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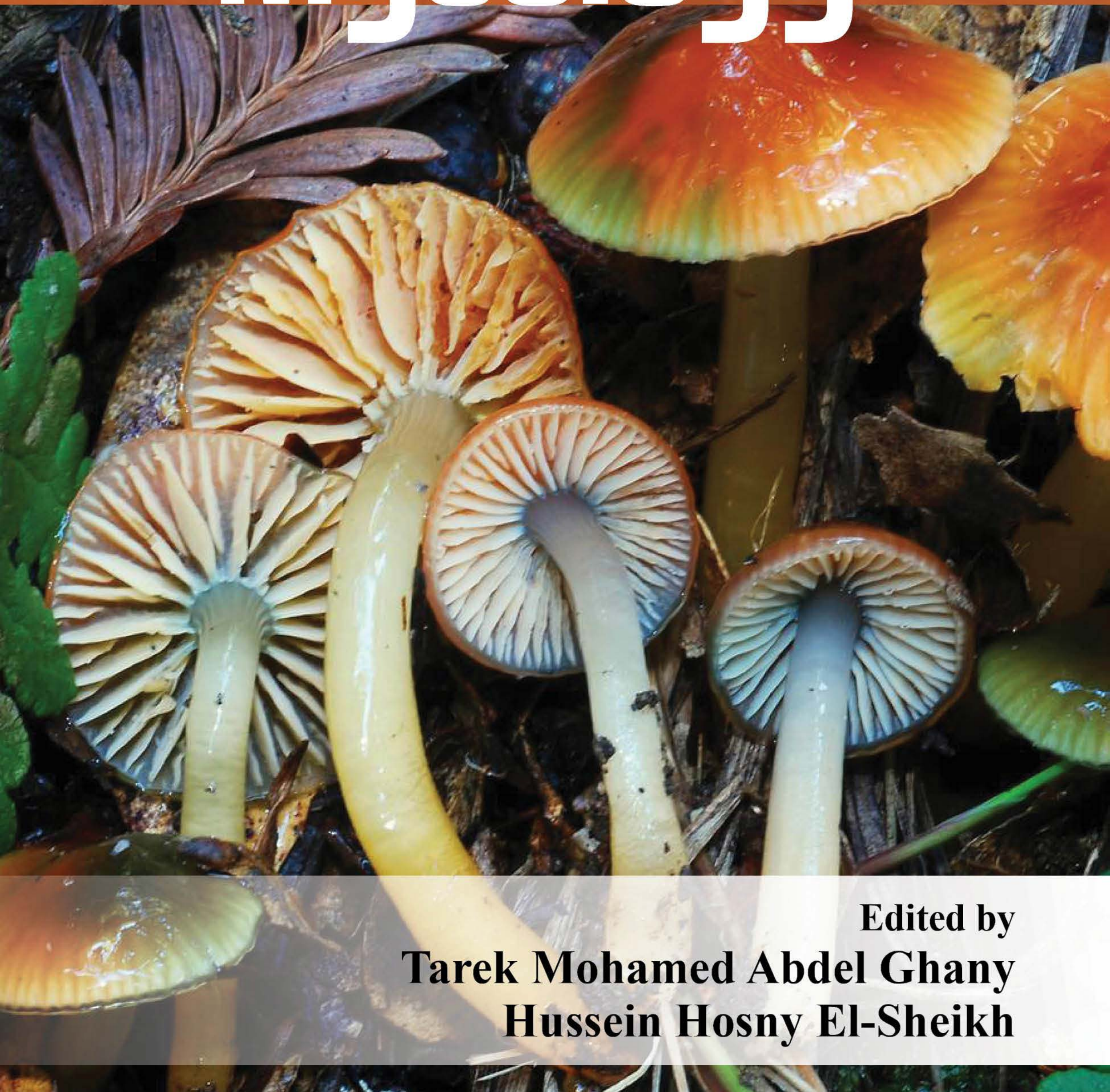
Mycology



Edited by
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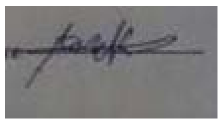
Preface

Mycology is an established text that continues to introduce fungi. Fungi are one of nature's most versatile organisms in their macro- and micro-structure, metabolism, ecology, and genomics. The first step is to understand fungal morphology; analysis and measurement of growth, and reproduction are included in this book. The taxonomic sections of this book are designed to facilitate study of fungi. It will appeal to undergraduate students taking courses in microbiology, mycology and biology. This textbook adopts a functional approach and contains extensive parts including introduction to the field of mycology, morphology, taxonomy as well as recent and old classification systems, ecology, life cycle and commercial utilization of the fungi, few for fungal role as plant, human pathogens and poisonous mushrooms.



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Introduction

Fungi are microscopic/macroscopic eukaryotic and heterotrophic organisms exhibiting growth on various natural and synthetic substrates and are capable of continuing their function almost indefinitely. Unlike other microorganisms such as algae, fungi lack the chlorophyll necessary for photosynthesis and must therefore live as parasites or saprobes. Fungi encompasses an enormous diversity of taxa with varied ecologies, life cycle strategies, and morphologies ranging from unicellular aquatic chytrids and yeasts to large truffles, morels and mushrooms. Impression of most people's for fungi was that they were responsible for diseases of human and animal. However, this impression was not entirely wrong. Fungi considered beneficial microorganisms. For example, without fungi, not all peoples would have leavened bread, many types of cheeses such as Roquefort and Camembert cheeses, beer, wine and other alcoholic beverages and some mushrooms, truffles and morels considered delicacies among gourmands. Fungi perform and play an essential role in the decomposition of organic matter and have fundamental roles in nutrient cycling and exchange in the ecosystem. For example, fungi play an important role in bioremediations including heavy metal removal, dyes and chemical pesticides degradations. They have contributed a lot toward shaping human welfare since the beginning of civilization. Their contribution ranges from natural to industrial use. The discovery of the value of fungi in ecosystem has brought greater success and has thus stimulated research throughout the world. Research on the fungi which cause food spoilage, and the mycotoxins they produce, can only be carried out effectively if based on accurate identification of the microorganisms responsible. Some fungi are pathogenic to humans and animals, such diseases called as mycoses. On the other hand, some molds, in particular, produce toxic compounds called mycotoxins that can result in poisoning or death. Various fungi can also cause serious damage to fruit harvests and other crops including seeds and grains.

Mycology

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About Mycology

Biology includes many branches as well as mycology, which is concerned with the study of fungi. The study includes their, genetic and biochemical properties, their taxonomy, use and importance to humans as a source of medicine, food, and psychotropic substances consumed for religious purposes, as well as their dangers, such as poisoning or infection, destruction of food, lumber, paper, cloth, toxins produced by poisonous mushrooms and within food (Mycetism and Mycotoxicosis). Mycology compared with other sciences is a relatively new science that became systematic after the development of the microscope in the 16th century. Although Giambattista Della Port first observed fungal spores in 1588, the seminal work in the development of mycology considered as the publication of Pier Antonio Micheli's 1729 work Nova plantarum genera. Micheli not only observed spores, but also showed that, they could induce into growing into the same species of fungi from which they originated under the proper conditions. The ability of fungi to invade animal and plant tissue was observed in early 19th century but the first documented animal infection by any fungus was made by Bassi, who in 1835 studied the muscardine disease of silkworm and proved the that the infection was caused by a fungus *Beauveria bassiana*.

The study of any group of organisms must begin with a consideration of their nomenclature. Expansibility the use of the binomial system of nomenclature introduced by Carl Linnaeus in his Species plantarum (1753), the Dutch Christian Hendrik Persoon (1761-1836) established the first taxonomy of mushrooms with such skill so as to be considered a founder of modern mycology. Elias Magnus Fries (1794-1878) further elaborated the taxonmy of fungi, using spore color and various microscopic characteristics, methods still used by taxonomists today. The 20th century has seen a modernization of mycology that has come from advances in biochemistry, molecular biology, genetics and biotechnology. Recently, DNA sequencing technologies and phylogenetic analysis has provided new insights into fungal relationships and biodiversity, and has challenged traditional morphology-based groupings in fungal taxonomy.

Fungi

Fungi (singular fungus) are almost entirely multicellular (with yeast, Saccharomyces cerviseae, being a prominent unicellular fungus), heterotrophic (deriving their energy and food from another organism, whether a live or dead), and usually having some cells with two nuclei (multinucleate, as opposed to the more common one, or uninucleate, condition) per cell.

Fungi are widely distributed in nature including soil, air, and water, decaying organic debris of plant or animal. There are approximately 400,000 types of fungi. There are several groups of organisms i.e. "fungi". Some of these groups have 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, but some fungus-like organisms do.

True fungi

Not all species of fungi have cell walls but in those that do, three layers of cell wall material follow the plasma memberane. From inside out these are:

1. A chitin layer 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.
2. A layer of β-1,3-glucan: 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.
3. A layer of mannoproteins (mannose-containing glycoproteins)-Most of the structural proteins found in the cell wall are glycosylated and contain mannose, thus these proteins are called mannoproteins or mannans

True fungi do not have cellulose in their cell walls.

