ii. Fungi

General Characters

The word fungus comes from the Latin word for mushrooms. Indeed, the familiar mushroom is a reproductive structure used by many types of fungi. However, there are also many fungi species that don't produce mushrooms at all. Being eukaryotes, a typical fungal cell contains a true nucleus and many membrane-bound organelles. The kingdom Fungi includes an enormous variety of living organisms collectively referred to as Ascomycota, or true Fungi . While scientists have identified about 100,000 species of fungi, this is only a fraction of the 1.5 million species of fungus probably present on earth. Edible mushrooms, yeasts, black mold, and the producer of the antibiotic penicillin, *Penicillium notatum*, are all members of the kingdom

(a) (b) (c)

Examples of Fungi

Many species of fungus produce the familiar mushroom (a) which is a reproductive structure. This (b) coral fungus displays brightly-colored fruiting bodies. This electron micrograph shows (c) the spore-bearing structures of Aspergillus, a type of toxic fungi found mostly in soil and plants.

Fungi, once considered plant-like organisms, are more closely related to animals than plants. Fungi are not capable of photosynthesis: they are heterotrophic because they use complex organic compounds as sources of energy and carbon. Some fungal organisms multiply only asexually, whereas

others undergo both asexual reproduction and sexual reproduction with alternation of generations. Most fungi produce a large number of spores, which are haploid cells that can undergo mitosis to form multicellular, haploid individuals. Like bacteria, fungi play an essential role in ecosystems because they are decomposers and participate in the cycling of nutrients by breaking down organic and inorganic materials to simple molecules.

Fungi often interact with other organisms, forming beneficial or mutualistic associations. For example most terrestrial plants form symbiotic relationships with fungi. The roots of the plant connect with the underground parts of the fungus forming mycorrhizae. Through mycorrhizae, the fungus and plant exchange nutrients and water, greatly aiding the survival of both species Alternatively, lichens are an association between a fungus and its photosynthetic partner (usually an alga). Fungi also cause serious infections in plants and animals. For example, Dutch elm disease, which is caused by the fungus *Ophiostomaulmi*, is a particularly devastating type of fungal infestation that destroys many native species of elm (*Ulmus* sp.) by infecting the tree's vascular system. The elm bark beetle acts as a vector, transmitting the disease from tree to tree. Accidentally introduced in the 1900s, the fungus decimated elm trees across the continent. Many European and Asiatic elms are less susceptible to Dutch elm disease than American elms.

In humans, fungal infections are generally considered challenging to treat. Unlike bacteria, fungi do not respond to traditional antibiotic therapy because they are eukaryotes. Fungal infections may prove deadly for individuals with compromised immune systems.

Fungi have many commercial applications. The food industry uses yeasts in baking, brewing, and cheese and wine making. Many industrial compounds are byproducts of fungal fermentation. Fungi are the source of many commercial enzymes and antibiotics.

Classification of fungi by Alexopoulos, Mims & Blackwell (1996):

Alexopoulos, Mims & Blackwell (1996)

"Fungi" [polyphyletic group]

- Kingdom **Fungi**
  - Phylum Chytridiomycota
  - Phylum Zygomycota
  - Phylum Ascomycota
  - Phylum Basidiomycota
- Kingdom Stramenopila [including some algae]
  - Phylum Oomycota
  - Phylum Hyphochytriomycota
  - Phylum Labyrinthulomycota
- Kingdom Protista
  - Phylum Plasmodiophoromycota
  - Phylum Dictyosteliomycota
  - Phylum Acrasiomycota
  - Phylum Myxomycota
- Kingdom **Fungi**
  - Phylum Chytridiomycota
  - Phylum Zygomycota
  - Phylum Ascomycota
  - Phylum Basidiomycota
- Kingdom Stramenopila [including some algae]
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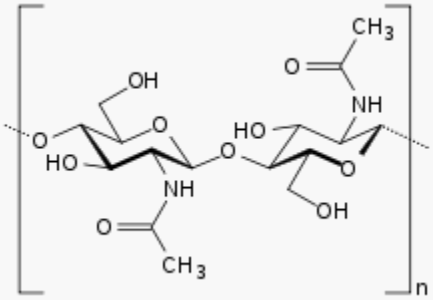
- Kingdom Protista
  - Phylum Plasmodiophoromycota
  - Phylum Dictyosteliomycota
  - Phylum Acrasiomycota
  - Phylum Myxomycota

Fungal cell wall composition



Chemical structure of a unit from achitin polymer chain.

There are several groups of organisms that have been called "fungi". Some of these groups (Oomycete and Myxogastria) have been transferred out of the Kingdom Fungi, in part because of fundamental biochemical differences in the composition of the cell wall. Most true fungi have a cell wall consisting largely of chitin and other polysaccharides. True fungi do not have cellulose in their cell walls.

