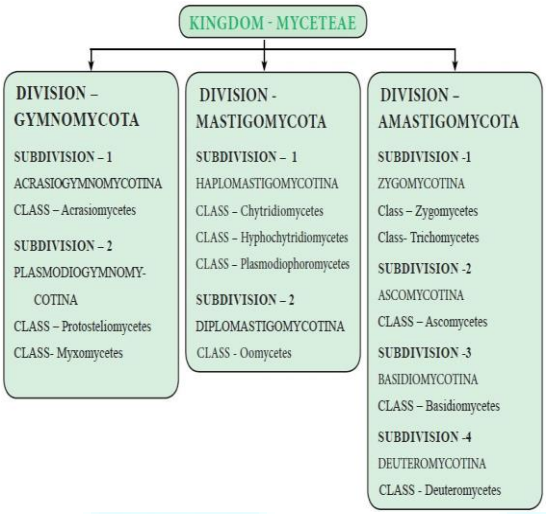
MYCOLOGY

CLASSIFICATION OF FUNGI

1. ALEXOPOULOS AND MIMS CLASSIFICATION OF FUNGI – 1979



- C. J. Alexopoulos and C. W. Mims (1979) placed fungi and slime molds under the kingdom of their own, called Myceteae under the superkingdom Eukaryonta.
- The kingdom is divided into three divisions and further the divisions are divided into sub-division, class and form-class.

Kingdom. Myceteae (Fungi):

- Achlorophyllous, saprobic or parasitic organisms.
- With unicellular or more typically, filamentous soma (thallus),

- Usually surrounded by cell walls that characteristically consists of chitin and other complex carbohydrates, nutrition absorptive, except in the slime molds

(Division Gymno- mycota)

- It is phagotrophic.
- Propagation typically by means of spores produced by various types of sporophores.
- Asexual and sexual reproduction usually present.
- They divide the kingdom mycetae into three divisions namely:

1. Gymnomycota
2. Mastigomycota and
3. Amastigomycota

Division 1- Gymnomycota:

- Phagotrophic organisms with somatic structures devoid of cell walls.
- This division comprises two subdivisions.

a) Acrasiogymnomycotina and
b) Plasmodiogynomycotina.

Subdivision 1. Acrasiogymnomycotina

- It includes a single class Acrasiomycetes.
- Class 1. Acrasiomycetes
    - Lacks flagellated cells except for one species.
    - The class comprises two subclasses.

a) Acrasiomycetidae
b) Dictyosteliomycetidae

Subdivision 2. Plasmodiogymnomycotina

- It is divided into two classes:
  - Class 1 Protosteliomycetes
  - Class 2 Mycomycetes
- It includes the true slime mould and comprises three sub classes namely:

  - Sub class 1. Ceratiomyxomycomycetidae
    - Order – Ceratiomyxales
  - Sub Class 2. Mycogasteomycetidae

    It comprises four orders.

1. Liceales
2. Echinosteleales
3. Trichlales
4. Physarales

Sub Class 3. Stemonitomycetidae

Order 1. Stemonitales

Division 2. Mastigomycota

Fungi with

- Centrioles.
- Flagellate cells typically produced during the life cycle.

- Nutrition typically absorptive.
- varying from unicellular that becomes converted into a sporangium, to an extensive, filamentous, coenocytic mycelium.
- Asexual reproduction typically by zoospores.
- Sexual reproduction by various means.

Sub division 1 Haplomastigomycotina

- Includes fungi with uni-orbi-flagellate zoospores.

Class 1 Chytridiomycetes– Fungi producing zoospores furnished with a single whiplash flagellum inserted at the posterior end.

Class 2 Hyphochytridiomycetes- Motile cells with a single tinsel flagellum inserted at the anterior end.

Class 3 Plasmodiophoromycetes- Parasitic fungi producing biflagellate motile cells with both the flagella of whiplash type inserted at the anterior end.

Sub division 2. Diplomastigomycotima

- Sexual reproduction ooagamous, zoospores biflagellate.
- **Class 1 Oomycetes** – It comprises four orders:
  - Order 1 Lagenidiales
  - Order 2 Saprolegnailes
  - Order 3. Leptomitales
  - Order 4. Peronosporale

Division 3- Amastigomycota

- Fungi without centriole,

- No motile cells.
- Nutrition absorp¬tive.
- Single-celled to mycelial with a limited or extensive, septate or aseptate mycelium.
- Asexual reproduction by budding, fragmen¬tation, sporangiospores or conidia.
- Sexual reproduction, where known by various means; haplobiontic-haploid life cycle with zygotic meiosis.
- This includes four sub divisions.
  - Sub division 1 Zygomycotina
  - Class 1 Zygomycetes – it includes six orders.
  - Class 2 Trichomycetes – it comprises five orders.
  - Sub division 2- Ascomycotina

Fungi usually with a septate mycelium producing haploid ascospores in sac like cells called asci.

Class 1 Ascomycetes- divided into five sub classes:

- Sub class 1. Hemiascomycetidae- comprising three orders.
- Sub class 2. Plectomycetidae- Five orders
- Sub class 3. Hymenoascomycetidae – Ten orders
- Sub class 4 Laboulbeniomycetidae – Two orders
- Sub class 5 Lowloascomycetidae – five orders

Sub division 3- Basidiomycotina

- Septate mycelium,
- produces basidiospores exogenously on various types of basidia.

