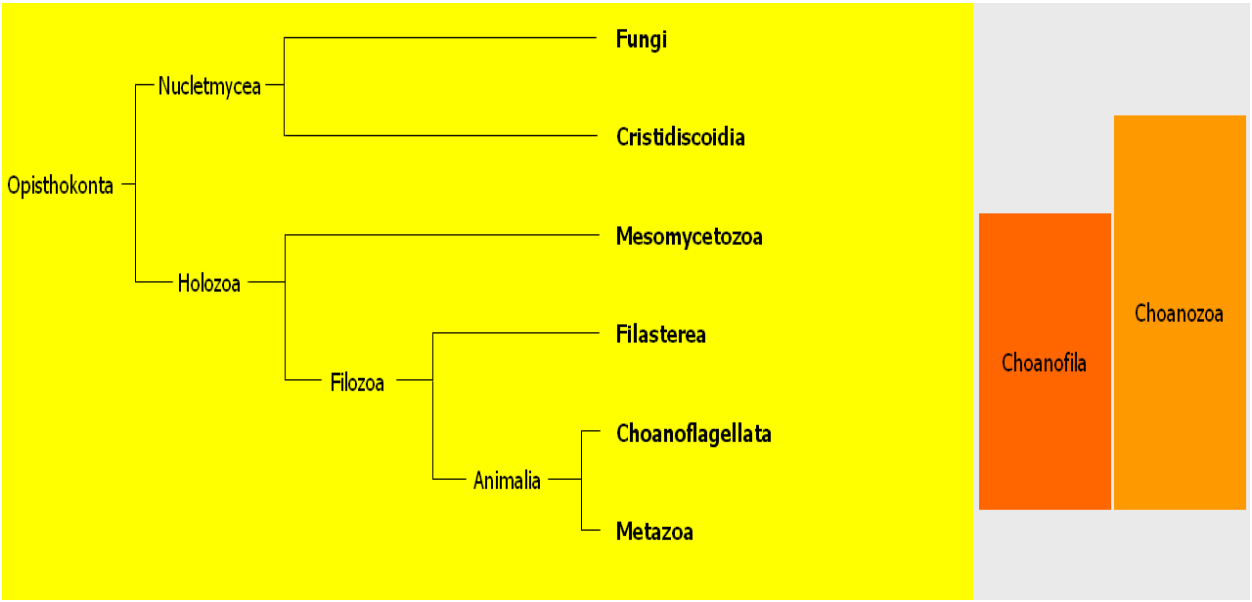
Principals of Mycology

What is a fungus

A fungus is a eukaryote that digests food externally and absorbs nutrients directly through its cell walls. Most fungi reproduce by spores and have a body (thallus) composed of microscopic tubular cells called hyphae. Fungi are heterotrophs and, like animals, obtain their carbon and energy from other organisms.They are found in just about any habitat but most live on the land, mainly in soil or on plant material rather than in sea or fresh water.

Some fungi obtain their nutrients from a living host (plant or animal) and are called biotrophs; others obtain their nutrients from dead plants or animals and are called saprotrophs (saprophytes, saprobes). Some fungi infect a living host, but kill host cells in order to obtain their nutrients; these are called necrotrophs

Fungi were once considered to be primitive members of the plant kingdom, just slightly more advanced than bacteria. We now know that fungi are not primitive at all. In fact, recent taxonomic treatments such as the Tree of Life Project show that fungi and animals both belong to the group Opisthokonta (Fig. 1).



Fungi are more closely related to animals than they are to plants. We also recognize that organisms traditionally studied as "fungi" belong to three very different unrelated groups: the true fungi in Kingdom Fungi (Eumycota), the Oomycetes, and the slime molds.

There are four main groups (phyla) of true fungi—Ascomycota, Basidiomycota, Chytridiomycota and Zygomycota. Recent studies have provided support for the recognition of additional phyla, such as Glomeromycota, a group of fungi once placed in Zygomycota that form an association with the roots of most plants.
A group of parasitic organisms called Microsporidia that live inside the cells of animals are also now considered to belong in the fungal kingdom

How old are fungi?

Fungi are an ancient group—not as old as bacteria, which fossil evidence suggests may be 3. 5 billion years old—but the earliest fungal fossils are from the Ordovician, 460 to 455 million years old . Based on fossil evidence, the earliest vascular land plants didn't appear until approximately 425 million years ago, and some scientists believe that fungi may have played an essential role in the colonization of land by these early plants .
Mushrooms were preserved in nature from the Late Cretaceous age (94 million years ago).
Molecular data suggest that fungi are much older than indicated by the fossil record, and may have arisen more than one billion years ago

How many fungi are there

No one knows for sure how many species of fungi there are on our planet at this point in time, but what is known is that at least 99,000 species of fungi have been described, and new species are described at the rate of approximately 1200 per year.

A conservative estimate of the total number of fungal species thought to exist is 1. 5 million .

To come up with this figure, Hawksworth estimated the known numbers of plant and fungal species from countries in which both plants and fungi have been well-studied—Great Britain and Ireland, in this case—and determined there were six fungal species for every native plant species. The total number of plant species worldwide is approximately 250,000, and if the ratio of fungi to plants in Great Britain is typical of what occurs elsewhere, there should be at least 1. 5 million species of fungi.

What do fungi do?

Fungi are involved in a wide range of activities—some fungi are decomposers, parasites or pathogens of other organisms, others are beneficial partners in symbiosis with animals, plants or algae. Let's take a brief look at these various ecological groups
Fungi are one of the most important groups of organisms on the planet. This is easy to overlook, given their largely hidden, unseen actions and growth. They are important in an enormous variety of ways.