Fungus-like protists

Oomycetes group are saprotrophic plant pathogens like fungi, which also known as water molds. Until recently they were widely believed to be fungi, but structural and molecular evidence has led to their reclassification as heterokonts, related to autotrophic brown algae and diatoms. Unlike fungi, oomycetes typically possess cell walls of cellulose and glucans rather than chitin, although some genera (such as Achlya and Saprolegnia) do have chitin in their cell wall. The fraction of cellulose in the walls is no more than 4 to 20%, far less than the fraction comprised by glucans. Cell wall of oomycete also contains hydroxyproline (amino acid), which is not present in fungal cell walls.The dictyostelids are another group formerly classified among the fungi. They are slime molds that feed as unicellular amoebae, but aggregate into a reproductive stalk and sporangium under certain conditions. Cells of the reproductive stalk, as well as the spores formed at the apex, possess a cellulose wall. The spore wall has shown to possess three layers, the middle of which is composed primarily of cellulose, and the innermost is sensitive to enzymes of cellulase and pronase (mixture of proteases).

General characteristics of true fungi

1. All are eukaryotic: Possess membrane-bound nuclei (containing chromosomes) and a range of membrane-bound cytoplasmic organelles (e.g. mitochondria, vacuoles, endoplasmic reticulum).
2. Most of fungi are filamentous: Composed of individual microscopic filaments called hyphae, which exhibit apical growth and which branches to form a network of hyphae called mycelium.
3. Some of fungi are unicellular: Some fungi consist of one cell containing all organles such as yeasts.

4. Protoplasm of hyphae or a rigid wall surrounds cell of fungi: Consists of primarily of glucans and chitin, although the cellulose enters in walls composition of some species.
5. Many of fungi reproduce both sexually and asexually: Production of spores in fungi formed as aresult of sexual and asexual reproduction in most cases.
6. Fungal nuclei are typically haploid and hyphal compartments are often multinucleate: Although the diploid nuclei present in Oomycota and in some yeasts.
8. Nutrition categories of fungi are chemoheterotrophic (chemo-organotrophic): They utilize organic sources of carbon in their environment as carbon source and the energy from biochemical reactions of organic compounds oxidation, they require for growth and energy
9. Storage compounds: Food storage is generally in the form of lipids glycogen and sugar alcohols.
10. May be free-living or may form intimate relationships with other organisms: i.e. may be free-living, parasitic or mutualistic (symbiotic).

How does a fungus feed?

Fungi absorb food from their surroundings. Depending on what type of fungi they are, their surroundings could be soil, wood or other types of living or dead plant or animal material. Many fungi grow stringy strands called hyphae. These strands absorb nutrients and water from their surroundings, giving energy to the fungi for further growth and reproduction. This mat of fungal hyphae called as fungal mycelium.

Fungal nutrition

All fungi are chemoheterotrophic (chemo-organotrophic)-synthesising the organic compounds they need for growth and energy from pre-existing organic sources in their environment, using the energy from chemical reactions.Since the protoplasm are protected by a rigid wall, fungi must obtain their nutrients by the process of absorption.

* Small molecules (e.g. simple sugars, amino acids) in the medium can be absorbed directly across the fungal wall and plasma membrane.
* Larger, more complex molecules (e.g. polymers such as polysaccharides and proteins) must be first broken down into smaller molecules, which can then be absorbed. This degradation takes place outside the fungal cell or hypha and that achieved by enzymes, which either released through or bound to the fungal wall. Because these enzymes act outside the cell, they called as extracellular enzymes.

There are three main types of fungal nutrition:

- Saprophytic
- Parasitic
- Symbiotic

Saprophytic fungi: Many fungi feed in a saprophytic way. This means that they feed on the dead materials of plants or animals, or on the waste materials (such as dung) of other living things. The saprophytic fungi are either obligates or facultative. They often found in woodlands, where the floor are covered with massive amounts of dead plant material such as fallen leaves, twigs and logs. Many mushrooms feed in this way.

Parasitic fungi: These fungi do not wait until a plant or animal is dead before feeding on it. Instead, parasitic fungi feed on other organisms while they are still alive. As you can imagine, many of these parasites cause serious damage to trees and other plants. The parasitic fungi, which grow on and inside humans and other animals, cause problems such as athlete's foot and ringworm. The parasitic fungi are either obligates or facultative.

Symbiotic fungi: Although these fungi do live on or inside other living things, they do not cause damage. The fungi, and the organism on which it lives, both receive benefits from living with each other. Many fungi live in such harmonious "give and take" relationships with trees, and other plants including many orchids. The fungi grow underground, and their threadlike "hyphae" grow into a thick mat known as a mycelium. This mycelium absorbs nutrients and water from the soil and passes what it does not need through into the roots of the tree. Such relationships between fungi and trees, are known as mycorrhiza .Another intimate relationship that works very well, is that found when we look at Lichen. This grows as a flat, green or yellow growth on the surface of rocks and trees. Lichen is a fungus and an alga growing together, helping each other to survive and grow.

Cell biology of the fungi

Their basic cellular units described as hyphae (singular: hypha). Hyphae of fungi may be branched and their dense mass called as mycelium. Hypha form is usually a tubular cell developed from growing spore (Figure 1) and surrounded by a rigid, chitin-containing cell wall. The hypha extends by tip growth, and multiplies by branching, creating a fine network called a mycelium. Hyphae contain all organs including nuclei, mitochondria, ribosomes, Golgi and membrane-bound vesicles within a plasma membrane bound cytoplasm. The sub-cellular structures supported and organized by microtubules and endoplasmic reticulum.

Each hypha is essentially a tube consisting of a rigid wall and containing protoplasm .Tapered at its tip - this is the region of active growth (i.e. the extension zone).

Septa (cross-walls), if present, usually been observed down a light microscope. Some fungi possess septa (that divide the hyphae into separate cells) at regular intervals along the lengths of their hyphae. In others, cross-walls form only to isolate old or damaged regions of a hypha or to isolate reproductive structures. Some septa possess one of more pores - such septa divide the hyphae into a series of interconnected hyphal compartments, rather than separate, discrete cells. Coenocytic hyphae lack septa (Figure 2).

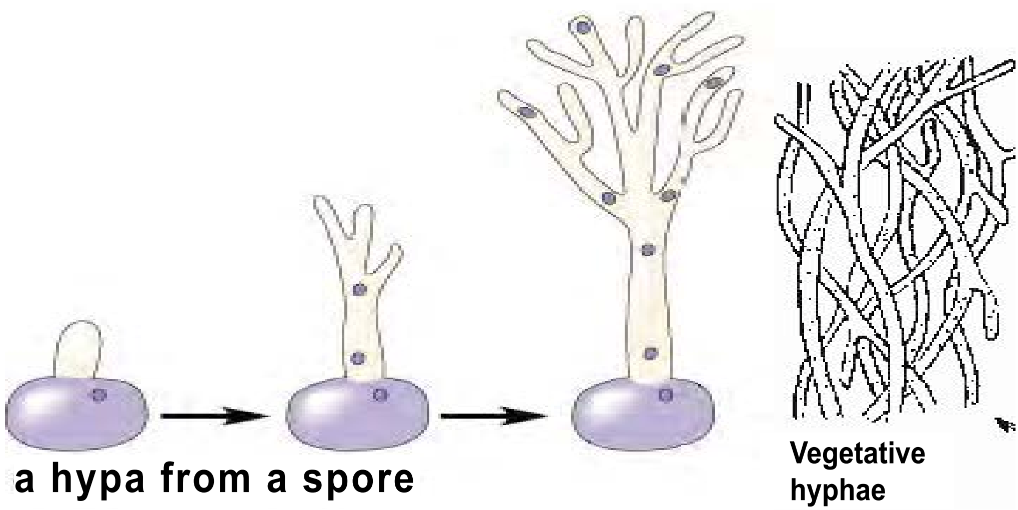

Figure 1: Vegetative hyphae.

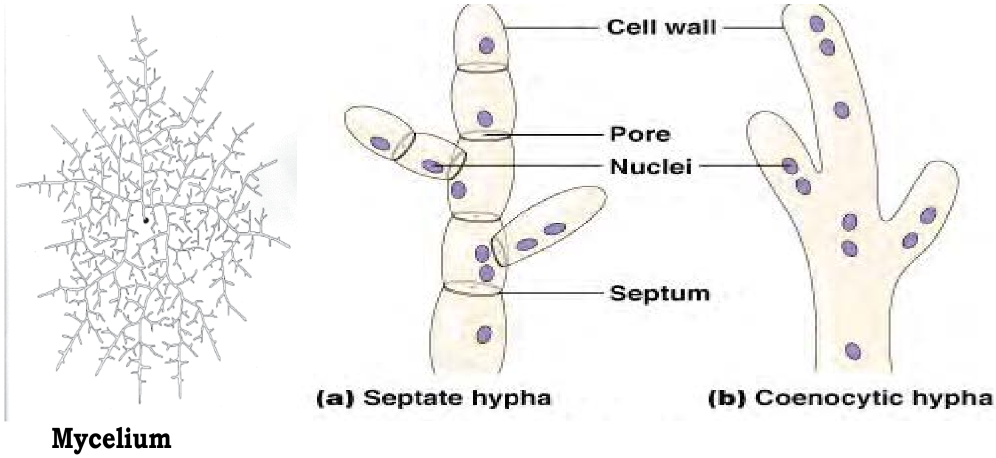

Figure 2: Different forms of hyphae.

The plasma membrane is closely associated with the hyphal wall and in some regions even be firmly attached to it - making it difficult to plasmolyse hyphae.

