University of Diyala
College of Science
Department of Biology

Mycology

Third Classes

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Lec. 1: Introduction to fungi

Definitions:

What is mycology? Mycology is the study of fungi and their multiple functions in nature.

What are fungi? Fungi are eukaryotic organisms that do not contain chlorophyll, but have cell walls, filamentous structures, and produce spores. These organisms grow as saprophytes and decompose dead organic matter also as pathogens of plants, animals and humans, and in food spoilage and as producers of secondary metabolites.

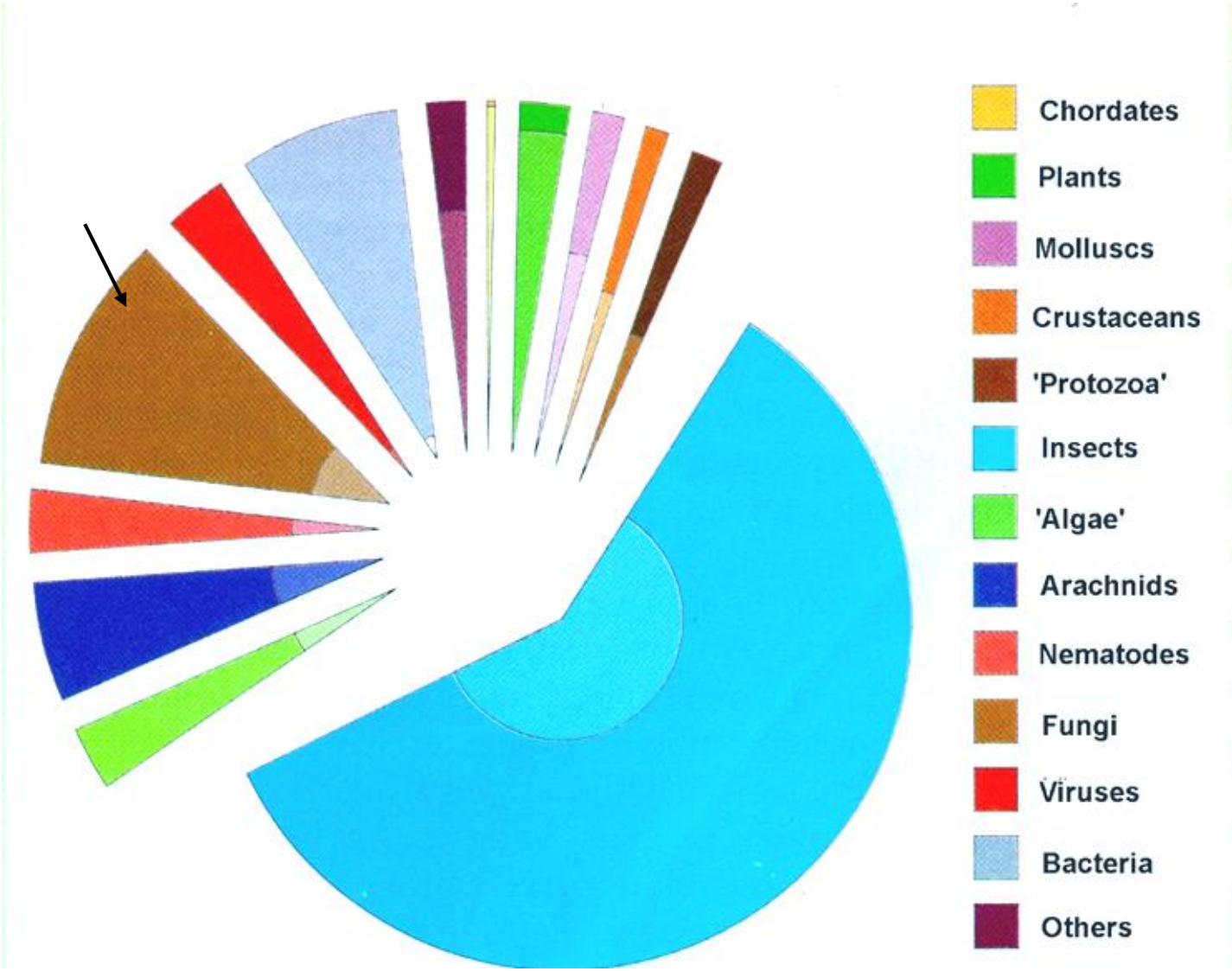
Why study fungi?

Fungi are among the most diverse organisms on Earth, and are considered only second to the Insects in species diversity. There are between 100,000 to 200,000 species depending on how they are classified. About 300 species are presently known to be pathogenic for human.

Mycology (from Greek term μύκης (mykes, mukos) "fungus" and logy "science"

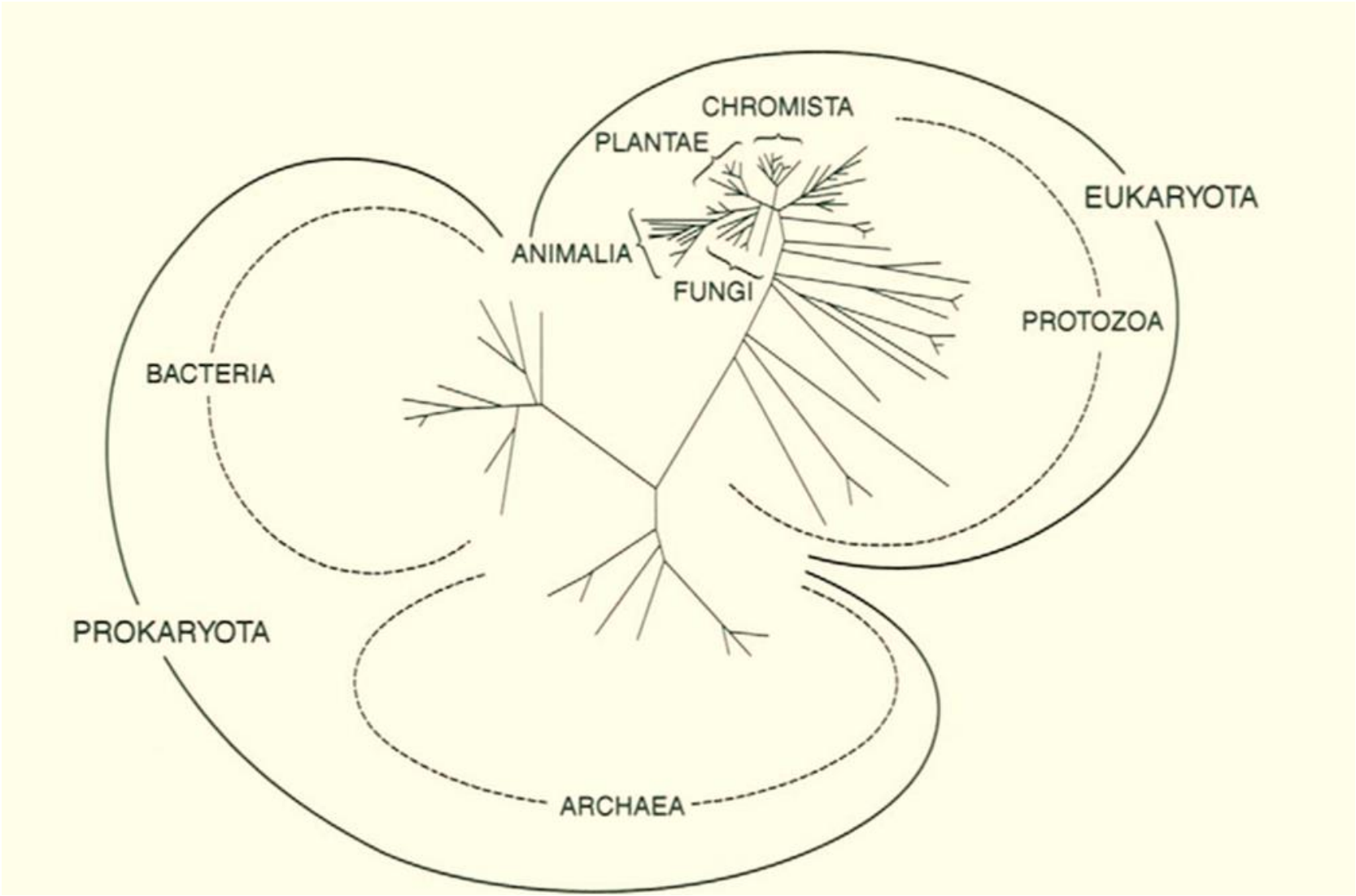
According to Whittaker 1969; there are five kingdoms of living things, and the fungi are in the Kingdom Mycetae.

Kingdom	Characteristic	Example
Monera	Prokaryote	Bacteria Actinomycetes
Protista	Eukaryote	protozoa
Mycetae	Eukaryocyte	fungi
Plantae	Eukaryocyte	Plants Moss
Animalae	Eukaryocyte	Arthropods Human Mammals Birds


Chordates
Plants
Molluscs
Crustaceans
'Protozoa'
Insects
'Algae'
Arachnids
Nematodes
Fungi
Viruses
Bacteria
Others

The taxonomy of the Kingdom Fungi is evolving and is controversial. Formerly based on gross and light microscopic morphology, studies of ultra-structure, biochemistry and molecular biology provide new evidence on which to base taxonomic positions.

According to Carlile et al., 2001; fungi are recognized as one of five Eucaryotic kingdoms including Animalae, Plantae, Chromista (straminipila) and Protozoa.



A phylogenetic tree showing the relationships between the two Prokaryote and five Eukaryote kingdoms (Carlile et al., 2001)

Characteristics of fungi:

1. Nutrition: Heterotrophic (lacking photosynthesis), feeding by absorption rather than Ingestion except slime molds.

2. Vegetative state: On or in the substratum, typically as a non-motile mycelium of

hyphae showing internal protoplasmic streaming. Motile reproductive states may

occur.

3. Cell wall: Typically present, usually based on β-glucans and chitin, rarely on glucans and cellulose (Oomycota).

4. Nuclear status: Eukaryotic, uni- or multinucleate, the thallus being homo- or heterokaryotic, haploid, dikaryotic or diploid, the latter usually of short duration (but exceptions are known from several taxonomic groups).

5. Life cycle: Simple or, more usually complex.

Characteristics of fungi:

6. Reproduction: The following reproductive events may occur: sexual (i.e. nuclear fusion and meiosis) and/or Parasexual (i.e. involving nuclear fusion followed by gradual de-diploidization) and/or asexual (i.e. purely mitotic nuclear division).

7. Propagules: These are typically microscopically small spores produced in high numbers. Motile spores are confined to certain groups.

8. Sporocarps: Microscopic or macroscopic and showing characteristic shapes but only limited tissue differentiation.

9. Habitat: Ubiquitous in terrestrial and freshwater habitats, less so in the marine environment.

10. Ecology: Important ecological roles as saprotrophs, mutualistic symbionts, parasites, or hyper parasites.

11. Distribution: Cosmopolitan, fungi are among the most diverse organisms on earth and are considered only second to the insects in species diversity.

Importance of Fungi:

1-Fungi are the agents responsible for much of the disintegration of organic matter and such they affect us directly by destroying food, fabrics, leather and other consumer goods manufactured from materials subject to fungal attack ex : Aspergillus niger.

2-Species of endophytic fungi can break down and digest like polyurethane and Polyethylene Terephthalate (PET) Ex: Pestalotiopsis microspora by its ability for both aerobic and anaerobic biodegradation of plastic. So, it is able to be used for digesting plastic from the landfills.

Importance of Fungi:

3-Fungi live in uranium remediation can transform uranium into less mobile and less toxic forms. For example, some fungi can convert uranium into a stable uranyl phosphate compound, which is less likely to enter the food chain in a process called radiosynthesis. Ex: Cladosporium sphaerospermum

4-Production of many organic acids of some drugs such as Ergotamine and cortisone and some vitamin preparations, and are responsible for manufacture of a number of antibiotics, notably Penicillin and Cephalosporin.

5-Some of them are good for human consumer such as Agaricus bisporus - edible mushroom, and single cell proteins.

Importance of Fungi:

6-As saprotrophs, particularly as decomposers, fungi are essential components of the carbon cycle and are among the few organisms that can break down lignin. Many fungi are particularly important in the decomposition of plant debris because of their ability to utilize cellulose such as Xylaria

7-Fungi form symbiotic relationships with a number of organisms: Lichens, Mycorrhizas and Endophytes

8-Use it as important research tools in cytologists, Geneticists, and biochemists such as Neurospora.

Importance of Fungi:

9-They are the basis of a number of industrial processes involving fermentation, such as making of bread example: Saccharomyces cervisae, wines, beers, and the fermentation of cacao, bean and the preparation of certain cheeses.

10-Over 70% of all plant diseases are caused by fungi. They cause majority of known plant disease such as Botrytis, and many diseases of animals and humans such as Fusarium.

11-Estimates suggest that around 6.5 million invasive fungal infections occur annually worldwide, with about 3.8 million deaths attributed to these infections. Among these, Candida and Aspergillus species are particularly prominent and in animals, fungi that can cause disease in animals, leading to various health issues.

History of mycology:

Mycology is a relatively new science that became systematic after the development of the microscope in the 16th century.

*Fungal spores were first observed by Giambattista della Porta in 1588,

*The seminal work in the development of mycology is considered to be the publication of Pier Antonio Micheli's 1729 work Nova plantarum genera. Micheli not only observed spores but also showed that, under the proper conditions, they could be induced into growing into the same species of fungi from which they originated.

*Extending the use of the binomial system of nomenclature introduced by Carl Linnaeus in Species plantarum.

History of mycology:

*Hendrik Persoon (1761–1836) established the first classification of mushrooms with such skill so as to be considered a founder of modern mycology.

*Elias Magnus Fries (1794–1878) further elaborated the classification of fungi, using spore color and various microscopic characteristics, methods still used by taxonomists today.

*Anton de Bary (1861) established modern mycology; he studied slime molds, rusts and late blight of potato diseases.

*Berfield (1875) studied smut disease and he used copper sulphate to control plant diseases caused by fungi.

* Robert Koch (1843-1910) the first one who discovered artificial medium to isolate and growth fungi.

The 20th century has seen a modernization of mycology.

Principles of living fungi

Living mode of fungi :

In nature fungi obtain their food either by infecting living organisms as parasites or by attacking dead organic matter as saprobes, many also form symbiotic relationships with higher plants as in mycorrhiza (Ectotrophic in glomeromycetes fungi and Endotrophic) and with blue green algae as in Lichens, example: foliose lichen.

Fungi that live on dead matter and incapable of infecting living organisms are called (obligate saprobes example Mucor); those capable of causing disease or of living on dead organic matter (facultative parasites (or) facultative saprobes: leaf curl fungi example Taphrina deformans); and those that can't live except on living protoplasm, (obligate parasites such as downy and powdery mildews). A living organisms infected by parasite is known as the host.

Cultivation of fungi :

Fungi which we can cultivated them on nutrient media are (saprobes and facultative parasites), and those fungi cultivate on different culture media such as:

1. Natural media: They are plant extract such as wheat extract, potato extract, carrot and others vegetable extract, also we can use fruit to prepare this kind of media.

2. Synthetic media: The main compositions of this medium are certain chemicals and some salts such as Czapek`s Dox Medium .

3. Semi synthetic media: they are mixed of two kinds of media (natural and synthetic) such as Potato Dextrose Media.

These three types of culture media are liquid so we can solidified them by adding (1.5 – 2.0 %) agar.

Optimum conditions suitable for fungal growth

1. Temperature: Fungi are living in wide range of temperature and according to it, fungi classified in to :

A. Mesophilic fungi: The range is (10–40ºC) and the optimum is (25 – 35ºC)

B. Psychrophilic fungi: The range is (5–25ºC) and the optimum is (15ºC)

C. Thermophilic fungi: The range is (20 – 50ºC) and the optimum is (40ºC)

2. Light: In some species the pigment melanin may play a role in extracting energy from ionizing radiation, such as gamma radiation. This form of "radiotrophic" growth has been described for only a few species, the effects on growth rates are small, and the underlying biophysical and biochemical processes are not well known

3-Aeration: All fungi prefer living in aerobic condition

4- Hydrogen Ion concentration: pH: (acidic).

Optimum conditions suitable for fungal growth

5. Humidity:

A) Some fungi are water mold.

B) Some fungi need some water for growth.

C) Some fungi are capable to growth in near-dry condition.

What are the important elements for fungal growth?

1. Carbon sources: (carbohydrates) such as mono sugar (glucose and fructose) or di sugar such as sucrose and maltose and multi sugars such as starch.

2. Nitrogen sources:

A. Organic source: such as Amino acids and peptone.

B. In organic source: such as nitrate and ammonia.

The salts are added according to fungi requirements.

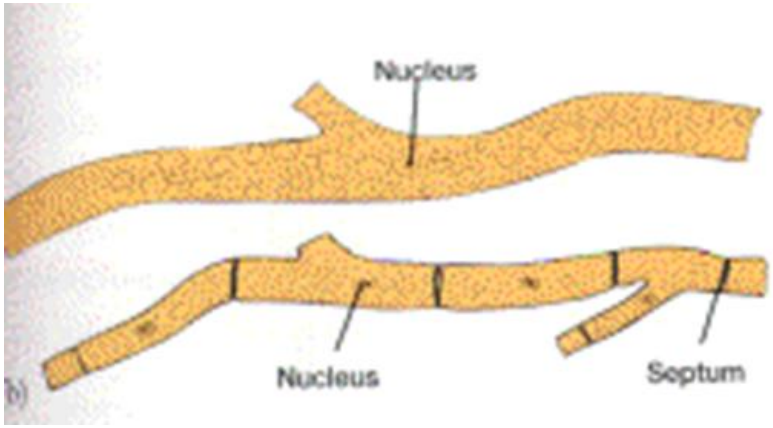
A. Macro elements: which add in large quantities such as Na, Mg, k, Zn.

B. Micro elements: which add in trace quantities.

Lec.2 : Morphology of fungi

When fungi are grown on suitable medium, produce long, branching filaments, those called -Mold- . Each filament is called hyphae. Hyphae are long, slender transparent, wall filled or lined with a large of protoplasm varying in thickness. Generally 3-10 microns in diameter. If hyphae have cross wall, the fungus is said to be

septate- if not -aseptate-(coenocytic hyphae).



Aseptate (or coenocytic) and septate hyphae

The presence or absence of these cross wall can be important in differentiating between certain classes. Hyphae may become divided into a chain of cells by the formation of septa (septum). As the hyphae continue to growth and branched a mat of growth called mycelium. The part of growth which project above the surface of substrate called aerial mycelium- which hold the spores-. The part which penetrate into the substrate and absorbs food is known vegetative mycelium.

The mycelium of parasitic fungi grows either by spreading between the cells or penetrating into them. The mycelium of fungus generally beings as a short-germ-tube emerging from a germinating spore. Fungal colony tend to be circular in out-line on solid medium, while the mycelium has a tendency to grow more or less equally in all directions from central point, and to develop colony- you can observe this by growing certain fungi on liquid and solid media.

A: Somatic phase (Soma)

Fungi can be classified into four groups according to their morphology:

1-Mold – Mould - : Which grow as branching filaments - hyphae - and produce the mycelium, while in slime molds the somatic phase grow as plasmodium .

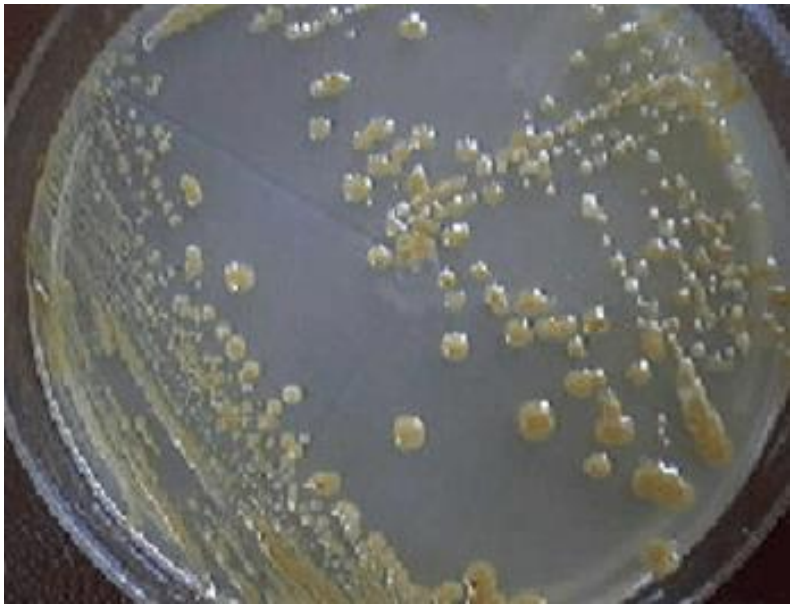
2-Yeast: are eukaryotic, single-celled microorganisms (Unicellular cells) which appears as round cells, do not form spores but reproduce by budding of the parent cells. This process of budding results in the production of two cells. Most are single celled structure with a thick cell wall such as Cryptococcus neoformans. Note: The word "yeast" comes from Old English gist, gyst, and from the Indo-European root yes-, meaning "boil", "foam", or "bubble.

3-Yeast-like fungi: Also reproduce by budding and grow as non branching filament-pseudohyphae- such as Candida albicans.

