DC-1

SEM-2

Paper: Mycology and Phytopathology

Lesson: Zygomycota

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Introduction

- Division Zygomycota is a division of true fungi represented by the fast-growing moulds that we encounter on spoiled strawberries and other fruits high in sugar content.

Figure: *Rhizopus* on strawberry (above) and Pear (below)

Source:http://gardener.wikia.com/wiki/File:Strawberry_Rhizopus_soft_rot_Rhizo, http://synapse.koreamed.org/DOIx.php?id=10.4489/MYCO.2006.34.3.151&vmod

e=PUBREADER#!po=16.6667pus_spp.jpg (CC)

- Majority of the members are saprotrophs and are commonly known as 'black moulds' or 'pin moulds'. This includes several common species of the genera, such as *Absidia*, *Phycomyces*, *Rhizopus, Mucor, Zygorhynchus,* and *Thermomucor* (a thermophilic fungus that can tolerate temperature of upto 60^{o}C).
- They are widely distributed in soil, or on substrates in contact with soil, humus and other organic debris and are particularly common as primary colonizers of animal remains, on the droppings of rodents and large herbivores (coprophilous), on composts in the case of thermophilic species, on over-ripe fruits and also in the rhizosphere of plants where they utilize soluble root exudates.

Characteristic Features of Phylum Zygomycota

The Division Zygomycota comprises a group of fungi which are characterized by the following features:

1. Majority of these fungi are **mycelial** and typically **lack cross walls**, i.e. **coenocytic** (non-septate), so all the nuclei are present within a common cytoplasm, but in some orders the presence of septa can be seen.
2. Some species may be **dimorphic,** i.e. they can grow both in mycelial form and yeast form exhibiting **yeast-mold dimorphism**, e.g. *Mucor rouxii* and *M. racemosus*.

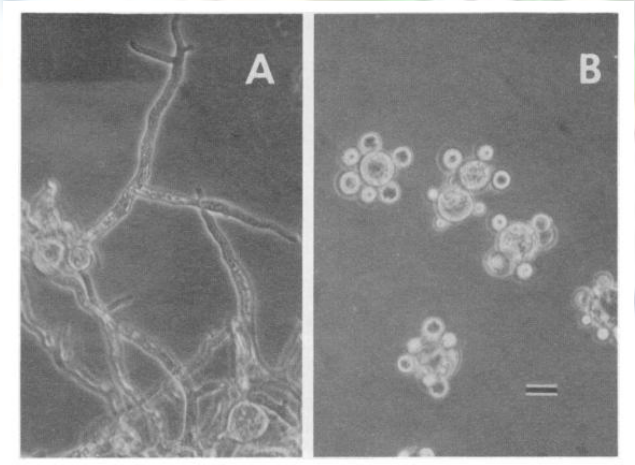


Figure: (Orlowski, 1991) showing vegetative morphologies of dimorphic *Mucor* sps.

(A) coenocytic hyphae and (B) multipolar budding yeast.
Source: http://lyonsfungiatlas.blogspot.in/2012/10/09-26-2012-practice-summary.html

3. Somatic body is haploid.
4. The cell wall is composed of a mixture of **chitin** and **chitosan** (a poorly acetylated or deacetylated form of chitin) and **polyglucuronic acid**.
5. As in all Eumycota, **lysine is synthesized** by the □□**aminoadipic acid (AAA) pathway**
6. **Mitochondria possess lamellar cristae** as also observed in Chytridio-, Asco- and Basidiomycota.

Did you know?

The Zygomycetes are certainly polyphyletic but controversy still prevails regarding the precise evolutionary relationships within the class. In order to reach at a satisfactory conclusion, comparisons have to be made between representative organisms with respect to DNA sequences, and other properties such as cytochrome oxidase, ribosomal RNA, and cytoskeleton protein.

7. Asexual reproduction is by **non-motile spores**, called **sporangiospores**, also called **aplanospores** because they are formed within a sporangium by cytoplasmic cleavage.
8. Sexual reproduction is by the fusion of two **gametangia** which may be typically isogamous and are formed at the tips of specialized structures known as **zygophores**.
9. The fusion of the two gametangia leads to the development of a thick-walled resting spore known as **zygospore** produced within a **zygosporangium**.

Two classes, **Zygomycetes** and **Trichomycetes** are included in this division. In the following sections Zygomycetes has been dealt in detail with special reference to R*hizopus.*

Class- Zygomycetes

This class includes about 900 species belonging to 10 orders.

- Majority of these fungi are **mycelial** and **coenocytic**; but in some orders the presence of septa can be seen.
- Some species may be **dimorphic**, i.e. they can grow both in mycelial form and yeast form, e.g. *Mucor rouxii* and *M. racemosus*, while there are other forms which can grow as protoplasts in insect host.
- Nutitionally Zygomycetes range from saprophytes through weak parasites to specialized parasites of plants and animals. Thus can be isolated from a variety of substrata, i.e. soil, dung, degrading plants and animal parts. Some of the species are mycoparasites.

