Lecture # 1 Introduction to Mycology, Structures and Reproductive of Fungi

Mycology and Classification of Mycology Course is designed to offer a basic understanding of the biology, diversity and taxonomy of fungal-like organisms and the true fungi. The course comprises two hours lectures and two hours' laboratory sessions per week. The course will cover fungal characteristics, isolation, growth, and identification techniques, classification, reproduction and life cycles of major taxa of fungi. Also focus on major fungal infections, their etiologies, three lecture exams and three lab exams will be given during the course. All students will be required to present a report on a selected topic of interest as part of the course requirements. Demonstrations, experiments, will be used to illustrate particular principles and information regarding the biology of fungi, as applicable.

Definition of Mycology

Mycology is the study of fungi

mykes (Gr.); mushroom

Fungus (L.) = Sphongos (Gr.) – Sponge.

Carl Linnaeus (1707-1778) the "Father of Taxonomy" Fungi are primitive plants under this classification of organisms.

What are fungi?

Eukaryotic, spore-bearing, heterotrophic organisms that produce extra-celluar enzymes and absorb their nutrition

Modes of nutrition

Fungi=absorptive heterotrophs

Animals=phagotrophic heterotroph

Heterotroph (chemo-organotrophs):

an organism incapable of synthesizing carbohydrates from inorganic sources; requires preformed organic compounds produced by other organisms

Plants=autotrophs

Why study fungi?

Fungi are among the most diverse organisms on earth, and are considered only a second to the insects in species diversity.

Importance of fungi: Fungi inhabit almost every place in the environment and humans are exposed to these organisms in various fields of life.

How many species of fungi exist?

80,000 species of fungi described 1,700 new species described each year

Estimating the number of fungal species

Hawksworth, D.L. (2001). The magnitude of fungal diversity: the 1.5 million species estimate revisited. Mycological Research 105, (12): 1422-1432.

- Flowering plants on British Isles described = 2,000 species
- Fungi on British Isles described = 12,000 species
- Ratio of 6 fungi to each plant species

- Total number of described plant species = 250,000 (most plant species are believed to be described)
- 6 x 250,000=1.5 million species of fungi!
- Less than 5% of which are described, and at the current rate of description, it will take >800 years to describe all extant species.

Beneficial Effects of Fungi:

1. Decomposition - nutrient and carbon recycling.
2. Biosynthetic factories. The fermentation property is used for the industrial production of alcohols, fats, citric, oxalic and gluconic acids.
3. Important sources of antibiotics, such as Penicillin.
4. Model organisms for biochemical and genetic studies. Eg: *Neurospora crassa*
5. *Saccharomyces cerviciae* is extensively used in recombinant DNA technology, which includes the Hepatitis B Vaccine.
6. Some fungi are edible (mushrooms).
7. Yeasts provide nutritional supplements such as vitamins and cofactors.
8. Penicillium is used to flavour Roquefort and Camembert cheeses.
9. Ergot produced by Claviceps purpurea contains medically important alkaloids that help in inducing uterine contractions, controlling bleeding and treating migraine.
10. Fungi *(Leptolegnia caudate* and *Aphanomyces laevis*) are used to trap mosquito larvae in paddy fields and thus help in malaria control.

Harmful Effects of Fungi:

1. Destruction of food, lumber, paper, and cloth.
2. Animal and human diseases, including allergies.
3. Toxins produced by poisonous mushrooms and within food (Mycetism and Mycotoxicosis).
4. Plant diseases.
5. Spoilage of agriculture produce such as vegetables and cereals.
6. Damage the products such as magnetic tapes and disks, glass lenses, marble statues, bones and wax.

General properties of fungi:

1. They are eukaryotic; cells contain membrane bound cell organelles including nuclei, mitochondria, golgi apparatus, endoplasmic reticulum, lysosomes etc. They also exhibit mitosis.
2. Have ergosterols in their membranes and possesses 80S ribosomes.
3. Have a rigid cell wall and are therefore non-motile, a feature that separates them from animals. All fungi possess cell wall made of chitin.
4. Are chemoheterotrophs (require organic compounds for both carbon and energy sources) and fungi lack chlorophyll and are therefore not autotrophic.
5. Fungi are osmiotrophic; they obtain their nutrients by absorption.
6. They obtain nutrients as saprophytes (live off of decaying matter) or as parasites (live off of living matter).
7. All fungi require water and oxygen and there are no obligate anaerobes.
8. Typically reproduce asexually and/or sexually by producing spores.
9. They grow either reproductively by budding or non-reproductively by hyphal tip elongation.

