

Zygomycota

'Pin' or 'Sugar' Molds

(Comparative study of habit, habitat, somatic organization, anamorphs (mitotic), teleomorphs (meiotic) and evolutionary tendencies within members of Zygomycetes)



Sporangia of *Spinellus fusiger* (Mucorales) parasitic on fruitbodies of the mushroom *Mycena pura*.



- **Zygomycota are also pathogens for animals, amebas, plants, and other fungi. They form symbiotic relationships with plants.**
- **In addition, they form commensalistic relationships with arthropods, inhabiting the gut of the organism and feeding on unused nutrients.**
- **However, Zygomycota can also be found in aquatic ecosystems. While Zygomycota are largely known to humans for the negative economic impact they have on fruit, they also have some practical use.**
- **For example, certain species are used in Asian food fermentations.**
- **In addition, people have used their pathogenic powers to control insect pests.**

Characteristics of Zygomycota

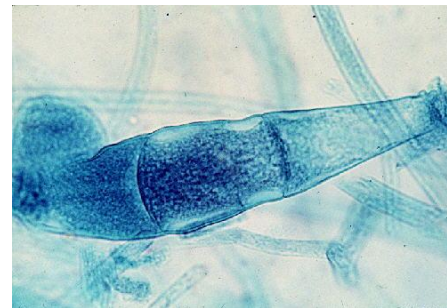
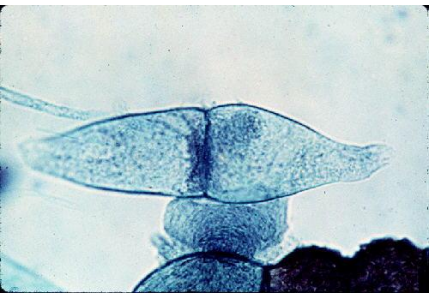
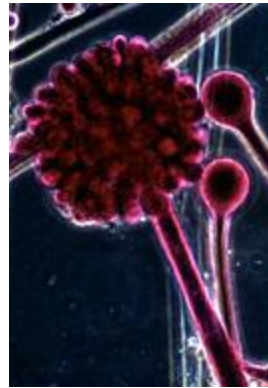
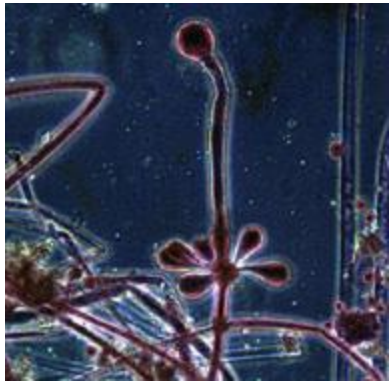
1. Zygomycota ,all true fungi, produce cell wall contain chitin
2. Somatic phase as mycelia, hyphae which are generally coenocytic because they lack cross walls of septa.
3. Gametangial Copulation is a type of sexual reproduction in zygomycota in general *the gametangia fuse with each other, lose their identity and develop into a zygospore*
4. most reproduce asexually by producing sporangiospore.
5. Chlamydospores are another type of asexual spores different from sporangiospores

- The Zygomycota is thought to be the most primitive of the terrestrial fungi.
- coenocytic mycelium
- asexual spores (= **sporangiospores**), in **sporangia** borne on stalks (= **sporangiophores**).
- These characteristics are shared with the divisions of flagellated fungi that were just studied. For this reason the Zygomycota were once thought to be closely related to the aquatic fungi.
- However, cell wall composition is chitin-chitosan and flagellated spores and gametes are absent in this division as well as in the remaining taxa of terrestrial fungi.
- Sexual reproduction occurs with the fusion of undifferentiated **isogametangia** or **anisogametangia** to produce a zygote.
- The zygote later develops into a thick-walled **zygospore**, the diagnostic feature of this division.
- Two classes are recognized in this division; the Trichomycetes and Zygomycetes.

Asexual Reproduction

- A typical sporangium is produced on a sporangiophore, singularly or in clusters, where rhizoids have formed and grown in the substrate. Within the sporangium proper are **sporangiospores** and a **columella**.





Pair of **progametangia** of different mating strains: "+" and "-" grow towards each other. Migration of nuclei will occur in the tips of both progametangia where gametangia will form.

Septa are laid down at the apex of the progametangia to form **isogametangia**. The outside, larger cells are the **suspensors** that support the gametangia.

Plasmogamy occurs following fusion of the gametangia. Karyogamy immediately follows to form a multinucleate **zygote**.

The zygote will form a thick, pitted wall around itself to form the **zygospore**. Further development will not develop until after it has gone through a period of dormancy.

Sexual Reproduction

- Sexual reproduction occurs when opposite mating strains, designated as "+" and "-", grow towards one another.
- As the opposite mating strains near one another a hormone, trisporic acid, induces formation of progametangia which meet to initiate sexual development.
- Nuclei migrate into the apex of the **progametangia** where septa will form. The terminal cells are the **isogametangia** and the remainder of what was the progametangia are the **suspensors**.
- Fusion of gametangia will take place, followed by plasmogamy and karyogamy, and zygote formation. A dark, thick cell wall then forms around the zygote which may now be referred to as a **zygospore**.
- The formation of the zygospore is the unifying characteristic of the fungi in this division. Life cycle images of *Rhizopus stolonifer*

ZYGOMYCETES

- The zygomycetes comprise about 1,060 species, including common bread molds, as well as both freshwater and marine species.
- Most have rapidly growing hyphae, but some are unicellular.
- Zygomycete hyphae may be coenocytic, forming septa only where reproductive structures are formed.