4-Dimorphic fungi: They grow as yeast form in tissue when incubated at 37ºC in vitro, but when incubated at 22ºC grow as mycelium form. This group of fungi have two phases of growth – Dimorphic such as :-Histoplasma capsulatum ; Blastomyces

dermatitidis

Molds growing on a solid medium



Yeast growing on a solid medium

Plasmodium (of slime mold)

Hyphal Aggregation and Modifications in Fungi

In majority of fungi, hyphae are simple. But, in some advanced fungi, hyphae may undergo certain modification in response to functional needs. Hyphal modifications are hyphal aggregations are required to do specific functions during the life cycle of fungi Important hyphal modifications in fungi are:

(1). Prosenchyma

(2). Pseudo parenchyma

(3). Sclerotia (Sclerotium)

(4). Rhizomorphs (Mycelial cords)

(5). Appressoria (Appressorium)

(6). Haustoria (Haustorium)

(7). Stroma (stromata)

(8). Snares (hyphal traps)

(9). Rhizoides

(10). Clampconnection

Hyphal Aggregation and Modifications in Fungi

1. Prosenchyma (Plectenchyma or Proso-plectenchyma)

It is formed by the loosely packed tissue like organization of fungi and is formed when the component hyphae is arranged more or less parallel to one another and the whole mass become a felt like structure. ex: ***Claviceps purpurea***

2. Pseudoparenchyma

hyphae are closely intertwined and forms a tissue like structure in cross section and the hyphae lose their individuality and they are not distinguishable from each other. ex: **higher fungi.**

Hyphal Aggregation and Modifications in Fungi

3. Rhizomorphs

Rhizomorphs (mycelial cords) are thick strands or root like aggregation of somatic hyphae in some fungi, gelatinous, dark brown and rope like coiled structures. the intertwining of hyphae is too tight so that hyphae loose its individuality. Individual hyphae are arranged in parallel way they are perennating structures with high penetration and survive for many years and they give rise new mycelia in the favourable conditions. Ex: ***Armillariella mellea.***

Hyphal Aggregation and Modifications in Fungi

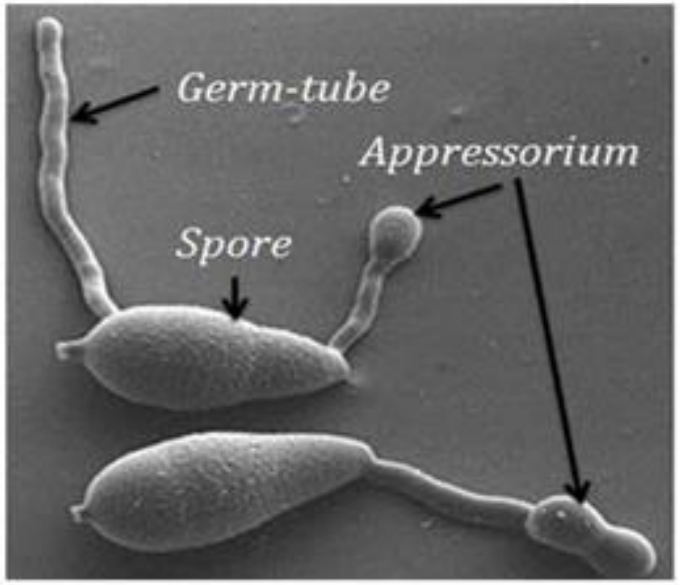
4. Sclerotia

Sclerotium is a compact dark brown with inner cells are colourless globose structure formed by the aggregation of hyphae in some fungi. The interwoven hyphae are very much compact so that the individuality of hyphae is lost and the mass become rounded and cushion like structures. Sclerotium survives for long periods, sometimes for many years and they represent the resting stage of some fungi. They accumulate food materials and helps in vegetative reproduction. Ex: ***viceps purpurea.***

Hyphal Aggregation and Modifications in Fungi

5. Appressorium

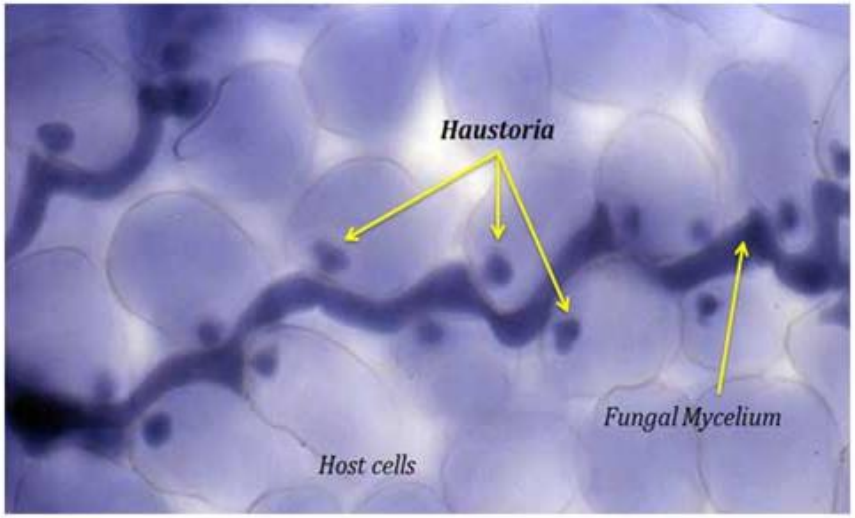
Appressorium is a terminal simple or lobed swollen structure of germ tubes on infecting hyphae, It adheres to the surface of host and help in the penetrating of hyphae. The infection peg is originated from the appressorium, ex***: Erysiphae***



Hyphal Aggregation and Modifications in Fungi

6. Haustorium

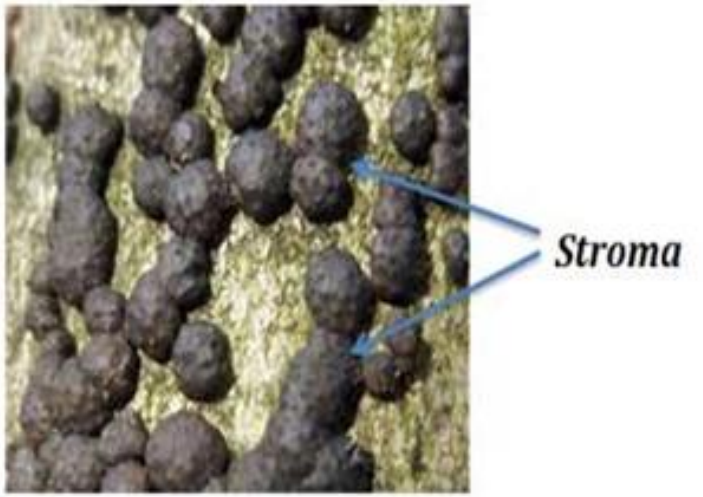
Is the intracellular absorbing knob like, elongated, finger like or branched structure of obligate parasites , it is the meant for absorbing food materials from the host tissue and They secrete some special enzymes which help in hydrolyzing proteins and carbohydrates of host, ex : ***Albugo***



Hyphal Aggregation and Modifications in Fungi

7. Stroma

Stroma are compact somatic structures, they are flat cushion like pseudoparenchymatous structures and the fructifications are usually found on or in them ex: ***Venturea inaequalis***



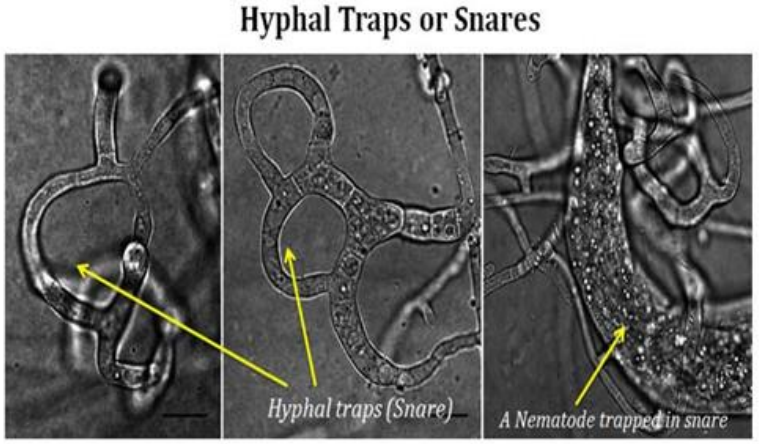
Hyphal Aggregation and Modifications in Fungi

8. Snares

Snares are trap like structures produced by predaceous fungi to capture small animals such nematodes and protozons. ex: ***Cordyceps milletaria***

9. Rhizoides

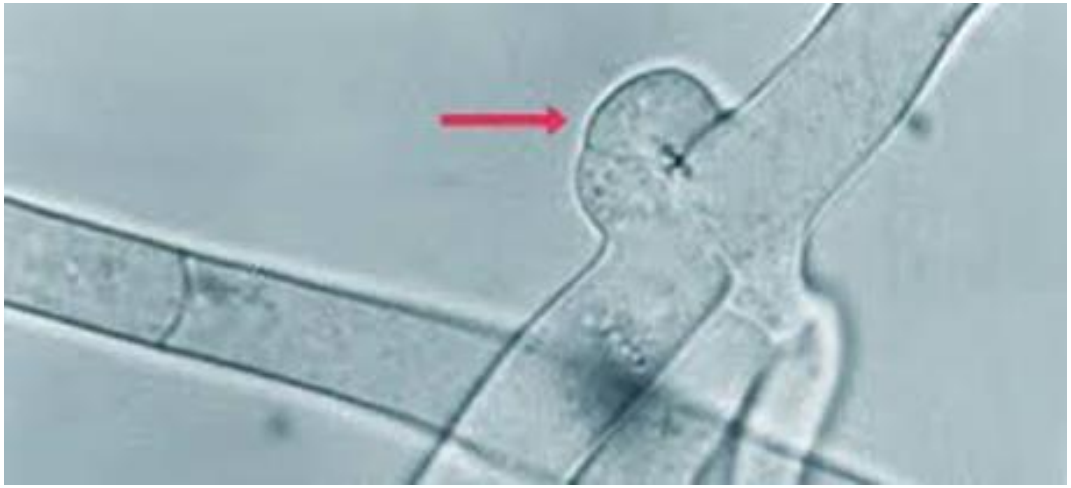
a short, thin filament, resembles a root that anchors the growing (vegetative) body to a substratum and that is capable of absorbing nutrients. It may serve either as a feeding organ (in ***Rhizopus***).



Hyphal Aggregation and Modifications in Fungi

10. Clamp connection:

A bridge like hyphal connection characteristics of the secondary mycelium of many **Basidiomycota;** involved in maintaining the dikaryotic condition.



Lec.3 : Morphology of fungi

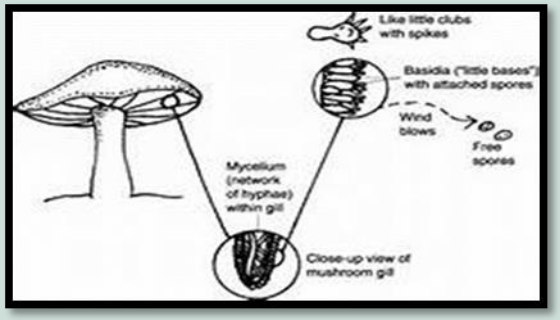
B: Sporocarp (Fruiting body) and spores

In fungi, the sporocarp (also known as fruit body or fruitbody) is a multicellular structure on which spore-producing structures, such as basidia or asci, are borne. The fruitbody is part of the sexual phase of a fungal life cycle, with the rest of the life cycle being characterized by vegetative mycelial growth and asexual spore production. The sporocarp of a Basidiomycota is known as a basidiocarp or basidium, while the fruitbody of an ascomycota is known as an ascocarp. Many shapes and morphologies are found in both basidiocarps and ascocarps: these features play an important role in the identification and taxonomy of fungi.

The sexual fruiting bodies are:

Basidium: In fungi a basidiocarp, basidium or basidioma (plural: basidiomata) is the sporocarp of a basidiomycota, the multicellular structure on which the spore-producing hymenium is borne. All basidiocarps serve as the structure on which the hymenium is produced. Basidia are found on the surface of the hymenium, and the basidia ultimately produce spores. In its simplest form, a basidiocarp consists of an undifferentiated fruiting structure with a hymenium on the surface; such a structure is characteristic of many simple jelly and club fungi. In more complex basidiocarps, there is differentiation into a stipe, a pileus, and/or various types of hymenophores.

Basidium



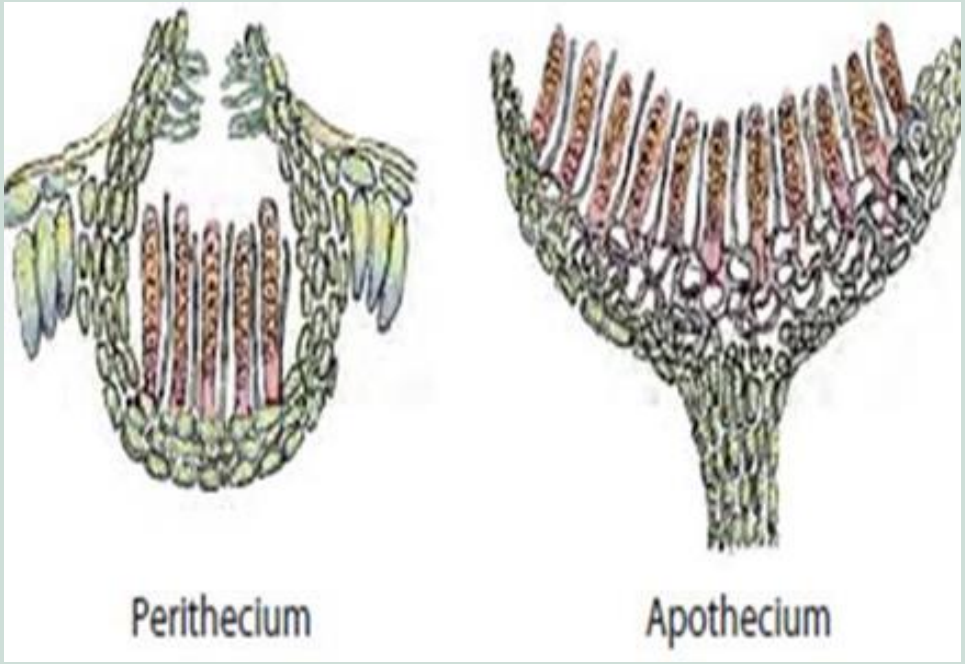
Apothecium: is a wide, open, saucer-shaped or cup-shaped fruit body. It is sessile and fleshy. The structure of the apothecium chiefly consists of three parts: hymenium (upper concave surface). EX: Tuber

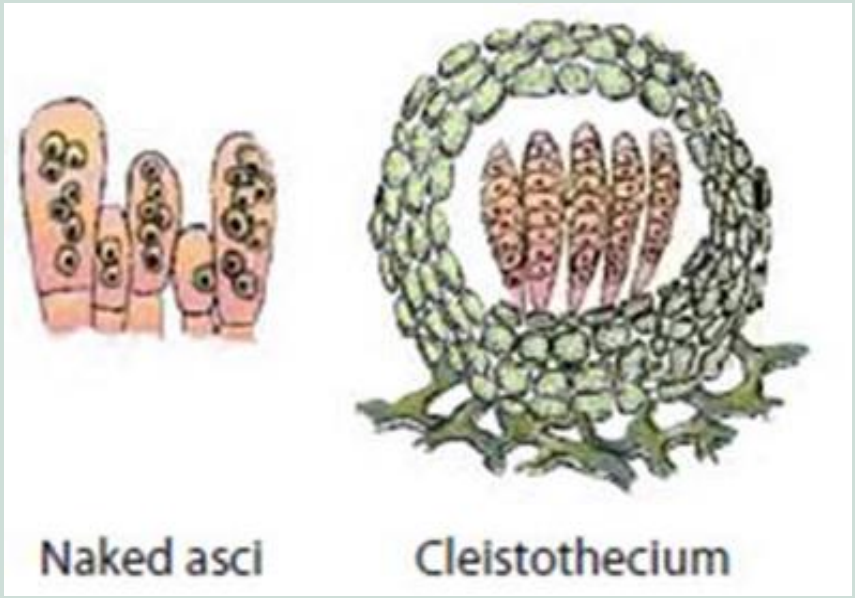
Cleistothecium: is a globose, completely closed fruit body with no special opening to the outside. The ascomatal wall is called peridium and typically consists of densely interwoven hyphae or pseudoparenchyma cells. Ex: Penicillium

Gymnothecium: similar to a cleistothecium, a gymnothecium is a completely enclosed structure containing globose or pear-shaped, deliquescent asci. However, unlike the cleistothecium, the peridial wall of a gymnothecium consists of a loosely woven "tuft" of hyphae, often ornamented with elaborate coils or spines. examples are the Gymnoascus, Talaromyces and the dermatophytes Arthroderma.

Perithecium: a flask shaped structure opening by a pore or ostiole (short papilla opening by a circular pore) through which the ascospores escape. The ostiolar canal may be lined by hair-like structures called periphyses. The unitunicate asci are usually cylindrical in shape, borne on a stipe (stalk), released from a pore, developed from the inner wall of the perithecium and arise from a basal plectenchyma-centrum. Examples are members of Sphaeriales and Hypocreales. Perithecia are also found in ***Xylaria*** and ***Nectria.***

Pseudothecium (ascostroma): This is similar to a perithecium, but the asci are not regularly organised into a hymenium and they are bitunicate, having a double wall that expands when it takes up water and shoots the enclosed spores out suddenly to disperse them. Example species are Apple scab (***Venturia inaequalis***) and the horse chestnut disease Guignardia aesculi





The sexual fruiting bodies In Ascomycota

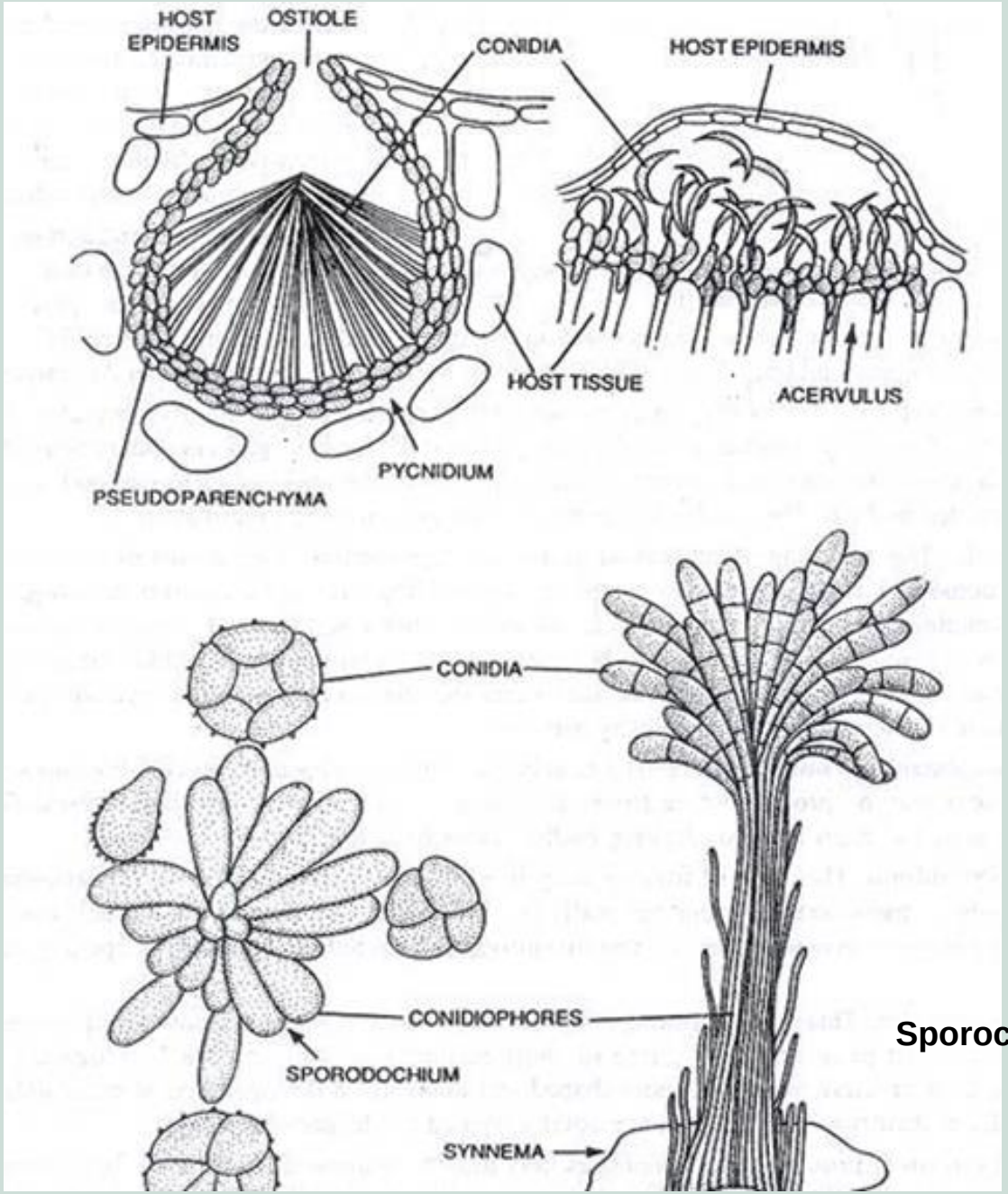
In imperfect fungi (Deutromycetes), the Sporocarps are

Pycnidium: a flask-shaped, globose or oval-shaped structure that looks like a cleistothecium or a perithecium but has a cavity filled with conidiophores and conidia instead of asci- and ascospores and often identified incorrectly as an ascocarp.

