never place contaminated pipette tips (or pipettes), inoculating loop, or any other contaminated material on the bench top. Sterilize loops before and after each use. Place contaminated pipette tips in the orange biohazard buckets on your bench. Place all other contaminated materials in their designated waste containers. Do not place or put anything containing live microorganisms in the sink.
6. Aerosols should be avoided by the use of proper technique for sterilizing the inoculating loops and by performing any mixing of cultures and reagents in such a way as to avoid splashing.
7. Cultures or reagents should always be transferred with an automatic pipettor that will be provided. In no case should one employ mouth pipetting.

8. Always keep cultures capped and in proper storage racks when not being used during an exercise.
9. In the event of an accidental spill involving a bacterial culture, completely saturate the spill area with disinfectant, then cover with paper towels and allow the spill to sit for 10 minutes. Then carefully remove the saturated paper towels, dispose of them in the biohazard waste, and clean the area again with disinfectant. Notify your instructor about the spill. If the chemical is marked "danger" or "caustic" you should notify the instructor who will handle this type of spill.
10. Immediately report all accidents such as spills, cuts, burns, or other injuries to the instructor
11. Make sure that lab benches are completely cleared (everything either thrown away or returned to storage area) before you leave the lab.
12. Clothing worn in the microbiology laboratory should be washed before being subsequently worn in a facility such as a hospital, clinic or nursing home, or in an area of public food preparation.
13. In the event of a fire alarm, follow the directions of your instructor, and meet at the place designated by your instructor.

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.



K. Mycophyta

D. Myxomycophyta

C. Myxomycetes

O: *Plasmodiophorales*

F: *Plasmodiophoraceae*

Ex. *Plasmodiophora brassicae*

Please check images in the following link

https://www.shutterstock.com/search/plasmodiophora-brassicae

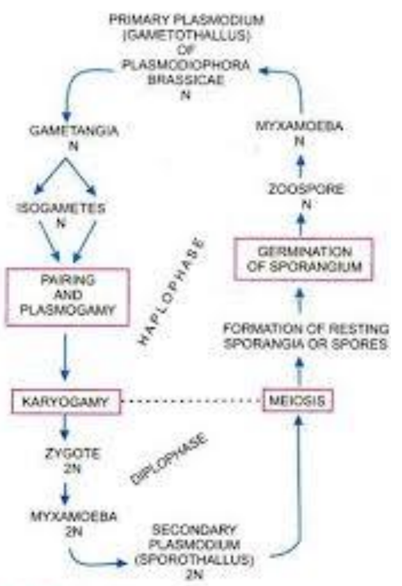
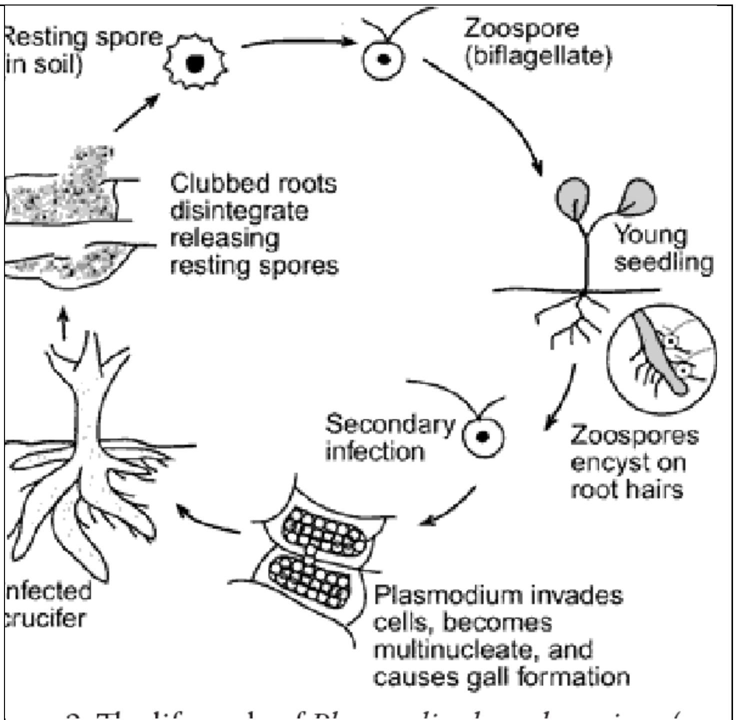


Fig. 5.7. *Plasmodiophora* sp. Graphic representation of the life cycle.

