PHYSIOLOGY AND REPRODUCTION IN FUNGI

Dr. Ariyah Terasawat

GENERAL CHARACTERISTICS

- Fungi are a kingdom of usually multicellular eukaryotic organisms that are heterotrophs and have important roles in nutrient cycling in an ecosystem. They can form symbiotic association with plants and with bacteria. They are also responsible for some diseases in plants and animals.
- Mycology – Study of fungi

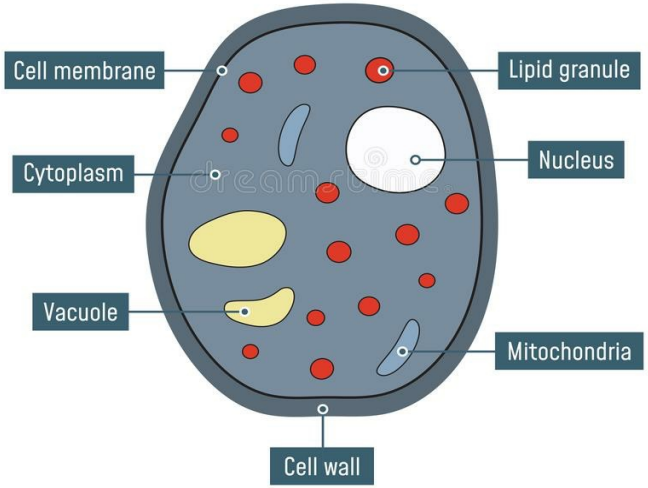
  Mycologists – Scientists who study about fungi

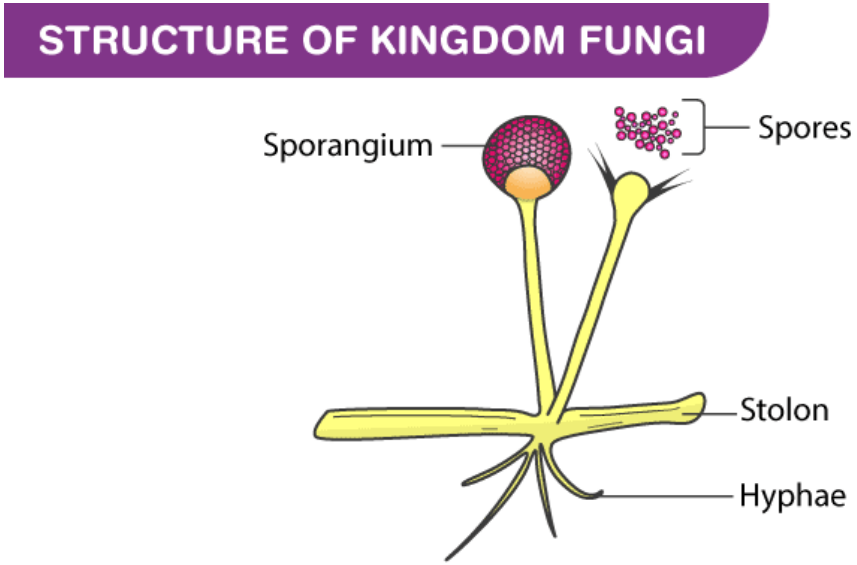
  Mycotoxicology - Study of fungal toxins and their effects

  Mycoses – Diseases caused by fungi

STRUCTURE OF FUNGI

- Eukaryotic
- Non motile
- Some fungi are single celled, while others are multicellular. Single celled fungi are also called yeasts.
- Fungi cells have a very small nuclei with little repetitive DNA and organelles like plant and animals do.
- The cell walls of fungi contain chitin, which is a hard substance found in the exoskeletons of insects and arthropods





- Multicellular fungi have many branching filaments called hyphae. The are tubular shaped and are split into cell like compartments that are known as septa. The network of hyphae in fungus is called mycelium.

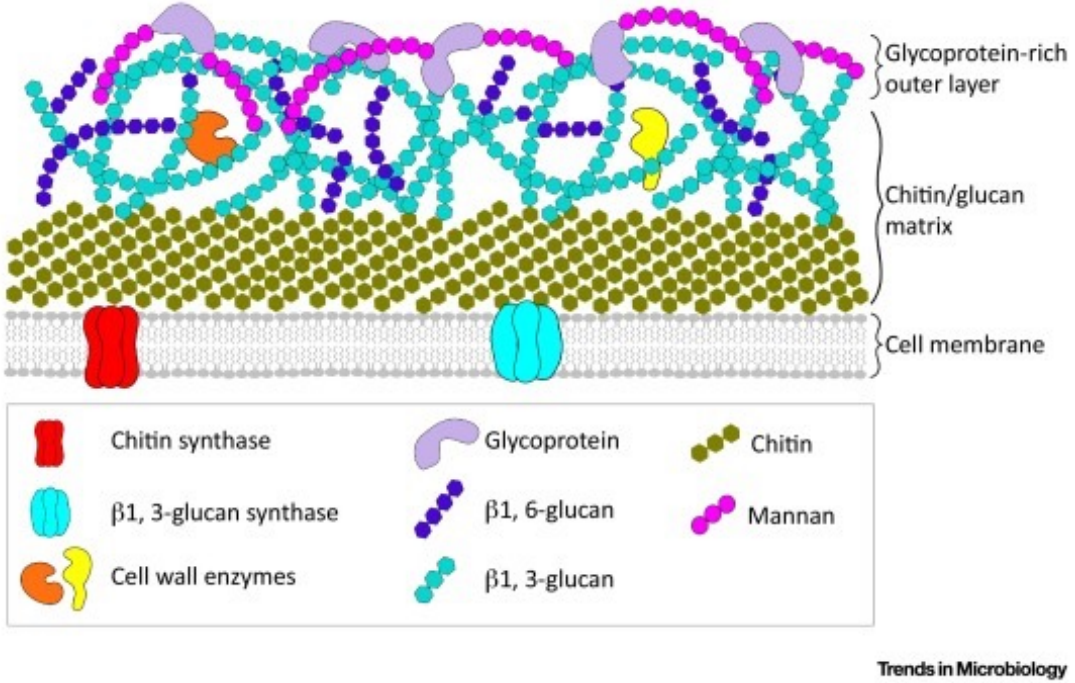
- They are heterotrophs, and can't make their own food so they must obtain nutrients from organic material.
- They can be :
    * Saprobes (absorb nutrients from dead material)
    * Parasites
    * Mutualistic symbionts (association of fungi with algae is termed as lichens,

      association of fungus and plant root is called mycorrhiza)
- All fungi reproduce through spores. Spores are microscopic cells that disperse from their parental fungus, usually through wind or water. Fungi can produce spores through sexual and asexual reproduction.
- Both asexual and sexual method of reproduction can be opted, asexual reproduction occurs through the release of spores or through mycelial fragmentation, where mycelium separates into multiple pieces that grow separately and in sexual reproduction separate individuals fuse their hyphae together.

CELL WALL

❖CHARACTARISTICS OF CELL WALL

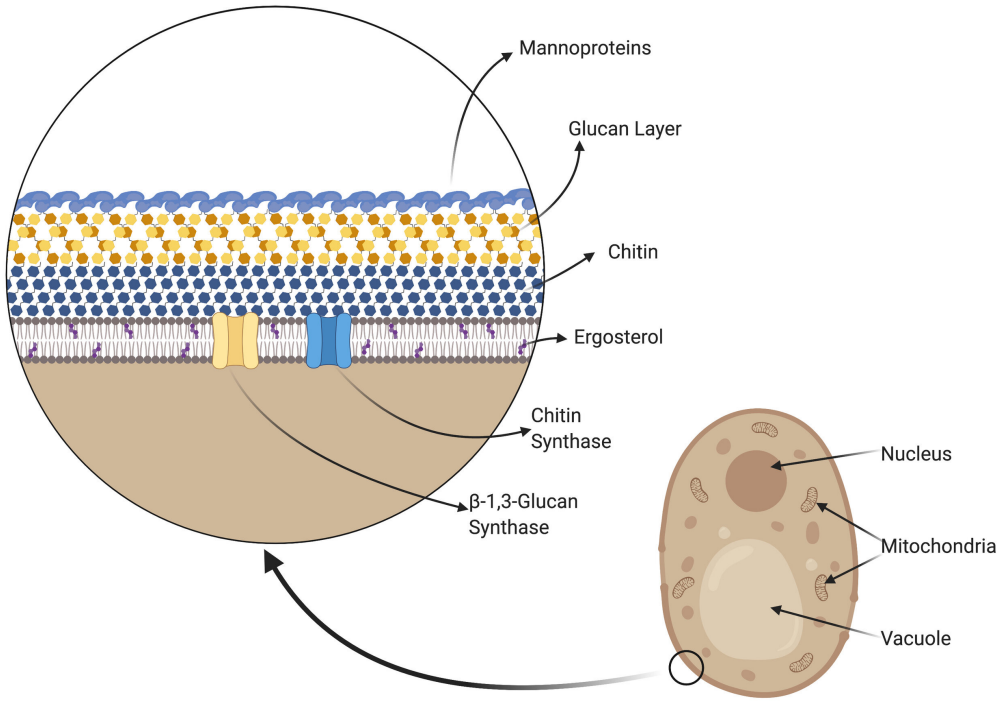
- Tough, flexible and sometimes rigid.
- Gives shape to fungi.
- Gives strength to fungi.
- Provides protection for the protoplasm from ultraviolet rays(presence of melanins).
- Ability to resist lysis by organic solvents such as enzymes, toxins, osmotic integrity.
- Ability to bind to metal ions.
- Secretes enzymes from their cell walls (invertase hydrolyses sucrose to glucose and fructose) and so assisting in nutrition.
- The main identifying characteristic of fungi is the makeup of their cell walls. Many contain a nitrogenous substance known as chitin which is not found in plants, but can be found in the exoskeletons of arthropods and insects.