Each hyphal cell or compartment normally contains one or more nuclei. In species whose septa possess a large central pore, the number of nuclei within a hyphal compartment will not remain static because the nuclei are able to pass between adjacent compartments, via the central septal pore.

Other cytoplasmic organelles are those commonly found in all eukaryotic cells such as:

Nuclei: Small (1-2µm) nuclear envelope does not break down during division, chromosomes not distinct. In apical region there are 1-50 nuclei Fungal DNA less complex than other eukaryotes - fewer repeated DNA segments compared to other eukaryotes (less than 10% compared to 35% in mammals).

- Mitochondria: Elongate with platelike cristae.
- Endoplasmic reticulum: Narrow membrane bound channels.
- Golgi: Ringed cisternae not flattened stacks.

The growing tip is structurally and functionally very different from the rest of the hypha in the following:

1. Its cytoplasm appears denser.
2. There are no major organelles at the extreme tip.
3. At the extreme tip, there is an accumulation of membrane-bound vesicles, the Apical Vesicular Cluster (complex) (AVC) - which plays an important role in apical growth.

Vacuoles may be visible in sub-apical hyphal compartments, although small at first, they grow larger and merge with one another; they store and recycle cellular metabolites, e.g. enzymes and nutrients.

In the oldest parts of the hypha, the protoplasm may breakdown completely, due either to autolysis (self-digestion) or in natural environments heterolysis (degradation due to the activities of other microorganisms) (Figure 3).

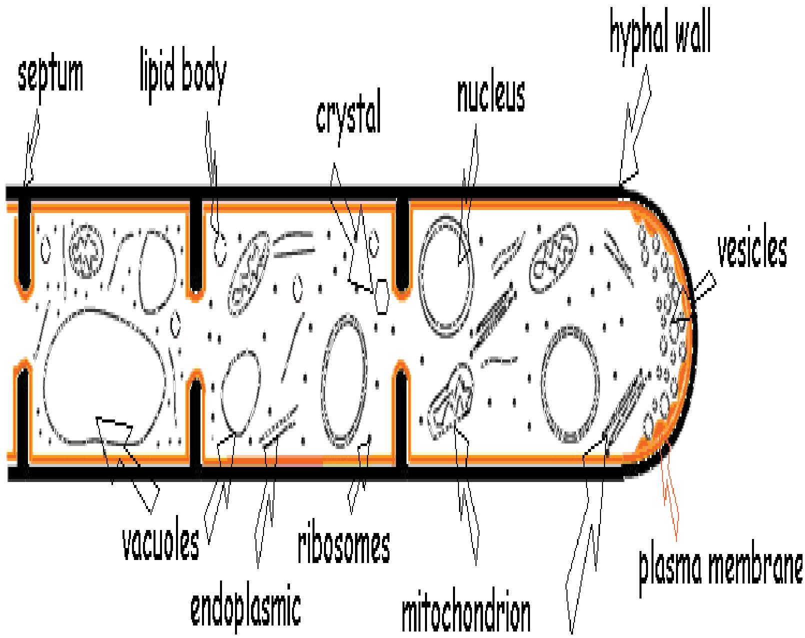

Figure 3: Diagram illustrating the ultrastructure of hypha.

Fungal growth

Definition of growth in fungi: Fungal growth defined as an irreversible increase in the volume of an organism, usually accompanied by an increase in biomass. Mycelial fungi exhibit extension growth of hyphae, accompanied by an increase in biomass. Unicellular fungi (e.g. yeasts) may exhibit an increase in individual cell volume, accompanied by an increase in biomass. However, collectively, the number of yeast cells within a culture (i.e. cell concentration) may also increase, resulting in an increase in biomass of the culture as a whole. Fungal colonies show a differentiation from margin to the centre of the colony.

1. The extension zone: Hyphae are advancing into fresh media. Branching patterns tend to be at a 90° angle and monopodial. The branches arranged to give the most effective colonization and utilization of the substrate, and the growth of the hyphae is oriented to avoid the other hyphae. The mechanism by which this occurs is unknown, but probably relates to food gradients and toxin gradients.
2. The productive zone: Here the major increase in biomass occurs. Aerial mycelium formed, and the hyphae thicken.
3. The fruiting zone: Biomass gain has ceased, and spores formed. This is equivalent to the stationary phase of batch culture.
4. Ageing zone: Vacuolate or empty hyphae are present, autolysis occurs. This is equivalent to the decline phase of batch culture.

If we plotted biomass or cell concentration as fungal growth against time, we might obtain the following characteristic S-shaped growth curve (Figure 4).

Characteristic S-shaped growth curve

1- Rate of growth or cell division is very slow. Fungal cell adapt themselves to growth conditions. It is the period where the individual fungi are maturing and not yet able to divide. During this phase of the fungal growth cycle, synthesis of RNA, enzymes and other molecules occurs. So in this phase the fungal cell are not dormant.

2-Growth or cell division then starts to accelerate into the exponential phase - when, for example, with a unicellular organism (e.g. yeast species) any one cell produces two in a given period of time, those 2 produce 4, the 4 produce 8, 8 produce 16 and so on. This exponential phase (central red region in the graph opposite) represents the period when the fungus is growing or multiplying most rapidly. The actual rate of this growth depends upon the growth conditions, which affect the frequency of cell division events and the probability of both daughter cells surviving. This phase will continue until one or more nutrients become limiting, oxygen becomes depleted and/or metabolic by-products accumulate to toxic levels.

3-Growth will start to decelerate (decline).This may be followed by a stationary phase, during which there is no discernible change in cell concentration or biomass. This phase (stationary phase) is a constant value as the rate of fungal growth is equal to the rate of fungal death

4-Finally, cell death and lysis-which results in a decrease in cell number and/or biomass were, observe a phase

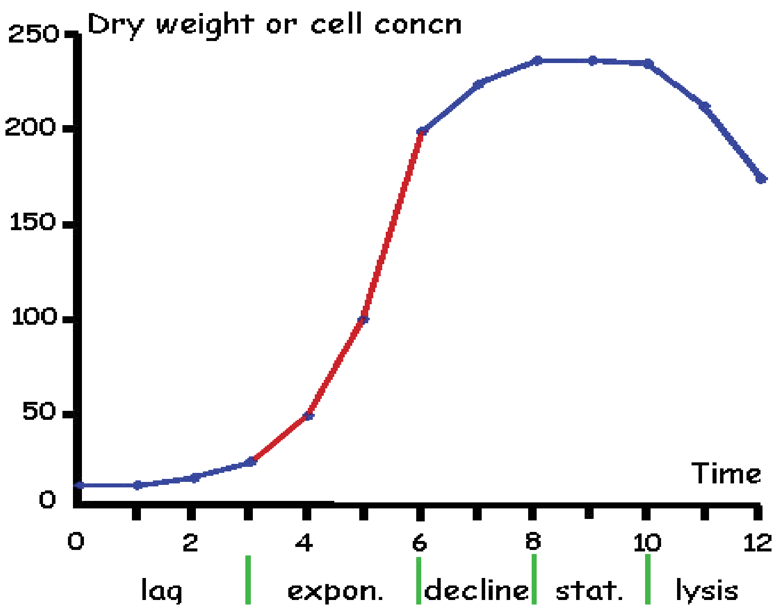

Figure 4: Illustrating fungal growth curve.

Fungal sporulation

Many (not all) fungi are capable of reproducing both sexually and asexually spores. Many fungi are capable of producing more than one type of spore - each has its own role to play in the life cycle of the fungus. The environment plays an important role in determining whether a fungus forms sexual or asexual spores. Spores commonly formed as a fungus depletes its energy sources. A variety of environmental triggers may be involved in determining which type of spores formed. Some fungi are unable to form spores under conditions of high nutrients and therefore those fungi continue to grow vegetatively in abundant nutrient conditions. For example, many wood rotting fungi require inoculation and growth on wood blocks before basidiomes formed in the laboratory. For others, the exhaustion of a key nutrient induces sporulation. Low carbon/nitrogen ratios induce formation of hyphal arthrospores, in some fungi, while depletion of carbon regardless of the nitrogen status induces formation of conidia (e.g. *Fusarium*) in others. Temperature influences formation of sporocarps. Sporulation takes place in a narrower range of temperatures than vegetative growth. Similarly, sporulation appears to require aerobic conditions in most cases. In some fungi, light initiates the sexual structures. In *Pleospora*, a fungus of plant surfaces, UV induces ascocarps formation. Light needed for basidiocarp initiation in *Schizophyllum*, a wood degrading fungus. However, light and night needed to complete the formation of sporangia of *Pilobolus*, a dung fungus.

Purpose of sporulation

Dispersal: Spores ensure that a small portion of the fungus' protoplasm, widely and efficiently dispersed away from the site currently occupied by the organism, e.g. zoospores, sporangiospores, conidia.

Preservation: Certain types of spore preserve the potential for growth at the same site because they provide a means by which the fungus can survive unfavourable environmental conditions, e.g. oospores, zygospores, chlamydospores.

Genetic variation: Sexual sporulation provides the potential for genetic variation.

Factors influencing the type of sporulation

1-Genotype of the species - Each species possesses its own genetic 'programme.
2-Genotype of the mycelium - One strain may behave differently to another.
3-Extent of somatic growth - A certain amount of growth is often necessary before sporulation occurs.
4-Specific environmental conditions - e.g. Temperature, light, specific nutrients.