The most prominent orders of the Zygomycetes are: Mucorales, Entomophthorales, and Zoopagales. Only Mucorales will be discussed in detail. A summary of the important families of Mucorales with examples has been listed in the Table:

Table: Families of Mucorales with examples

Family	***Examples***
Mucoraceae	*Absidia, Mucor, Phycomyces, Rhizopus, Syzygites* and *Zygorhynchus*.
Pilobolaceae	*Pilaira* and *Pilobolus*
Thamnidiaceae	*Thamnidium*
Chaetocladiaceae	*Chaetocladium*
Choanephoraceae	*Blakeslea and Choanephora*
Syncephalastraceae	*Syncephalastrum*
Cunninghamellaceae	*Cunninghamella*

Mortierellaceae	*Mortierella*

Mucorales

1. This order includes the largest number of species and also the greatest diversity.
2. Most members of Mucorales reproduce asexually by the formation of non-motile spores known as **sporangiospores** which are formed in a **sporangium.**
3. The sporangium, is produced on tip of aerial **sporangiophore,** which is generally large and globose (e.g. *Mucor*) and contain a number of spores.
4. Within the sporangium the spores may surround a central core or **columella**. In some species the columella is greatly reduced (e.g. *Mortierella* spp).
5. Some genera produce narrow sporangia with linearly arranged spores inside a cylindrical sac called **merosporangia** (e.g. *Syncephalustrum*).
6. Some produce rounded, few-spored, non-collumellate sporangia, known as **sporangiola** along with normal collumellate sporangia as observed in *Thamnidium.*

Ecology

1. Members of this order are very widespread and abundant in nature. Majority of the members are **saprotrophs** and are commonly known as **'black moulds' or 'pin moulds'**.
2. This includes several common species of the genera, such as *Absidia*, *Mucor, Phycomyces*, *Rhizopus, Thermomucor* (a thermophilic fungus that can tolerate temperature of upto 60^{o}C) and *Zygorhynchus*. The largest genus in Mucorales is *Mucor* itself, including many species, which are common in soil and on decaying plant materials.
3. They are widely distributed in soil, or on substrates in contact with soil, humus and other organic debris and are particularly common as primary colonizers of animal remains, on the droppings of rodents and large herbivores (**coprophilous**), on composts in the case of thermophilic species, on over-ripe fruits and also in the rhizosphere of plants where they utilize soluble root exudates.

4. They have large hyphae that ramify in all directions and soon sporulate to produce spores in large numbers which spread readily by wind, as the spores are very light.
5. In addition, *Rhizopus stolonifer* and *Mucor racemosus* produce pectic enzymes causing rots of sweet potatoes or fruits such as apples, tomatoes and strawberries.
6. Some others, such as *Syzygites megalocarpus* occurs on the decaying fruiting bodies of mushrooms and toadstools, especially *Boletus, Lactarius*, and *Russula* while some species, are **necrotrophic parasites** of mushrooms.
7. As starch can be decomposed by some species (e.g. *Mucor circinelloides, M. indicus, Rhizopus microsporus* and *R. oryzae*) so are **used as starters in the saccharification** of starchy polysaccharides in rice, cassava and sorghum, releasing simple sugars for the preparation of fermented foods or alcohol.
8. Most members have little ability to attack structural polysaccharides, such as pectin, cellulose and chitin.

Did you know?

- ***That Mucorales are some of the worst contaminants in the laboratory. Because of very simple nutritional requirements, we find these fungi to be the pioneers in attacking substrata which are rich in simple, soluble monomeric sugars, often covering it in 24-36 hours.***
- ***Because of the inability to produce invertase, Rhizopus nigricans cannot consume sucrose.***
- ***Mortierella spp. can degrade chitin by producing chitinases and may be encountered on the fecal pellets or shed exoskeletons of microarthropods abundant in decomposing materials. Thus, this genus is thought to play a significant role in the ecology of temperate forest soils.***

Significance

1. Many species are capable of producing several important industrial products such as **amylases**, **organic acids**, **rennins** and various secondary metabolites.
2. *Rhizopus stolonifer* has been used in the production of **fumaric acid** and **cortisone**. Some species produce **citric acid, succinic acid** and **oxalic acid**.
3. Generally, for the commercial production of lactic acid, bacteria are used. But now-a-days use of *Rhizopus* spp is preferred for the process, as the end product is easier to purify.
4. Since, many of the members need an external supply of vitamins, like thiamine, the amount of growth of *Phycomyces* can be used as a sensitive **bioassay** for the concentration of **thiamine.**
5. Some members of mucorales (e.g. *Blakeslea*) may produce □□□**carotene** in cultures which may be used for its commercial utilization.
6. *Rhizopus* and *Mucor* spp have been used to convert rice **starch to sugar**, and the sugar thus produced is used to convert it into alcohol by yeasts.
7. A number of species have been used in the production of **fermented foods** from rice, wheat and soybean (e.g. Asian foods- sufu, ragi and tempeh). Soyabean has 50% protein but is associated with fat and trypsin inhibitors, so is unavailable in diet. To make the protein digestible, cooked beans are inoculated with *R. oligosporus* at 30^{o}C for 24 hrs. Besides improving the nutritional quality, these fungi also **improve the flavour** of the fermented foods.
8. Other species are used in the production of **antibiotic - Raymycin and Fusidic acid** (*M. ramannianus*) which is active against Gram + bacteria.
9. *Phycomyces blakesleeanus,* an organism often found on dung or other decaying organic material, has been widely used in **experimental studies**.
10. In modern biotechnology, many Mucorales members have been employed in **biotransformation processes**.
11. A number of species are able to synthesize and accumulate lipids (**oleaginous**) to over 20% (dry weight) of their biomass. These lipids (mainly triglycerides) may be used to enrich polyunsaturated fatty acids (PUFAs). Because of this, several members of Mucorales are of interest biotechnologically.

A summary of the members of Mucorales being used commercially is listed below:

Table: Examples of Mucorales members being used commercially

Fungal Source	**Product**	**Applications / Remarks**
Mucor miehei	Rennet	Milk coagulation
Mucor species	Glucose isomerase	High fructose syrups
Mucor miehei, Rhizopus arrhizus, R. delemar, R. japonicus, R. niveus and *R. oryzae.*	Lipases	Dairy industry, detergents, dietary supplement to digest fat
Mucor rouxii, Rhizopus microsporus , *R. oryzae* and *R. stolonifer*	Amylases	Used to convert rice starch to sugar thus is used in alcohol production
Rhizopus arrhizus	Fumaric acid	Saccharification and fermentation processes using starch waste effluents
Rhizopus arrhizus	Cortisone (steroid)	Used in various skin problems
R. oryzae R. stolonifer, R. sinensis, R. nodosus	Lactic acid	In the manufacture of the biodegradable solvent - ethyl lactate and in the food industry as a preservative and flavour enhancer

Did you know?