CELL MEMBRANE

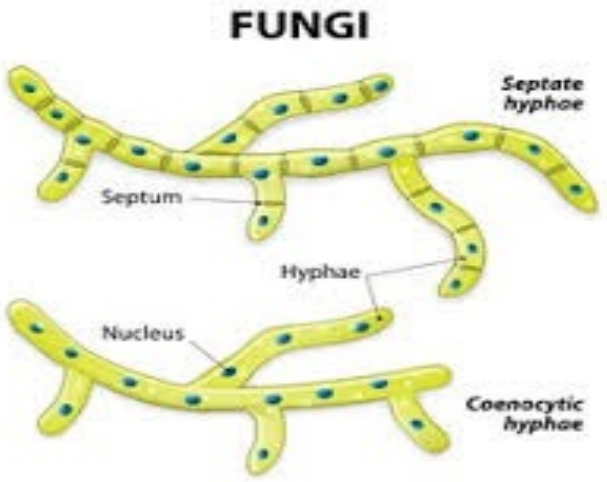
In fungi, the primary membrane sterol is ergosterol, which is unique in contrast to animals. There located various functional proteins, such as enzymes, proton pumps, and ion transporters, on the membrane surface, essential for cell permeability, signal transduction, and cell wall morphogenesis.

- Ergosterol is a sterol that resides on the cell membranes of fungi and acts to maintain cell membrane integrity, similar to mammalian cholesterol.
- Most of the current antifungal agents interfere with ergosterol function in some way, either through inhibition of various steps in ergosterol biosynthesis (allylamines, azoles, morpholines) or by complexing directly with membrane ergosterol (polyenes).
- Polyene antimycotic agents (amphotericin B, nystatin) are a subset of macrolide antibiotics that bind to ergosterol on the cell membranes of fungi. The bound drug molecules form a pore in the ergosterol which allows electrolytes and small molecules to leak out of the cell.
- Azole antifungals (fluconazole, itraconazole, ketoconazole) act to prevent the conversion of lanosterol to ergosterol. Without the protective layer of ergosterol, the cell membrane becomes permeable, leaking intracellular contents. Interestingly, the azoles have an antagonistic effect on the polyene antimycotics—they can only bind to ergosterol.

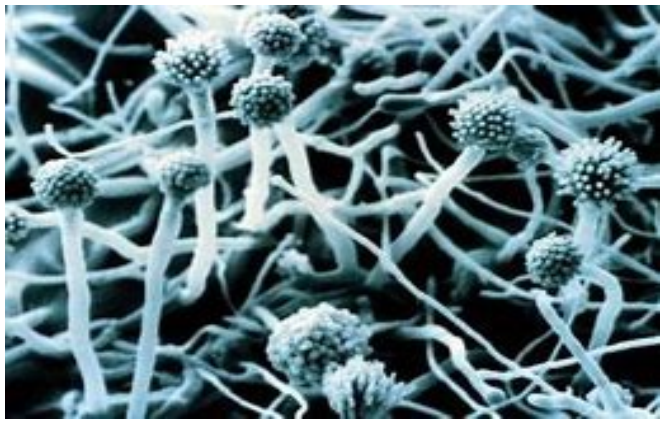


HYPHAE

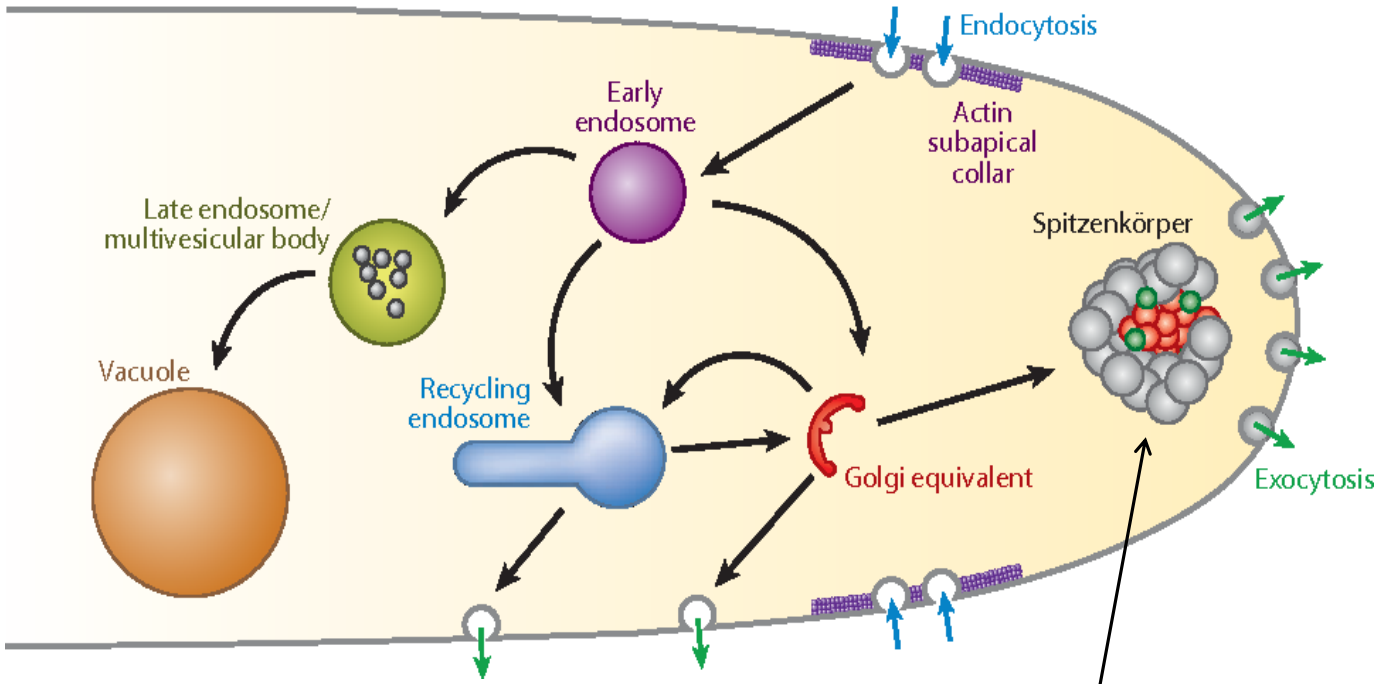
- Hyphae are comprised of hypha, which are the long filamentous branches found in fungi. Hyphae are important structures required for growth in these species, and together, are referred to as mycelium(tangled mass of hypahe)
- Each hypha is comprised of at least one cell encapsulated by a protective cell wall typically made of chitin, and contain internal septa, which serve to divide the cells. Septa are important as they allow cellular organelles (e.g., ribosomes) to pass between cells via large pores. However, not all species of fungi contain septa. The average hyphae are approximately 4 to 6 microns in size.
- Hyphae growth occurs by extending the cell walls and internal components from the tips. During tip growth, a specialized organelle called the spitzenkörper, assists in the formation of new cell wall and membrane structures by harboring vesicles derived from the golgi apparatus and releasing them along the apex of the hypha. As the spitzenkörper moves, the tip of the hypha is extended via the release of the vesicle contents, which form the cell wall, and the vesicle membranes, which create a new cell membrane. As the hypha extends, new septa can be created to internally divide the cells. The characteristic branching of hyphae is the result of the formation of a new tip from a hypha, or the division of a growing tip.



HYPHAE



MYCELIUM



Spitzenkörper

MORPHOLOGICAL CLASSIFICATION

1. Yeast – These occur in the form of round or oval bodies which reproduce by asexual process called budding in which cell develops can't protuberence which enlarges and eventually seperates from parent cell.

   Eg: Saccharomyces cerevesiae(used in production of bread and brewing)

2. Yeast like fungi – These type of fungi grow partly as yeast and partly as elongated cells resembling hyphae. The latter form pseudomycelium.

   Eg: Candida albicans

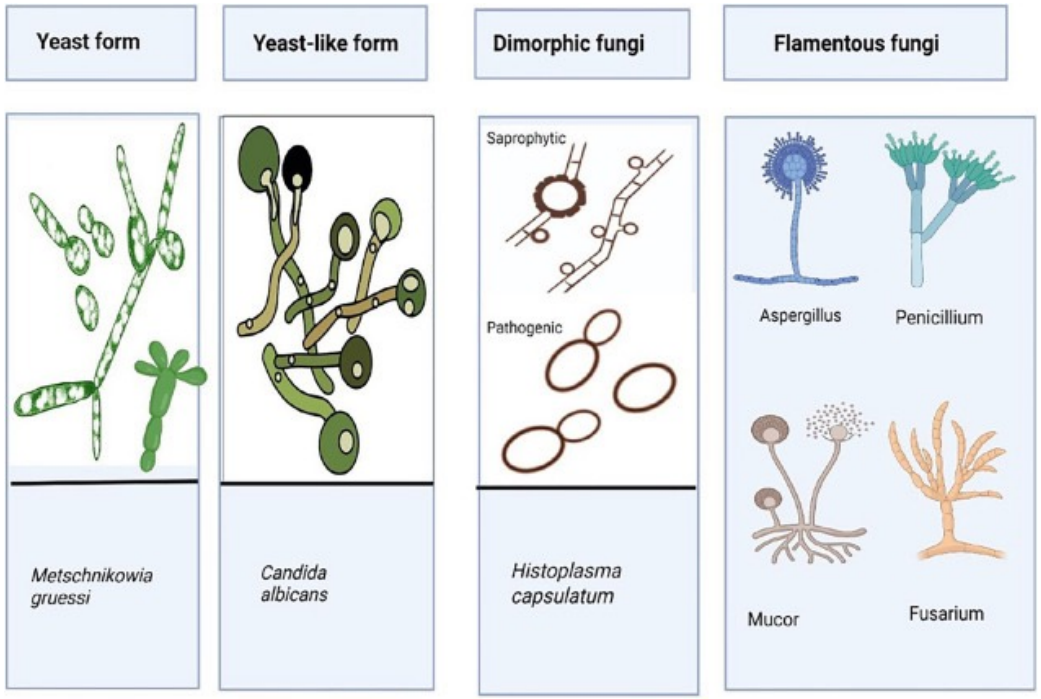
3. Dimorphic fungi – These fungi can exist in the form of both mold and yeast. This is usually brought about by change in temperature and the fungi are also described as thermally dimorphic fungi.