What do fungi do? Fungal importance

Fungi are involved in a wide range of activities—some fungi are decomposers, parasites or pathogens of other organisms, others are beneficial partners in symbiosis with animals, plants or algae. Let's take a brief look at these various ecological groups

Fungi associated with animals
Fungi have the ability to grow on and in both invertebrate and vertebrate animals.
Many fungi can attack insects and nematodes, for example, and may play an important role in keeping populations of these animals under control. Insect-

attacking fungi, called "entomopathogens," include a wide range of fungi in phyla Ascomycota, Zygomycota and Chytridiomycota.

Some of the best-known and most spectacular entomopathogens belong in the Ascomycota genus Ophiocordyceps and related genera. These fungi infect and consume insects such as caterpillars and ants, and then form conspicuous stromata that emerge from their victim's body in a most dramatic manner.

Ophiocordyceps sinensis

These fungi can also alter the insect's behavior. "Zombie- ant" fungi from Brazil infect insect brains, directing the victim to climb up plants and bite into the plant tissue in a "death grip" Paradoxically, humans have been using one of these entomopathogens, Ophiocordyceps sinensis, for thousands of years to treat a wide range of ailments.
This fungus is an important component of traditional Asian medicine and is commonly called "winter worm, summer grass. "

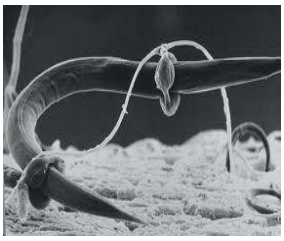
Entomopathogens such as Beauveria bassiana are so effective in killing insects that they are used as biological control agents for insect pests.

Beauveria bassiana

One group of fungi called Entomophthorales ("insect killers") includes a number of highly specialized entomopathogens. A common example is Entomophthora muscae, which is often observed forming a ring of white spores discharged around the body of a parasitized fly on panes of glass.

Entomophthora muscae

Some fungi are specialized parasites of nematodes, and other microscopic animals in the soil . A common nematode predator is Arthrobotrys oligospora, a fungus that has evolved sticky networks of hyphae for trapping nematodes. Once the nematode is immobilized, the fungus invades and consumes its body.



Arthrobotrys oligospora

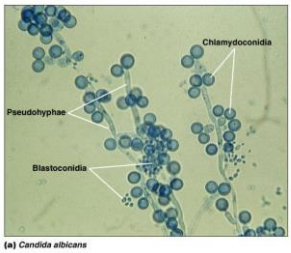
Fortunately, there are relatively few fungal pathogens of vertebrates—only 200-300 species—but some of these fungi can have devastating impacts. Consider the frog killer, Batrachochytrium dendrobatidis, a member of phylum Chytridiomycota. when it was discovered associated with frogs that had died from a mysterious skin disease at the Zoological Park in

Washington. The fungus doesn't invade the frog's body, but it is lethal, possibly because it disrupts electrolyte balance leading to cardiac arrest infected frogs appear to die of a heart attack. The frog chytrid is implicated in the widespread decline of frog populations around the world. Fortunately, this is the only chytrid known to parasitize a vertebrate animal and it appears to infect only amphibian.

Another devastating parasite of animals is Geomyces destructans, a cold-loving fungus that causes 'white-nose syndrome' in bats . This fungus colonizes the skin on the muzzles, ears and wing membranes of some types of bats, and infected bats exhibit unusual behavior.

Geomyces destructans

In humans, there are several different types of fungal infections, or "mycoses. " The most common are caused by dermatophytes, fungi that colonize dead keratinized tissue including skin, finger-, and toenails. Dermatophytes cause superficial infections such as 'ringworm‘.
Some fungi are members of the resident microflora in healthy people, but become pathogenic in people with predisposing conditions.



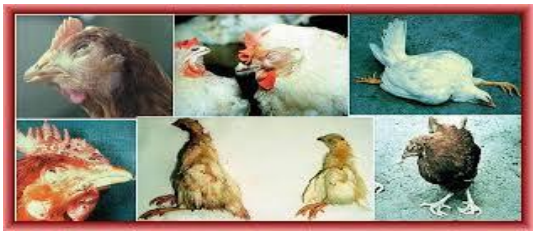
For example, Candida species cause annoying yeast infections in the mucosal tissues of many healthy people, but can also cause diseases collectively called candidiasis in babies and immunocompromised individuals.

Another group of fungi are inhaled as spores and initiate infection through the lungs. These fungi include Coccidioides immitis (coccidioidomycosis, commonly known as valley fever), and Histoplasma capsulatum (histoplasmosis).

Opportunistic fungal pathogens are normally not associated with humans and other animals, but can cause serious infections in weakened or healthy individuals when inhaled or implanted in wounds.

Aspergillus fumigatus, one of the most important of these opportunists, produces small, airborne spores that are frequently inhaled; in some individuals the fungus starts growing invasively, causing a disease known as aspergillosis, especially in immunocompromised individuals.

Aspergillosis is most often a respiratory infection in chickens and turkeys. It less often affects a wide range of other domestic and wild birds. Sick birds may display respiratory distress, suppressed growth, and general unthriftiness.



Aspergillosis

A remarkable discovery was that **Pneumocystis carinii**, the organism causing pneumonia-like symptoms in immunocompromised patients, is a fungus and not a protozoan as had been thought for decades.

Fungi and plants

The association of fungi and plants is ancient and involves many different fungi. Fungi are an important group of plant pathogens—most plant diseases are caused by fungi—but fewer than 10% of all known fungi can colonize living plants .

Plant pathogenic fungi represent a relatively small subset of those fungi that are associated with plants. Most fungi are decomposers, utilizing the remains of plants and other organisms as their food source. Other types of associations that include the role of fungi as decomposers, as beneficial symbionts, and as cryptic plant colonizers called endophytes.

Most fungi are associated with plants as saprotrophs and decomposers. These fungi break down organic matter of all kinds, including wood and other types of plant material. Wood is composed primarily of cellulose, hemicellulose, and lignin. Lignin is a complex polymer that is highly resistant to degradation, and it encrusts the more readily degradable cellulose and hemicellulose.