Acervulus: functionally a structure similar to a pycnidium, but structurally different by being formed by hyphae of plant pathogenic fungi in association with plant tissue and often appears to be a pustule formed just under plant epidermis, which erupts and exudes conidia. Sporodochium: large mass of short conidiophores and hyphae which arise together from the surface of a structure (multihyphal aggregate) called a stroma (stromata).

A synnema: derivation: Threads together) is a large, erect reproductive structure borne by some fungi, bearing compact conidiophores, which fuse together to form a strand resembling a stalk of wheat, with conidia at the end or on the edges, ex: ***Aspergillus caelatus***.

A Sporodochium: is a small, compact stroma (mass of hyphae) usually formed on host plants parasitised by mitosporic fungi of the form order Tubercullariales (sub - division Deuteromycota).This stroma bears the conidiophores on which



Sporocarps of imperfect fungi (Deutromycetes)

Sporophores and Spores

when the mycelium of a fungus reaches a certain stage of growth, it begins to produce spores either directly on the somatic hyphae or, more often, on special sporiferous (spore-producing) hyphae, which may be loosely arranged or grouped into intricate structures called fruiting bodies, or sporophores.

1- Asexual spores:- Which occurs by the process of mitosis. This is most common process by which spores are reproduced in fungi.

There are four types of medically important:

a- Blastospores: The type of spore develop by budding.

b- **Chlamydospores**: In some fungi the hyphal cell become specialized spore when the cell enlarged and develop thick walls

c- **Arthrospores:** Other hyphal cells break apart and produce arthrospores. Fragmentation may also happen naturally by the action of wind, soil movement or insects.

d- **Conidia:** A conidium is produced on a specialized structure called conidiophore. A spore which is produced directly on a hyphae or hyphal tips is called Aleuriospore, when a fungus produce two sizes of aleuriospores : The large one is called Macro- aleuriospore., The smaller one is called Micro- aleuriospore.

Sporophores and Spores

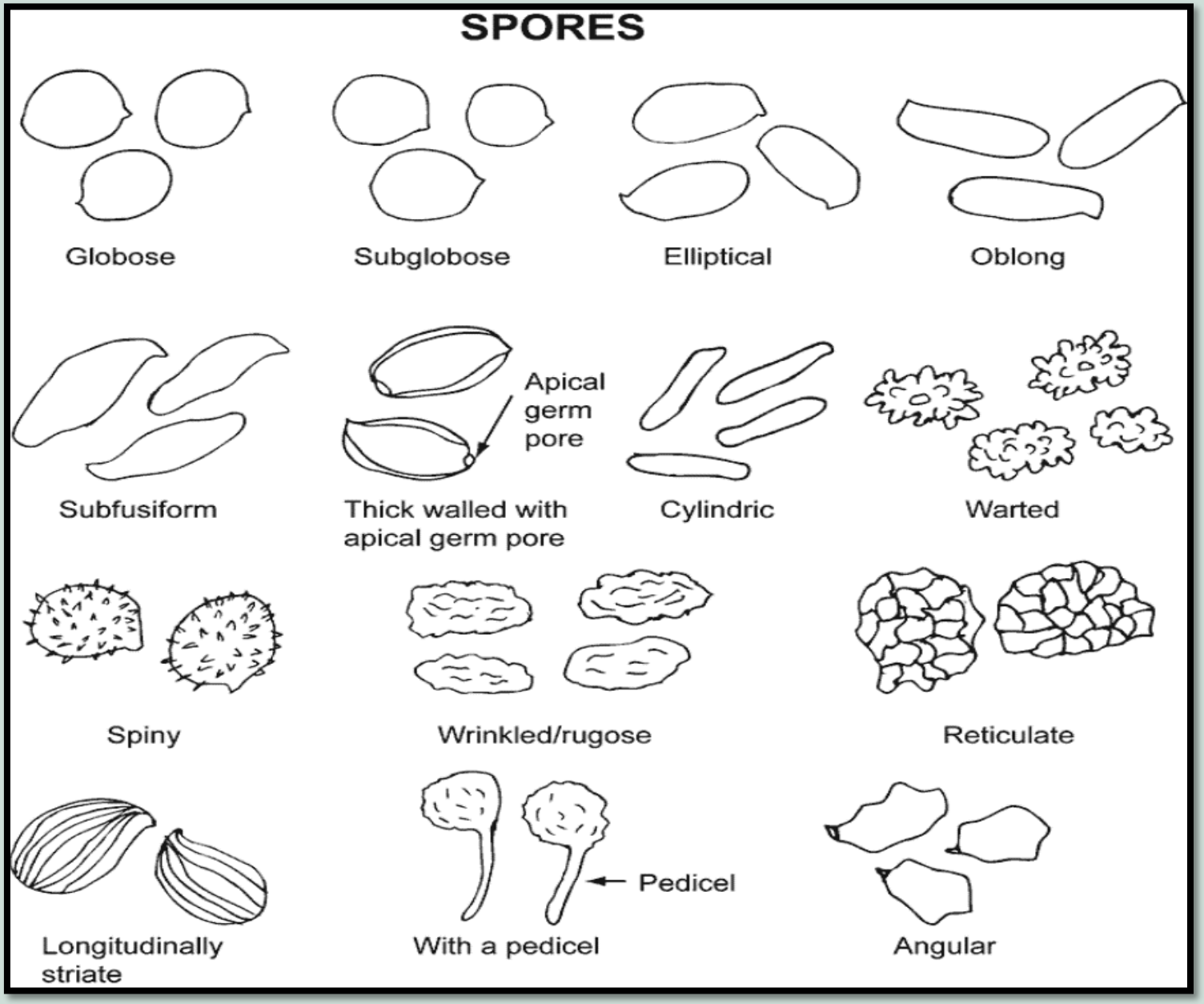
2- Sexual spores: Reproduce by meiosis

a- Ascospores: Usually 4-8 spores found in a cell called ascus- asci.

b- Basidiospores: Usually 4- spores found in the surface of cell called basidium.

c- Zygospores: Large-thick walled spore formed on hyphae.

d- Oospores: This type of spore formed inside cell called Oogonium.



Microscopic features of spores

Lec.4 : Fungal cell Structure and Function

Overview of the Hypha

- The hypha is a rigid tube containing cytoplasm. Growth occurs at the tips of hyphae. Behind the tip, the cell is aging.
- Many hyphae possess septa. Septa contain pores through which cytoplasm flows and Hyphae are actually interconnected compartments, not individual cells.
- Cell wall of hyphae are complex in structure and composition, thinner at apical (growing) end, Plasma membrane closely associated with inner portion of the wall.

Fungal Ultrastructure

- Zonation of organelles in hyphae
  - Hyphae show a defined polarity in the arrangement of organelles
  - Apical tip
- Extreme end - no organelles, but numerous membrane-bound vesicles of differing
  - electron densities (Golgi derived?), cell wall is dynamic and rather 'plastic' (site of synthesis)
  - Chitin synthase is present
  - Apical vesicle cluster (AVC) - Spitzenkörper
  - Actin microfilaments

Fungal Ultrastructure

- Apical tip (cont.)

○Short zone following apex - no organelles, but rich in mitochondria

○ Nuclei - distribution varies

- Sub-apical regions contain a diverse array of organelles, septa are present, and the cell walls are less dynamic, more rigid in structure

Yeast ultrastructure

 Typical cellular structures of a yeast include those found in other eukaryotes

 Reproduction by budding does impact the structure of the cell wall producing

O Bud scars on the mother cell

O Birth scars on the newly-formed daughter cell

Fungal Cell Wall Functions

O Structural barrier

O Determines pattern of cell growth and is partly dependent upon:

- Chemical composition

- Assembly of the wall components

O Environmental interface of the fungus

-Protects against osmotic lysis

-Acts as a molecular sieve

-Contains pigments for protection

O Binding site for enzymes

O Mediates interactions with other organisms

Cell wall components

o Two major types of components

- Structural polymers - polysaccharide fibrils that provide rigidity/integrity of the wall

- Matrix components - cross-link the fibrils as well as coat/embed them

o Main wall components differ between the major taxonomic groups of fungi

- Chitin - straight chain polymers of b-1,4-linked N-acetyl glucosamine residues;

- chitosan is de-acetylated chitin

- Glucan - polymers of b-1,3-linked glucose residues with short b-1,6-linked side chains

-Cellulose - b-1,4-linked glucans.

-- Matrix polymers: Glucouronic acids, Mannoproteins - mannose attached to protein.

Wall architecture

O Hyphae tend to have separate layers of wall components

O Layers actually grade into one another

O Components of one layer tend to be covalently bond to those of another

O Subapical regions are relatively thicker than apical region

O Yeasts have less complex wall architecture

Extrahyphal matrix - two types:

• Defined zone of polysaccharide - capsule

• Diffuse area outside hyphal wall

Septa

• Septa occur at generally regular intervals along a length of a hypha

•Perforations allow cytoplasm to flow from one cell to another

•When a cell is damaged, a Woronin body or coagulated cytoplasm serves a plug to prevent loss of cytoplasm

• Coenocytic fungi are more susceptible to cellular damage

Functions of septa

-Structural support of the hypha.

-Enables differentiation by dividing hypha into different cells that can undergo separate modes of development.

Types of septa

- **Simple**
- **Dolipore**

Fungal Nucleus

- Double membrane bound organelle ranging in size from 1-2 μm to 20-25 μm in diameter

- Unique features of fungal nucleus

- Membrane remains intact during mitosis

- No clear metaphase plate

- Various types of spindle-pole bodies (microtubule-organizing centers) depending upon species

- The nucleus divides by intracellular mitosis called "karyokinesis" where the nuclear envelope remains intact during nuclear division and the internal spindle develops.

Fungal Nucleus

- **Ploidy**

-Most fungi are haploid with the number of chromosomes ranging from 6 to 20

-Some fungi are naturally diploid

-Others alternate between haploid and diploid states

Possible reasons for haploidy:

-Multiple haploid nuclei can mask mutations

-Advantageous mutations can be selected

• Cytoplasm

-The cytoplasm contains organelles such as the Endoplasmic reticulum (ER), mitochondria, ribosome, Golgi bodies etc. and inclusion bodies (stored foods, pigments and secretory granules).

• **Plasma membrane (Plasmalemma)** bears occasional coiled ingrowths called "lomasomes" which lie below the cell wall

- It is phospholipid bilayer

-Involved in uptake of nutrients

-Anchorage for enzymes/proteins, e.g., chitin synthase, glucan synthase, etc.

-Signal transduction

-Differs in that it contains ergosterol

*Site of action for certain antifungal drugs

*Oomycota contain plant-like sterols

- **Secretory system**

•Consists of the following:

- Endoplasmic reticulum (ER)

-Golgi apparatus (or equivalent) - different in than those found in animals, plants, and the Oomycota in that they lack cisternae

- Membrane-bound vesicles

•Involved in fungal tip growth

•Commercially important in the production of extracellular products

Chitosomes- microvesicles that are capable of synthesizing chitin

•First noted from homogenized hyphae

•Able to self-assemble

•Controversial as to whether or not they are an integral part of the plasma membrane

•Function primarily within the region of the apical tip

Vacuoles

• Functions

-Storage

-Recycling of materials

-Contain proteolytic enzymes

-Regulation of cellular pH

-Possible role in cellular expansion/growth

- Reserve food (Storage granules) is glycogen and oil.

• Shape of vacuoles

-Round

-Tubular - may be involved in material transport

Endocytosis and vesicle trafficking - data is still unclear if fungi have an endosomal system: like that found in other types of eukaryotes

Fungal Cytoskeleton

•Cytoskeleton functions:

-Transport of organelles

-Cytoplasmic streaming

-Chromosome separation

•Three types of cytoskeletal filaments:

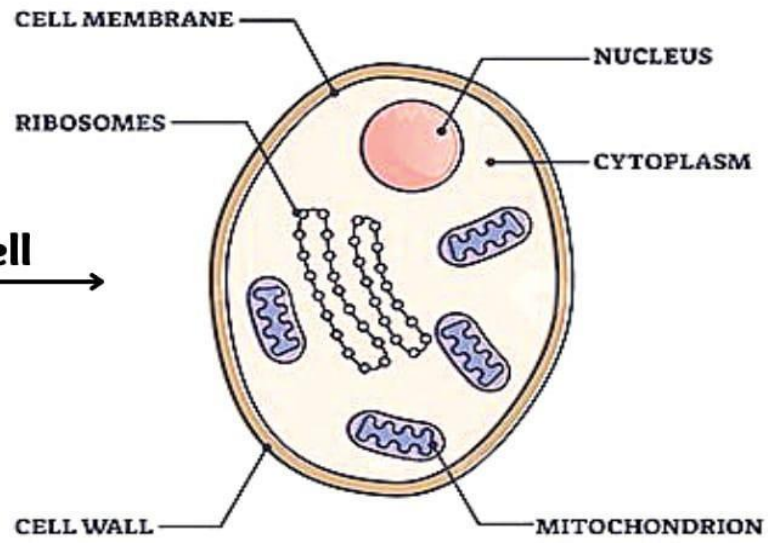
- Microtubules - composed of tubulin

-Microfilaments - composed of actin

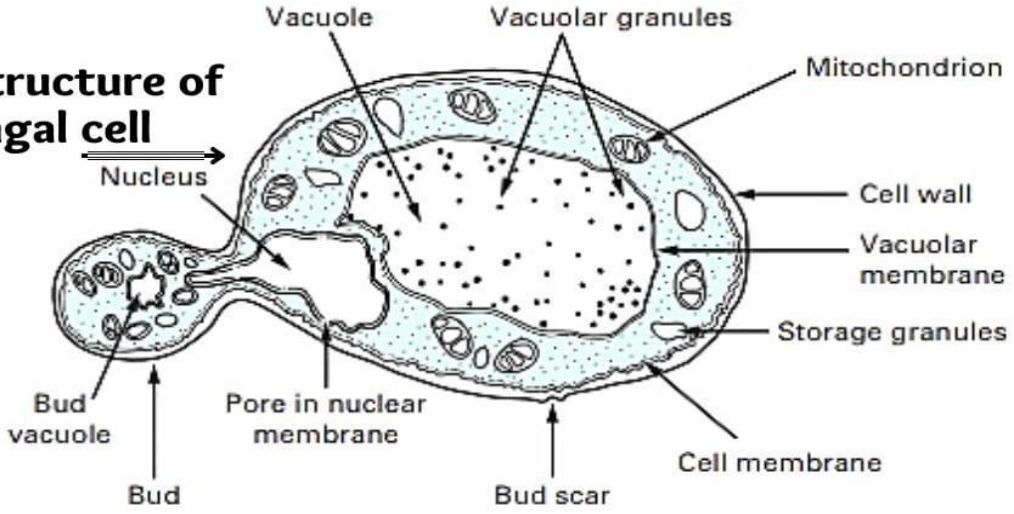
- Intermediate filaments - provide tensil strength

•All play a major role in hyphal tip growth

Basic Fungal Cell



Ultrastructure of Fungal cell



Lec.5 : Reproduction of fungi

Reproduction is the formation of new individuals having all the characteristics typical of the species. Two general types of reproduction are recognized: Sexual and asexual. Asexual reproduction sometimes called somatic or vegetative, does not involve the union of nuclei sex cells or sex organs. Sexual reproduction on the other hand, is characterized by union of two nuclei.

In the formation of reproductive organs, either sexual or asexual, the entire thallus may be converted into one or more reproductive structure, so that somatic and reproductive phases do not occur together in the same individual, fungi that follow this pattern are called (Holocarpic). In the maturity of fungi, however the reproductive organs arise from only a portion of the thallus, while the remainder continuous its normal somatic activities, the fungi in this category are called (Eucarpic).

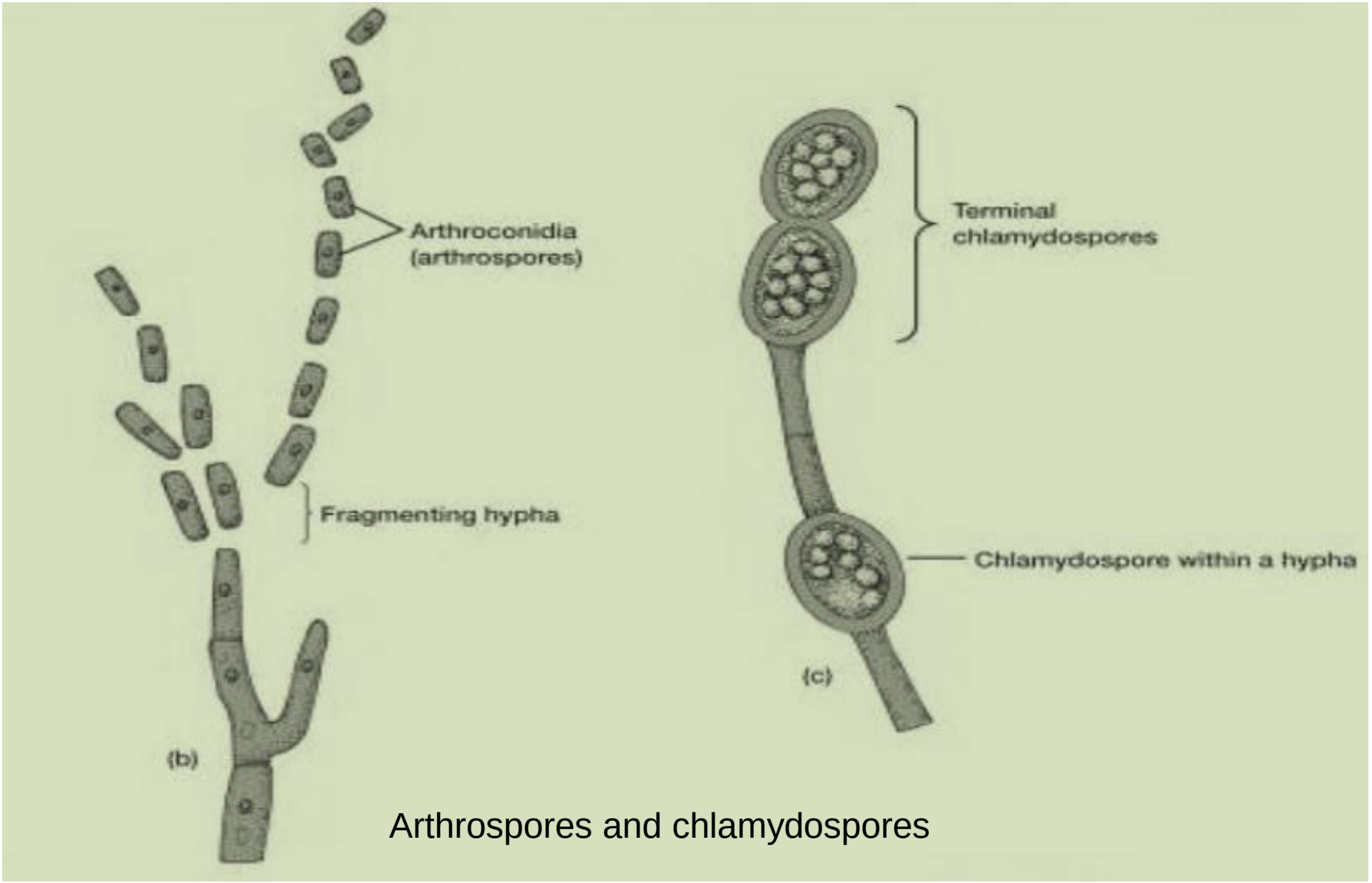
Asexual Reproduction: In general, asexual reproduction is more important for the propagation of the species because it results in the production of numerous individuals, and particularly since the asexual cycle is usually repeated several times during the season, whereas the sexual stage of many fungi is produced only once a year.

The asexual methods of reproduction commonly found in fungi may be summarized as follows

1) Fragmentation

Each fragment growing into a new individual. Some fungi employ fragmentation of hyphae as a normal means of propagation. The hyphae may break up into their component cells that behave as spore. These spores are known as arthrospores. If the cells become enveloped in a thick wall before the separate from each other or from other hyphal cell, they are often called chlamydospores. Fragmentation may also occur accidentally by the tearing off of parts of the mycelium through external forces. Such pits of mycelium under favorable conditions will start a new employ mycelia fragmentation to keep fungal cultures growing on artificial media by transferring a bit of mycelium to fresh media and thus starting a new colony.

Chlamydospores: Thick-walled, resistant spores formed by the direct differentiation of hyphae.