   Eg: Histoplasma capsulatum

4. Molds or filamentous fungi – They have long branching filaments or hyphae which interwine to produce a mass of filaments or mycelium. Their colonies are strongly adherent to the medium and unlike most bacterial colonies it cant be emulsified in water. They reproduce by the formation of different types of spores.

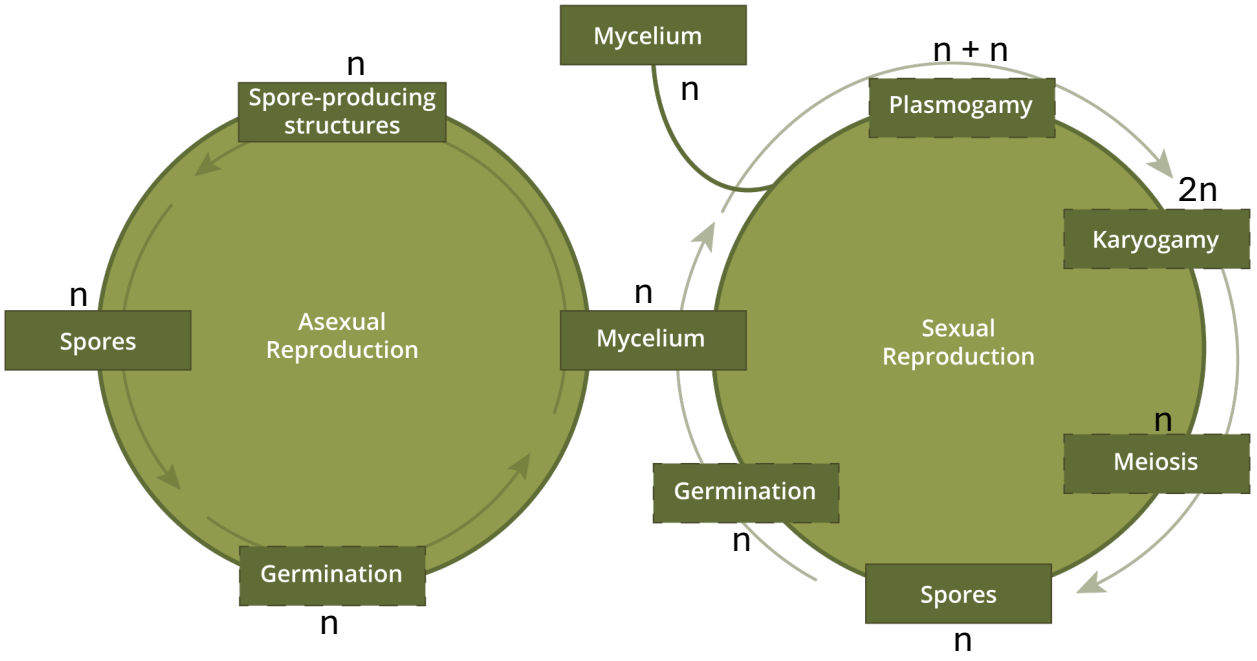
   Eg: Aspergillus(fermentation organism used for production of citric acid)

   Pencillium(source of antibiotic pencillin)



FUNGAL REPRODUCTION

- Fungi reproduce sexually and/or asexually.
- Perfect fungi reproduce both sexually and asexually, while imperfect fungi reproduce only asexually (by mitosis).
- In both sexual and asexual reproduction, fungi produce spores that disperse from the parent organism by either floating on the wind or hitching a ride on an animal. Fungal spores are smaller and lighter than plant seeds. The giant puffball mushroom bursts open and releases trillions of spores. The huge number of spores released increases the likelihood of landing in an environment that will support growth.

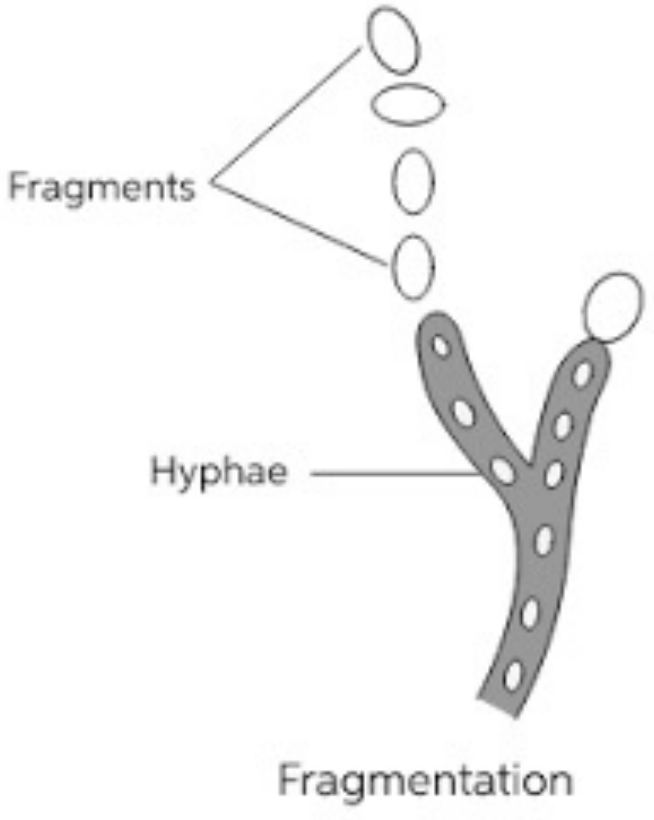


ASEXUAL REPRODUCTION

- Fungi reproduce asexually by:

1. Fragmentation
2. Budding
3. Producing spores

❖ Fragmentation : Fragmentation is seen in various types of fungi such as molds, yeasts, mushrooms. They do reproduction by fragmentation using a specific type of structure called hyphae. Hyphae can be defined as each of the branching filaments that make up the mycelium of a fungus. It is branched portion of parent fungi body and they can easily get rid of it. During the life cycle of hyphae, the obtain food and other nutrients from the parent fungal body. By doing this, hyphae eventually grow and become mature, and ultimately, they become ready for fertilization. Now a piece of hyphae breaks off from the parent body and enters into a growth phase as an individual body. Eventually they also mature and grow hyphae and this way the cycle continues.



❖ Budding : Budding, which is another method of asexual reproduction, occurs in most yeasts and in some filamentous fungi.

- In this process, a bud develops on the surface of either the yeast cell or the hypha, with the cytoplasm of the bud being continuous with that of the parent cell.
- The nucleus of the parent cell then divides; one of the daughter nuclei migrates into the bud, and the other remains in the parent cell.
- The parent cell is capable of producing many buds over its surface by continuous synthesis of cytoplasm and repeated nuclear divisions. After a bud develops to a certain point and even before it is severed from the parent cell, it is itself capable of budding by the same process.
- In this way, a chain of cells may be produced. Eventually, the individual buds pinch off the parent cell and become individual yeast cells.
- Buds that are pinched off a hypha of a filamentous fungus behave as spores; that is, they germinate, each giving rise to a structure called a germ tube, which develops into a new hypha

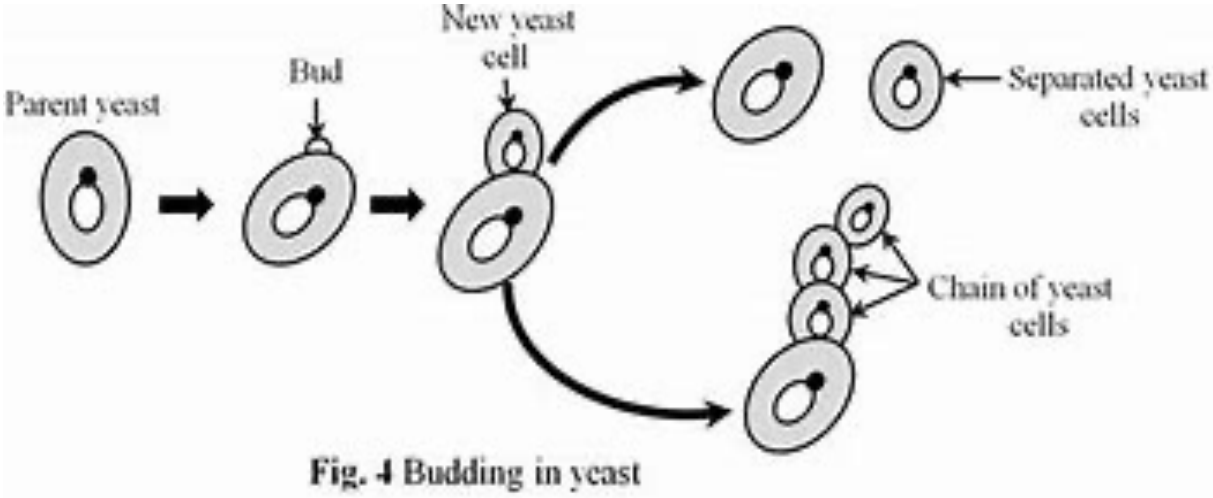


Fig. 4 Budding in yeast

❖ Spore formation : Spore formation is the characteristic feature of fungi.