Fungal Lipases.

- ***That fungal lipases are used in the treatment of excessive cholesterol and triglycerides; in heart problems, high blood pressure, plaque build-up in the arteries, obesity, and indigestion; as digestive enzyme, in pancreatic insufficiency; in cosmetic industry as moisturizers and in leather industry for degreasing the skin /hide.***
- ***The chief producers of commercial lipases are Mucor miehei, Rhizopus arrhizus, R. oryzae, R. delemar, R. japonicus, and R. niveus.***
- ***Besides Zygomycetes, other fungi used for the commercial production of lipases are, Aspergillus niger, Candida cylindracea and Humicola lanuginosa.***

R. stolonifer	Citric acid Succinic acid Oxalic acid	Food and beverage products; pharmaceuticals
Blakeslea	□-carotene ɣ-carotene (lycopene)	Colourant and food additive; dietary supplement for vitamin A. Natural antioxidant; treatment of high blood pressure
Thamnidium	Proteolytic enzymes□	Used to tenderize steak
Rhizopus oryzae	Pectinases	Clarifying fruit juices
Cunninghamella elegans , *C.echinulata* and *Mortierella alpina*		Used in biotransformations of pharmaceutical products

General Characteristics

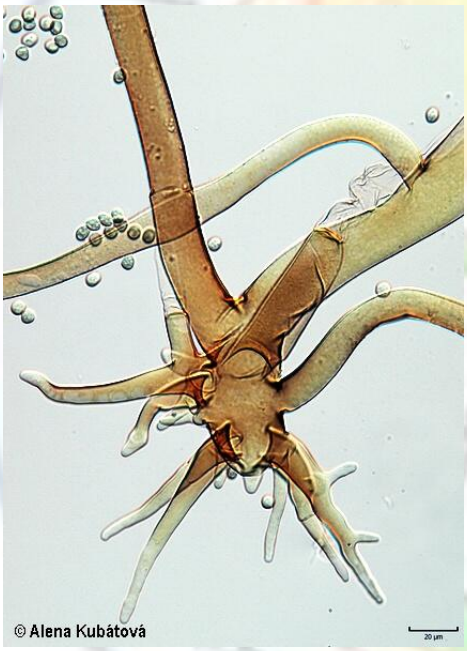
- The sporangiospores that form inside a sporangium, swell to many times the original volume when placed on a suitable substratum and synthesize a new wall beneath the original spore wall and germinate.
- The mycelium from a germinating sporangiospore, establishes itself on a solid substrate as coarse, coenocytic, richly branched structure, which shows active **protoplasmic streaming**.

Source:http://www.homepages.indiana.edu/2006/01-13/images/yellowstoneelk.jpg

- No network is seen as anastomosis between the branched hyphae is rare, but is a common feature in other fungi.
- The cell wall of Mucorales is chemically complex and contains **chitin** microfibril, which are deacetylated to **chitosan.** Other compounds constituting the wall are

polysaccharides like **glucosamine** and **galactose**, **polyphosphates**, **proteins, lipids, purines, pyrimidines, magnesium and calcium**.

- **Chitosomes**, small spheroidal bodies, 40-70nm in diameter and surrounded by a covering of 7nm thickness, were first demonstrated in *M. rouxii* and now has been described from sporangiophores of *Phycomyces* and several other fungi. The synthesis of chitin microfibrils is associated with the presence of these bodies.
- Hyphae contain organelles typical of other true fungi. Cytoplasm is granular, **mitochondria** are short at the hyphal tips but longer and filamentous in older segments. Beside this, **sap vacuoles** and **nuclei** are present.
- In some genera like in *Absidia* and *Rhizopus,* stout rapidly growing aerial hyphae known as **stolons** are produced. Wherever, these stolons touch substratum slender hyphae known as **rhizoids** develop.



Source:https://botany.natur.cuni.cz/sites/default/files/images/rhizopus_microsporus_ccf1362_sl4_3_me64xdic1.jpg

- In addition to mycelium production, some of the Mucorales can also exist in a yeast form.

