Terrestrial Fungi & Aquatic Fungi

3rd Microbiology-Chemistry Program

Course code: 305 Mic

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Introduction to Fungi

Mycology: is the branch of science dealing with study of fungi "Greek, Mykes = mushrooms or fungus + Logos = subject. The term fungus (PL. Fungi) which originally means mushroom, but it is now applied to all types of fungi"

According to Alexopolus (1952), the fungus is defined as a nucleated achlorophyllous, thallophytes and usually filamentous, branched organisms which typically reproduce sexually and asexually and varies from bacteria by these previous features and the presence of cell wall surrounding the somatic cells split them from animal kingdom.

General structure of fungi

Fungi are eukaryotic cells their structure corresponds essentially to that of the plant cell but it is devoid of chlorophyll. Fungal cells are composed of:

1. **Cell wall:**

<u>Composition:</u>

* Chitin:

The cell wall is composed mainly of chitin which is a polymer of N-acetyl glucosamine. It is synthesized by enzyme chitin synthase which is present in membrane bound pockets called chitosomes.

* Cellulose.

* Polysaccharides as mannans and glucans.

* Glycoproteins that contain large amount of sulphr containing amino acids and disulphide bonds which are more prevalent in hyphae than in yeast. Reduction of these disulphide bonds is associated with transformation of hyphae to yeast form.

Functions:

* It maintains the shape of the fungus.

* Osmotic strength.

* Protection.

* Antigenic determination.

2. **The cytoplasmic membrane:**

The fungal cytoplasmic membrane contains ergosterol rather than cholesterol present in mammalian membranes. Prokaryotes (except mycoplasma) do not contain sterols in their membranes.

3. **Cytosol:**

It is complex structure and contains many membrane bound organelles such as nucleus, mitochondria, vacuoles, glycogen and volutin granules, endoplasmic reticulum…etc.

4. **Nucleus:**

Fungi differ from the bacteria in containing a true nucleus which is demarcated from the cytoplasm of the cell by a nuclear membrane. The nucleus contains; as a rule; a nucleolus and always several chromosomes.

5. **Capsule:**

It helps adherence and clumping. Also it protects against phagocytosis.

Differences between bacteria and fungi.

	Bacteria	**Fungi**
Type	Prokaryotic	Eukaryotic
Size	0.2 to 8 um.	4-15 um.
Cell wall	*****peptidoglycan.	*****Cellulose. *****polysaccharides as mannose and glycans. *****Chitin.
Cell membrane	No sterols	Sterols
Nucleus	*****No nuclear membrane. *****No nucleolus. *****DNA has no histones. *****One Chromosome	*****Enclosed by nuclear membrane. *****Nucleolus is present. *****DNA has histones. *****Many Chromosomes.
Ribosomes	70S	80S
Membrane bound	No	Yes

	Bacteria	**Fungi**
organelles		
Division	Binary fission	Budding
Spores	Endospores for survival, not reproduction	Spores for reproduction
Thermal dimorphism	No	Some
Metabolism	Many do not require organic carbon, many strict anaerobes	All require organic carbon, no strict anaerobes

Classification of Fungi

- The word classification may be defined as the scientific categoration of the organisms in a series group. Despite the existence of many varieties, biological strains and physiological or cultural races, the species is generally considered as the smallest group.

- More similar species are grouped together into a genus; similar genera are grouped into a family, families into order, orders into a class, similar classes into a division, and divisions into a kingdom. The latter is supposed to be the highest taxonomic rank.
- Generally, it is believed that there exist only two kingdoms i.e. plant and animal kingdoms, and all living organisms belong to one of the two great kingdoms.
- Barkley (1968) suggested a four-kingdom system. Whittaker (1969) suggested a five-kingdom system and raised fungi to the status of separate kingdom.
- The five-kingdom system based on the level of organization and mode nutrition of the living things provides fungi a status of an independent kingdom.
- Fungi are classified based on the characters of the sexual spores e.g.: oospores (Oomycota), zygospores (Zygomycota), ascospores (Ascomycota), basidiospores (Basidiomycota).

- Deuteromycetes (fungi imperfecti) are mainly characterized by absence of sexual spores in their life cycles.
- Botanical nomenclature recommended the use of the following suffixes for the divisions of fungi:

  Kingdom.....mycetae

  Divisions.....mycota

  Sub-divisions.....mycotina

  Calsses.....mycetes

  Sub-classes.....mycetidae

  Orders .....ales

  Family.....aceae

- Each fungus, according to Linnaeus binomial system has two names a generic and species names. The generic name is always capitalized while the species name is not.

Classification of Fungi

I- According to morphology:

1) Yeasts:

- Unicellular round or oval fungi 4-15 um in size.
- Reproduce by budding (blastoconidia formation).
- Sometimes buds do not separate off and extend to form pseudohyphae that show constrictions at the attachment sites. This form is known as yeast like fungi e.g. *C. albans.*
- They form moist mucoid, creamy or waxy colonies.

2) Moulds:

- Multicellular filamentous, "fluffy" colonies consisting of branching tubular structures called hyphae. Collection of intertwined hyphae called mycelium.
- Hyphae may be septate (with transverse walls); these septa are typically perforated or nonseptate (coenocytic which is hollow multinuclear structure). e.g. zygomycetes have nonseptate hyphae.
- Moulds identified primarily by microscopic morphology with particular attention to size, separation and branching pattern of

hyphae as well as appearance of reproductive structures. On laboratory media moulds form:

- Vegetative hyphae act like roots, penetrating the supporting medium and absorbing nutrients.
- Aerial hyphae project above the surface of the mycelium and bear the reproductive structures of the mould that often spread through the air. They give the mould colony a characteristic velvety like appearance.

3) Dimorphic Fungi:

- Grow as moulds at environmental temperatures (25°C), forming reproductive spores that if inhaled by a host grow as yeasts at body temperature (37°C).
- Staining of tissues shows the yeast forms and cultures at 25°C show moulds with characteristic colony appearance and microscopic morphology.

II- According to mode of habitat:

Fungi are described according to their habitat and way of living as:

1) Saprophytic:

Saprophytic fungi live on inanimate material; in the soil, in water, in dust, in the air, on clothes or on dead bodies.

2) Parasitic:

Parasitic fungi live on or in the body of living creatures. They are subdivided into:

a- true pathogenic fungi:

Those cause disease in man or animals or plants.

b- Commensal fungi (opportunistic fungal pathogens):

Live on or in the body without exerting any harmful effect but many cause disease if the body resistance is lowered by any means (I.e. opportunistic infection).

III- According to the method of reproduction:

All fungi can reproduce asexually and many of them can also reproduce sexually.

Anamorph: is the asexual phase in fungus life cycle. This phase is commonly detected in clinical specimens.

Telomorph: is the sexual phase in fungus life cycle. This phase is detected only under specialized conditions e.g. in laboratory.

Medically important fungi are classified into four phyla:

- Ascomycota: Sexual reproduction in a sack called an ascus with the production of ascopspores.
- Basidiomycota: Sexual reproduction in a basidium with the production of basidiospores.
- Zygomycota: usually reproduce asexually by producing sporangiospores. Zygomycota reproduce sexually when environmental conditions become unfavorable. To reproduce sexually, two opposing mating strains must fuse or conjugate, thereby, sharing genetic content and creating zygospores.
- Mitosporic Fungi (Fungi Imperfecti - deuteromycetes) - no recognizable form of sexual reproduction. It includes most pathogenic fungi.

Classification systems:

The kingdom of fungi is mainly divided into two subkingdoms:

A- Subkingdom: Gymnomycetae

In which the somatic phase is naked thallus (plasmodium) where as the reproductive cells are mainly with outer cell wall which includes the following common divisions:

Division: Myxomycota

Class: Myxomycetes (True slime moulds)

B- Subkingdom: Eumycetae

Division (1): Mastigomycota (motile form)

Subdivision (a): Haplomastigomycotina (uniflagellated forms)

Class: Chytridiomycetes

Subdivision (b): Diplomastigomycotina (biflagellated forms)

Class: Oomycetes

Division (2): Amastigomycota (immotile form)

Subdivision (a): Zygomycotina

Class: Zygomycetes

Subdivision (b): Ascomycotina

Subdivision (c): Basidiomycotina

Subdivision (d): Deuteromycotina

Reproduction of fungi

Fungi exhibit three major modes of reproduction; asexual, sexual and parasexual reproduction.

I-Asexual Reproduction:

Asexual reproduction is the production of new individuals by mitotic division from a single parent. It does not involve the fusion of gametes. It occurs by one of two forms:

A- Vegetative reproduction.

B- Spore formation.

A- Vegetative Reproduction:

It is the type of reproduction which involves the fungal thallus (body of the fungus) with expression of yeast and mould forms. It occurs by the following methods.

a- Fragmentation:

In this process, the mycelium breaks into two or more similar fragments either accidentally or due to some external force (as when a part of the colony is sub cultured). Each fragment grows into a new mycelium.

b- Budding:

The parent cell produces one or more projections called buds, which later develop necessary structures and detach to grow into new individuals. Budding is common in unicellular forms like yeast.

c- Fission:

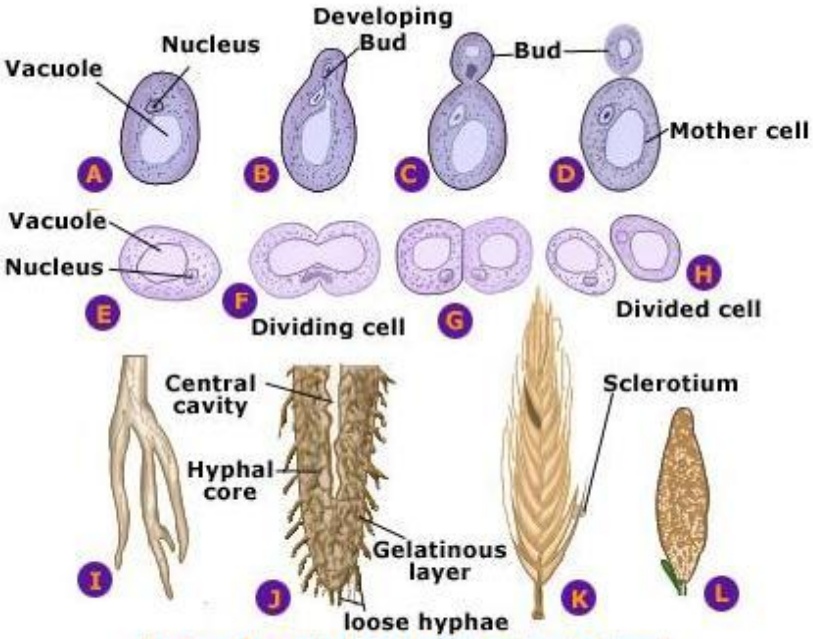
In this process, the parent cell splits into two equal halves, each of which develops into a new individual. Fission is also common in yeast.

d- Sclerotia:

In some cases the hyphae become interwoven to form a compact mass and get surrounded by a hard covering. Such structures are called sclerotia. They remain dormant under unfavorable conditions and germinate into new mycelia on the return of favorable conditions.

e- Rhizomorphs:

In some higher fungi, several hyphae may become interwoven to form rope-like structures called rhizomorphs. Under favourable conditions, they resume growth to give rise to new mycelia.



Modes of vegetative reproduction in fungi.
A-D. Budding. E-H. Fission. I-J. Rhizomorph; K-l. Sclerotia

B-Spore formation:

It is the type of reproduction in which special reproductive structures called spores are formed. These asexual spores always result from mitosis and hence are described as mitospores. These spores are easily disseminated by air and they are more resistant to unfavorable environmental conditions. Most medically important fungi reproduce asexually and are known as imperfect fungi (Dueteromycetes).

Types and mechanism of production of asexual spores:

I- Conidia:

That may be unicellular i.e. micro conidia or multicellular i.e. macro conidia. They are formed by one of two mechanisms:

A- Fragmentation or conversion of an existing hypha or cell via:

Thallic conidiogenesis (thallic spores or thallic conidia):

They are formed by fragmentation or disarticulation of existing hyphae. It is a common mechanism for spore formation. They include:

1- Arthrospores (Oidia):

These are spore like structures formed by the breaking up of hypha cells. They do not store reserve food and hence cannot survive under unfavorable conditions. Such spores are produced in *Rhizopus*.

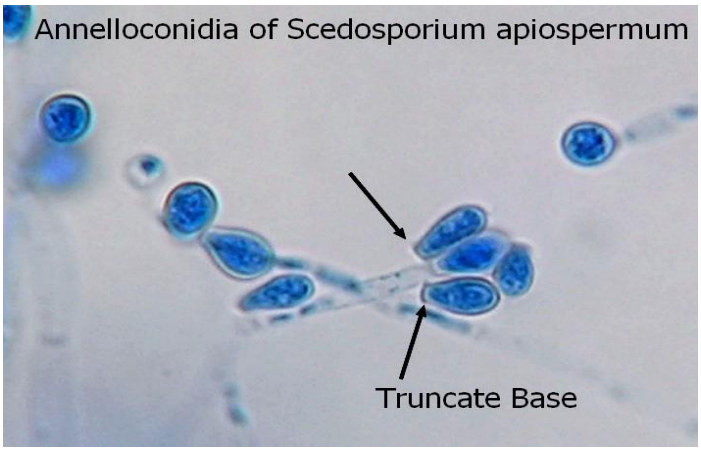
2- Chlamydospores (chlamydoconidia):

These are thick walled resting spores which arise directly from hyphal cells. They store reserve food.

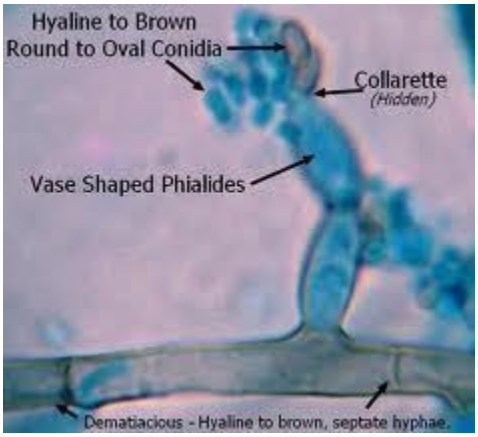
Blastic conidiogenesis (blastpores or blastoconidia):

In the Ascomycota and Basidiomycota, a sporogenous region on a hypha expands like a balloon, or budding. The process is called blastic conidiogenesis, and the resultant spore a 'blastospore'. Several different types of blastic conidiogenesis have been described. E.g.

Annelloconidia: The conidium emerges from the apex of a cell, and leaves a scar behind.



Phialides: conidia emerge from a vase shaped cell called a phialide.



B- Formation and release via specialized cells called conidiophores following specific developmental pathways. These conidia are non motile and produced singly or in chains.

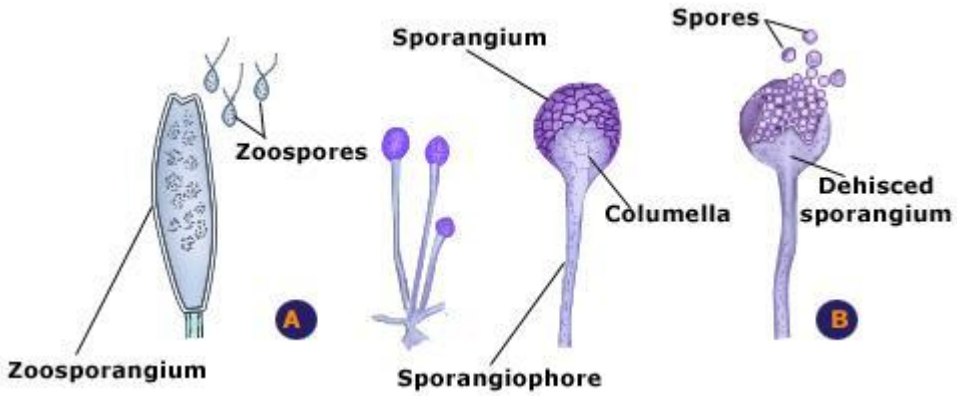
II- Sporangiospores and zoospores:

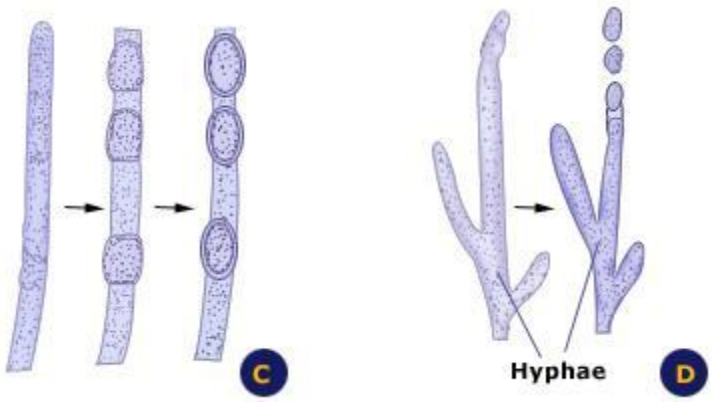
a- Sporagiospores:

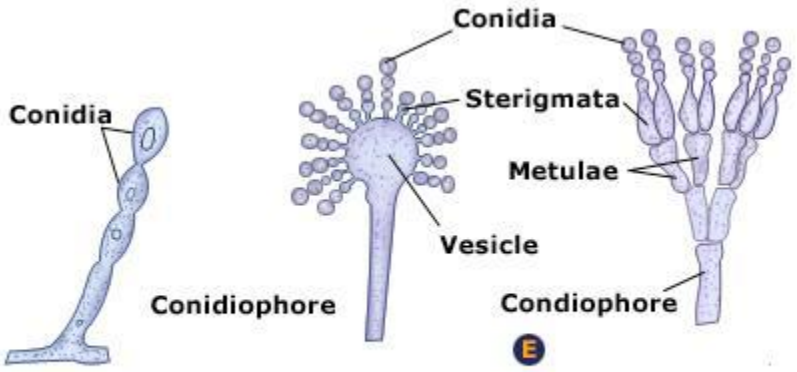
In the zygomycota the hyphal apex or cell swells. Within the sac, called a sporangium, spores are formed following division of the cytoplasm into one or more parts. Sporangiospores are non-motile and dispersed by wind.

b- Zoospores:

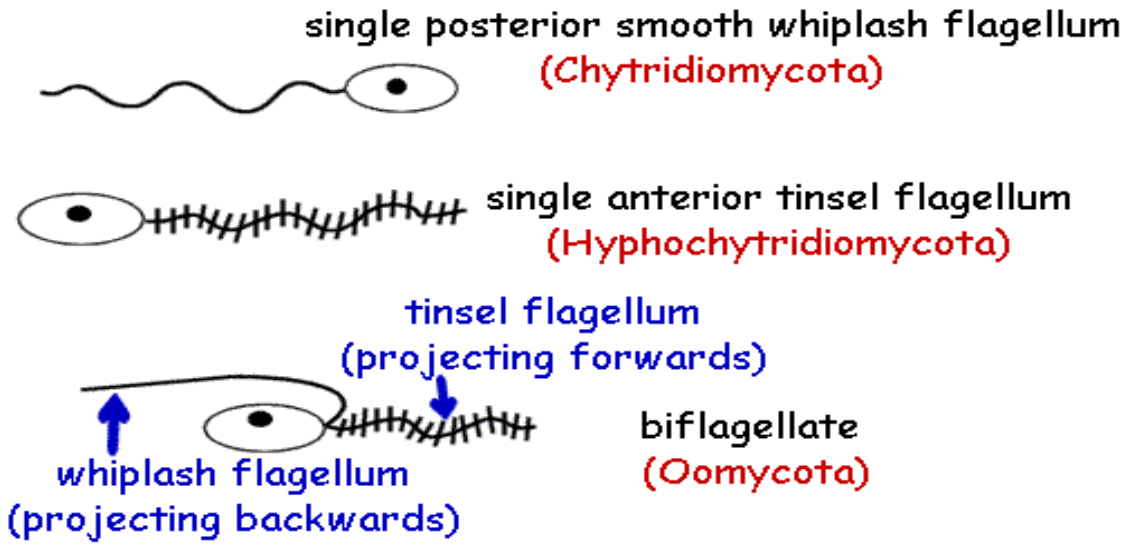
They are flagellated, motile spores produced inside structures called zoosporangia. These spores do not have a cell wall. Such spores are produced in lower fungi and require the presence of water in any phase of fungus life cycle for its dissemination.



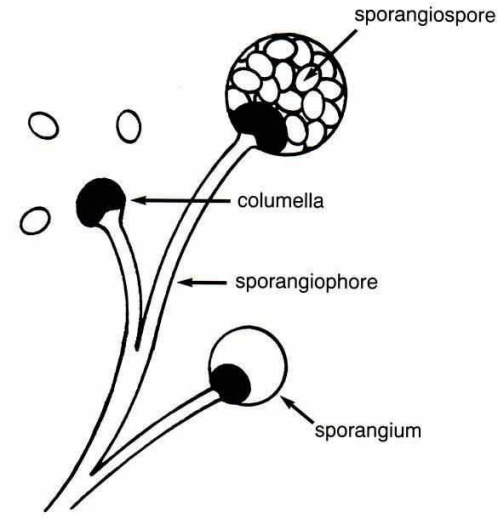




A. Zoospores; B. Sporangiospores; C. Chalmydospores; D. Oidia; E. Conidia



Aplanospoes (non-motile or true sporangispores): Formed in sac like structure called sporangium. The protoplasm of sporangiospores is surrounded by cell wall.