True fungi

In fungi, the cell wall is the outer-most layer, external to the plasma membrane. The fungal cell wall is a matrix of three main components:[24]

- Chitin: polymers consisting mainly of unbranched chains of β-(1,4)-linked-N-Acetylglucosamine in the Ascomycota and Basidiomycota, or poly-β-(1,4)-linked-N-Acetylglucosamine (chitosan) in the Zygomycota. Both chitin and chitosan are synthesized and extruded at theplasma membrane.[24]
- Glucans: glucose polymers that function to cross-link chitin or chitosan polymers. β-glucans are glucose molecules linked via β-(1,3)- or β-(1,6)- bonds and provide rigidity to the cell wall while α-glucans are defined by α-(1,3)- and/or α-(1,4) bonds and function as part of the matrix.[24]
- Proteins: enzymes necessary for cell wall synthesis and lysis in addition to structural proteins are all present in the cell wall. Most of the structural proteins found in the cell wall are glycosylated and contain mannose, thus these proteins are called mannoproteins or mannans.

Nutrition:

Important classes in which the nutrition of fungi may be classified are as follows:

The fungi are achlorophyllolus plants and cannot synthesize their own food unlike green plants from carbondioxide and water in the presence of sunlight. They are so simple in structure that they cannot obtain inorganic food directly from the soil, and therefore they are always dependent for their food on some dead organic material or living beings.

The fungi which obtain their food from dead organic materials are called the saprophytes, whereas the fungi obtaining their prepared food from living plants or animals are called the parasites. The living beings on which the fungi parasitize are called the hosts. Some grow in the association of other plants and are mutually beneficial.

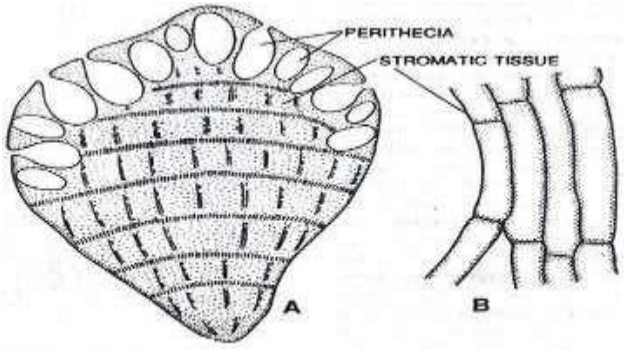


Fig. 8.7. Stroma. A, section through a stroma; B, structural detail of stroma.

Saprophytes:

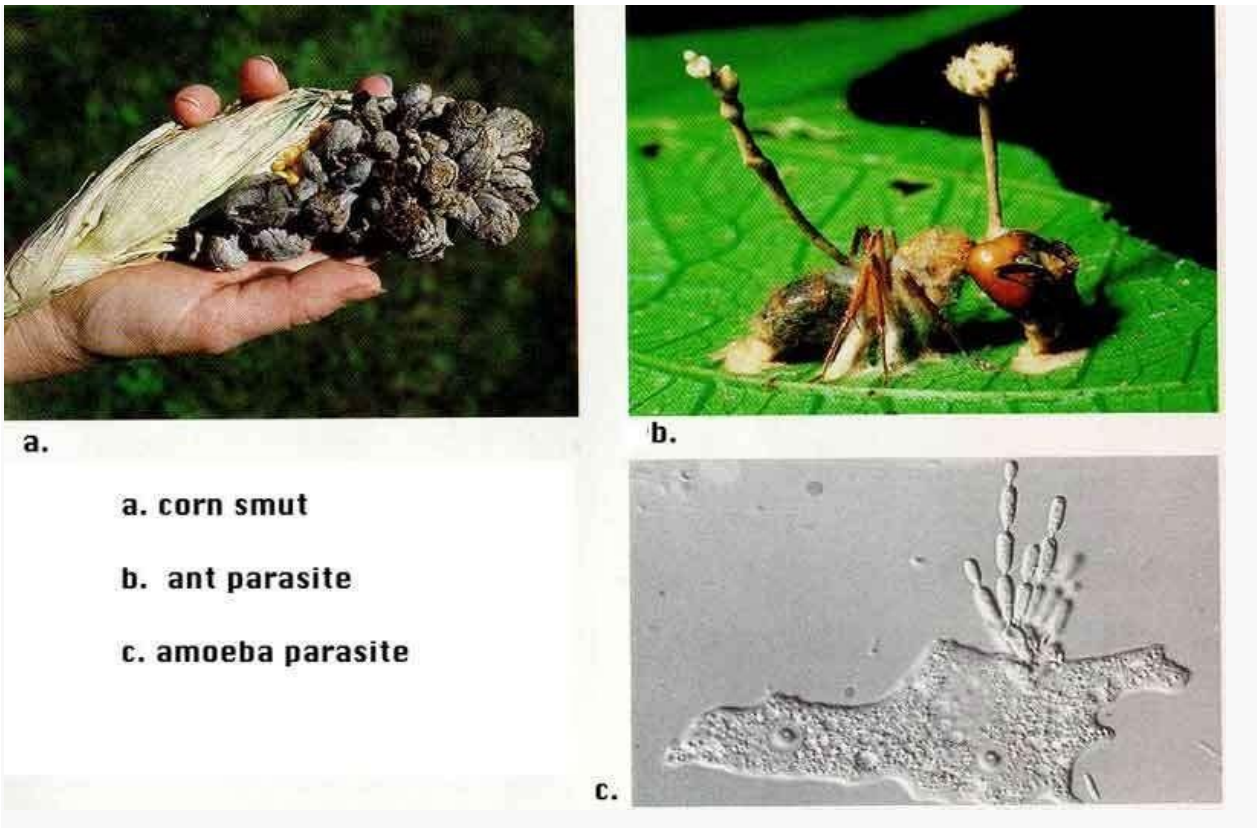
The saprophytic fungi live on dead organic materials produced by the decay of animal and plant tissues. They grow upon dead organic matters such as rotten fruits, rotten vegetabes, moist wood, moist leather, jams, jellies, pickles, cheese, rotting leaves, plant debris, manures, horse dung, vinegar, moist bread and many other possible dead organic materials. Saprolegnia, Mucor,