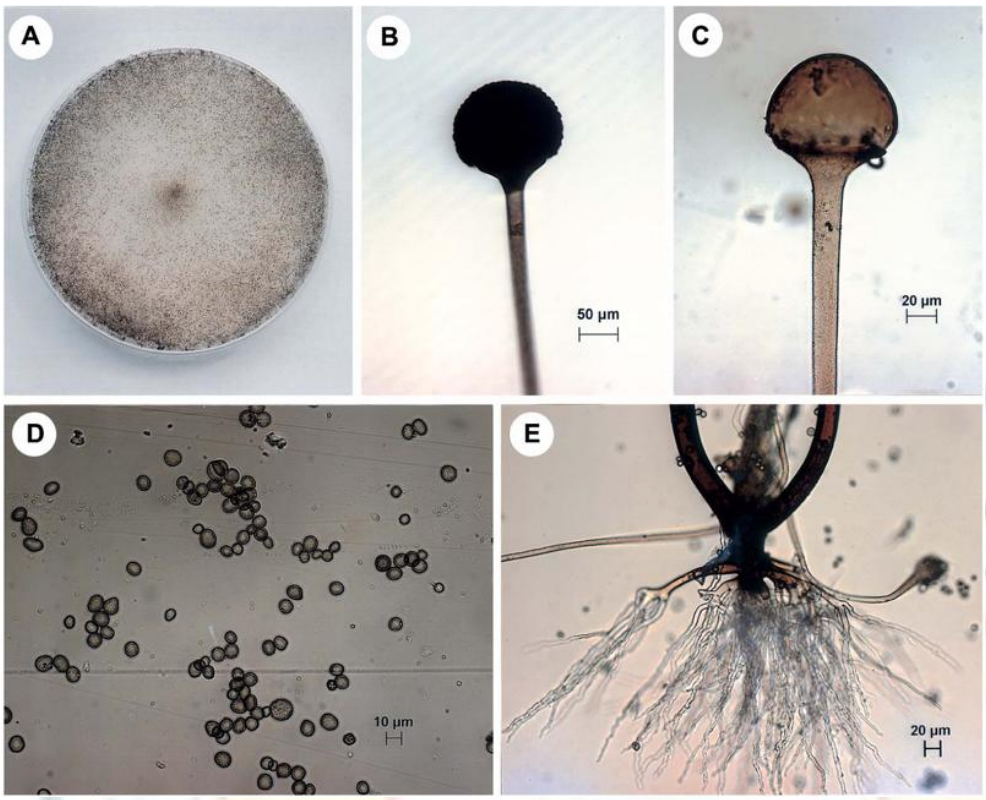


Figure: *Rhizopus* **A.** Mycelial growth on PDA medium; **B.** S[porangium and sporangiophore;**D.** Coumella **E.** Sporangiospores ; **E.** Rhizoids and stolons.

Source:http://synapse.koreamed.org/DOIx.php?id=10.4489/MYCO.2006.34.3.151&vmode=PUBREADER#!po=16.6667 (CC)

- In addition to mycelium production, some of the Mucorales can also exist in a yeast form, especially under anaerobic conditions. *Mucor rouxii* and *M. racemosus* respond specifically to change in oxygen levels; they grow as budding yeasts in anaerobic conditions but as mycelia in the presence of even micromolar concentrations of oxygen. Such forms aid in fermentation and alcohol production from sugar.

Asexual Reproduction

- The most widespread mode of asexual sporulation in the Mucorales is the production of sporangiospores inside a sporangium. The details of the form and arrangement of the sporangium on the sporangiophores, is highly variable in different genera.
- Genera like *Mucor, Rhizopus, Mortierella* etc. produce multispored **sporangia (sing. sporangium)** with or without **columella.**

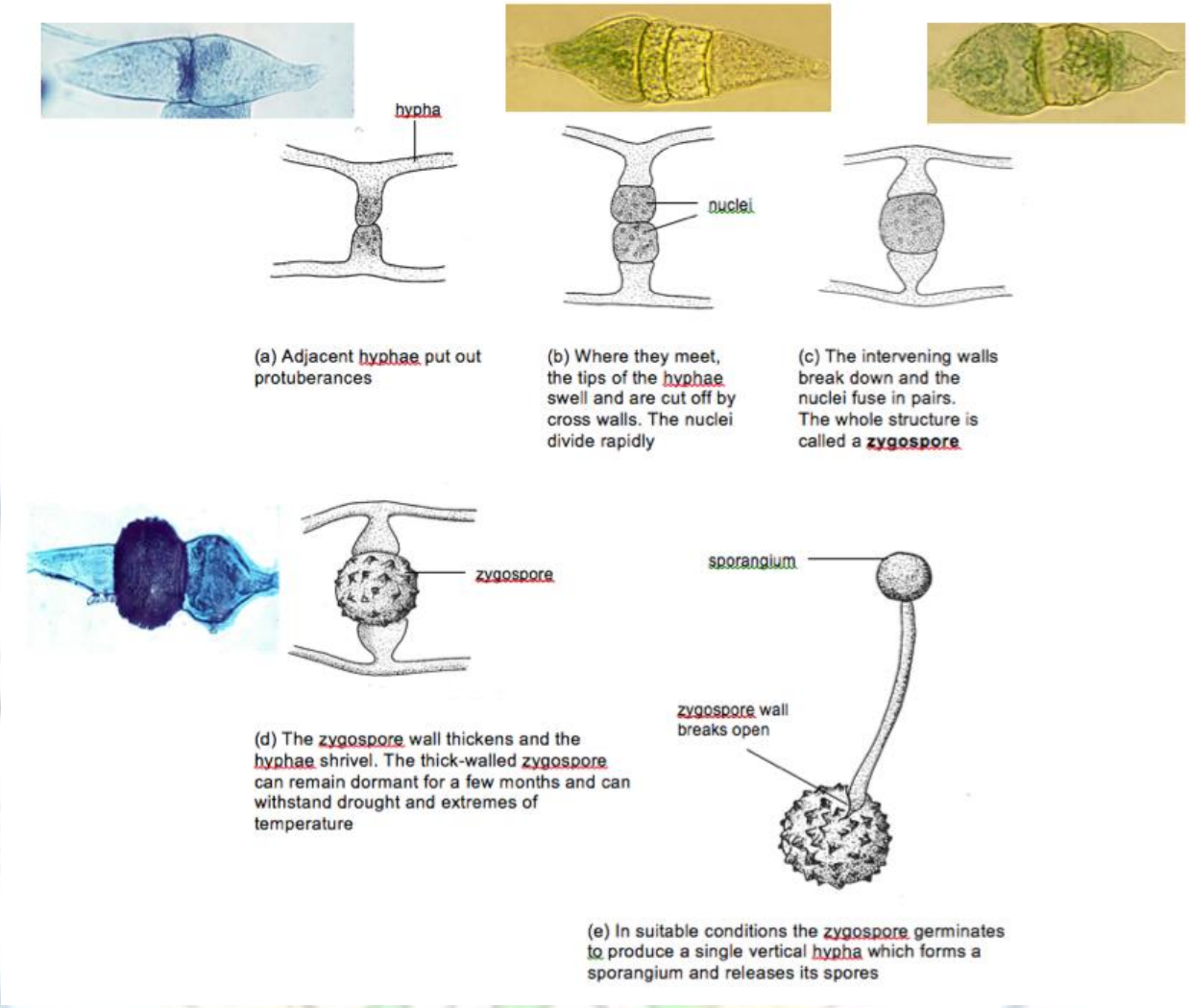
Source:https://botany.natur.cuni.cz/en/obrazek/mucor-petrinsularis-ccf-3238-sporangiofory