10. Food storage is generally in the form of lipids and glycogen.

Classification of fungi:

Fungi were initially classified with plants and were a subject of interest for botanists; hence the influence of botany can be seen on their classification. In 1969 R.H Whittaker classified all living organisms into five kingdoms namely

Monera, Protista, Fungi, Plantae and Animalia.

Traditionally the classification proceeds in this fashion:

Kingdom - Subkingdom - Phyla/phylum - Subphyla - Class - Order - Family - Genus- Species

This classification is too complicated to be dealt here.

There are alternate and more practical approaches, one based on sexual reproduction and the other based on morphology of the thallus (vegetative structure).

Modern Classification

Morphology of fungi:

At least 7 kingdoms are now recognized:

Eubacteria, Archaebacteria, Animalia, Plantae, Eumycota, Stramenopila (Chromista), Protoctista (Protozoa, Protista). Fungi exist in two fundamental forms; the filamentous (hyphal) and single celled budding forms (yeast). But, for the classification sake they are studied as moulds, yeasts, yeast like and dimorphic fungi.

All fungi have typical eukaryotic morphology. They have rigid cell wall composed of chitin, which may be layered with mannans, glucans and other polysaccharides in association with polypeptides. Some lower fungi possess cellulose in their cell wall. Some fungi such as Cryptococcus and yeast form of Histoplasma capsulatum possess polysaccharide capsules that help them to evade phagocytosis.

Inner to the cell wall is the plasma membrane that is a typical bi-layered membrane in addition to the presence of sterols. Fungal membranes possess ergosterol in contrast to cholesterol found in mammalian cells. The cytoplasm consists of various organelles such as mitochondria, golgi apparatus, ribosomes, endoplasmic reticulum, lysosomes, microtubules and a membrane enclosed nucleus. A unique property of nuclear membrane is that it persists throughout the metaphase of mitosis unlike in plant and animal cells where it dissolves and re-forms. The nucleus possesses paired chromosomes.

Fungal Cell Wall

1 – Cell wall components

- ★ Two major types of components
  - o Structural polymers - polysaccharide fibrils that provide rigidity/integrity of the wall
  - o Matrix components - cross-link the fibrils as well as coat/embed them
- ★ Main wall components differ between the major taxonomic groups of fungi [see Table 3.1, Deacon]
  - o Chitin - straight chain polymers of b-1,4-linked N-acetylglucosamine 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

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

★ **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

Cytoplasmic Organelles

★ Plasma membrane - phospholipid bilayer

- Involved in uptake of nutrients

- 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

★ Chitosomes - microvesicles that are capable of synthesizing chitin

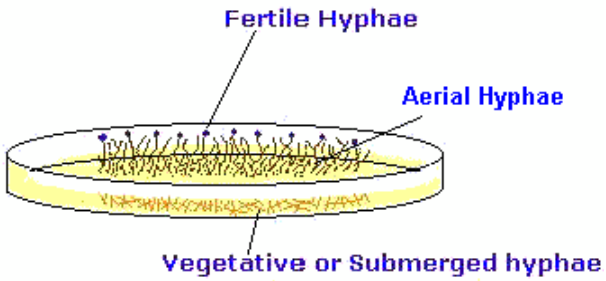
★ Vacuoles

- Functions
  - Storage
  - Recycling of materials
  - Contain proteolytic enzymes
  - Regulation of cellular pH
  - Possible role in cellular expansion/growth
- Shape
  - Round
  - Tubular - may be involved in material transport

Mycelium are of three kinds:

1. **Vegetative mycelium** are those that penetrates the surface of the medium and absorbs nutrients.
2. **Aerial mycelium** are those that grow above the agar surface
3. **Fertile mycelium** are aerial hyphae that bear reproductive structures such as conidia or sporangia.

Since hypha is the structural unit of mould, the mycelium imparts colour, texture and topography to the colony. Those fungi that possess melanin pigments in their cell wall are called phaeoid or dematiaceous and their colonies are coloured grey, black or olive.



Examples are species of Bipolaris, Cladosporium, Exophiala, Those hyphae that don't possess any pigment in their cell wall are called hyaline. Hyphae may have some specialized structure or appearance that aid in identification.

Some of these are:

a) **Spiral hyphae**: These are spirally coiled hyphae commonly seen in *Trichophyton mentagrophytes*.

b) **Pectinate body**: These are short, unilateral projections from the hyphae that resemble a broken comb. Commonly seen in *Microsporum audouinii*.