Rhizopus, Penicillium, Morchella, Aspergillus, Agaricus and many others are good examples of saprophytic fungi.

The saprophytic fungi absorb their food from the substratum by ordinary vegetative hyphae which penetrate the substratum, e.g., Mucormucedo. In other cases of the saprophytic fungi such as Rhizopus and Blastocladiella the rhizoids develop which penetrate the substratum and absorb the food material. In the case of saprophytic fungi the mycelium may be ectophytic or endophytic. In the case of Rhizopus the mycelium is ectophytic whereas the rhizoids remain embedded in the substratum and said to be endophytic.

(b) Parasites:

The parasitic fungi absorb their food material from the living tissues of the hosts on which they parasitize. Such parasitic fungi are quite harmful to their hosts and cause many serious diseases. These fungi cause the great losses to the human beings or indirectly. Many diseases of the important crops are caused by parasitic fungi. The rusts, smuts, bunts, mildews and many other plant diseases are important examples of fungal diseases of crops. Their mode of life is parasitic and the relation of host and parasite is called the parasitism.



a. corn smut

b. ant parasite

c. amoeba parasite

The parasites which survive on living hosts and only on living hosts are called the obligate parasites. Such parasites cannot be grown upon dead organic culture media, e.g., Puccini a, Peronospora, Melampsora, etc. The parasitic fungi which usually live on living hosts and according to their need they adopt saprophytic mode of life for some time are called the facultative saprophytes, e.g., Taphrinadeformans and some smuts.

Some parasitic fungi usually pass saprophytic mode of life, but under certain conditions they parasitize some suitable host and are called the facultative parasites, e.g., Fusarium, Pythium, etc.