- The sporangia may be formed singly at the tip of an unbranched or a branched sporangiophore. In *Absidia,* the sporangia may be arranged in whorls on aerial branches.
- Most of the sporangium is occupied by sporangiospores, but the sporangiophore projects into the sporangium as a **columella**.
- In general, the **sporangia** of Mucorales are **black** in colour therefore the common name '**black mould**' and may develop a spiny surface due to crystal formation.
- However, the sporangium of *Phycomyces* is bright-yellow initially because of the presence of □□carotene, but then turns metallic-green or black as the carotene form **sporopollenin**, a substance very resistant to chemical and biological degradation.
- Dispersal of spores occurs by different mechanisms, like in some *Mucor* species (e.g. *M. hiemalis*) it occurs by dissolution of sporangium wall at maturity and in *R. stolonifer* by the drying of sporangia. When sporangia dry, collumella collapses leading to the fragmentation in sporangial wall thus releasing dry spores in wind currents.

Sexual Reproduction

- The members of this order reproduce sexually by a process of gametangial conjugation resulting in the formation of a **zygospore** produced within a **zygosporangium** with outer wall of dark warty ornamentations. However, for

convenience the term zygospore is used very widely instead of zygosporangium.



Source: http://www.biology-resources.com/fungi.html, http://bioweb.uwlax.edu/bio203/2011/olbrantz_chri/reproduction.htm (CC)

- It was in Mucorales first of all, that the phenomenon of **sexual incompatibility** was demonstrated by the American geneticist, **AF Blakeslee in 1904.**
- Mucorales contain both homothallic and heterothallic species. **Homothallic** or **self-fertile** species are those, where the zygospores are derived from a single sporangiospore e.g. *Absidia spinosa, Rhizopus sexualis* etc.
- However, the majority of the members are **heterothallic** or **self-sterile**, e.g. *M. hiemalis, R. stolonifer* and *Phycomyces blakesleeanus.*
- In some members of Mucorales, if gametangial copulation fails to take place

normally, one or both gametangia may give rise parthenogenetically to a structure morphologically similar to the zygospore, which is known as **azygospore** and is present within **azygosporangium.** Azygospores usually appear as warty spherical structures borne on a single suspensor-like cell and are regular features in cultures of *Mucor azygospora.*

Figure: *Mucor bainieri* azygospores

Source: http://zygomycetes.org/index.php?id=84

- Since it is not possible to designate one strain as male and the other as female, these are labeled as plus (+) and minus (-) strains.
- Mating hormones (pheromones, gamones, sex hormones) control the mating process in all members of the Mucorales. These are chemical signals emitted by one individual that influences the behaviour of another individual.
- Hormones identified as trisporic acid have several effects:
  i. Suppresses sporangiophore formation.
  ii. Induces zygophore formation in a wide range of Zygomycetes, including self-fertile species.
  iii. In addition to inducing zygophores, trisporic acid stimulates the production of □-carotene and other intermediates in its own biosynthetic path, thus greatly increasing its own rate of biosynthesis, an example of positive feedback or metabolic amplification.
- **Germination of Zygospore:** In *M. mucedo*, zygospore wall is rich in sporopollenin. Sporopollenin enables zygospores to remain resistant to degradation therefore they remain viable in the soil for a long time.
- The conditions necessary for the germination of zygospores are not very clear. In some genera, the maturation period required before the germination can take place

is few days, while in others it may extend to months.

- Zygospores germinate by producing a **vegetative mycelium,** a **germ sporangium** or a **germ sporangiolum** depending on the species.

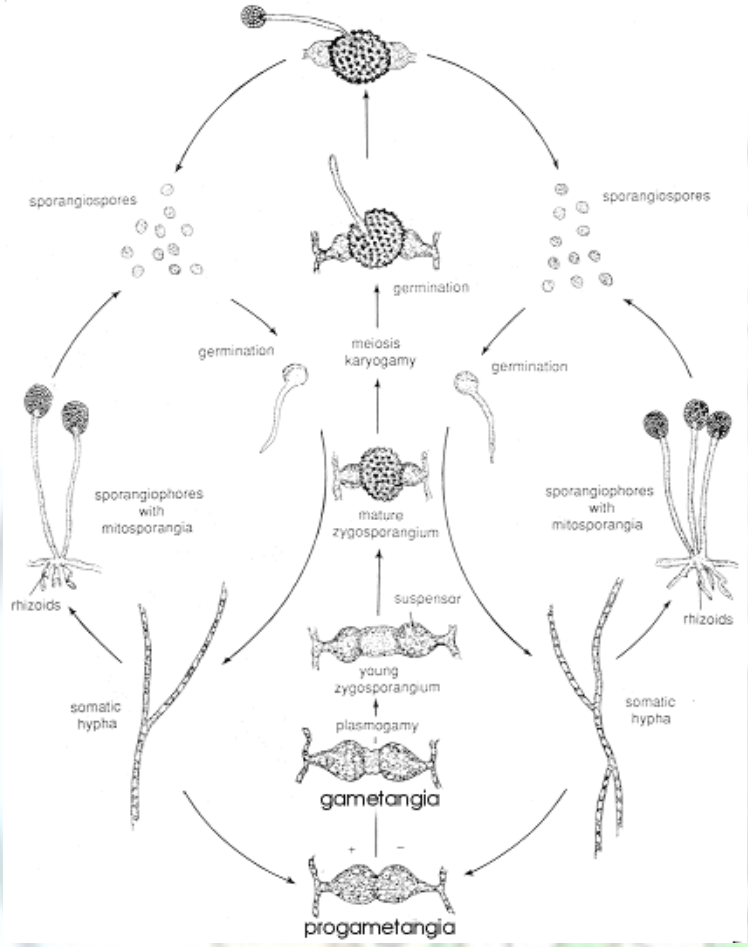


Figure: Life cycle of mucorales

Source: www.mycolog.com/CHAP3b.htm

Rhizopus / Mucor (Black Bread Moulds)