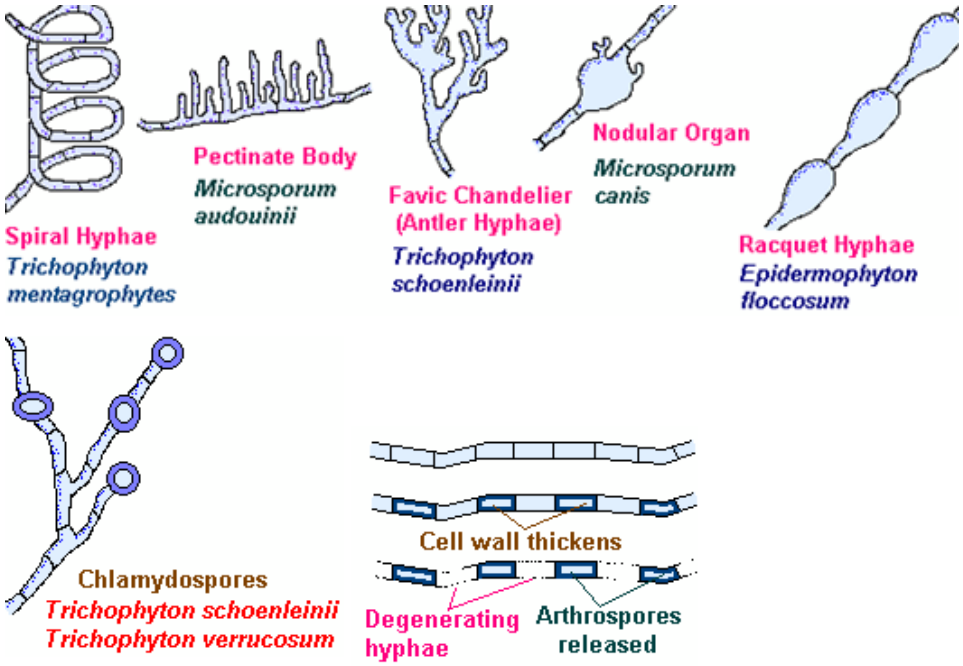
c) **Favic chandelier**: These are the group of hyphal tips that collectively resemble a chandelier or the antlers of the deer (antler hyphae). They occur in *Trichophyton schoenleinii* and *Trichophyton violaceum*.

d) **Nodular organ**: This is an enlargement in the mycelium that consists of closely twisted hyphae. Often seen in *Trichophyton mentagrophytes* and *Microsporum canis*.

e) **Racquet hyphae**: There is regular enlargement of one end of each segment with the opposing end remaining thin. Seen in *Epidermophyton floccosum, Trichophyton mentagrophytes.*

f) **Rhizoides**: These are the root like structures seen in portions of vegetative hyphae in some members of zygomycetes.

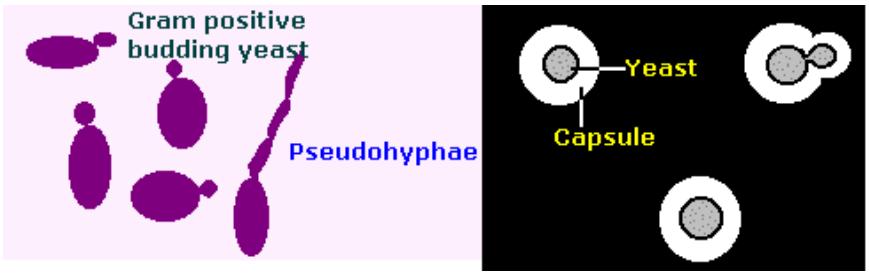
g) There are structures in the hyphae, which arise out of modification of a single cell and transform into thick walled resting cells. Chlamydospore (or chlamydoconidia), which are produced by *Trichophyton schoenleinii* and *Trichophyton verrucosum* are thick walled cells that are larger than other cells and arranged singly or in groups. In some fungi such as *Trichosporon beigeilli* and *Coccidioides immitis* some alternating cells become thick walled and subsequently the intervening cells disintegrate leaving behind arthrospores (or arthroconidia).



Yeasts:

Yeasts are unicellular spherical to ellipsoid cells. They reproduce by budding, which

result in blastospore (blastoconidia) formation. In some cases, as the cells buds the buds fail to detach and elongate thus forming a chain of elongated hyphae like filament called pseudohyphae. This property is seen in *Candia albicans*.