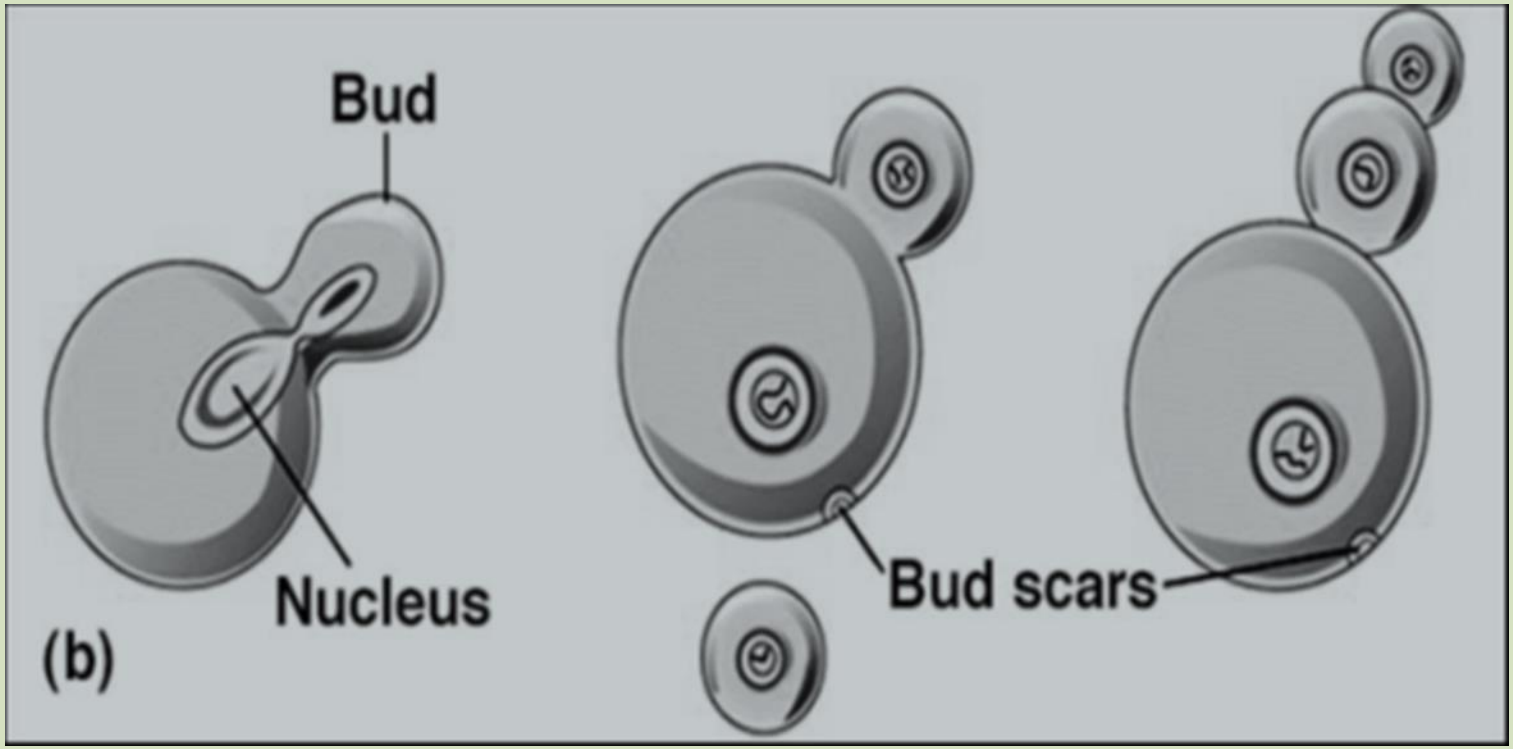
Arthrospores and chlamydospores

2) Simple fission of somatic cells into daughter cells

Fission, the simple splitting of a cell into two daughter cells by constriction and formation of a cell wall, is characteristic of a number of simple organisms including some yeast.

3) Budding of somatic cell or spores

Each bud producing a new individual. As the bud is formed, the nucleus of parent cell divides and one daughter nucleus migrates into the bud. The bud increases in size while still attached to the parent cell and eventually breaks off and form a new individual, example Saccharomyces (blastopore)

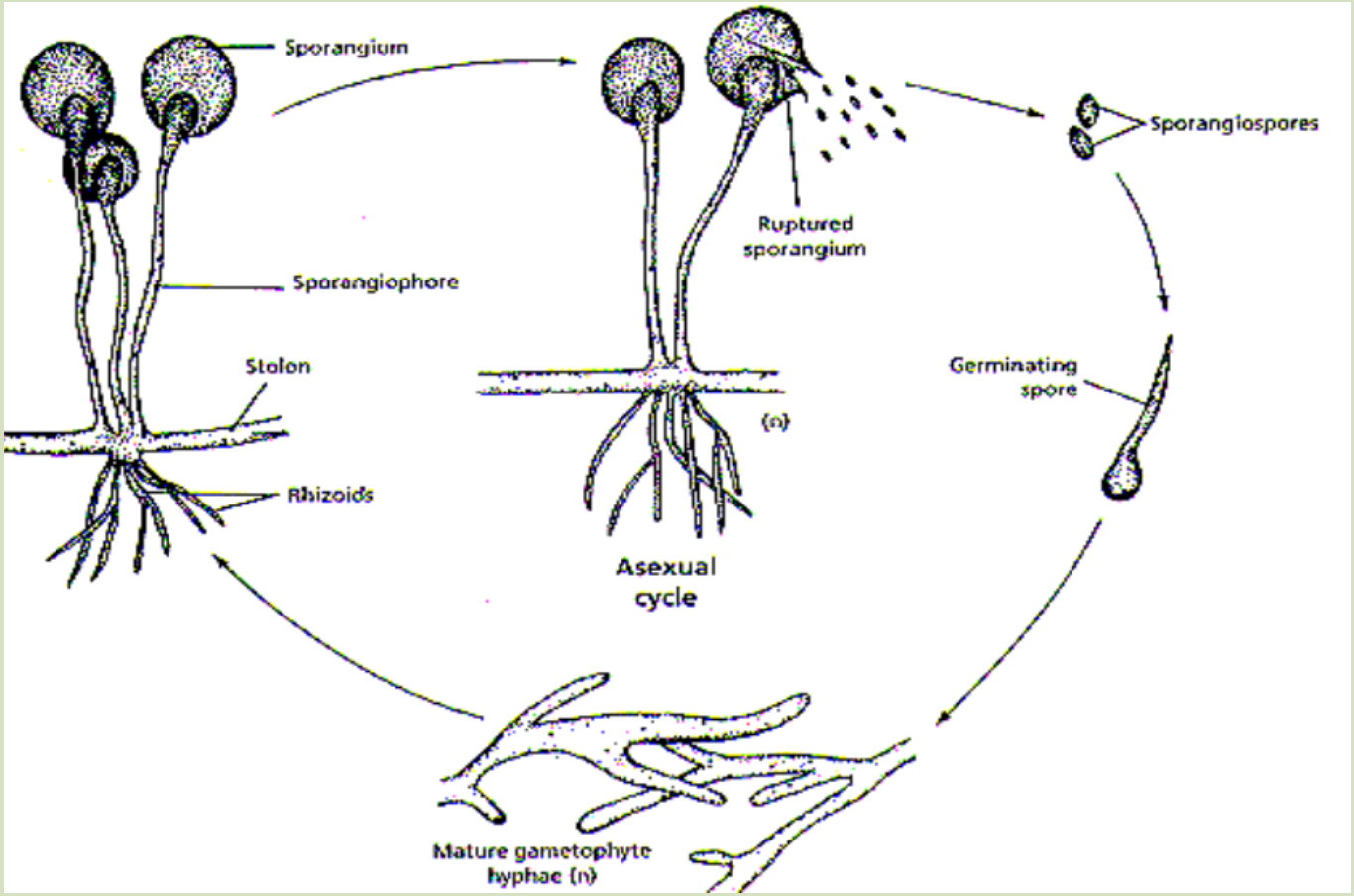


Reproduction by budding

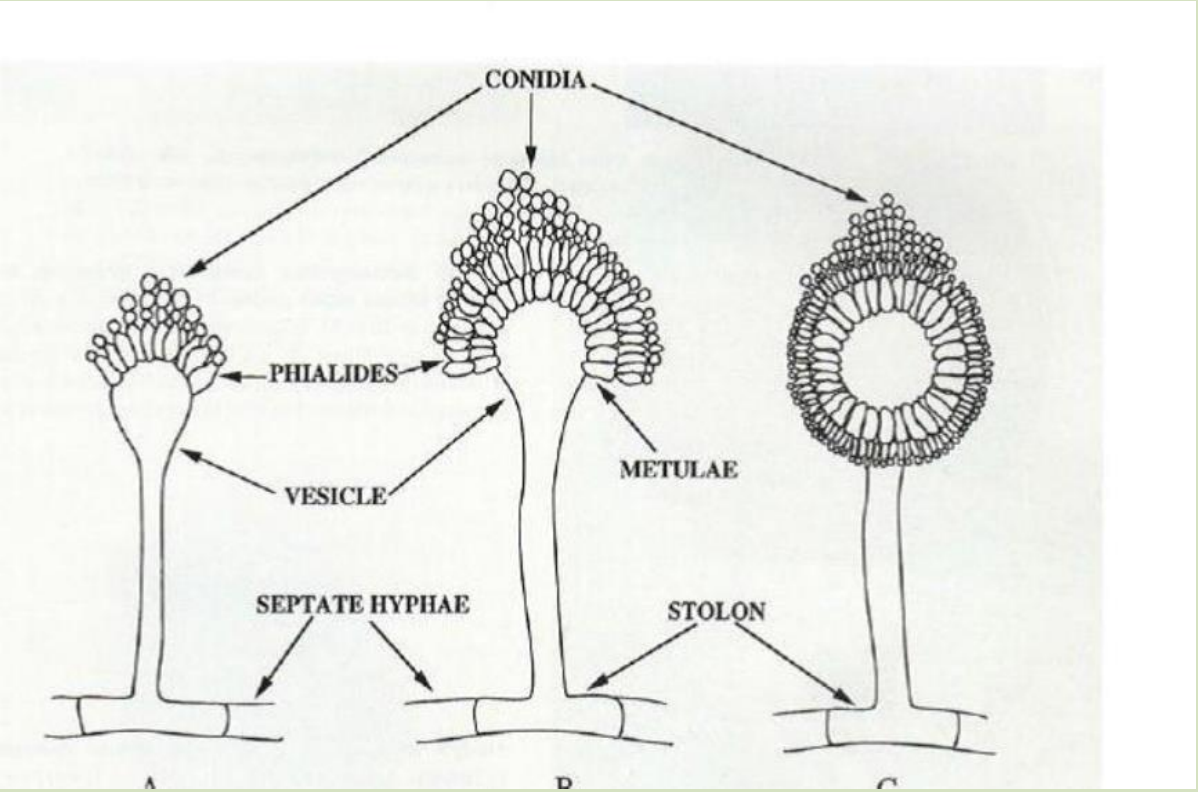
4) Spore formation (vegetative reproduction)

The most common method of asexual reproduction in fungi is by means of spores. Spores vary in color from hyaline through green, yellow, orange, red, brown to black; in size from minute to large; in shape from globose through oval, oblong, needle-shape to helical; in number of cell, from one to many; in the arrangement of cells; and in the way in which the spores them-self is borne . Some fungi produce only one type of spore, whereas other produces as many as four types. Fungal spores produced asexually are either borne in sporangia (sporangium) and then are called Sporangiospores as in ***Rhizopus*** and ***Mucor,*** or are produced at the tips or sides of hyphae in various ways and are then called conidia (conidium) as in ***Aspergillus*** spp.

Sporangiospores may be motile or non- motile. In simpler fungi the Sporangiospores are usually motile and are called zoospores, if non-motile are called aplanospores. Fungal zoospores are equipped with one or two flagella (flagellum). There are at least two types of flagella in the fungi: The whiplash and tinsel. The flagella in fungi are differing in position, types, and number.



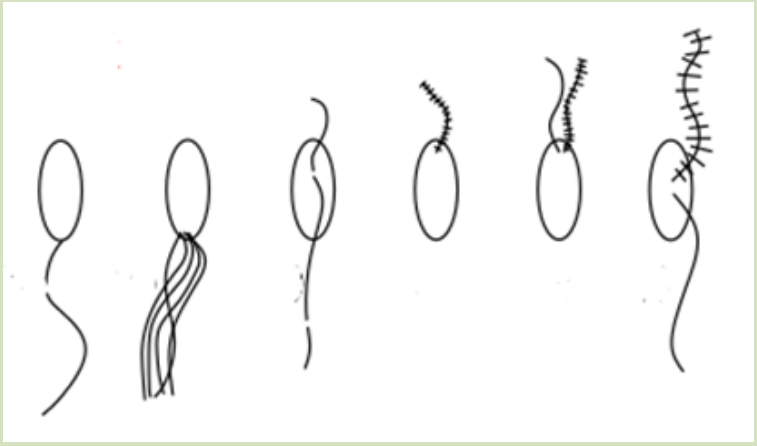
Sporangiospores formation in *Rhizopus*



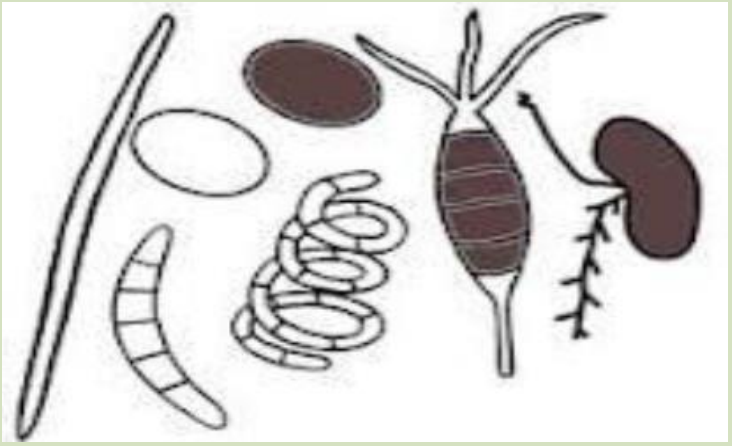
Conidia formation in *Aspergillus* spp.

Conidium: An asexual spore formed from hyphae by abstriction, budding, or septal division.

Conidiophore: A stalklike branch of the mycelium on which conidia develop either singly or in numbers.



Whiplash and tinsel flagella



Varity of spore shapes and size

Sexual reproduction: Sexual reproduction in fungi as in other living organisms involves the union of two compatible nuclei. The process of sexual reproduction typically consist of three distinct phases**:**

1. Plasmogamy: a union of two protoplasts brings the nuclei close together within the same cell.

2. Karyogamy: The fusion of the two nuclei brought together by plasmogamy**.**

3. Meiosis: The reduction of chromosomes number to the half.

Karyogamy follows plasmogamy almost immediately in many of the simpler fungi.

In the more complex fungi, however, those two processes are separated in time and space, with plasmogamy resulting in a binucleate cell containing one nucleus from each parent. Such pair of nuclei we call a (Dikaryon). The sex organs of fungi are called gametangia (gametangium), these may form differentiated sex cell called gametes or may contain instead one or more gamete nuclei. We use the terms (isogametangia and isogametes) to designated gametangia and gametes that are morphologically indistinguishable; we use (heterogametangia and heterogametes) to designate male and female gametangium and gamete that are morphologically different, in the later case , the male gametangium is called the(antheridium) and the female is called the (Oogonium).

We now list the various methods by which compatible nuclei are brought together in the process of plasmogamy. These methods are often referred to as methods of sexual reproduction. Fungi employ five general methods to bring compatible nuclei together for fusion. These methods are:

1. **Planogametic copulation:** Planogametic copulation involves the fusion of two naked motile gametes (planogametes) as in ***Allomyces.***

2. **Gametangial contact**: Here gametes are not released from gametangia, instead male and female gametangia come in close contact with help of fertilization tube. Then one or more male nuclei migrate in to the female gametangium. The gametangia never fuse or lose their identity during the sexual act. Male gametangium is called antheridium and female gametangium called Oogonium (Ascogonium in Ascomycota) Example: ***Albugo, Aspergillus, Pythium***

3. Gametangial copulation: The entire content of two compatible gametangia fuse each other; gametangia come in close contact, wall at the point of contact dissolves and their contents mix each other, then karyogamy is established .Example **zygomycota**

4. Spermatization: In some higher fungi sex organs are completely absent Here sexual process is accomplished by minute spore like spermatia and specialized (receptive) hyphae acting as male and female structures respectively spermatia are carried by air, water or insect to the receptive hyphae. Spermatia attached to the trichogyne of receptive hyphae and migrate in to the cytoplasm

5. Somatogamy: in this method, sex organs are not formed and two vegetative cells or vegetative hyphae take over the sexual function and fuse together advanced fungal groups such as ***Morchella, Peziza, Agaricus.***

Sexual compatibility: Those in which every thallus is sexually self-fertile and, can therefore, reproduce sexually by itself without the aid of anther thallus, these type of fungi we called (Homothallic fungi). Those in which every thallus is sexually self-sterile, and requires the aid of anther compatible thallus or a different mating type for sexual reproduction, these types of fungi called (Heterothallic fungi).

Lec. 6 : Taxonomy of Fungi

Taxonomy: is branch of biology concerned with identifying, naming and classifying organisms.

Classification: is the systematic arrangement of organisms into groups based on specific standards.

According to Whittaker 1969; there are five kingdoms of living things: (Monera, Protista, Mycetae, Plantae and Animalia), **and the fungi are in the Kingdom Mycetae**.

The taxonomy of the Kingdom Fungi is evolving and is controversial. Formerly based on gross and light microscopic morphology, studies of ultra-structure, biochemistry and molecular biology provide new evidence on which to base taxonomic positions

According to **Carlile *et al.*, 2001**; **fungi are recognized as one of five Eucaryotic kingdoms** including Animalia, Plantae, Chromista (straminipila) and Protozoa.

Taxonomy of Fungi

Taxonomy is the science of classification, i.e. the assigning of objects to defined categories. Classification has three main functions: it provides a framework of recognizable features by which an organism under examination can be identified; it is an attempt to group together organisms that are related to each other; and it assists in the retrieval of information about the identified organism in the form of a list or catalogue.

Traditional and modern taxonomic methods

- Early philosophers classified matter into three Kingdoms: Animal, Vegetable, and Mineral. **Fungi were placed in the Vegetable Kingdom** because of certain similarities to plants such as their lack of mobility, absorptive nutrition, and reproduction by spores.

- Early systems of classification were based on morphological (macroscopic) similarity. But the invention of the light microscope revealed that structures such as fruit bodies which looked alike could be anatomically distinct and reproduce in fundamentally different ways, leading them to be classified apart.

- Until the 1980s, the taxonomy of fungi was based mainly on light microscopic examination of typical morphological features, giving rise to classification schemes which are now known to be unnatural. Useful ultra-structural details, provided by transmission electron microscopy TEM, concern the appearance of mitochondria, properties of the septal pore, and details of the cell wall during spore formation or germination, or the arrangement of secretory vesicles in the apex of growing hyphae.

Traditional and modern taxonomic methods

- Biochemical methods have also made valuable contributions, especially in characterizing higher taxonomic levels. Examples include the chemical composition of the cell wall, alternative pathways of lysine biosynthesis, the occurrence of pigments and the types and amounts of sugars or polyols. Microscopic features are still important today for recognizing fungi and making an initial identification which can then, if necessary, be backed up by molecular methods. Indeed, the comparison of DNA sequences obtained from fungi is meaningful only if these fungi have previously been characterized and named by conventional methods. It is therefore just as necessary today as it ever was to teach mycology students the art of examining and identifying fungi.

Traditional and modern taxonomic methods

- Fungi are a specific and large kingdom and it is difficult to classify them. So we must collect a lot of information starting with cultural characters reaching to the spore. Generally, the characters used in fungal classification are:

1. Cell wall

Cell wall present: true fungi

Cell wall absent: slime molds

2. Chemical components of cell wall
3. Somatic phase
4. Reproduction
5. Structure formed by fungi
6. Spores: size, color, shape, number of cell and type of spores.

Process of Classification

Have three distinct steps:

1.Identification

2.The relationships among other fungi and living organisms

3.Nomenclature

The mycologists of fungal taxonomy:

1.Carl Linnaeus (1707-1778) the “Father of Taxonomy”

“ Minerals exist; plants exist and live; animals exist, live and sense.”

Plants without obvious sexual organs were classified in Class Cryptogamia (lichens, fungi, mosses, ferns), fungi are primitive plants under this classification of organisms.

2.Bessey (1950) classified the fungi into three classes- Schizomycetes, Myxomycetes and Eumycetes.

3.R. H. Whittaker's 1969 Classification: divided the living organisms in to five kingdoms according to cellular characterizations and he placed all eukaryotes, heterotrophs and have cell wall organisms in kingdom fungi.

4.The classification of fungi, as proposed by Ainsworth (1973), commonly followed: Kingdom: Mycota divided in to two divisions 1. Eumycota and Myxomycota

5.Alexopoulos et al.: in his book "Introductory Mycology" 1962 ,2nd ed.

He put the fungi in one division "myota" and divided it into two subdivision as follow:

1. Organisms of uncertain affinity Slime molds :

Order: Acrasiales some of slime molds

Order: Labyrinthulales

2.Division: Mycota

A. Sub division: Myxomycotina (slime molds)

B. Eumycotina (true fungi)

Classes: Chytridiomycetes, Hyphochytridiomycetes, Oomycetes, Plasmodiophoramycetes. Zygomycetes, Trichomycetes, Ascomycetes, Basidiomycetes and Deutromycetes.