- Most species of zygomycetes live in soil, or on decaying plant and animal matter.
- Aquatic species are primarily found in sediments or algae, but some species are free-floating or attached to aquatic animals or decaying leaves.
- Some are parasites of plants, insects, or small soil animals. Still, others cause serious infections in humans and domestic animals.
- The different genera may be distinguished based on the size and shape of the sporangia, the presence or absence of rhizoids and their location..

- Zygomycetes carry out asexual reproduction by means of spores produced in sporangia. They also produce thick-walled sexual structures called zygosporangia (singular zygosporangium), which can remain dormant for long periods.
- These sporangia, Many zygomycetes produce multiple sporangiospores inside a single sporangium. Some have multiple small sporangia that contain only a few sporangiospores, or even a single one.

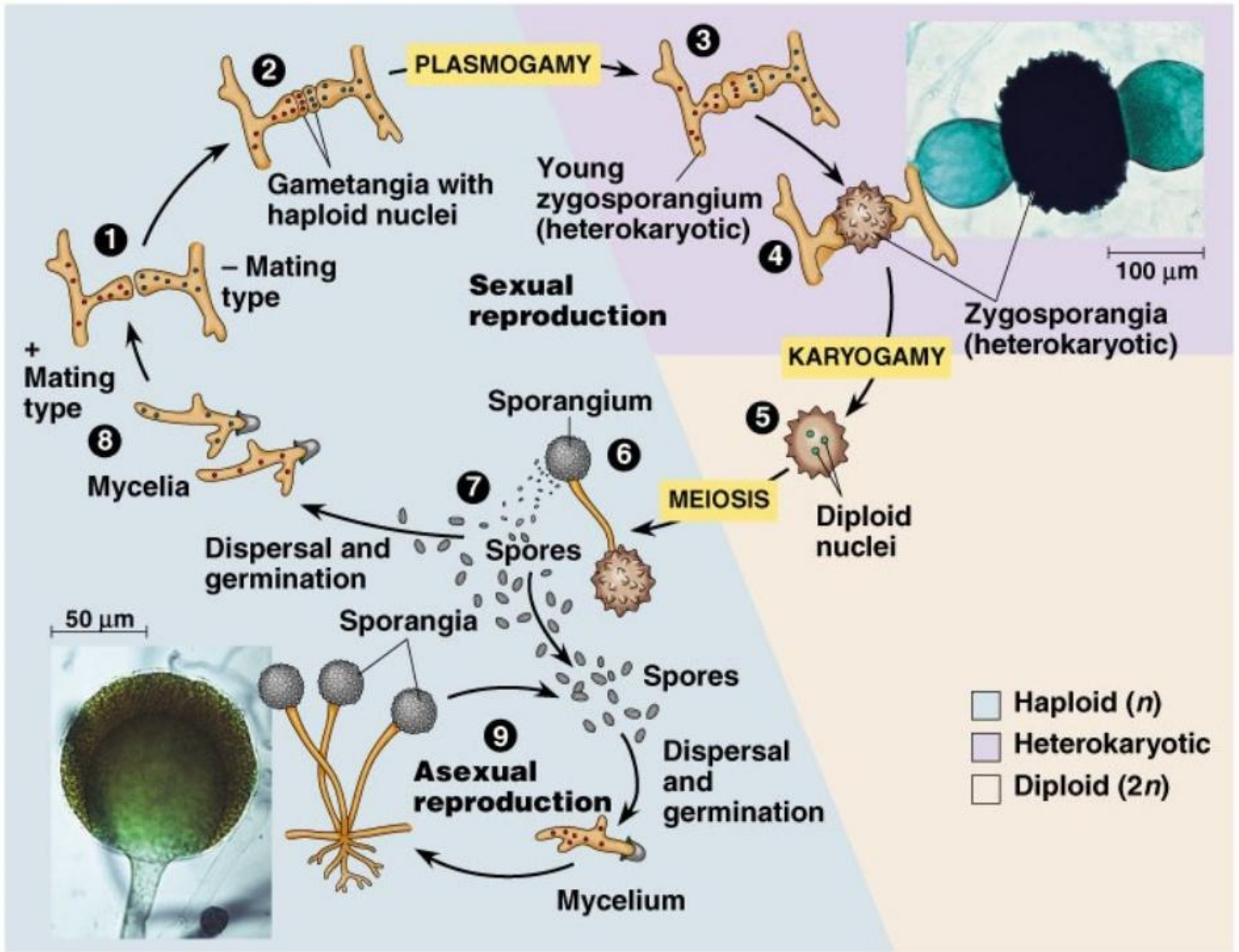
Asexual reproduction

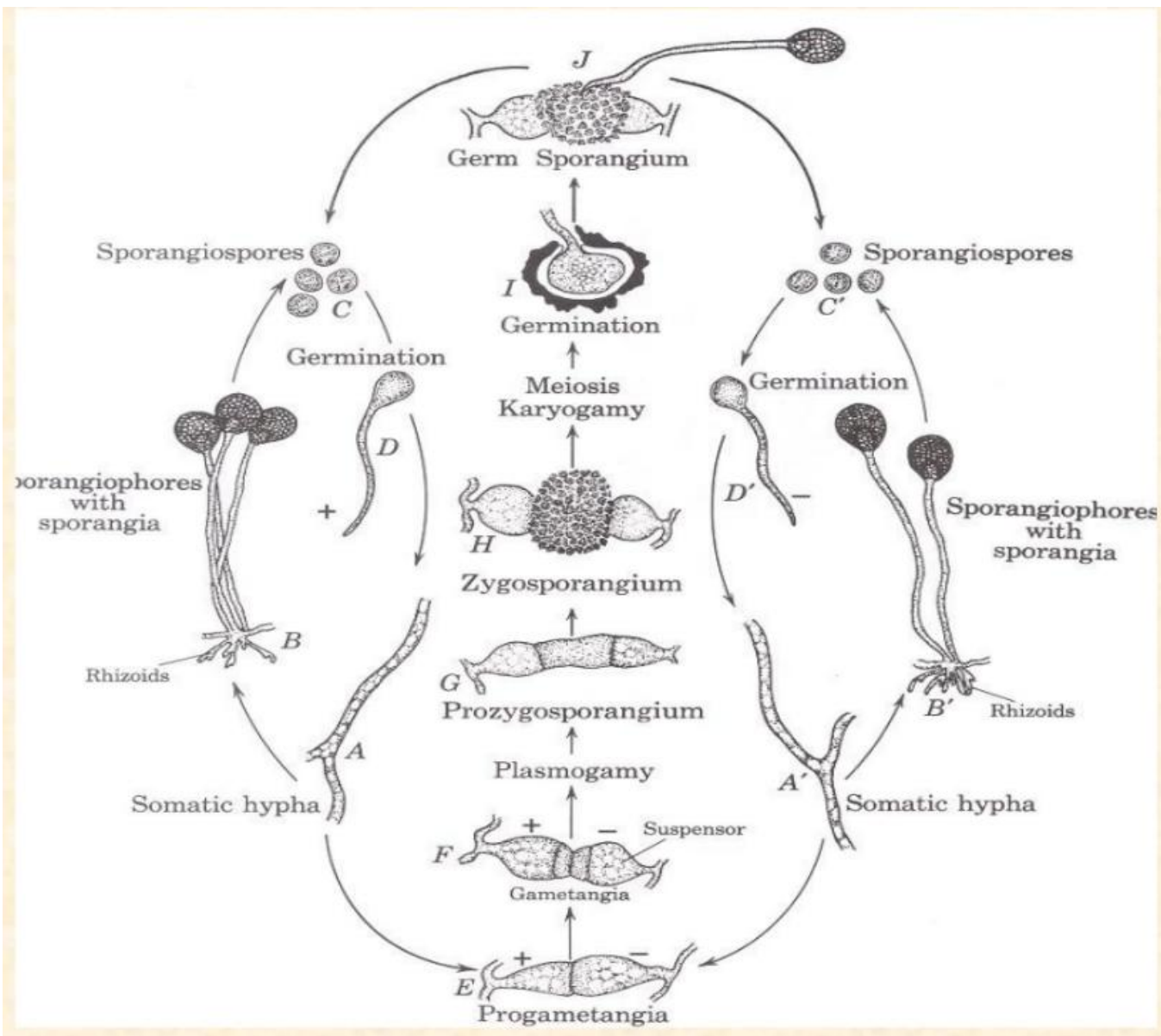
- Reproduce asexually by sporangiospores within a special sac called sporangium in most of the order of zygomycetes. conidia in the Entomophthorales and arthrospores in some Trichomycetes
- Sporangium types (4 types)
 - **True sporangium**
 - **Sporangioles** - much smaller than true sporangia. No columella produced and few spores (1-50)
 - **Monosporous sporangium** (one-spored sporangium)
 - **Merosporangium** - sac containing 10 -15 sporangiospores that occur in a linear sequence

Sexual Reproduction

- Gametangial copulation is a type of sexual reproduction
- Sexual spores are called zygospore contained within a zygosporangium
- Most of them are heterothallic.
 - **Heterothallism** : requiring a partner for sexual reproduction