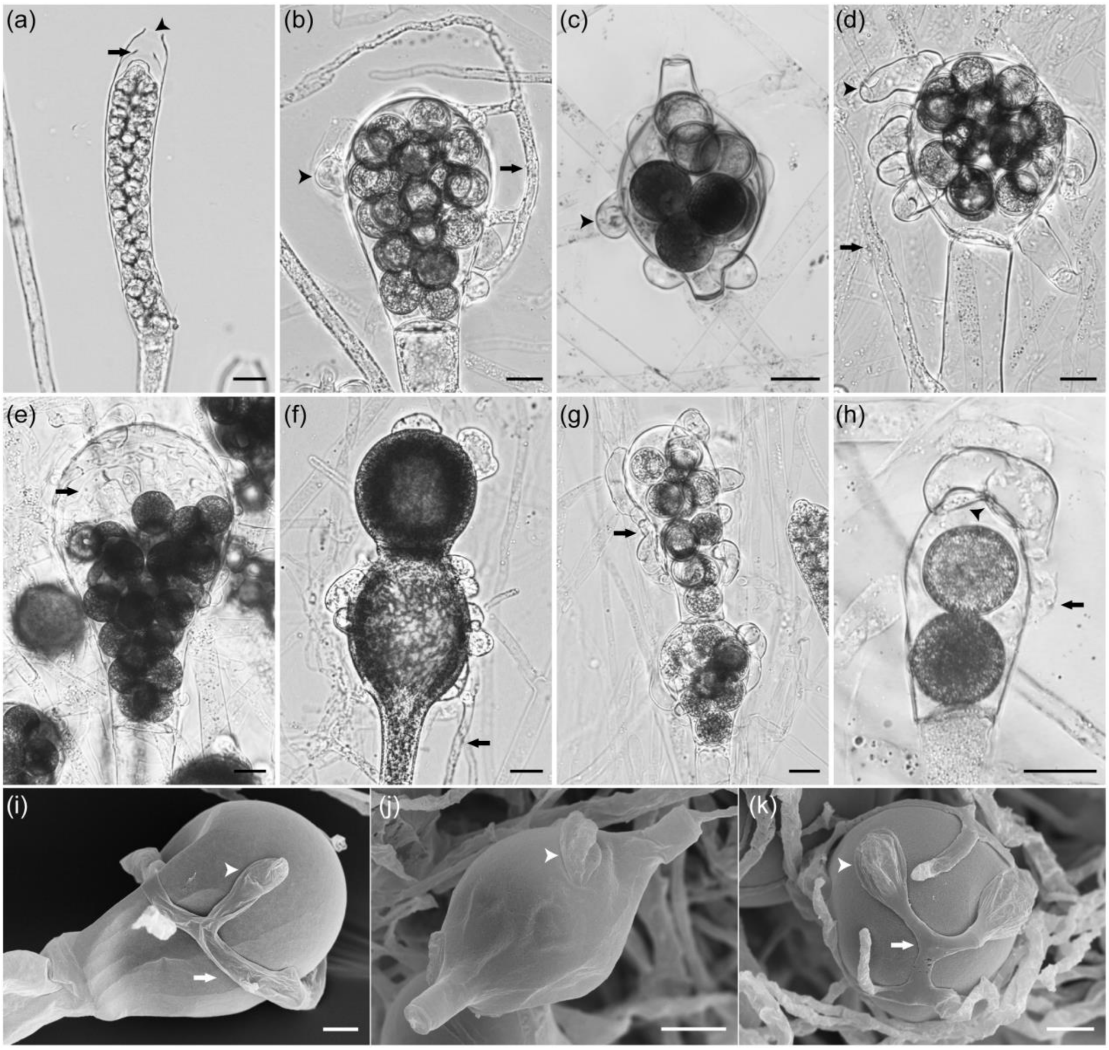


C: Phycomycetes

O: Saprolegniales

F: Saprolegniaceae

Ex.: *Saprolegnia* sp.