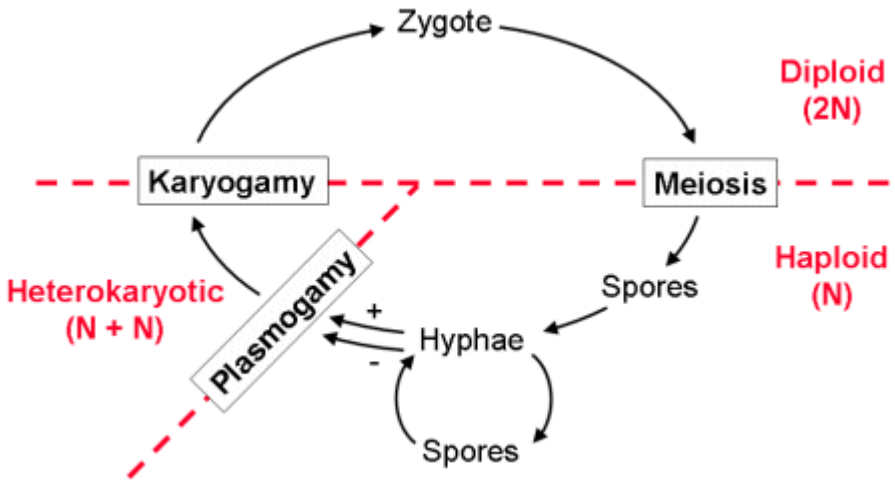
II- Sexual Reproduction:

In case of sexual reproduction a union occurs between two sexually different cells. This enlarges and becomes surrounded by a thick wall and it is called zygospore. In higher forms of fungi, sexual spores are formed in an enlarged specialized cell in the mycelium called an ascus. Fusion of nuclei is followed by meiosis and mitosis giving rise usually, to eight haploid nuclei around each of which an ascospore is formed.

Sexual reproduction is known to occur in all groups of fungi except the Fungi imperfecti or Dueteromycetes. It may involve fusion of gametes, gametangia or hyphae. The process may involve only fusion of cytoplasm (plasmogamy) or fusion of nuclei (karyogamy) or production of meiotic spores (meiospores)

In most of the lower fungi plasmogamy is immediately followed by karyogamy and meiosis. In higher fungi karyogamy is often delayed so that the hyphae remain dikaryotic. This phase of fungal life cycle is

called dikaryophase. Such fungi complete their life cycle in three phases a haplophase, a dikaryophase and a diplophase.



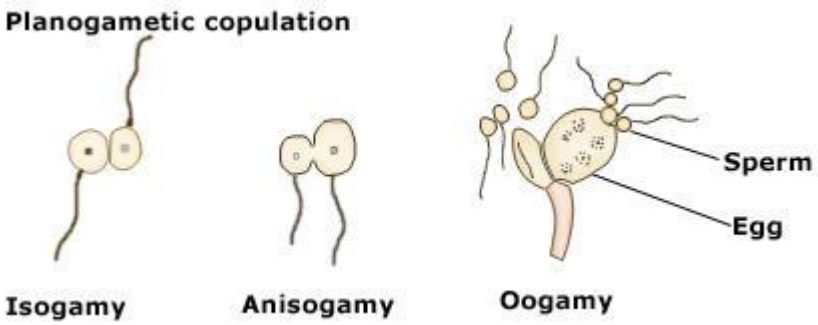
Sexual fusion in fungi is of different types, as follows:

a- Planogametic Copulation:

Here motile gametes called planogametes undergo fusion.

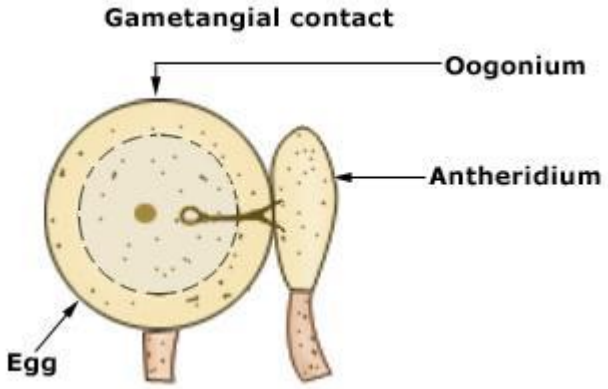
- When both gametes are motile and morphologically similar, the fusion process is called isogamy e.g. *Synchytrium*.
- When both gametes are motile but differ in their size, the fusion process is called anisogamy e.g. *Allomyces*.

- When one gamete (male) is smaller and motile and the other (female) gamete is larger and non motile, the fusion process is called heterogamy.



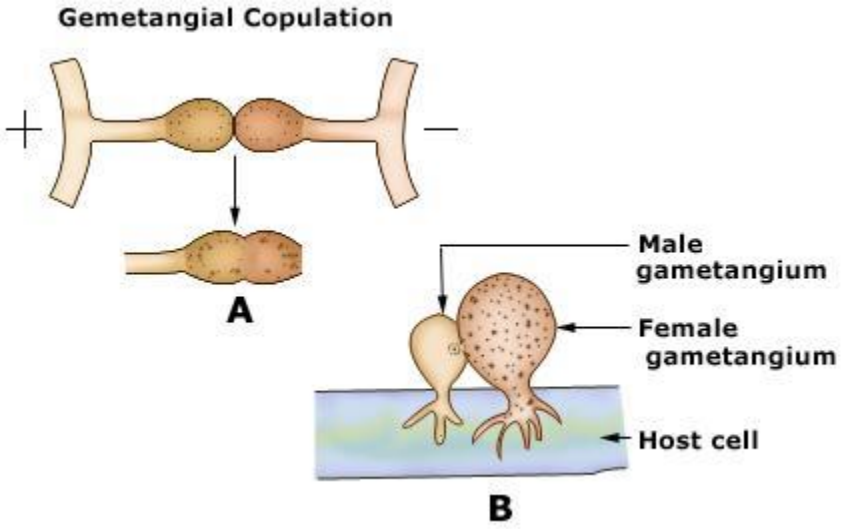
b- Gametangial Contact:

Here, gamete bearing structures called gametangia come closer to each other and develop a fertilization tube through which the male gamete migrates into the female gametangium e.g. Phytophthora, Albugo.



c- Gametangial Copulation:

Here, the gametangia fuse with each other, lose their identity and develop into a zygospore e.g. Mucor, Rhizopus.

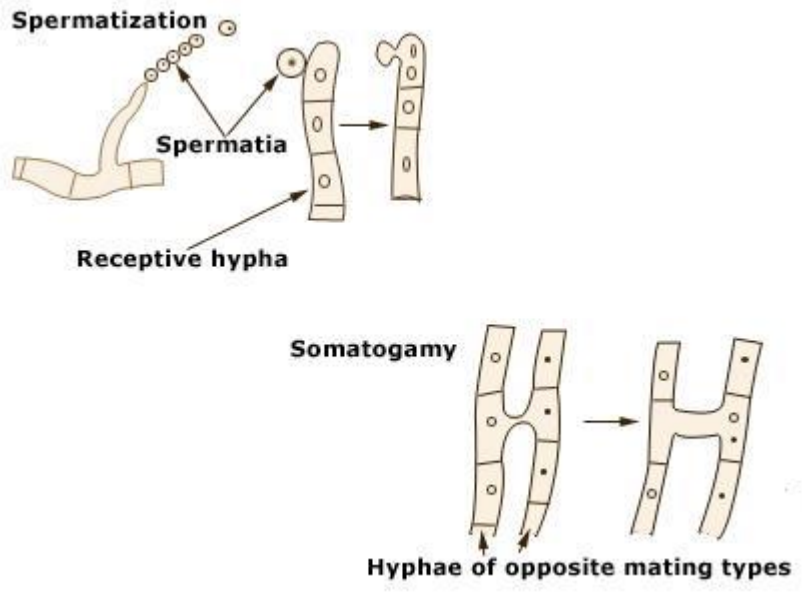


d- Spermatisation:

In some fungi like Puccinia, tiny unicellular spore like structures called spermatia are formed. They get transferred to female gametangia through various agencies.

e- Somatogamy:

In examples like Agaricus, fusion occurs between two somatic cells and involves only plasmogamy. This results in the formation of dikaryotic hyphae. Hence, the process is called dikaryotization.



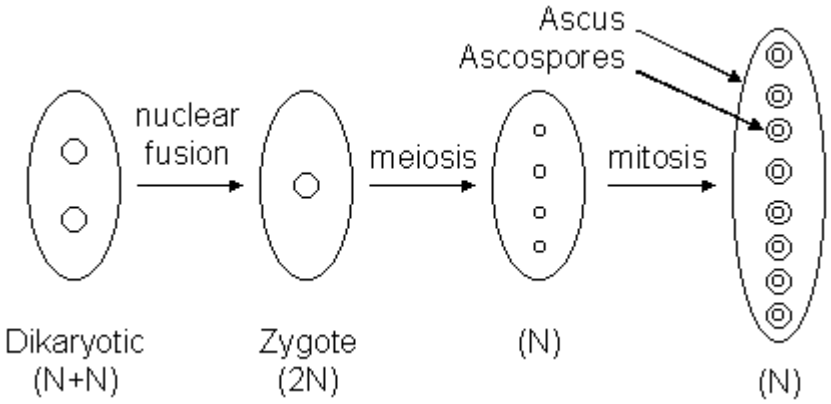
Homothallism and Heterothallism:

Based on the compatibility in sexual reproduction the fungal hyphae can be distinguished into two types homothallic and heterothallic. In homothallic forms, fusion occurs between the genetically similar strains or mating types. In such forms, meiosis results in the formation of genetically identical spores. In the heterothallic forms, fusion occurs between the genetically different mating types or strains. The strains are

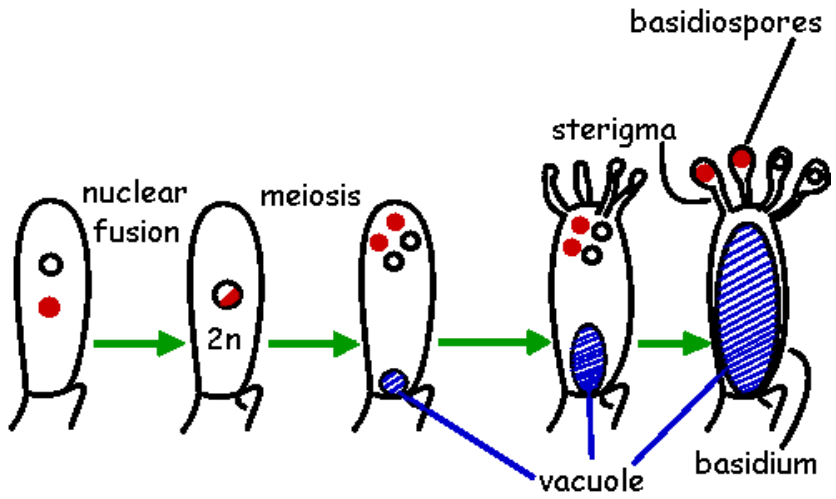
genetically compatible and are designated as + strain and -strain. In such forms meiosis results in the formation of both the strains, in equal numbers.

Sexual Spores Include:

- **Zygospores**: which are thick-walled zygotes formed by fusion of two hyphal tips.
- **Ascospores**: which occur in multiples of four inside a structure called an ascus.



- **Basidiospores**: which are sexual spores formed on the outside of a structure called a basidium.

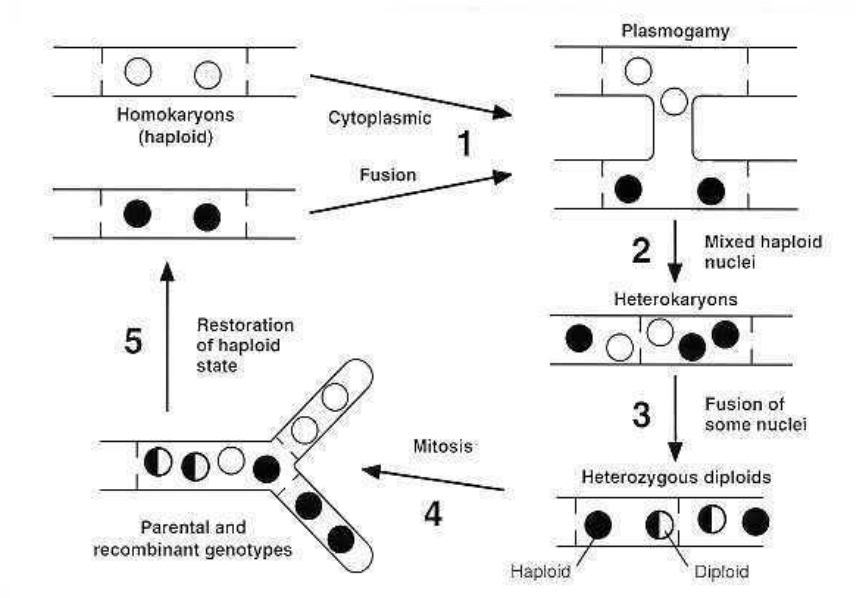


III- Parasexual Reproduction:

Despite the absence of meiosis during the life cycle of imperfect fungi, recombination of hereditary properties and genetic variation still occur by a mechanism called parasexuality.

The major events of this process include the production of diploid nuclei in a heterokaryotic, haploid mycelium that results from plasmogamy and karyogamy; multiplication of the diploid along with haploid nuclei in the heterokaryotic mycelium; sorting out of a diploid homokaryon; segregation and recombination by crossing over at mitosis; and haploidization of the diploid nuclei. Sexual and parasexual cycles

are not mutually exclusive. Some fungi that reproduce sexually also exhibit parasexuality.



Stages of the parasexual cycle are numbered as follows (1) Hyphal conjugation (plasmogamy). (2) Heterokaryosis. (3) Nuclear fusion (karyogamy). (4) Mitotic recombination and non disjunction. (5) Haploidization and nuclear segregation leading to homokaryosis.

MODERN TAXONOMY

Systematics is field of biology dealing with diversity and evolutionary history of life. It includes

1-Taxonomy: DINC is the branch of systematics concerned with (Description, Identification, Nomenclature, Classification)

2-Phylogeny is the branch of systematics concerned with Determine Evolutionary History of Life. involes monophyletic and polyphyletic.

monophyletic group is a taxon (group of organisms) which meaning that it consists of an ancestral species and all its descendants. All fungi Monophyletic groups contain all the descendents from a common ancestor or all the branches come from a common ancestor and no branches from another ancestor are included just because they converged on a similar character.

Poly phyletic group is a taxon (group of organisms) which meaning that it consists of more than one ancestral species and all its descendants.

Phytophthora

Division: Mastigomycota

Subdivision: Diplomastigomycotina

Class: Oomycetes

Order: Peronosporales

Family: Pythiaceae

Genus: *Phytophthora* sp.

An terrestrial fungi, there are about 75 species of *phytophthora* some of them live as saprophytes but the majourity live on flowing plants attacking the aerial parts and causing leaf blight, canker and fruit rot diseases. One of the species *Phytophthora infestans* is great economic importance causes a serious potato disease known as potato blight or late blight of potato resulting in rot of tubers.

Asexual reproduction

The fungus survive in potato tubers in form dormant mycellium and when such tubers are used as seeds they grow intercellulary in host tissues and form haustoria to derive nutrition from adjacent cells.

Sporangiphores emerge from the lower surface of leaves through stomata bearing terminal, lemon shaped sporangia with distinct papilla.

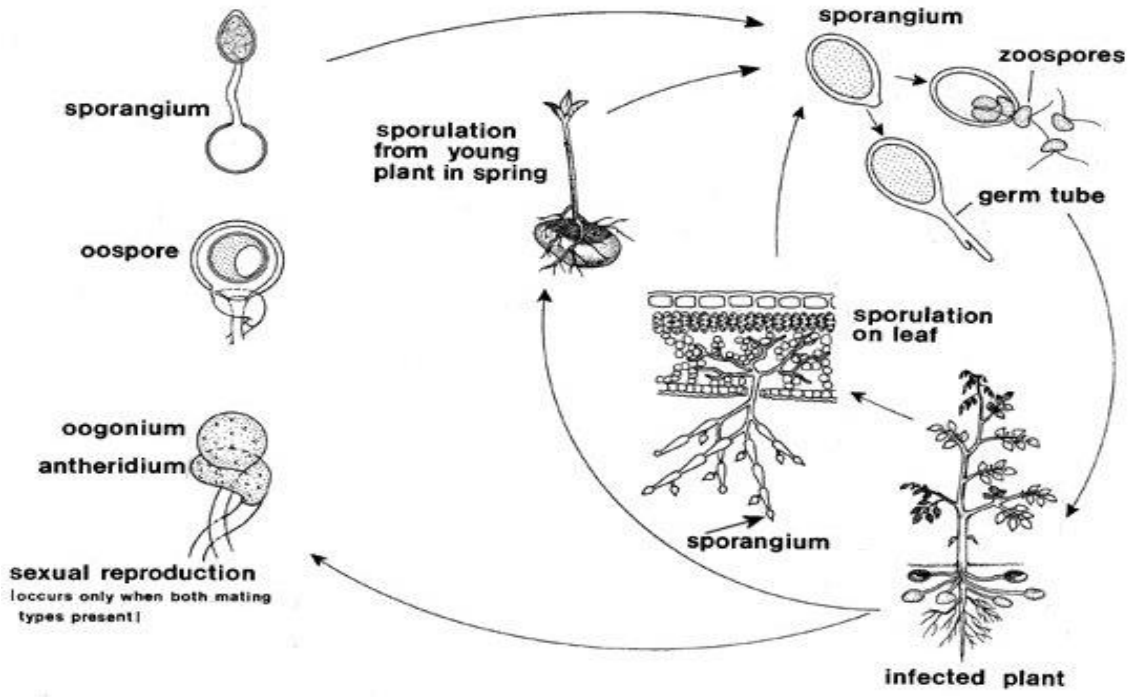
1- Under low temperature (18-20 ºC) and high relative humidity (91-100%) sporangium content split forming zoospores, liberating zoospres swim in water for some times then come to rest. Each zoospore retracts its flagella and may encyst. The encysted zoospores then germinates forming short hypha called germ tube which grow to new fungus

2- Under high temperatura and low humidity: sporangium germinate (as conidia) directly to germ tube which produce new fungus.

Sexual reproduction

In *phytophthora* sexual reproduction is oogamous take place by forming antheridium and oogonium. Antheridium and oogonium arises as short lateral hypha from mycelium. The antheridium and oogonium of opposite mating types (A_1 and A_2) grow and curve towards each other. Eventually the tip of oogonium of one strain comes in contact with the

young antheridium of the opposite mating strain, punctures and grows through it to emerge on the other side where it swells into globose structure. The antheridium now forms a collar-like structure surrounding the base of the oogonium. The oogonial wall swell at one point into the antheridium. This point is called the receptive spot. Then dissolves at this point through the resulting opening the antheridium pushes the fertilization tube, then the male nucleus transfere to fuse with female egg. Fertilized egg secretes a heavy wall around it and become oospores. Oospores nucleus divides repeatedly forming germ tube which grow either directly to new fungus or forming short hypha bearing sporangium contain large numbers of zoospores.



Life cycle of *phytophthora*

Amastigomycota

Subdivision: Zygomycotina

The class of zygomycetes derives its name from thick-walled resting spores (zygospores) formed as result of complete fusion of two gametangia. It is comprises 450 species which are grouped under 70

genera. They all are terrestrial molds which show a wide range in thier habitate.

General features of zygomyctes

1- The hyphal walls are composed of chitosan.

2- The hyphae are coenocyte not contain cross wall (septa)

3- The motile cells are completely absent in the life cycle.

4- Asexual reproduction typically take place by means of non-motile sporangiospores commonly produced in large numbers within sporangia. Sometimes the entire sporangium functions as a single spore in the same manner as the conidium.

5- Chlamydospore formation is of frequent occurrence.

6- Sexual reproduction involves gametangial copulation.

7- The thick-walled sexually produced zygospore formed by the complete fusion of two gametangia is the resting structure.

8- The zygospore germinates to produce hyphae (promycelium) which bear a terminal sporangium.

Classification of zygomycetes

Traditionally Zygomycetes class comprises 3 orders: -

1- **Mucorales:** Chiefly saprophytes, some weak parasites on plants, a few endoparasites of vertebrates. Mycelium extensive, asexual reproduction by sporangiospores or rarely by conidia; zygospore wall may be formed by modification of gametangial walls.

2- **Entomophthorales:** Typically, parasitic on animals, rarely saprophytes, mycelium limited. Asexuall reproduction by sporangia turned to conidia or true conidia; gametangial wall not transformed to zygospore wall.

3- **Zoopagales**: Typically, parasite on animals, rarely saprophytes, mycelium present with complicated haustoria, asexual reproduction by conidia; gametangial wall not transformed to zygospore wall.

***Rhizopus* sp.**

Division: Amastigomycota

Subdivision: Zygomycotina

Class: Zygomycetes

Order: Mucorales

Family: Mucoraceae

Genus: *Rhizopus* sp.

Occurrence: It is the commonest and the best known fungus found growing frequently on stale bread and thus is commonly called bread mold. It exclusively lives as saprophyte. Besides it occurs on damp decaying fruits, vegetables and other food material such as pickles, jams and jellies.

It consists of numerous, slender, freely branched filaments called hyphae. The hyphae are tangled and form a fluffy, white mass which makes up the thallus of the fungus. It is called the mycellium. It is cottony white during the vegetative phase, how ever, it son enters the reproductive phase, numerous black, pin head-like structures develop on the mycelium giving the mass a blackish appearance.

The thallus consists of three kinds of hyphae: -

1- **Stolons**: These hyphae that grow horizontally over the surface of substratum. The stolons grow rapidly in all directions and cause further spread of the mycelium over the substratum.

2- **Holdfast (Rhizoids):** It is cluster of brown, slender, branched rooting hyphae which arise from the lower surface of the apparent node of each stolon and penetrate the starchy substanc of the substratum. The rooting or rhizoidal hyphae has two functions: -

   a- They anchor the fungus to substratum.

   b- Absorb water and nutrients from it for the entire thallus.

3- **Sporangiophores:** Just opposite each holdfast one or more vertically growing hyphae rise into the air. They are reproductive in function and bear sporangia singly and terminally. These negatively geotrophic, unbranched special hyphae are called the sporangiophores.