Fungi are among the few organisms that can effectively break down wood, and fall into two main types—brown and white rot fungi.
Brown rot fungi selectively degrade the cellulose and hemicellulose in wood, leaving behind the more recalcitrant lignin.
The decayed wood is brown in color and tends to form cubical cracks due to the brittle nature of the remaining lignin.

White rot fungi are more common than brown rot fungi; these fungi degrade cellulose, hemicellulose, and lignin at approximately equal rates. The decayed wood is pale in color, light in weight, and has a stringy texture. White rot fungi are the only organisms that can completely degrade lignin. Lignin is one of the most abundant organic polymers, accounting for 30% of the organic carbon on the planet—only cellulose is more abundant.

An important group of fungi associated with plants is mycorrhizal fungi. Mycorrhiza means 'fungus root', and it refers to a mutually beneficial association (a type of symbiosis) between fungi and plant roots. There are seven major types of mycorrhizal associations, the most common of which is the arbuscular mycorrhizae, involving members of phylum Glomeromycota associated with roots of most major groups of plants.

Another common type of association is ectomycorrhizae formed between forest trees and members of phyla Basidiomycota and Ascomycota.

In this association, the fungus forms hyphae around host root cortical cells—the "Hartig net"— and a sheath of hyphae around the host roots called a "mantle. "Many of the ectomycorrhizal fungi are mushroom-forming species including highly prized edibles such as chanterelles (Cantharellus cibarius and related species), boletes (Boletus edulis and related species), and matsutake (Tricholoma magnivelare).

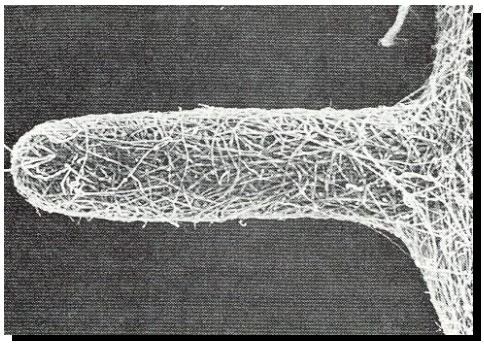
A valuable group of ectomycorrhizal fungi are truffles, members of phylum Ascomycota that form underground fruiting bodies.

Mycorrhizae

Specific, mutualistic association of plant roots and fungi

Fungi increase absorptive surface of roots and exchange soil minerals

Found in 95% of vascular plants. Necessary for optimal plant growth.



Lichens are examples of a symbiotic association involving a fungus and green algae or less frequently Cyanobacteria. The lichen thallus is composed mostly of fungal hyphae, usually with the alga or cyanobacterium confined to discrete areas of the thallus.

In lichens, reproductive structures of the fungus are often conspicuous, for example disc- or cup-like structures called apothecia. The fungus obtains carbohydrates produced by photosynthesis from the algae or cyanobacteria, and in return provides its partner(s) with protection from desiccation and ultraviolet light. The alga:Provides fungus with food. May fix nitrogen Fungus provides good environment for growth:
Hyphal mass absorbs minerals and protects algae Produces compounds that: shield algae from sunlight are toxic - prevents predation.

Lichens Symbiosis of algae with fungal hyphae

Some fungi are hidden inside their plant hosts; these are endophytes, defined by their presence inside asymptomatic plants. All plants in natural ecosystems probably have some type of symbiotic association with endophytic fungi .

Endophytic fungi have been shown to confer stress tolerance to their host plant, for example, to disease, herbivory, drought, heat, salt and metals.

Food

Fungi are also important directly as food for humans. Many mushrooms are edible and different species are cultivated for sale worldwide. While this is a very small proportion of the actual food that we eat, fungi are also widely used in the production of many foods and drinks. These include cheeses, beer and wine, bread, some cakes, and some soya bean products.

Medicines

Penicillin, perhaps the most famous of all antibiotic drugs, is derived from a common fungus called Penicillium. Many other fungi also produce antibiotic substances, which are now widely used to control diseases in human and animal populations. The discovery of antibiotics revolutionized health care worldwide.

Some fungi which parasitise caterpillars have also been traditionally used as medicines. The Chinese have used a particular caterpillar fungus as a tonic for hundreds of years. Certain chemical compounds isolated from the fungus may prove to be useful treatments for certain types of cancer.

A fungus which parasitises Rye crops causes a disease known as Ergot. The fungus can occur on a variety of grasses. It produces small hard structures, known as sclerotia. These sclerotia can cause poisoning in humans and animals which have eaten infected material. However, these same sclerotia are also the source of a powerful and important drug which has uses in childbirth

Biocontrol

Fungi such as the Chinese caterpillar fungus, which parasitise insects, can be extremely useful for controlling insect pests of crops. The spores of the fungi are sprayed on the crop pests. Fungi have been used to control Colorado potato beetles, which can devastate potato crops. Spittlebugs, leaf hoppers and citrus rust mites are some of the other insect pests which have been controlled using fungi. This method is generally cheaper and less damaging to the environment than using chemical pesticides.

Food Spoilage

It has already been noted that fungi play a major role in recycling organic material. The fungi which make our bread and jam go moldy are only recycling organic matter, even though in this case, we would prefer that it didn't happen! Fungal damage can be responsible for large losses of stored food, particularly food which contains any moisture. Dry grains can usually be stored successfully, but the minute they become damp, moulds are likely to render them inedible. This is obviously a problem where large quantities of food are being produced seasonally and then require storage until they are needed.

Ecological classification introduces the need for usage of such terms as habitat, substratum and substrate.

Habitat is used to describe the place where a fungus lives, and so has some connotations as to the physicochemical environment within which development takes place.

Substratum refers to the medium within the habitat which physical supports the fungus during development

substrate to a specific biochemical constituent of the substratum.Fungal species living in a single habitat often occupy distinctly different ecological niches that is they exploit different facets of the substrata on which they are growing.