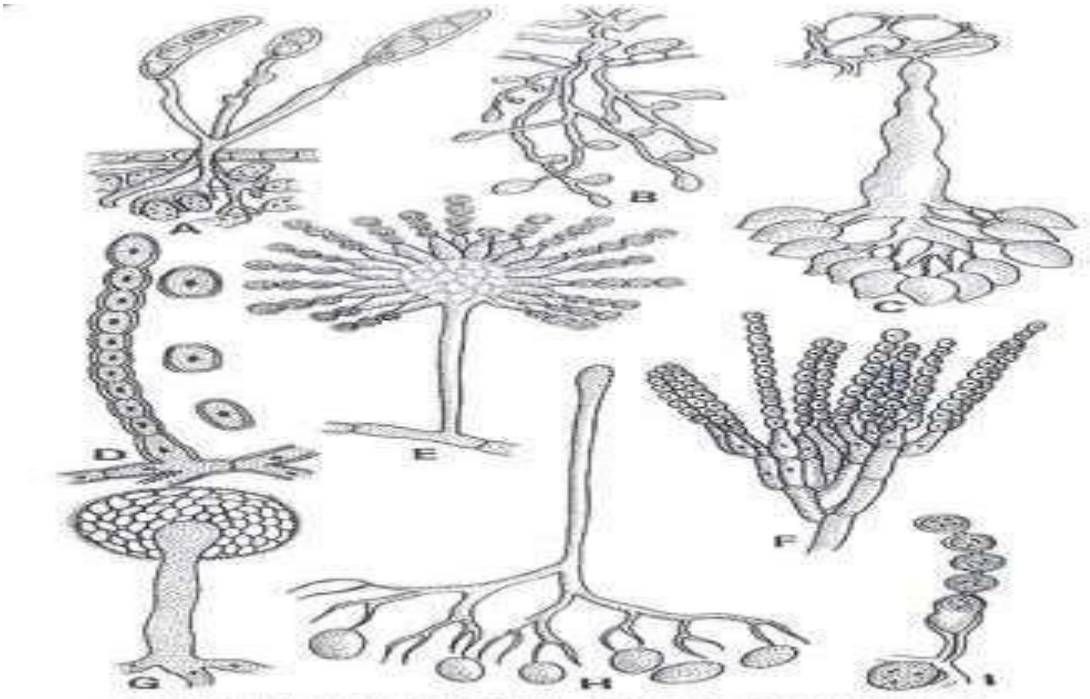


Fig 8.8. *The Fungi*. Various types of sporophores. A, conidiophores and conidia of *Helminthosporium*; B, sporangiophore and sporangia of *Phytophthora*; C, sporophore and sporangia of *Sclerospora*; D, conidiophore and conidia of *Erysiphe*; E, conidiophore and conidia of *Aspergillus*; F, conidiophore and conidia of *Penicillium*; G, sporangiophore and

The parasitic fungi absorb their food from the hosts in different ways. The fungus having the mycelium outside the host is called the ectoparasite, e.g., Erysiphe, whereas the fungus having the mycelium embedded in the host tissue is called the endoparasite. In the former type certain cushion-like appressoria develop on the surface of the host and from each appressorium a peg-like structure develops which penetrates the host epidermal cell giving rise to a branched or unbranched absorbing organ called the haustorium.

The haustoria may also develop from the mycelium of endoparasites. The haustoria vary in their shapes. They may be small, rounded, and button-like as in Albugo, branched and convolute as in Peronospora and highly branched as in Erysiphe.

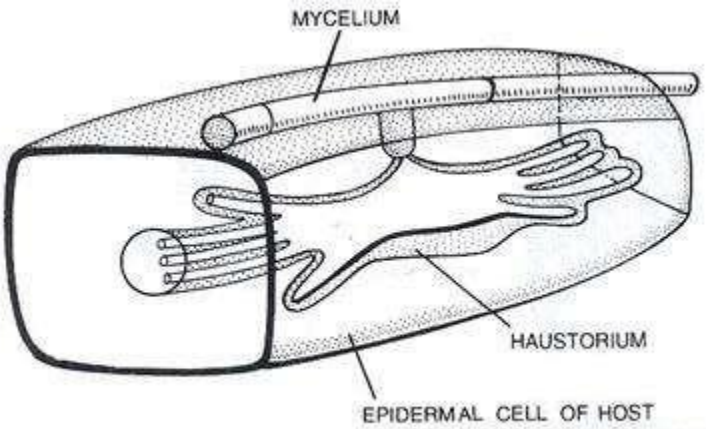


Fig. 8.9. Haustorium. Three-dimensional diagram of an infected epidermal cell with a branched haustorium of *Erysiphe* sp. (powdery mildew).

In the case of rusts and mildews the mycelium remains confined in the pustules and not in the whole body of the plant. This type of fungus is called the localized fungus. When the mycelium prevails in the whole of the plant it is said to be systemic fungus, e.g., smuts. When the mycelium is confined to the intercellular spaces it is called intercellular mycelium and in other cases the mycelium penetrates the host tissue and said to be intracellular. Usually the former bears haustoria and the latter does not.

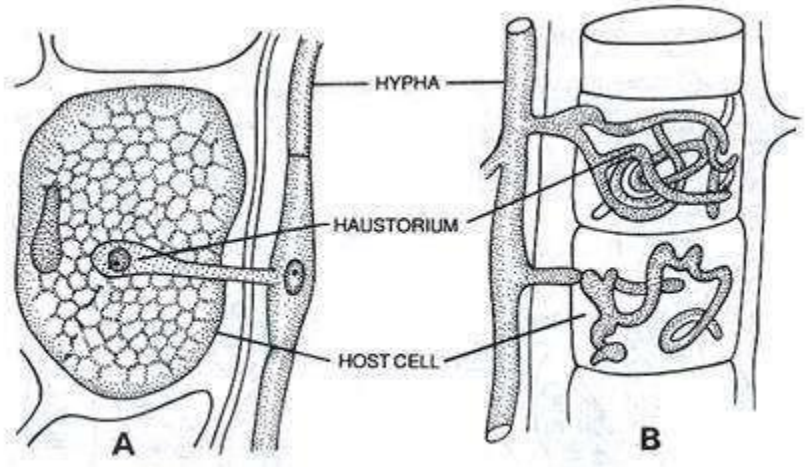


Fig. 8.10. Haustoria. A, elongated capitate haustorium; B, branched or digitate haustorium.