- Different fungi forms different types of spore.
- Asexual spores in fungi can be of:

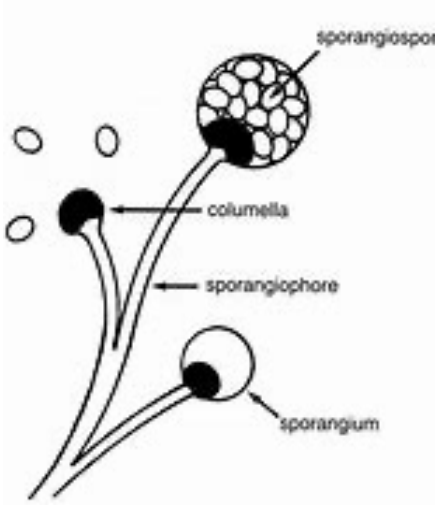
1. Sporangiospore:
   - This is a type of aerial spore.
   - These asexual spore are produced in a sac like structure called sporangia (singular;saprangium).
- Sporangium are produced at the end of special aerial hyphae called sporangiophore.
- Sporangium contains large numbers of haploid spores, which are released by rapture of

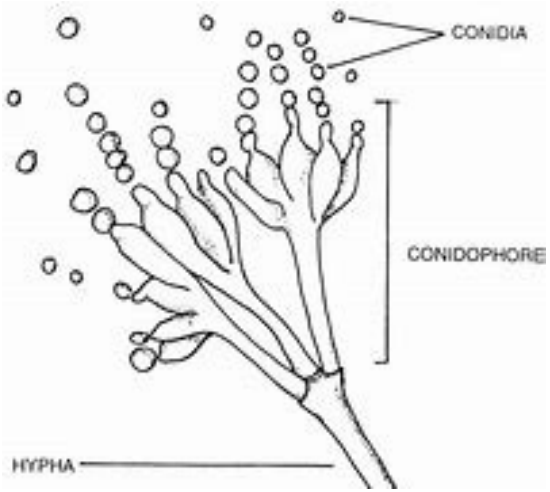
  sporangial wall

  Examples: *Rhizopus*

2. Conidiospore:
   - Type of aerial spore found in fungi.
- Conidiospore or conidia are single celled, bicelled or multicelled structure born on the tip or side of aerial hyphal structure called conidiophore
- Conidia are different from sporangiospore as these are not produced inside sporangium or any sac like structure.
- Conidia are born singly or in chain

  Examples: *Penicillium, Apergillus*

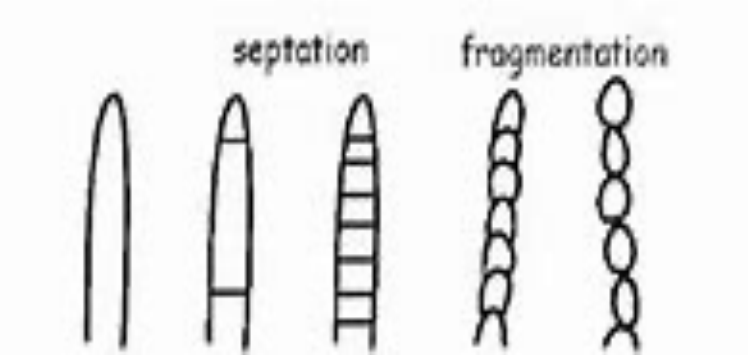




3. Arthrospore:

- They are a type of asexual vegetative spore in fungi.

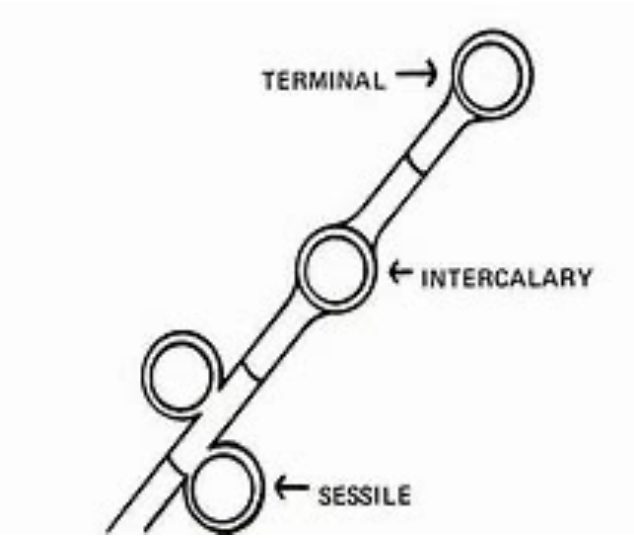
- Arthrospore are very primitive type of spore formed by the breaking up of fungal mycelium
- A spore is formed by separation followed by fragmentation of hyphae
- Examples: *Trichosporium, Geotrichum, Coccididious imitis*



4. Chlamydospore:

- A type of vegetative spore.

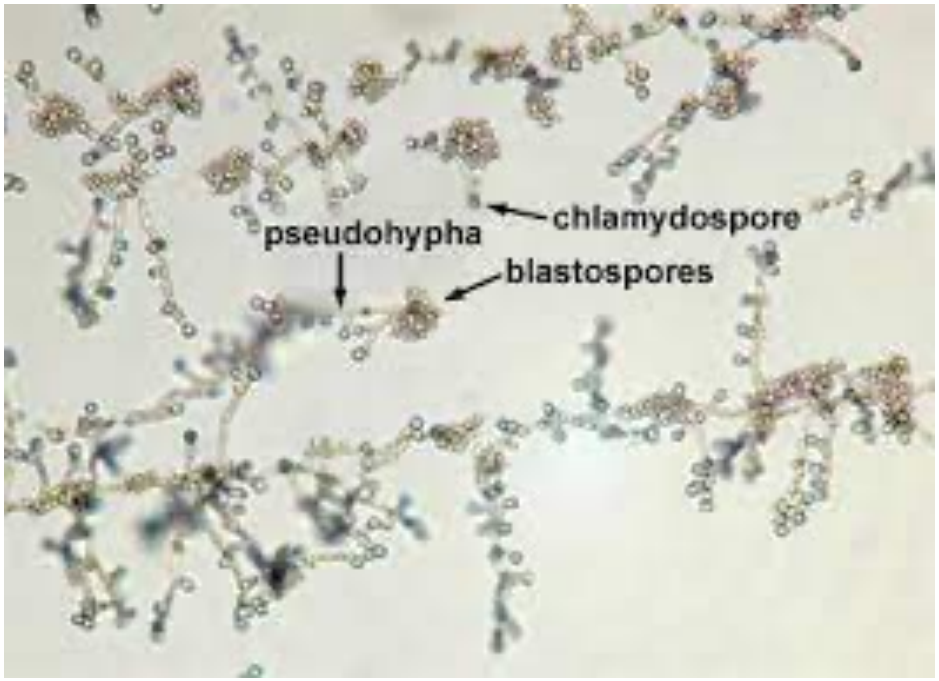
- These are usually formed during unfavorable condition and are thick walled single celled spore, which are highly resistant to adverse condition.
- Hyphal cell or portion of hyphae contracts, loose water, round up and develops into thick walled chalmydospore.
- When favorable condition returns, each chlamydospore give rise to a new individual fungi.
- Examples: ascomycetes, basidiomycetes, zygomycetes,
- *Histoplasma capsulatum, Candida albicans*



5. Blastospore:

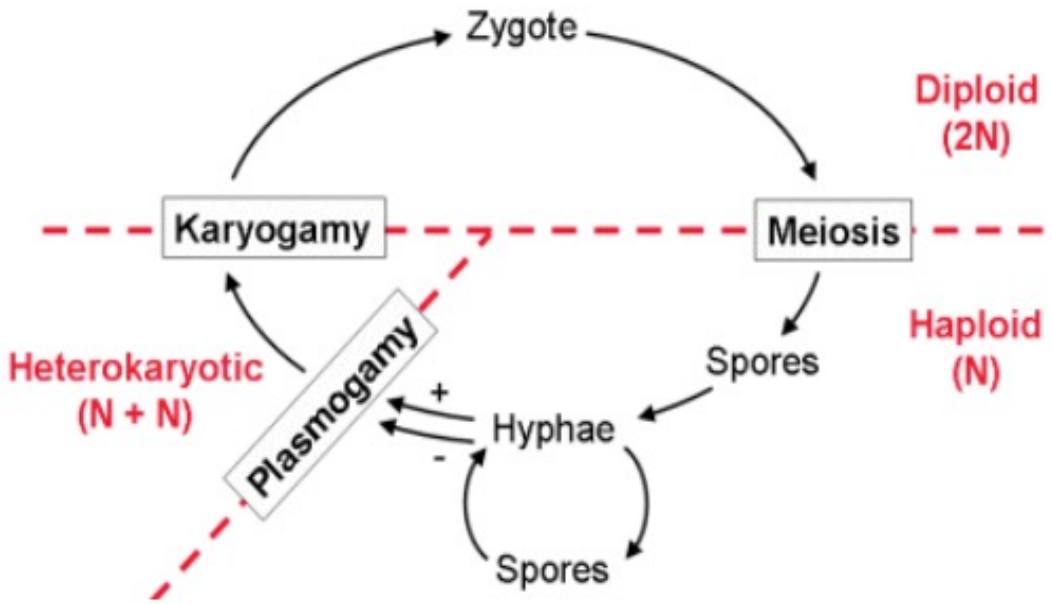
- A type of vegetative spore.

- It is a budding spores usually formed at the terminal end of hyphae.
- These spore may remains attached to hyphae and bud further to gibe branching chain of blastospores.
- Examples: ascomycetes, basidiomycetes, zygomycetes
- *Candida albicans*



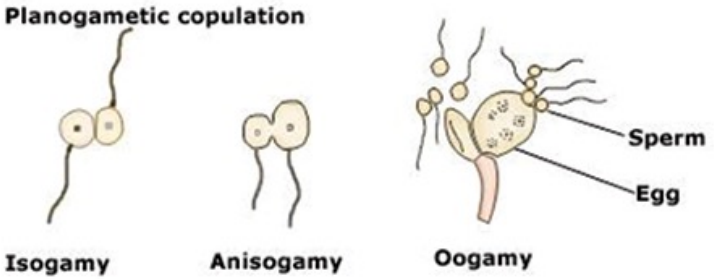
SEXUAL REPRODUCTION

- Sexual reproduction is carried out by diffusion of compatable nuclei from two parent at a definite state in the life cycle of fungi.
- The process of sexual reproduction involves three phases:
  - Plasmogamy: fusion of protoplasm
  - Karyogamy: fusion of nucleus
  - Meiosis: reductional nuclear division
- Various methods by which compatible nuclei are brought together in plasmogamy. Some are:
  1. Gametic copulation
  2. Gamete- gametangial copulation
  3. Gametangial copulation
  4. Somatic copulation
  5. Spermatization



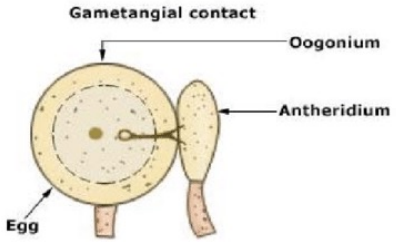
1. Planogametic copulation:

- Fusion of two naked gametes, one or both of them are motile
  - Isogamous – gamates of similar morphology.
  - Anisogamous – Fusion of two games which differ in size or form.
  - Oogamous – Small motile male gamate and large immobile female gamate.