 - **Homothallism** : able to reproduce sexually without a partner exhibited among species in this phylum
- They reproduce sexually when environmental conditions become unfavorable.

- To reproduce sexually, two opposing mating strains must fuse or conjugate, leading to karyogamy.
- The developing diploid zygosporangia have thick coats that protect them from other hazards. they remain dormant until environmental condition become favorable.
- When the zygosporangium germinates, it undergoes meiosis and produces haploid spores.
- Grown in to a new organism





Classification of Zygomycetes

- Traditional System
 - 3 Orders
 - Mucorales
 - Entomophthorales
 - Zoopagales
- Benjamin (1979)
 - 7 Orders
 - Mucorales
 - Demorgaritales
 - Kickxellales
 - Endogonales
 - Entomophthorales
 - Zoopagales
 - Harpellales

Class - Zygomycetes

- Generally divided into 7 orders
 - Mucorales – mainly saprotrophs, many to one sporangiospore/sporangium
 - Entomophthorales – mainly parasitic on arthropods, limited mycelium, one sporangiospore/sporangium
 - Glomales – obligate biotrophs, form arbuscular mycorrhizae

- Kickxellales – produced septate hyphae and modified one spored sporangia
- Dimargaritales – mycoparasites
- Zoopagales – parasites of small animals (amoeba, rotifers & nematodes) and fungi including the lethal lollipop, *Zoophagus*)
- Endogonales – saprotrophs

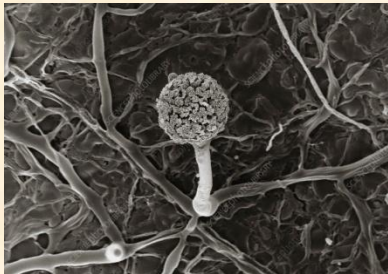
Order Mucorales

- Grow saprotrophically on decaying plant and animal remains in soils, dung, etc.
- Produce large numbers of asexual spores that are dispersed in the air
- Common contaminants in laboratory
- Some are important in spoiling food – common bread mold, storage diseases of fruits and vegetables
- Some infect humans and animals – opportunistic pathogens