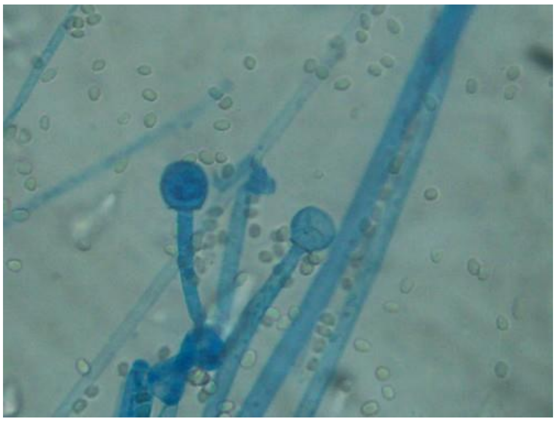


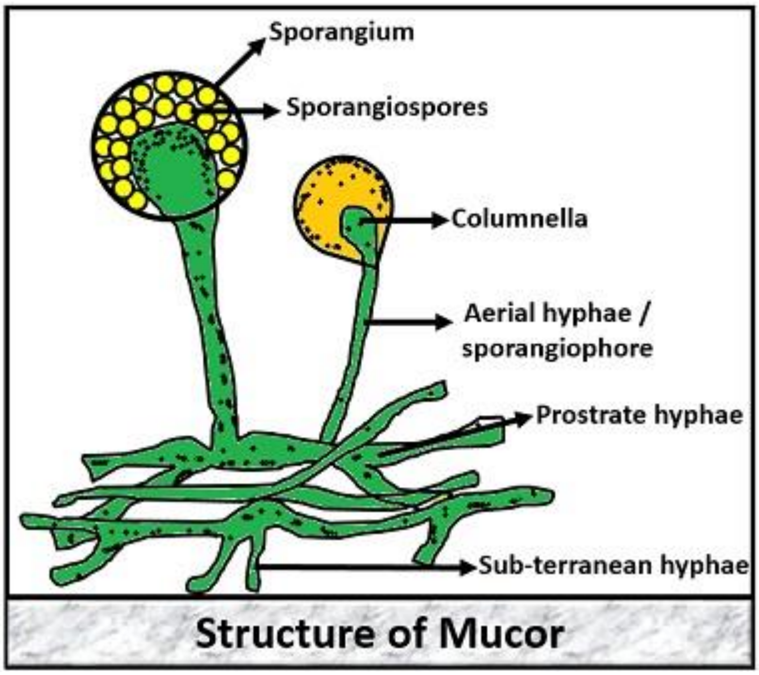
C: *Phycomycetes*

O: *Mucorales*

F: *Mucoraceae*

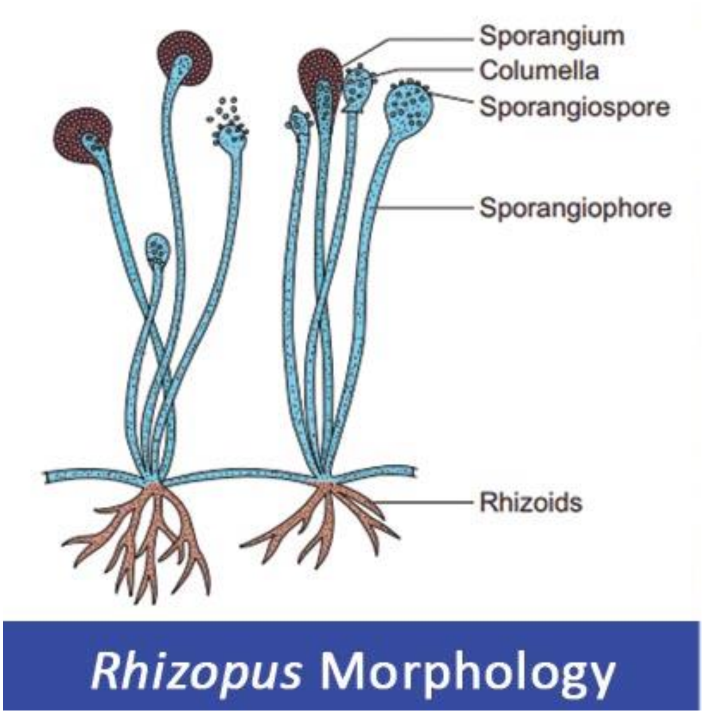
Ex.1. *Mucor*

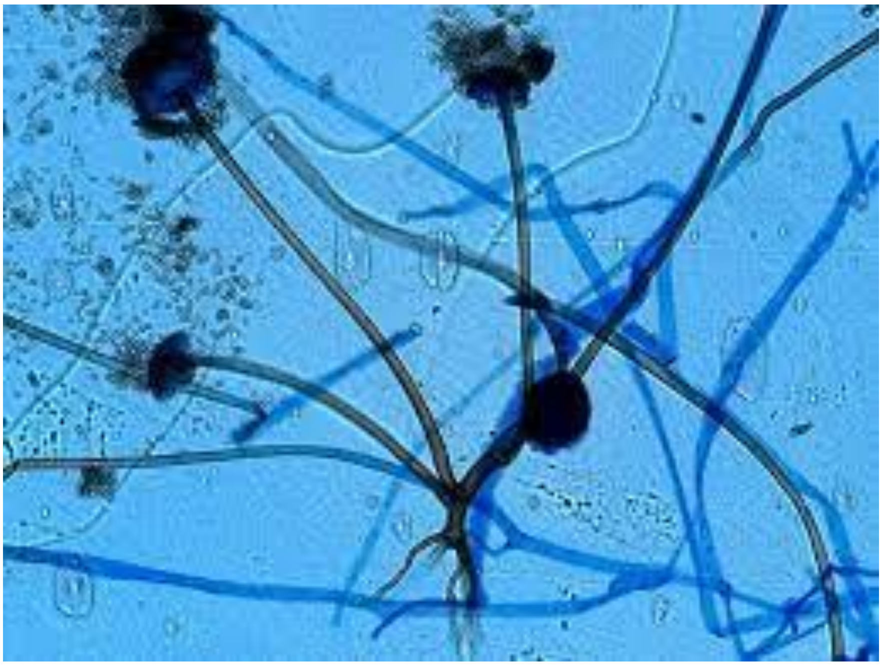




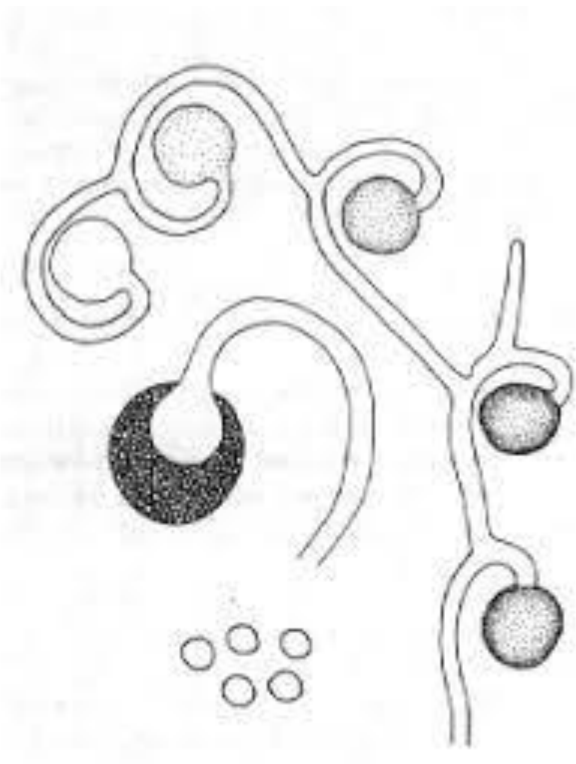
Ex. 2 *Rhizopus* sp.

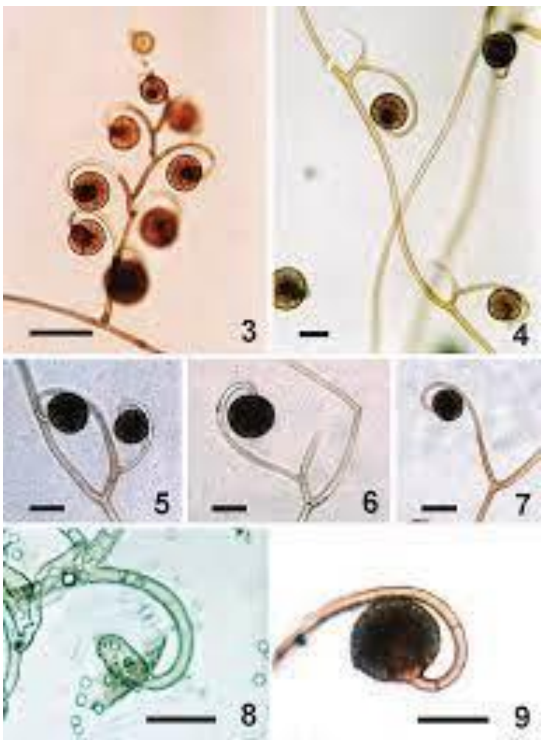
Rhizopus is **a genus of saprophytic and parasitic fungi**. They are found in moist or damp places. They are found on organic substances like vegetables, fruits, bread, jellies, etc. The vegetative structure is made up of coenocytic (multinucleated) and branched hyphae.