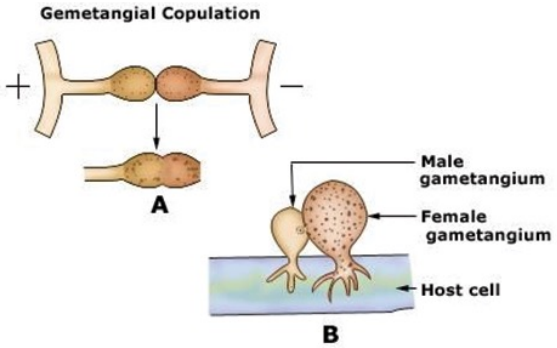
2. Gamete-gametangial copulation:

- Male and female gametangia (organ or cell in which gamates are formed) comes into contact but do not fuse.
- A fertilization tube formed from where male gametangium enters the female gametangium and male gamate passes through this tube.



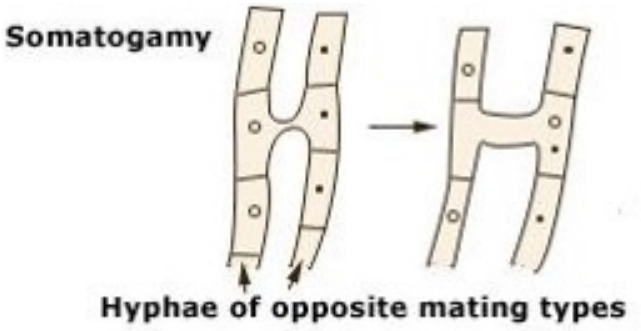
3. Gametangial copulation;

- Two gametangia or their protoplast fuse and give rise to zygospore



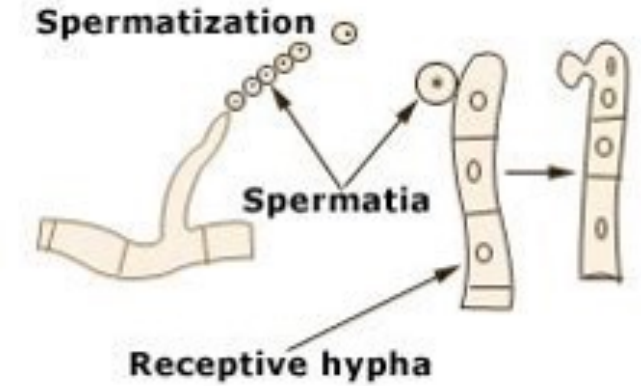
4. Somatic copulation:

- Also known as somatogamy.
- In this process fusion of somatic cell (cells except sperm and egg cells) occurs
- This sexual fusion of undifferentiated vegetative cell results in dikaryotic hyphae, so the process is also called dikarotization



5. Spermetization:

- It is an union of special male structure called spertatium with a female receptive structure.
- Spermatium empties its content into receptive hyphae during plasmogamy.

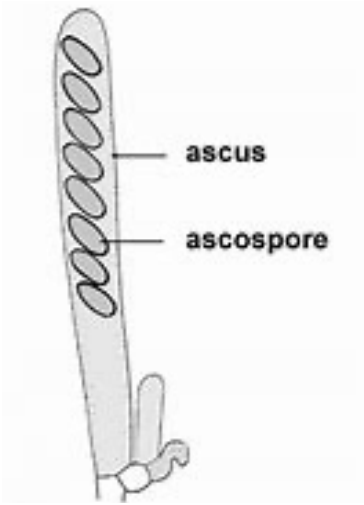


SEXUAL SPORES

- As a result of sexual reproduction sexual sores are produced.
- Sexual spores are fewer in number than asexual spores.
- Sexual spores in fungi can be of :

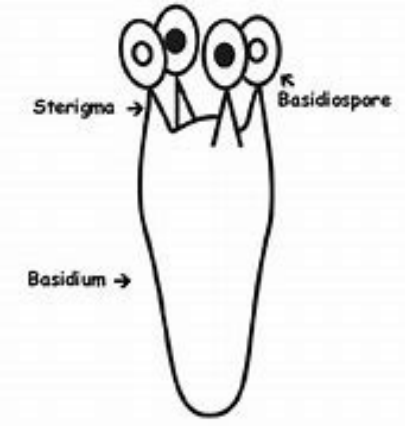
1. Ascospore:

- It is usually single celled produced in a sac called ascus (plural;asci) and usually there are 4-8 ascospore in an ascus but the number may vary from species to species
- The ascospore are usually arranged in a linear order. In some case ascospores are long, narrow and are arranged in parallel order.



2. Basidiospore:

- It is a reproductive spore produced by basidiomycetes.
- This single celled spores are born in a club shaped structure called basidium
- These basidiospore aerves as main air dispersal unit for the fungi.

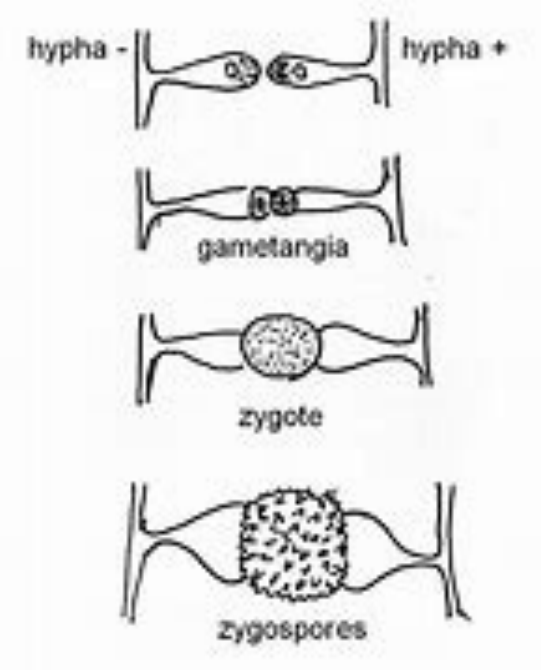


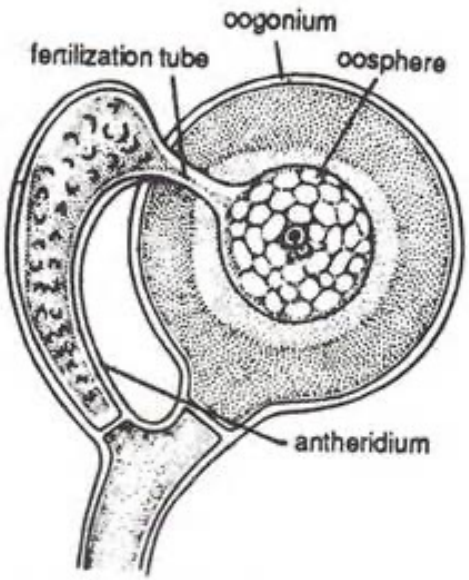
3. Zygospore:

- Zygospores are thick walled spores formed when two sexually compatible hyphae or gametangia of certain fungi fuse together.
- In suitable condition, zygospore germinates to produce a single vertical hyphae which forms a aporangium and releases its spores.

4. Oospore:

- These are formed within a special female structure called Oogonium.
- Fertilization of egg by male gamete in female sex organ give rise to oospoes.
- There are one or more oospores in each oogonium.





Fungal states

- **Teleomorph**: the sexual reproductive stage (morph),***Emericella nidulans***.

- **Anamorph**: an asexual reproductive stage (morph), often mold-like (e.g. *Aspergillus nidulans* .

- **Holomorph**: the whole fungus, including all anamorphs and the teleomorph.

Homothallic fungi

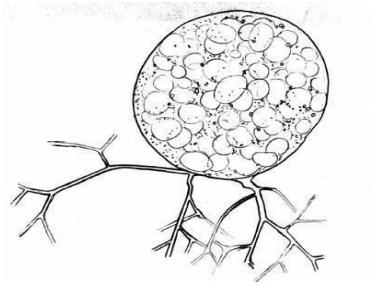
- possess both male and female nuclei derived from the same thallus for sexual reproduction. They do not need a partner for sexual reproduction. This is a form of self-fertilization or selling. Homothallism is a common condition in fungi . it causes reduced genetic variability.
- Self – fertile fungi

Heterothallic fungi

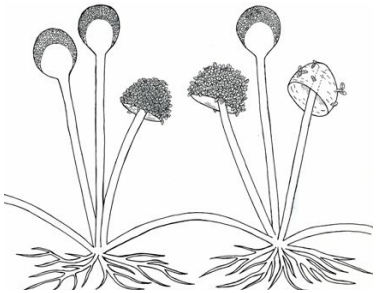
- are the fungal strains which bear one type of mating type. They are unisexual in nature. Sexual reproduction of heterothallic fungi occurs between two different compatible mycelia. the genetic variation within the populations is high.
- Self – sterile fungi.