General characteristics of Fungal Spores

1. Spores represent microscopic dispersal or survival propagules produced by most species of fungi.
2. Fungal spores vary in size, shape and colour.
3. Fungal spores may be unicellular or multicellular For example, conidia produced by *Alternaria* species are multicellular.
4. Some spores possess a textured or ornamented surface. For example, uredospores of *Melampsora epita* (causal pathogen of willow rust).
5. The protoplasm of most (not all) spores is surrounded by a rigid wall, which is often thicker and more multilayered than that of somatic cells or hyphae, may be impregnated with pigments (e.g. melanins) and lipids.
6. Spores often contain substantial amounts of nutrient reserves, which may take the form of lipids, trehalose and glycogen.
7. They possess relatively low water content.
8. While it dormant they exhibit a low rate of metabolic activity.
9. They vary in the primary functions they serve, which may include example-Dispersal to a fresh site or host, survival at the same site and increasing genetic variation.
10. They also vary in the methods by which they formed, released and dispersed.

Method of conidiogenesis

Production of a conidium involves the transformation of part of a cell into a separable spore. Sometimes a hypha or cell separated into one or more segments by septa. The separate cells then thicken, swell, and finally separate. This kind of conidiogenesis, where the septa appear before the conidium initiates called thallic (Figure 5A and 5C). When the new conidium is initiated, begins to swell or thicken, and then is cut off by a septum, the conidiogenesis is called blastic (Figure 5B-5D and 6). When the wall of the conidium is continuous with the cell that produced it, it is called either holothallic (when thallic) (Figure 5A) or holoblastic (when blastic) (Figure 5B). When only the inner walls of the conidium-bearing cell are involved in conidiogenesis, the prefix “entero-” is used, resulting in the terms enterothallic (Figure 5C) and enteroblastic (Figure 5D). Although enterothallic types are rare, enteroblastic types are probably the most common of all and represented by the ubiquitous phialide.

Sequence of conidiogenesis

If only a single conidium produced on a conidiogenous cell (Figure 6A), we can hardly speak of a sequence. If, however, more than one is produced they can occur either simultaneously (Figure 5A, 5B and 5C) or serially (i.e. one after another) (Figure 5D, 6B and 6C).

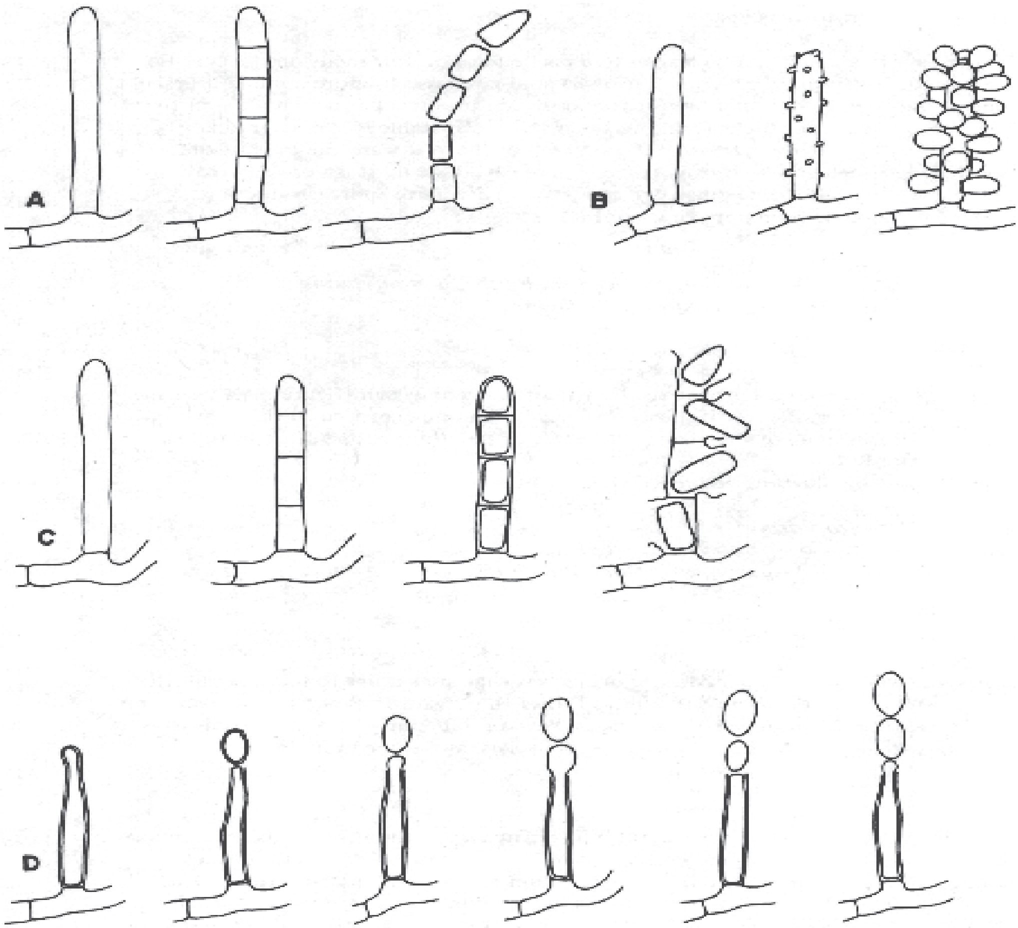

Figure 5: Conidiogenesis.

A: holothallic; the multiple conidia are produced simultaneously.
B: holoblastic; the multiple conidia are produced simultaneously.
C: enterothallic; the multiple conidia are produced simultaneously.
D: enteroblastic; the multiple conidia are produced serially from a stablelocus.

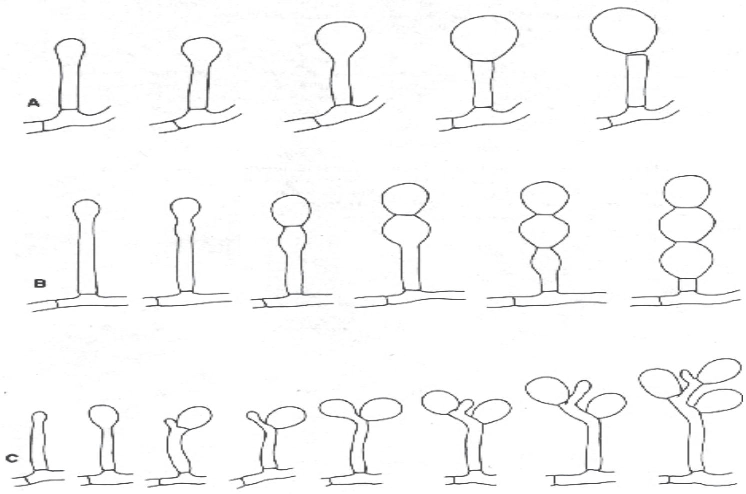

Figure 6: Conidiogenesis.

A: holoblastic; conidium is solitary.
B: holoblastic; multiple conidia are produced serially from a retrogressive locus.
C: holoblastic; multiple conidia are produced serially from a progressive locus

Types of asexual spore

Fungi produce two major types of asexual spore: Sporangiospores and Conidia.
Sporangiospores characteristic:

1. Endogenous - formed and contained within a sporangium (Figure 7).
2. They formed because of the cleavage of protoplasm around nuclei.
3. Formation of a wall around each nucleate portion of protoplasm follows in some cases.
4. A characteristic of fungi belongs to the chytridiomycota, oomycota and hyphochytridiomycota.
5. They include two main types. They are zoospores (motile) and aplanospores (non-motile).

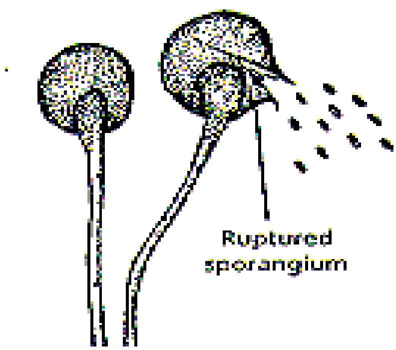

Figure 7: Sporangiospores inside sporangium.

Conidia:

Conidia are Exogenous - often formed at the tip of supporting hyphae called conidiophores (Figure 8). Develop in a variety of ways. Conidia characteristics include mitosporic fungi and fungi belonging to the ascomycota and basidiomycota. It includes two main types-Thallic and Blastic.

Thallic Conidia

This type characterized by:

1. Originate from septation and fragmentation of a hypha.
2. May develop in an intercalary (central) position of the hypha or develop at the tip of a hypha.
3. In both cases, all layers of the hyphal wall are involved in spore formation.

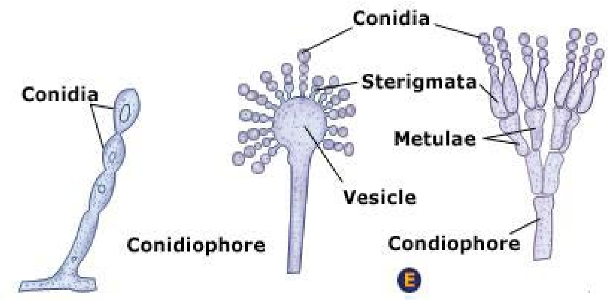

Figure 8: Exogenous conidiospores.

Blastic Conidia characterized by:

1.Develop by a budding or swelling process.