Sustrates are located in either living or non-living substrata, and three nutritional modes have been recognized in fungi according to the way in which they gain access to them.

Ultrastructure of fungal cell

Fungi can be single celled or very complex multicellular organisms.

1) **The cell wall**

The fungal cell wall is a dynamic structure that protects the cell from changes in osmotic pressure and other environmental stresses, while allowing the fungal cell to interact with its environment. Except slime molds (Myxomycetes), the fungal cell consists of a rigid cell wall and cell organelles. Chemical analysis of cell wall reveals that it contains 80-90% polysaccharides and remaining proteins and lipids. Chitin, cellulose or other glucans are present in cell walls in the form

of fibrils forming layers . The wall enables reproduction, recognition and reception. Fungal cell walls are composed of polysaccharides with relatively small amounts of proteins, lipids, and inorganic ions.

The polysaccharides occur in two major types of structures:

Microfibrils and matrix. Strands of polysaccharides chains are embeded in the matrix (smaller polysaccharides, protein and lipids which appears amorphous and granular.Wall resembles concrete with microfibrils functioning as steel rods and matrix the surrounding cement, these cause mechanical rigidity & strength of the wall.

2) **Plasma membrane**

In fungi too, cell wall is followed by plasma membrane that encloses the cytoplasm. It is semipermeable and in structure and function it is similar to that of prokaryotes. However, there are specialized organelles in the surface of plasma membrane where the fusion of secretory vesicles of cytoplasm occurs. • The plasmalemma invaginates and forms a pouch like structure enclosing the granular or vesicular materials. Scientists named it lomasomes. It has been defined as "membranous vesicular material embedded in the wall external to the line of "plasmalemma.

3) Cytoplasm

The cytoplasm and most organelles and inclusions of fungal cytoplasm are typical of eukaryotic organisms. Cytoplasm is colourless in which sap-filled vacuoles are found. The cytoplasm contains 1 or more globose or spherical nuclei of about 1-3µm in diameter.

4) **A nucleus** consists of a bilayered porous nuclear envelope that encloses the chromosomes and nucleolus. The chromosome consists of DNA and histones. The nuclear pores permit to interchange the materials between the cytoplasm and nucleus. 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. 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

5) **Cell organelles** are ER, mitochondria, ribosomes, golgi bodies and vacuoles. • Lomasomes are also present between plasma membrane and cell wall.

a) Mitochondria: The mitochondria of fungi are clearly recognisable. They have a double bilayer membrane and contain complex internal membranes. They differ from other eukaryotic organisms in that the mitochondria are commonly elongate, oriented along the hyphal axis. These are power house of the cell. It has machinery for transcription and translation of organelle specific DNA.

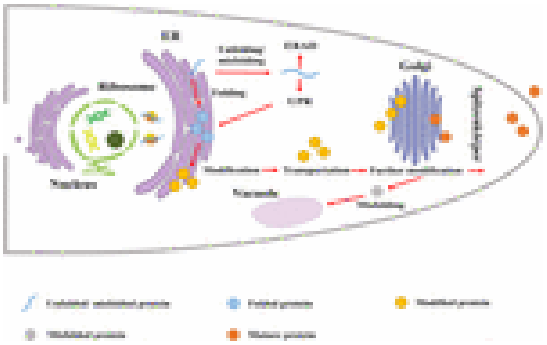
b) Endoplasmic reticulum. Presence of ER in fungal cytoplasm is observed through electron microscope. It is made up of a system of microtubules with small granules. • In most of the fungi, it is highly vascular. • It is loose and irregular as compared with cells of green plants. • In multinucleate hyphae, the nuclei may be connected by ER.

c- Vacuoles are essential for cell function in fungi. Fungi are characterised by the presence of spherical to tubular vacuoles. They are found in the old cells of hyphae. The end of hyphal tip of young hyphae lacks vacuole. They are surrounded by membrane called tonoplast. They play an important role in osmoregulation.

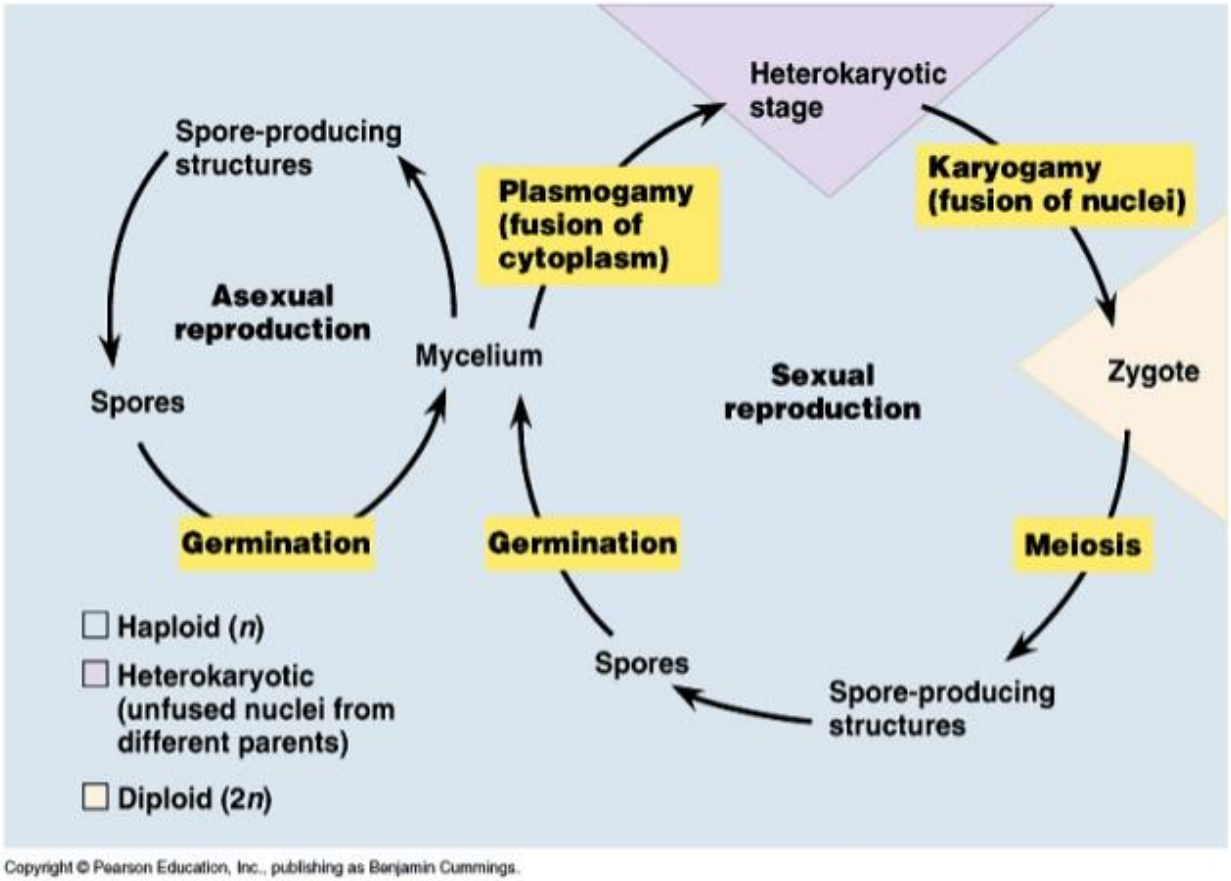
d) Golgi apparatus or Dictyosomes Except in Oomycetes, golgi apparatus is rare occurrence in fungal cells. In Oomycetes, golgi apparatus consists of stacks of folded membranes functioning in secretion. Major function is to process and package macromolecules (proteins) and transportation of lipids around the cell.