6.**Alexopoulos et al.: in his book "Introductory Mycology" 1979, 3rd ed.**

He put the fungi in kingdom "Mycetae" and divided them in to three divisions as follow:

Kingdom: Mycetae

Division1: Gymnomycota

Division2: Mastigomycota

Division3: Amastigomycota

The classification system in fungi at this edition started with kingdom and end with species as follows:

Kingdom: Mycetae (Fungi)

Division: mycota

Subdivision: mycotina

Class: mycetes

Subclass: mycetidae

Series: mycetes

Order: ales

Family: aceae

Genus and Species: There is no special standard ends

7.Alexopoulos et al.: in his book "Introductory Mycology" 1996, 4th ed.

He put the fungi in three kingdoms and divided them in to phylum as follows:

Kingdom1: Protista

Kingdom2: Straminipila

Kingdom3: True Fungi

8. Kendrick in his book " fifth kingdom"(2002) put the fungi in three groups

as follows:

1: Pseudo Fungi: Included Slime Molds

2: Simple Fungi

3: True Fungi

9. Minnesote University classification in USA(2005): divided fungi in

To two large super kingdoms as follows:

1.Super kingdom Eumycota : included Kingdom Eumycota

(Phylum: Chytridiomycota, Zygomycota, Ascomycota, Basidiomycota and form group Deurtomycota).

2.Super kingdom Pseudomycota: included

a. kingdom Mycetozon (phylum: Myxomycota)

b. kingdom protozoa (phylum: Plasmodiophoromycota)

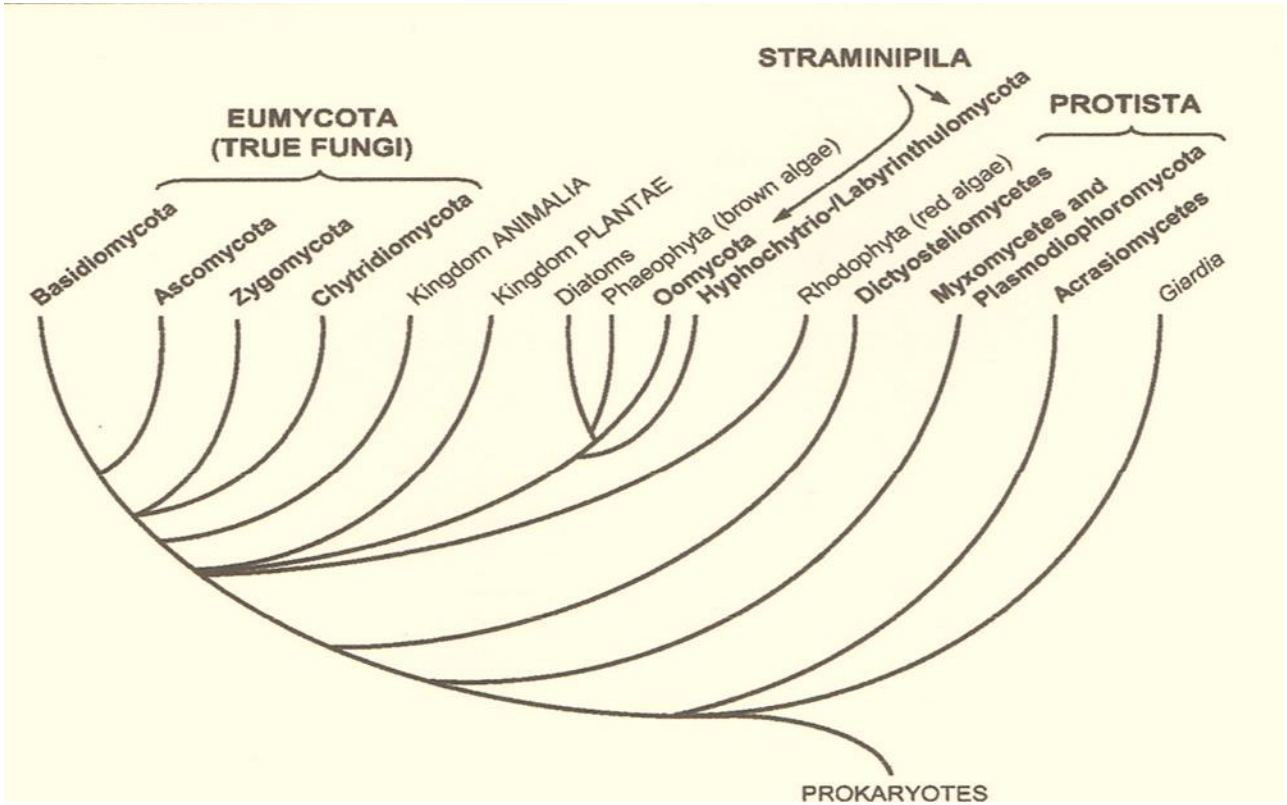
c. kingdom Straminipila or Chromista

(Phylum: Oomycota and phylum: Hyphochytriomycota)

10.The modern classification: <u>At least 7 kingdoms are now recognized</u>

Eubacteria, Archaebacteria, Animalia, Plantae, Eumycota, Straminipila (Chromista), Protoctista (Protozoa, Protista).

True fungi are recognized as kingdom: Fungi. While slime molds and lower fungi were distributed on two kingdoms: Chromista (Straminipila) and Protozoa.



The classification scheme adopted in book of Webster and Weber (Introduction to Fungi, 2007 3rd ed.), showing mainly those groups treated in some detail.

Kingdom1: Protozoa

Phylum1: Myxomycota

Phylum2: Plasmodiophoromycota

Kingdom2: Straminipila

Phylum1: Hyphochytriomycota

Phylum2: Labyrinthulomycota

Phylum3: Oomycota

Kingdom3: Fungi (Eumycota)

Phylum1: Chytridiomycota

Phylum2: Zygomycota

Phylum3: Basidiomycota

Phylum 4: Ascomycota

Phylum 5: Anamorphic fungi

Lec.7: Kingdom1: Protozoa

Kingdom1: Protozoa

Phylum1: Myxomycota: (Most of these individuals are saprophyte , and its nutrition phagotrophic)

Phylum2: Plasmodiophoromycota: (Most of these individuals are parasite on plants, and its nutrition by absorption)

Phylum1: Myxomycota

Slime moulds differ substantially from the Eumycota not only in phylogenetic terms, but also regarding their physiology and ecology. Their vegetative state is that of individual amoebae in the cellular slime moulds, or of a multinuclear (coenocytic) plasmodium in the plasmodial slime moulds. Motile stages bearing usually two anterior whiplash-type flagella may be present in the plasmodial slime moulds and in the Plasmodiophoromycota. Amoebae or plasmodia feed by the ingestion (phagocytosis) of bacteria, yeast cells or other amoebae. This is followed by intracellular digestion in vacuoles. The mode of nutrition in slime moulds is therefore fundamentally different from extracellular degradation and absorption as shown by Eumycota.

This phylum includes four classes: Dictyosteliomycetes, Protosteliomycetes and Myxomycetes are related to each other whereas the Acrasiomycetes have a different evolutionary origin. The general evolutionary background is, however, still rather diffuse in these lower eukaryotes.

Class 1: Myxomycetes

The term myxomycetes (Gr. myxa = slime). Link used the suffix mycetes because of the superficial similarity of the fructifications of slime moulds with the fruit bodies of certain true fungi, notably Gasteromycetes

The Myxomycetes (zool.: Myxogastrea) are by far the largest group of slime moulds, comprising some 800 species in 62 genera which are currently divided into five orders. One founders of mycology considered the slime molds animals and called them –Mycotozoa-; because the vegetative phase is like-plasmodium. They have a free-living, a cellular, multinucleate somatic plasmodium. Produce flagellated swarm cells inside a fructification-sporophore- that usually develops a –peridium- enclosing the spores.

Somatic phase (vegetative phase) of Myxomycetes is a free-living plasmodium

What is plasmodium?

It is a mass of protoplasm, de limited only by a thin plasma membrane and a gelatinous sheath. The plasmodium does not have a definite size or shape. The protoplast is fluid in some portions and gelatinous in others –veins- , the fluid portion of protoplast is usually in the form of an intricately branched network streaming through the gelatinous portion.

Reproductive phase of Myxomycetes is various

Types of reproductive organs (sporophores) in Myxomycetes:

1- Sporangium:

This sporangium either bearing on stalk or stalkless –sessile-, each sporangium has a peridium of its own. There may also a thin, cellophane-like base, the hypothallus, and there are spores and capilitium inside sporangium Ex: Physarum.

2- Plasmodiocarp:

Is similar to a stalk less sporangium. In the formation of plasmodiocarp, the protoplasm concentrates around some of the main veins of the plasmodium and secreting a membrane around itself Ex: Trichia.

3- Aethalia:

A group of sporangia that have not separated into individual units. In some aethalia the wall of the individual sporangia are quite evident, in other they are difficult to see Ex: Lycogala.

Classification of Class 1; Myxomycetes:

The class myxomycetes classified into five orders:

I. Spores born outside (no fruiting body):

Order: Ceratiomyxales……. Genus: *Ceratiomyxa*

This genus called exospores, there is no sporangium, we can found them in root, leave, as white columns, and under microscope we can see the spine bearing the spores.

II. Spores born inside sporangia (fruiting body: Endospores): classified into 4 orders according to: The color of sopres, Presences or absence of capilitium and Presence or absences of lime.

Order 1: Liceales ..... Genus: *Lycogala*

- Aethalium :Spores in mass are pallid or brightly colored.

- The capilitium and columella are lacking.

- Pseudocapilitium is often present.

Order 2: Trichiales ……. Genus: *Arcyria*

- Sporangium is large, stalked or sessile.

- Columella is lacking.

- Sporangium contains spores and capilitium.

Order 3: Stemonitales…… Genus: *Stemonitis*

- Spores are dark or black in color.

- Columella is presence.

- Lime is absences.

Order 4: Physarales ……. Genus: *Physarum*

- The same characteristics of order Stemonitales except lime is presence.

Life cycle of a typical Myxomycetes:

- The sequence of events in the life history of the endosporous species is usually as follows:

- The spores germinate under favorable conditions and release one to four rarely more myxamoebae or flagellate cells- swarm cells- that feed an bacteria.

- Myxamoebae divide repeatedly until a considerable population has been formed, and then copulate in pairs.

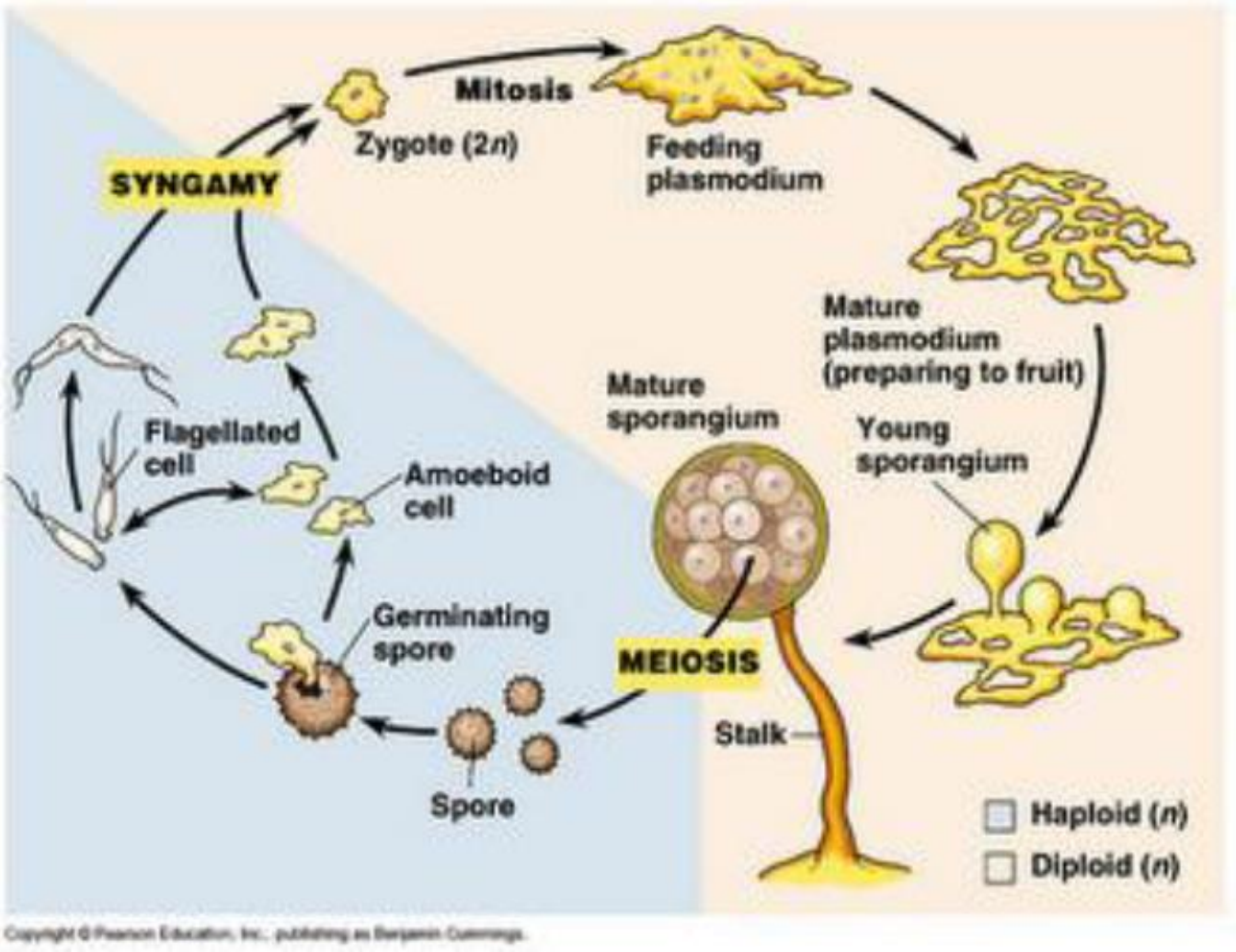
  - In the presence of free water, myxamoebae may develop flagella and converted into swarm cells.

  - If so, they eventually lose their flagella forming myxamoebae

- The two forms- myxamoebae and swarm cells are thus interconvertible, with the presence of water favoring the flagellate form and drier conditions inducing the amoeboid form.

Life cycle of a typical Myxomycetes:

- Swarm cells as such do not divide, wherease myxamoebae do so regularly.-Both stages are typically uninucleate and haploid-.
- After copulation, karyogamy occurs with formation of zygote.
- The resulting zygotes are either flagellate at first, later becoming amoeboid, or amoeboid from the start depending on the nature of the gametes.*Growth of the zygote is accompanied by a series of mitotic nuclear divisions resulting in a multinucleate plasmodium with diploid nuclei.
- The plasmodium grows by nuclear division and enlarge.
- At maturity , the plasmodium thickens and converts itself into one or more sporophore.
- Its protoplasm then cleaves into numerous spores.
- Meiosis now take place in young spores .



Life cycle of a typical Myxomycetes

Phylum2: Plasmodiophoromycota

General characteristics:

1-The somatic phase is a plasmodium that develops within the host cells (Endoparasite)

2- Produce two types of spores –zoospores and resting spores-.

3-When the resting spores are germinated give zoospores

The Plasmodiophoromycota are a group of obligate (i.e. biotrophic) parasites. The best known examples attack higher plants, causing economically significant diseases such as club root of brassicas (*Plasmodiophora brassicae*). Other species infect roots and shoots of non-cultivated plants, especially aquatic plants, the phylum currently comprises 12 genera and 51 species. Genera are separated from each other largely by the arrangement of resting spores in the host cell. This feature has also been used for naming most genera.

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Class: Plasmodiophoramycetes

Order: Plasmodiophorales

Family: Plasmodiophoraceae

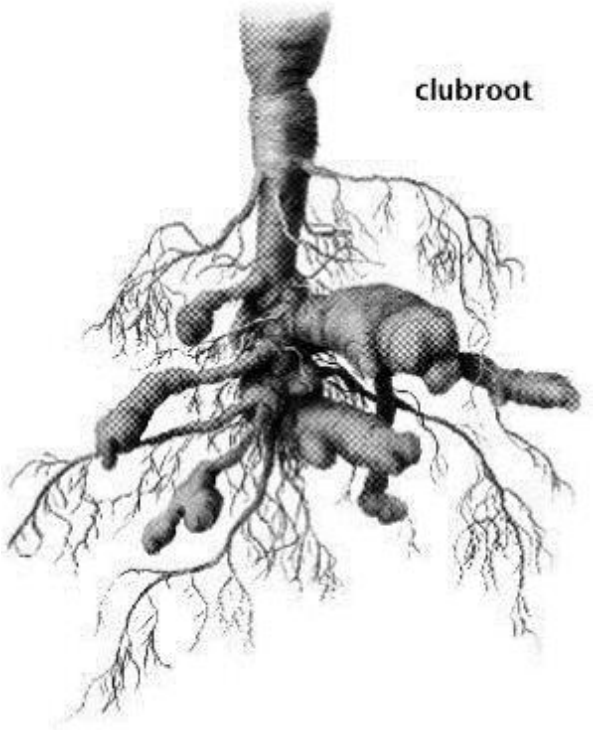
Exam. : *Plasmodiophora brassicae* (Causes: Club-root disease in Brassicaceae)

Life cycle of *Plasmodiophora brassicae*

The life cycle is initiated when resting spores-cysts- germinate. Each giving rise to a zoospore capable of infecting the host plant. Zoospore attaches to the wall of a root hair and then penetration occur and converted to the myxoamoeba. Following penetration of a host small sporangiogenous plasmodia appear within the host cells. It is possible that, these plasmodia develop directly from individual amoebae. Plasmodia increase in size with some fusion with one anthers, nuclear division during this phase is happened, and after the plasmodium reaches a certain size, it cleaves into segments that develop into zoosporangia. Zoospores are then formed and released from the zoosporangium either directly into host tissue or to the outside of the host. – Asexual cycle-.

Life cycle of *Plasmodiophora brassicae*

In the sexual cycle , the zoospores behave as gametes and couple in pairs forming – binucleate amoeboid cells-.* Then karyogamy occur to give zygote-2n- , also the cells of host increase in size – Hypertrophy- .* The young plasmodium then converted to old one and Meiosis take place and each nucleus converted to resting spore.



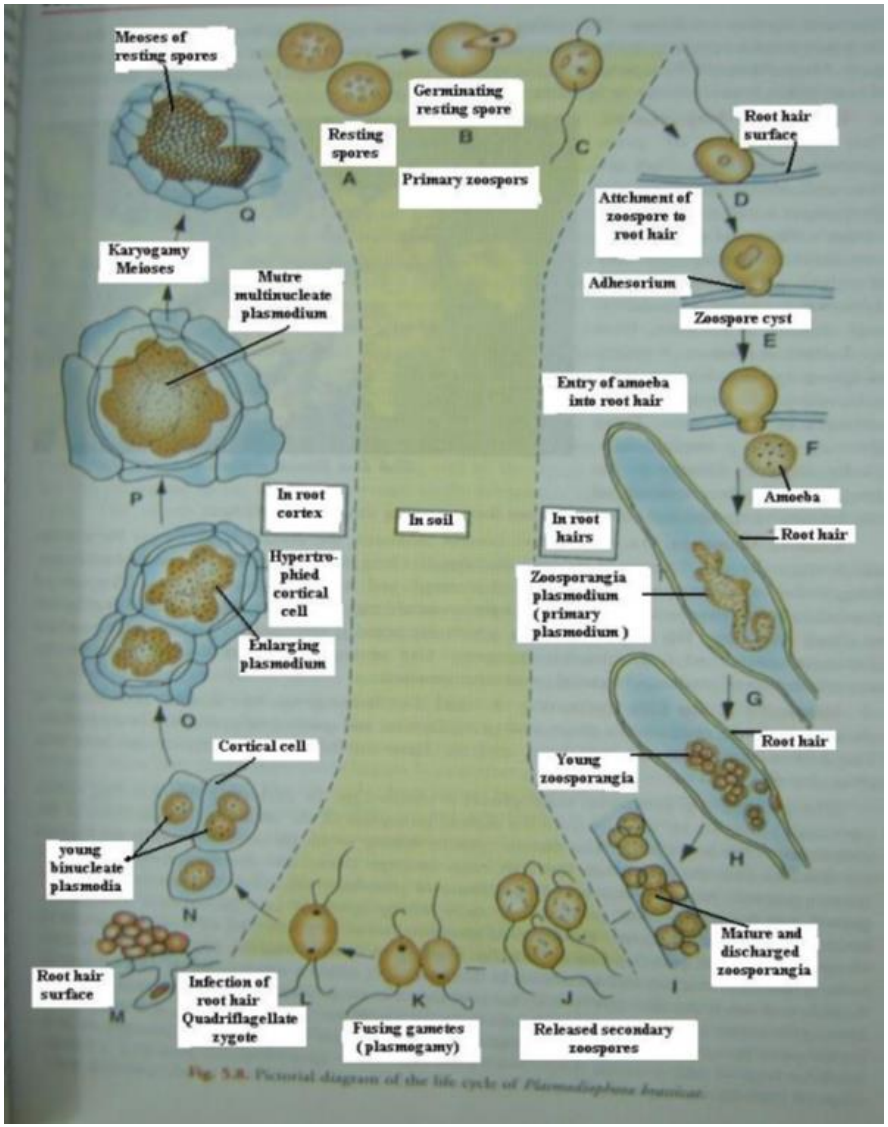


Fig. 5.8. Pictorial diagram of the life cycle of *Plasmodiophora brassicae*

Life cycle of Plasmodiophora brassicae

Lec. 8: Kingdom2: Straminipila

Kingdom2: Straminipila

The individuals are different from protozoa (kingdom1) in forming cell wall and nutrition by absorption, and different from true fungi (kingdom 3) in forming zoospores and the chemical components of cell wall is cellulose.