Class 1 Basidiomycetes: it is split into 3 sub clases:

Sub class 1 Holobasidiomycetidae

Sub class 2 Phragmobasidiomycetidae

Sub class 3 Teliomycetidae

Sub division 4-Deuteromycotina

- It includes imperfect fungi in which sexual stage is unknown.
- It comprises a single form class.
- Form Class Deuteromycetes with three form sub classes namely

a) Blastomycetidae,
b) Coelomycetidae and
c) Hyphomycetidae

2. AINSWORTH & BISBY'S CLASSIFICATION OF FUNGI

- 7 Phyla
- 10 Subphyla
- 35 Classws
- 12 Subclasses
- 129 Orders

PHYLUM

1. **Chytridiomycota**

2. **Neocallimastigomycota**
3. **Blastocladiomycota**
4. **Microsporidia**
5. **Glomeromycota**
6. **Ascomycota**
7. **Basidiomycota**

Ainsworth & Bisby- 1971

Division- Gymnomycota

Division- Eumycota

Sub div- Mastigomycotina

Class- Oomycetes

Class- Chytridiomycetes

Sub div- Zygomycotina

Sub div- Ascomycotina

Sub div- Basidiomycotin

Sub div- Deuteromycotina

GENERAL FEATURES OF FUNGI

- Study fungi is known as mycology.
- The word mycology comes from the Greek word mykes which means "mushroom" and logos means "discourse".
- They are cosmopolitan in distribution.

NUTRITION OF FUNGI

- Fungi don't produce their food by own because they lack chlorophyll.
- Based on the type of source fungi are classified into 3 groups

1. **Saprotrophtic**

    - Saprotrophs get their nutrition from dead and decaying organic matter by releasing digestive enzymes which digest the substratum and then absorb nutrients.
    - Example: *Mucor, Agarious. Rhizopus* (bread mould) etc.

2. **Parasitic**

- Parasitic fungi get their nutrients from living cells.
- They can be facultative or obligate.
- They grow on the host cell surface and absorb nutrients through haustoria.
- e.g., *Ustilago, Pythium, Puccinia, Mucor, Erisphae*

3. **Symbiotic**

    - Fungi can be found in a mutualistic relationship with another organism, where both organisms are benefited.
    - Example: *lichens and mycorrhiza*.

ENTRI

THALLUS STRUCTURE OF FUNGI

- If both male and female gametes produce in the same individual can fertilize each other homothallic.
- On the other hand if the gametes can only be fertilized by gametes from another individual of the same species are known as heterothallic. Heterothallism is responsible for the variations in the species.
- There are present two types of thallus in fungi such as
    1. Unicellular Thallus
    2. Filamentous Thallus.

- Fungal plant body is known as Mycelium.
- It consists of network of long, slender, thread like structure called hyphae.
- Mycelium later forms the thallus.
- Hyphae may be septate (with cross wall) or aseptate (without cell wall).
- In aseptate condition hyphae will be multinucleated and is called coenocytic.
- The septate mycelium in its cell may contain only one (monokaryotic), two (dikaryotic) or many nuclei (multinucleate) with vacuolated protoplasm.
- In Basidiomycotina, except rust and smuts, the complicated type of pore with single opening is called **dolipore** (dolium, a large Jar or cash, i.e., barrel) septum.
- This dolipore septa was first described by **Royall Moore** and **James McAlear** in 1962.
- Dolipore septa have a barrel- shaped swelling around their centre pore. This structure is typically capped at either end by specialized membranes, called "parenthesomes" or simply "pore caps".

FUNGAL CELL WALL

- The most common cell wall material is chitin.

- But in some other fungi, cellulose or other glucans are present.

- According to **Aronson** (1965) and **Bartnicki-Garcia** (1970), the cell wall consists of about 80-90% polysaccharides along with proteins (1-15%) and lipids (2-10%).

- The composition of cell wall varies in different groups of fungi.

- These are cellulose- glycogen (Acrasiomycetes), cellulose-glucan (Oomycetes), cellulose-chitin (Hyphochytridiomycetes), chitin-chitosan (Zygomycetes), chitin- glucan (Chitridiomycetes, Asco-, Basidio- and Duteromycotina), mannan-glucan (Saccharo- mycetaceae and Cryptococcaceae), mannan- chitin (Sporobolomycetaceae), Polygalacto- samine-galactan (Trichomycetaceae).

HETEROTHALLISM

Morphological heterothallism

- Morphological heterothallism may be defined as the condition when morphologically different male and female sex organs are produced in two closely associated mycelia.

- The two sex organs or gametes are so morphologically different that it is easier to term one of them as male and the other as female-examples of such type of morphological heterothallic fungi are: *Achlya ambisexualis*, *A. bisexualis, Blastocladiella variabilis.*

Physiological Heterothallism:

- In physiological heterothallism, the interacting thalli differ in mating type or incompatibility, irrespective of the presence or absence of the sex organs or gametes.

- This means that sexual reproduction takes place by two morphologically similar but physiologically different hyphae in physiological heterothallism.

- The gametangia as well as gametes do not show morphological differentiation but physiologically they behave differently.

- The following types are observed:

(i) **Two-allelomorph**, e.g. *MucorMucedo, Ascobolusmagnificus, Sclerotinia Gladioli, Neurospora sitophila, Puccinia graminis.*

(ii) **Multiple-allelomorph:**

a. **Bipolar,** e.g. *Coprinus comatus.*

b. **Tetrapolar,** e.g. *Coprinus fimetarius*

REPRODUCTION IN FUNGI:

The fungi reproduces by all the three means:

- Vegetative,
- Asexual
- Sexual.

1. VEGETATIVE REPRODUCTION:

It takes place by the following ways:

(a) Fragmentation:

- It is common in filamentous fungi (*Rhizopus, Alternaria, Fusarium*) where the hyphae break up into two or more fragments due to some external force and each one develops into a new individual.

(b) Budding:

- It takes place in unicellular fungi (*Saccharomyces, Schizosaccharo- myces*).
- A small outgrowth, the bud emerges out from the parent cell.
- Nucleus divides into two and one passes to the bud.
- The bud is then separated by partition wall, but continues its growth.
- Later on, it breaks off from the mother and grows individually.
- Sometimes, the process repeats very fast and the buds remain attached with the mother in chain, that looks like mycelium, called pseudomycelium.