Asexal reproduction

During their growing season fungus reproduces repeatedly by the formation of small, non motile spores (sporangiospores). They

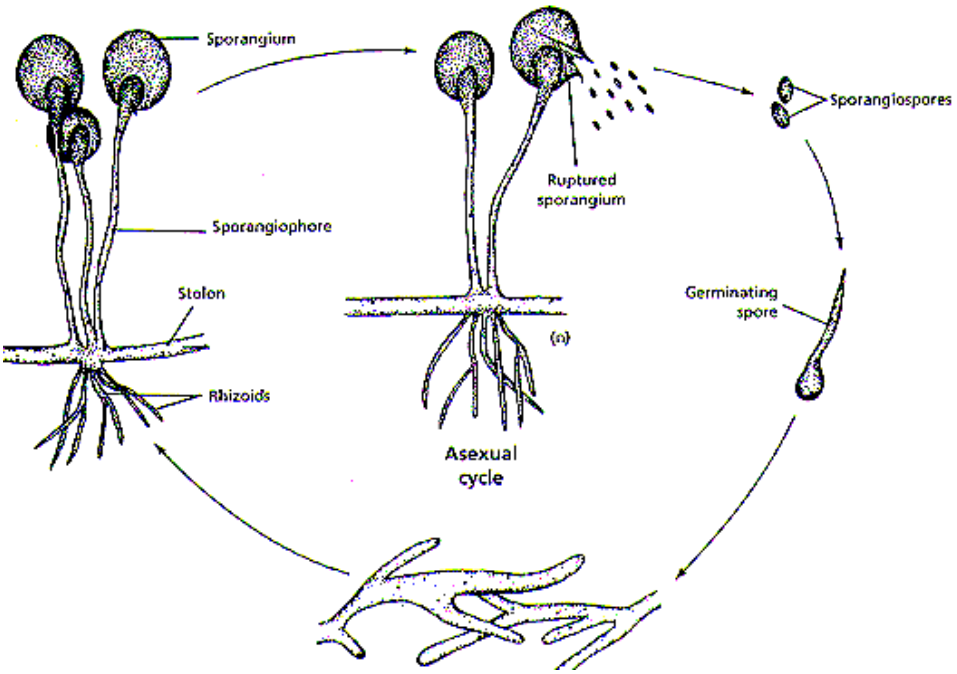
reproduced in large numbers within round black structure known as sporangium. Sporangium produced by swelling of end of the sporangiophore forming knob-like vesicle. The vesicle grow in size due to flow into it the cytoplasm and nuclei then undergo to cleavage to form segment which round and secrete walls around them to become the sporangispores. After spores maturation columella strart to rise pushing spores to ward sporangium wall leading to sporangiospores liberation. Liberating spores under unsuitable condition remain viable for long periods when become suitable the germinate forming new fungus.

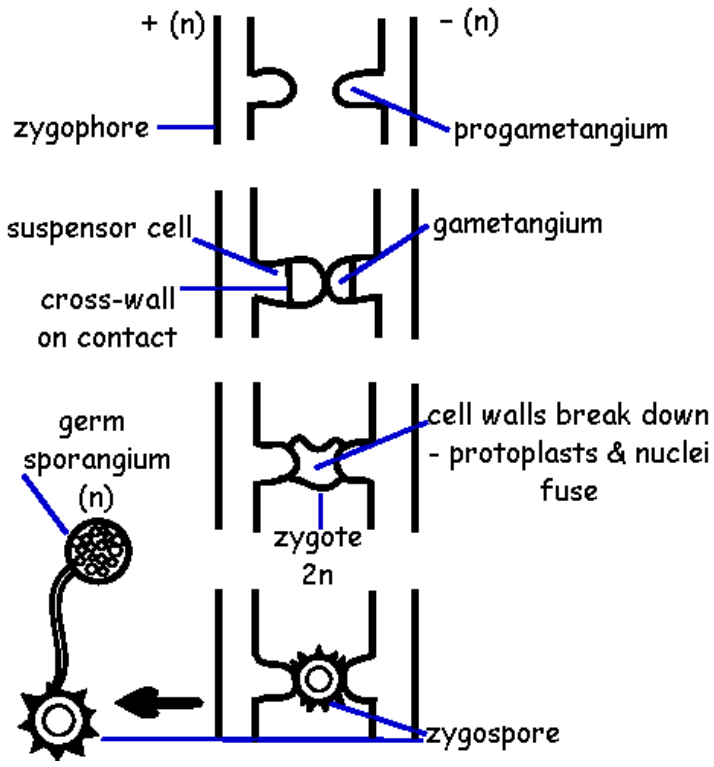
Sexal reproduction

Sexual reproduction take place by gametangial copulation. Under unsuitable condition each to hypha from different strains arranged and start to form zygophores. The zygophores begin to swell due to the follow of cytoplasm and nuclei into them. The swollen tips known as progametangia then trasverse seta (gametangial septum) appear in each progametangium splitting it into suspensor and small terminal cell called gametangium. When gametangia are mature the septum between them

dissolves then fusion of cytoplasm take place followed by nuclei fusion forming zygote (2N) which surounded by thick wall and become dark in color forming zygospores.

Zygospores split from the suspensor and then enters to a resting period, after this period, zygospores undergo to meiosis division then germinate producing germ tube which form sporangiophore bearing sporangium containing sporangiospores. After spores maturation, spores liberate from sporangium and germinate to form new fungus.





Life cycle of *Rhizopus*

Characteristics of Mucor

Some common characteristics of Mucor include:

1. Mucor is also called "**Black** or **Bread mould**".
2. It belongs to the class of Zygomycetes.

3. For most of the Mucor, the mode of nutrition is "**Saprophytic**" (grows in the dead decaying matter), and for others, it is "**Coprophilous**" (grows in cow dung or the dung of other herbivorous animals).
4. Mucor grows on a variety of substrates like bread, jam, jellies, vegetables etc. The absorption of nutrition is through the mycelial surface or hyphae.
5. The vegetative body of Mucor is "**Eucarpic**" because in this the only thallus differentiates into the reproductive structure.
6. The major reserve food material is in the form of glycogen and oil droplets.
7. The cell of Mucor is composed of mainly cellulose and chitin.

Structure of Mucor

Morphological Features

- **Mycelium**: The mycelium of Mucor is highly branched, and it forms a fine network of hyphae. A mycelium is simply a cluster of hyphae.

- **Hyphae**: These are the thread-like and very thin structures that form a “Mycelial network”. Hyphae of Mucor is filamentous, aseptate or coenocytic. In Mucor, the hyphae are of three types:

1.

    1. **Sub-terranean hyphae** are the type which is highly branched, more penetrating and is present horizontally to the substratum.
    2. **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.
    3. **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.

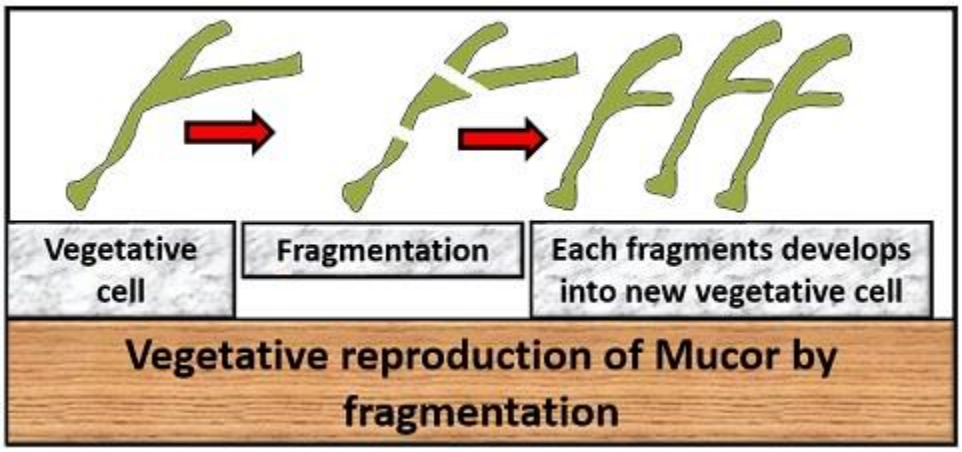
Life Cycle of Mucor

It has three modes of reproduction in its lifecycle:

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 unfavourable conditions. After which, each fragment then develops into a new vegetative body.



Asexual Reproduction

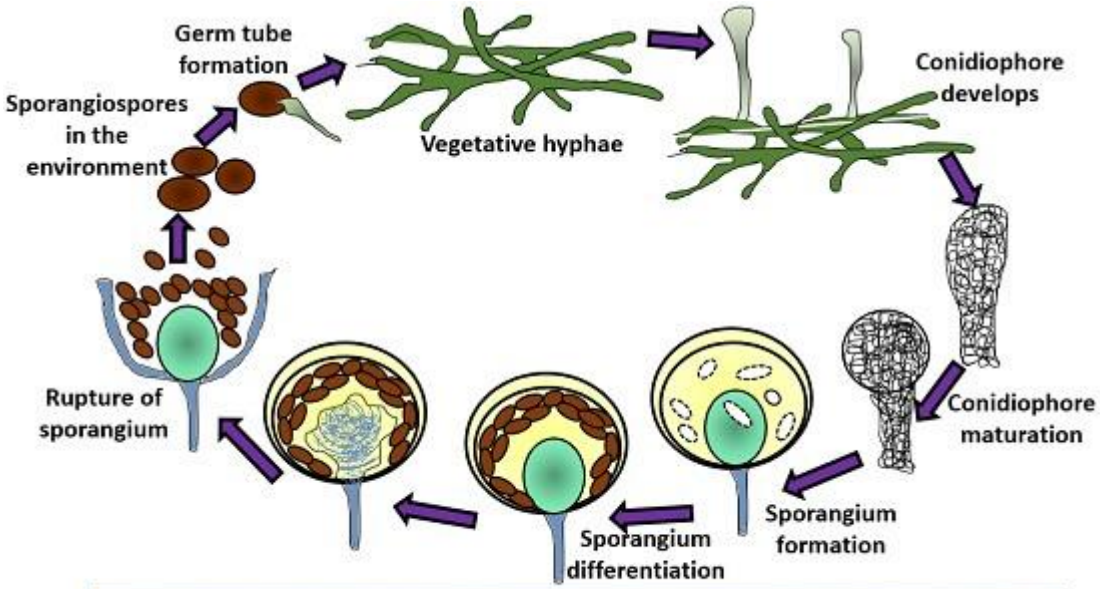
It occurs through the asexual and non-motile spores like:

- Sporangiospores

- chlamydospores
- Oidiospores

Sporangiospores

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



Asexual reproduction of Mucor by sporangiospores

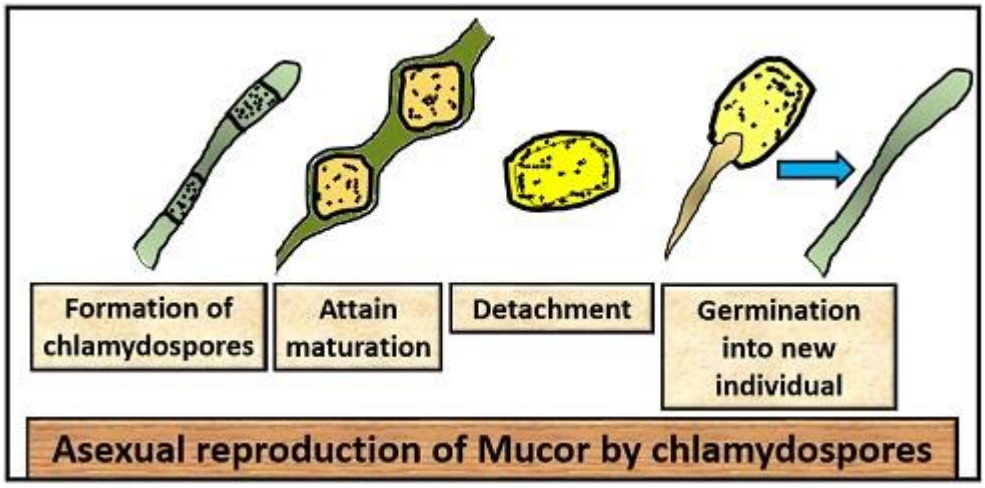
1. From the hyphae, first **sporangiophores** arise singly that are erect in position and unbranched.

2. Then, maturation of sporangiophore occurs where the cytoplasm and nuclei push upwards by making the aerial hyphae swollen from the apical end.
3. After that, it develops a large round **sporangium**.
4. During the 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.
5. After this, several small vacuoles appear between these differentiated portions. The space between the vacuoles forms cleavage furrows (cavity for cleavage).
6. Then, a septum forms to the inner side of the cavity, which further divides into the **inner columella** and **upper sporoplasm**. This septum then grows to form a dome shape and later it pushes itself into the sporangium.

7. Cleavage occurs in the sporoplasm between the nucleus and the cytoplasm. This division forms a wall around many thin-walled, multinucleate spores called "**Sporangiospores**".
8. The sporangiospores then releases out of the sporangia after the columnella swells up due to the pressure exerted on the sporangial wall. As a result, **cell lysis** occurs.
9. The spores remain dormant for some time, and when they obtain suitable substratum, they germinate to a new vegetative body through the germ tube.

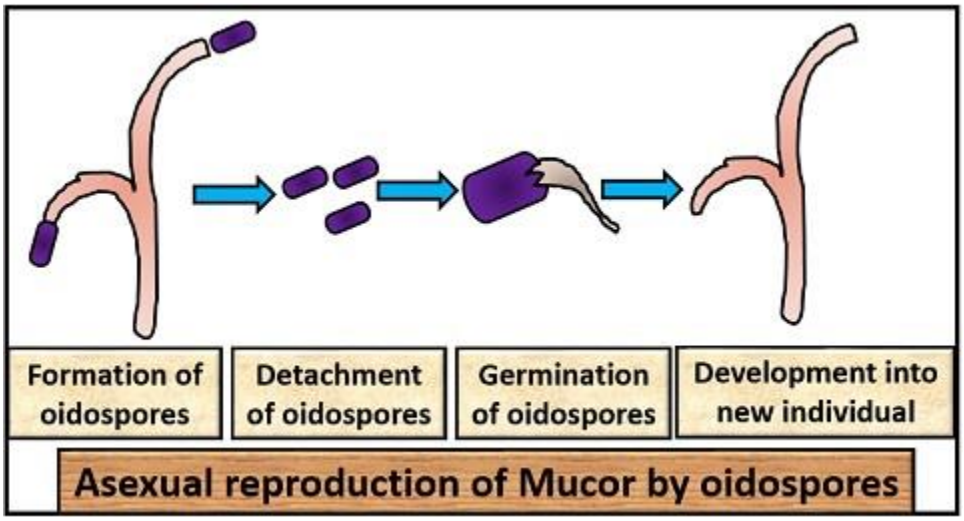
Chlamydospores

A hard wall covers these spores, and it develops inside the vegetative cell during unfavourable conditions. In unfavourable conditions, mycelium becomes septate by the accumulation of nuclei and cytoplasm in a certain portion and becomes surrounded by a thick wall called chlamydospores. This spore then detaches from the mycelium and remains dormant. On favourable conditions, they form a germ tube.



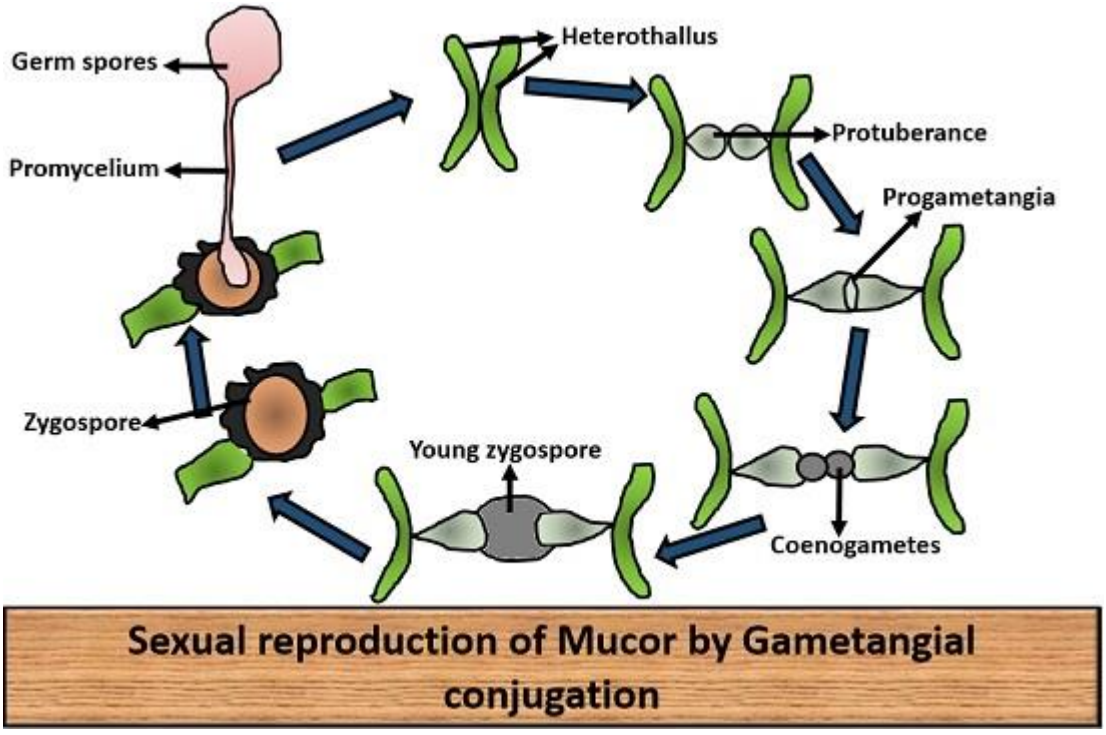
Oidiospores

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



Sexual Reproduction

In Mucor, the sexual reproduction occurs by the method that is called as Gametangial conjugation, which involves the following steps:



Sexual reproduction of Mucor by Gametangial conjugation

1. First, the thallus of two opposite strains, i.e. one is (+), and other is (-), comes in contact with each other.
2. When they come in contact, there develops a small outgrowth or protuberance from both of the thalli.
3. After that, the outgrowth swells to form "**Progametangium**".
4. Then septum develops between the progametangium, and the fusion of progametangia occurs that results in the formation of gametes called "**Coenogametes**".
5. Then gametes of both the strains fuse to form a "**Zygote**".

6. The zygote then enlarges in size and get surrounded by a thick-walled structure called "**Zygospore**".
7. Zygospore is dark black in colour, which gets covered by the two layers, namely:
    - Outer layer: Also called **Exosporium**.
    - Inner layer: Also called **Endosporium**.
8. The zygospore remains dormant for some time and on favourable conditions, promycelium develops out from the zygospore, forming a new vegetative body.

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

Subdivision: Ascomycotina

It is a large group comprising fungi more complex in structure and mainly landforms which vary in form and grow in varied habitats.

General features: -

1- The somatic phase consists of a well-developed branched mycelium with regular septation of the hyphae. The cross wall has each a minute, central, simple pore.
2- There is complete absence of motile cells in life cycle.
3- Asexual reproduction take place by formation non-motile, exogenously produced spores called conidia. They are reproducing terminally on special, reproductive hyphae called conidiophores.
4- Sexual reproduction take place by formation ascospores which formed in special thin-walled sac like structure called ascus.
5- Asci in most species are grouped to form definite complex fruit bodies called ascocarps.

Development of Asci

Formation of ascus started by: -

1- Producing of ascogonium (female organ) and antheridium (male organ).

2- With migration of male protoplast (cytoplasm + nuclei) each nucleus in the ascogonium becomes paired with one from the antheridium.

3- From dikaryons ascogonium arise papilla-like outgrowths forming ascogenous hyphae.

4- The apical compartment of a dikaryotic ascogenous hypha elongates and bends over to form a hook (Crozier).

5- The two compatible nuclei in the apical compartment then undergo mitosis simultaneously.

6- Two septa develop in such a way that the crozier becomes divided into three compartments, the tip and basal compartments are uninucleate; the middle compartment is binucleate and is called the ascus mother cell (since it is destined to become an ascus).

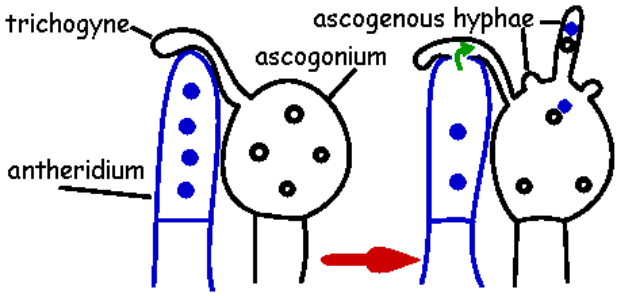
7- The nuclei in the ascus mother cell fuse to form a diploid nucleus, which then undergoes meiosis to form four haplid nuclei.

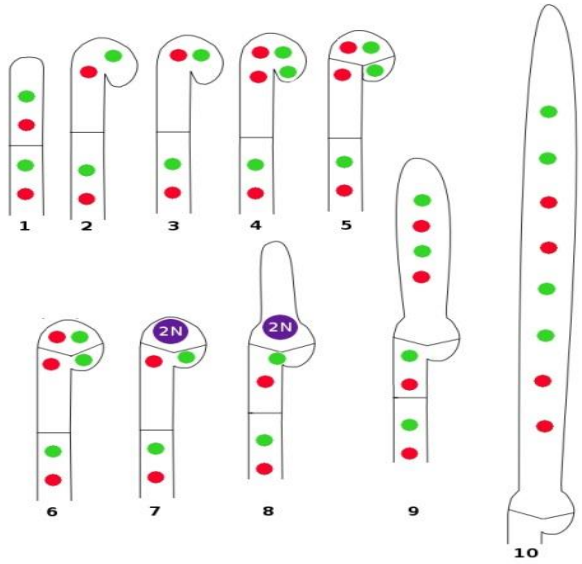
8- Each haploid nucleus then divides mitotically, resulting in eight haploid nuclei.

9- A portion of protoplasm surrounds each nucleus - this becomes enveloped by a wall and matures into an ascospore.

10- Meanwhile, another ascus mother cell will have been developing alongside the first.

11- In most (not all) fungi belonging to the ascomycota the asci don't occur singly; they form in groups surrounded by hypha and are enclosed in fruiting bodies (ascocarps).