TYPES OF FUNGI

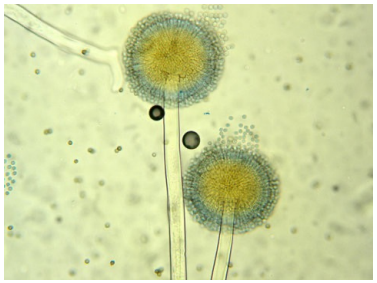
- There are mainly five types of fungi
  * Chytridiomycota
  * Zygomycota
  * Ascomycota
  * Basidiomycota
  * Deuteromycota



Chytridiomycota



Zygomycota



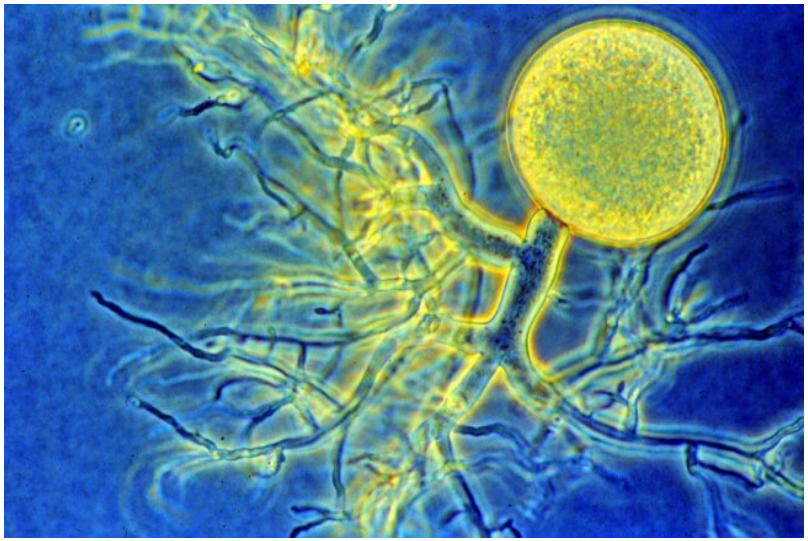
Deuteromycota

Ascomycota

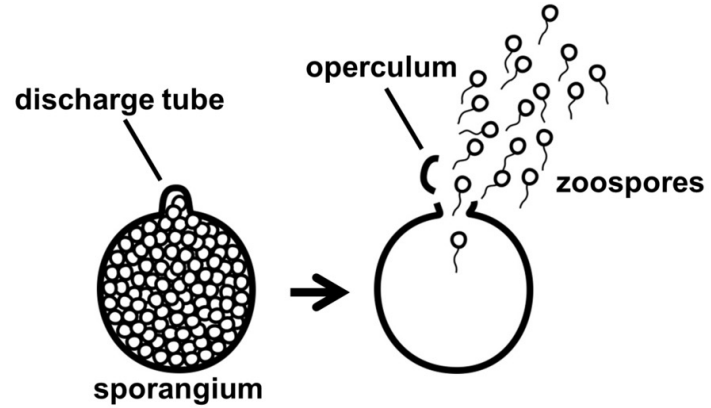
Basidiomycota

Phylum Chytridiomycota

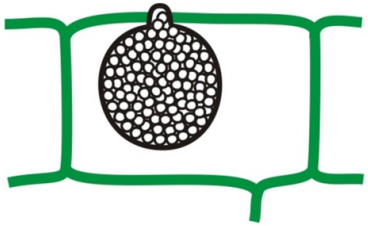
- Earliest fungal phlyum to diverge
- Relatively simple; most unicellular
- ONLY FUNGI with flagellated cells
- Most have no sexual reproduction
- Most decomposers; few cause disease
- Some species are saprotrophic; others are parasites of plants, animals, algae and other fungi



Dead frog with chytridiomycosis

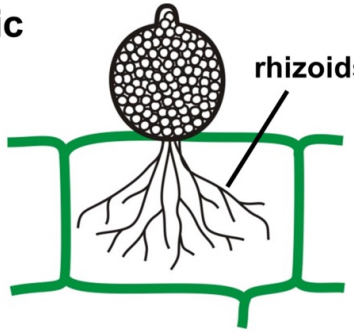


holocarpic

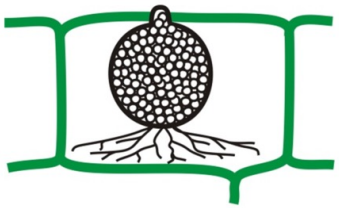


eucarpic monocentric

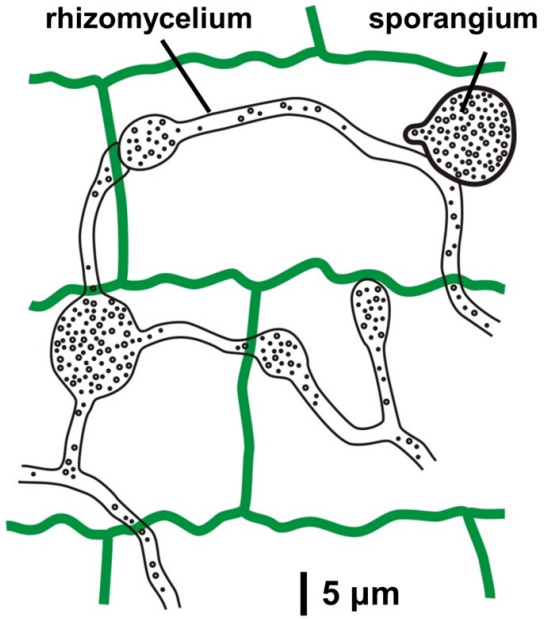
epibiotic



endobiotic

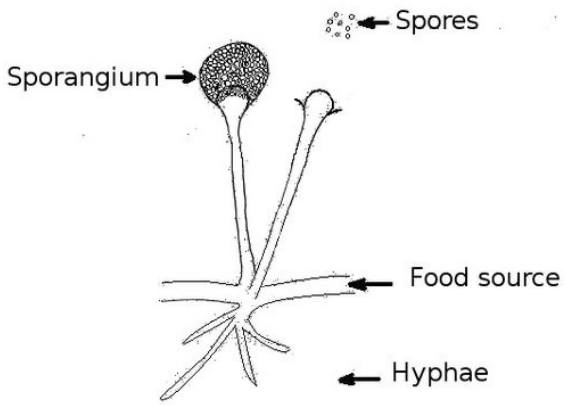


eucarpic polycentric



Phylum Zygomycota: The Conjugation Fungi

The Zygomycota, or conjugation fungi, include molds, such as those that invade breads and other food products. The identifying characteristics of the Zygomycota are the formation of a zygospore during sexual reproduction and the lack of hyphal cell walls (non-septate or coenocytic hypha) except in reproductive structures. Many (~100 species) are known plant root symbionts

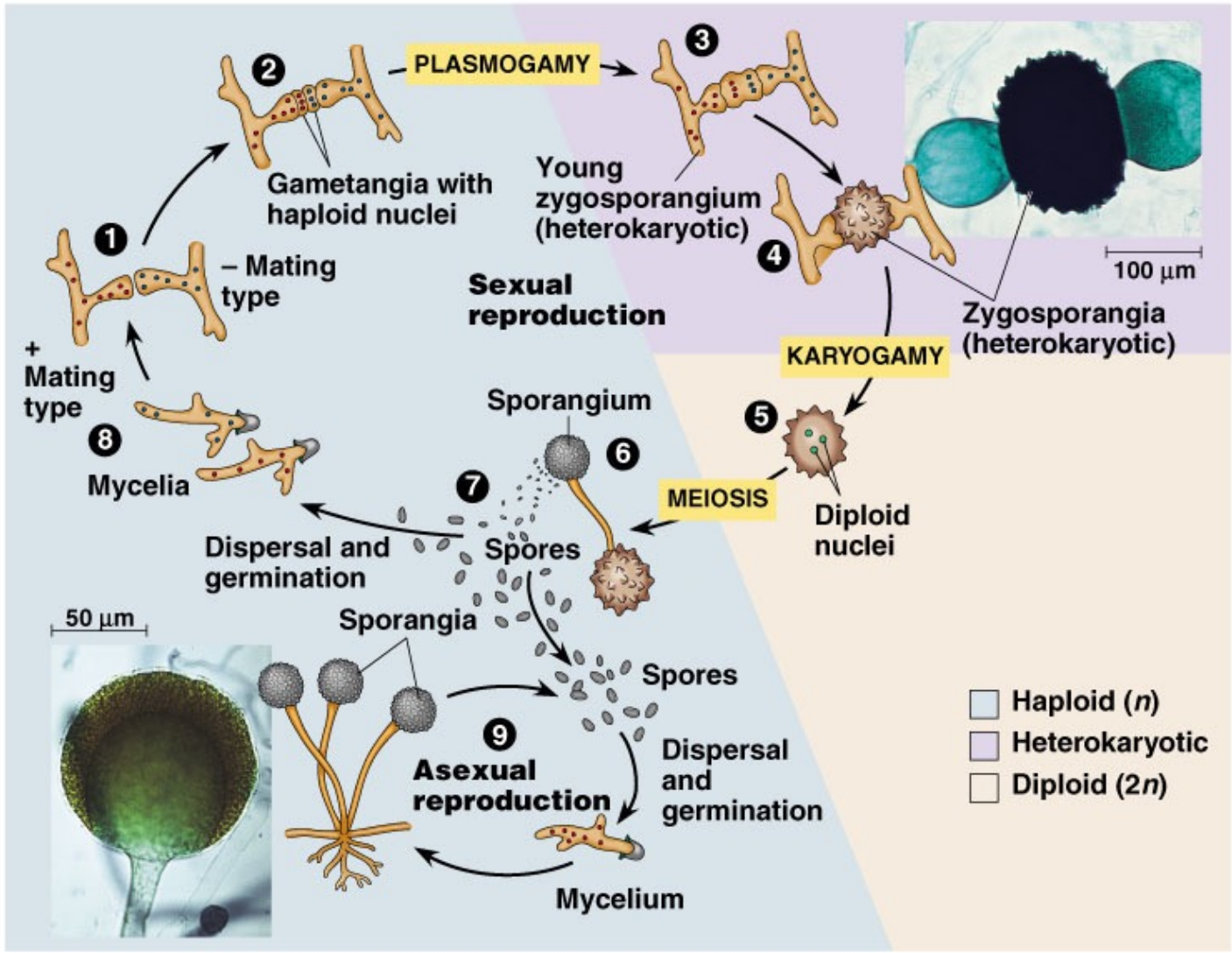


- several species of zygomycota cause serious human infections and animals
- They are being increasingly used in the biological control of insect pests of crops.