Mucorales

- Typically form aseptate hyphae.
- Some species form rhizoids
- rhizoids: root-like hyphae that adhere reproductive structures to substrate



Mucor



Rhizopus

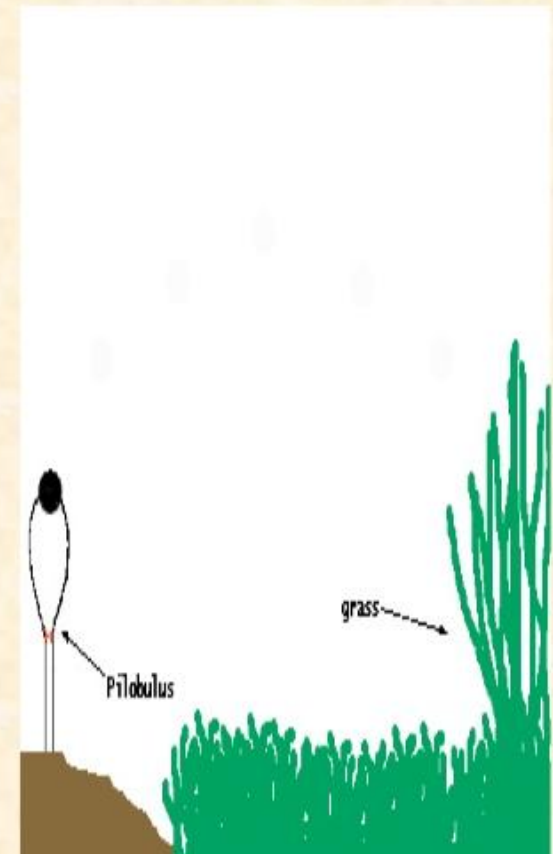
- Members of this group are the "weeds" of the fungal world
- Common genera include *Mucor*, *Absidia*, *Rhizopus*, and *Pilobolus*.
- Grow and invade quickly on easily digestible substrates, such as those containing starches, sugars, and hemicelluloses
- Can act as parasites and/or cause diseases in plants, animals and some insects and humans
- In humans, such diseases are opportunistic and occur in an immunocompromised person (e.g., uncontrolled diabetes, AIDS)

Classification of mucorales

Mucorales is divided into the following families:

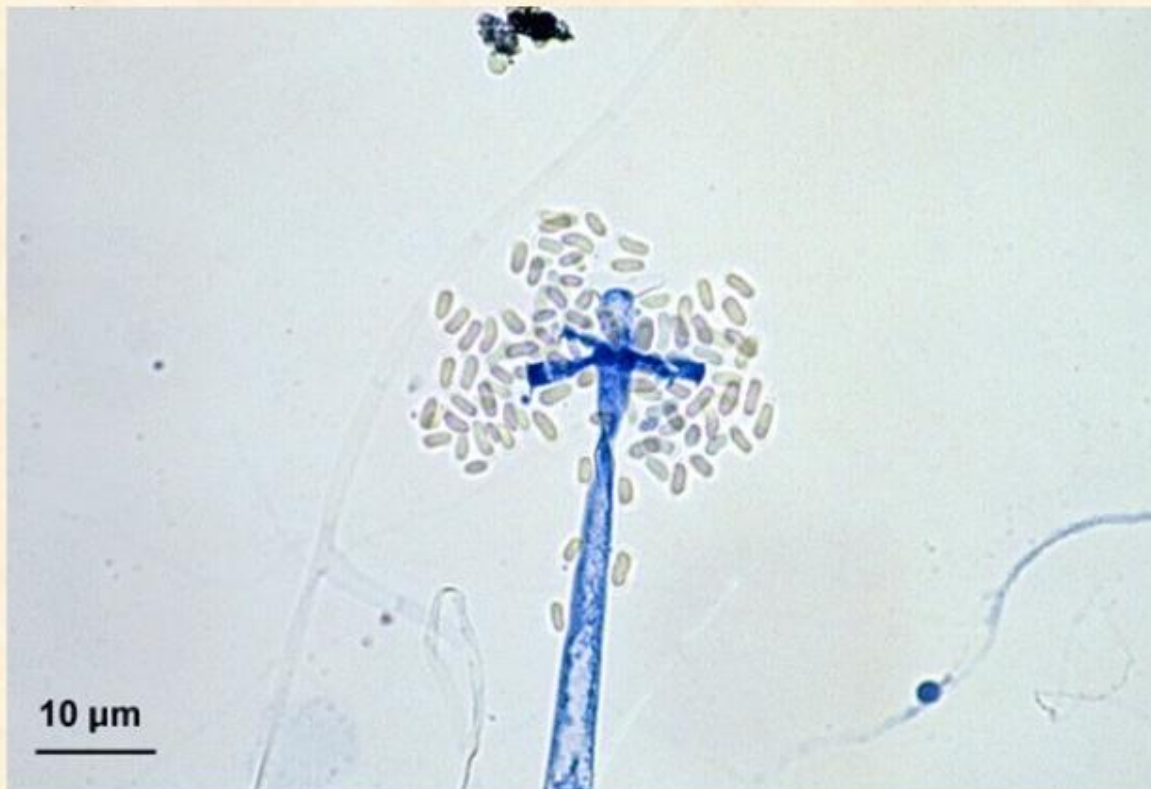
- 1- **Mucoraceae**: sporangia always present, columellae present, zygosporangium usually naked; wall of the sporangium homogenous, not cuticularized, usually diffluent, sporangia of one sort.
- 2- **Thamniaceae**: sporangia of two – sorts, primary and secondary. e.g. *Thamnidium* sp.