Use of ascocarps in the classification of fungi belonging to the Ascomycota:

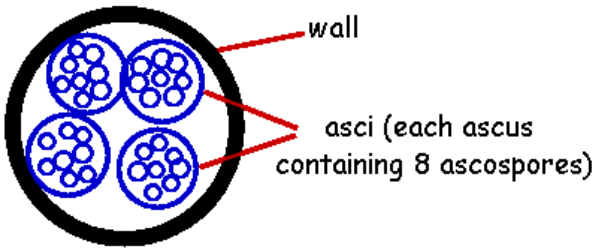
1- Hemiascomycetes (includes yeasts)

- In this case the asci are not enclosed in an ascocarp.
- In which, the diploid cell (zygote) in yeast is transformed directly into an ascus containing four or eight ascospores.

2- Plectomycetes

Fungi belonging to this group form **cleistothecia**. These are round, completely closed ascocarps, possessing no natural opening. The

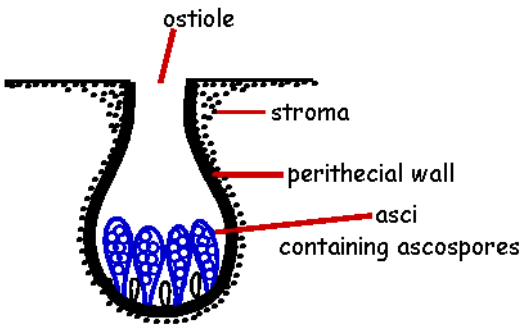
asci are arranged irregularly within them. When mature the cleistothecia burst open to release their asci and ascospores.



3- Pyrenomycetes

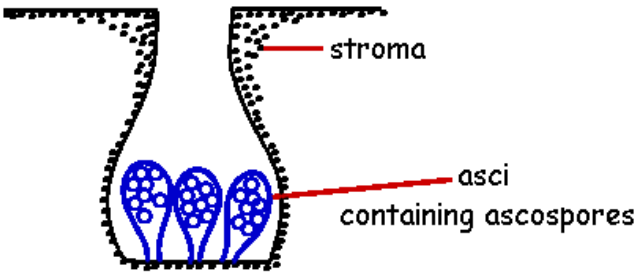
Fungi belonging to this group form **perithecia**. Perithecia are spherical or flask-shaped ascocarps. They open via a neck-like ostiole with a terminal pore through which the ascospores are liberated. The asci are arranged in an orderly layer at the base of the cavity.

Warning: do not confuse perithecia with pycnidia which contain conidia.



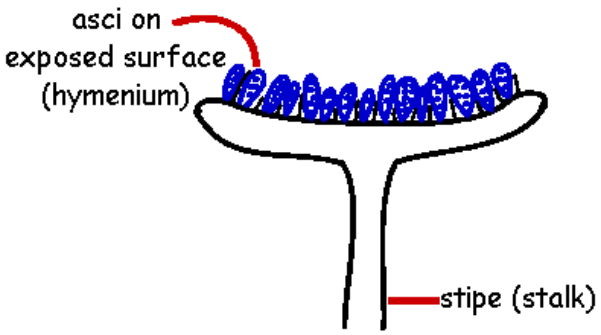
4- Loculoascomycetes

Fungi belonging to this group form **ascostromata** (or pseudothecia). Ascostromata resemble perithecia but in the former there is no wall surrounding the central region of the ascocarp, only a cavity within the mass of hyphal tissue (stroma) in which the asci are located.



5- Discomycetes

Fungi belonging to this group form **apothecia**. An apothecium is an open or cup-shaped ascocarp. The asci are arranged on the exposed surface (hymenium).



Yeasts

Division: Amastigomycota

Subdivision: Ascomycotina

Class: Ascomycetes

Subclass: Hemiascomycetidae

Order: Endomycetales

Family: Saccharomycetaceae

Genus: *Saccharomyces*

Mostly the yeasts are saprophytes. They are widespread in their distribution and like bacteria are found everywhere on the face of the earth usually in substrates containing sugar. The most common species is *Saccharomyces cerevisiae* which used in bread making and beer brewing.

Unlike other sac fungi the thallus is non-mycelial; it is not made up of hypha. It consists of single minute oval or spherical cell, has cell wall made up of two polysaccharides, namely glucans and mannan in combination with traces of protein, lipid and chitin, there is no cellulose.

Reproduction

Yeast reproduces both asexually as well as sexually.

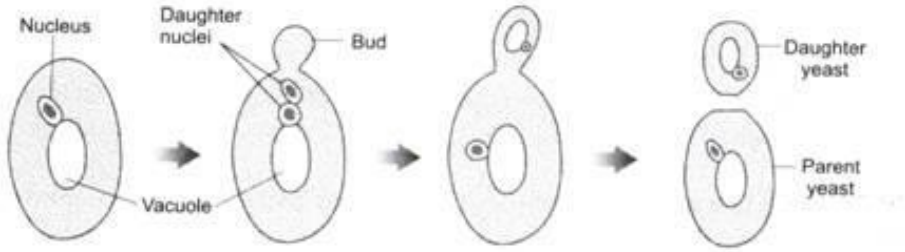
Asexual Reproduction

Budding: Most of the yeasts multiply asexually by vegetative method called budding, under favourable conditions *Saccharomyces* reproduce by this method. At the time of budding, a small portion of the cell wall at

or near one pole of the yeast cell softens and thin. The protoplast in this region, bulges out in the form of an outgrowth (protuberance), covered by the thin softened membrane. Outgrowth gradually increases in size and known as the bud. As the bud is forming, the nucleus of parent yeast cell divides forming two nuclei. The daughter nuclei migrate into enlarging bud. The bud grows, and the cytoplasm of the bud and mother cell remains continuous for sometimes. Eventually the opening between the two cells closes, and then the bud separates from mother cell leaving a scar on both cells. In the presence of abundant food supply, the process of budding is quickened. It becomes so rapid that the buds often produce buds before separation from the mother cell, the process is repeated, in this way many buds are formed without being detached from one another, this result in the formation of branched or unbranched chains of cells constituting the pseudomycelium.

Fission: Vegetative reproduction by fission has also been reported but it occurs in some other yeast and not in *Saccharomyces*. They are called fission yeasts for this reason. The division is transverse. The mother cell

elongates, and the nucleus divides into two. Meanwhile a ring-like ingrowth appears at the wall of the yeast cell in the middle, it grows in ward toward the centre of the cell. Finally, it stretches across the cell forming a complete partition called septum. The septum thickens and then splits into two layers, one for each daughter cell.

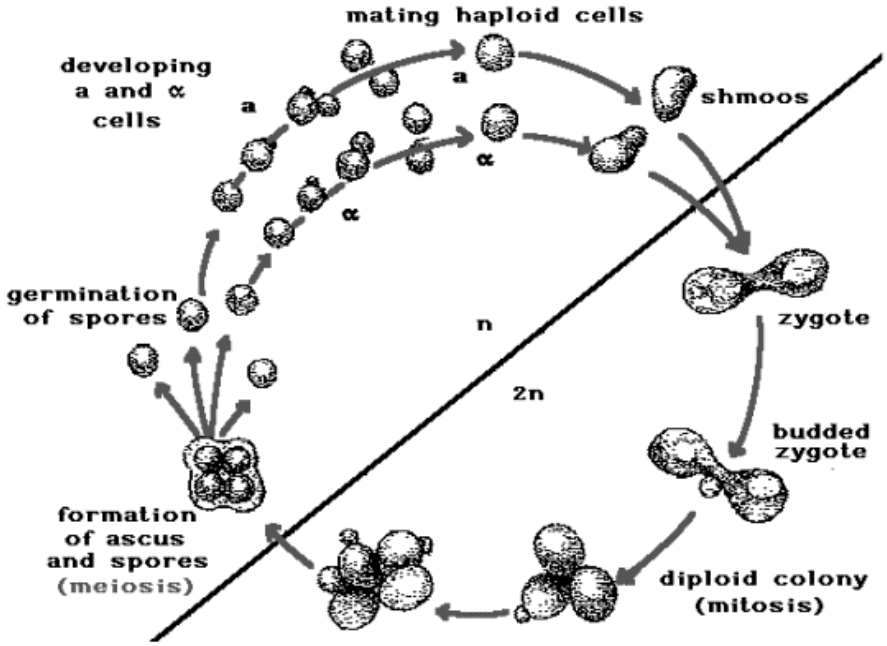


Budding in yeast

Sexual reproduction

Sexual reproductions started by two haploid cells of the opposite mating types bends towards each other and fuse to form Conjugation Bridge. Fusion between the protoplast of the (+) and (–) strains takes place through the conjugation bridge called plasmogamy. Then karyogamy occurs by fusion of two nuclei forming diploid nucleus (2N) called

zygote. The zygote become spherical in shape and directly functions as ascus mother cell. Then the diploid nucleus of ascus mother cell undergoes meiosis forming four haploid nuclei which surrounded by cytoplasm to produce ascospores. Ascospores liberate from the ascus mother cell and germinate forming new yeast cell.



Life cycle of *Saccharomyces*

Genus *Aspergillus*

Division: Amastigmycota

Subdivision: Ascomycotina

Class: Ascomycetes

Subclass: Plectomycetidae

Order: Eurotiales (Aspergillales)

Family: Eurotiaceae (Aspergillaceae)

Genus: *Aspergillus*

- The genus is widely distributed fungus from the very cold region of arctic to the tropics. The name is derived from aspergillum, which means a special bruch resemblance to the conidial apparatus of *Aspergillus*.

- *Aspergillus* colonies are usually fast growing, some shades of green, blue, or other colour than green e.g. white, yellow, brown, to black and they mostly consist of erect conidiophores.
- *Aspergillus* produce antibiotics, mycotoxins and cause a lot of food spoilage.
- Spores of *Aspergillus* are carried by air, everywhere, and that is why of spoilage of organic materials.
- The successful colonization of numerous types of media, made by *Aspergillus* indicates that they are provided with an active enzyme system.

Asexual reproduction

- It takes place through the production of conidia. Conidiophore arises as aerial unbranched hypha. The cell from which the conidiophores emerge is known as foot cell.
- Conidiophores are produced singly and are non septate, unbranched and each end with a head known as vesicle.

- Vesicle covered with either a single phialides (strigmata) or a layer of metulae which bear small phialides (uniserriate or biserriate). The vesicle, phialides, metulae (if present) and conidia form conidial head.
- Conidia born from phialides, are one-celled, smooth, or rough-walled, hyaline or pigmented and are basocatenate, forming long chains may be divergent (radiate), or aggregated in compact columns (columnar).
- Condia split from phialides and spread away, when find suitable substrate, it germinates forming new fungus

Sexual reproduction

The sexual reproduction is rare. *Aspergillus* is **homothallic**, a male (Antheridium) and female (Ascogonium) sex organs are developed close together on the same hypha or on separate nearby hyphae of the same mycelium. Both are elongate, multinucleate and generally coil around each other.

Ascogonium: A small, loosely coiled septate hyphal branch arises from vegetative hypha. It is differentiated into three parts.

a- **Trichogyne**: the terminal segment is generally the longest and single celled it contains up to 20 nuclei called. It is functions as the receptive part of the female organ.

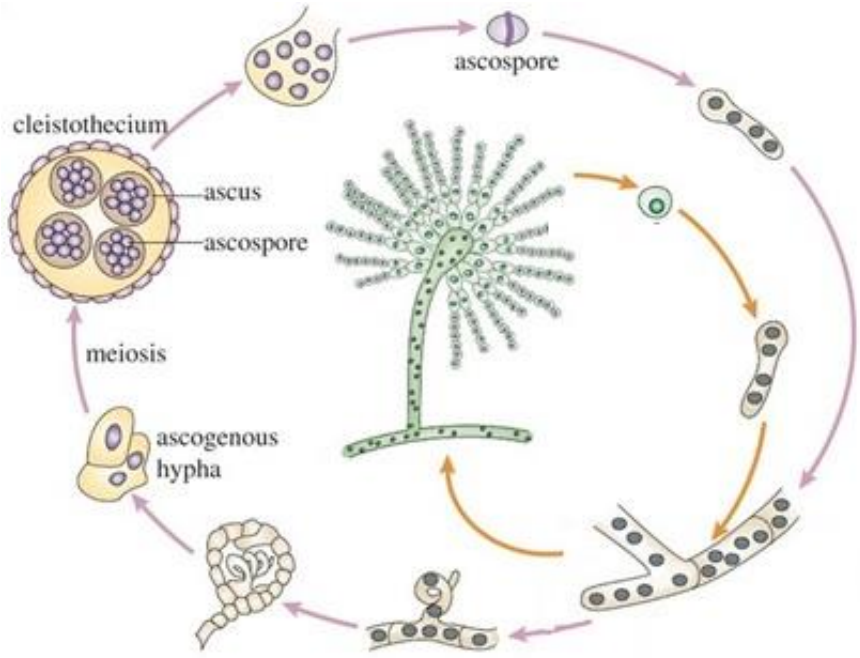
b- **Ascogonium**: the segment below trichogyne functions as the female gametangium.

c- **Stalk**: below ascogonium and consisting of few cells.

Fusion takes place between the antheridium and trichogyne. The tip of the antheridium arches over the apex of the trichogyne and fuse with it. The contents of antheridium then pass through the opening into the trichogyne.

The haploid male and female nuclei in the ascogonium come to lie in pairs (dikaryons). After pairing of the nuclei, ascogenous hyphae arise which differentiated to form ascus mother cell which produce ascus contain 8 ascospores. Ascospores after liberation germinate at suitable condition producing new fungus.

The ascocarp in *Aspergillus* is a small, rounded, and yellow with smooth walls. Even at maturity it remains closed called cleistothecium or cleistocarp.



Life cycle of *Aspergillus*

Economic importance

1. *Aspergillus* causes rot of dates, decay of tobacco and cigars.
2. It spoils nuts, bread and other foodstuffs.

3. Some of *Aspergillus* produce mycotoxins such aflatoxin and ochratoxin.
4. They cause many diseases grouped under the name Aspergilloses also ear disease called otomycosis.
5. *Aspergillus* used for antibiotic production such as flavicin, aspergillin, geodin, patulin and ustin.
6. *Aspergillus gossypii* used for production of certain vitamins such as B 12.
7. Certain species used for production of many enzymes, lipids and several organic acids.

Subdivision: Basidiomycotina

It is the most advanced of all the fungal classes. It includes about 15.000 species with more than 500 genera. This big group of fungi includes both saprophytic and parasitic species. The saprophytic species live in moist, decaying wood, dung, wet dead leaves or humus of the soil.

As in ascomycetes motile structures are lacking in this class and the mycelium is septate. The basidiomycetes produce highly complicated fruiting bodies called the basidiocarps. The basidiocarps in the higher forms are visible portion of the fungus and they are concerned with production and bear reproductive structures called basidia

General features of basidiomycetes.

- The somatic phase consists of a well-developed, septate, filamentous mycelium which passes through two stages: -
  a) **Primary mycelium:** it is formed by germination of basidiospore and contains a single haploid (n) nucleus in each cell.
  b) **Secondary or dikaryotic mycelium:** it constitutes of the main food absorbing phase and consist of cells each containing two haploid nuclei (n+n). It is long lived and play prominent role in the life cycle also bearing basidia and basidiospores.
- Except in rusts and smuts the septal pores in basidiomycetes is complex. It is dolipore **parenthesome** type.

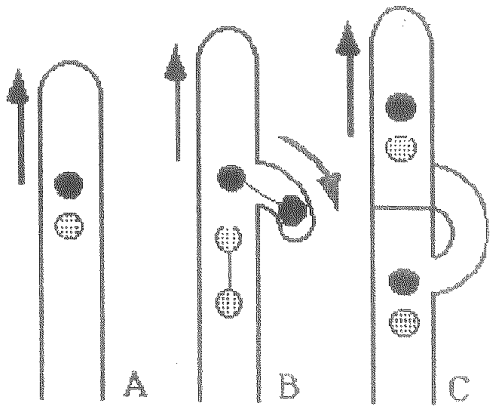
- The motile cells are absent in the life cycle.
- The clamp connections on the dikaryotic hyphae are of universal occurrence
- Asexual reproduction by spores plays a significant role in life cycle.
- The sex organs are lacking in the basidiomycetes
- Basidium is the reproductive organ of basidiomycetes in which both karyogamy and meiosis take place.
- Typically, the basidium bears four basidiospores.
- The basidiospores germinate to form primary mycelium.

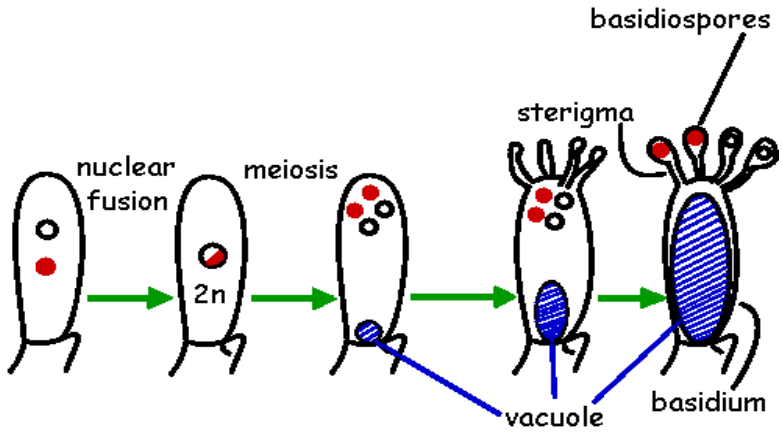
Formation of basidiospores

Firstly, basidiospores germinate forming primary mycelium contain a single haploid (n) nucleus in each cell (monokaryon). Then take place interaction between two compatible primary mycelia forming secondary or dikaryon mycelium which consists of binucleate cells. During nuclear divisions of the dikaryotic cell special structure called the clamp

connections are formed. These clamp connections ensure that the sister nuclei of the dikaryon at each division separate into daughter cells.

- Two haploid nuclei in an apical dikaryotic hyphal compartment (often within a basidiocarp) fuse to form a diploid nucleus.
- The diploid nucleus undergoes meiosis to yield four haploid nuclei.
- Four small outgrowths sterigmata begin to form at the top of the hyphal compartment and the tip of each sterigma begins to inflate.
- A fluid-filled vacuole develops near the base of the compartment and gradually enlarges as it enlarges it forces protoplasm into the inflated portions of the sterigmata.
- When each swelling at the tip of a sterigma has almost attained its full size, a nucleus passes into it.
- The uninucleate swelling at the the tip of each sterigma matures into a basidiospore.
- The compartment supporting the sterigmata and basidiospores is called a basidium.





Formation of basidium

Classification of basidiomycetes

Classification of fungi belonging to the basidiomycota is based upon the presence or absence of fruiting bodies (basidiocarps) and the type of basidiocarp formed. Basidiocarps are amongst the most familiar of

fungal structures, including toadstools, brackets and puff-balls. But the basidiomycota also contains many species that produce microscopic sporulating structures, i.e. micro-fungi.

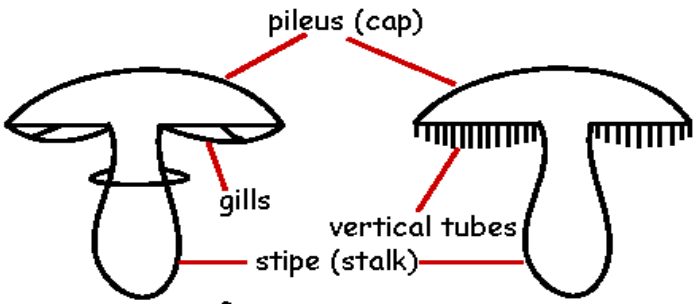
Classification of fungi belonging to the Basidiomycota:

1. **Teliomycetes**

   In this group the basidia are not grouped together side by side in or on a basidiocarp (fruiting body). The uredinales and ustilaginales are two important orders of plant pathogenic fungi belonging to the teliomycetes.

2. **Hymenomycetes**

   The largest class in the basidiomycota, the basidia are arranged in a layer known as a hymenium that is fully exposed at maturity. The hymenium may cover the surface of gills, line vertical downward-facing pores, or cover an erect club or system of vertical branches or teeth.



3. Gasteromycetes

Gasteromycetes includes fungi known as Puff-balls, Earth-stars and Birds' nest fungi. The spore-producing hymenium is not exposed at maturity. But these fungi have evolved a variety of mechanisms to ensure efficient spore liberation. In other word: they include those basidial fungi having basidiospores produced within closed basidiocarp which will not open except after complete maturation of spores. Basidiocarp is either permanently subterranean or above ground.

Genus: *Agaricus*

Division: Amastigomycota

Subdivision: Basidiomycotina

Class: Basidiomycetes

Subclass: Holobasidiomycetes

Series: Hymenomycetes

Order: Agaricales

Family: Agaricaceae

Genus: *Agaricus*

Agaricus is a saprophyte and grow in the open fields, grass land and in soil in cellulose and lignin materials. It is also found growing in the

decaying litter on forest floors or in the humus deposited at the surface and below the surface of the ground. It grows best in moist and is commonly seen during the rainy season. Some species are used for eaten by human such as *Agaricus campestris*, *A. rodmani*, *A. silvaticus* and *A. placomyces*.

Asexual reproduction

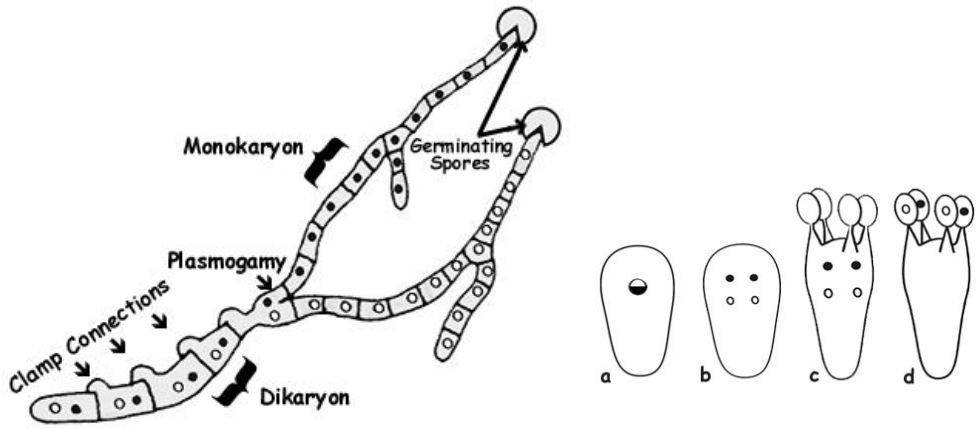
This type of reproduction is very rarely of occurrence. Take place by formation of chlamydiospores which germinate to form new mycelium

Sexual reproduction

The mushroom basidiocarp is typically composed of a stipe that elevates the basidiocarp above the substrate, a pileus and in some species a partial veil that encloses and protects the lamella as the basidia and basidiospores are developing.