(c) Symbionts:

Some fungi live in close association of other higher plants where they are mutually beneficial to each other. Such relationship is called the 'symbiosis' and the participants the 'symbionts'. The most striking examples are the lichens and mycorrhiza. The lichens are the resultants of the symbiotic association of algae and fungi.

Here, both live together and are beneficial to each other. The algal partner synthesizes the organic food and the fungal partner is responsible for the absorption of inorganic nutrients and water. Certain fungi develop in the roots of higher plants and the mycorrhiza are developed.

Here the fungi absorb their food from the roots and in response are beneficial to the plants. The mycorrhiza may be external or internal. The external mycorrhiza also called the ectophyticmycorrhiza are confined to the outer region of the roots whereas the internal mycorrhiza are found deeply in the root cells.

It is to be remembered that in all the cases whether they may be saprophytes, parasites or symbionts, the food is absorbed in the form of solution by cell walls, rhizoids and haustoria.

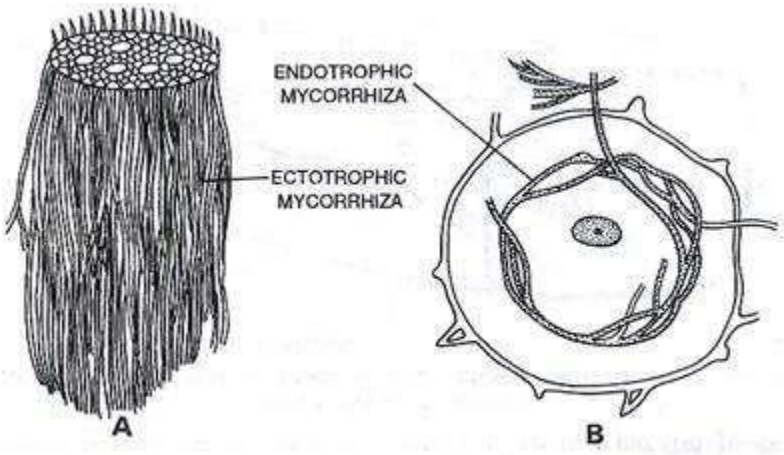


Fig. 8.11. Mycorrhiza. A, ectophytic mycorrhiza, B, endophytic mycorrhiza.

The hyphal cell walls are permeable and the plasma membranes lining to the cell walls are semipermeable. The osmotic pressure of the hyphal cells is higher than that of the host cells and thus the food materials are absorbed from the substratum and host cell. The fungi secrete some enzymes which dissolve the cellulose walls of the host, hydrolyse the starch and make it available to the fungus.

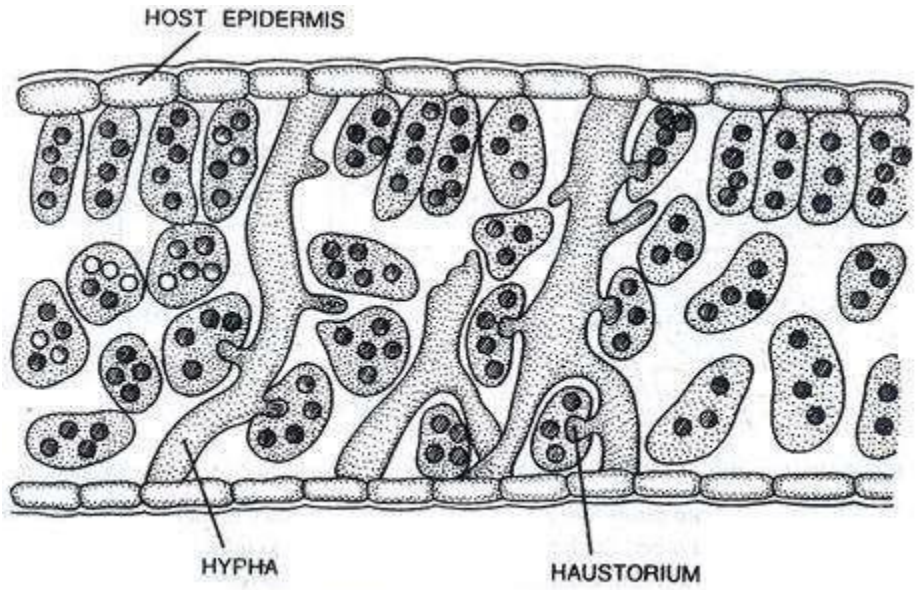


Fig. 8.12. Haustorium. Button-like or globular.

Many elements such as hydrogen, oxygen, nitrogen, small amounts of potassium, phosphorus and sulphur with the traces of magnesium and iron are required for the growth and other metabolic activities of the fungi. The carbon is always required in its organic form for growth.