(c) Fission:

- Normally unicellular fungi (*Saccharomyces, Schizosaccharomyces*) reproduce by this method.
- In this vegetative cell elongates, and divides into two daughter cells of equal size by simple constriction in the middle with simultaneous nuclear division.

2. ASEXUAL REPRODUCTION:

- It takes place by means of several types of spore generally form during favourable condition.
- The spores may be unicellular (*Penicillium, Aspergillus*) or multicellular (*Fusarium, Helminthosporium*).
- They may be exogenous, developed on conidiophore (*Penicillium*) endogenous, developed in sporangium (*Mucor*) or pycnidium (*Ascochyta pisi*).

Some of the spores are:

(a) Zoospore:

The zoospores may be uni- or biflagellate, generally pear-shaped, produced in sporangium, e.g., *Synchytrium, Phytophthora*.

(b) Conidia:

These are exogenously produced non-motile spores develop by constriction at the end of specialised hyphal branches, called conidiophores. They may produce singly (*Phytophthora, Pythium*) or in chain (*Penicillium, Aspergillus*).

(c) Oidia:

In some fungi *(Mucor mucedo*), the hyphal tips often divide by transverse wall into large number of small segments, may remain in chain or becomes free from each other, these are known as oidia. The oidia on germination develop into new plants.

(d) Chlamydospore:

The chlamydospores are thick walled round to oval in outline, coloured brown or black. They produce either terminally or in intercalary at some intervals throughout the length of hyphae, e.g., *Fusarium*.

(e) Sporangiospores:

These are globose, multinucleate, non-motile aplanospores, formed inside the sporangium. The sporangiospore germinates by producing germ tube. Later on, it develops profusely branched mycelium.

SEXUAL REPRODUCTION:

It is the process of union between two compatible nuclei. The nuclei in some members are contributed by two well-organized gametes.

The whole process of sexual reproduction consists of three phases, in the sequence of plasmogamy, karyogany and meosis:

(i) **Plasmogamy**:

It involves the union of two protoplasts, brings two haploid nuclei close together in the same cell.

(ii) **Karyogamy**:

It involves the fusion of two haploid nuclei brought together during plasmogamy. This results in the forma¬tion of diploid nucleus i.e., zygote, which is ephemeral (short-lived).

(iii) **Meiosis**:

It follows karyogamy and reduce the number of chromosome from diploid zygote nucleus to original haploid number in the daughter nuclei.

The plasmogamy i.e., the first phase of sexual reproduction, differs in different fungi.

The different methods of plasmogamy are:

(a) Planogametic Copulation:

Planogametes are motile gametes. This process involves the fusion of two gametes, where either one or both are motile.

Depending on the structure and nature of gametes, it is of three types:

Isogamy, Anisogamy and Oogamy:

(i) Isogamy:

The uniting gametes are morphologically similar, but physiologically different. This process is common in primitive unicellular fungi, e.g., *Synchytrium*

(ii) Anisogamy:

Both the uniting gametes are morphologically similar, but different physiologically and in size. The smaller one is more active, considered as male and the larger less active one as female, e.g., Allomyces

(iii) Oogamy:

Both the uniting gametes are morphologically and physiologically different. The male gamate is smaller and motile, and the female gamete is larger and non-motile, e.g., *Monoblepharis*

(b) Gametangial Contact:

- The uniting gametes are present in different gametangium, thus the male and female gametangia are known as antheridium and Oogonium (Ascogonium in Ascomycotina), respectively.
- The gametes are never released from gametangium. Both the gametangia come in close contact and transfer male gamete to the egg through fertilization tube.
- The gametangia do not lose their identity, e.g., *Ascobolus, Pythium*

(c) Gametangial Copulation:

- The process involves the fusion of the entire content of the uniting gametangia.

Such fusion occurs in the following two ways:

(i) The two gametangia fuse by the dissolution of their common wall resulting into the formation of a single cell in which content of both the gametangia mix with each other and their morphological identity are completely lost, e.g., *Rhizopus, Mucor .*

(ii) The entire thallus acts as gametangium. Both the gametangia come in close contact and the male gametangium transfer its entire content to the female gametangium through the pore developed in contact area e.g., *Rhizophidium, Polyphagus.*

(d) Spermatisation:

- Certain fungi produce many unicellular non-motile, male cells, the spermatia.
- The spermatia are brought in contact by agents like wind, water and insect either to the trichogyne of the ascogonium or to somatic hyphae or even to special receptive hyphae.
- The wall at the point of contact dissolves and content of spermatia passes to the female organ, e.g., *Puccinia, Podospora*

(e) Somatogamy:

- In many higher fungi belonging to Asomycotina and Basidiomycotina, the development of gametes and gametangia are completely lacking.
- In such fungi, somatic hyphae anastomose with each other to bring together the compatible nuclei.
- It is regarded as a reduced and efficient form of sexuality, designated as somatogamy, e.g., *Polyporus, Agaricus, Morchella*

PARASEXUAL CYCLE IN FUNGI

• In some fungi, true sexual cycle comprising of nuclear fusion and meiosis is absent. These fungi derive the benefits of sexuality through a cycle known as Parasexual Cycle.

• The Parasexual Cycle is defined as a cycle in which plasmogamy, karyogamy and meiosis (haploidisation) take place but not at a specified time or at specified points in the life-cycle of an organ.

• Generally parasexual cycle occurs in those fungi in which true sexual cycle does not take place. The members of class Deuteromycetes (Deuteromycotina) in which sexual cycle does not occur, exhibit parasexual cycle generally.

• Parasexual cycle was first discovered by **Pontecarvo** and Roper of University of Glasgow in 1952 in *Aspergillus nidulans*, the imperfect stage of Emericella nidulans.

Steps Involved in Parasexual Cycle:

i) Formation of heterokaryotic mycelium

(ii) Fusion between two nuclei (Karyogamy)

(a) Fusion between like nuclei

(b) Fusion between unlike nuclei

(iii) Multiplication of diploid nuclei

(iv) Occasional Mitotic crossing over.