Rhinocerebral zygomycosis (disease)

- Sexual Reproduction - zygosporangia
- Asexual reproduction– by common (sporangia – bags of asexual spores)

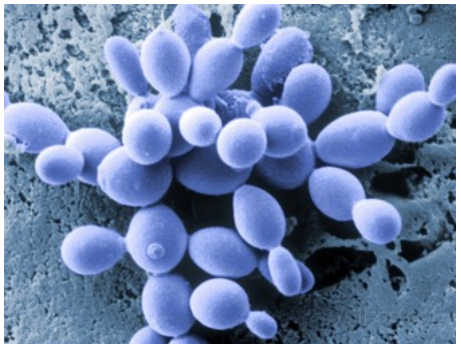
Zygomycosis

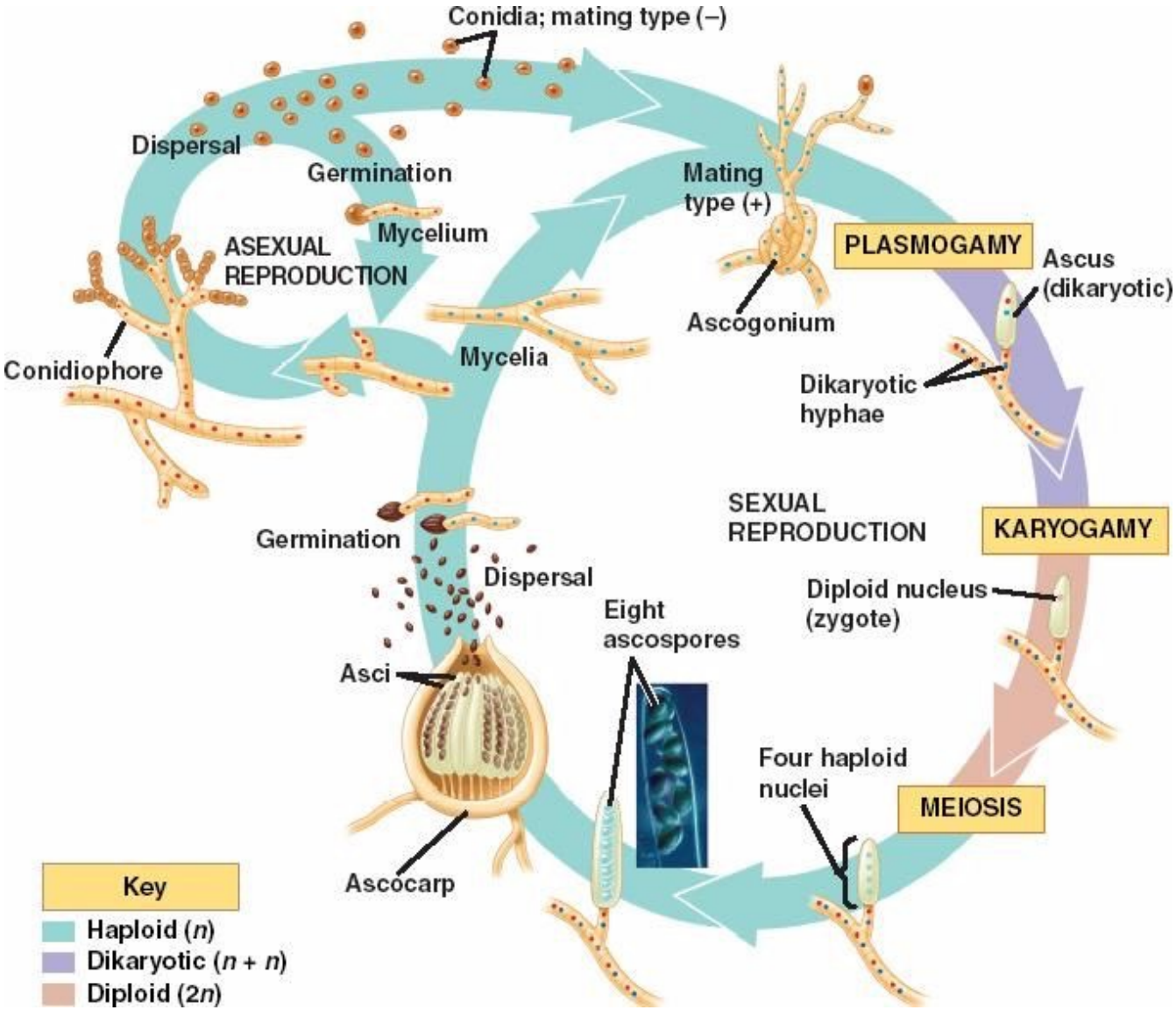


Phylum Ascomycota

"sac fungi" or "cup fungi"

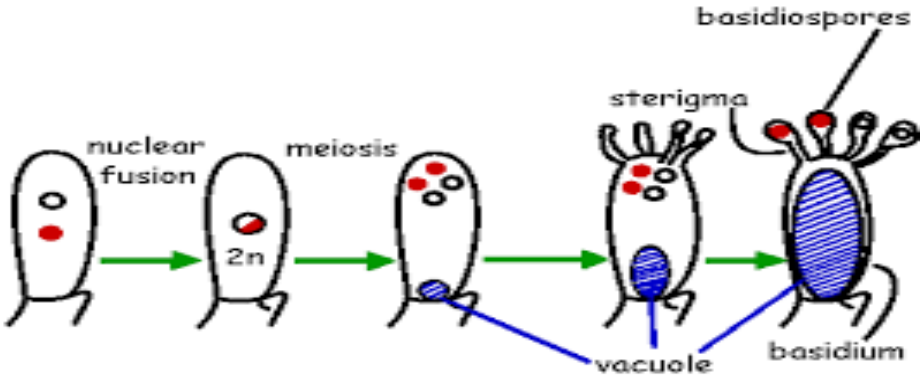
- Includes yeasts, powdery mildews, molds
- Hyphae with perforated septa
- Asexual reproduction by conidiophores
- The Ascomycota are morphologically diverse. The group includes organisms from unicellular yeasts to complex cup fungi.
- Characterized by:
- First, they can produce conidiophores for asexual reproduction.
- Secondly, ascomycota produce structures for sexual reproduction called Asci.
- There are many famous and infamous organisms: *Saccharomyces cervisiae* (baker's yeast), *Penicillium chrysogenum* (penicillin), *Morchella esculenta* (morels), *Neurospora crassa*,
- Used in genetic studies and molecular studies *Aspergillus flavus* (aflatoxin and ochratoxin). *Claviceps purpurea* (Ergot)