2.They may develop as single spores or in succession to form a chain of spores containing the following forms.

a) Blastospores: characterized by:

1.Blastospores formed by budding of a hypha (Figure 9) or yeast cell.

2.Both wall layers are involved. The spore may remain attached and bud further blastospores - giving rise to a branched chain of spores.

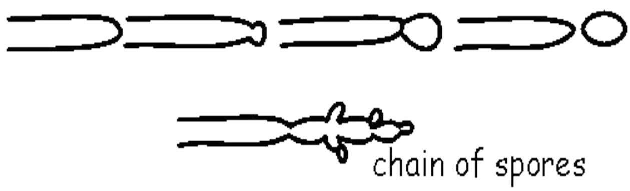

Figure 9: Blastospores formation.

b) Porospores: characterized by

1. The developing spore emerges through a distinct 'pore' in the hyphal wall (Figure 10).
2. The inner layer of the hyphal wall is only involved in spore development.
3. The new spore then develops its own new inner wall layer.
4. The outer spore wall is often thickened and pigmented.
5. A scar is usually obvious at the point of detachment from the hypha (conidiophore).

Figure 10: Porospores formation.

c) Aleuriospores: characterized by

1. Develop as single, terminal spores.
2. Conidiophore apex inflates and becomes separated by a septum at an early stage in spore development.
3. Both wall layers are involved in spore formation.
4. The spore possesses a wide, truncate scar (Figure 11).
5. Normally no further development of spores occurs at the point of detachment.
6. Therefore, the next spore usually has to develop by production of a branch below the scar on the conidiophore.

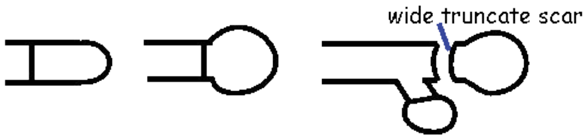

Figure 11: Aleuriospores formation.

d) Annellospores: characterized by

1. In some species that form conidia in a manner similar to that described for aleuriospores, a new growing point does develop at the scar.
2. A chain of spores may develop.
3. The conidiophore gets a little longer with each spore produced.
4. Annellations (ring-like scars) observed around this elongating portion (Figure 12).
5. Each annellation represents the production of one annellospore.

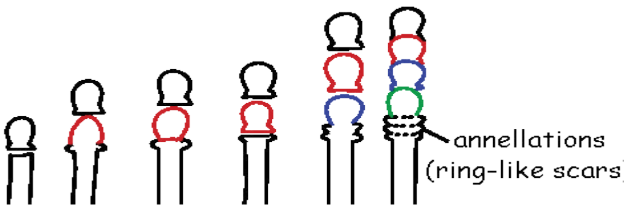

Figure 12: Annellospores formation.

e) Phialospores: characterized by

1. Form in succession.
2. Each spore pushes up from the tip of the conidiophore, which called now as phialide (Figure 13).
3. The spore wall is new and distinct from both wall layers of the phialide.
4. 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.

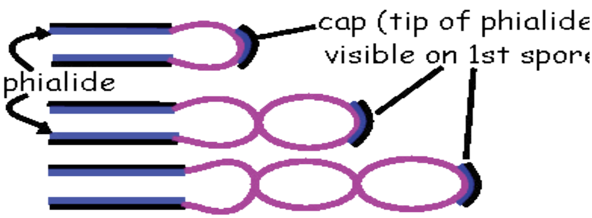

Figure 13: Phialospores formation.

f) Arthrospores: characterized by

1. Arthrospores formed by septation and fragmentation of an existing hypha.
2. Elements of the hypha (incl. all wall layers) become converted into conidia (Figure 14).
3. Each fragment rounds off and liberates in succession.
4. Separation of the conidia from one another is due to breakdown of the middle region of each septum.

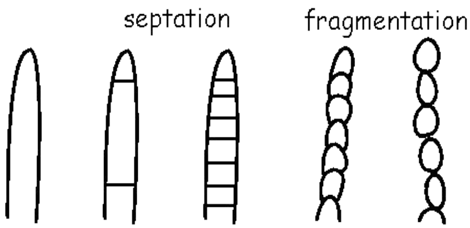

Figure 14: Arthrospores formation.

g) Chlamydospores: characterized by

1. Chlamydospores are a type of resting (survival) spore.
2. Found in several groups of fungi.
3. An intercalary or apical hyphal cell or compartment enlarges rounds up and develops a thickened, often pigmented wall (Figure 15).
4. Contain dense cytoplasm and nutrient storage compounds.
5. All wall layers are involved in their formation.
6. Usually develop under conditions of stress that are unfavourable for normal somatic growth.

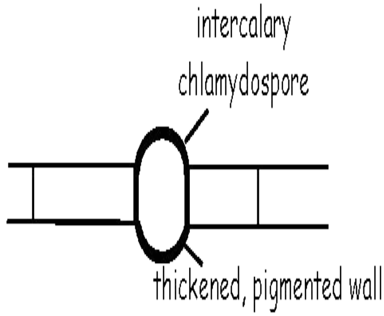

Figure 15: Chlamydospores formation.

h) Zoospores: characterized by

1. Zoospores are motile sporangiospores - and the sporangia in which they form called as zoosporangia.
2. A wall does not surround the protoplasm of zoospores. In some respects, they resemble flagellate protozoa.
3. Because zoospores are motile, the fungi that produce them will require water at some stage during their life cycle.
4. Three different types of zoospore distinguish the Chytridiomycota, Hyphochytridiomycota and Oomycota.

Chytridiomycota (zoospores have one posterior whiplash). Oomycota (zoospores have two flagella, one whiplash and one tinsel flagellum). Hyphochytridiomycota (zoospores have one anterior tinsel flagellum) (Figure 16).

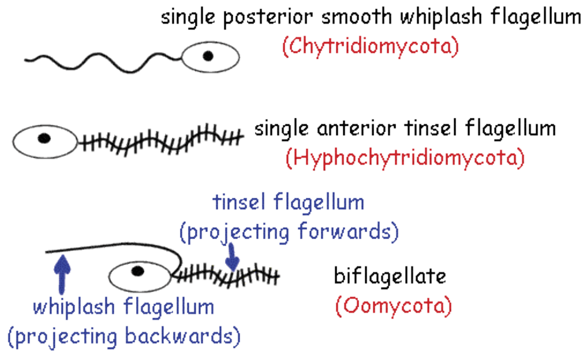

Figure 16: Zoospores forms.

Sexual spores

a) Ascospores: The ascospores (Figure 17) formed as the following:

1. The apical compartment of a dikaryotic ascogenous hypha elongates and bends over to form a hook (crozier).
2. The two compatible nuclei in the apical compartment then undergo mitosis simultaneously.
3. Two septa develop in such a way that the crozier becomes divided into three compartments - the tip and basal compartments are uninucleate; the middle compartment is binucleate and is called the ascus mother cell (since it is destined to become an ascus).
4. The nuclei in the ascus mother cell fuse to form a diploid nucleus, which then undergoes meiosis to form four haplid nuclei.
5. Each haploid nucleus then divides mitotically - resulting in eight haploid nuclei.
6. A portion of protoplasm surrounds each nucleus; these become envelope by a wall and mature into an ascospore.

Meanwhile, another ascus mother cell will have been developing alongside the first. In most (not all) fungi belonging to the Ascomycota the asci do not occur singly - they form in groups, surrounded by hyphae and are enclosed in fruiting bodies (ascocarps).

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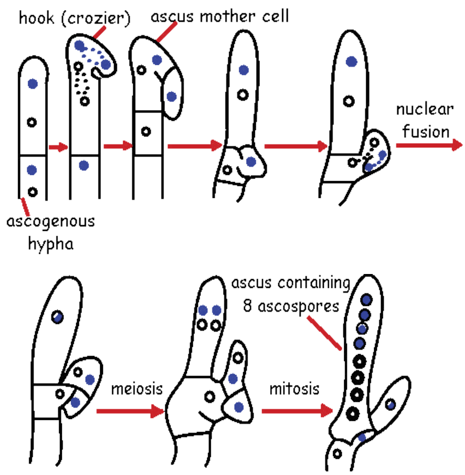

Figure 17: Formation of ascospores.

b) Basidiospores

The basidiospores (Figure18) formed as the following:

1. Two haploid nuclei in an apical dikaryotic hyphal compartment (often within a basidiocarp) fuse to form a diploid nucleus.
2. The diploid nucleus undergoes meiosis to yield four haploid nuclei.
3. Four small outgrowths - sterigmata - begin to form at the top of the hyphal compartment and the tip of each sterigma begins to inflate.
4. A fluid-filled vacuole develops near the base of the compartment and gradually enlarges - as it enlarges it forces protoplasm into the inflated portions of the sterigmata.
5. When each swelling at the tip of a sterigma has almost attained its full size a nucleus passes into it.
6. The uninucleate swelling at the tip of each sterigma matures into a basidiospore. The compartment supporting the sterigmata and basidiospores called a basidium.

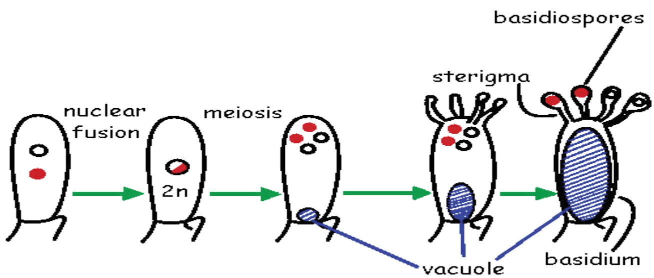

Figure 18: Formation of basidiospores.

c) Zygospores

The Zygospores formed as the following: Fusion of haploid mating hyphae to produce a diploid zygospore, a process shown in the following Figure 19 [1].