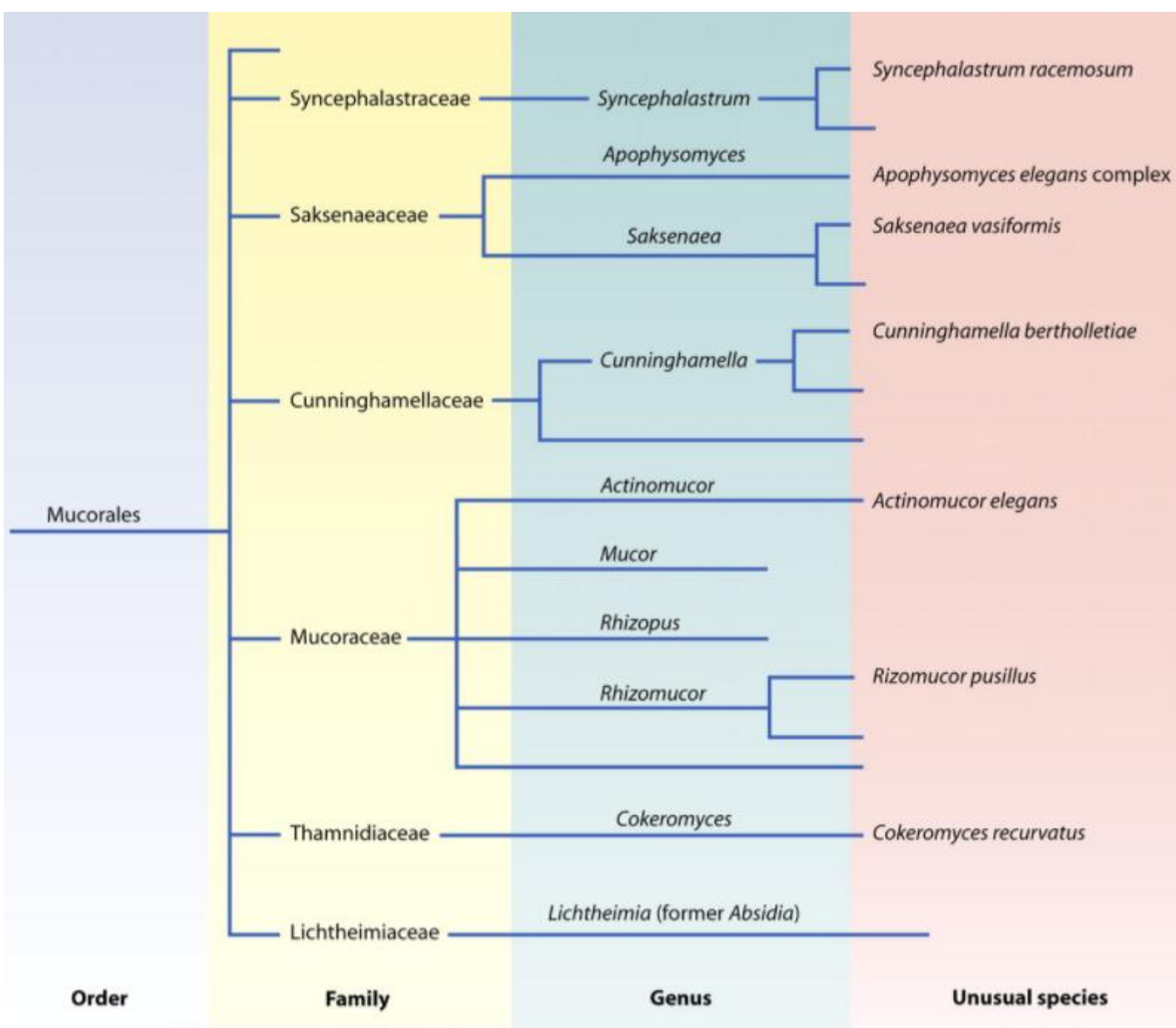
3- Pilobolaceae: wall cuticularized and persistent above, thin and diffluent below. E.g. *pilobolus* sp



4- Mortierellaceae: columella absent;
zygospore enveloped in a dense
hyphal covering.

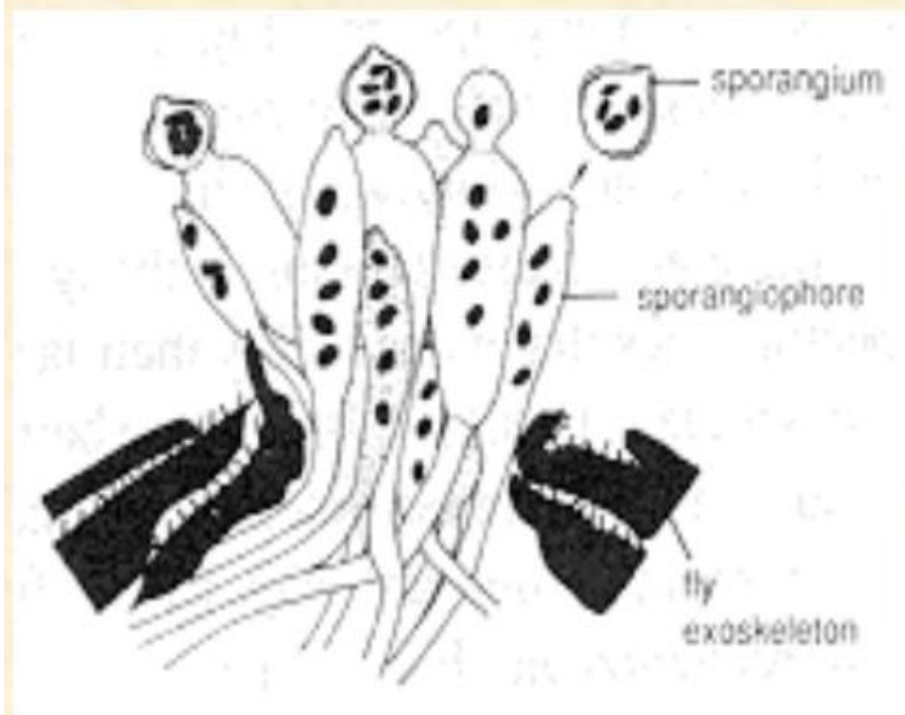
E.g. *mortierelle* sp.