Depending upon the species, the protoplasm may form a continuous, uninterrupted mass running the length of the branching hyphae, or the protoplasm may be interrupted at intervals by cross-walls called **Septa.** Septa divide up hyphae into individual discrete cells or interconnected **Hyphal compartment**. There can be various type of septa present in different fungi. They are complete septa, perforated septa, dolipore septa, etc. Functions of septa: act as **structural supports**.

and as the **first line of defense** when part of a hypha is damage. Facilitate **differentiation** in fungi.



Cytoplasmic inclusions • Cytoplasm consists of various inclusions such as lipid droplets and glycogen, carbohydrate trehalose, proteinaceous material and volutin. The vacuoles contain glycogen. Several metabolites are secreted by the .cytoplasm. In matured cell, lipids and glycogen are abundantly present

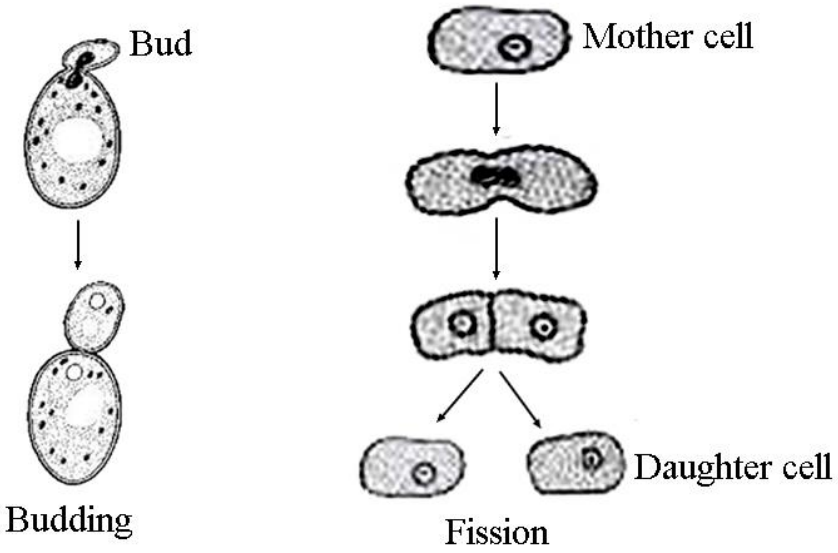


Reproduction in fungi:

Some simple types of thalli are converted entirely into reproductive cells and are termed holocarpic .In eucarpic thalli,which are typical of most fungi, only part of the thallus becomes reproductive and the cells formed for this purpose are usually highly specialized in form and development.

Vegetative, Asexual and Sexual methods

1- **Vegetative reproduction**: The most common method of vegetative reproduction is fragmentation. The hypha breaks up into small fragments accidentally or otherwise. Each fragment develops into a new individual. In the laboratory the hyphal tip method is commonly used for inoculation of saprophytic fungus.It occurs by
   - **1-** Fragmentation: Mycelium gets fragmented into small fragments, each of which is able to develop into new individual. It is common in filamentous fungi.
   - **2-** Fission occurs in unicellular fungi such as yeasts. Mature cells divided mitotically into two and the two daughter cells separates and give rise to two individual.
   - **3-** Budding Bud like growth emerges out from the mature cells. It is commonly occurs in unicellular forms such as yeast.
   - **4-** Formation of gemmae: Gammae are specialized thick walled aggregation of chlamydospores like structures. They are formed in unfavorable condition.