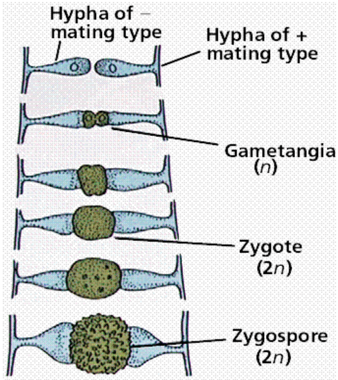

Figure 19: Formation of zygospore.

Reproduction of Fungi

Reproduction in fungi can be sexual or asexual. Many, but not all, fungi reproduce both sexually and asexually. Some reproduce only sexually, others only asexually. All divisions, however, share similar patterns of reproduction and morphology

Asexual reproduction

Budding

The initial events of budding can be seen as the development of a ring of chitin around the point where the bud is about to appear. This reinforces and stabilizes the cell wall. Enzymatic activity and turgor pressure the act to weaken and extrude the cell wall. New cell wall material incorporates during this phase. Cell contents forces into the progeny cell, and as the final phase of mitosis ends a cell plate, the point at which a new cell wall will grow inwards from, forms. Separation of the bud from the parent leaves a scar. When chains of yeast cells do not fully separated this can create a pseudo-mycelium (Figure 20).

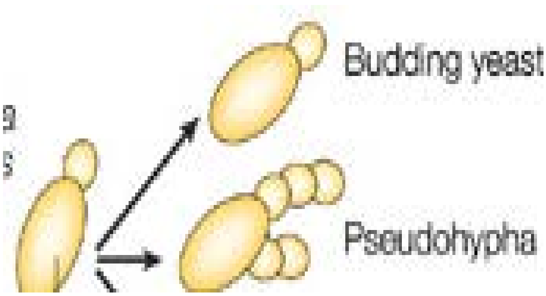

Figure 20: Pseudo-mycelium in yeast.

Binary fission

Binary fission is the form of asexual reproduction used by most prokaryotes and protists to reproduce. This process results in the reproduction of a living cell by division into two equal or near-equal parts. Binary fission begins when the DNA replication occurs. Each circular DNA strand then attaches to the cell membrane. The cell elongates, causing the two chromosomes to separate. The cell membrane then invaginates (grows inwards) and splits the cell into two daughter cells through a process called cytokinesis (Figure 21).

Fragmentation

Many fungi can reproduce by fragmentation. Any mycelium that is fragmented or disrupted, if the fragment contains the equivalent of the peripheral growth zone, can grow into a new colony. Many fungi sub-cultured using this hyphal fragment technique. All of this week's practical plates been inoculated in this way with a cork bore taken from a colonized donor plate. Cut mycelial tips do not regenerate, but branches can form some distance from the damage point.

Sclerotia

In some cases, as in *Claviceps*, the hypha becomes interwoven to form a compact mass and surrounded by a hard covering or rind. Such structure called sclerotia. They remain dormant under unfavorable conditions and germinate into new mycelia on the return of favorable conditions (Figure 22).

Sporulation

By far the most important type of asexual reproduction is that of spore formation (Figure 21). Asexual reproduction is extremely important to fungi. It is responsible for the production of large numbers of spores throughout the year. These asexual spores formed on a phase of the fungal life cycle termed in some texts as the mitosporic, or anamorphic phase. There can be more than one mitosporic state for each species of fungus, and in some cases the mitosporic state of very different species can look very similar, any spore germinate to giving germ tube, the elongate to giving new mycelium (Figure 23).

Rhizomorphs

In some higher fungi, several hyphae may interweave to form rope-like structures called rhizomorphs. Under favorable conditions, they resume growth to give rise to new mycelia (Figure 22).

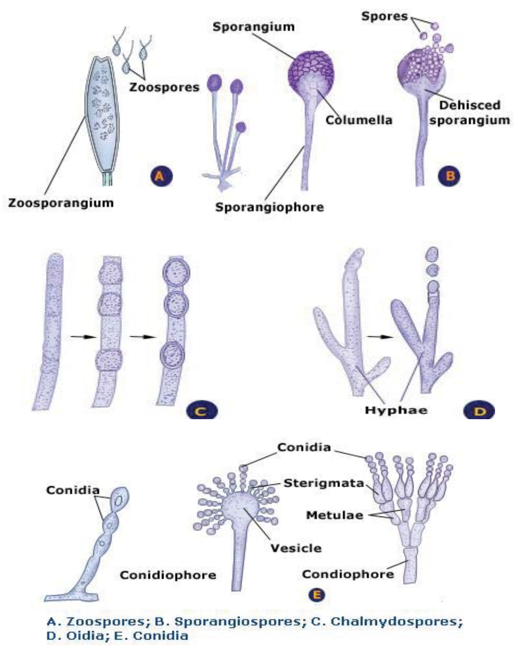

Figure 21: Asexual spores in fungi.

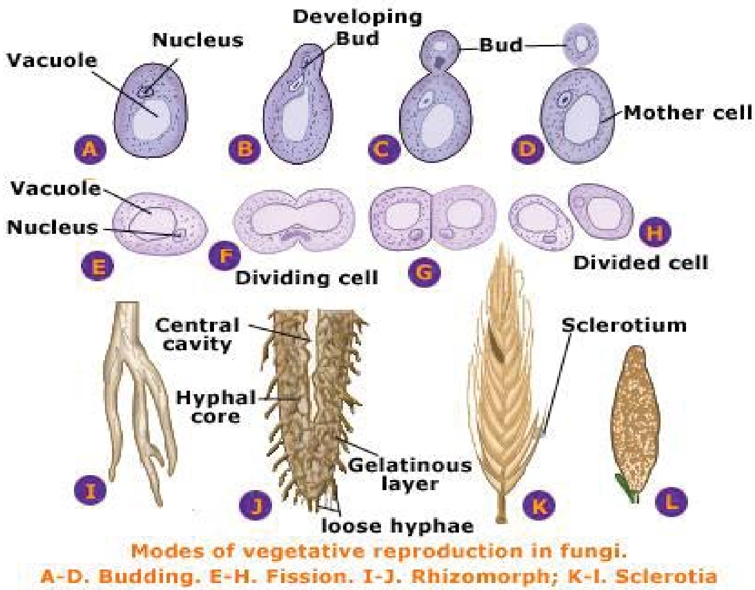

Figure 22: Asexual reproduction in fungi.

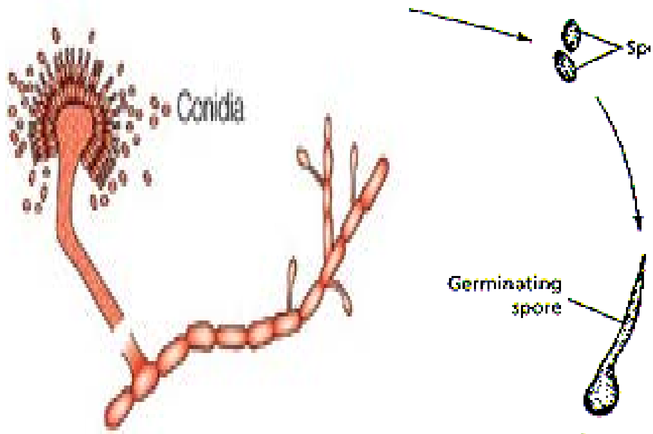

Figure 23: Asexual reproduction by fungal spore.

Sexual reproduction

In general, the sexual reproduction life cycle, (Figure 24) involves the fusion of hyphae from two individuals, forming a mycelium that contains haploid nuclei of both individuals. There are typically three phases in the sexual reproduction of fungi: plasmogamy, karyogamy and meiosis.

1- Plasmogamy is a stage in the sexual reproduction of fungi. In this stage, the cytoplasm of two parent mycelia fuse together without the fusion of nuclei, as occurs in higher terrestrial fungi. After plasmogamy occurs, the secondary mycelium forms. The secondary mycelium consists of dikaryotic cells, one nucleus from each of the parent mycelia.

2-Karogamy is the two nuclei that originated from different individuals fuse to form a diploid zygote.
3-Meiosis The diploid nucleus will undergo meiosis as a preliminary to the formation either four haploid nuclei or four haploid cells (ascospores or basidiospores).

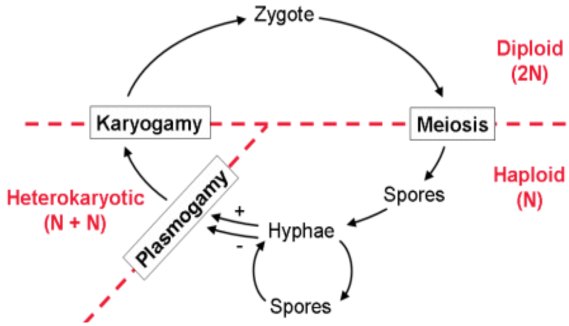

Figure 24: Generalized life cycle of fungi.

Methods of compatible nuclei in sexual reproduction

At some stage during the life cycle of the fungus, two compatible nuclei brought together by various methods, but they do not usually fuse immediately.