(v) Sorting out of diploid nuclei

(v) Occasional haploidisation of diploid nuclei, and

(vii) Sorting of new haploid strains.

1. MYXOMYCOTA

- Also known as Mycetozoa, phylum of fungus like organisms within the kingdom Protista,
- Commonly known as true slime molds.
- Exhibit characteristics of both protozoans (one-celled microorganisms) and fungi.
- Worldwide distribution
- They usually occur in decaying plant material.
- The Myxomycota differ from true fungi because their vegetative body consists of only protoplast bounded by membrane and devoid of cell wall.
- During favorable situation it forms sporangia and during unfavourable conditions it transforms into resting structure - **Sclerotium**
- Nutrition – phagotrophic

REPRODUCTION

- Vegetative reproduction
- Asexual reproduction
- Sexual reproduction

Vegetative reproduction

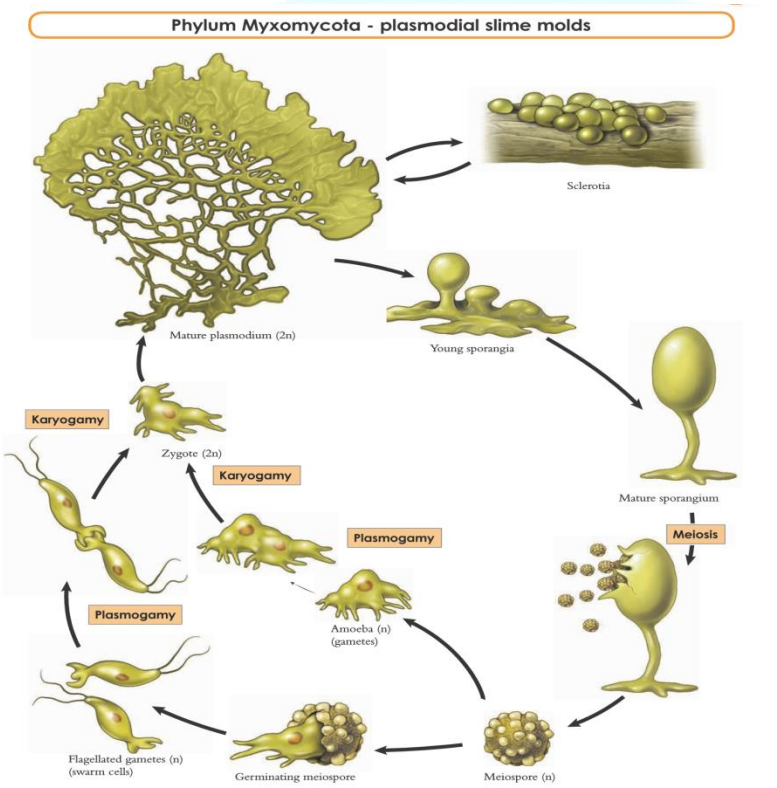
- During unfavourable condition
- Involves sclerotisation.

Asexual reproduction

- Through sporulation
- During this plasmodium moves to a dry place and produce reproductive structure – frutification.

Sexual reproduction

- Oogamous
- The diploid zygote formed undergoes repeated nuclear divison without cytokinesis and forms multinucleated plasmodium.
- Plasmodium often undergoes coalescence or somatic fusion, witout nuclear fusion.



CLASSES OF MYXOMYCOTA

SI.NO	CLASS	FEATURES
1.	Acrasiomycetes	• Cellular, amoeboid or communal slime molds. • Haitat: deciduous forest

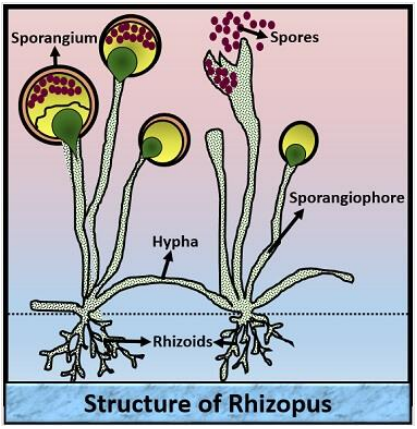
		• Flagellated cells • Spore wall with cellulose • Frutification: sporocarp and sorocarp
2.	Hydromyxomycetes	• Plasmodium forms network
3.	Plasmodiophoromycetes	• Parasitic within host plant
4.	Myxomycetes	• Acellular slime molds • Found in moist soil, decaying woods and dungs. • Not true fungi (lack cell wall) • Possess characters of both plants and animals. • Hetrotrophic

2. ZYGOMYCOTA

- Derives its name from the thick-walled resting spores, the zygospores formed as a result of the complete fusion of the protoplasts of two equal or unequal gametangia.
- Comprises the first group of fungi which lacks any motile stage.
- The hyphal walls are chiefly composed of chitinchitosan.
- Most of them are saprobes.
- Some are soil saprophytes and others coprophilous (growing on dung).
- Septa also appear in connection with development of reproductive bodies or to seal off injuries.

- A few mycelia produces rhizoids (root like hyphal branches penetrate the substrare) and stolon (horizontal connenction hyphae).