Sexual organs are completely absent. After germination of basidiospore give monokaryon mycelim, then dikaryon formation begins with the fusion of hyphal cells between compatible monokayons. The monokaryon stage of the Basidiomycotina is short-lived and fusion with

a compatible monokaryon occurs soon after basidiospore germination. The dikaryon is the mycelium that produces the basidiocarp. The terminal cells develop into basida and are where karyogamy will take place to form the zygotes. The zygote is the only diploid stage in the life cycle. The zygote immediately undergoes meiosis to form four haploid nuclei, and the future basidiospores are formed as blown out structures, on the tips of sterigmata, of the basidium. The nuclei migrate into the blown-out areas which may then be properly referred to as basidiospores.



Life cycle of *Agaricus*

Puccinia graminis

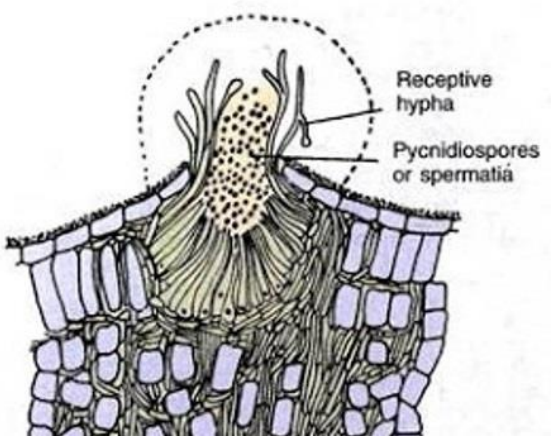
It causes rust disease known as the black stem rust of wheat in all wheat growing areas of the world. It had been considered strictly obligate in its parasitism. Normally the fungal parasite passes a part of its life cycle constituting the dikaryophase on wheat and a part constituting the haplophase on barberry plant. The full life cycle is thus completed only when both hosts are present. The wheat plant called primary host and barberry is called secondary or alternate host.

Life cycle can summarize as following: -

Spermogonium (Stage 0)

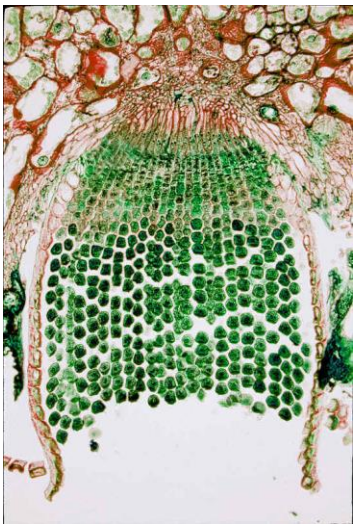
The spermogonium stage produces the sex organs in rusts. They are produced on the upper surface of the *Berberis* (barberry) leaf. Since the spermogonia are derived from basidiospores, they are of two mating types. They are flasked-shaped reproductive structure in which spore-like spermatia and specialized (receptive) hyphae are produced. Spermatia ooze out, from the neck, in a sweet-smelling nectar. The spermogonia are visited by flies which are attracted by the nectar secretions, and as they visit different spermagonia, spermatia of both

mating types, adhere to their bodies and are transferred to receptive hyphae of the other mating types. This begins the dikaryon stage of the life cycle.



Aecium (Stage I)

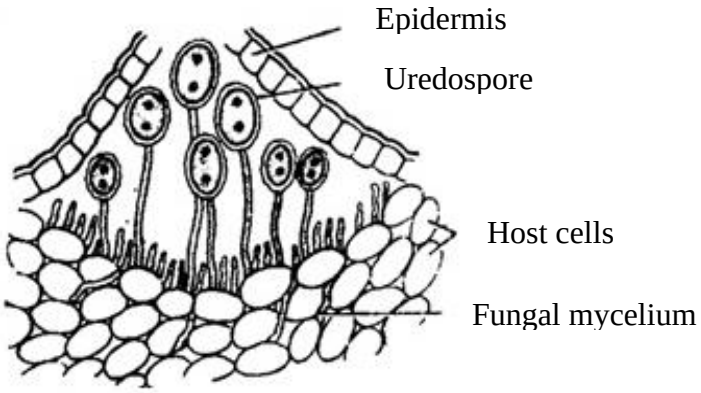
The aecium stage is directly linked to the spermagonium stage. When spermatia are transfered to compatible receptive hyphae, this begins the dikaryotic stage of the life cycle and directly produces the aecium on the lower surface of the barberry leaf. The aecium is an upside-down, sac-shaped structure in which chains of aeciospores are formed. The aeciospores burst through the lower surface of the leaf and are dispersed by wind. Aeciospores are unicellular containing two nuclei.



Uredium (Stage II)

The aeciospores cannot reinfect the barberry host. Instead, infection can only occur on the primary host, *Triticum aestivum* (wheat), where a new dikaryotic infection occurs. When two hosts are required in the completion of a rust life cycle, the rust is said to be **heteroecious**. The wheat is said to be the primary host while barberry is said to be the alternate host. The dikaryons infect the wheat stems and leaves and will form uredia that contain orange-brown uredospores. This order is commonly called the rusts because of the orange-brown (rusty) colored pustules that form on the wheat plant after the uredospores have broken through the epidermal surface. The urediospores are comparable to

conidia in that they will reinfect wheat plants and produce more uredia and uredospores. This stage begins during summer and continues until late summer in North America. Uredospores are unicellular containing two nuclei.



Telium (Stage III)

Towards the end of summer, the uredium begins to produce **teliospores**, a dark, thick-walled, two celled spores. Teliospores do not produce telia. It is the uredium that gradually becomes a telium by producing more and more teliospores. Because of the color of the teliospores, the telium is black and the teliospore overwinters. In spring, karyogamy and meiosis

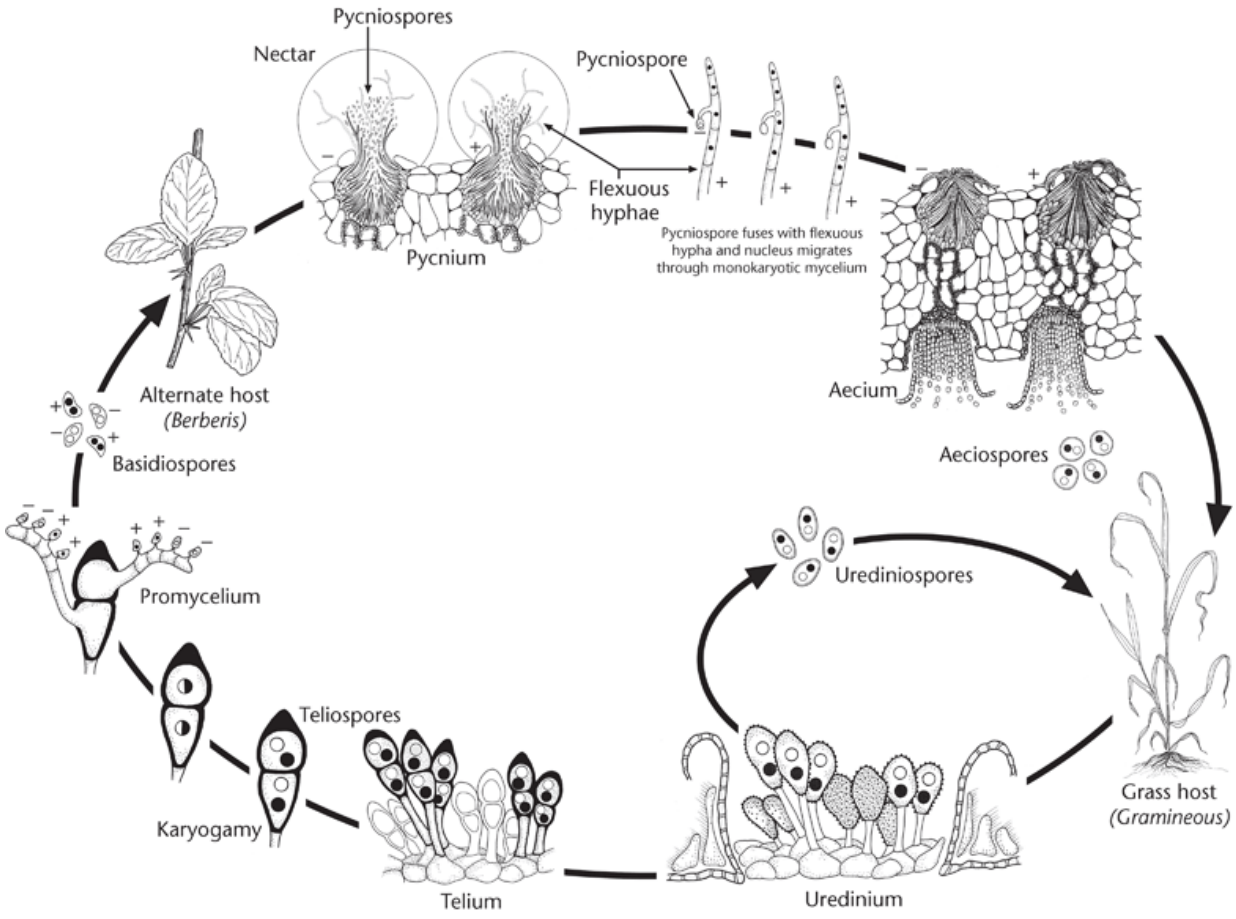
takes place in each cell of the teliospore, and germinates to form the **promycelium** (=basidium). The promycelium becomes transversely septate, forming four cells. Each cell produces a sterigma and a basidiospore, and this now completes the life cycle.

Teliospores

Basidium (Stage IV)

Puccinia graminis is heterothallic and **basidia** produce **basidiospores** that are of two mating types, Basidiospores are capable of only infecting the leaves of *Berberis* sp. (barberry), the **alternative host** for this species. Species that require two hosts to complete their life cycles are said to be **heteroecious**. The cells of the **teliospore** germinate to produce

a short germ tube that will develop into a basidium that is essentially transversely septate.



Life cycle of *Puccinia graminis*

Deuteromycotina (Fungi imperfecti)

This group of fungi is reproducing by asexual means usually by conidia, but lack perfect sexual stage. Deuteromyctes economically highly important, their number goes up to thousands. Many of them live as saprophytes and many more as parasites. The latter are the causative agents of diseases in plant and animals including man, some cause spoilage of stored products.

The somatic phase in the majority of these fungi consists only of the haploid mycelium, it is septate and profusely branched. Reproduction takes place chiefly by formation of conidia. Formation of oidia and chlamydospores has been also reported.

Conidia and conidial development

The conidia are exogenously produced spores. They are non-motile and are borne externally from growing hyphae called conidiophores. The apical region of conidiophore may produce a single conidium or a chain of conidia usually in basipetal succession.

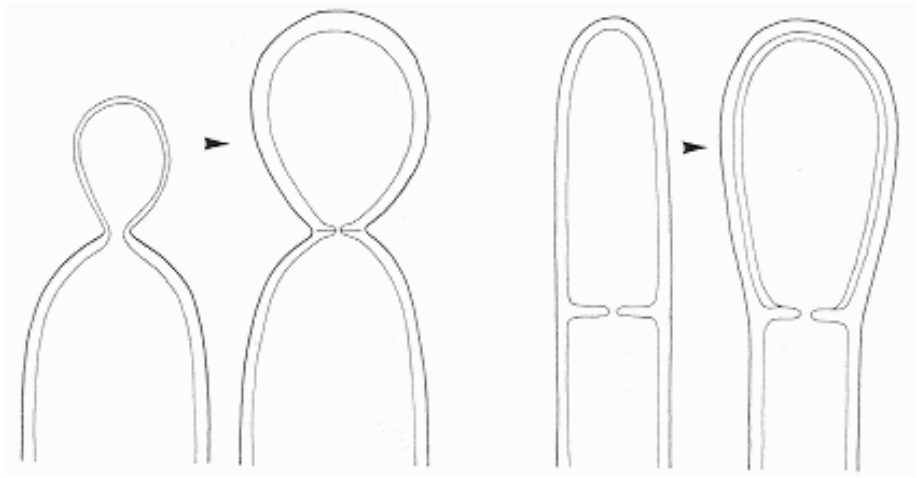
Ellis (1971) has recognized two types of conidial developments

A- Blastic: in this type of conidial development marked enlargement of conidial initial take place before it is delimited by a septum. It may be of two types:

1- Holoblastic: both the inner and outer wall of conidiogenous cells takes part in the formation of conidia.

2- Enteroblastic: only the inner wall of conidiogenous cells takes part in the formation of conidia

B- Thallic: in this type of conidial development there is no enlargement of conidial initial. It takes place after the initial has been delimited by septum.



Blastic **Thallic**

Genus: *Fusarium*

This genus includes many species and many forms within species. Many of these are saprophytic, some are facultative parasites and others are parasitic.

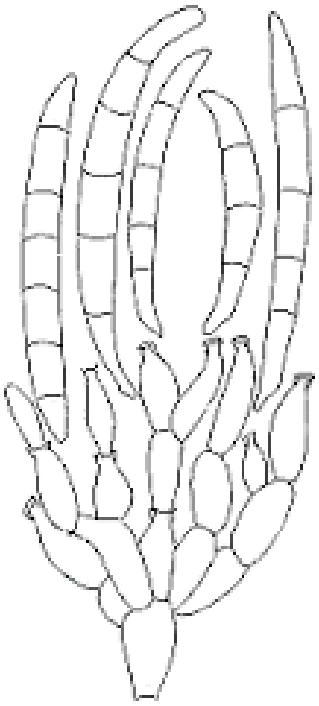
Mycelium: it is extensive. The hyphae are septate and branched. When young they may be colourless or with a tinge of pink, purple or yellow and become dark coloured at maturity.

Asexual reproduction

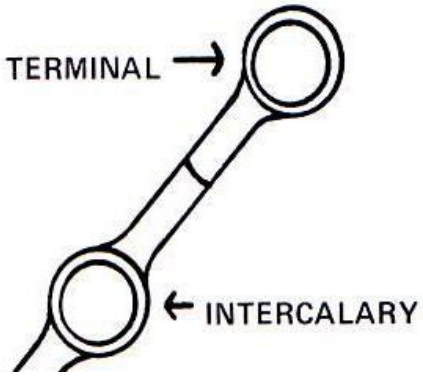
It takes place by the formation of three kinds of asexual spores, microconidia, macroconidia and chlamydospores. Sclerotia are also formed.

Micoconidia: they are very small conidia produced from the tips of simple or branched conidiophores. The conidiophores are distinguishable from the vegetative hyphae. The microconidia vary in shape from the rounded to oval, they are often held in small masses.

Macroconidia: they are large and multicellular. In form they are elongated, sickle-shaped or crescent-shaped. They are produced at the tips of simple or branched conidiophores which are assembled to form sporodochium.



Chlamydospores: they are rounded, oval, thick-walled cell formed in hyphae. They may be formed singly or in chains of two or more. They become separated from the parent hyphae after maturing and function as resting spores. Under suitable conditions, the chlamydospores germinate by means of germ tubes to form fresh mycelium.



Sclerotia: the mycelium often forms compact, resting bodies of thick-walled hyphae these called sclerotia. They function as storage organs and also serve as means of vegetative propagation.

Aquatic Fungi

Microbiology

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

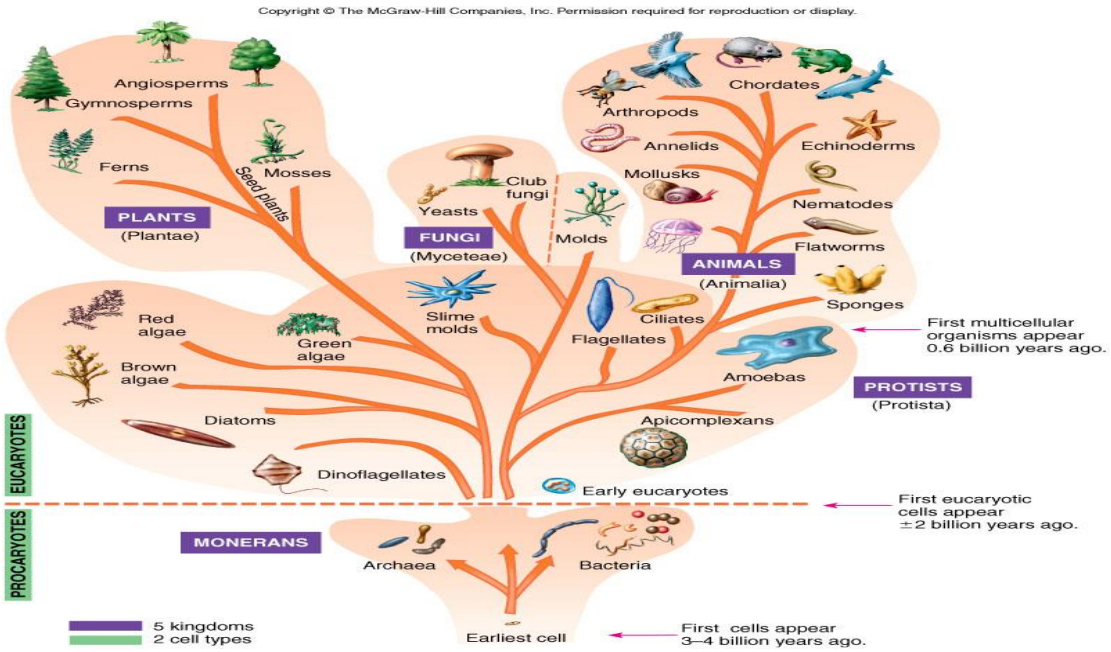
Microbes or Microorganisms

- commonly referred to as “germs” or “bugs”
- include bacteria, viruses, fungi, algae, protozoa and helminths.
- Prions (“infectious proteins”) are recent addition.

Branches of Microbiology

- **Bacteriology** study of bacteria
- **Mycology** study of fungi and yeast
- **Virology** study of viruses
- **Parasitology** study of parasitic protozoans and helminths

- **Immunology** study of the humoral and cellular immune response to disease agents and allergens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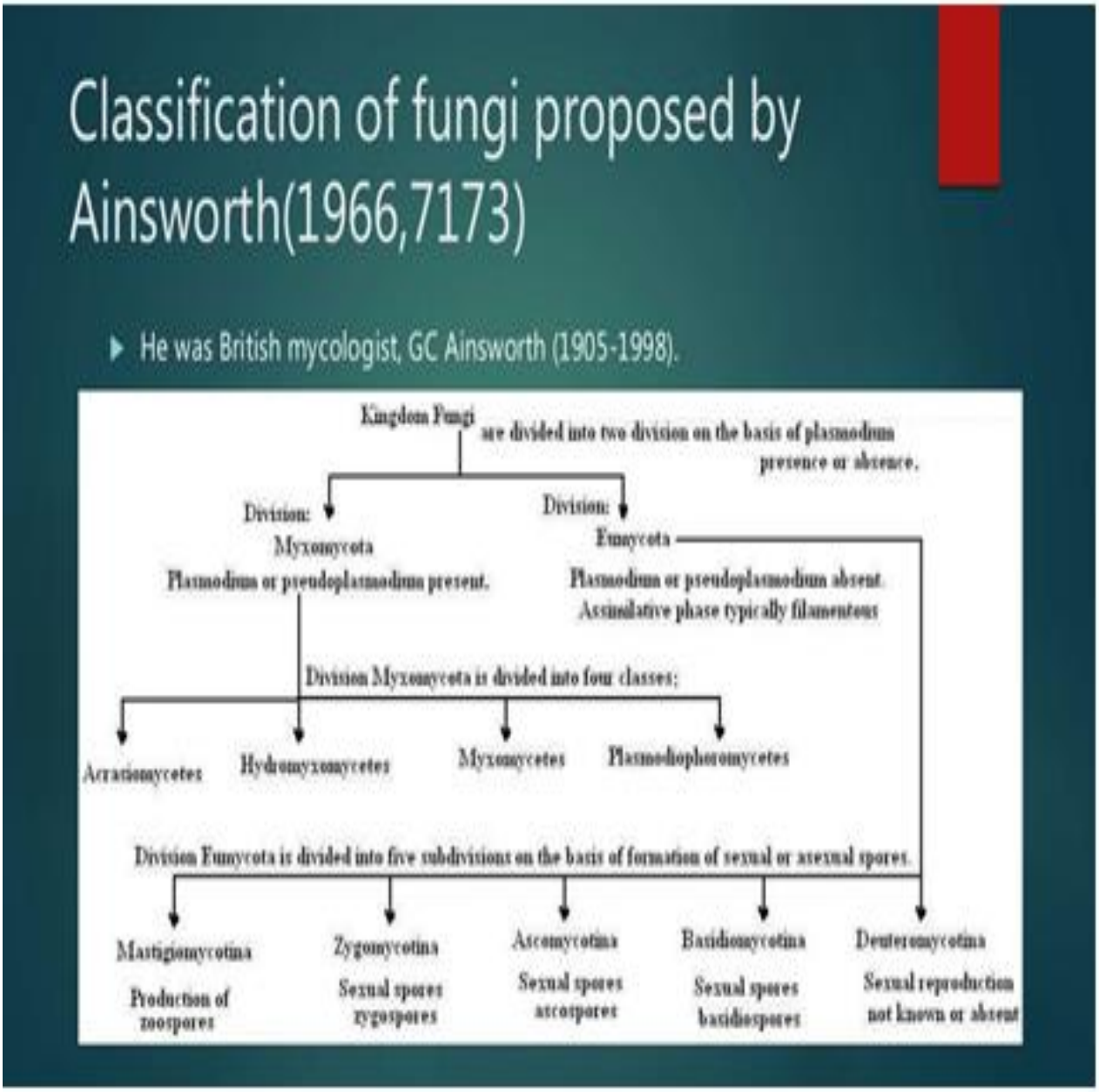
Angiosperms
Gymnosperms
Ferns
Mosses
Seed plants
PLANTS
(Plantae)
Club fungi
Yeasts
FUNGI
(Myceteae)
Molds
Slime molds
Chordates
Arthropods
Annelids
Echinoderms
Mollusks
Nematodes
Flatworms
ANIMALS
(Animalia)
Sponges
Ciliates
Flagellates
Amoebas
PROTISTS
(Protista)
Red algae
Green algae
Brown algae
Diatoms
Dinoflagellates
Apicomplexans
First multicellular organisms appear 0.6 billion years ago.
EUCARYOTES
Early eucaryotes
First eucaryotic cells appear ±2 billion years ago.
PROCARYOTES
MONERANS
Archaea
Bacteria
Earliest cell
First cells appear 3–4 billion years ago.
5 kingdoms
2 cell types

Fungi

It classified according to Ainsworth to the following



Eumycota

- True fungi
- Approximately 75.000 known species
- Thalli do not posses plasmodia or pseudoplasmodia
- Unicellular or filamentous
- Definite cell wall
- Growth of hyphae is apical

Mastigomycotina

- It also called zoosporic fungi
- They reproduce asexually by zoospores that formed in zoosporangium there are 3 shapes of zoospores
    1- Posteriorly uniflagellate
    2- Anteriorly uniflagellate
    3- Laterally biflagellate
- It is a sub-division of division Eumycota
- Plasmodium or pseudoplasmodium are absent

- Assimilative vegetative phase typically filamentous, ceonocytic mycelium. However unicellular form are present and some genera show pseudosepta formation.
- Live either saprophytes or parasites
- Centric nuclear division, centrioles remains functional during nuclear division
- Sexual reproduction by oospore formation
- Adapted mostly in aquatic habitats

Previously it divided in to 4 classes

1- Chytridiomycetes

2- Hypochytridiomycetes

3- Plasmidiophoromycetes

4- Oomycetes

In the new classification plasmidiophoromycetes was not involved

Although water covers three quarters of the earths surface, the percentage of fungi that are found in the aquatic environment does not exceed 2% of the known fungi.