A compatible nucleus unites by one of the following four methdods, depending upon the group and species of fungus.

1. Gametangial conjugation:

Gametangial conjugation confined to the Ascomycota. Two similar gametangia meet one another and fuse (Figure 25).There is no prolonged dikaryotic phase in this instance, since nuclear fusion occurs immediately after fusion of the gametangia. In the example illustrated, two yeast cells of different but compatible mating types behave like gametangia and fuse, resulting in a diploid zygote, which transformed directly into an ascus (containing eight ascospores).

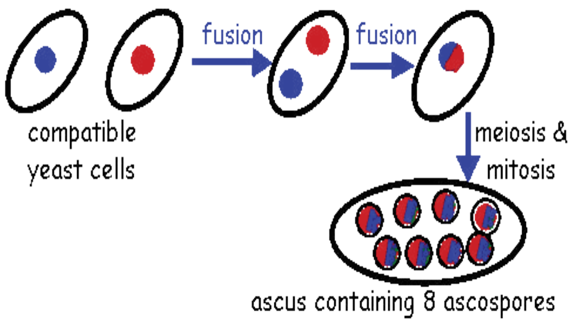

Figure 25: Gametangial conjugation (two similar hyphae, a; two similar yeast cells).

2. Gametangial contact:

Gametangial contact also confined to the Ascomycota. In this case, morphologically distinct gametangia are formed - called antheridia (male) and ascogonia (female) (Figure 26). The trichogyne (receptive neck of the ascogonium) receives the male nuclei from the antheridium.

Upon passing along the trichogyne into the ascogonium each male nucleus pairs with a female nucleus in the ascogonium, but the pairs of nuclei do not fuse. Ascogenous hyphae emerge from the ascogonium and the nuclei, still in their compatible pairs, pass into these hyphae - which are now dikaryotic.The ascogenous hyphae are destined to develop into asci.

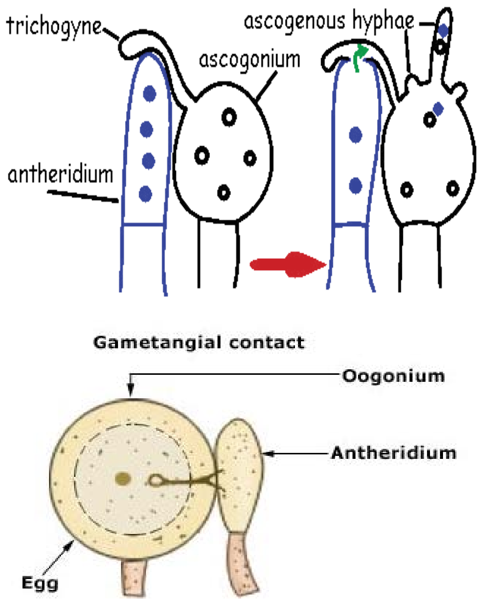

Figure 26: Gametangial contact.

3. Spermatization:

Spermatization occurs in some species, in both the Ascomycota and Basidiomycota.

Air currents, water or insects to the sides of somatic receptive hyphae (Figure 27) carry uninucleate spore-like structures (known as spermatia in the Ascomycota and oidia in the Basidiomycota). A pore develops at the point of contact between the hypha and the 'spore'. The contents of the 'spore' (including its nucleus) pass into the hyphal compartment, which as a result becomes dikaryotic.

Some conidia have the potential to behave like spermatia, but unlike true spermatia, conidia are asexual spores and capable of germinating to produce germ-tubes.

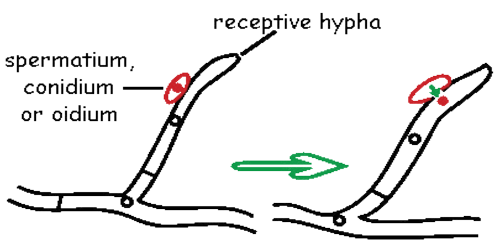

Figure 27: Spermatization.

4. Somatogamy:

Somatogamy occurs in both the Ascomycota and Basidiomycota.

The fusion of somatic hyphae of two compatible mycelia results in a dikaryon from which a dikaryotic mycelium may develop.

In the Ascomycota, the dikaryotic phase is limited to mycelium within the fruiting body (ascocarp). However, in the Basidiomycota, the mycelium continues to grow in the dikaryotic state for some time and fruiting bodies (basidiocarps) form only at a much later stage (Figure 28).

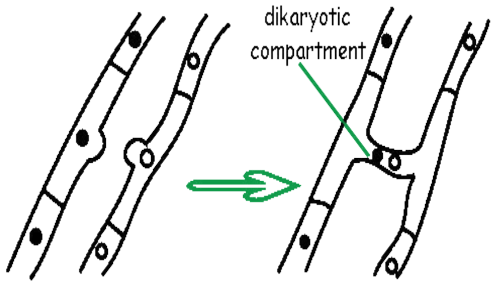

Figure 28: Somatogamy.

Homothallism and Heterothallism in fungi

Based on the compatibility in sexual reproduction the fungal hyphae 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 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.

Importance of fungi

1-Fungi are agents of biodegradation and biodeterioration:

Saprotrophic fungi utilize dead organic materials as sources of nutrients and are responsible for the biodegradation of organic materials in our environment, particularly plant materials in the form of leaf litter and other plant debris. Such fungi play a vital role in recycling essential elements, particularly carbon. Fungi are very effective and efficient biodegraders because of the wide range of extracellular enzymes they produce, whuich are capable of degrading complex polymers, such as cellulose, proteins and lignins.

2- Fungi are responsible for the majority of plant diseases and several diseases of animals (including humans:

Some fungi are actively parasitic in humans and other animals, while others induce severe allergic reactions if their spores are inhaled - resulting in attacks of asthma or hay fever. On the other hand, for example, *Phytophthora infestans* is the causal agent of late blight disease in potatoes. The disease reached epidemic proportions across Europe in the mid 19th century and resulted in the Irish potato famine.

3-Fungi used in industrial fermentation processes:

Yeasts and mycelial fungi used in a variety of industrial fermentation processes. For example, *Saccharomyces* species used extensively in brewing beers and wines, as well as in bread making.

4-Fungi also used in the commercial production of many biochemicals:

Aspergillus Niger used in the large-scale commercial production of citric acid.

5- Many fungi provide us with a direct source of food:

Some yeasts and mycelial fungi cultured on a large scale and then undergo further processing to provide various protein-rich food products for human or livestock consumption. For example, mycoprotein produced commercially from the mycelial fungus *Fusarium venanatum.* The mycelium harvested and processed to provide a protein-rich meat substitute in a range of convenience foods. Some species are cultivated for their edible fruiting bodies, e.g. the basidiocarps of *Agaricus bisporus*.

6- Fungi used in bioremediation:

Some species of yeasts and mycelial fungi are used in processes aimed at reducing the concentrations and toxicities of waste materials, particularly from industrial processes, before those wastes are released into the environment - a process known as bioremediation. For example, *Aspergillus Niger* is used to breakdown tannins in tannery effluents to less toxic compounds.

7-Some fungi prove highly beneficial in agriculture, horticulture and forestry:

For example, some species form symbiotic relationships with the roots of plants, known as mycorrhizas. Mycorrhizas significantly improve plant growth and vigour, resulting in increased yields in crop plants.

Other fungal species also used in the biological control of insect and nematode pests, weeds and pathogenic microorganisms. For example, the fungus *Beauvaria bassiana* used to control a number of insect pests [2].

8-Some fungi prove highly beneficial in Cheese manufacture:

Cheeses such as Gorgonzola, Roquefort, Stilton, and bleu have fungal colonies that give theses cheeses their distinctive flavors.

9-Some fungi prove highly beneficial in medicin products:

Penicillin, perhaps the most famous of all antibiotic drugs and 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.

10- Fungi cause Food Spoilage:

Already it has noted that fungi play a major role in recycling organic material. The fungi, which make our bread and jam go mouldy, are only recycling organic matter, even though in this case, we would prefer that it did not happen. Fungal damage can be responsible for large losses of stored food, particularly food that contains any moisture.

Diversity and Classification of Fungi

Fungi grow in a wide range of habitats, such as extreme environments including deserts or areas with high high osmotic conditions of sugar and salt concentrations, ionizing radiation, as well as in deep-sea sediments. Some of fungi can survive the intense UV and cosmic radiation encountered during space travel. Most grow in terrestrial habitats, though many species grow partly or solely in aquatic habitats, such as the chytrid fungus *Batrachochytrium dendrobatidis*, a parasite that has been responsible for a worldwide decline in amphibian populations. This fungus spends part of its life cycle as a motile zoospore, enabling it to propel itself through aquatic habitats and enter its amphibian host. Other examples of aquatic fungi include those living in hydrothermal areas of the ocean. Therefore, fungi have a worldwide distribution (Figure 29).