  Eg., *Rhizopus*, *Mucor*, and *Phycomyces*



REPRODUCTION

- Asexual reproduction
- Sexual reproduction

Asexual reproduction

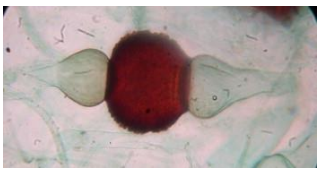
By means of non-motile sporangiospores commonly produced in large numbers within sporangia

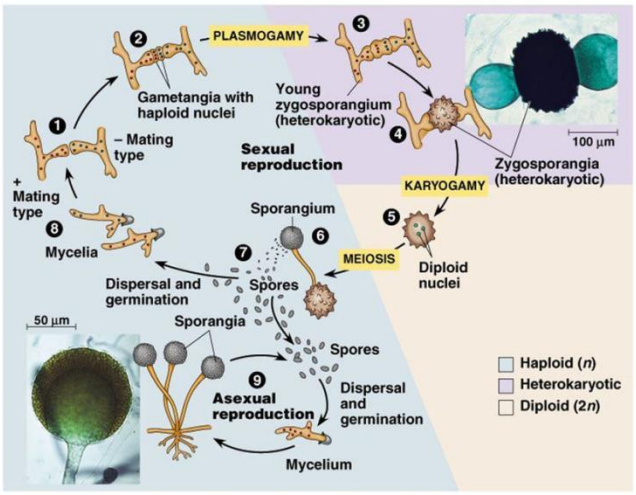
- Sometimes the entire sporangium functions as a single spore in the same manner as the conidium.
  - Through chlamydospores- most frequent
  - Trichospores

Sexual reproduction

- Isogamous
- Sexual fusion involves gametangial copulation.
- The thick-walled sexually produced zygospore formed by the complete fusion of the protoplasts of two gametangia is a resting structure.
- Zoospore formation is absent.
- The zygospore germinates to produce a hypha, the promycelium which bears a terminal sporangium.

- **Zygospore** formation is the key feature of members of Zygomycota and it contain sporopollenin, a complex polymer found in outer layer of pollen grains.





CLASSIFICATION

Two classes:

i. Zygomycetes
ii. Trichomycetes

Zygomycetes

- Saprobs on plants or animal debris
- Parasite or symbiont
- Zygospores, sporangiospores or conidia are produced.
- E.g., *Rhizopus, Mucor*

- Pilobus is a genus of fungi that commonly grows on herbivore dung.

Trichomycetes

- Parasites or commensals or obligate symbionts of terrestrial, freshwater and marine arthropods.
- Holdfast present
- Produce trichospores
- E.g., *Smittium species*

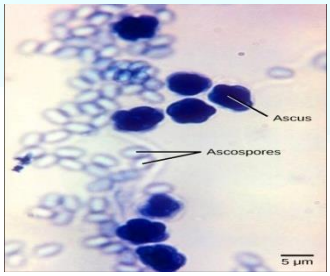
ECONOMIC IMPORTANCE OF ZYGOMYCOTA

- Active decomposers
- Known as "sugar fungi", due to saprobs on carbohydrates.
- Mycorrhizal association
- Some members active producers of organic acids, such as fumaric acid, lactic acid etc..
- *Rhizopus oryzae* – fermentation for production of rice wine.
- Causes disease in plants, animals and insects.

3. ASCOMYCOTA

- Commonly known as sac-fungi.
- They are produced in a sac-like structure known as an ascus. Each ascus contains 4-8 ascospores
- Produce sexual non-motile spores known as ascospores.
- One of largest phylum of kingdom fungi, with around 64,000 species.
- Mostly they are terrestrial, parasitic or coprophilous.

- They are unicellular or multicellular fungi
- The mycelium is made up of septate and branched hyphae.
- The cell wall is made up of chitin or β-glucans.
- There is cytoplasmic continuity due to septal pores.
- Asexual reproduction is by the formation of conidia exogenously on conidiophores.
- Yeast reproduces asexually by budding.
- Sexual reproduction is by conjugation between two gametangia. They are either homothallic or heterothallic
- The fruiting body is known as ascocarp.
- There are four types of ascocarps:
    i. Cleistothecium- The fruiting body is spherical and remains tightly closed, e.g. Aspergillus
    ii. Perithecium- The fruiting body is flask-shaped with one external opening, e.g. Neurospora
    iii. Apothecium- The fruiting body is cup-shaped and asci are present in hymenium, e.g. Peziza
    iv. Ascostroma- There is no differentiated fruiting body. Asci are present in the stroma, e.g. Mycosphaerella



REPRODUCTION

- Vegetative reproduction
- Asexual reproduction
- Sexual reproduction

Vegetative reproduction

- Fragmentation
- Fission
- Budding

Asexual reproduction

1. Conidia
2. Oidia
3. Chlamydospores

Conidia

- Exogenously produced.
- Non-motile spores.
- They are typically formed at the ends of specialized hyphae, the conidiophores.
- Conidiospores commonly contain one nucleus and are products of mitotic cell divisions and thus are sometimes called as mitospores, which are genetically identical to the mycelium from which they originate.
- The diverse conidia and conidiophores sometimes develop in asexual sporocarps with different characteristics (e.g. *acervulus, pycnidium, sporodochium*)
- Some species of Ascomycetes form their structures within plant tissue, either as parasite or saprophytes. These fungi have evolved more complex asexual sporing structures, probably influenced by the cultural conditions of plant tissue as a substrate. These structures are called the sporodochium. This is a cushion of conidiophores created from a pseudoparenchymatous stroma in plant tissue.
- The pycnidium is a globose to flask-shaped parenchymatous structure, lined on its inner wall with conidiophores.

- The acervulus is a flat saucer shaped bed of conidiophores produced under a plant cuticle, which eventually erupt through the cuticle for dispersal.
- Synnemata is elongated fruiting body in which the conidiophores remain very closely applied to each other.