The number of studies conducted on aquatic fungi is very much less than those conducted on terrestrial fungi; the reason of this is that the seas and oceans provide an environment with limited changes in temperature and salinity, in addition to the fact that organic materials such as algae, seaweeds, and driftwood that provide the nutritional needs of these fungi are concentrated on or near the beaches.

Aquatic fungi are distinguished by the fact that they spend their life cycle in water, while some of them spend part of their life in water, and the other part on land. Such fungi are called amphib- ious

Aquatic fungi are those that preferred to live in aquatic environment, and their structures were modified to suit this environment called indwellers.

Fungi that spend their life period in water, they are called migratory fungi (immigrants). While, fungi that spend a temporary period of their life by chance in water are known as free fungi (versatiles).

The growth in fungi in aquatic environment is controlled by:

1- The provision of nutrients

2- 2- The efficiency of the fungus in lysing water

Class: Chytridiomycetes

General Features

1- Formerly referred to as phycomycetes

2- Thought to be evolved from algae by losing chloroplast

3- The vegetative body is unicellular or chain of cells attached to substratum by rhizoids

4- Cell wall contain chitin & glucan

5- Plant body is normally haploid except Allowmycetes

6- Chytrids and rest of fungi are hypothesized to be more closely related to protozoan ancestor

7- Produces posteriorly uniflagellate zoospores

8- The calss contains 18 families, 112 genera and 793 species

9- The class contains 5 orders

- Blastocladiales
- Chytridiales
- Monoblepharidales
- Neocallimastigales
- Spizellomycetales

10- Asexual reproduction by zoospores formed in zoosporangium (Uniflagellate, whiplash type, posteriorly placed)

11- Sexual reproduction by gametangial copulation and form zygote and divided meiosisally to form haploid thallus

Ecology & Importance

1- Aquatic and terrestrial

2- Most aquatic fungi found in fresh water although, some forms found in marine water

3- Saprobes and some parasites of protists, invertebrates fungi and plants

4- Most species complete their life cycle in a matter of just a few hours or days

5- Most saprophic species can be isolated from soil and water samples by baiting with sterile substrates such as pollens, leaves, fruits, snake skin, exoskeletons of insects

6- Barr (1990) emphasis their importance as primary invaders and decomposers of organic materials including chitin, cellulose, hemicellulose and keratin

7- Some chytrids are plant pathogens

8- Species of *Coleomomyces* parasite mosquito larvae may prove to be valuable biological control agents

9- Some species of free living saprobes have become popular experimental organisms in cellular and molecular biology

10- Currently, there is a considerable interest in the anaerobic chytrids found in the rumen of cattle and sheep

Thallus Structure

- **Holocarpic:** primitive forms in which the entire thallus may be converted into one or more reproductive structures
- **Eucarpic:** in which reproductive organs arise from only one portion of the thallus which rhizoids not incorporated
- **Endobiotic:** (Endo=within, bio=life) the most morphologically simple forms, living entirely with the cells of their hosts. The mature thallus surrounded by a cell wall, although the early stages may be naked.
- **Epibiotic:** (Epi= upon, bio=life) producing their reproductive organs on the surface of either living host or some pieces of dead organic matter with their nutrient absorbing structures sunken into the living or dead tissues on which they live
- **Monocentric:** in which the thallus give rise to only a single center for growth and reproduction
- **Polycentric:** in which thallus bear more than center for growth and reproduction

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

General characteristics of a sexual reproduction in chytrids.

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

Types of zoosporangia

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

General characteristics of sexual reproduction in chytrids:

There are 3 types of sexual reproduction in chytrids

1- Planogametic copulation: it has 3 forms

a) Isogamous (morphologically similar and physiologically different)

b) Anisogamous (one is considerably larger than the other)

c) Non-motile egg fertilized by a motile antherzoid

2- Gametangial copulation:

Transfere of protoplast from one gametangium to another

3- Somatogamy:

Fusion between somatic structures (e.g. rhizoidal filaments)

Order: Chytridiales

General Features

1- It is the largest and less understood order of chytridiomycetes

2- Mainly fresh water species

3- Water or soil inhabiting fungi

4- Many of fresh water forms are parasitic on algae and water molds

5- A few parasitize animal eggs and protozoa while other are saprobic on the decaying remains of dead plants

6- Some of the better known genera are: *Chytridium*, *Chytriomyces*, *Polyphagus*, *Rhizophydium*, *Endochytrium*, *Synchytrium*,…. Etc

7- Only few species of this order are economically important, Synchytrium endobioticum causes black wart to potato

8- Thallus types ranges from holocarpic to eucarpic, monocentric to polycentric (rhizomycelial forms).

Family: Chytriomyctaceae

e.g.: *Chytriomyces hyalinus*

General Features:

1- The fungus is ubiquitous monocentric, eucarpic chytrid

2- Can be isolated by baiting water and soil samples

3- In nature it grows saprophytically in fresh water on skeleton of may flies and on bits of chitin
4- It can be grown in pure cultures in the laboratory on 0.5% chitin
5- It is an ideal expirmental organism for demonstrating the production of extracellular chitinase

Life cycle of *Chytriomyces hyalinus*

Chytriomyces forms a well-developed rhizoidal system in the substrate it invades. The zoosporangium which develop form encysted zoospores has an apical or sub-apical shallow from which zoospores escape in to discharge net which they soon escape.When released to the water and after swimming for peroids of time, the zoospores encyst and germinate either forming new sporangia and rhizoids (a sexual thalli) or producing thalli that functioning as (sexual thalli).

Family: Rhizidaceae

e.g.: *Rhizophydium couchi*

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

1- Thallus is eucarpic, monocentric and may be epibiotic, endobiotic or both.

2- The zoospore body encysts and wholly or partly enlarge to form zoosporangium or gametangium.

3- In epibiotic genera thallus is attached to substrate by rhizoids.

4- Sexual reproduction occur by gametangial copulation.

5- There are 18 genera and about 100 species.

6- *Rhizophydium* thallus consists of an epibiotic zoosporangium.

7- Grow on avariety of living or dead plant and animal substrata.

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

R. couchi parasites on *Spirogyra* spp.

Asexual reproduction:

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

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

3- The zoospore enlarges and transforms into zoosporangium

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

Sexual reproduction:

Sexual reproduction takes place by gametangial copulation

1- When two thalli grow together, one of them grow bigger than the other and acts as the female gametangium (oogonium); the smaller acts as male gametangium (antheridium).

2- The entire content (protoplast) of antheridium migrates into the oogonium through a pore formed at the point of contact between the two gametangia.

3- After fertilization oogonium form a thick wall and becomes a resting spore (= resting sporangium).

4- Karyogamy is delayed at the time of germination of the resting spore.

5- A pore is formed on the thick wall of resting spore through which the protoplast moves out surrounded by a thin wall to form a zoosporangium.

6- Zoospores liberated through an apical exist papilla.

Family: Phlyctidiaceae

e.g.: *Polyphagus euglenae*.

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

1- The thallus is eucarpic, monocentric and interbiotic with a richly-branched rhizoidal system.

2- Sporangium, pro-sporangium or resting spores are formed wholey or in part from the enlarged body of encysted zoospore.

3- The family includes both parasitic and saprophytic genera

4- The parasites usually attack fresh water algae.

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

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

Asexual reproduction:

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

1- The cyst functions as a prosporangium and gives rise to a lateral outgrowth which develops into the sporangium.
2- The contents of the prosporangium are emptied into the outgrowth.
3- The empty prosporangium is cut off from the sporangium by a septum.
4- After many nuclear divisions, the cytoplasm cleaved into hundreds of uninucleate portions which develop into posteriorly uniflagellate zoospores.

5- Apore is dissolved at the apex of the sporangium through which the zoospores escape and swim.

Sexual reproduction:

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

1- The male gametangium puts out a slender lateral filament, the conjugation tube, which comes in contact with the female gametangium.

2- The contents of the male gametangium migrate into the enlarged tip of the conjugation tube to connect with the female gametangium to form zygote.

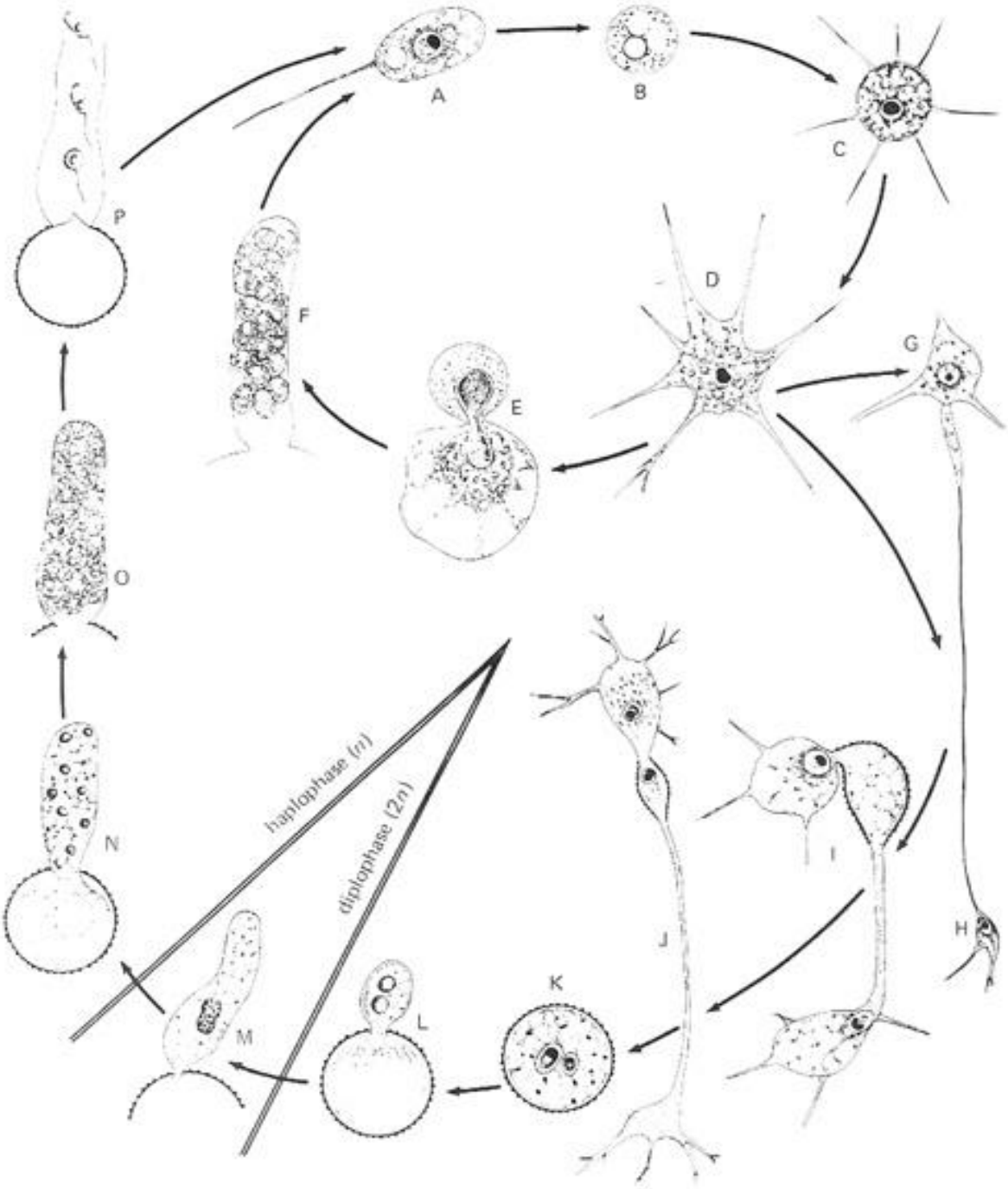
3- The wall becomes thick and the zygote transforms into a resting spore.

4- Resting spore lies dormant until the environment conducive for growth returns.

5- During germination the two nuclei undergo fusion and diploid nucleus formed

6- Meiosis takes place and haploid nuclei and multiplied by repeated mitotic divisions.

7- Zoopspores are formed and liberated through an apical pore on the sporangium.



Life cycle of *Polyphagus euglena*

Family: Physodermataceae

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

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

1- Life cycle of fungi belonging to this family involves two independent phases: 1- a monocentric, epibiotic, or zoosporangial phase. 2- a polycentric, endobiotic phase.

2- The family comprises two genera, *Urophlyctis* and *Physoderma*, both parasites on vascular plants.

Differences between *Urophlyctis* and *Physoderma* genera:

1- *Physoderma* does not induce hypertrophy while *Urophlyctis* induces strong gall formation.

2- Resting spores of *Urophlyctis* are confined within a lysiogenous cavity in the host; *Physoderma* does not form its resting spores in any such cavity.

3- Rhizoids in the epibiotic stage are dense and bushy in *Urophlyctis* but scant and stubby in *Physoderma*.

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

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

The epibiotic phase (monocentric, epibiotic or zoosporangial phase)

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

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

Disease Cycle

The thick-walled, brown sporangia (resting spores) formed within infected cells enable *P. maydis* to overseason in corn debris or in the soil. The sporangia are released from infection pustules, disintegrating corn debris, and soil and are carried to susceptible plants by air currents, insects, splashing rain or flowing water, and humans. Corn becomes increasingly

susceptible to Physoderma until the plants are about 45 to 50 days old; susceptibility declines steadily after that. Free water is required for infection. When moisture is present in the whorl or behind the leaf sheaths and temperatures are relatively high (73° to 90°F, 23° to 30°C), a sporangium “germinates” to release 20 to 50 swimming zoospores. The zoospores move about in water for 1 to 2 hours before settling down, becoming amoeba-like, and penetrating yong meristematic tissue with fine infection hyphae. The resulting mycelium enters mesophyll or parenchyma cells and forms larger, vegetative structures (Figure 5). Infection commonly occurs in a diurnal cycle, resulting in alternating lateral bands of infected and healthy leaf tissue as it emerges from the whorl. Zoospores of P. maydis can infect corn tissue only during certain hours of the day and within a few hours after being released. The development of symptoms and the germination of new sporangia occur approximately 6 to 20 days after infection, completing the disease cycle

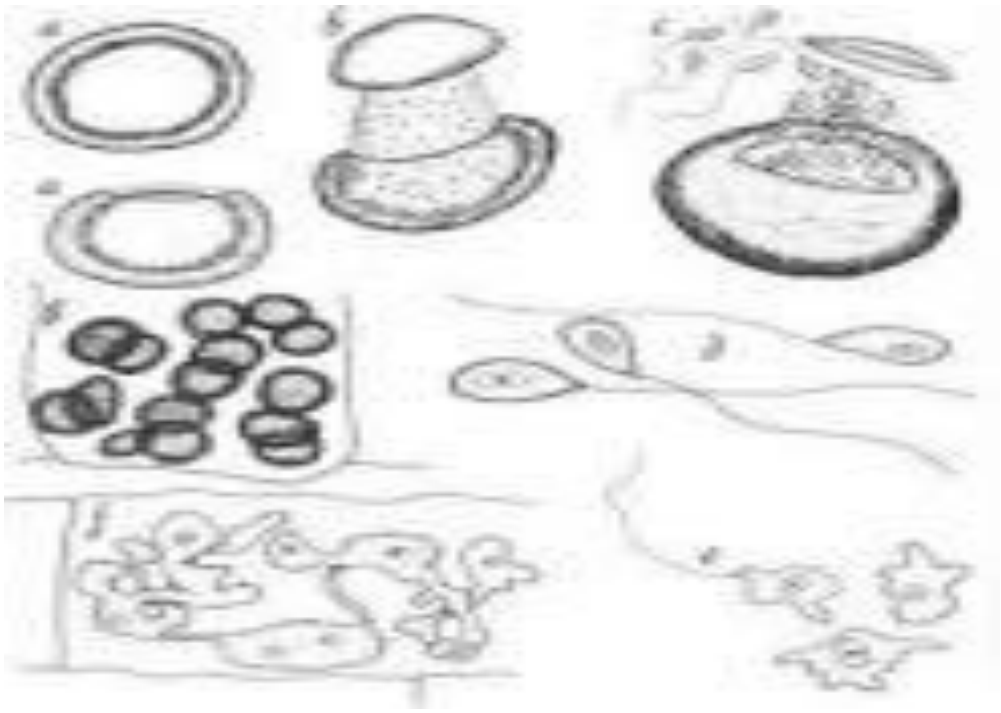


Figure 5. Stages in the life cycle of Physoderma maydis as seen through a high-power microscope. Stages a through g can occur in as short a period as 16 to 20 days. (a Two sporangia (resting spores), top view and side view. (b) stage in opening of a sporangium, showing the early stage of zoospore formation. Note the dehisced operculum (lid) being carried up by the enlarging sporangium. (c) Mature zoospores escaping through the ruptured apex of the resting spore. (d) Three zoospores with a single flagellum from a germinated resting spore. (e)

Germinating zoospores, amoeboid stage. (f) Rhizomycelium within a corn epidermal cell showing young sporangia at the ends of short hyphae . (g) Corn leaf cell filled with mature resting sporangia

Family: Synchytriaceae

e.g.: *Synchytrium endobioticum*

*********General Features *********

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

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

3- The sporangia are inoperculate.

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

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

Occurrence:

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

Start of infection

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

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

structure gets surrounded by a golden brown thick wall and now it called prosorus.

The fungus shows following drastic changes in its ultrastructural organization

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

Changes in host cell:

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

4- The infected host cell dies ultimately.

Prosorus germination and zoosporangium development:

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

Ultrastructure of zoospore:

1- It is uniflagellate, spherical to elongate in shape and attain a diameter of approximately 3µm.

2- Ribosomes are evenly distributed.

3- An anteriorly located, large, lipid globule is present.

4- Mitochondria surrounded the nucleus from all sides.

5- Cytoplasmic microtubules remain associated with the functional kinetosome.

6- Most of the cell organelles are partially encapsulated by an extensive system of endoplasmic reticulum.

7- A contractile vacuole like structure is also present.

Gametangium:

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

Zygote and resting sporangium:

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

Germination of resting sporangium:

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

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

Order: Blastocladiales.

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

1- Mostly saprobic in soil and water

2- Thallus varies among taxa from thin-walled and thick-walled (resting) sporangia

3- Resting sporangia are thick-walled and often pitted

4- Characterized by a distinctive zoospore

5- All members of this order have zoospores with a distinct nuclear cap surrounds the nucleus

6- This ribosome-filled cap is easily observed with an oil immersion lens

Light micrograph of resting sporangia in *Allomyces macrogynus*

This order shows advancement over chytridiales in the following respects:

1- **Development of true hyphae in some genera**. The hyphae of the genus *Coelomomyces* lack cell wall which is a feature of great mycological importance not found elsewhere in true fungi.

2- **Differentiation of male and female gametes and gametangia**. Male gamete is smaller than female in size. Gametangia are also distinguishable into male and female.

3- **Presence of alternation of generations in life cycle of some genera**.

Family: Blastocladiaceae.

Genus: *Allomyces*

General features:

1- First reported in India (1911) by Butler

2- Species exist in soil and water as saprobes

3- Can be isolated by using semsame and hemp seeds as baits

4- The genus exhibits filamentous, polycentric development

5- Thallus consists of well developed, branched rhizoids

6- Species of this genus exhibit a distinctive alternation of generation, in which haploid gametothalli alternate with diploid sporothalli and the two types of thalli are indistinguishable until they begin to form reproductive organs

7- When they reach the certain stage of maturity, the gametothalli produce colorless female gametangia and orange male gametangia

in ratio 1:1. The orange color is in the cytoplasm due to γ- carotene synthesized by the fungus.

8- The male gametangium is smaller than the female and may be borne on the latter or below them.