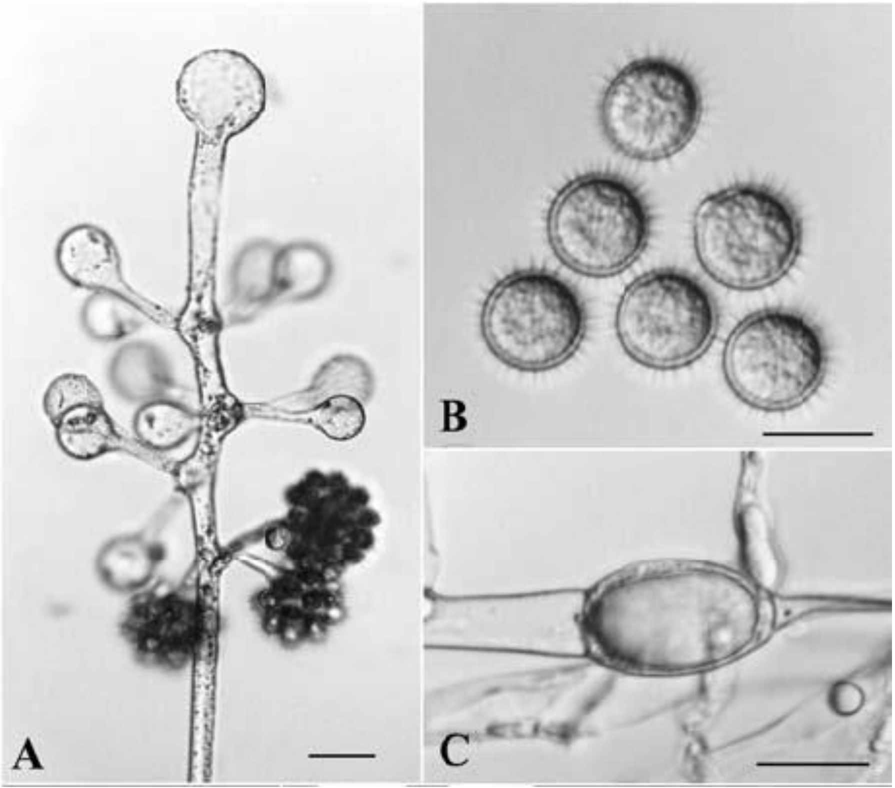
Ex. 3 *Circinella* sp.