Reproduction in fungi:

Fungi reproduce by asexual, sexual and parasexual means.

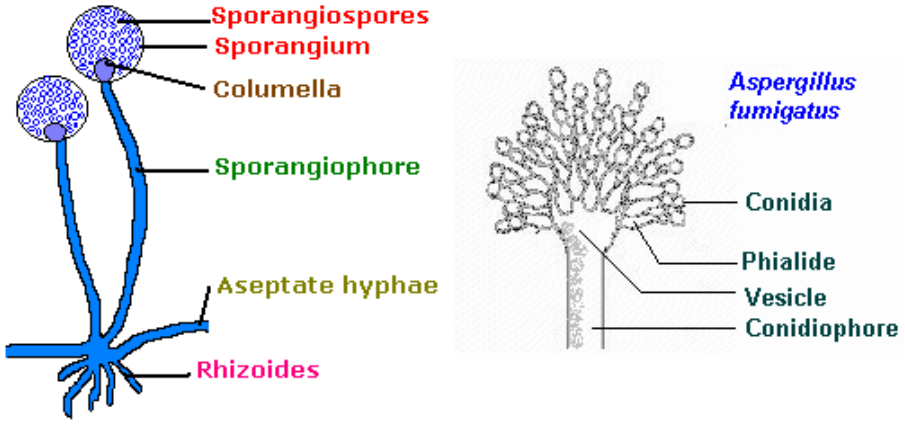
Asexual reproduction is the commonest mode in most fungi with fungi participating in sexual mode only under certain circumstances. The form of fungus undergoing asexual reproduction is known as anamorph (or imperfect stage) and when the same fungus is undergoing sexual reproduction, the form is said to be teleomorph (or perfect stage). The whole fungus, including both the forms is referred as holomorph.

Asexual reproduction:

Asexual propagules are termed either spores or conidia depending on their mode of production. Asexual spores are produced following mitosis whereas sexual spores are produced following meiosis.

The asexual spores of zygomycetes, which are known as sporangiospores form within sac like structure known as sporangia. The sporangiospores result from the mitotic cleavage of cytoplasm in the sporangium. The sporangia are

borne on special hyphae called sporangiophore. This endogenous process of spore formation within a sac is known as sporogenesis.



Conidia arise either by budding off conidiogenous hyphae or by differentiation of preformed hyphae. These develop following mitosis of a parent nucleus and are formed in any manner except involving cytoplasmic cleavage. This exogenous process is known as conidiogenesis, a process that occurs both in yeasts and moulds. Conidia are borne on specialised structures called conidiophore.

It is the type of reproduction which involves the somatic portion of the fungal thallus. It occurs by the following methods.

Fragmentation

In this process, the mycelium breaks into two or more similar fragments either accidentally or due to some external force. Each fragment grows into a new mycelium.

Budding

The parent cell produces one or more projections called buds, which later develop necessary structures and detach to grow into new individuals. Budding is common in unicellular forms like yeast.

Fission

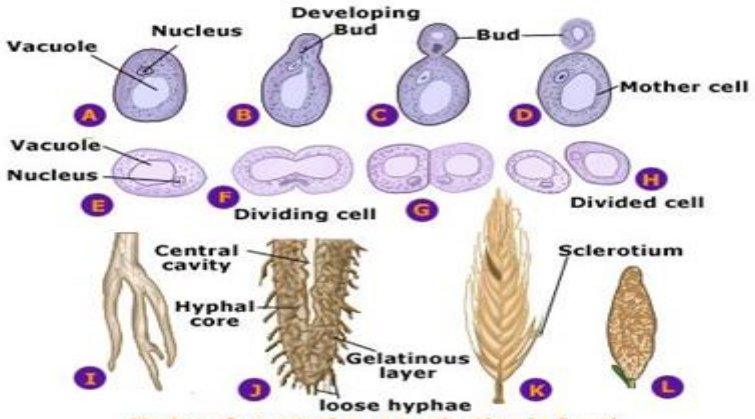
In this process, the parent cell splits into two equal halves, each of which develop into a new individual. Fission is also common in yeast.

Sclerotia

In some cases, as in Claviceps, the hyphae become interwoven to form a compact mass and get surrounded by a hard covering or rind. Such structures are called SCLEROTIA. They remain dormant under unfavourable conditions and germinate into new mycelia on the return of favourable conditions.

Rhizomorphs

In some higher fungi, several hyphae may become interwoven to form rope-like structures called rhizomorphs. Under favourable conditions, they resume growth to give rise to new mycelia.