Oidia

- A single celled asexual spores produced by fragmentation of fungal hyphae

Chlamydospores

- Thick walled resting spores

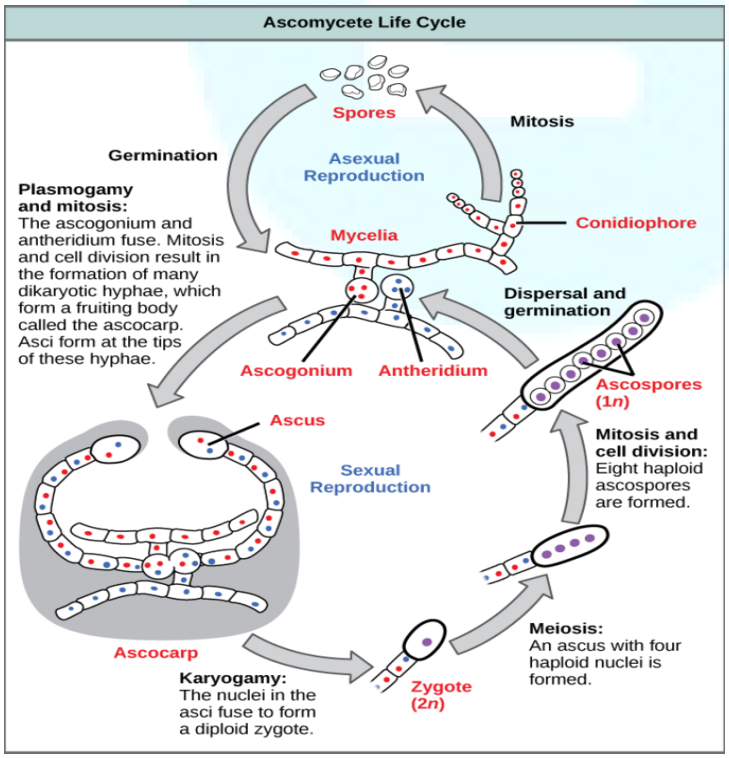
SEXUAL REPRODUCTION IN ASCOMYCETES

- Two different mating types hyphae come together and fuse.
- Plasmogamy takes place, but it does not follow karyogamy immediately
- The fused structure contains two haploid nuclei from each parent, i.e. dikaryon
- New hyphae are produced with dikaryotic cells.
- At the tip of the hyphae, asci develop in the ascocarp
- In each ascus, two nuclei fuse together (karyogamy) to form a diploid zygote
- Formation of Ascospores: The diploid zygote undergoes meiosis to form 4 haploid nuclei, which undergo mitotic division to form 8 haploid nuclei. Each of the nuclei accumulates cytoplasm and a thick cell wall surrounds it. These are known as ascospores
- Ascospores are released from asci through pore, slit or hinged lid and dispersed by air currents

Under favourable conditions, ascospores germinate to form new mycelia.

ECONOMIC IMPORTANCE OF ASCOMYCETES

- Entire brewing, bread and cheese making industry depends on yeast for fermented products.
- Who doesn't know about antibiotic, Penicillin, which we get from *Penicillium chrysogenum*.
- *Ciclosporin*, an immunosuppressor is derived from the fungus *Tolypocladium niveum*. It is used in organ transplants and autoimmune diseases
- Many organic acids and enzymes are produced by ascomycetes, e.g. citric acid, gluconic acid, amylases, proteases, etc.
- *Claviceps purpurea* (Ergot) is used as medicine to stop excessive bleeding during menstrual periods and to speed up labour
- Different kinds of cheese are prepared from different *Penicillium species*, e.g. Camembert, Brie, Roquefort, etc.
- *Aspergillus* is used to prepare soy sauce and to prepare other Asian alcoholic beverages
- Morels, Truffles and lobster mushroom are used as fungal delicacies
- *Neurospora*, *Saccharomyces*, etc. are widely used to study genetics



4. MASTIGOMYCOTA

- They are commonly known as zoosporic fungi.
- The cell wall is made up of chitin and cellulose
- They are mostly aquatic while another group are primarily terrestrial, although the organisms still form motile zoospores when open water is available.
- Three types of zoospores are common in this group. These are: (a) Laterally biflagellate, (b) Posteriorly uniflagellate, and (c) Anteriorly uniflagellate type having "9 + 2" arrangement of component fibrils.
- Most of them are filamentous and have coenocytic mycelium. However, unicellular form are present.
- Some genera show the pseudosepta (false cross wall) formation.
- Rhizoids are present in some of unicellular forms.
- Saprophytes or parasites.
- Due to presence of haustoria in a majority of Mastigomycotina, the mode of nutrition is typically absorptive.
- Sexual reproduction takes place by gametic copulation, gametangial copulation and gametangial contact.
- Oospores formation are common in almost all Mastigomycotina.

Eg., *Pythium, Albugo, Phythophora* etc...

REPRODUCTION

- Vegetative reproduction
- Asexual reproduction
- Sexual reproduction

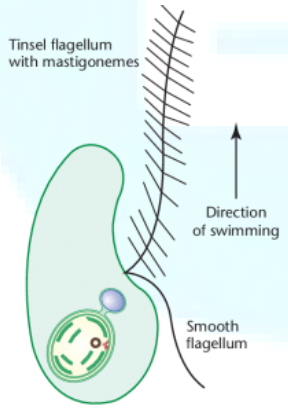
Vegetative reproduction

1. Fragmentation- The vegetative mycelium or hyphae break into several fragments and these fragments have the capability to grow into new mycelium under favorable conditions.
2. Clamadospores- Hyphal tips are mostly swollen and they get separated by a septum and then germinate to form mycelium**.**

Asexual reproduction

Through Zoospores-

- The difference is by type of flagellum, the position of the flagellum, and a number of flagellum attached.
- uniflagellate posterior type or uniflagellate tinsel type or biflagellated.
  - Single Anterior flagellum- Tinsel type
  - Single Posterior flagellum – Whiplash type
  - Biflagellated zoospore (Reniform or kidney-shaped) – Anterior Tinsel type and posterior whiplash-type



SEXUAL REPRODUCTION

1. **Gametic Copulation or Planogametic copulation**

- the fusion of two naked gametes

2.**Gametangium Copulation**–

- The conjugation between the gametangia that leads to protoplasm fusion and ultimately nucleus forming spores.

3.**Gametangial contact**–

- The conjugation tube is formed between the gametangia and the transfer of nucleus tales place leading to meiosis and formation of spores that form new hyphae.