Classification

Kingdom-	**Fungi**
Division-	**Zygomycota**
Class-	**Zygomycetes**
Order-	**Mucorales**
Family-	**Mucoraceae**
Genus-	***Rhizopus / Mucor***

Ecology and Importance

This genus belongs to the family Mucoraceae, which incidentally is one of the largest families of the order Mucorales.

- *Rhizopus* has about 10 species and is abundant in soil, on decaying fruits, on dung, and on moist fresh organic matter in contact with soil.
- Most of the species are **saprotrophic,** and play an important role in the early colonization of substrata in soil.
- Occasionally *Rhizopus* causes spoilage of bread and other food and together with *Mucor* is commonly known as '**Black bread mould**' or **Pin-head mould.**

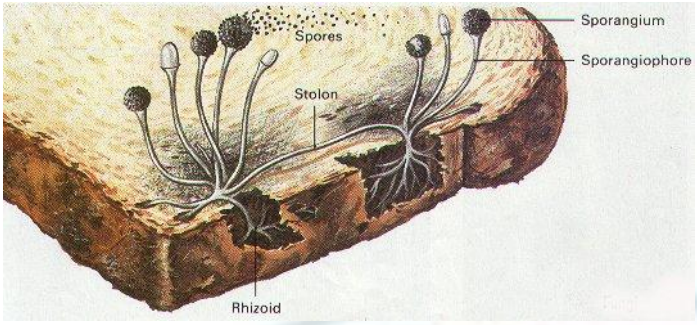


Figure: Bread mold

Source: http://treediseases.cfans.umn.edu/photooftheweek.htm

- It may also be found on ripe bananas if they are incubated in a moist chamber.
- It is very common laboratory contaminant.
- Sometimes, however, it can behave as a weak parasite of plant tissues, e.g. *Rhizopus stolonifer* (syn. *R. nigricans*) can cause rot of sweet potatoes, tomatoes or fruit such as apples, strawberries and raspberries during shipping and marketing.
- Many species of *Rhizopus,* have been used commercially to produce several organic acids, amylases, cortisone.
- Other species have been employed for improving the nutritional quality and flavour of fermented foods like 'Sufu' & 'Tempeh'.

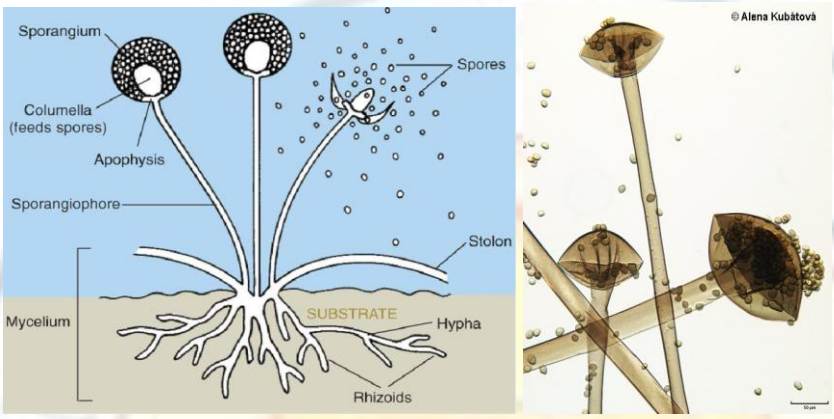
Did you know?

Rhizopus oryzae and R. microsporus are used as starters in ragi fermentation. The latter is also the cause of rice seedling blight in which root growth is strongly impaired by a toxin, rhizoxin, excreted by the soil-borne pathogen. This toxin interferes with mitosis by binding with β-tubulin. Interestingly it is synthesized by a bacterium (Burkholderia spp.) which lives endosymbiotically within the cytoplasm of Rhizopus hyphae.

Life Cycle

Asexual Reproduction

1. After the sporangiospores mature, the wall of the sporangium dries out with the collapse of columella, which thus looks like an inverted cup-like dish on the end of a stick.



Source:https://botany.natur.cuni.cz/sites/default/files/images/rhizopus_stolonifer_ccf3225_mea4_me32xdic1.jpg (CC)

2. The sporangial wall being brittle, breaks up into pieces liberating the spores.
3. Sporangiospores are globose to oval and multinucleate.
4. Under favourable conditions these spores germinate to produce a white, branched, coenocytic, fluffy aerial mycelium.
5. From the mycelium develop many aerial stolons which develop rhizoids at the point of contact with the substratum.
6. A group of sporangiophores develop directly above the rhizoids. Sporangia develop at the tip of the sporangiophore which is multinucleate initially.
7. A dome-shaped septum develops separating the central columella from the peripheral spore bearing zone, which later become divided into a large number of multinucleate spores.
8. The asexual cycle of the fungus is completed with the liberation of aerial spores of the fungus.

Sexual Reproduction

1. Most species of *Rhizopus* are heterothallic, but *R. sexualis* is homothallic and

forms zygospores freely within 2 days in the laboratory. In the homothallic strain, a single spore from the germ sporangium is capable of forming a zygospore.