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

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

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

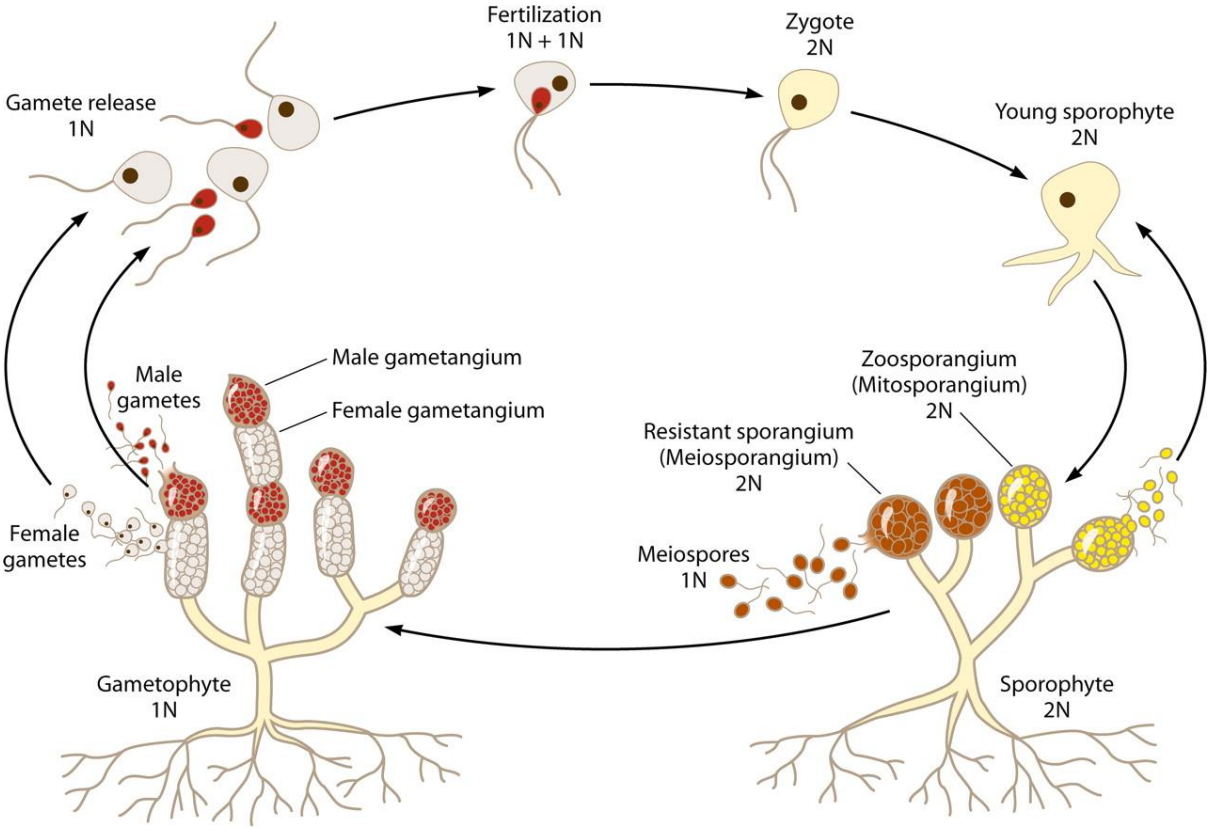
The female gametangia and gametes of *Allomyces* produce a pheromone called Sirenin to which male gametes are attracted. Male gametes also produce a female attracting pheromone called Parisin.

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

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

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

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



Family: Coelomomycetaceae.

e.g.: *Coelomomyces psorophorae*

General features:

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

2- There are 80 species of this genus.

3- The thallus consists of non septate irregularly branched or lobed hyphae which lacks a cell wall and it resembles the strands of myxomycete plasmodium

4- Fragmentation of the thallus results in the spread of the fungus and more thalli are formed.

5- The lobed hyphal branches transform into thick-walled resting sporangia which break off and become free. The outer wall is coloured, pitted or striate while the inner wall is thin and hyaline.

6- Thin- wall zoosporangia are not formed the resting sporangia germinate and release of zoospores through discharge papilla

7- Sexual reproduction is not reported in *Coelomomyces*.

8- Zoospores produced in the coelomome of mosquito larvae fail to reinfect the mosquitoses.

9- The life cycle of *C. psorophorae* (which infects Culistea, mosquitoes) requires two hosts to complete the life cycle.

10- The alternate host in this life cycle is *Cyclops vernalis*

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

The genus *Coelomomyces* is composed of over 70 species another source comprises 80 species of obligately parasitic fungi that have a complex life cycle involving an alternation of sexual (gametophytic) and asexual (sporophytic) generations (Couch & Bland, 1985; Whisler, 1985). In all species studied to date, the sexual phase parasitizes a microcrustacean host, typically a copepod (*Cyclopus*), whereas the asexual generation develops, with rare exception, in mosquito larvae. In the life cycle, a biflagellate zygospore invades the hemocoel (coelomome) of a mosquito larva where it produces a sporophyte that colonizes the body and forms resistant sporangia. The larva dies and subsequently the sporangia undergo meiosis, producing uniflagellate meiospores that invade the hemocoel of a copepod host, where a gametophyte develops. At maturation, the gametophyte cleaves, forming thousands of uniflagellate gametes. Cleavage results in death of the copepod and in escape of the gametes, which fuse and form biflagellate zygospores that seek out another mosquito host, completing the life cycle. The life cycles of these fungi are highly adapted to those

of their hosts. Moreover, as obligate parasites these fungi are very fastidious in their nutritional requirements, and as a result no species of *Coelomomyces* has been cultured *in vitro.*

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

Family: Blastocladiaceae.

Sub-genus: *Brachy-Allomyces*

General features:

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

2- This species characterized by lack of alternation of generations

3- The gametophyte is absent.

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

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

6- Meiosis does not occur in the resting sporangia.

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

Order: Monoblepharidales

General features:

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

2- Resting sporangia are not formed

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

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

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

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

7- The family Gonapodyaceae includes two genera Gonapodya and Monoblepharella and the zygotes of these genera are propelled out of the oogonium by the flagellum of the antherozoid and undergo a

period of motility before encystment and transformation into the oospore

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

Family: Gonapodyaceae.

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

Genus: Monoblepharella.

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

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

Asexual reproduction:

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

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

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

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

Sexual reproduction:

It takes place in the unfavourable conditions. Gametangia (antheridia and oogonia) are formed on sympodially branched hyphae. The antheridia are cylindrical while the oogonia are globular or obovate. Antherozoid, which smaller than zoospores liberated through apical pore. They swim and reach to the adjacent oogonium usually contains a single oosphere (non-motile, naked, female

gamete). A receptive spot develops at the apex of the oogonium which dissolves to form a pore. The antherozoid enters the oogonium and fuses with the oosphere. The flagellum of the antherozoid remains functional and propels the zygote out of the oogonium and the karyogamy does not occur immediately. The zygote lose the flagellum and secret a thick wall and transformed into oospore and karyogamy occur at the time of wall formation. When the favourable conditions return it germinates and gives rise to thallus after meiosis division.

Family: Monoblepharidaceae.

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

Genus: Monoblepharis.

General features:

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

2- Low temperature (3°C) favours the development of Monoblepharis.

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

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

Asexual reproduction:

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

Sexual reproduction:

In the unfavourable conditions, zoosporangia are not formed but gametangia are formed. Antheridium is initiated from a terminal cell cut off by a septum and the second segment, oogonial is formed below the antheridial cell. Antheridia are narrow and elongated while the oogonia are globular and much bigger. At

maturity antheridia appears as inserted in the oogonia, which appear in chains. Posteriorly uniflagellate antherozoids (4-8 in number) which smaller than zoospores are released from the antheridium through apical pore. The protoplast of oogonium form a single, uninucleate, naked, non-motile female gamete called the egg or oosphere. At maturity an apical papilla is formed on the oogonium which dissolves to form a pore. Antherozoid enters the oogonium and retracts the flagellum and fuse with the oosphere to form zygote. Zygote encystment may occur inside the oogonium (endogenous), where it lies as an oosphere. In *M. polymorpha* oospore formation is exogenous; the zygote oozos out and encyst at the oogonial orifice. Karyogamy occur during encystment. The oospore may be smooth or thick-walled with warts and undergo resting period. At the return of cooler temperature it germinates and gives rise to haploid thallus after meiosis division during germination.

Class: Hypochytridiomycetes (Anteriorly uniflagellate fungi)

General features:

1- Anteriorly uniflagellate zoospores and gametes.

2- The flagellum of tinsel type

3- Presence of cellulose along within chitin in the cell wall of some species.

4- The fungi show great resemblance to chytridiomycetes in thallus organization and life cycle pattern.

5- Most of these fungi once included under chytridiales.

6- This class is very small compared to chytridiomycetes and includes only 6 genera.

7- They are found as endoparasites of fresh water and marine algae, aquatic fungi or saprobes growing on a variety of organic remains of plant and animal origin.

8- The thallus is holocarpic or eucarpic, monocentric or polycentric.

9- In holocarpic species the thallus, which may is always endobiotic, transforms into zoosporangium.

10- The eucarpic species may be epibiotic and monocentric having a single reproductive organ anchored to the substratum

by rhizoids. Or polycentric and endobiotic having many reproductive organs connected by branched hyphae with occasional septa.

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

12- Sexual reproduction is generally unknown in this group.

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

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

The families:

1- Anisolpidiaceae

Thallus holocarpic and endobiotic (*Anisolpidium canteriomyces*)

2- Rhizidomycetaceae

Thallus eucarpic, monocentric and epibiotic (Rhizidomyces, Rhizidomycopsis)

3- Hypochytriaceae

Thallus eucarpic, polycentric, intrarnatrical (Hypochytrium).

Family: Rhizidomycetaceae.

Genus: Rhizidomyces.

General features:

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

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

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

Asexual reproduction:

Uniflagellate zoospores swim for some times and settle down the host or substratum lose the flagellum and encyst then germinate by forming germ tube which penetrates the host and gives rise to branched rhizoids. The germ tube which lies at the top of rhizoids swells and form the apophysis and the rhizoids seem to be

originate from the swelling and hence the name apophysis (apo=from and physis=growth). The cyst develops into zoosporangium. A discharge tube emerges from the sporangium the protoplast which by divisions give multinucleate flows out through the discharge tube and lie in a vesicle. The protoplast then cleaved into uninucleate segements which form the zoospores that released by dissolution of the vesicle they swim and repeat the life cycle.

Sexual reproduction: is un-known.

Family: **Hypochytriaceae**

Genus: **Hypochytrium**

General features:

1- *Hypochytrium* is the sole genus of this family.

2- The species of this genus occur as parasites of algae and fungi or as saprophytes on plant debris ex. *H. hydrodicytii* grows on green algae hydrodicyton and *H. catenoides* is saprophytic on vegetables debris.

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

Asexual reproduction:

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

Sexual reproduction: is not reported.

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

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

Class: Plasmodiophoromycetes.

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

General features:

1- There are obligate parasites in plants. Some attack crop plants and cause economically important diseases while others attack algae and fungi or economically unimportant plants.

2- The thallus is plasmodium (a naked mass of nucleated cytoplasm with amoeboid movement).

3- The life cycle is completed entirely within the plant host.

4- The plasmodium which may be haploid or diploid, is holocarpic and develops into thin-walled sporangia, (aggregated in sori) or into resting spores (cysts).

5- The plasmodium is designated as zoosporogenous or cytogenous depending on whether it produces zoospores or cysts.

6- The zoospores are anteriorly biflagellate, heterokont (unequal in size) and uninucleate; both flagella are of whiplash type. During movement the flagella take opposite directions.

7- Nuclear divisions called cruciform division or promtosis.

8- The resting spores or cysts, which are formed by all the genera, are surrounded by smooth two-layered wall made of chitin. The spores can survive in soil, in absence of the host plants, for many years.

e.g.: *Plasmodiophora brassicae*

General features:

1- *P. brassicae* causes the club root disease of crucifers, especially the mustard.

2- The roots become hypertrophied and club-shaped.

3- The disease occurs in areas where the soil is poorly drained and has acidic pH.

General features of *Saprolegnia:*

1- Species of *saprolegnia* are common in soil and well-aerated, fresh water ponds.

2- Most of these species colonize dead plant and animal remains, a few like *S. ferax* and *S. parasitica* parasitize fishes and cause their death and death occurs within 24 hours.

3- These fungi are primary sugar fungi they fail to decompose and utilize polysaccharides like cellulose**.**

4- Oospore with ooplast, thallus extensive and mycelial hyphae non-septate, normally eucarpic morophologically-distinct gametangia formed, zoospores showed dimorphism.

Taxonomic criteria:

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

1- Shape of zoosporangia

2- Variations in the discharge and behavior of the spores

3- Oospore type

4- Oogonial wall ornamentations and pitting

5- Shape and position of the oogonium

General features of *Pythium*:

1- Having 92 species and this largest genus of the family.

2- Majority of species are soil-inhabitants which mainly cause root-rot (particularly of Graminae) and damping off disease of seedlings. A few are mycorrhizal, while some others are aquatic.

3- The characters used in speciation are: 1- the morphology and dimensions of sporangium. 2- Sporangial proliferation. 3- oogonial dimensions and morphology of spines. 4- The point of origin of antheridium in relation to oogonium and their number. 5- plerotic or aplerotic nature of oospore 6- the maximum temperature for growth.

General features of *Albugo*:

1- The genus has 30 species, all obligate parasites of higher plants causing white blisters (areas of raised host epidermis) on the foliage.

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

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

Class: Oomycetes

General features:

1- laterally-biflagellate, reniform zoospores.

2- Presence of cellulose in the cell wall.

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

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

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

6- The oogamous type of sexual reproduction usually involves a club-shaped antheridium and more or less globose oogonium, containing one or more non-motile female gametes called oosphere or egg. However, in some primitive members of oomycetes (order Lagenidiales), the

gametangia are not differentiated into male and female. The holocarpic thalli of different sizes act as gametangia and fuse to form zygote.

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

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

Pythium

Class: Oomycetes

Order: Peronosporales

Family: Pythiaceae

e.g. : *Pythium*

Occurrence: It is the largest genus of this family, it represented by 92 species. Many species occur only in aquatic situations as saprophytes, whereas some may be weak parasites on aquatic plants

and animals. A majority of species are soil inhibitants and a few occur in mycorrhizal association. *Pythium* species are rarely host specific.

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

Life cycle of *P.debaryanum*

Somatic structure:

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

Asexual reproduction:

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

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

germinates by germ tube into a new somatic hypha. This young hypha infects fresh seedling.

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

Evolution of conidium

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

Sexual reproduction:

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

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

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

Fertilization:

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

Germination of oospore:

In *P.debaryanum* and many other species the oospores require a resting period of several weeks before germination. At relatively high temperature of about 28°C the oospore germinates by putting out a germ tube, which soon develops into well-developed mycelium. But at lower temperature 10-17°C, a short germ tube is given out at the tip

which develops a vesicle and in *P.ultimum* the contents pass into the vesicle through a small tube and get differentiated into many zoospores and in some species develops a germ tube containing sporangium at its tip.

Phylum:	Oomycota
Order:	Albuginales
Family:	Albuginaceae
Genus:	*Albugo*

Fungus *Albugo* reproduces both asexually and sexually.

Asexual Reproduction

- Conidia, condiosporangia, and zoosporangia are used for asexual reproduction. They are generated by sporangiophores. Mycelium develops and branches quickly in suitable conditions.

- It creates a dense mat-like growth just beneath the epidermis of the host after reaching maturity, and some of the hyphae begin to behave as sporangiophores or conidiophores. There are around a dozen nuclei and abundant cytoplasm in these sporangiophores.
- Later, the sporangiophore's apical portion swells, and confinement forms below the enlarged end, resulting in the formation of the first sporangium. A second sporangium grows from the tip of the first one, immediately below it. Above each sporangiophore, a chain of sporangia or conidia is formed in basipetal succession.
- Due to the disintegration of the separating disc, the sporangia are released as they reach maturity. When sporangia are carried away by the wind or rainwater and land on an appropriate host, it germinates within 2 or 3 hours.
- The sporangia germinate to produce zoospores, which germinate and enter the host through stomata when they come into contact with it.

Sexual Reproduction

- It takes place at the end of the growing season. The mycelium penetrates into the host's deeper tissues. Its type of sexual reproduction is oogamous in nature. The male sex organ is known as antheridium, whereas the female sex organ is known as oogonium.
- **Antheridium** is a club-shaped elongated structure. It is multinucleate; in some situations, only one nucleus is functioning, while in others, many are.
- **Oogonium** is a multinucleate spherical organism with 65 to 115 nuclei. The cytoplasm contains an even distribution of nuclei.
- The contents of the oogonium become organised into an exterior peripheral region of periplasm and an interior dense centre region of ooplasm or oosphere or the egg as the oogonium matures. All nuclei, with the exception of a single functioning nucleus, dissolve at maturity.

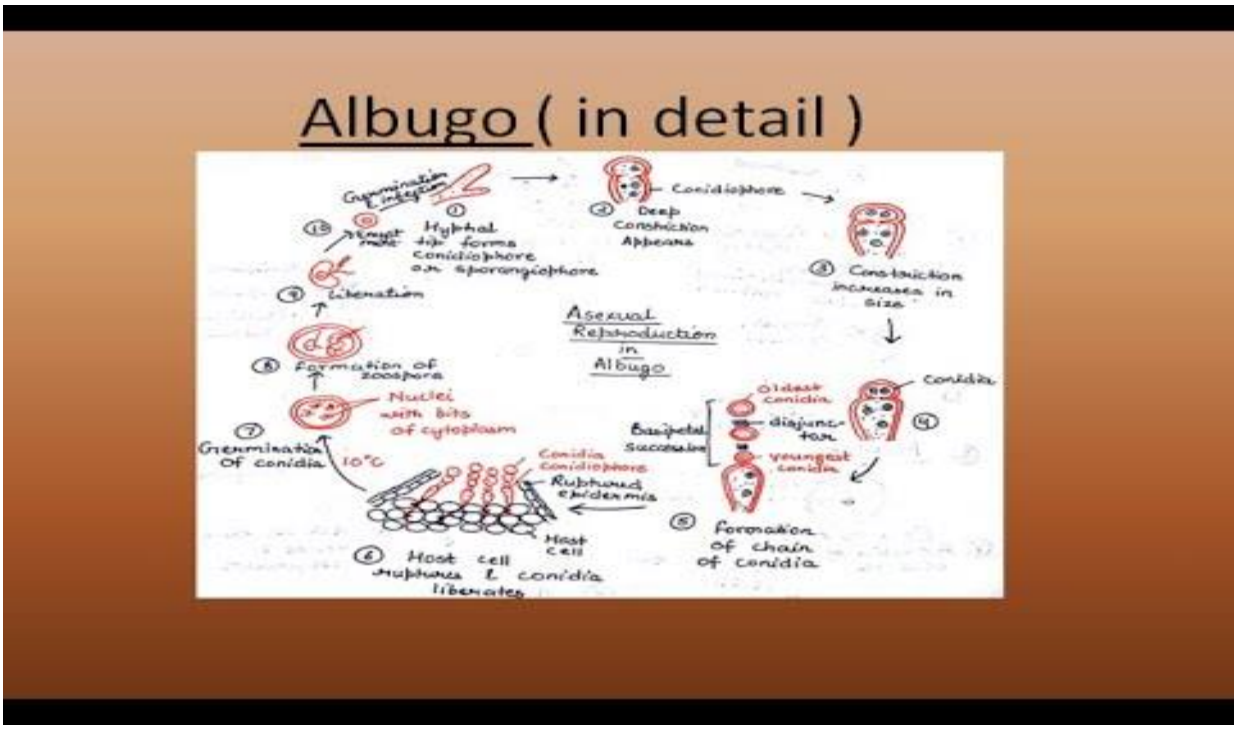
- The coenocentrum is a highly stained mass of cytoplasm that forms in the middle of the ooplasm before fertilisation. The functioning female nucleus is drawn to it and attaches itself to a spot nearby.
- At the site of contact with the antheridium, the oogonium forms a papilla-like outgrowth. The receptive papilla fades away soon, and the antheridium produces a fertilisation tube.
- It passes through the receptive papilla, the oogonial wall, and the periplasm before reaching the ooplasm. It has only one male nucleus. It ruptures at the tip, releasing the male nucleus close to the female nucleus. The male nucleus eventually merges with the female nucleus (karyogamy).
- The oosphere and the fusion nucleus result in the formation of the oospore. When the oospore reaches maturity, it produces a two to three-layered wall. The exospore is represented by the thick, warty, or tuberculated outer layer. The endospore is the thin inner layer of the spore.

- The zygotic nucleus divides repeatedly with the secretion of the wall, resulting in roughly 32 nuclei. Meiosis is the first division. The oospore rests for a long time at this stage until unfavourable conditions have subsided. Meanwhile, the oospore is freed as the host tissues dissolve. The oospore germinates after a long period of dormancy. Its nuclei divide mitotically, resulting in a huge number of nuclei.
- Each nucleus is enveloped by a small portion of the cytoplasm. Protoplasm is segmented, and each segment eventually rounds up and transforms into a zoomeiospore or zoospore. The endospore emerges as a thin vesicle once the exospore is broken. The zoospores spread out into the thin vesicle, which eventually dies, releasing the zoospores. After swimming for a while, the zoospores encyst and germinate via a germ tube, reinfecting the host plant.

Economic Significance of Albugo

The fungus is the cause of the crucifer “white rust” disease, which causes major yield losses in rapeseed, turnips, and mustard. The thick-walled oospores make up the majority of the deformed and hypertrophied inflorescences, or “stage heads.”

Another species, *A. ipomoeae-panduratae* parasitises sweet potatoes, and *A. bliti* thrives like a parasite on various members of the Amaranthaceae family. White rust is a minor crucifer disease in terms of economic significance



Mycelium of Saprolegnia

The mycelium is coenocytic and branched.

During the vegetative phase it is composed of two kinds of hyphae:

(i) Rhizoidal or intramatrical hyphae:

These are short hyphae which penetrate the substratum. They anchor the mycelium and absorb nutrition.