CLASSIFICATION OF MASTIGOMYCOTA

•Ainsworth (1973) classified the subdivision Mastigomycotina into three classes**:**

1.	Chytridiomycetes	• They produces posteriorly uniflagellate zoospores Chytridiomycetous fungi occur as saprobes on plants and animal remains in water while other members occur as parasites on algae and aquatic animals.
2.	Hyphochytriomycetes	• Zoospores are anteriorly uniflagellate. • The hyphochytridiomycetes are those aquatic fungi whose thallus is holocarpic or eucarpic, monocentric or polycentric and their vegetative system is rhizoidal or hypha-like with intercalary swellings
3.	Oomycetes:	• The Oomycetes contain 74 genera and 580 species, • which are mostly aquatic, though some are terrestrial and live as parasites or saprophytes. • Includes classic “water molds” in the Order Saprolegniales and the “downy mildews” in the Order Peronosporales.

ECONOMIC IMPORTANCE

- Chytrids cause wart disease of potato, wart diseases in roots of crucifers, crown wart of alfalfa, a brown spot of maize,
- Oomycetes are responsible for late blight of potato, downy mildew, damping-off, fruit rot(Pythium species), footrot (Pythium species), white rust (Albugo),
- Few have been reported as biocontrol agents.
- Hypochytrids form an important group in marine or freshwater biodiversity.

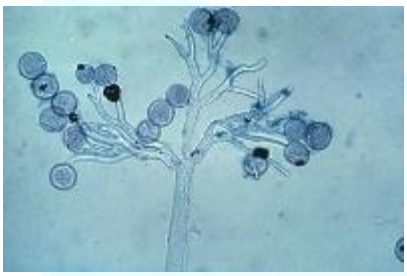
OOMYCETES

- The oomycetes, also known as "water molds", are a group of several hundred organisms that include some of the most devastating plant pathogens.
- The diseases they cause include seedling blights, damping-off, root rots, foliar blights and downy mildews.
- Some notable diseases are the late blight of potato, downy mildew of grape vine, sudden oak death, and root and stem rot of soybean.
- Because of their filamentous growth habit, nutrition by absorption, and reproduction via spores, oomycetes were long regarded by plant pathologists as lower fungi.
- However, as our understanding of evolutionary relationships has grown, it is now clear that this group of organisms is unrelated to the true fungi.
- Indeed, fungi appear more closely related to animals than to oomycetes, and oomycetes are more closely related to algae and to green plants

CHARACTERISTICS OF OOMYCETES

- One of the most distinguishing characteristics is the production of zoospores produced in sporangia.

- The anterior flagellum of a zoospore is a tinsel type, while the posterior flagellum is a whiplash type; both are typically attached in a ventral groove.
- Although wall-less, zoospores retain a consistent but flexible shape. Zoospores can swim in water films on leaf surfaces, in soil water, in hydroponic media and in natural bodies of water.
- Oomycetes can often be "baited" from soil water, streams or ponds, and it is thought that zoospores are attracted to the baits.
- After a time of free swimming the zoospores settle on a surface, retract their flagella, and secrete a mucilaginous matrix which affixes them to the surface.
- Sporangia of different taxa within the group are of diverse shapes and characteristics.
- They may be terminal or intercalary (within a hyphal filament), bulbous or not, and if terminal, caducous (sporangia detach readily) or not.



- In some species, the ability to produce zoospores has been lost, and sporangia are thought to have evolved into structures that germinate directly to produce germ tubes.
- In this case, the sporangia are sometimes termed "conidia". In yet other species, sporangia can germinate directly to produce germ tubes or "indirectly" to produce zoospores, a trait which is often temperature dependent, with zoospores being produced at cooler temperatures.

- Sexual reproduction occurs via the production of gametangia: oogonia and antheridia. Because meiosis does not occur until the formation of gametangia occurs, the vegetative nuclei are diploid.

- The morphology of antheridium attachment has been an important feature in morphological taxonomy of some genera.

- In some genera the antheridium is attached to the side of the oogonium,but in other genera, the antheridium surrounds the base of the oogonium.

- Typically each individual produces both antheridia and oogonia. There may be differences in “femaleness” and “maleness” and sexual preference is relative to other individuals.

- In some species, two distinct mating types occur and both are required for sexual reproduction (these are heterothallic as opposed to homothallic species).

- In heterothallic oomycetes, the gametangia are produced only in the presence of both mating types due to the fact that a hormone produced by one thallus stimulates the other to produce gametangia.

- In other species, sexual reproduction occurs within a single individual (these are homothallic individuals).

- Unlike the heterothallic species, homothallic individuals do not require distinct mating types, but can reproduce sexually by selfing.

- All Pythium and some Phytophthora species are homothallic.

- The fertilized oogonium develops into a thick-walled oospore.

- When the oospores are produced in plant tissue, they may occupy a large portion of the tissue.

- Oospores of many species have been shown to be able to survive for years in soil.

5. BASIDIOMYCOTINA

- It is a large phylum that includes forms commonly known as mushrooms, boletes, puffballs, earthstars, stinkhorns, birds-nest fungi, jelly fungi, bracket or shelf fungi, and rust and smut fungi.
- The common name bird's nest fungus includes species of the genera Crucibulum, Cyathus, and Nidularia of the family Nidulariaceae
- Both parasite and saprophytic.
- Some of the groups are mycorrhizal.
- Filamentous fungi composed of hyphae.
- Reproduce sexually by the formation of specialized club-shaped end cells called **basidia** that normally bear external spores (usually four).
- specialized spores in this phylum called basidiospores .
- the basidiospores on the basidium is naked in nature or inside a vegetable composition called basidiocarp.
- the threaded fungal(hyphae) in basidiomycota forming a clamp connection between adjacent cells, which are characteristic of this phylum.
- **Dolipore Septum**: characteristic feature of Basidiomycota, the dolipore septum. It is a mechanism to stop nuclear movement from one cell to the other.

VEGETATIVE STRUCTURE

The mycelium of most basidiomycetes passes through three distinct stages of development: the primary, the secondary, and the tertiary – before the fungus completes its life cycle

• Primary mycelia: Also known as homokaryon to emphasize the fact that all the nuclei are identical, usually develops upon the germination of a basidiospore.