2. In the heterothallic strain, e.g. *R. stolonifer* the germ sporangia are either pure (+) or pure (-) or sometimes a mixture of (+) and (-). Because the strains although morphologically same are distinct physiologically therefore both types of spores are required for the formation of a zygospore.
3. Zygophores of two compatible strains come in direct contact with each other leading to the formation of progametangia.
4. Delimitation of gametangia takes place followed by dissolution of the wall between the two.
5. The two gametangia fuse to form a **prozygosporangium**.
6. A single thick-walled black warty zygospore develops in each zygosporangium.
7. The zygospores can germinate after a maturation period of 1-3 months at temperature of 21°C.
8. The zygosporangium crack open on germination, develops a sporangiophore and a germ sporangium at its tip.
9. Somewhere, during this time the process of meiosis takes place and depending upon the survivability of haploid nuclei the germ sporangium contains either all (+) or all (-), or a mixture of both types of spores.
10. The life cycle of the common heterothallic strain, *Rhizopus stolonifer* is drawn as below.
11. Important differences between *Rhizopus* and *Mucor* are given in the Table below.

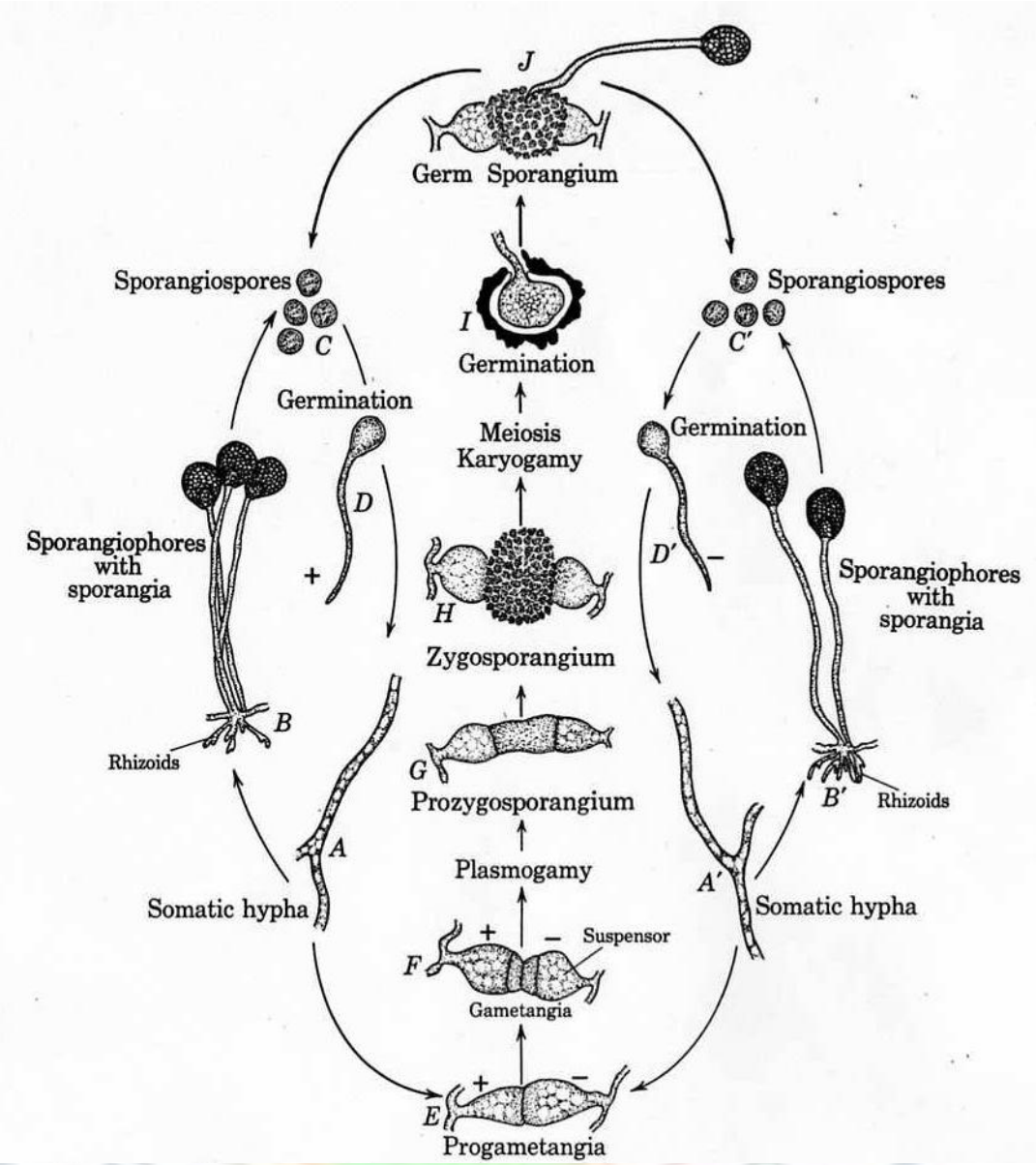
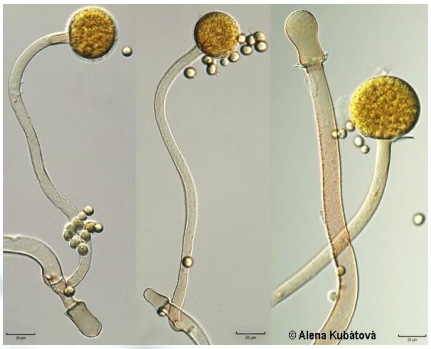