<u>This kingdom consist of 3 minor phyla classified according to zoospore</u>:

Phylum1: Hyphochytriomycota: (anteriorally uniflagellate zoospore)

Phylum2: Labyrinthulomycota (Zoospore with long anterior straminipilous flagellum and a short posterior whiplash flagellum with a pointed tip)

Phylum3: Oomycota: (biflagellate zoospore)

Phylum: Oomycota

General characteristics:-

1- They produce biflagellate zoospores, one flagellum is tinsel and the second is Whiplash.

2- Most of them are living in water so they called as water mold.

3-Some of them are obligate parasites on higher plant caused downy Mildew diseases. Others are parasites on algae or small animals such as Fish.

4- Sexual reproduction is gametangial contact produce Oospore.

5- Their cell walls consist of mainly glucan, but also contain cellulose. In most species there is no chitin.

Class: Oomycetes

Order 1: Saprolegniales

General characteristics:-

1- Some species such as Saprolegnia parasitica causes diseases of fish and fish eggs.

2- Mycelium is coenocytic, we can see septum only in the bases of reproductive Organs(sporangium)ia or gametangia.

3- Asexual reproduction by biflagellated zoospores. There are two types of zoospores:

A- Pyriform zoospores, they called also primary zoospores.

B- Reniform zoospores: they called also secondary zoospores.

Species that produce only one type of zoospore are monomorphic, while these which producing two types are dimorphic.

According to the swarming period, fungi in this order divided into:

1- Monoplanetic fungi: Those that have only one swarming period and only one type of zoospore ex: ***Pythiopsis.***

Pyriform zoospore →Swarming→ encystment → germination →new thallus

2- Diplanetic fungi: Those that have two swarming period and two types

of zoospores ex: ***Saprolegnia.***

Pyriform zoospore →Swarming→ encystment → reniform zoospore Swarming→ encystment → germination →new thallus

3- Polyplanetic fungi: Those that have more than two swarming period,

the zoospore which is repeated is secondary zoospore ex**: *Dictyuchus***.

Pyriform zoospore →Swarming→ encystment → reniform zoospore Swarming→ encystment → reniform zoospore→ encystment → germination → new thallus

4- Aplanetic fungi: Those that have no swarming period and so there is

no motile spores ex: ***Geolegnia.***

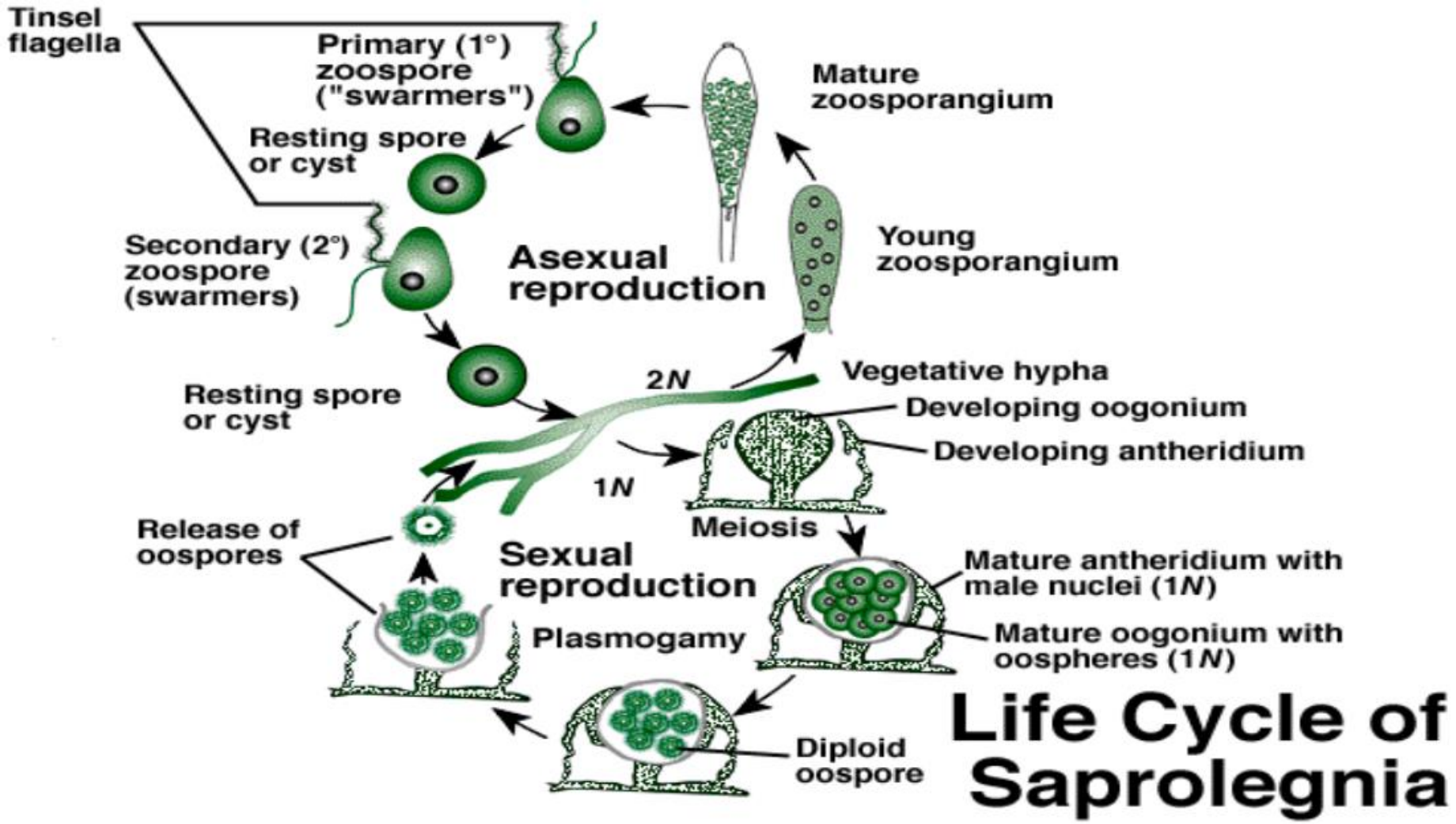
Family: Saprolegniaceae

Ex: *Saprolegnia parasitica*

Life cycle

* The sporangia are elongated, tapering structures borne at the tips of somatic hyphae and separated from them by a septum. An opening develops at the tip of the sporangium, and the primary zoospores escape into surrounding water, they swim about for some time, come to rest and encyst. After a short resting period, a thin papilla develops on the cyst, its tip dissolves, and a reniform zoospore with two lateral flagella creeps out. The encysted spore now germinates that develops into a new thallus. By internal proliferation; sporangia continue to be formed, with several a sexual generations following one anther -

Sexual cycle-. When conditions favorable to sexual reproduction, the somatic hyphae give rise to Oogonia and antheridia. Meiosis now takes place in gametangia, producing haploid Oospheres in Oogonia and haploid gamete nuclei in antheridia. The antheridia are much smaller than the Oogonia, and they are often borne on the same hyphae that bears the Oogonia. Fertilization tubes originating in the antheridium penetrate the Oogonial wall and reach the Oospheres. One male nucleus enters each Oosphere through the fertilization tubes forms a diploid zygote nucleus. Then a thick wall develops around each Oosphere, converting it into Oospore. After rest period, the oospores are liberated from Oogonial wall and germinated to give rise a new thallus.


Tinsel flagella
Primary (1°) zoospore ("swarmers")
Resting spore or cyst
Secondary (2°) zoospore (swarmers)
Asexual reproduction
Mature zoosporangium
Young zoosporangium
Resting spore or cyst
2N
Vegetative hypha
Developing oogonium
Developing antheridium
1N
Meiosis
Release of oospores
Sexual reproduction
Mature antheridium with male nuclei (1N)
Mature oogonium with oospheres (1N)
Plasmogamy
Diploid oospore
Life Cycle of Saprolegnia

Order 2: Peronosporales

The peronosporales are the most specialized of the Oomycetes. This large order of fungi includes aquatic, amphibious, and terrestrial species as a group of highly specialized obligate parasites that cause:

1- Witting or Damping off diseases.

2- White rust diseases.

3- Downy mildew diseases.

General characteristics:-

1- The mycelium is branched and coenocytic, the hypha of parasitic species are intercellular or intracellular. Those of the most parasites growing between host cells and producing haustoria.

2- Sporangia are separated from mycelium after maturation – Spores are released after the separation of sporangia-.

3- In some species, sporangia act as conidia and germinated into a new thallus.

4-Asexual reproduction occurs by reniform zoospores with only one swarming period.

5- Sexual reproduction occurs by gametangial contact.

Family1: Peronosporaceae

Sporangia borne on sporangiophores of determinate growth; periplasm is conspicuous; obligate parasites of plants; sporangia are wind- borne.

Family 2: Albuginaceae

Sporangia borne in chain; periplasm is conspicuous; obligate parasites of plants. This family includes the fungi known as white rusts. All are obligate parasites causing diseases of vascular plants.

Family1: Peronosporaceae: This is most highly specialized family in the order peronosporales. All species are obligate parasites of vascular plants causing diseases called downy mildew. The family includes a number of common genera differentiated chiefly by the branching of their sporangiophores as follows:

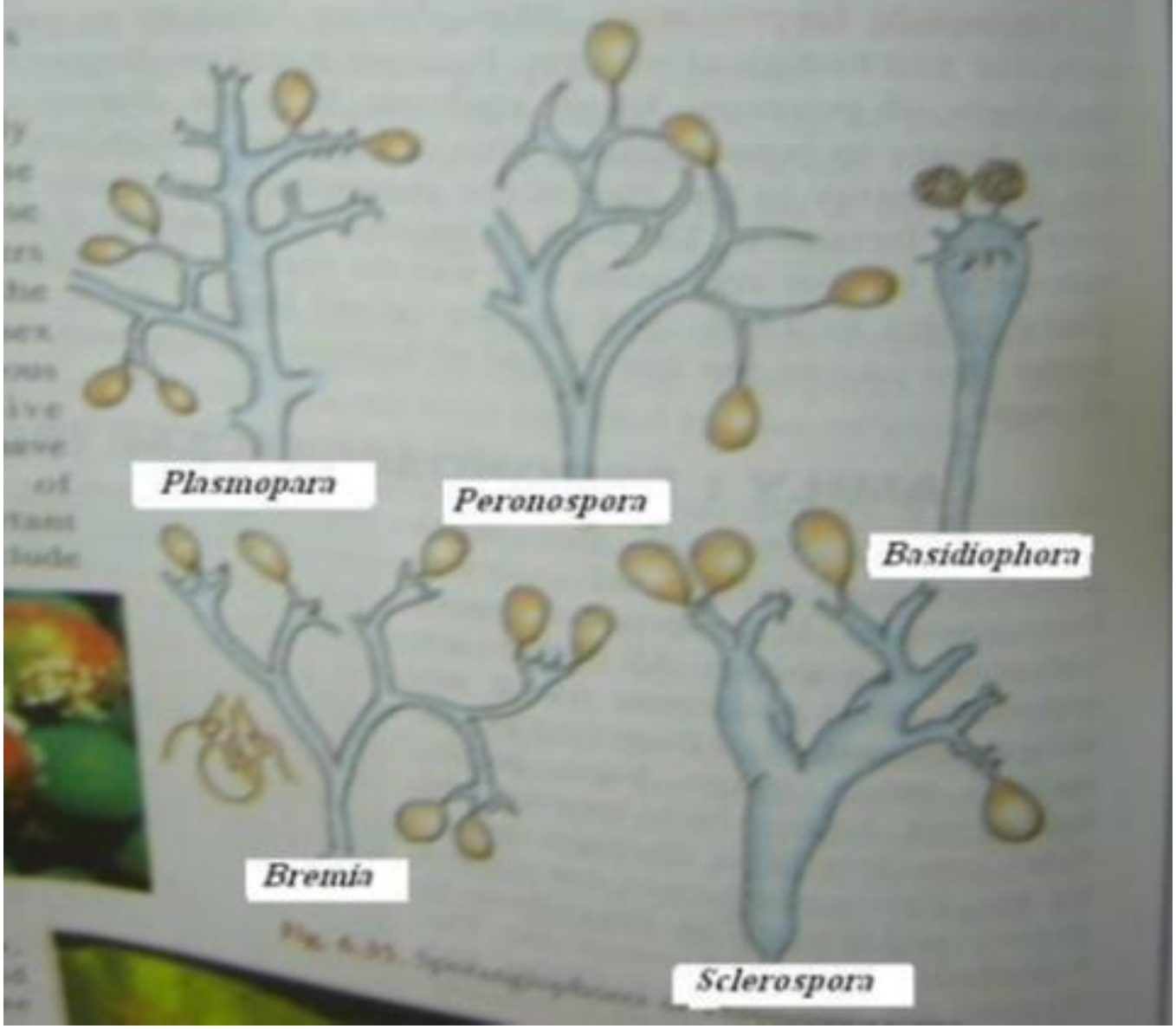
Genus 1:- *Peronospora*: The sporangiophores are dichotomously branched at acute angles with curved pointed tips on which sporangia are borne. This genus causes D.M. on Radish.

Genus 2:- *Plasmopara*: The branches and their subdivision occur at right angles. This genus causes D.M. on Grape.

Genus 3:- *Bremia*:- Is similar to *peronospora* except that the tips of branches are expanded into cup-shaped apophyses with four sterigmata each bearing the sporangia. This genus causes D.M. on Lettuce.

Genus 4: *Basidiophora* The sporangiophore is club-shaped with swallen head over which the sporangia are borne in minute sterigmata. This genus causes D.M. on Onion.

Genus 5: *Sclerospora* The sporangiophore is a long-stout hypha, with many upright branches near the end, bearing sporangia at the tips. This genus causes D.M. on Mongra.


Plasmopara
Peronospora
Basidiophora
Bremia
Sclerospora

Family 2: Albuginaceae

Genus: *Albugo*

There are several species of Albugo, the only one genus in this family. The more important species is ***A. candida*** which attack Crucifers.

Order 3:- Pythiales

Sporangia on somatic hyphae or on sporangiophores of indeterminate growth, periplasm a thin layer or absent; facultative, or saprobes.

Family: Pythiaceae

Genus 1: *Pythium:*

General characteristics:-

1- This fungus causes damping off seedling. Some species are saprobes, other are parasites.

2- mycelia are coenocytic, sporangia are globose to oval and either terminal or intercalary on somatic hyphae.

3- Production of zoospores is preceded by the formation of a bubble-like Vesicle.

4- Zoospores are biflagellated- reniform.

5-This fungus does not form haustorium.

Genus 2: *Phytophthora*

General characteristics:-

1- This fungus causes Late blight disease on Potato.

2- Mycelia are coenocytic but more branching than the mycelia in Pythium.

3- Sporangia are smaller and lemon-shaped with terminal papillae.

4- It does not form vesicle.

5- Producing haustoriun.

Lec.9: Kingdom3: Fungi

Kingdom Fungi (Eumycota) is classified in to 5 phyla according to sexual spore or gamete

Phylum1: Chytridiomycota (reproduce by planogametes)

Phylum2: Zygomycota (reproduce by zygospores)

Phylum3: Ascomycota (reproduce by ascospores)

Phylum4: Basidiomycota (forming basidiospore)

Phylum5: Anamorphic fungi (Sexual reproduction unknown)

Phylum1: Chytridiomycota

General characteristics

1- Production motile cell –zoospores and planogametes - each with a single, posterior, whiplash flagellum.

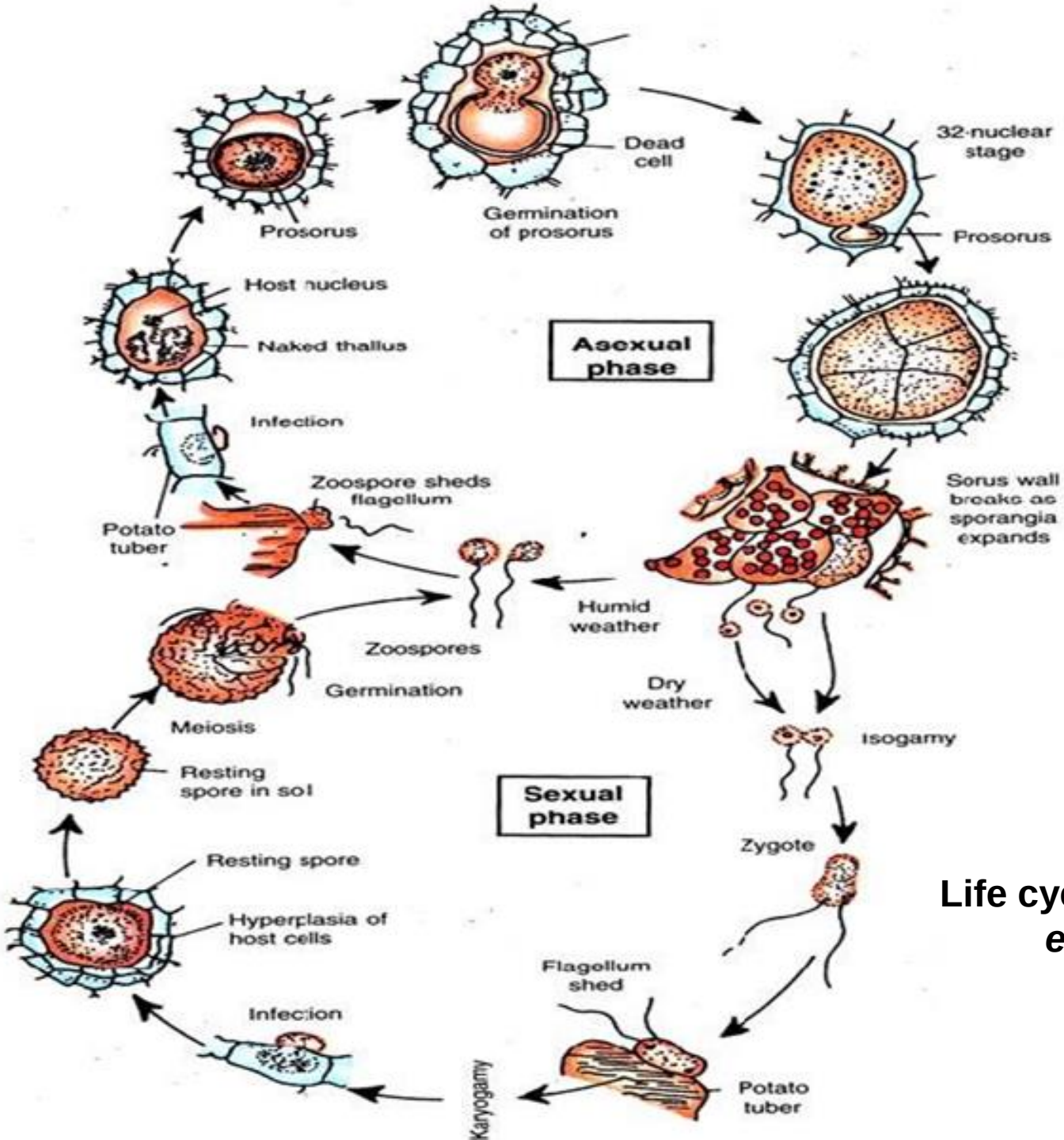
2- Class: Chytridiomycetes are more prevalent in aquatic habitats, many of them, however, also inhabit the soil, some of them are parasites on plant and animals such as Chytrid fungus.

3- Somatic structures are: Coenocytes structure, Multinucleate globose or oval with or without rhizoid, Well-develops mycelium

This phylum was classified into many orders such as:

Order1: Chytridiales: 80 genera (600 spp.) ex: ***Synchytrium***

The organisms which included in this order are unicellular, globose, with or without rhizoid and holocarpic, ***Synchytrium endibioticum*** causes the disease known as Potato Wart -Black wart disease on Potato.