When fungi are cultured in the laboratory on synthetic media, the necessary elements may be supplied in the following way: C is usually supplied in the form of a carbohydrate, such as

glucose or maltose sucrose and soluble starch are utilized by many fungi also. N may be supplied in the form of NH_4 salt or as amino acids.

Many fungi can utilize NO_3 salts. Each fungus has its own specific requirements which may be known experimentally. Most fungi are able to synthesize the vitamins they need. However, several fungi may need thiamine or biotin or both these substances are generally added to synthetic media.

(d) Predacious fungi:

There are many animal trapping fungi which have developed ingenious mechanisms for capturing small animals such as eellworms, rotifers or protozoa which they use for food. The most interesting of these mechanisms is that which utilizes a rapidly constricting ring around a nematode which holds it captive while the hyphae sink haustoria into the body of the victim.

Several species of fungi in the genera Arthrobotrys, Dactylella and Dactylaria employ this method. In the presence of an eelworm population, the hyphae of the fungi produce loops which are stimulated to swell rapidly and close the opening when an eelworm passing through the loop rules against its inner surface.

It is assumed that the amount of osmotically active material in the ring cells increases greatly as a result of stimulation and causes water to enter the cells increasing their turgor pressure. The ring cells swell rapidly and the ring closes around the eelworm which is thus held tightly in the

trap. Some predacious fungi secrete a sticky substance on the surface of their hyphae to which a passing small animal adheres. Haustorium like hyphae then grow into the body of the animal and absorb food. The animals ultimately die.

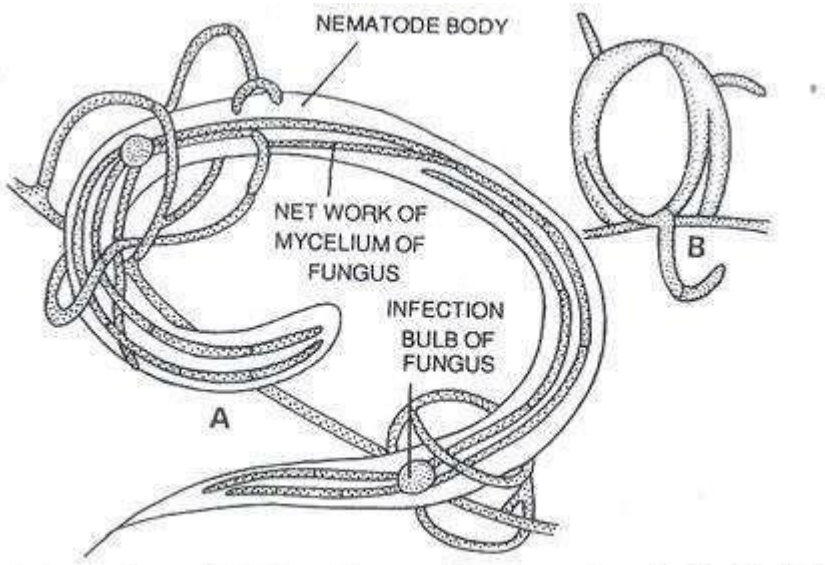


Fig. 8.13. Predacious fungus. *Arthrobotrys oligospora:* A, hyphae growing out of the infection bulb inside the body of the nematode; B, a fully developed network of fungus.

Vegetative Reproduction

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.

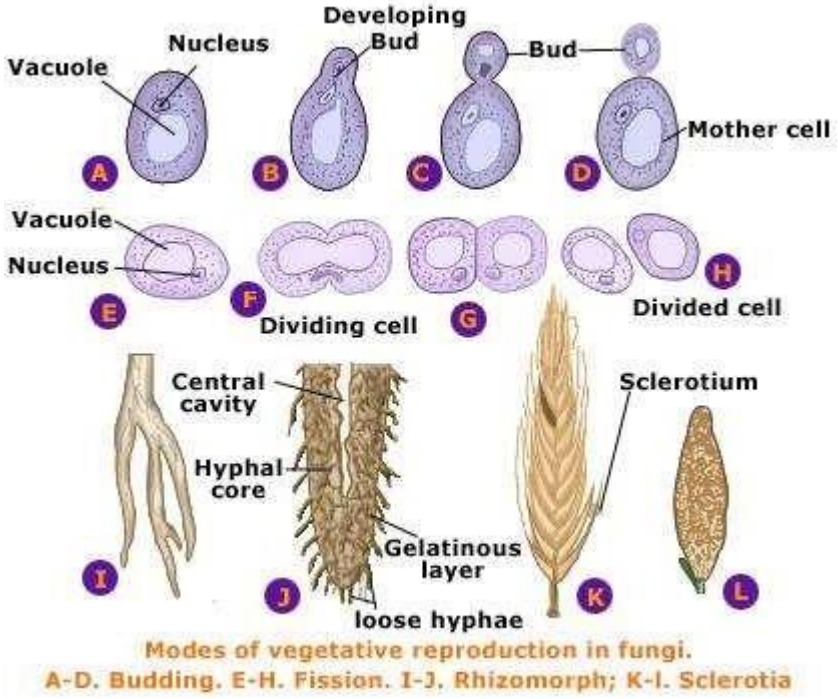


Fig. 8.19 - Modes of Vegetative Reproduction

Asexual Reproduction

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.