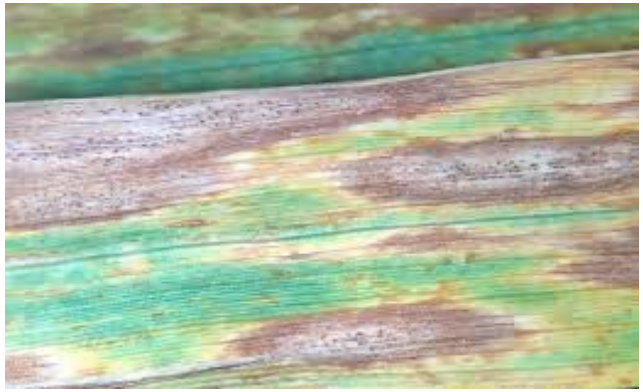


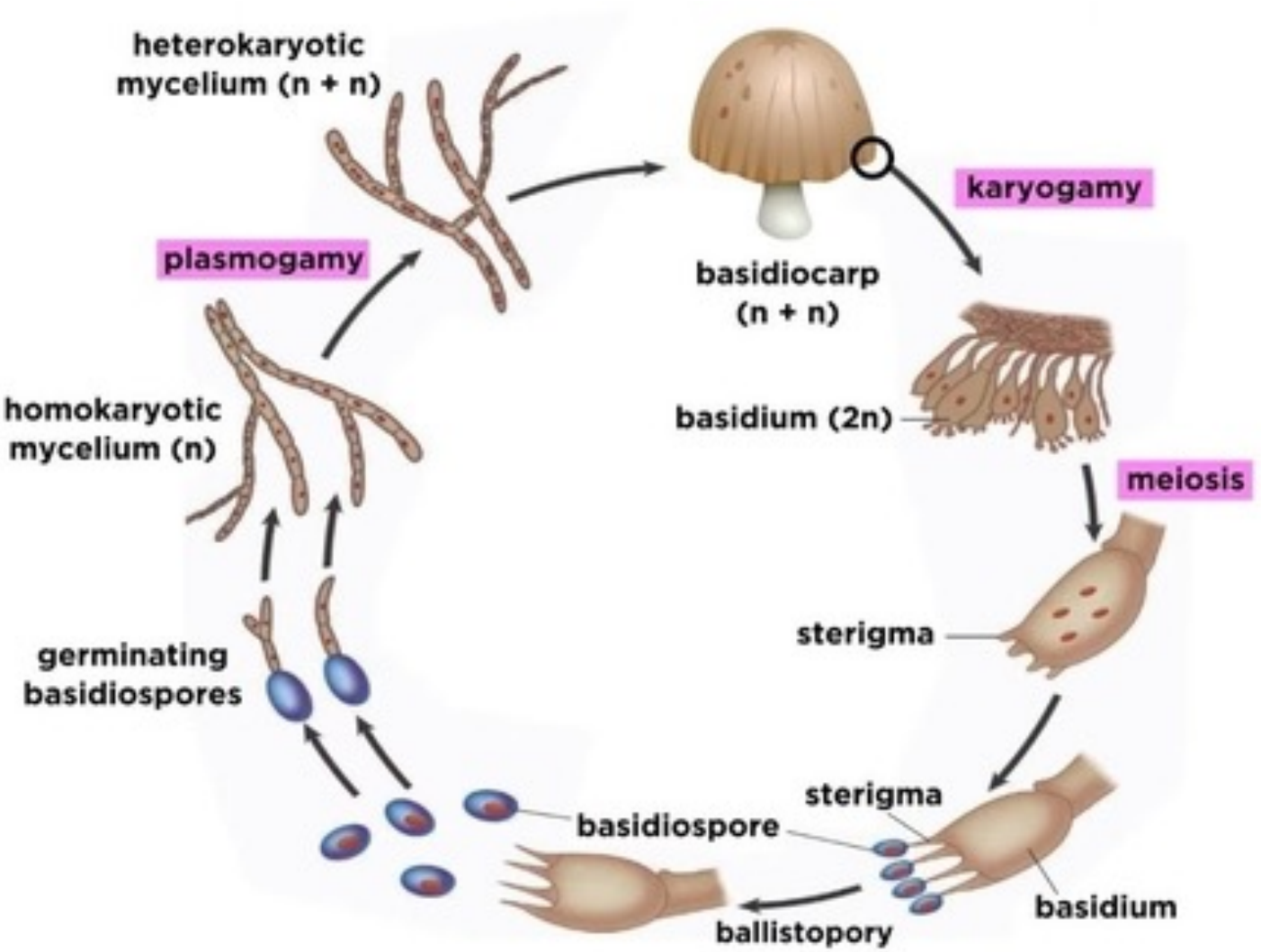

Conidia; mating type (–)
Dispersal
Germination
Mycelium
ASEXUAL REPRODUCTION
Conidiophore
Mycelia
Mating type (+)
Ascogonium
PLASMOGAMY
Ascus (dikaryotic)
Dikaryotic hyphae
SEXUAL REPRODUCTION
KARYOGAMY
Diploid nucleus (zygote)
MEIOSIS
Four haploid nuclei
Eight ascospores
Germination
Dispersal
Asci
Ascocarp
Key
Haploid (n)
Dikaryotic (n + n)
Diploid (2n)

Phylum Basidiomycota

- Also called “club fungi”
- Mushrooms, bracket fungi, puffballs
- The members include rusts, smuts, mushrooms, puff balls, toad stools, bracket fungi etc.
- Basidiospores are developed exogenously on the horn-shaped structure, called sterigmata (generally 4) on the Basidium






heterokaryotic
mycelium (n + n)
karyogamy
basidiocarp
(n + n)
basidium (2n)
meiosis
sterigma
sterigma
basidiospore
basidium
ballistopory
germinating
basidiospores
homokaryotic
mycelium (n)
plasmogamy

Examples of Phylum Basidiomycota

Orange Jelly

Pigskin Poison Puffball

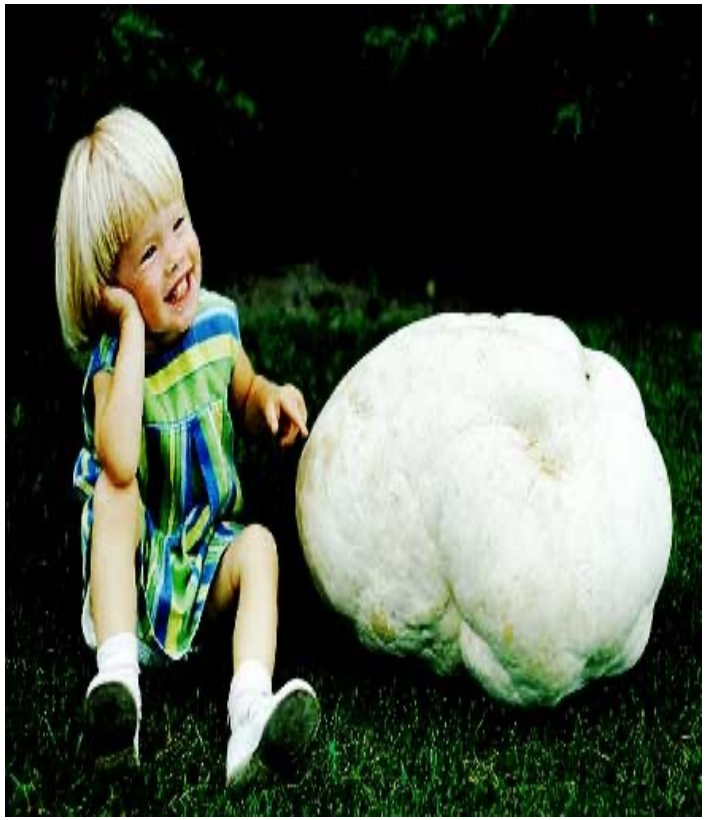
Fly Agaric

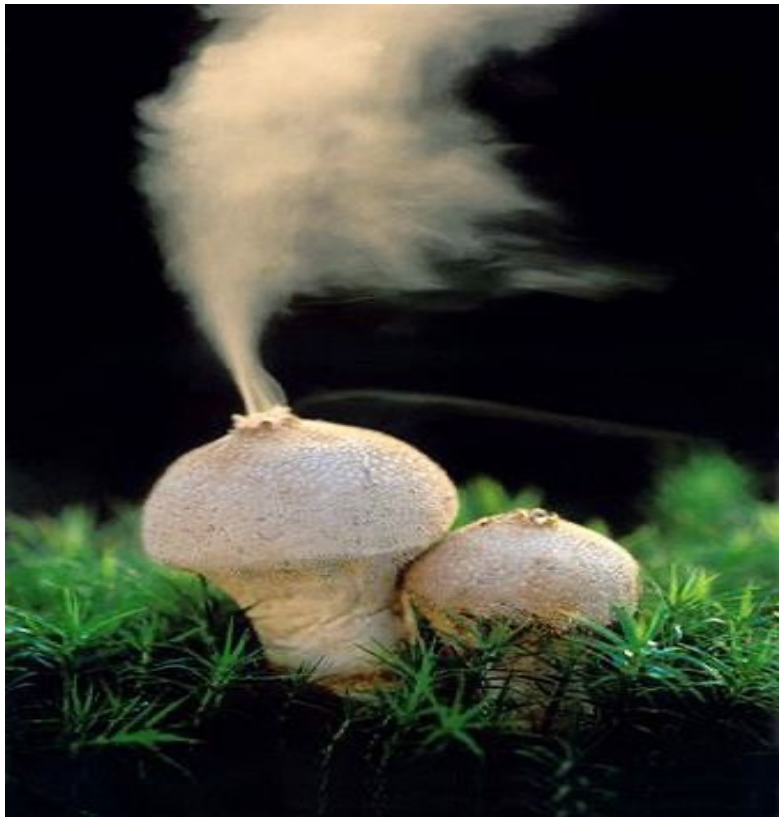
Bird's Nest Fungus

Star Stinkhorn

Shelf Fungus

Fairy Ring





- Basidiomycota play a significant role in the carbon cycle. Unfortunately, Other Basidiomycota cause diseases in animals, including humans. Basidiomycota frequently attack the wood in buildings and other structures, which has negative economic consequences for humans.

PHYLUM DEUTEROMYCOTA

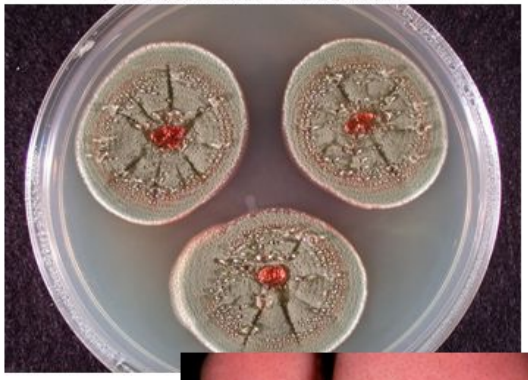
No Longer Exist!!

- 22,000 species.
- No known sexual stage.
- Saprophytic, parasitic and predatory.
- Many produce conidia.
- Most classified as Ascomycota.
- *Fusarium* wilt of tomato, potato and cotton.
- Athletes foot, ring worm
- Imperfect fungi

(*Penicillium* sp. *and Aspergillus* sp.)

Examples of Phylum Deuteromycota

Penicillium notatum



Ringworm

Athlete's Foot

FUNGI AND FOOD SPOILAGE

- Fungi have been seen as a method of food spoilage, causing only an undesirable appearance to food, however, there has been significant evidence of various fungi being a cause of death of many people spanning across hundreds of years in many places through the world. Fungi are caused by acidifying, fermenting, discoloring and disintegrating processes and can create fuzz, powder and slimes of many different colors, including black, white, red, brown and green.
- Mold is a type of fungus, but the two terms are not reciprocal of each other; they have their own defining features and perform their own tasks. Very well known types of mold are Aspergillus and Penicillium, and, like regular fungi, create a fuzz, powder and slime of various colors.
- *Yeast* is also a type of fungus that grows vegetatively via single cells that either bud or divide by way of fission, allowing for yeast to multiply in liquid environments favoring the dissemination of single celled microorganisms. Yeast forms mainly in liquid environments and anaerobic conditions, but being single celled, it oftentimes cannot spread on or into solid surfaces where other fungus flourish. Yeast also produces spoilage at a slower rate than bacteria.
- Yeasts can be responsible for the decomposition of food with a high sugar content. The same effect is useful in the production of various types of food and beverages, such as bread, yogurt, cider, and alcoholic beverages.
- Signs of food spoilage may include an appearance different from the food in its fresh form, such as a change in color, a change in texture, an unpleasant odour, or an undesirable taste. The item may become softer than normal. If mold occurs, it is often visible externally on the item.

THANK YOU