Asexual reproduction

It is the more important type of reproduction as it occurs several times throughout the season. Progeny is genetically identical to the parent. Asexual reproduction takes place during favorable condition by the formation of variety of spores. Such spores produced by asexual reproduction are called mitospores. Spores may be unicellular or multicellular so they are classified into

1- Amerospores one celled spore

2- Didymospore two celled spore

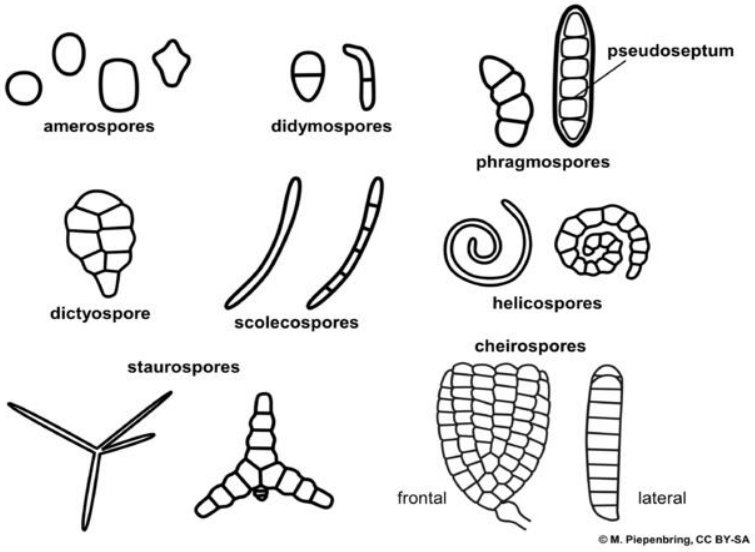
3- Phragmospore spore with two or moretransverse septa

4-Dictyospores sporeswith one or more transverse and vertical septa

5- Scolecospores vermiform or filiform shaped spores

6- Staurospores stellate or spores with radiating arms

7- Helicospores spirally coiled spores



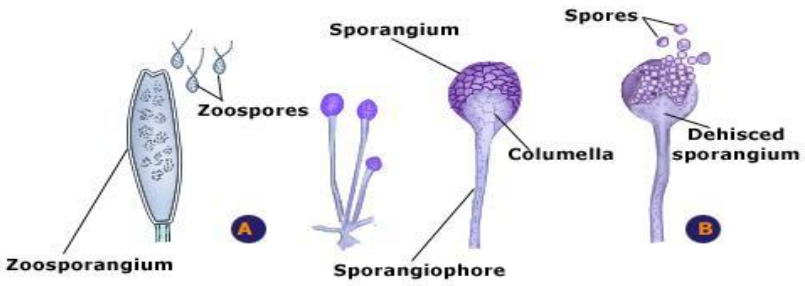
Fungi produce two major types of asexual spore: sporangiospores and conidia.
Types of Asexual Spore:

Sporangiospores: ENDOGENOUS formed and contained within a sporangium as a result of the cleavage of protoplasm around nuclei and followed in some cases by formation of a wall around each nucleate portion of protoplasm.

Two main types Zoospores (motile) and Aplanospores (non- motile).

a) Aplanospores: a nonmotile, asexual spore formed within cell, the wall of which is distinct from that of the parent cell.

b) Zoospores : Zoospores are MOTILE SPORANGIOSPORES and the sporangia in which they are formed are called ZOOSPORANGIA. Because zoospores are motile, the fungi that produce them will require water at some stage during their life cycle. Three different types of zoospore distinguish the Chytridiomycota, Hyphochytridiomycota and Oomycota.



Exogenous spores

The spores produced externally are either called the exogenous spores or conidia. They are produced externally on the branched and unbranched conidiophore which may be septated or non –septated (aseptated). The conidia borne upon the terminal apices of the conidiophores or the end of the branches of conidiophores. The conidia may be produced singly on each sterigma or in chain. The conidial chains may be basipetal or acropital in succession. The conidia are diverse in shape and size. Two main types - THALLIC and BLASTIC

a) **Thallic conidia**: Develop by septation and fragmentation of a hypha. May develop at the tip of hypha or in an intercalary (central) position. In both cases, all layers of the hyphal wall are involved in spore formation. It is further divided into 2 types: Arthrospores and Chlamydospores.

1. Arthrospores: Formed by septation and fragmentation of an existing hypha. Elements of the hypha (incl. all wall layers) become converted into conidia. Each fragment is rounded off and liberated in succession. Separation of the conidia from :one another is due to breakdown of the middle region of each septum.

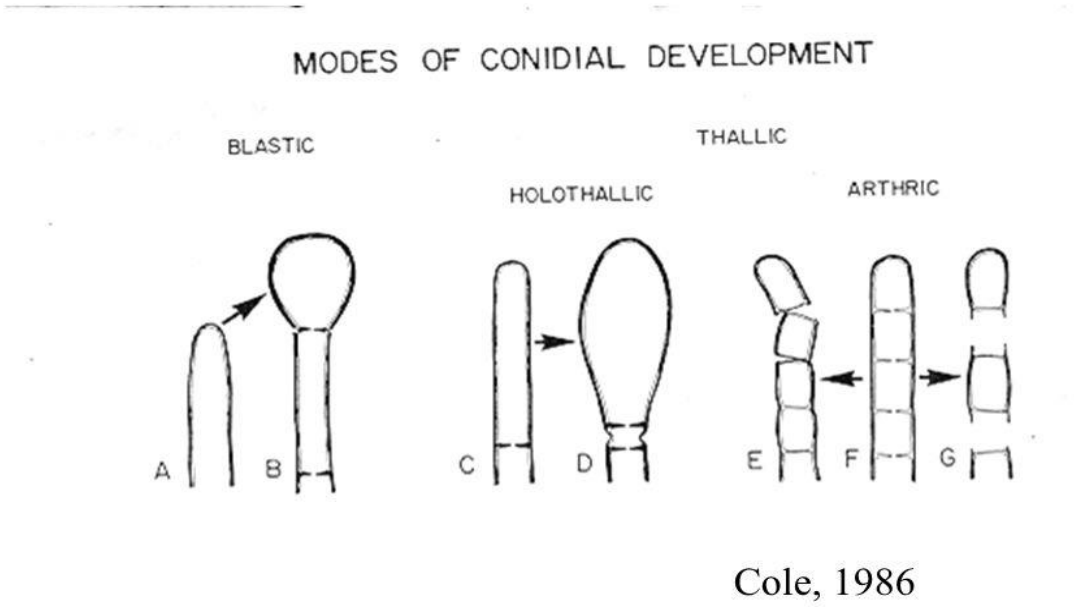
2-Chlamydospores: A type of resting (survival) spore. An intercalary or apical hyphal cell or compartment enlarges, rounds up and develops a thickened, often pigmented wall. Contain dense cytoplasm and nutrient storage compounds. All wall layers are involved in their formation. Become isolated from adjacent hyphal compartment(s) by the sealing of septal pores (if present). Usually develop under conditions of stress that are unfavourable for normal somatic growth.

b) **Blastic conidia:** Develop by a budding or swelling process. May develop as single spores or in succession to form a chain of spores.