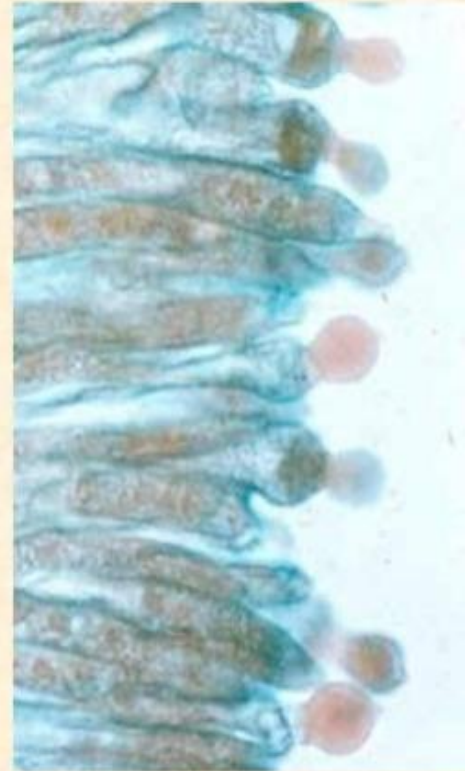
Entomophthorales

- Arthropod parasites.
- Asexual reproduction by one spored sporangiola (conidia)
- Mycelium exhibits limited growth in the body of the host, forms septa and fragments
- *Entomophthora* is a parasite of flies – seen when fly is stuck to window, white halo around it



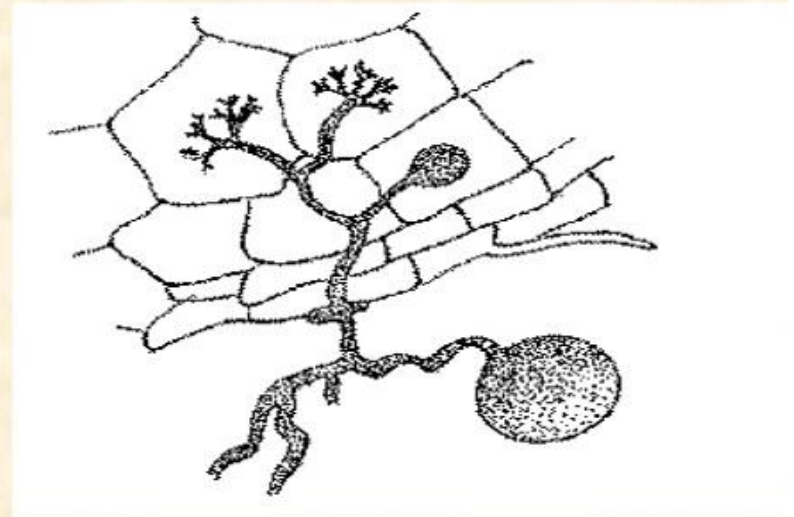
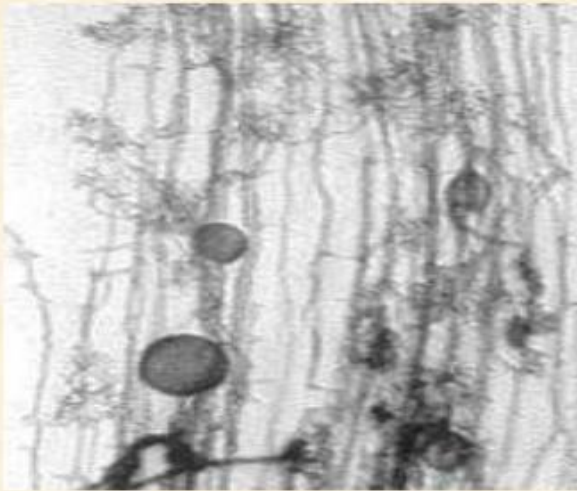
Entomophthorales

- Mycelium fills up body of fly, forms sporangiophores that extend out of segments of abdomen
- Sporangiospore builds up pressure, shoots off sporangium when there is air movement (another fly)
- If misses, can form another structure that shoots it off, up to 3 times
- Sexual reproduction not well understood, form resting spores that are similar to zygospores



Glomales

- Obligate biotrophs
- Biotrophic in the roots of higher plants, form arbuscular mycorrhizae
- It is referred to as “VAM fungi”
- Now placed in a separate phylum – the Glomeromycota