Modes of Vegetative Reproduction

Asexual Reproductive Structures

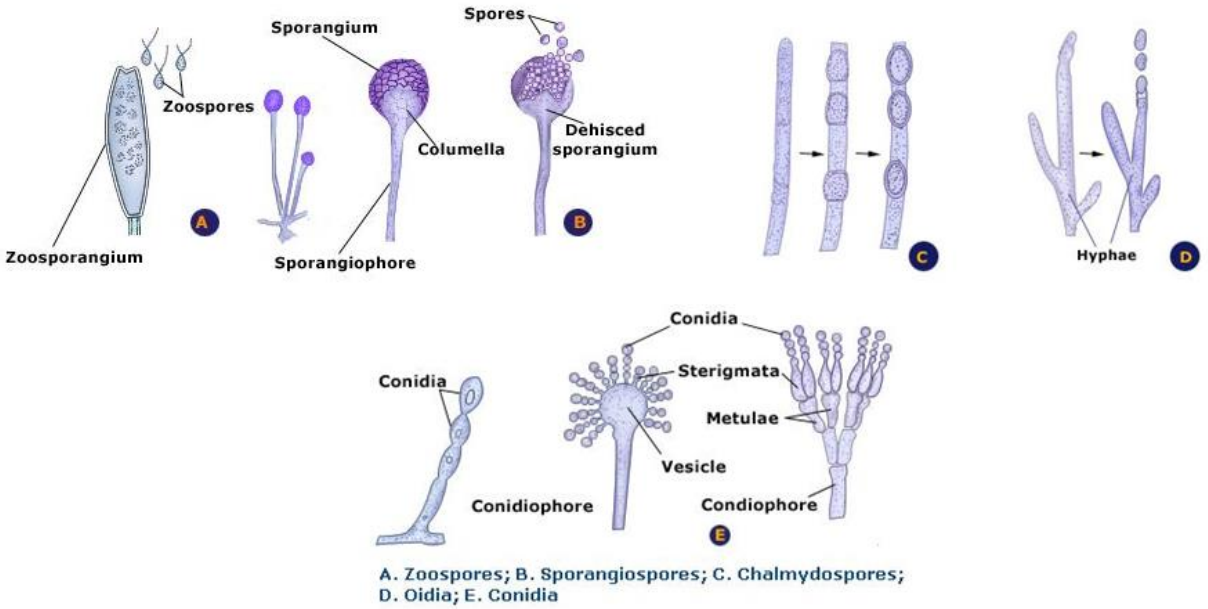
It is the type of reproduction in which special reproductive structures called spores or propagates are formed. The fungal spores always result from mitosis and hence are described as mitospores. Following are the types of spores produced in different groups of fungi:

Zoospores

They are flagellated, motile spores produced inside structures called zoosporangia. These spores do not have a cell wall. Such spores are produced in lower fungi such as Achyla and Saprolegnia.

Sporagiospores

These are non-motile spores produced inside structures called sporangia in fungi such as Rhizopus and Mucor. These spores are dispersed by wind.



A. Zoospores; B. Sporangiospores; C. Chalmydospores; D. Oidia; E. Conidia

Modes of Asexual Reproduction

Chlamydospores

These are thick walled resting spores which arise directly from hyphal cells. They store reserve food.

Oidia

These are spore like structures formed by the breaking up of hypha cells. They do not store reserve food and hence cannot survive under unfavourable conditions. Such spores are produced in Rhizopus.

Conidia

These are non-motile spores produced singly or in chains at the tip of the hypha branches that are called conidiophores. Such spores are produced in fungi like Aspergillus and Penicillium.

Sexual Reproduction

Sexual reproduction is known to occur in all groups of fungi except the Fungi imperfecti or Dueteromycetes. It may involve fusion of gametes, gametangia or hyphae. The process may involve only fusion of cytoplasm (plasmogamy) or fusion of nuclei (karyogamy) or production of meiotic spores (meiospores)

In most of the lower fungi plasmogamy is immediately followed by karyogamy and meiosis. In higher fungi karyogamy is often delayed so that the hyphae remain dikaryotic. This phase of fungal life cycle is called **dikaryophase.** Such fungi complete their life cycle in three phases a haplophase, a dikaryophase and a diplophase.

Sexual fusion in fungi is of different types, as follows :

Planogametic Copulation

Here motile gametes called planogametes undergo fusion. When both the gametes are motile and morphologically similar, the fusion process is called isogamy.