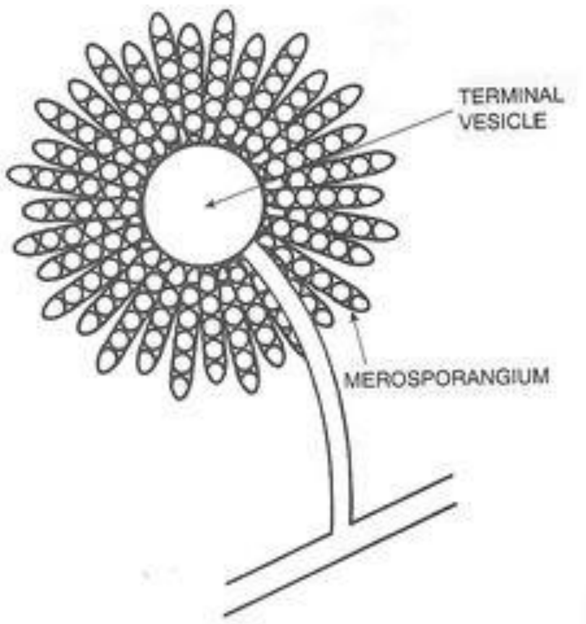
Family 2: *Choanephoraceae*

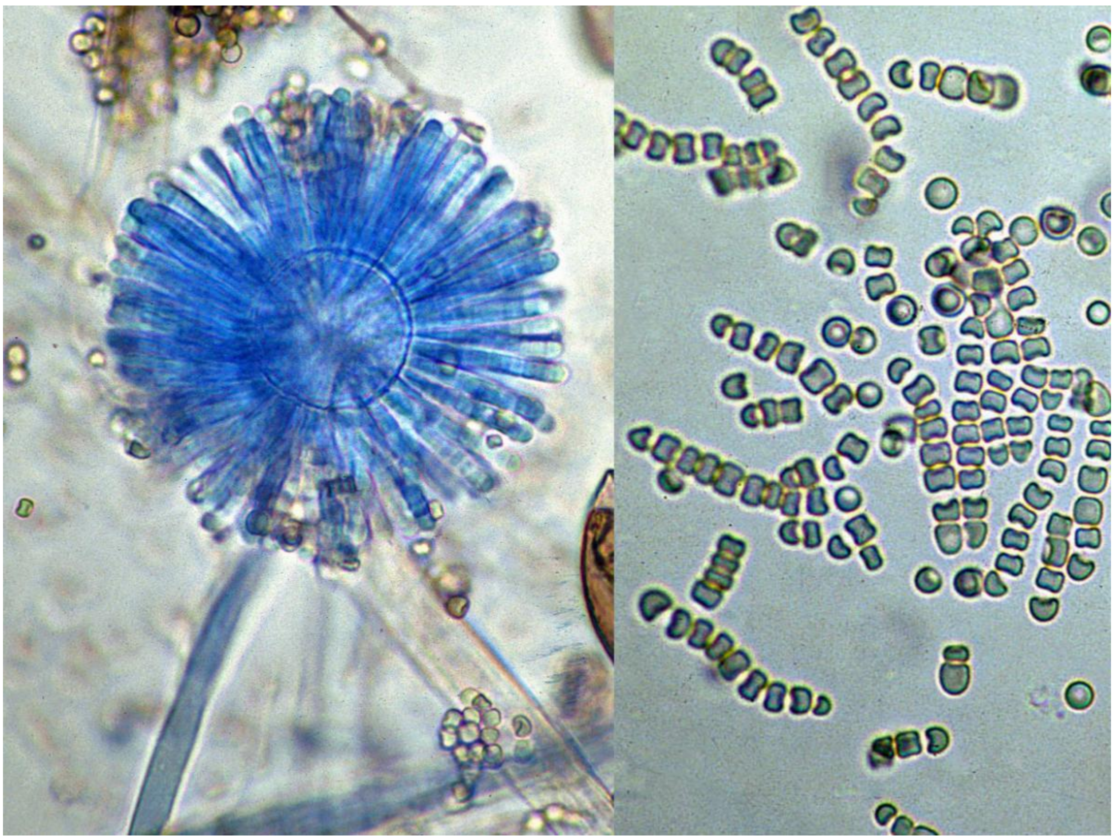
Ex. *Cunninghamella echinulata*



Family 3 : *Cephalidaceae*

Ex. *Syncephalastrum* sp.





Class 2: *Ascomtcetes*

Subclass: *Euascomycetes*

Series: *Plectomycetes*

Order: *Aspergillalaes*

Family : *Aspergillaceae*

Ex.1 *Aspergillus*

General characteristics

1- Colony colour
2- Colony reverse
3- Sterigmata: Biserriate – uniserriate
4- Conidia: globose – subglobose –elliptical – ovate – rough – smooth – hyaline – pigment.
5- Vesicle : globose – subglobose – clavate.
6- Conidial head: radiate – columnar – clavate.
7- Conidiophore: long – short – branched – unbranched – smooth – rough – hyaline – pigment – straight – sinuate.
8- Ascospre
9- Hull cell
10- Sclerotia

Different *Aspergillus* sp.

1	*Aspergillus clavatus*
2	*Aspergillus chevalieri*
3	*Aspergillus fumigatus*
4	*Aspergillus candidus*
5	*Aspergillus flavus*
6	*Aspergillus ochraceus*
7	*Aspergillus niger*
8	*Aspergillus versicolor*
9	*Aspergillus nidulans*
10	*Aspergillus ustus*
11	*Aspergillus flavipes*
12	*Aspergillus terreus*

Ex. 2 *Penicillium*

General characteristics

1- Colony colour
2- Colony reverse
3- Metulae: Present – Absent
4- Penicillin: Monoverticillata – biveticillata – symmetrica – asymmetrica – divaricate – nondivaricata (velutina – lanata – fasiculata).
5- Conidia: globose – subglobose –elliptical – ovate – rough – smooth – hyaline – pigment.
6- Conidiophore: long – short – branched – unbranched – smooth – rough – hyaline – pigment – straight – sinuate.
7- Ascospre
8- Hull cell
9- Sclerotia

Different *Penicillium* sp.

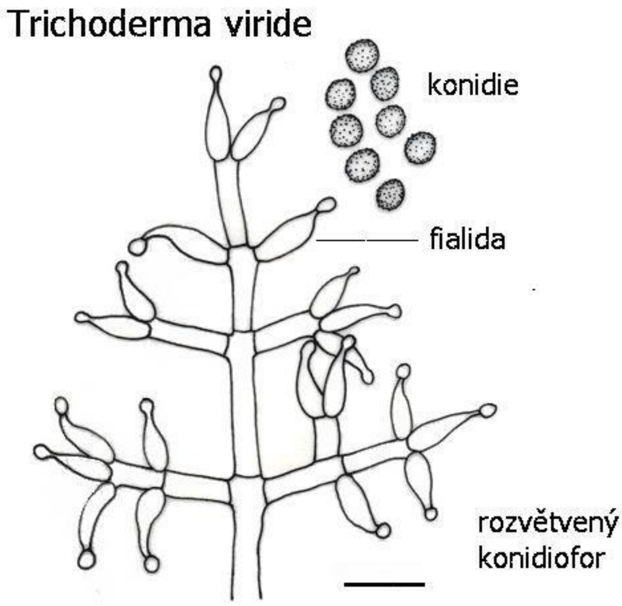
1	*Penicillium corylophilum*
2	*Penicillium duclauxi*
3	*Penicillium funiculosum*
4	*Penicillium chrysogenum*
5	*Penicillium steckii*
6	*Penicillium waksmani*
7	*Penicillium purpurogenum*
8	*Penicillium corylophilum*
9	*Penicillium duclauxi*
10	*Penicillium funiculosum*
11	*Penicillium chrysogenum*
12	*Penicillium steckii*
13	*Penicillium waksmani*
14	*Penicillium purpurogenum*