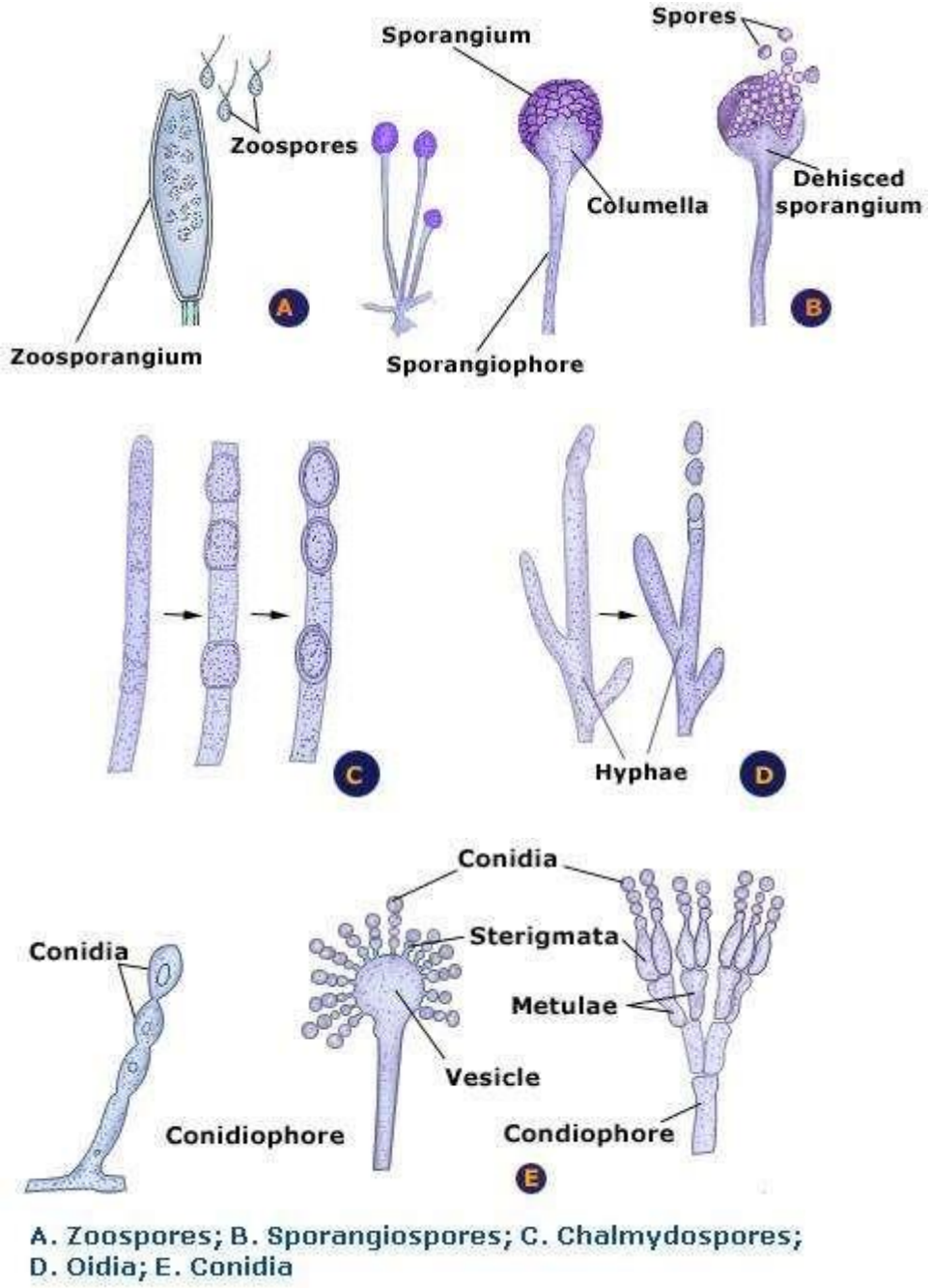


Fig. 8.20 - Modes of Asexual Reproduction

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.