Eg.: Synchytrium When both the gametes are motile but differ in their size, the fusion process is called **anisogamy.**

Eg.: Allomyces. When one gamete (male) is smaller and motile and the other (female) gamete is larger and non motile, the fusion process is called **heterogamy.**

Gametangial Contact

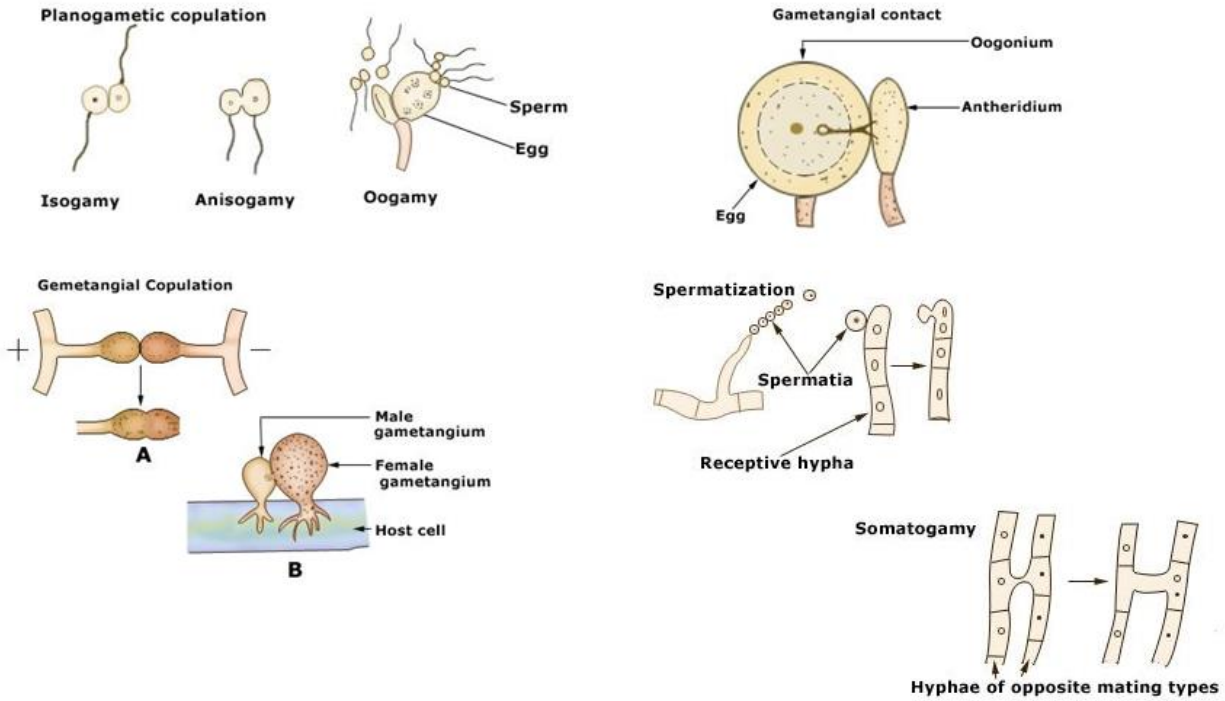
Here, gamete bearing structures called gametangia come closer to each other and develop a fertilisation tube through which the male gamete migrates into the female gametangium. Eg. : Phytophthora, Albugo.

Gametangial Copulation

Here, the gametangia fuse with each other, lose their identity and develop into a zygospore. Eg.: Mucor, Rhizopus

Spermatisation

In some fungi like Puccinia, tiny unicellular spore like structures called spermatia are formed. They get transferred to female gametangia through various agencies.



Types of Sexual Reproduction in Fungi

Somatogamy

In examples like Agaricus, fusion occurs between two somatic cells and involves only plasmogamy. This results in the formation of dikaryotic hyphae. Hence, the process is called dikaryotization.

Homothallism and Heterothallism

Based on the compatibility in sexual reproduction the fungal hyphae can be distinguished into two types **homothallic** and **heterothallic**. In homothallic forms, fusion occurs between the genetically **similar strains** or **mating types**. In such forms, meiosis results in the formation of genetically identical spores. In the heterothallic forms, fusion occurs between the genetically **different mating types or strains**. The strains are genetically compatible and are designated as **+ strain** and **strain.** In such forms meiosis results in the formation of both the strains, in equal numbers. Heterothallism is a device to prevent inbreeding and promote out breeding.