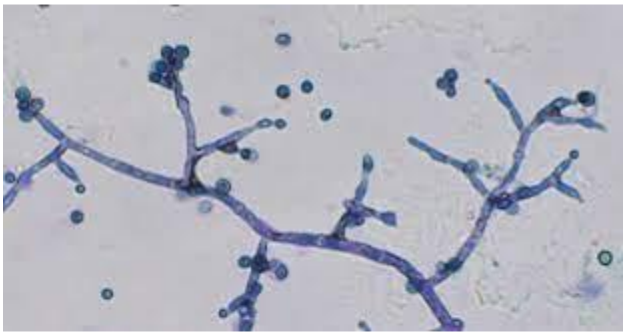
Class 3 : *Deuteromycetes*

Order: *Moniliales*

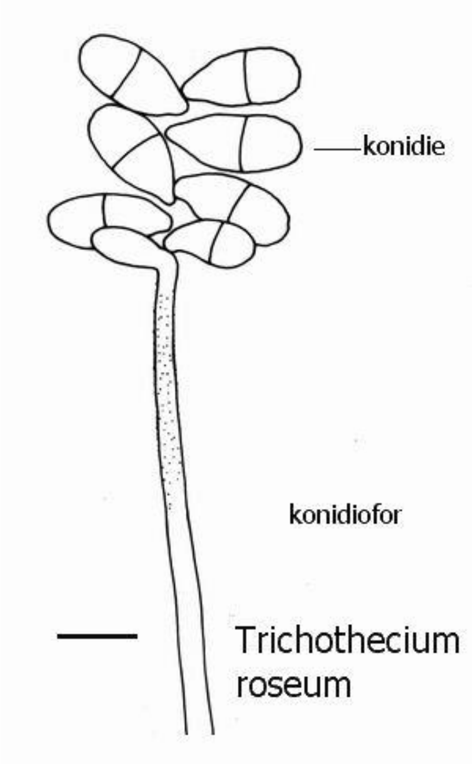
Family: *Moniliaceae*

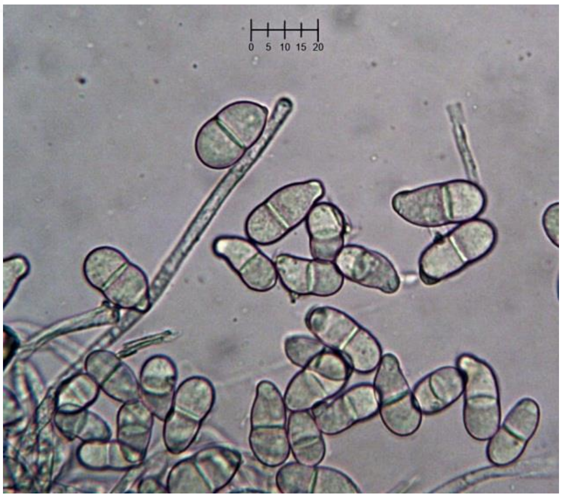
Ex. 1: *Trichoderma*



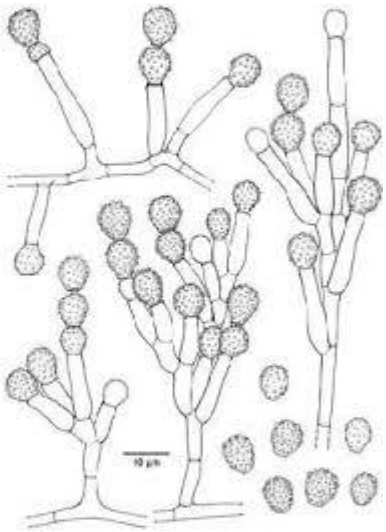


Ex. 2: *Trichothecium roseum*

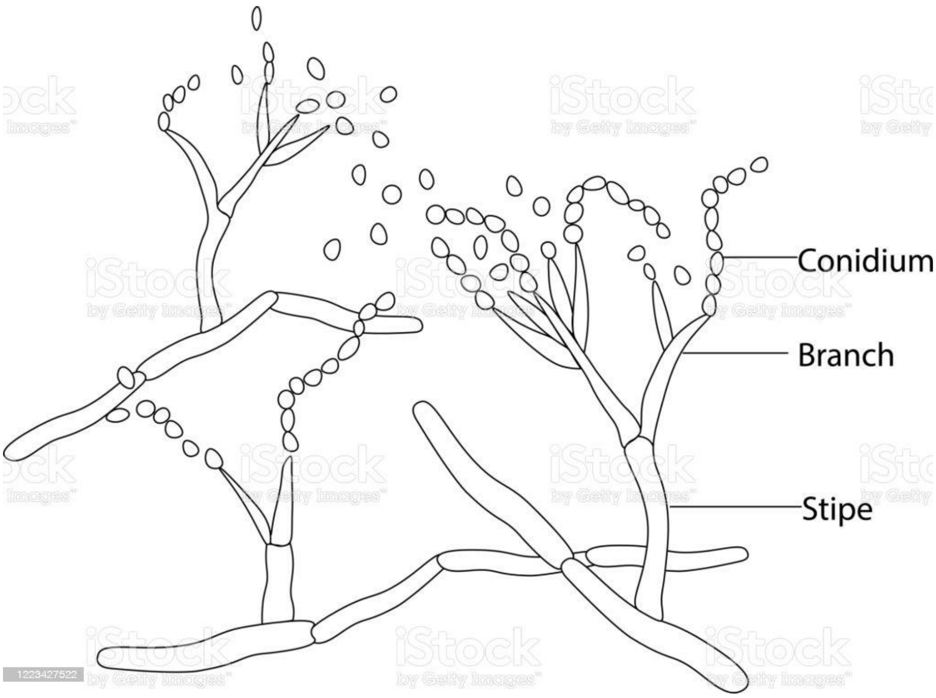




Ex. 3: *Scopulariopsis*