Figure: Life cycle of *Rhizopus*

Differences between *Rhizopus* and *Mucor.*

Char acter	*Rhizopus*	*Mucor*

	 Source:https://botany.natur.cuni.cz/sites/default/files/images/rhizopus_microsporus_ccf1362_sl4_3_me_32xdic1.jpg	 Source:https://botany.natur.cuni.cz/sites/default/files/images/mucor_fuscus_ccf3238_sl4_8_me_63xdicb.jpg (CC)
1.	Mycelium differentiated into three kinds of hyphae: stoloniferous, rhizoidal and sporangiophore	Mycelium is not differentiated. It has only aerial sporangiophores on prostrate hyphae
2	Rhizoids present for absorption of food material.	Rhizoids generally absent, so food is absorbed by the entire mycelium
3	Stolons present	Stolons absent
4	Sporangiophores arise from the junction of rhizoids and stolons	Sporangiophores may arise from any point
5	Sporangiophores are in groups of 2-3 mainly above the rhizoids	Sporangiophores arise singly, and not in groups
6	Spores remain attached to columella and do not disseminate easily	Spores easily disseminated by wind

Summary

Class Zygomycetes is represented by the fast-growing moulds that we encounter on spoiled strawberries and other fruits high in sugar content. Majority of the members are saprotrophs and are commonly known as 'black moulds' or 'pin moulds'. This includes several common species of the genera, such as *Absidia*, *Phycomyces*, *Rhizopus, Mucor, Zygorhynchus,* and *Thermomucor* (a thermophilic fungus that can tolerate temperature of upto 60^{o}C). They are widely distributed in soil, or on substrates in contact with soil, humus and other organic debris and are particularly common as primary colonizers of animal remains, on the droppings of rodents and large herbivores (coprophilous), on composts in the case of thermophilic species, on over-ripe fruits and also in the rhizosphere of plants where they utilize soluble root exudates. Fewer than half of the species have been cultured and the majority of the members are some of the fastest growing fungi.

Majority of these fungi are mycelial and typically lack cross walls, i.e. coenocytic (non-septate), so all the nuclei are present within a common cytoplasm, but in some orders the presence of septa can be seen. Some species may be dimorphic, i.e. they can grow both in mycelial form and yeast form while there are other forms which can grow as protoplasts in insect host. Somatic body is haploid. Asexual reproduction is by non-motile spores, called aplanospores, also called sporangiospores because they are formed within a sporangium by cytoplasmic cleavage. Sexual reproduction is by the fusion of two gametangia which may be typically isogamous and are formed at the tips of specialized structures known as zygophores. The fusion of the two gametangia leads to the development of a thick-walled resting spore known as zygospore produced within a zygosporangium. Both *Rhizopus* and *Mucor* are common laboratory contaminants and are abundant in the soil, on decaying fruits, on dung, and on moist fresh organic matter in contact with soil. Most of the species are saprotrophic, and play an important role in the early colonization of substrata in soil. Occasionally *Rhizopus* causes spoilage of bread and other food and together with *Mucor* is commonly known as 'Black bread mould'. It may also be found on ripe bananas if they are incubated in a moist chamber. Sometimes, however, it can behave as a weak parasite of plant tissues, e.g. *Rhizopus stolonifer* (syn. *R. nigricans*), and *Mucor racemosus* can cause rot of sweet potatoes, tomatoes or fruit such as apples, strawberries and raspberries during shipping and

marketing.

Young mycelium consists of white, coarse, coenocytic, richly branched, tubular hyphae which show active protoplasmic streaming. Asexual reproduction takes place by the formation of sporangia which develop at the tip of the sporangiophore. The spores are globose to oval and multinucleate. The asexual cycle of the fungus is completed with the liberation of aerial spores of the fungus.

Most species of *Rhizopus* are heterothallic, but *R. sexualis* is homothallic and forms zygospores freely within 2 days in the laboratory. In the homothallic strain, a single spore from the germ sporangium is capable of forming a zygospore. In the heterothallic strain, e.g. *R. stolonifer* the germ sporangia are either pure (+) or pure (-) or sometimes a mixture of (+) and (-). Because the strains although morphologically same are distinct physiologically therefore both types of spores are required for the formation of a zygospore. A single thick-walled black warty zygospore develops in each zygosporangium. On germination, the zygosporangium crack open, develops a sporangiophore and a germ sporangium at its tip. Whether Zygomycetes (e.g. *Rhizopus*) reproduce sexually or asexually, they always make use of sporangiospores. Under favourable conditions, spores germinate to produce a white; much branched coenocytic, aerial mycelium which is fluffy, therefore, is called a mould.

Glossary

Aplanospores: Non motile spores

Azygospore: A spore that develops parthenogenetically

Coenocytic: Non septate

Dimorphism: A process of production of two morphologically different types of zoospores or a fungus able to occur in yeast and mycelial forms.

Merosporangium: A cylindrical sporangium producing uniseriate spores

Necrotroph: A pathogenic fungus that kills host cells in advance of its hyphae and lives on dying and dead cells.

Sporangiolum: A small sporangium containing few spores

Sporangiospores:A spore borne within a sporangium

Zygophores: A special hypha capable of developing into a progametangium

Zygosporangium: A sporangium containing a zygospore; develops following the fusion of two gametangia

Zygospore: A resting spore resulting from the fusion of two gametangia

Exercises

I. Define the following terms

1. Columella
2. Sporangiophore
3. Zygospore
4. Heterothallism
5. Coprophilous
6. HoldFast
7. Saccharification
8. Azygosporangium
9. Chitosomes
10. Dimorphic Fungi

II. Match the following:

1	Unable to produce invertase	a	A.F. Blakslee
2	Cortisan	b	*Mortierella alpina*
3	Biotransformation of pharmaceutical products	c	*Rhizopus nigricans*
4	Fungi accumulating lipids	d	*Rhizopus stolonifer*
5	Sexual incompatibility	e	Oleaginous

Answers: 1-c, 2-d, 3-b, 4-e, 5-a

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Web Links

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