(ii) Extramatrical hyphae (Fig. 6.1):

These are long hyphae which grow out from the surface of the substratum into the water and extend in all directions. They form the visible portion of the mycelium and produce the reproductive organs (Fig. 6.2A). The extramatrical hyphae are long, slender andextensively branched. They are aseptate and coenocytic. Septa, however, appear in connection with the formation of reproductive organs and rarely in older hyphae. The hyphal wall contains cellulose and not chitin. In addition glucans or mannans are also involved. Next to the hyphal wall is the vacuolate cytoplasm in the form of a thin lining layer containing several nuclei (A). Food is stored in the form of oil globules and glycogen. The mycelium is eucarpic.

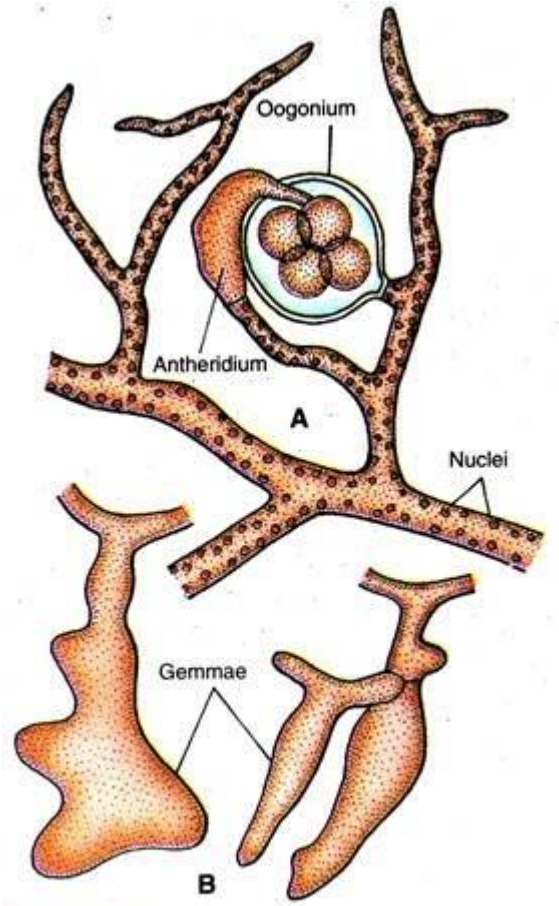


Fig. 6.2 (A-B). *Saprolegnia sp.* A, Hyphae showing structure as seen under the light microscope and bearing sex organs;

Reproduction of Saprolegnia:

After a certain period of growth and under suitable conditions of food, temperature and other environmental factors Saprolegnia enters the reproductive phase. It bears reproductive organs at the tips of hyphae. Saprolegnia reproduces asexually as well as sexually.

1. Asexual reproduction:

It takes place by vegetative methods and sporulation.

(a) Vegetative reproduction:

It takes place by the following two methods:

(i) Fragmentation:

Under favourable circumstances the hyphae break up into pieces of variable lengths. Each such piece or fragment by further elongation and nuclear division develops into a mycelium.

(ii) Formation of Gemmae (Fig. 6.2B):

They are formed at the tips of hyphae and are unicellular. The

formation of gemmae is marked by a conspicuous swelling of the hyphal tips. The swollen portion contains abundant food material and possesses several nuclei. It is separated from the hypha by means of a cross wall. The gemmae vary in shape and size.

They may be rounded, ovoid or irregular and developed singly or in chains of variable lengths. At maturity the gemmae get detached. The detached gemma germinates by giving out a tubular hypha on a new

substrate and develops into a mycelium or short-stalked sporangium typical of the species. Some mycologists call these gemmae as chlamydospores.

(b) Sporulation (Fig. 6.3)::

It takes place by means of pip or pear-shaped, biflagellate zoospores which are produced in long, cylindrical tapering zoosporangia. The zoosporangia are formed at the tips of somatic hyphae which are not differentiated into sporangiophores.

The zoosporangia are only slightly greater in diameter than the hyphae bearing them. They are densely filled with protoplasm whereas the somatic hyphae are only lined with a thin layer of protoplas

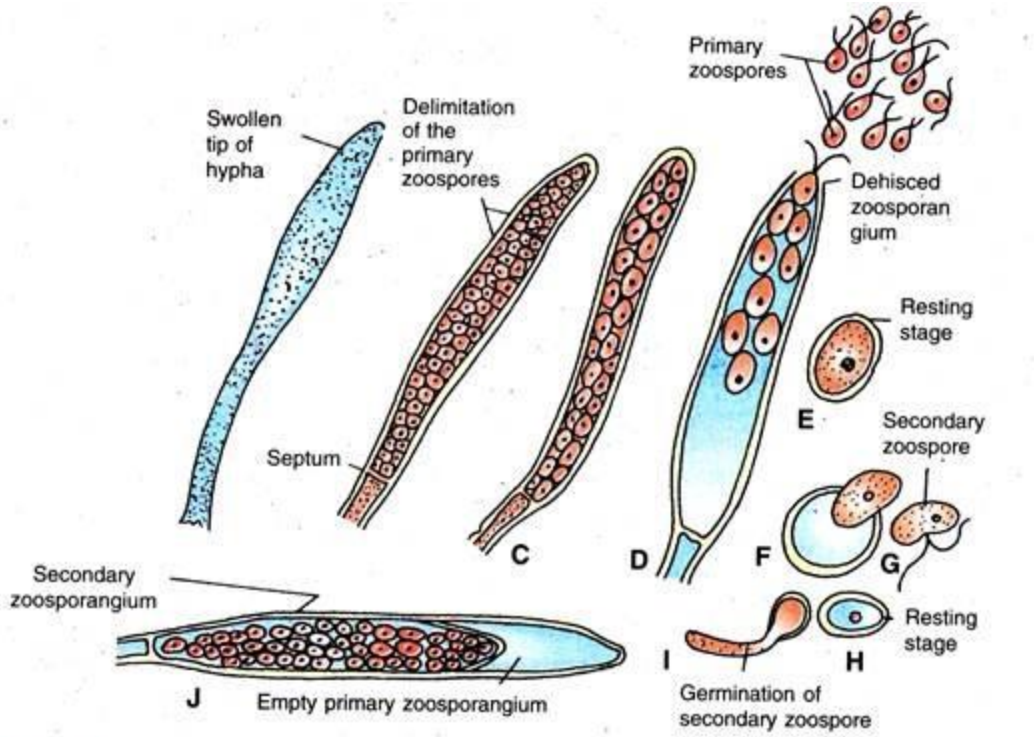


Fig. 6.3. (A-J) *Saprolegnia sp.* A-D, Formation and liberation of primary zoospores; E, Resting primary zoospores; F, Liberation of secondary zoospore; G, Active secondary zoospore; H, Resting stage of the same; I, Germinating secondary zoospore; J, Empty primary zoosporangium showing the development of a secondary zoosporangium inside the old primary one (proliferation of zoosporangia).

Development of Zoosporangia (Fig. 6.3, A-J):

The apical portion of external or extramatrical hyphae shows a slight amount of swelling (A). The swollen portion is conspicuous by its denser granular cytoplasmic contents. A large number of nuclei migrate into this club-shaped apical portion.

Finally it becomes cut off from the remaining hypha by a cross wall and is known as the zoosporangium (B) which is usually club-shaped or it may be tubular with ends slightly tapering (cigar-shaped). The mature zoosporangium has a well-defined thin-walled apex.

Differentiation of Zoospores (Fig. 6.4):

The colourless multinucleate protoplast of the zoosporangium divides into several uninucleated portions by progressive cleavage of the entire protoplast (A). Each unicleate daughter protoplast rounds off and later assumes a pear-shaped form (A). It is furnished with two apically inserted flagella. One of these is of tinsel or pantonematic type and the other of whiplash or acronematic type (B). These pyriform, biflagellate, uninucleate structures are known as the primary zoospores. They are released into the surrounding water, through an apical pore that suddenly develops at maturity in the zoosporangium (A). The liberated zoospores swim about in water with the pointed end forward for some time (B). They are propelled by their flagella with the shorter tinsel type directed

forward and the longer whiplash type trailing behind. The tinsel flagellum bears two rows of fine, lateral fibrillar hairs 2-3 um long.

The fibrillar hairs end in shapely defined fine tips. After a swarming period of brief duration which according to Ingold is of a few minutes and according to Manton extends over 1-2 hours, each one of them comes to rest and withdraws its flagella.

The quiescent zoospore becomes spherical and secretes a thin wall around it (C). The zoospore enclosed, in a sac or cyst is said to encyst. The cyst wall bears numerous delicate projections on the outside. The projections are double headed hooks on long, slender stalks.

ADVERTISEMENTS:

The encysted primary zoospore rests for a while (a few hours). After the resting period the cyst breaks and the contents emerge as a single bean or kidney-shaped secondary zoospore through the dissolved tip of a slender papilla developed on the cyst wall (D).

The ruptured cyst is left behind. The escaping secondary zoospore is somewhat smaller than the primary zoospore and is reniform (kidney-shaped). It is furnished with two laterally inserted and oppositely directed flagella (E). They arise from the shallow groove of the concave side. One flagellum is of

tinsel type and the other of whiplash type. The hind whiplash flagellum is about twice the length of the fore-tinsel flagellum.

The secondary zoospore embarks upon a second swarming period. It is of a longer, duration. According to Alexopoulos and Mims (1979), the swarming period of both kinds (primary and secondary) of zoospores is of considerable duration.

Finally the secondary zoospore comes to rest. It withdraws its flagella and encysts (F). The cyst immediately germinates like a fungal spore. There is no emergence of a zoospore in this case. On a new substrate it produces a short germ tube (G). The germ tube grows into a hypha and finally into the mycelium.

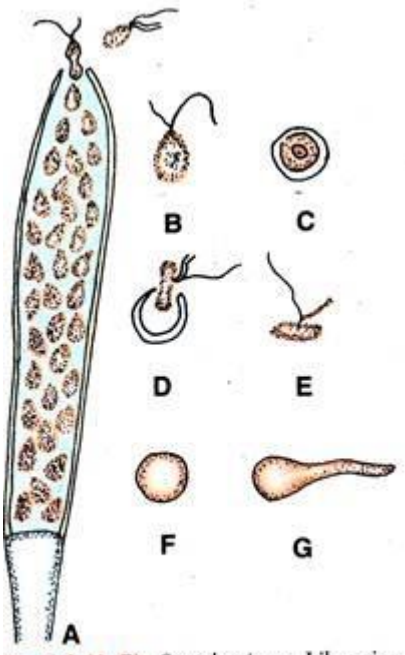


Fig. 6.4 (A-G). *Saprolegnia sp.* Liberation of zoospores and stages showing diplanetism. Explanation in the text.

Proliferation of Zoosporangia:

It is an interesting and characteristic feature in Saprolegnia. The basal septum of the empty zoosporangium initiates the development of a secondary zoosporangium (Fig. 6.3 J). It grows and bulges into the empty sporangium to form a new sporangium. The new sporangium matures within the primary one.

Sometimes it matures some way beyond the primary zoosporangium. This process may be repeated and several zoosporangia may thus be formed within the walls of the next older one. Each of these matures and

releases its contents before the next one is formed. Intercalary and catenulate zoosporangia have also been reported in some species such as S. torulosa.

2. Sexual Reproduction (Fig. 6.5):

It is oogamous and by gametangial contact. The sex organs are called antheridia and oogonia. They are formed at the tips of somatic hyphae (A) when conditions favourable for sexual reproduction appear or conditions unsuitable for somatic growth set in. Many species are monecious or homothallic. A few are dioecious or heterothallic. Following is an account of sexual reproduction in a homothallic species.

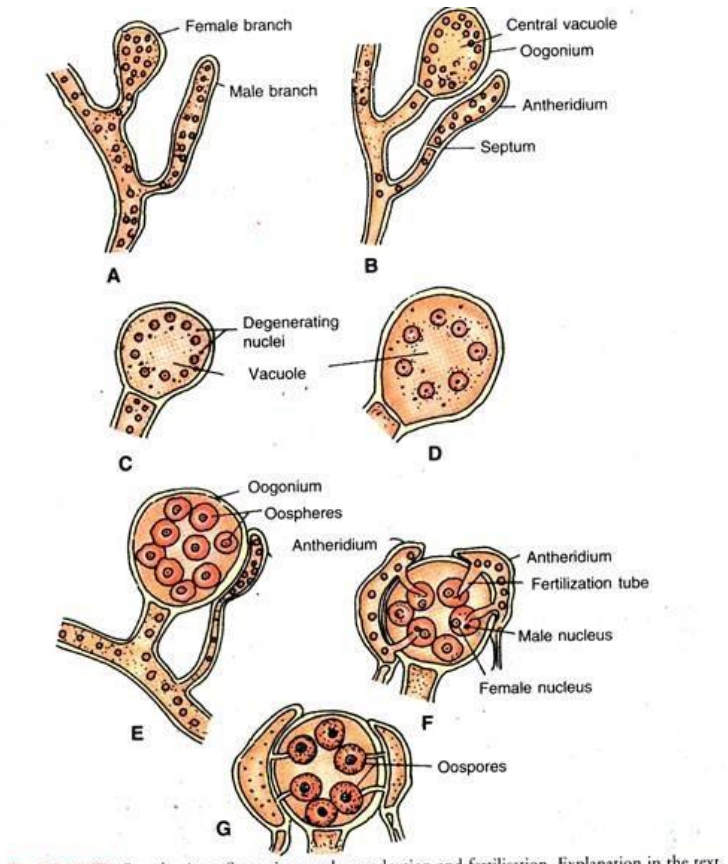


Fig. 6.5 (A-G). *Saprolegnia sp.* Stages in sexual reprodcution and fertilisation. Explanation in the text.

Oogonium (A):

(a) Structure:

The oogonium is generally a more or less a spherical structure with a thick wall. It is delimited from the supporting hypha (stalk) by a septum which is a solid plate. The oogonial wall is usually smooth. In some species it is spiny or papillate. Rarely it has pits (S. ferax). Usually the oogonia are produced singly and terminally on short lateral branches of the hyphae projecting from the substratum (A).

They may also arise from the main hyphae themselves. Sometimes oogonia are intercalary in position (S. litorales). The, multinucleate protoplasm of the oogonium which is uniformly granular, at first, becomes cleaved into several eggs or oospheres. The mature oogonium contains usually four to ten naked, uninucleate, spherical oospheres or eggs (E).

Rarely the number may go up to 32. Each oosphere contains a number of oil globules. These oil globules may unite to form a single, larger oil globule. In case this oil globule lies in the centre, the egg is known as centric. If it lies toward one side the oospohere is known as eccentric. The mature oosphere is dark in colour and is uninucleate.

(b) Development:

The tip of a lateral branch or the end of the main hypha swells. The swelling inflates to form a spherical structure. Thy cytoplasm and a large number of nuclei stream into the swollen portion. Finally a septum appears separating the terminal swelling from the supporting hypha (B). The former is the young oogonium and the latter is termed the stalk.

Following oogonium delimitation some of its nuclei and cytoplasm start degenerating. The process starts from the centre towards the periphery of the oogonium and continues till a conspicuous central vacuole forms. The nuclei left over along with the cytoplasm which is packed with lipid globules are restricted, at this stage, to a thin layer along the periphery of the oogonium (C).

The nuclei in the peripheral layer undergo another mitotic division which is again followed by the degeneration of some of them. The surviving nuclei gather cytoplasm around them and develop into uninucleate oospheres (D & E). The oospheres enlarge and become spherical. The entire protplasm of oogonium is used up in the formation of oospheres. The oogonium in Saprolegnia thus has no periplasm.

Antheridium:

(a) Structure:

The antheridia are borne on long or short, slender hyphae called the antheridiophores (A). The antheridiophores (one or more) may arise from the same hyphal branch which bears the oogonium and

immediately below it or from a different hypha in the neighbourhood or on an entirely different thallus.

In the first case the antheridia are said to be monoclinous or androgynous and in the latter two cases diclinous. The mature antheridium is an elongated, tubular, multinucleate structure delimited by a basal cross wall (Fig. 6.5 B). It contains abundant protoplasm and is smaller than the oogonium. No sperms are organised.

(b) Development:

An antheridiophore arises as a lateral outgrowth. As it elongates its terminal portion becomes inflated to form a tubular or even an irregular, swollen structure. Several nuclei move up into the swelling along with sufficient amount of cytoplasm.

Finally a septum separates the- terminal portion from the rest of the antheridiophore. This structure is known as antheridium. It is stated that the nuclei in the antheridium undergo one or more mitotic divisions.

Fertilisation in the Saprolegnia:

At maturity, the antheridiophore grows towards the oogonium till the antheridium becomes closely attached to it (Fig. 6.5 E). One or more antheridia may become closely appressed against the oogonial wall in this way. A fine tubular outgrowth arises from the antheridium at the point of contact (F).

It is the fertilisation tube. It pierces the oogonial wall and may give out slender branches. Each branch makes its way to one of the oospheres within the oogonium. Sometimes each oosphere in the oogonium receives a separate fertilisation tube from another antheridium (F & G).

On coming in contact with the oosphere the fertilisation tube or its branch pierces it and discharges one male nucleus into it. The male nucleus fuses with the female nucleus to accomplish fertilisation.

The fertilised egg or oosphere secretes a thick smooth wall around it to become an oospore which is gorged with fatty reserve stored in the form

of oil globules or droplets outside the large membrane bound cell inclusion termed the ooplast.

The reserve food may be stored outside the ooplast in a central (S. hypogyna), eccentric (S. aunisosphorio), subcentric (S. tenespora) or subeccentric (S. seccentrica) arrangement. The resultant oospore is a resting structure.

Germination of Oospore (Fig. 6.6 A-E):

Mature oospores are liberated by the degeneration of the oogonial wall. The oogonia degenerate after the mycelium bearing them has also undergone degeneration. The liberated oospores may remain inactive for a period of two to five months. In cultures oospores may not be liberated.

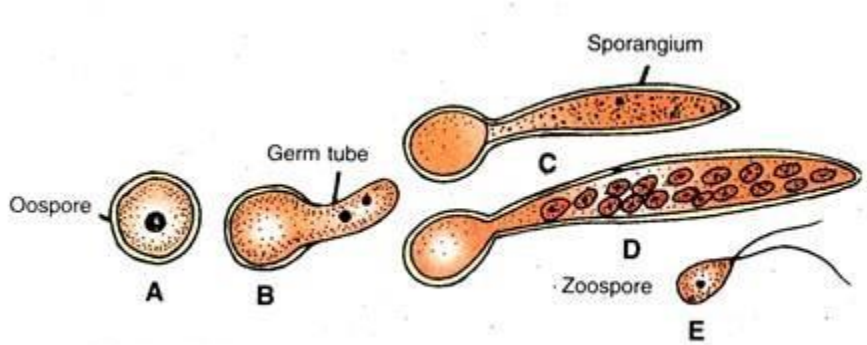


Fig. 6.6 (A-E). Stages in the germination of oospore of *Saprolegnia* sp.

They remain within the oogonium and germinate in situ (Fig. 6.7). The germ tube grows out through the wall of the old oogonium. At the approach of favourable conditions oospore germinates on a new substrate. It absorbs water and swells.

The oospore wall becomes thinner. The protoplasmic contents grow out in the form of a tubular outgrowth, the germ tube (B). According to the older view (Fig. 6.8) diploid nucleus undergoes meiosis at the time of zygote germination. The gem tube contains haploid nuclei.

During its further growth the germ tube may behave in either of the following ways:

1. It may directly grow into a new mycelium.

2. It may swell up to form a club-shaped germ sporangium typical of the species (C). The terminal germ sporangium is delimited by a basal cross wall. The protoplasmic contents of the germ sporangium produce

biflagellate zoospores (D). Each zoospore (E) germinates to form a new mycelium.

Oospheres which fail to be fertilized develop parthenogenetically. In some species such as S. ferax no antheridia are developed next to many oogonia. The eggs such oogonia function as parthenospores. Each parthenospore apparently is similar to an oospore. It develops parthenogenetically into a new mycelium.

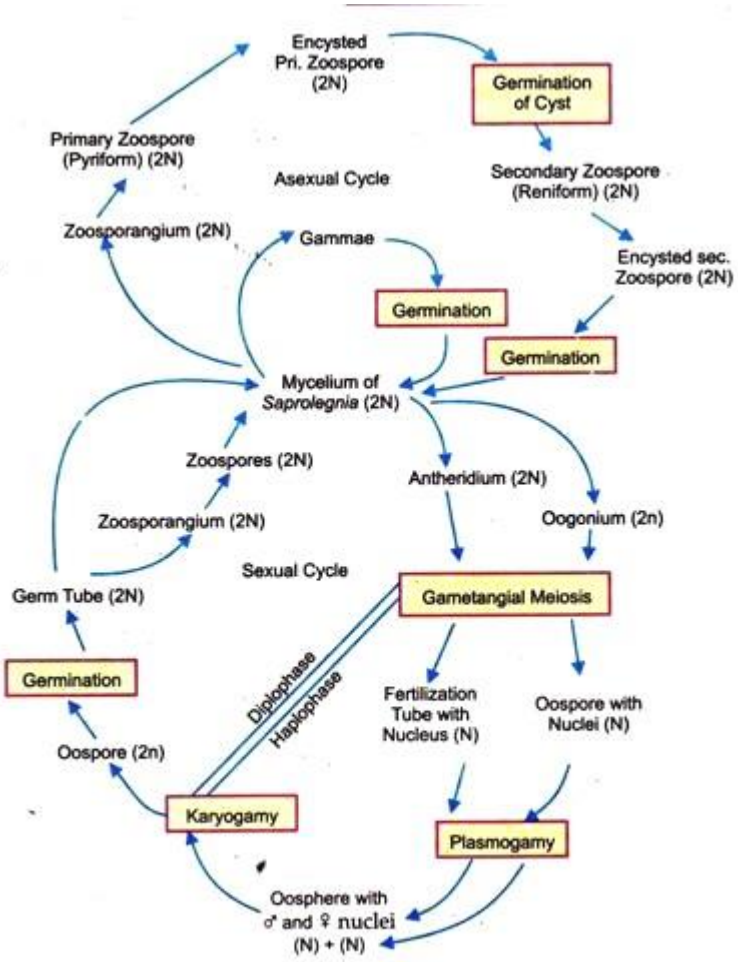


Fig. 6.8 B. Graphic representation of the life cycle of *Saprolegnia* with gemetangial meiosis.

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