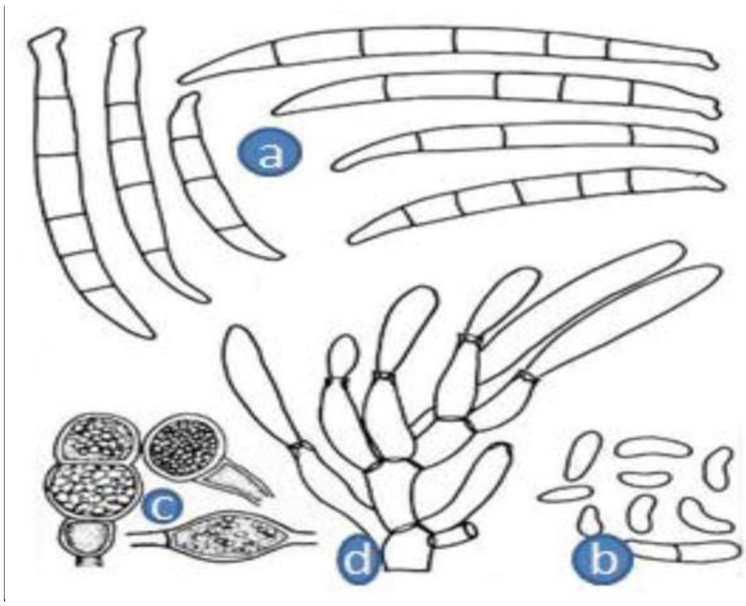


Ex. 4: *Pacielomyces*

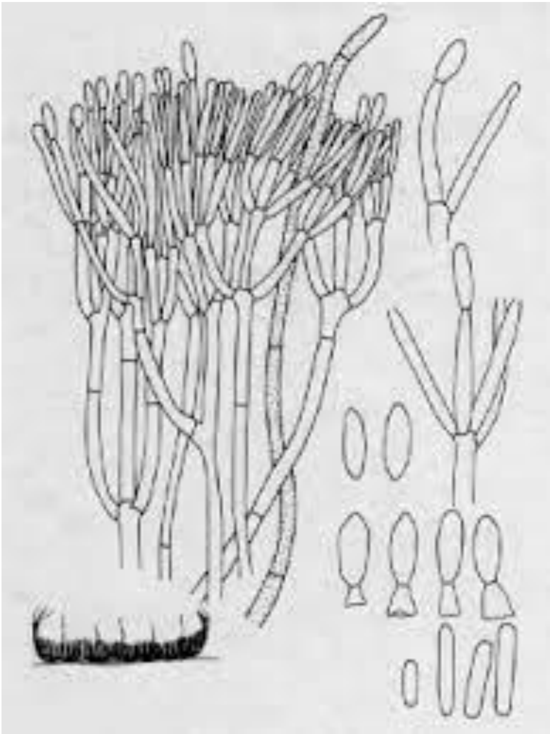


Family 2: *Tuberculariaceae*

Ex. 1: *Fusarium*

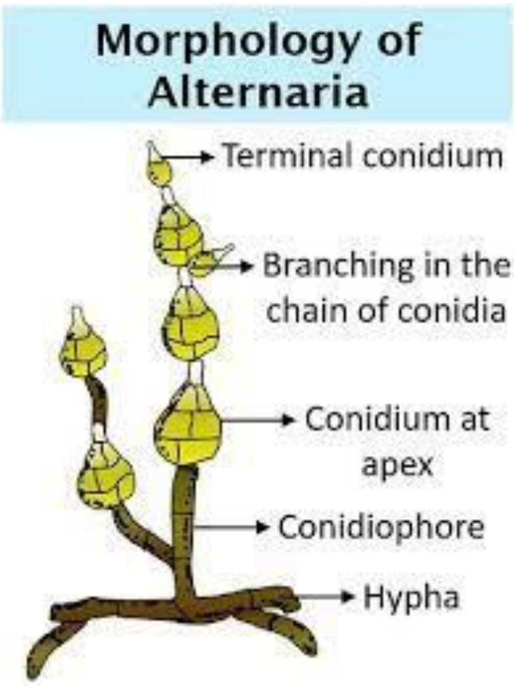


Ex. 2: *Myrothecium*

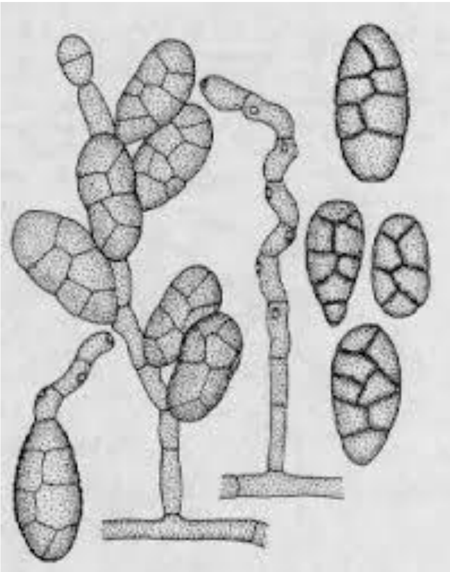


Family 3: *Dematiaceae*

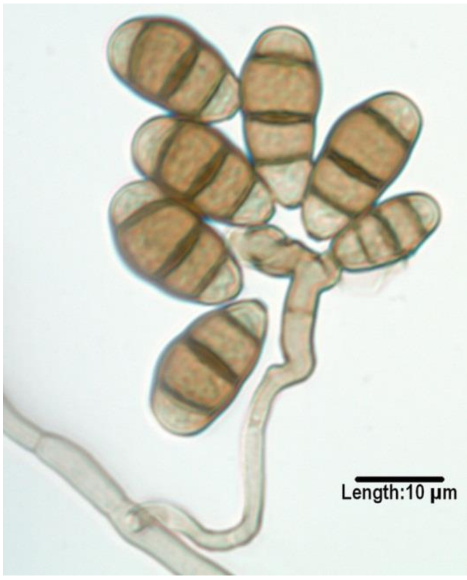
Ex. 1: *Alternaria*