1. Blastospores: • Formed by budding of a hypha or yeast cell. • Both wall layers are involved. • The spore may remain attached and bud further blastospores - giving rise to a branched chain of spore.

@

Blastic versus **thallic**



Cole, 1986

Porospores: • The developing spore emerges through a distinct 'pore' in the hyphal wall. • Only the inner layer of the hyphal wall is involved in spore development. • The new spore then develops its own new inner wall layer. • The outer spore wall is often thickened and pigmented. • A scar is usually obvious at the point of detachment from the hypha (conidiophore).

Aleuriospores: • Develop as single, terminal spores. • Conidiophore apex inflates and becomes separated by a septum at an early stage in spore development. Both wall layers are involved in spore formation . • The spore possesses a wide, truncate scar. • Normally no further development of spores occurs at the point of detachment. So the next spore usually has to develop by production of a branch below the scar on the conidiophore.

Annellospores: • In some species that form conidia in a manner similar to that described for aleuriospores a new growing point develop at the scar. A chain of spores may develop. • The conidiophore gets a little longer with each spore produced. • Annellations (ring-like scars) are observed around this elongating portion. • Each annellation represents the production of one annellospore.

Phialospores: • Form in succession. • Each spore is pushed up from the tip of the conidiophore, which is now called a PHIALIDE. • The spore wall is new and distinct from both wall layers of the phialide. • The first spore has a cap, which represents the tip of the phialide wall through which the spore emerged - all other spores in the chain are smoothly rounded.

3-Sexual Reproduction

In fungi, as in other organisms, sexual reproduction greatly increases variability in a species. In fungi, sexual reproduction often occurs in response to adverse environmental conditions.

Sexual reproduction in fungi consists of three sequential stages: plasmogamy, karyogamy, and meiosis .

1- Plasmogamy, the fusion of two protoplasts (the contents of the two cells), brings together two compatible haploid nuclei .

2-Karyogamy, two nuclei types are present in the same cell, but the nuclei have not yet fused. Karyogamy results in the fusion of these haploid nuclei and the formation of a diploid nucleus (i.e., a nucleus containing two sets of chromosomes, one from each parent). The cell formed by karyogamy is called the zygote.

3-Meiosis (cell division that reduces the chromosome number to one set per cell) generally follows and restores the haploid phase. The haploid nuclei that result from meiosis are generally incorporated in spores called meiospore

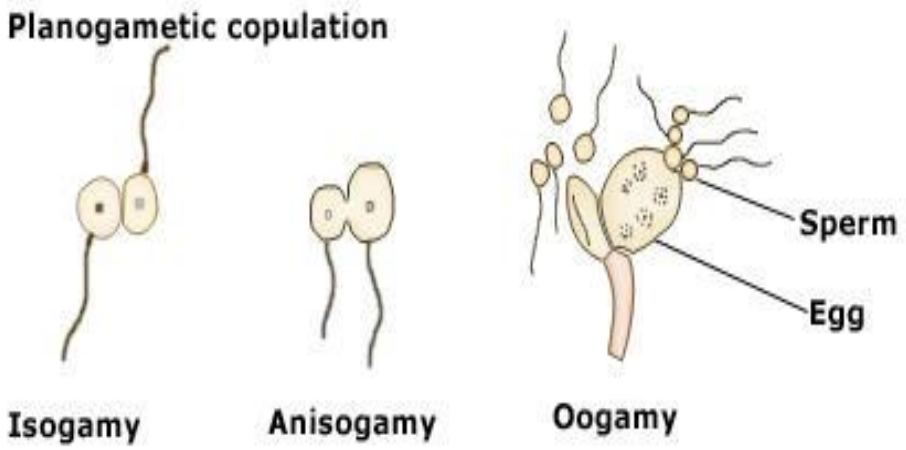
In most of the lower fungi plasmogamy is immediately followed by karyogamy and meiosis. In higher fungi karyogamy is often delayed so that the hyphae remain dikaryotic. This phase of fungal life cycle is called dikaryophase. Such fungi complete their life cycle in three phases :

a haplophase, The phase in the life cycle of an organism in which its nuclei are haploid. A dikaryophase In higher fungi, karyogamy is delayed and occurs just before meiosis. In the stage intervening between plasmogamy and karyogamy the cells often contain two nuclei or Dikaryons (n+n). Such cells are called dikaryotic cells. The phase is known as Dikaryophase which takes place in Ascomycetes and Basidiomycetes. A diplophase The phase in the life cycle of an organism in which its nuclei are haploid.

The types of sexual reproduction in different groups of fungi:

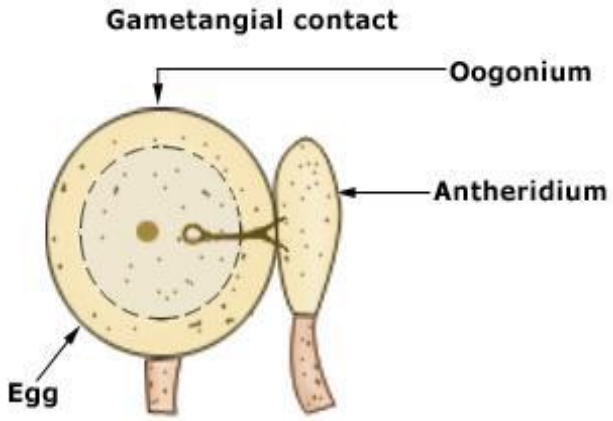
Planogametic Copulation

Here motile gametes called planogametes undergo fusion. When both the gametes are motile and morphologically similar, the fusion process is called isogamy. But Anisogamy two motile gametes are fused and morphologically different .