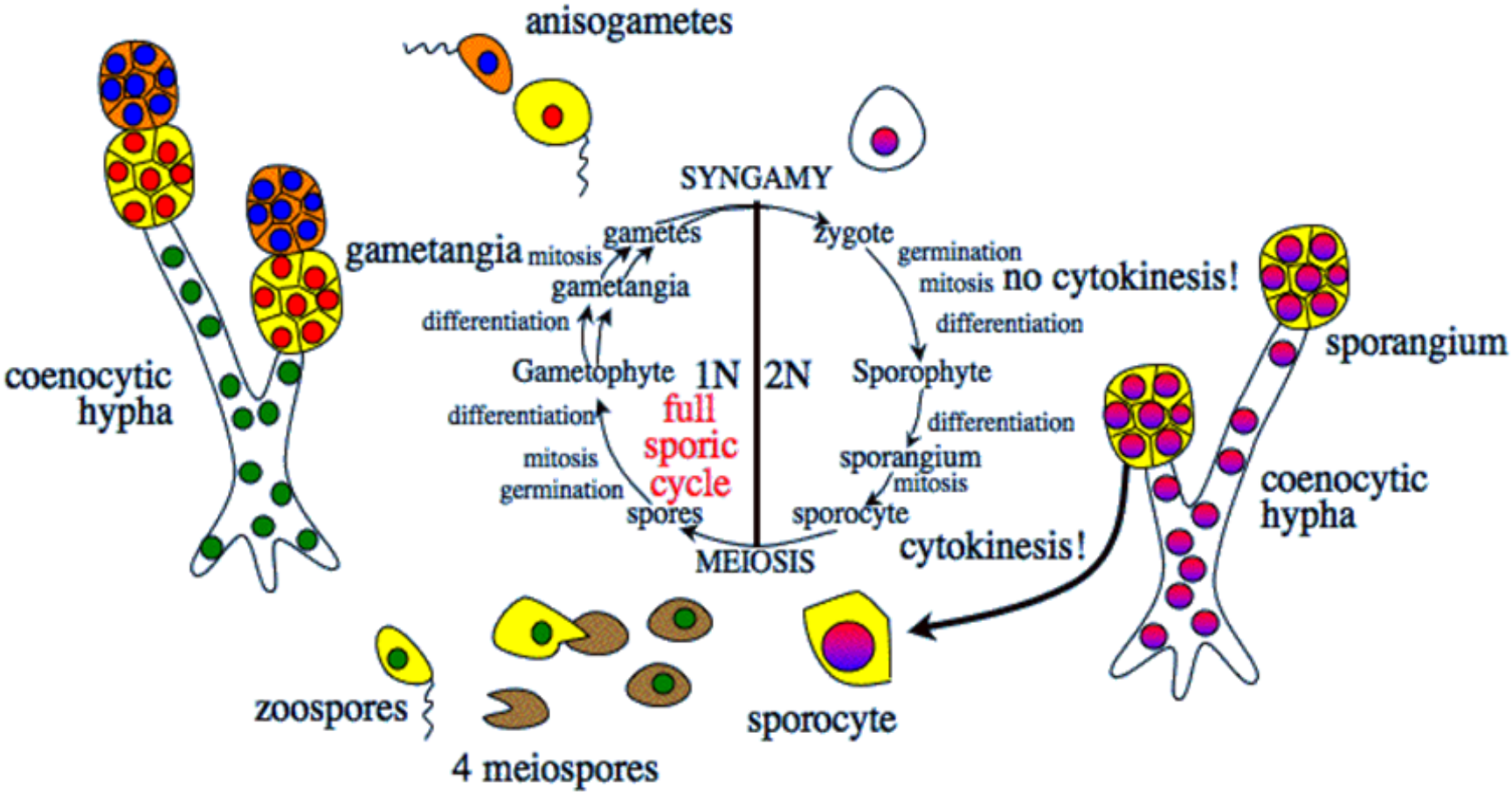


Life cycle of *Synchytrium endobioticum*

Order2: Blastocladiales: 14 genera (179 spp.) ex: Allomyces

Most of them are saprobes on animals and plants debris. Vegetative structure is Eucarpic. Somatic structure consists of basal cell with rhizoid and bearing one sporangium or more. Species of the genus Allomyces exhibit a definite alternation of generations, haploid gametothallus alternating with diploid sporothallus. The gametothalli produce colorless female gametangia and orange male gametangia usually in a 1:1 ratio.

Life Cycle of *Allomyces arbuscula*



Order3: Monoblepharidales: 4 genera (19 spp.)
ex: ***Monoblepharis polymorpha***

The somatic thallus consists of hyphae whose protoplasm which is highly vacuolated, appears foamy. Elongated sporangia are borne singly at the hyphal tips

Phylum2: Zygomycota

General characteristics

1- Most (class) zygomycetes produce a well- developed mycelium consisting of coenocytic hyphae with chitin chitosan in hyphal wall.

2- Producing a thick- wall resting spore called a zygospore (sexual spore) that develops within a zygosporangium formed as a result of complete fusion of two equal or unequal gametangia.

3- Asexual reproduction by production sporangiospores or aplanospores.

4- Most of zygomycetes are saprobes, such as bread-mold, others are parasites such as Fly fungi, and some are obligate parasites in other zygomycota or facultative parasites in plants and some genera are pathogenic for animal and human.

Classification of zygomycota

Two classes are included in the Zygomycota, namely **Zygomycetes** comprising 870 species in 10 orders, and **Trichomycetes** with 218 species in 3 orders

Class1: Zygomycetes

Most common orders are: Mucorales, Entomophthorales and Zoopagales

Order 1: Mucorales

General characteristics

1- Most of Mucorales are saprobes, living on decaying plant or animal matter such as Pilobolus. Few are parasites and pathogenic such as Rhizopus and Mucor (causing mucormycosis or saprobes in fruits during the storage) *Rhizopus stolonifer* cause rot on vegetable and fruit , *R. microsporus* produce mycotoxins rhizonin and rhizoxin, *R. arrhizus* cause mucormycosis.

Order 1: Mucorales

General characteristics

2- Basidiobolus ranarum which is commonly present in decaying fruit and vegetable matter, and as a commensal in the intestinal tract of frogs, toads and lizards. It has been reported from tropical regions of Africa and Asia including India, Indonesia and Australia typically causes subcutaneous infections involving the trunk, buttock, thigh and perineal areas

3- Some of them produce organic acids such as oxalic, lactic and succinic acids.

4- Classified in to genera according to asexual sporangium.

Order 1: Mucorales

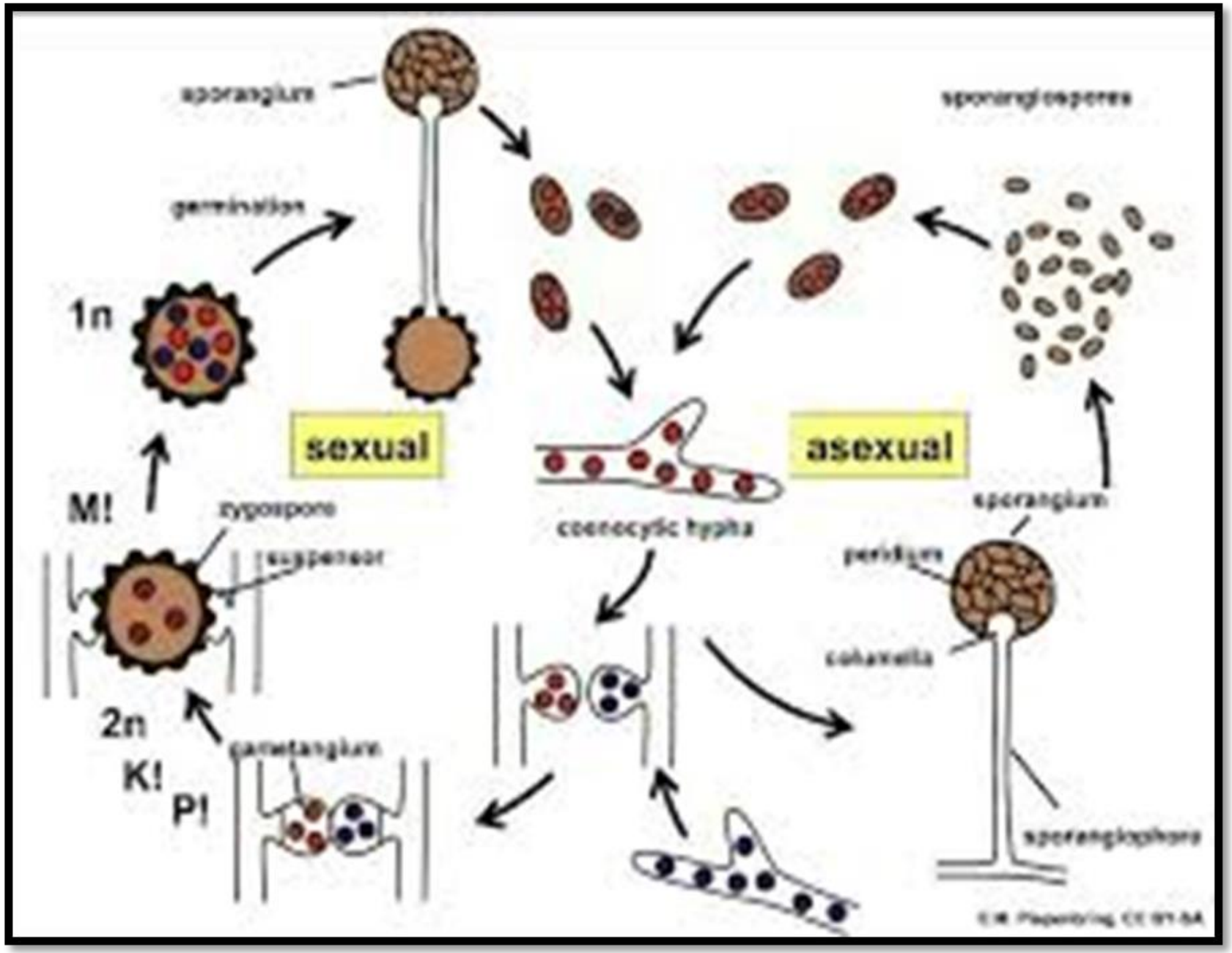
General characteristics

5- Reproduce asexually by aplanospores that are produced in sporangia. The sporangia are borne on simple or branched sporangiophores. Such sporangium is formed at the tip of a sporangiophore as globose swelling into which nuclei and cytoplasm have moved from the somatic hyphae below. The part of sporangiophore within sporangium is called columella and sporangium contains many thousands of sporangiophores.

Order 1: Mucorales

General characteristics

6- Sexual reproduction in the Mucorales takes place by the copulation of two multinucleate gametangia that are mainly similar in structure, but that may differ in size. The first step leading to the formation and fusion of these gametangia involves the formation of special hyphae called zygospore types of sporangia. The tips of the two zygophores as well as to from progametangia. A septum termed the gametangial septum then forms near the tip of each progametangium, separating it into two cells, a terminal gametangium and a suspensor cell. The fusion septum then dissolves; plasmogamy and Karyogamy are take place forming prozygosporangium. It enlarges, develops a thick multilayered wall, and becomes the zygosporangium in which single zygospore develops.



Life cycle of Zygomycota

Order 2: Entomophthorales

Many of these fungi are parasites in insects. The most familiar species is Entomophthora muscae commonly called the fly fungus, which is often found on the dead bodies of house flies clinging to long unwashed window panes in attics, garages, and university classrooms. If you examine such a fly you will find a wide, white, halo –like zone on the glass surrounding the dead fly. The white zone consists of spores -conidia- that have been shot off the sporogenous cells growing out of the body of the fly.

Order 2: Entomophthorales

The spores, which are produced singly at the tips of unbranched sporogenous cells, are covered by a mucilaginous substance and adhere to any object. If this spore contacts another fly, it quickly germinates and penetrates the cuticle of the body. Infected fly usually die within a week or so after infection and the sporulation process is repeated.

Sexual reproduction in Entomophthora takes place when hyphal bodies acting as gametangia, copulate and develop a zygosporangium containing a zygospores.

Lec.10: Kingdom3: Fungi

Phylum3: Ascomycota

General characteristics

1- The one character distinguishing the ascomycetes from all other fungi is ascus, a sac-like cell containing usually definite number of ascospores formed by free cell formation after karyogamy and meiosis. Eight spores are typically formed within the ascus, but this number may vary from one to over thousand according to the species.

2- Mycelia are septate.

3- The absence of any type of flagellate cells.

Phylum3: Ascomycota

General characteristics

4- Ascomycota have two reproductive phases: the ascus or sexual stage, often called perfect stage, and the conidial or asexual stage (imperfect stage).

5- Fungi somatic structure either unicellular such as yeast or multicellular like other ascomycota.

6- Sexual reproduction by gametangial contact, gametangial copulation, somatogamy, and spermatization. The female gametangia called ascogonium and the male are antheridia. Male nucleus passes from the antheridium into the ascogonium through a pore developed at the point of contact between the two gametangia. The ascogonium is often provided with a trichogyne that receives the male nucleus. Sometimes the male and female nuclei do not fusion directly, resulting a binucleate cell which called dikaryon. .

Lec. 10: Phylum3: Ascomycota

General characteristics

7- There are two types of asci: unitunicate and bitunicate. In the so called unitunicate ascus the two layers are closely adherent and the spores are released through a terminal pore -operculum-. In the bitunicate ascus theendotunica – endoascus – separating from the exotunica (exoascus) at the time of spore release, while the exotunica remains as originally formed. Sterile, elongated hairs, arising between the asci often form a part of the hymenium, those hairs are called paraphyses (sin: paraphysis).

Phylum3: Ascomycota

General characteristics

8- With few exceptions, ascomycetes produce their asci in fruiting bodies called ascocarps. In general there are five major categories of ascomycetes, separated according to the way they bear their asci:-

a- Those that bear naked asci without any fruiting bodies.

b- Those that produce their asci inside a completely closed ascocarp called a cleistothecium.

c- Those whose ascocarp, the perithecium, is more or less closed, but at maturity is provided with a pore – ostiole- through which ascospores escape.

d- Those that produce their asci in an open ascocarp, called apothecium.

e- Those that form their asci directly in a cavity –locule- within stroma. The stroma itself thus forms the wall of the ascocarp in such species. We call such a structure an ascostroma

Classification of phylum: Ascomycota

Class 1: Archiascomycetes

Because of their diverse morphological appearances and modes of life, it is difficult to describe common characters typical of the Archiascomycetes. With the exception of Neolecta, which produces apothecium, ascocarps are lacking and asci are produced individually by yeast cells or by conversion of hyphal tips. ascospores and yeast cells are projected from the ascus which often opens by a characteristic slit.

Classification of phylum: Ascomycota

Class 1: Archiascomycetes

Order: Taphrinales , ***Taphrina deformans*** an obligate parasite causes Leaf curl disease. Asci are arising naked, no ascocarp. Asexual reproduction occurs by budding from the asci.

Order: Endomycetales, ***Schizosaccaharomyces octosporus***, this species growing well on honey and others materials and on solid and liquid media forming mature asci during three days.

Classification of phylum: Ascomycota

Class 2: Hemiascomycetes

contains the classical ascomycetes yeasts, saprotrophic colonizers of plant organs, specially where sugars are present, e.g. in the nectar of flowers, on fruits, and on wounded or exposed surfaces of plants also occur in the soil, although only a few exclusively soil-borne, Yeasts also occur in freshwater and marine situations. Some species are associated with insects and other animals, including the guts of vertebrates which have a thriving yeast mycota. may grow on skin surfaces and one species ***Candida albicans*** can, under certain circumstances, turn into a mild or severe pathogen of humans, especially of Immunocompromised patients. A very small number of species is of immense importance to biotechnology such as alcoholic fermentation, Bread-making mainly by ***Saccharomyces cerevisiae*** (which is heterothallic. The single cell is oval. Asexual reproduction occurs by budding).

Classification of phylum: Ascomycota

Class 2: Hemiascomycetes

contains the classical ascomycetes yeasts, saprotrophic colonizers of plant organs, specially where sugars are present, e.g. in the nectar of flowers, on fruits, and on wounded or exposed surfaces of plants also occur in the soil, although only a few exclusively soil-borne, Yeasts also occur in freshwater and marine situations. Some species are associated with insects and other animals, including the guts of vertebrates which have a thriving yeast mycota. may grow on skin surfaces and one species Candida albicans can, under certain circumstances, turn into a mild or severe pathogen of humans, especially of Immunocompromised patients.

Classification of phylum: Ascomycota

Class 3: Plectomycetes

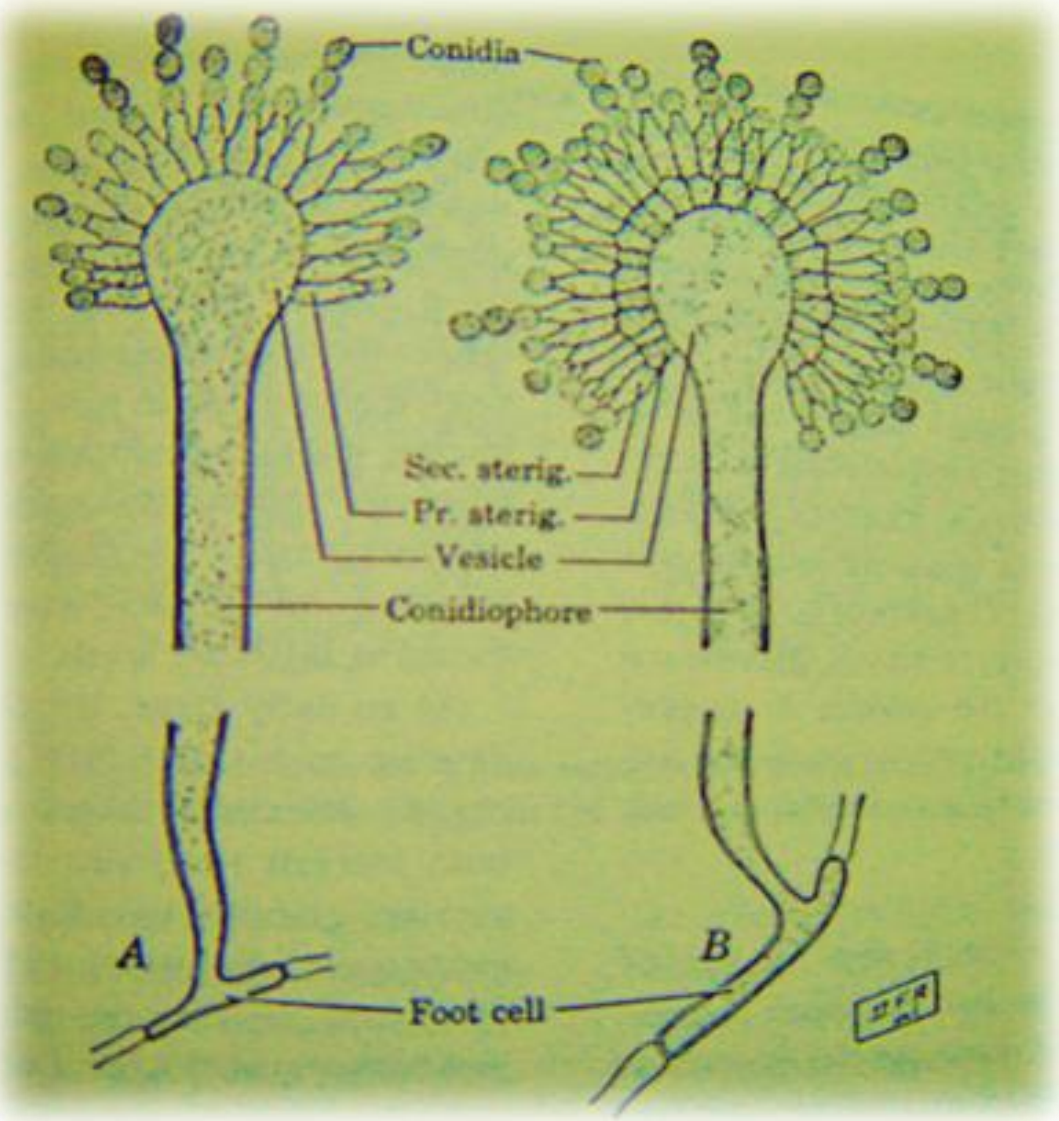
The class Plectomycetes originally contained all ascomycetes which produce their asci within a cleistothecium, i.e. a ‘closed case: have many orders.

Order: Eurotiales, Some individual are saprobes, others are parasites on animals, plant and human causing many diseases, some causing food spoilage.

Genus1: *Aspergillus* (=*Eurotium*)

Genus1: *Aspergillus (=Eurotium)*

The air everywhere seems to contain the conidia of these organisms. The genus ***Aspergillus*** contains 200 species and great many varieties. These organisms causing the spoilage of food, texture, and leathers, and some species causing diseases in human such as Aspergillosis which causes by ***A. fumigatus***. symptoms closely resemble those of tuberculosis and it is probable that some doctors mistakenly diagnosed the disease as tuberculosis. Because of their great enzymatic activities, Aspergilli are employed in several industrial processes. Such as production of citric acid and gluconic acid by ***A. niger,*** production of some enzymes by ***A. oryzae*** and some species are used to produce antibiotics, while ***A. nidulans*** causes nail infection, ***A. flavus*** is aflatoxin producer and cause liver cancer and ***A. clavatus*** cause granular lesions in lungs



Morphology of *Aspergillus*

Genus 2: *Penicillium*

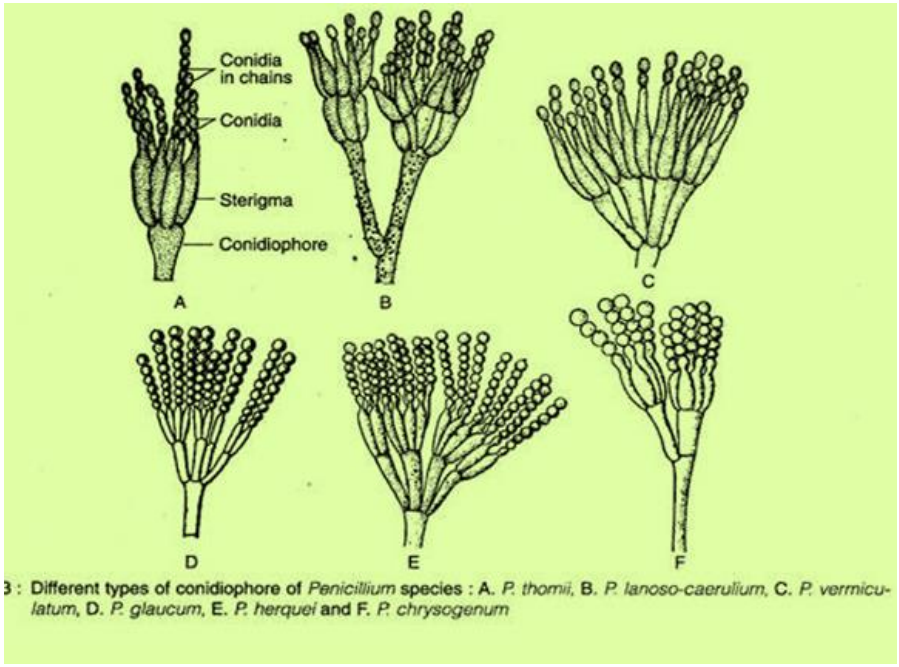
It is so called green molds and blue molds. We so frequently find on citrus and other fruits, on cheeses in the refrigerator, and other food stuffs. The conidia of Penicillium, like those of Aspergillus, are everywhere in the air and in the soil. In the biological Lab, they are as frequent contaminants as *Aspergillus* and *Rhizopus*.