TRICHOMYCETES

- ❑ Second class in Zygomycota
- ❑ Small class, contains 5 orders
 1. Harpella (Order -Harpellales)
 2. Smittium (Order -Harpellales)
 3. Amoebidium (Order -Amoebidiales)
 4. Asellaria (Order -Asellariales)
 5. Enterobyrus (Order -Eccrinales)

Found in freshwater (mayfly, stonefly, midges)

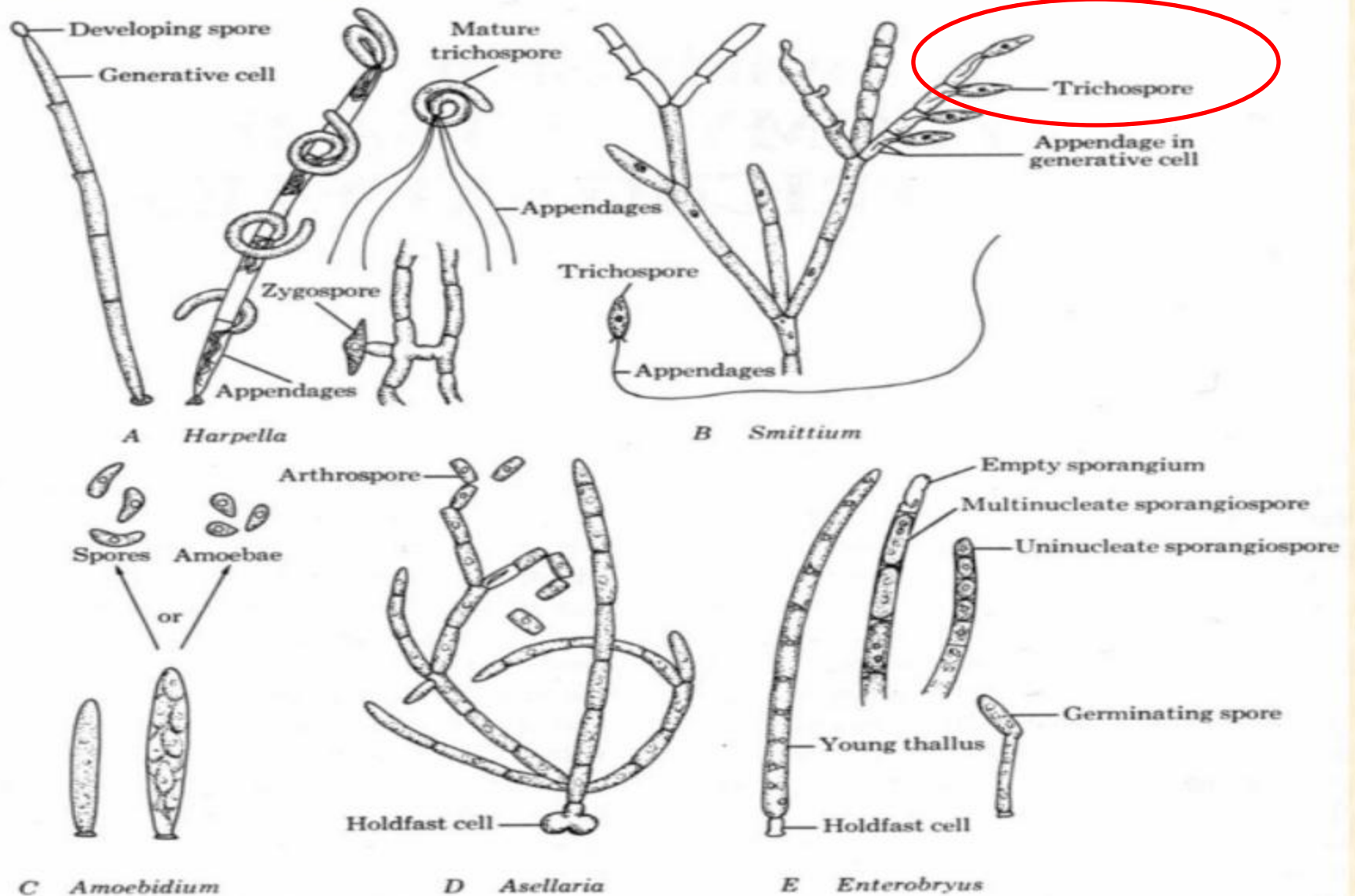


Figure 10-1. Representative genera of Trichomycetes. A. *Harpella* (Harpellales). B. *Smittium* (Harpellales). C. *Amoebidium* (Amoebidiales). D. *Asellaria* (Asellariales). E. *Enterobryus* (Eccrinales). Redrawn by R. W. Scheetz from Lichtwardt (1973a), by permission of Academic Press.

- ❑ Trichomycetes are obligately associated with an arthropod host; these fungi do not grow independently of their hosts. live on land or in fresh or marine waters.
- ❑ Arthropod hosts include insect larvae, crayfish, beetles and isopods; not found in predacious arthropods, only detritivores.
- ❑ Thallus are attached to host by a holdfast that penetrates the lining of the gut or exoskeleton only and does not penetrate living tissue.
- ❑ Thallus may be unbranched and aseptate or branched and septate
- ❑ These fungi are usually found in the gut but one genus *Amoebidium* (probably not really a trichomycete) is found on the outer surface of the host.

- ❑ Variety of asexual spore produced (generally 1 spore/sporangium)
- ❑ Sexual reproduction involves formation of zygospores (in one order Harpellales).
- ❑ Fusion of cells in thallus
- ❑ Formation of zygosporophore and then zygospore
- ❑ Zoospores in Harpellales, all of which are basically biconical in shape

- ❑ The asexual propagative structure is the “trichospore”-consist of an elongated sporangium that contains a single sporangiospore(Harpellales).
- ❑ Asexual reproduction in trichomycetes may involve amoeboid cells,arthrospore or sporangiospore.