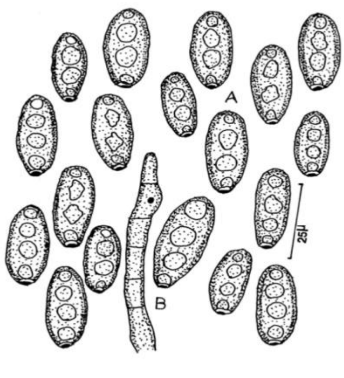
Ex. 2: *Ulocladium*



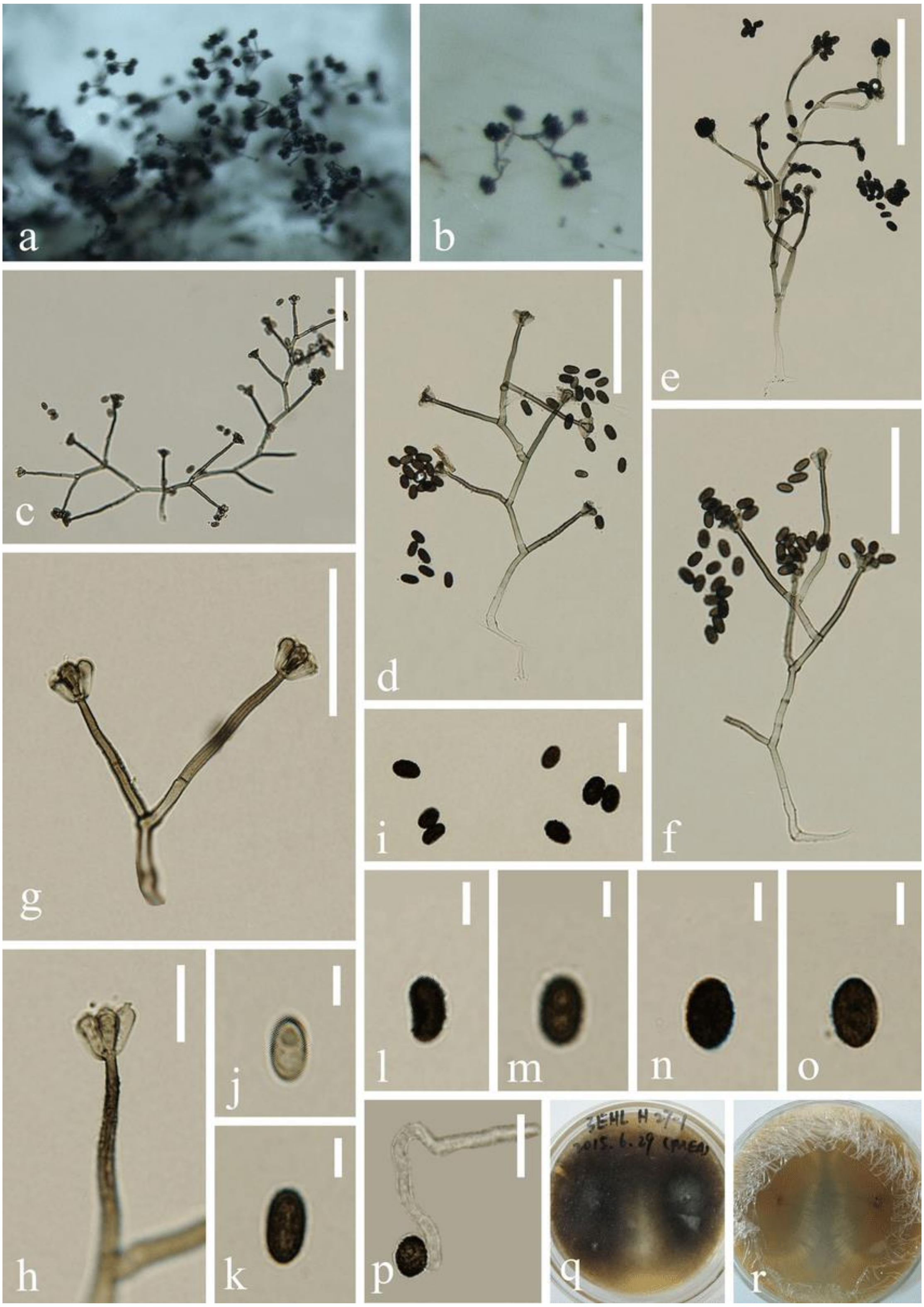
Ex. 3: *Curvularia*



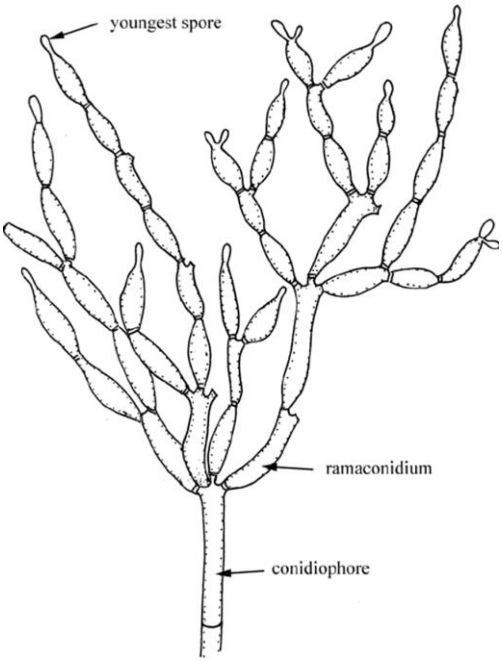
Ex. 4: *Drechslera*



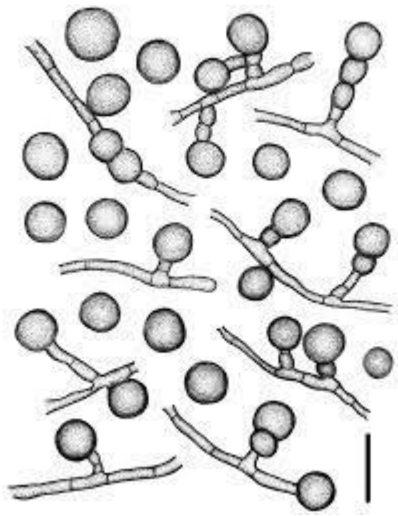
Ex. 5: *Stachybotrys*



Ex. 6: *Cladosporium*



Ex. 7*: Humicola*



Family 3: *Stilbaceae*

Ex. *Trichorus spirales*