Genus 2: *Penicillium*

Various species of ***Penicillium*** attack and destroy fruits; ***P. italicum and P. digitatum*** are common pathogens of citrus and fruits causing blue mold and green mold respectively. ***P. expansum*** causes a decay of apples in storage. ***P. roqueforti*** is responsible highly priced flavor of Roqueforti cheese and ***P. camemberti*** for of Camembert cheese. ***P. notatum*** or ***P. chrysogenum*** was used for penicillin production, and ***P. griseofulvum*** was used for griseofulvin production, which is the best antibiotic effective in control of fungal skin diseases (Dermatomycoses), such as athletes foot. The sexual stage of ***Penicillium*** *i*s called ***Talaromyces.***

Morphology of *Penicillium*

The mycelium produces simple, long, erect conidiophores that branch about two-thirds of the way to the tip, broom-like fashion. The conidiophore, commonly referred to as the brush. The multiple branching of the conidiophore ends in a group of phailides that bear the long conidial chain.



3 : Different types of conidiophore of *Penicillium* species : A. *P. thomii*, B. *P. lanoso-caerulium*, C. *P. vermiculatum*, D. *P. glaucum*, E. *P. herquei* and F. *P. chrysogenum*

Morphology of *Penicillium*

Fungi that includes the ascomycetous state of many of the dermatophytes and several of the systemic pathogens for humans :***Histoplasma capsulatum , Blastomyces dermatidis, Nannizzia(Microsporum), Blastomyces, Arthroderma (Trichophyton).***

Lec.9: Kingdom3: Fungi

Phylum3: Ascomycota

Class4: Hymenoascomycetes (Pyrenomycetes)

The ascocarp is perithecium, there is only one order which has cleistothecium. This class divided into **orders such as: Erysiphales, Claviceptales, Helotiales, Pezizales and Tuberales.**

Order 1: Erysiphales (The ascocarp is cleistothecium, but the asci are arranged as hymenial layer): they are obligate parasites on economic plants causing Powdery mildews (P.M). These appear to the unaided eye as a white, powdery coating on the infectious parts.

***Sphaerotheca*:** Causes P. M. on Rose,

***Erysiphe*:** Causes P.M. on Graminae**,**

***Podosphaera*:** Causes P.M. on Apple,

Phyllactinia: Cause P.M. on Morus,

Uncinulla: Causes P.M. on Grap,

Microsphaera: Causes P.M. on Lilac.

Order 2: Claviceptales (The ascocarp is perithecium type, and the ascospores are filamentous form), produce their perithecia with a well- developed, stroma composed entirely of fungal tissue. Ex1. : ***Claviceps purpurea***, Sclerotia of this fungus is the cause of ergot of Rye, Ex.2***: Cordyceps militaris***: The genus Cordyceps consists of clublike parasites that attack underground puffballs or insects. The victim for *C. militaris* is a pupa or larva (usually of a butterfly or moth).

Order 3: Helotiales: They are present on the surface of soil, and they involved operculate and inoperculate. Most of them are parasites and causes plant diseases. ***Sclerotia fructicola* (*Monilinia fracticola*** or ***M. laxa*), which causes the brown rot of peach and other stone fruits.

Order 4: Pezizales: Involve the fungi that apothecia on the surface of the soil, and their asci with operculum, most of them are saprobes and asexual reproduction is unknown. ***Peziza aurantia***: Orange in color, edible (spongefungus), sessile apothecium. ***Morchella* spp.*:*** Grayish white to a dark-brown in color.

Order5: Tuberales :Fungi in this order are mycorrhizal fungi living in association with the roots of Oak and beech-trees. There are two important genera; ***Trimania*** and ***Terfezia.***

Class 5: Loculoascomycetes

The asci are bitunicate and the ascocarps are ascostroma in which the asci are borne in locules. **Genus: *Venturia:*** is widespread, and contain an estimated 58 species

***V. inaequalis*:** attacks apple fruits and causes apple scab.

Lec.11: Kingdom3: Fungi

Phylum4: Basidiomycota

General characteristics

1-Basidiomycota consist of form people call mushroom. Some are saprobes, other are parasites which causes smut and rust diseases.

2-They produce their spores, called basidiospores on the outside of a specialized, spore-produced structure (the basidium).

3-The mycelium of most Basidiomycota passes through three distinct stages before the fungus completes its life cycle: The primary mycelium (1n):- Usually develops from the germination of a basidiospore. It is septate and uninucleate from the beginning. It gives rise to;-Secondary mycelium: Usually involves an interaction between two compatible mycelia (n+n) (Dikaryon).

Phylum4: Basidiomycota

General characteristics

4-There are no sexual organs in phylum Basidiomycota so the sexual reproduction occurs by spermatization or Somatogamy.

5-Basidiomycota characterized by presence of clamp connections, that are formed during nuclear division when the binucleate cell is ready to dived.

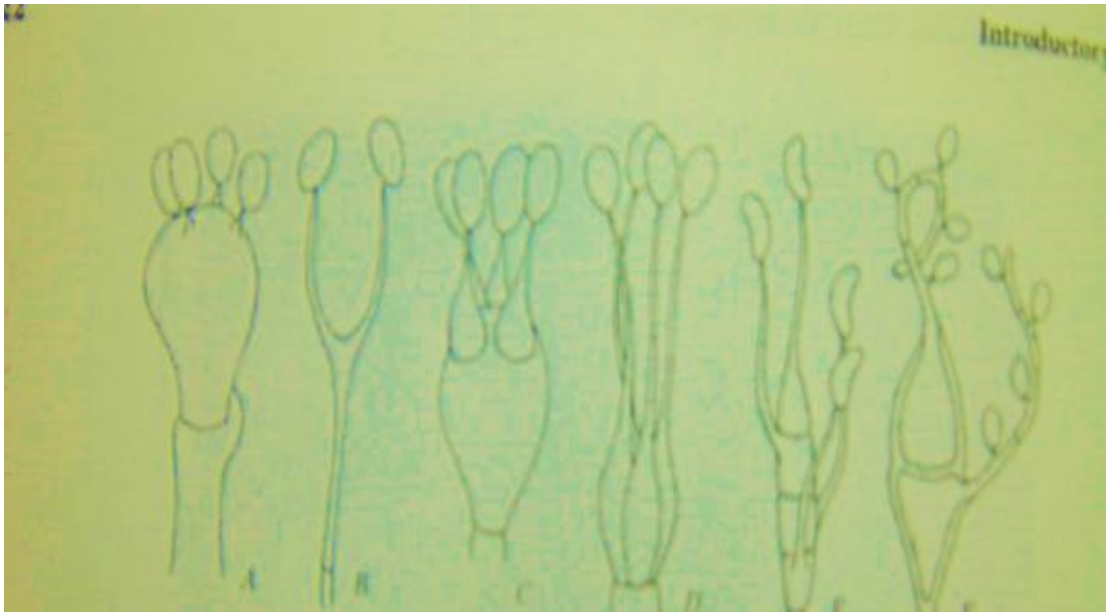
6. Asexual reproduction does not important in this class, and it occurs either by budding or fragmentation.

Classification of phylum Basidiomycota

(According to basidium)

Class I: Homobasidiomycetes (basidium not phragmented)

Class II: Heterobasidiomycetes (basidium is phragmented)



Types of basidium :
Holobasidium &
Phragmobasidium

Class I: Homobasidiomycetes (basidium not phragmented)

This class involves edible mushroom and other saprophytic fungi. The main characteristic of these fungi is the club-shaped basidium which bears four basidiospores on sterigmata.

Orders: Agaricales, Polyporales, Exobasidales, Hymenogastrales, Lycoperdales, Sclerodermetales, Phallales and Nidulariales

Order: Agaricales

The fruiting bodies are fleshy; the hymenial layers are bearing on gills (Mushroom).

This order involves mushroom which is saprophyte, such as ***Agaricus bisporus*.** Its basidium bears only two basidiospores. The other examples of edible mushroom is ***A. campestris*** which is growing well on animal wastes and it is brown in color**.** This order also involves poisoning mushroom which we can distinguished it by: Presence of scales on the cap, Presence of annulus and presence of volva.

Order: Agaricales

There are many examples of poisoning mushroom as follows:

Agaricus xanthodermus (Yellow staining fungus).

Inocybe (Red staining fungus),

Coprinus: Some species are edible mushroom, others are poisoning (Black liquid like ink).

Amanita which produces amanita toxins such as: ***A. phalloides***: Produces α-amanitine, β-amanitin and phalloid which are high toxic materials. ***A. muscaria*** which contains muscarine, causes nerve system damage. Its scales are red in color and called fly fungus.

Order: Polyporales :The fruiting bodies are not fleshy; the spores are bearing in different ways. ***Polyporus*:** The fruiting bodies contain pores which coated with hymenial layer. ***Clavaria*:** From Coral fungi) involves color fungi, white or yellow

Order: Lycoperdales **(Puff ball)** **ex: *Lycoperdon***

Order: Nidulariales **(Bird's nest)** **ex: *Cyathus***

Order: Sclerodermetales (Earth ball) **ex: *Scleroderma, Gasterum***

Phylum4: Basidiomycota

Class II: Heterobasidiomycetes (basidium is phragmented)

General characteristics

1. There is no basidiocarp.

2. Basidium septate by transverse septa.

3. Parasitic fungi

Class II: Heterobasidiomycetes (basidium is phragmented)

It involves two orders

Order 1: Uredinales (Rust fungi): This order involves fungi which economically important causes rust diseases. These fungi are obligate parasites on cereals crops causing black stem-rust. There are no basidiocarps but these fungi contain many spore stages which forming within pustules. The mycelium presence between host cells and send haustoriun. The fungi which have five types of spore stages called macrocyclic rust which needed either one host (autoecious rust) or two hosts that called (heteroecious rust), the life cycle of these fungi is long. Those which have short life cycle are called (microcyclic rust). The example of macrocyclic but autoecious is Melanposora lini which causes flax rust and macrocyclic heteroecious rust is Puccinia graminis which causes black rust on gramineae.

Symptoms of stem rust and life cycle of *Puccinia graminis*

- Stem rust predominantly impacts cereal crops such as wheat, barley, and rye. Signs consist of reddish-brown pustules seen on stems, leaves, and grains, resulting in stunted growth, weaker stems, and decreased grain yield. Its significance in agriculture lies in the threat it poses to crop productivity. Detecting and managing it early is vital to mitigate its harmful effects. The life cycle of stem rust fungus is fascinating undergoes a complex series of stages involving both sexual and asexual reproduction (Figure below) impacting various plant hosts especially cereal crops like wheat, barley, and rye.

- The two-celled teliospores that produce in midsummer on the leaves and stems of wheat remain dormant until the following spring, passing the winter on the stubble in the fields.

Symptoms of stem rust and life cycle of *Puccinia graminis*

- The two-celled teliospores (p) that produce in midsummer on the leaves and stems of wheat remain dormant until the following spring, passing the winter on the stubble in the fields. Over wintering takes place in the uninucleate, diploid stage after karyogamy has occurred. Early in the spring, each cell of the teliospore germinates and produces a promycelium (R) into which the diploid nucleus migrates, undergoes meiosis, and form four haploid nuclei. Septa are then laid down separating the nuclei from one another into four cells. Each cell of the promycelium produces a sterigma on which a minute basidiospore is formed. Two of the basidiospores are of one strain and two are of other (A). .

Symptoms of stem rust and life cycle of *Puccinia graminis*

- The basidiospores are carried away by the wind and then germinated producing germ tubes on barberry (B), with their germ tubes penetrating into the tissues of barberry through haustoria. Thus, a well-developed, branched, monokaryotic mycelium develops; its nuclei carry the factor (A1 or A2) that the parent basidiospore happens to carry (C). A few days after infection, the hyphae of the fungus nearest the upper epidermis of the host develop. Spermogonia -in the manner already described- that open to the surface of the leaf (D). Each spermogonium contains numerous spermatiophores that cut off a succession of minute spermatia (F). Several periphyses are also formed in the upper part of the spermogonium. Each spermatium contains a large nucleus carrying the A1 or A2 factor, depending on the strain of mycelium that produced the spermogonium. The same mycelium that produces the spermatia also gives rise to receptive hyphae with the same genetic makeup as the spermatia.

Symptoms of stem rust and life cycle of *Puccinia graminis*

- These arise in the spermogonia and protrude through the ostioles (E). If (A1) spermatia thus happen to be transferred to (A2) receptive hypha or (A2) spermatia to (A1) receptive hyphae, spermatization is effected and the spermatial contents pass into the receptive hyphae by a pore dissolved in the walls at the point of contact (G). Meanwhile the mycelium has penetrated the entire leaf, and the hyphae near the lower epidermis have formed a number of aecial primordia (H). The aeciosporese that first binucleate spores produced in life history of the fungus. The aeciospore chains eventually break through the lower epidermis of barberry, permitting the spores to escap (I). .

Symptoms of stem rust and life cycle of *Puccinia graminis*

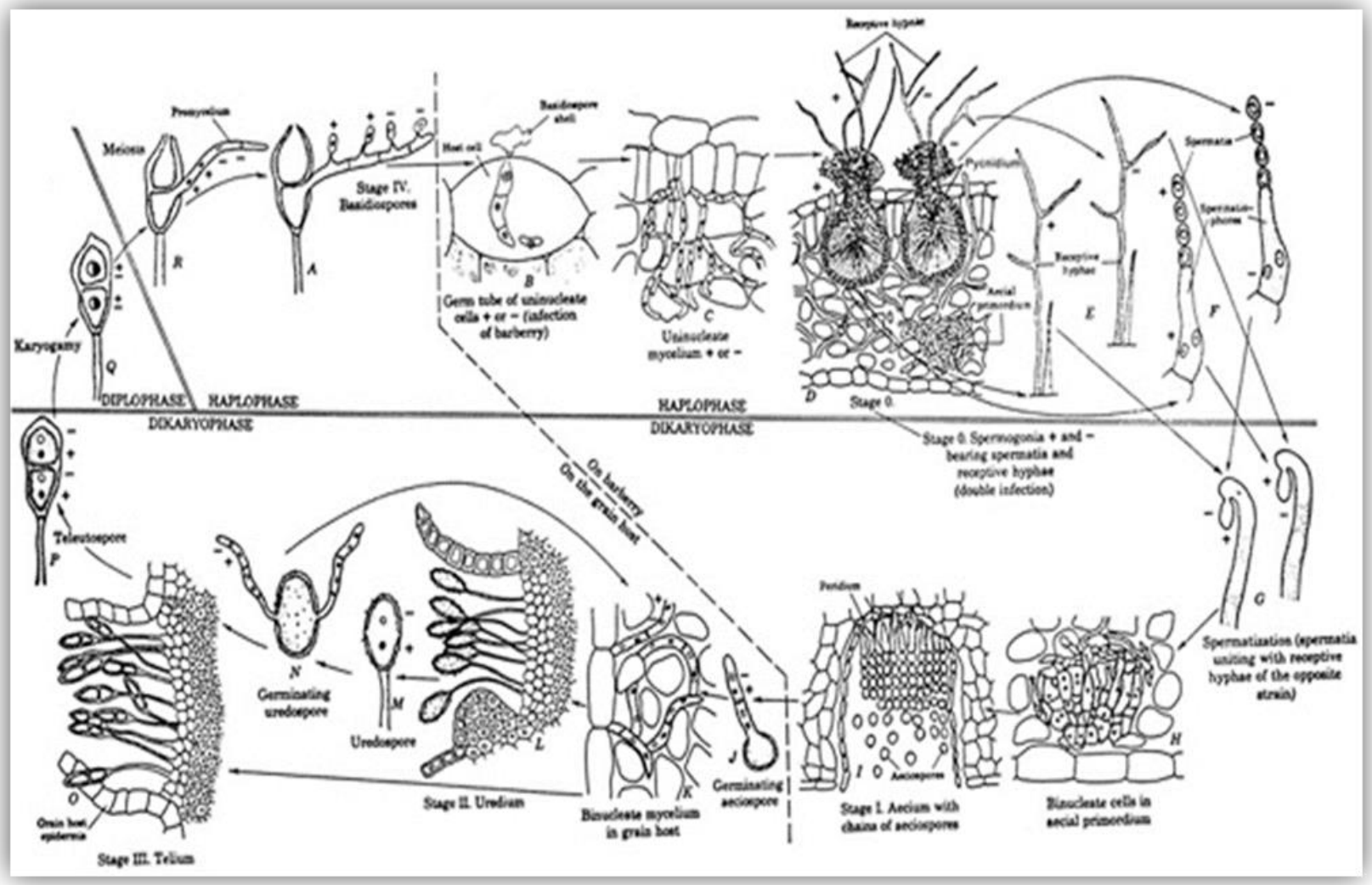
- The aeciospores are now disseminated by the wind and germinate (J). If germination occurs on a susceptible grass host, infection results and binucleate mycelium develops (K). Soon after infection, the binucleate mycelium in the grass host begins to form masses of cells – the uridinia- from which binucleate urediniospores are arise on rather long stalks. The urediniospores are oval, yellowish and spiny. The pressure from the developing spores causes a break in the host epidermis and an elongated streak-like rust-red pustule develops (L). The urediniospores upon germination produce binucleate mycelium (N) that grows between the cells of the grass plant and in a few days produces new uredinia and a new crop of urediniospores

Symptoms of stem rust and life cycle of *Puccinia graminis*

- This repeating cycle of Puccinia graminis recurs several times in the spring and summer. About the time the grain is ripening, the uredinia begin producing a few teliospores and a fewer uridiniospores are produced until finally only teliospores are formed (O).

- The pustules that produce teliospores are known as telia and constitute the black

- stage of the rust. The uredinia thus gradually change into telia



life cycle of *Puccinia graminis*

Order 2: Ustilaginales (Smut fungi): are obligate parasites fungi on Angiosperms such as wheat. The smuts are so called because they form black, dusty spores masses that resemble soot or smut. Basidiospores can be budding in asexual reproduction, and some of smut fungi do not obligate parasites so we can cultivate it in laboratory. The sexual reproduction occurs by somatogamy. ***Ustilago nuda*** causes loss smut on wheat. ***Ustilago hordei*** causes covered smut on wheat and ***Ustilago maydis*** cause the disease in corn. In ***Tilletia*** ,The promycelium is aseptate and only terminal basidiospores are produced. ***T. caries*** causes stinking smut on wheat.

Lec.12: Kingdom3: Fungi

Phylum5: Anamorphic fungi

They are known as form-class deuteromycetes or imperfect fungi which characterized by: They have septate hyphae, reproduce only by conidia and the majority are either saprobes or parasites of plants and animals. A few are parasitic on other fungi and some even trap and consume nematodes. Some are used in commercial production of certain chemicals including some antibiotics.

Form sub class 1: Hyphomycetidae

Form sub class 2: Coelomycetidae

Form sub class 3: Agonomycetidae

Form sub class 1: Hyphomycetidae

It is a very large group of probably over 7000 species. The conidia either bearing on free and separated conidiophore (sporodochium) or collected conidiophores (synnemata). fungi which their conidia bearing on conidiophore (colorless) and colorless hyphae such as ***Aspergillus, Penicillium, Botrytis***.

If dark-color or black conidia, conidiophore, and mycelium: ***Alternaria:*** Bottle-shaped conidia, and divided by longitudinal, ***Helmenthosporium***: All produce rather large phragmospores, multicellular conidia possessing transverse septa (2,3 or 4) septa .Cladosporium: All produce two types of conidia, the first is bicellular conidium and the second if unicellular small conidium, If dark- green to black in color. Produce sporodochium such as ***Fusarium.*** Produce synnemata: ***Graphium***: Reproduce by budding or forming oidium: ***Candida:, Trichophyton, Geotrichium, Cryptococcus***

Form sub class 2: Coelomycetidae

The distinctive structure is of course the pycnidium. Ex: ***Septoria apicola***

The asexual fruiting bodies are pycnidium which causes late blight disease on celery. The genera are characterized by small, ostiolatepycnidia sunken in the substratum, very short phialides and hyaline or greenish, long conidia (needle-shaped conidia).