- **Arbuscular mycorrhizae (AM):** a symbiotic association of members of the Glomales (Glomeromycota) with plant roots in which the penetrating hyphae produce finely branched haustorial branches (arbuscules), coils, or vesicles.
- **Centriole:** cylindrical cellular organelle involved in flagellum formation. Centrioles are approximately 0.3 μm long and 0.1 μm in diameter and are composed of nine sets of triplet microtubules.
- **Commensalistic:** a symbiosis in which neither organism is harmed.
- **Conidium (pl. conidia):** an asexual spore produced in the fungal phyla Ascomycota and Basidiomycota.
- **Ectomycorrhizae:** a mycorrhizal association in which the fungus produces a specialized sheath of hyphae on the surface of the root from which hyphae extend into the soil and into the outer cortical cells of the root.
- **Endocommensal:** an organism living as a commensal inside another organism (e.g. Harpellales).
- **Gametangium (pl. gametangia):** the specialized cell-type that becomes a fertile gamete producing cell during the sexual cycle.
- **Haustorium (pl. haustoria):** a morphologically differentiated hypha, especially one within a cell of the host, which aids in absorption of food.
- **Heterotrophic:** of organisms that utilize organic compounds as the primary source of energy.
- **Merosporangium (pl. merosporangia); Gr. *Meros* = portion + *sporangium*-** an elongated sporangiolum producing uniseriate spores

- **Monophyletic:** a clade or group of organisms that includes a most recent common ancestor and all the descendants from that ancestor.
- **Mutualism:** long term, intimate symbiotic association between organisms in which both partners benefit from each other.
- **Paraphyletic:** a group of organisms that includes some, but not all, of the descendants from a most recent common ancestor.
- **Polyphyly:** a group of organisms that does not include the most recent common ancestor of all the member organisms.
- **Progamentagium-** two copulating branches at the point of contact, later part separated by forming septum called suspensor
- **Saprophytic:** of organisms that utilize dead organic material as food.
- **Sporangiolum (pl. sporangiola):** a small sporangium containing one-to-few spores
- **Sporangium (pl. sporangia):** a sac-like structure, the contents of which are converted entirely into spores (sporangiospores).
- **Sporocladium (pl. Sporocladia ; Gr. *Spora* =seed, spore + *klados* =branch)**
- **Synapomorphy:** a shared, derived character; typically a morphological character that defines a clade.
- **Zygothore :** a special hyphae bearing progamentagia
- **Zygosporium (Gr. :*Zygos*=yoke+*spora* =seed, spore)** a resting spore produced by the fusion of two compatible gametangia.
- **Zygosporangium :** formed as a result of fusion of complete fusion of two equal or unequal gametangia.

Dube(1993), modify the classification of Ainsworth (1973) recognises following three orders under the class Zygomycetes

ORDER –MUCORALES

ORDER-ENTOMOPHTHORALES

ORDER-ZOOPAGALES

Class 5. Zygomycetes

Sexual reproduction is characterized by the production of a sexual resting spore called zygospore.

Zygomycetes are classified into three orders:

Mucorales, Entomophthorales and Zoopagales.

Key to the Orders of the Class- Zygomycetes

A. Chiefly saprobic, some weakly parasitic on plants, asexual reproduction by sporangia containing one to many aplanospores, sometimes by conidia-

Mucorales.

AA. Rarely parasitic on plants, sometimes saprobic; asexual reproduction by modified sporangia functioning as conidia, or by true conidia.

B. Modified sporangia functioning as conidia which are forcibly discharged Entomophthorales.

BB. Conidia not forcibly discharged-Zoopagales.

The **order Mucorales** is divided into a number of families. These are:

a. Mucoraceae-Sporangia large, many spored with well-developed columella; the sporangia are all alike.

b. Thamniaceae -In this family two types of reproductive structures are formed -columellate sporangia, and smaller non-columellate sporangia termed sporangiola, often borne in whorls at the tips of the branches.

c. Choaneophoraceae- In this family, as in the Thamniaceae, both sporangia and sporangiola occur. The sporangia are usually columellate and often hang downwards. Spores are striate epispores and bristle-like appendages.

d. Cunninghamellaceae- Primary sporangia are totally lacking. Sporangiola are borne on terminal or lateral vesicles and are finally reduced to conidia.

e. **Piptocephalidaceae**- Members are usually parasitic on other mucorales. Sporangia cylindrical with a linear row of spores.

f. **Pilobolaceae**- coprophilous.

g. **Kickxellaceae**- characterized by the formation of conidia on special structures called sporocladia.

h. **Mortierellaceae**- The sporangia are big and multispored but there is no columella.

i. **Endogoniaceae**- characterized by special structures Sclerotial bodies called sporocarps. Sporangia and zygospores are produced within these sclerotial bodies.

The **order Entomophthorales**, are chiefly parasitic on insects. A characteristic feature of this order is that the mycelium breaks into hyphal bodies from which conidiophores arise. Conidia are violently discharged. Sexual reproduction occurs when two hyphae enlargements acting as gametangia copulate. Waterhouse (1973) recognized a single family, **Entomophthoraceae**, with six genera. Entomophthora and Basidiobolus are the two important genera.

The **order zoopagales** are specially adopted for parasitizing small animals, such as amoebae, rhizopods and nematodes. They reproduce sexually by the formation of zygospores.