• Secondary mycleia: Also called heterokaryon. Usually this type of mycelia is formed due to the fusion of two uninucleate cells of the compatible homokaryotic mycelia. So a binucleate cell is produced that develops later into secondary mycelia. Then, further divisions produce mycelia in which every cell is dikaryotic.

• Tertiary mycelia: The tertiary mycleia of basidiomycetes is represented by the organized, specialized tissues that comprise the basidiocarps (fruiting body).

ASEXUAL REPRODUCTION:

- by budding or Fragmentation of the mycelium or
- by the formation of conidides or
- by Urediospores

SEXUAL REPRODUCTION:

• Distinguishable sex organs are not formed in Basidiomycota except in Puccinia, where spermatia and receptive hyphae are distinctly the male and female structures.

• The plasmogamy, karyogamy and meiosis, which comprise sexual reproduction,

• Plasmogamy occurs when secondary mycelium is initiated.

• Karyogamy is delayed due to the extensive dikaryophase.

• Eventually, the karyogamy occurs in the basidia formed by the terminal cells of the dikaryotic secondary mycelium, or in teliospores, and the promycelium.

• Segregation of characters occurs during the meiotic division, which follows karyogamy.

• Four haploid nuclei ace formed.

• Sterigmata arise as little outgrowths; their tips swell, into each of which a haploid nucleus migrates. The swellings develop into basidiospores.

• The teliospores germinate and form a club-shaped promycelium in which karyogamy and meiosis occur.

• It becomes are septate and four cells formed, each bearing a basidiospore on a short pointed sterigma.

• The karyogamy and meiosis, sometimes, occur in the teliospore.

• Thus, the teliospore and the promycelium jointly perform the function of a basidium.

• The germinating teliospore is called hypobasidium, and promycelium, the epibasidium.

• Both jointly form the basidial apparatus.

• The teliospore before germination is regarded as encysted probasidium.

ECONOMIC IMPORTANCE:

- Live parasitic on plants caused by plant diseases such as rust rust diseases and smut diseases .
- Some species are used as food for humans around the world, such as fungus Mushroom .
- Some species are toxic and deadly to humans called Toadstool, such as Amanita sp. Which is called the Death Angel.

6. DEUTEROMYCOTA

- Fungi impercti
- Mycelium septate and profusely branched

- Cells uninucleated and dolipore septum present
- They only reproduce through Asexual reproduction.
- Asexual reproduction through conidia formation.
- Asexual frutification: free conidiophores, synnema, sporodochia, pycnidia, acervuli
- Sexual stage is not observed.
- Incomplete life cycle

CERCOSPORA

- Pathogenic parasite
- Attacks ground nut, cotton, beet, pulses etc..
- *Cercospora personata* and *C.arachidicolo*- cause leaf spot in ground nut, commoly known as tikka diseases.

ECONOMIC IMPORTANCE OF FUNGI

1. ROLE OF FUNGI IN MEDICINE:

- Some fungi produce substances which help to cure diseases caused by the pathogenic microorganisms. These substances are called the antibiotics.
- In small amounts to the feed of slaughter animals promotes rapid growth and improves the quality of the meat products.
- Penicillin from *Penicillium notatum*
- Streptomycin is obtained from *Streptomyces griseus*
- The plasmodia of certain species of Myxogastres have been reported to yield soluble antibiotics

2. ROLE OF FUNGI IN INDUSTRY:

a) Alcoholic fermentation:

- The yeasts secrete the enzyme complex called zymase which brings about conversion of sugar into alcohol.
- *M. rouxii* and some species of *Rhizopus*, *Aspergillus flavus* is used in the production of African native beer

b) Enzyme preparations:

- on the basis of his intensive study of the enzymes produced by *Aspergillus flavus-oryzae* series has introduced in the market a few products of high enzymic activity.
- Invertase is extracted from *Saccharoymces cerevisiae*. It has many industrial uses. It hydrolyses sucrose to a mixture of glucose and fructose.
- Cultures of *Aspergillus niger* and *A. oryzae* on trays of moist, sterile bran yield a well-known amylase which contains two starch splitting components

c) Preparation of organic acids:

- Oxalic acid is the fermentation product of *Aspergillus niger*.
- Citric acid is made by mould fermentation.
- The gluconic acid is prepared from sugars. The moulds chiefly employed for this purpose are some species of *Penicillium* and *Aspergillus*.
- Gallic acid as the fermentation product of an extract of tannin by *Aspergillus gallomyces*.

d) Gibberellins:

- Produced by the fungus *Gibberella fujikuroi* which cause a disease of rice accompanied by abnormal elongation

e) Cheese Industry:

- The moulds concerned are *Penicillium camemberti* and *P. caseicolum* in the production of Camembert and Brie type cheese.
- *P. roqueforti* in the production of Roquefort Gorgonzola and Stilton type cheese.

3. ROTTING OF WOOD

- Some fungi results in degradation of cellulose and lignin and cause rotting of wood
- Eg., Polyporus, Ganoderma

4. DEGRADATION OF LIGNIN

- Fungi degrade lignin by secreting enzymes collectively termed "ligninases".

5. DECOMPOSITION OF ORGANIC MATTERS

- Fungi produce a variety of exoenzymes to digest nutrients
- These enzymes are either released into the substrate or remain bound to the outside of the fungal cell wall.
- Large molecules are broken down into small molecules, which are transported into the cell by a system of protein carriers embedded in the cell membrane.

6. FUNGAL TOXINS AND HUMAN HEALTH

- Some fungi have the ability to produce toxic secondary metabolite call mycotoxins
- which have a role in the infection of some diseases in both humans and other animals.
- The adverse health effects of mycotoxins range from acute poisoning tolong-term effects such as immune deficiency, Liver and kidney fibrosis and cancer.