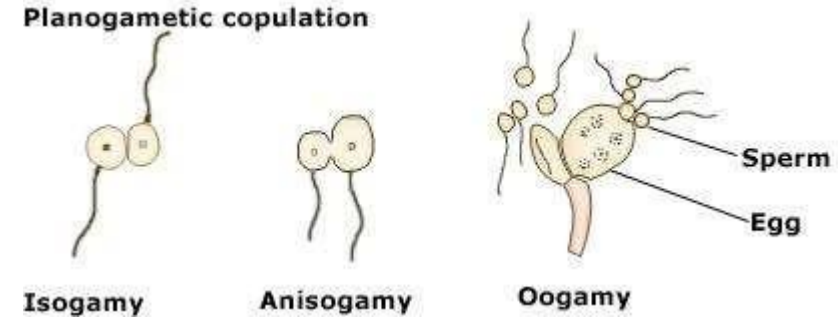
e,g. Phytophthora, Albugo.

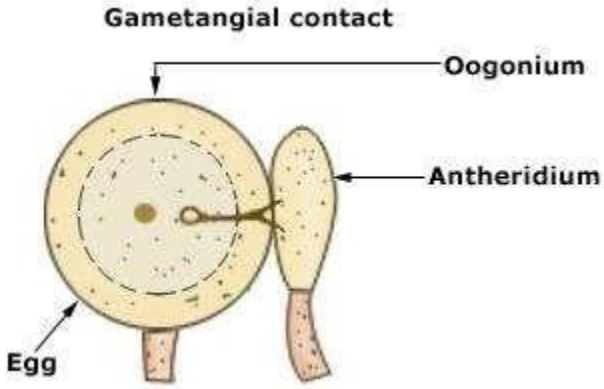
Gametangial Copulation

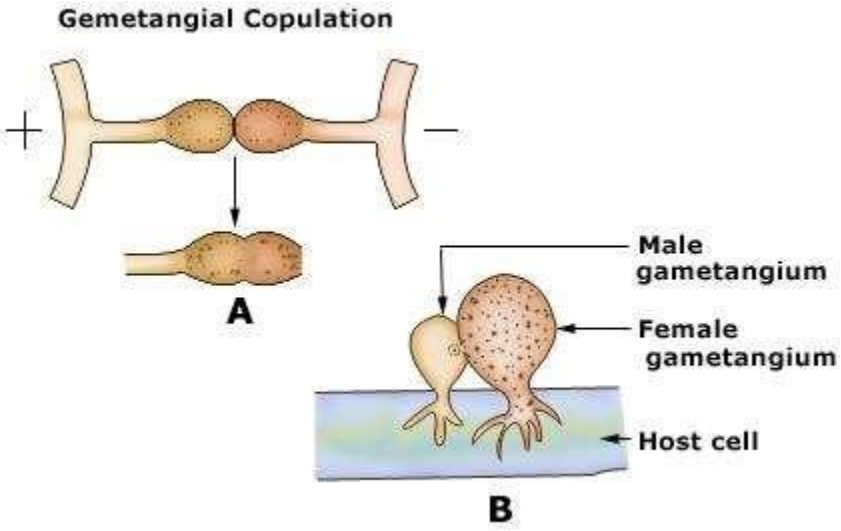
Here, the gametangia fuse with each other, lose their identity and develop into a zygospore e, g.:Mucor, Rhizopus

Spermatisation

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







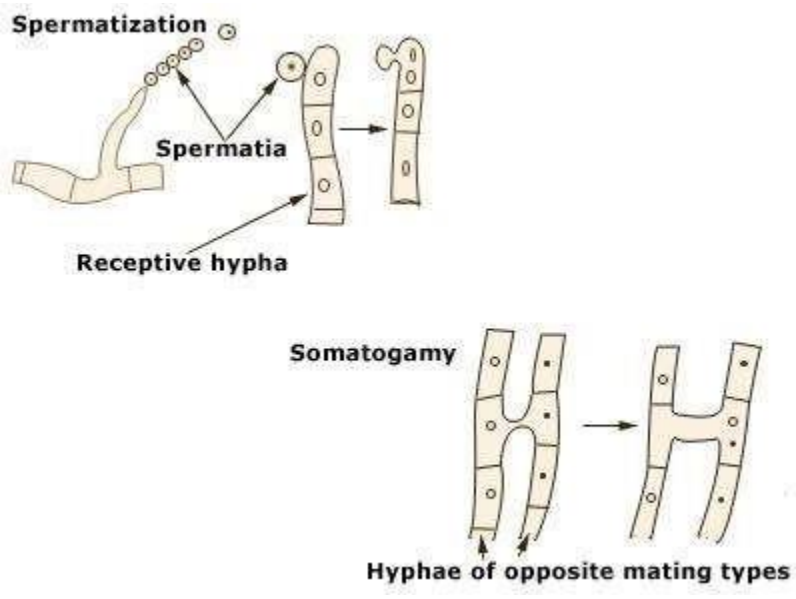


Fig. 8.21 - Types of Sexual Reproduction in Fungi

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.