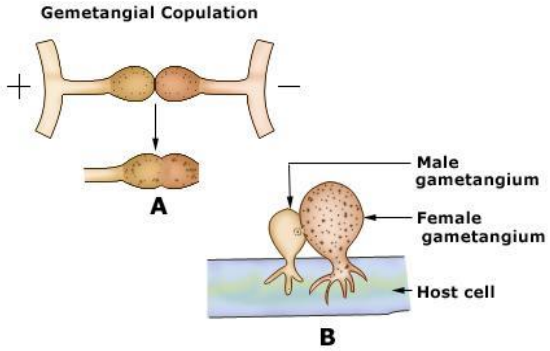
Gametangial Contact

Here, gamete bearing structures called gametangia (Antheridium male gametanium , Oogonium female gametangium) come closer to each other and develop a fertilization tube through which the male gamete migrates into the female gametangium.



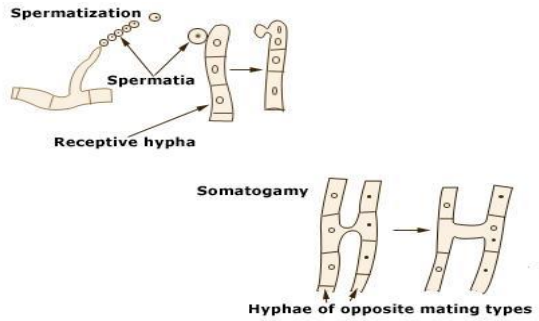
Gametangial Copulation

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

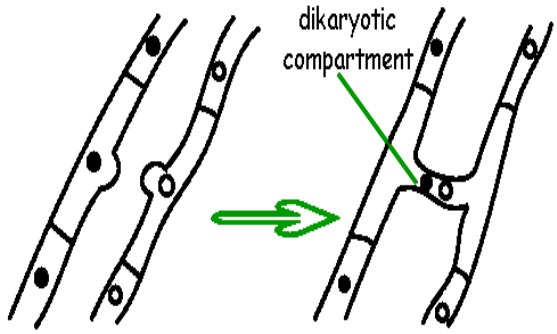


Spermatisation

In some fungi like Puccinia, tiny unicellular spore like structures (1n) called spermatia bearing on spermatophore and They get transferred to (receptive hypha) through various agencies (wind , insects , air ,water etc) , A pore develops at the point of contact between the hypha and the spermatium then the contents of spermatium(including its nucleus) pass into the hyphal compartment, which as a result becomes dikaryotic.



Somatogamy : this type occurs in higher fungi , The fusion of somatic hyphae of two compatible mycelia results in a dikaryon from which a dikaryotic mycelium may develop. the dikaryotic phase is limited to mycelium within the fruiting body.



Life Cycle

In general, fungi begin their lives as a spore, then germinate and develop into mycelium. in the life cycle of a sexually reproducing fungus, a haploid phase alternates with a diploid phase. The haploid phase ends with nuclear fusion, and the diploid phase begins with the formation of the zygote (the diploid cell resulting from fusion of two haploid sex cells). Meiosis (reduction division) and initiates the haploid phase, which produces the gametes. In the majority of fungi, all structures are haploid except the zygote. Nuclear fusion takes place at the time of zygote formation, and meiosis follows immediately

Fungi usually reproduce both sexually and asexually. The asexual cycle produces mitospores, and the sexual cycle produces meiospores. Even though

both types of spores are produced by the same mycelium, they are very

different in form and easily distinguished . The asexual phase usually precedes the sexual phase in the life cycle and may be repeated frequently before the sexual phase appears

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 (monoecious) , fusion occurs between the genetically similar strains or mating types. In such forms, meiosis results in the formation of genetically identical spores. Homothallic (monoecious) refers to the possession, within a single organism, of the resources to reproduce sexually; i.e., having male and female reproductive structures on the same thallus.

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. Heterothallic species have sexes that reside in different individuals. The term is applied particularly to distinguish heterothallic fungi, which require two compatible partners to produce sexual spores, from homothallic ones, which are capable of sexual reproduction from a single organism.

Sexually produced spores of the higher fungi result from meiosis and are formed either in sac-like structures (asci, typical of the Ascomycota) or on the surface of club-shaped structures (basidia, typical of the Basidiomycota). Asci and basidia may be borne naked, directly on the hyphae, or in various types of sporophores called ascocarps (also known as ascomata) or basidiocarps (also known as basidiomata), depending on whether they bear asci or basidia respectively.

Since fungi are often classified according to their spore-producing structures, these spores are often characteristic of a particular taxon of the fungi: • Zygospores: spores produced by a zygosporangium, characteristic of zygomycetes. • Ascospores: spores produced by an ascus, characteristic of ascomycetes. • Basidiospores: spores produced by a basidium, characteristic of basidiomycetes. • Aeciospores: spores produced by an aecium in some fungi such as rusts or smuts. Urediniospores: spores produced by a uredinium in some fungi such as rusts or smuts.

Teliospores: spores produced by a telium in some fungi such as rusts or smuts. • Oospores: spores produced by an oogonium, characteristic of oomycetes.

Sexually produced spores of the higher fungi result from meiosis and are formed either in sac-like structures (asci, typical of the Ascomycota) or on the surface of club-shaped structures (basidia, typical of the Basidiomycota). • Asci and basidia may be borne naked, directly on the hyphae, or in various types of sporophores called ascocarps (also known as ascomata) or basidiocarps (also known as basidiomata), depending on whether they bear asci or basidia respectively.

.

.