Fungal species are historically been distinguished by many methods and concepts. Classification based on morphological characteristics, such as the shape and size of spores or fruiting structures, has traditionally dominated fungal classification. Species may also distinguished by their biochemical and physiological characteristics, such as their ability to metabolize certain biochemical materials, or their reaction to chemical tests. Recently, the application of molecular tools, including DNA sequencing and phylogenetic analysis, to study diversity has greatly improved the resolution and added robustness to estimates of genetic diversity within various taxonomic groups. In addition, fungal taxonomy depends on macroscopically and microscopically observable characteristics. The phenotypic approach such as:

a) Color of the growth
b) Rate of growth
c) Method of spore production
d) Hyphal septation all aid in assigning a fungus a name

More technologies that are newer have aided in both identifying new organisms and recognizing the various forms of the same organism.

a) Electron microscopy allows recognition of structures not visible by light microscopy.
b) Physiological and biochemical techniques are being applied as well as identification of secondary metabolites.
c) Polymerase Chain Reaction (PCR) allows comparison of the DNA or RNA structure of organisms, including fungi.

In the earliest taxonomy, there were only two recognized kingdoms including Plants and Animals.This two kingdom system was used until Whitaker (1969) proposed that organisms be classified into five kingdoms including, Monera (=Bacteria), Protista (=Mostly Algae and Protozoans), Plantae (=Plants), Mycetae (=Fungi) and Animalia (=Animals). Fungi belong to Domain-Eukarya and Kingdom -Mycetae (=Fungi). The classification of fungi, as proposed by Ainsworth (1973), commonly followed:-

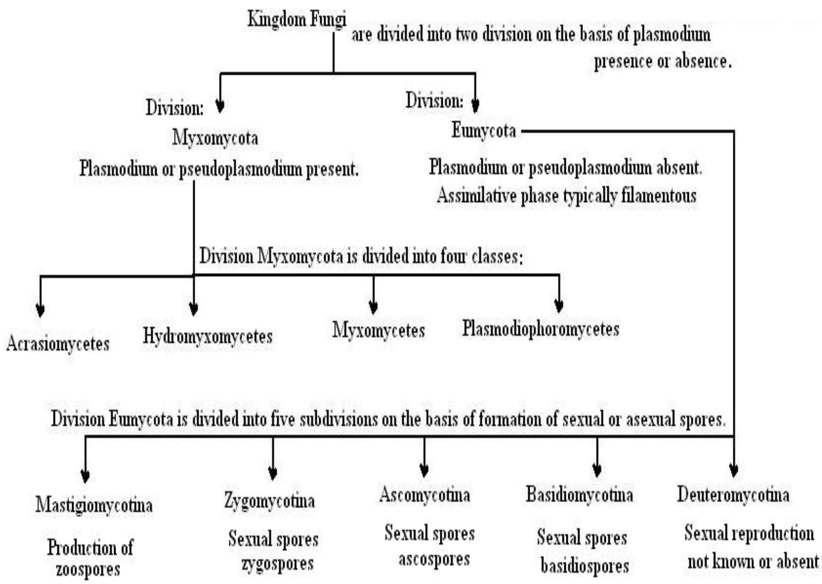

Figure 29: Classification of fungi.

There are more than 60,000 fungal species known. Classification of fungi is by their method of both sexual and asexual reproduction. It seems likely that fungi are not a monophyletic group. Historically they have divided into four taxonomic divisions:

1.Zygomycota
2.Ascomycota
3.Basidiomycota
4.Deuteromycota

The last group, the Deuteromycota, is not a monophyletic group and thus has no standing in a modern classification scheme.

The modern systematic grouping includes the Zygomycota, Ascomycota and Basidiomycota as well as the Chytridiomycota.

Schroter (1893) classified the fungi into four classes: (Figure 30)

1-Phycomycetes
2-Ascomycetes
3-Basidiomycetes
4-Deuteromycetes

Saccardo (1931) classified the fungi into 6 classes:

1-Schizomycetes
2- Myxomycetes
3-Ascomycetes
4-Deuteromycets
5-Basidiomycets
6-Phycomycetes

Bessey (1950) classified the fungi into three classes- Schizomycetes, Myxomycetes and Eumycetes

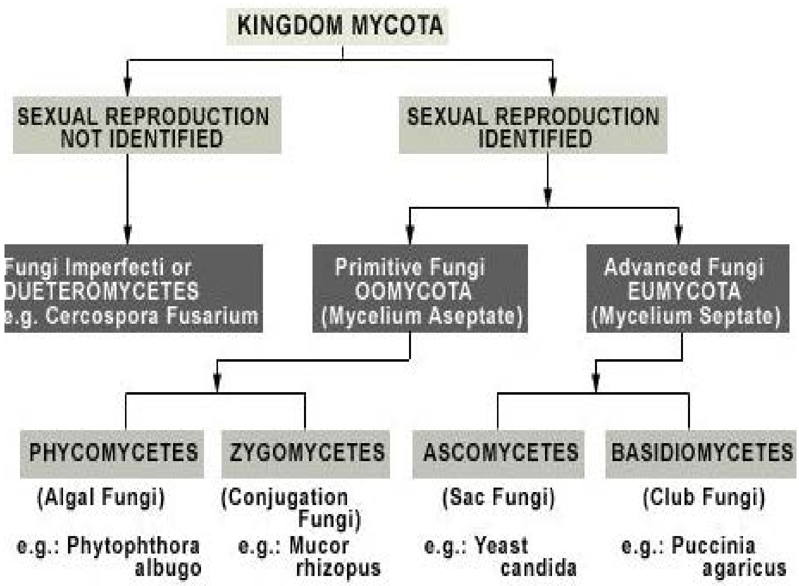

Figure 30: Classification of fungi by both sexual and asexual reproduction.

*Mycologists have traditionally studied these types of organisms and divided based upon phylogenetic relationships.

* These relationships are:

1- Kingdom Fungi - true fungi

2- Kingdom Straminipila - “water molds”
3- Kingdom Mycetozoa - “slime molds”

Kingdom Fungi (Mycota)

1- Phylum: Chytridiomycota
2- Phylum: Zygomycota
3- Phylum: Glomeromycota
4- Phylum: Ascomycota
5- Phylum: Basidiomycota
6- Form-Phylum: Deuteromycota (Fungi Imperfecti)

Kingdom Straminiplia (Chromista)

1- Phylum: Oomycota
2- Phylum: Hyphochytridiomycota
3- Phylum: Labyrinthulomycota

Kingdom Mycetozoa

1- Phylum: Myxomycota
2- Phylum: Dictyosteliomycota
3- Phylum: Acrasiomycota
4- Phylum: Plasmodiophoromycota

Fungus-like organisms

Because of similarities in morphology and lifestyle, the slime molds (myxomycetes) and water molds (oomycetes) formerly classified in the kingdom Fungi. Unlike true fungi, the cell walls of these organisms contain cellulose and lack chitin. Slime molds are unikonts like fungi, but grouped in the Amoebozoa. Water molds are diploid bikonts, grouped in the Chromalveolate kingdom. Neither water molds nor slime molds, closely related to the true fungi and therefore taxonomists no longer group them in the kingdom Fungi.

Divition: Chytridiomycota

Fungi produce zoosporic flagellated cells during their life cycle.

Class (a) Chytridiomycetes

Class (b) Plasmodiophoroimycetes

General characteristic of Chytridiomycetes:

The chytridiomycetes, or “chytrids,” are usually aquatic, either marine or freshwater.

The chytrids are mostly single-celled forms; chytrids have no light-sensitive pigments.

Presence of posterioraly uniflagellate celled zoospore. The flagella are of whiplash-type.

In fact, chytrids are the only large taxon of fungi, which produces a zoospore of any kind.

Chytrids have an absorptive mode of nutrition, like other Fungi.

Chytrids have cell walls composed of chitin.

Sexual reproduction is by isogamy to oogamy conjugation, asexual reproduction by uninucleate zoospores.

Chytridiomycetes classified into the following important orders, chytridiales and blastocladiales.

Thallus and life history diversity in Chytridiomycetes

a) Unicellular, holocarpic- may produce rhizoids that mainly serve to anchor thallus; rhizoids lack nuclei.   .

b) Filamentous, eucarpic- coenocytic mycelium; septa may form at base of reproductive structures. .
c) Endobiotic- live entirely within the cells of their hosts.
d) Epibiotic- producing reproduction organs on the surface of either a living host or dead organic matter with rhizoids or mycelium remaining inside

Flagellated stages of life cycle

- Zoospores - asexual reproduction
- Planogametes - sexual reproduction
- Both zoospores & planogametes possess a single, posterior whiplash flagellum

General characteristic of order Chytridiales

1- Chytrideiales found in aquatic as well as terrestrial conditions. They occur parasitically on algae, vascular plants e.g. *Synchytrium endobioticum.*
2- Many forms are endobiotic, live completely within the cells of the host, whereas some are also epibiotic life on the host surface.
3- Asexual reproduction takes place with the help of zoospores, which are posteriorly uniflagellate.
4- Zoospore-containing body is a spherical or pear-shaped sac, called zoosporangium.
5- Sexual reproduction has not observed in a majority of the chytrids. A thick- walled resting spore or resting sporangium formed after sexual reproduction.
6- Chytridiales classified into many important families from which synchytriaceae (e.g. *Synchytrium endobioticum*).

General characteristic of family Synchytriaceae

1. Members are unicellular, holocarpic and lacking a true mycelium.
2. Thallus divides into many compartments at the time of reproduction, which used as sporangia or gametangia.
3. Many gametangia or sporangia remain enveloped in a common membrane to form a sorus.
4. A sexuall reproduction by uniflagellated zoospores whereas sexual by gametes. e.g. *Synchytrium endobioticum*

Like some other Chytridiales, *Synchytrium endobioticum* develops no mycelium. The fungus produces a thick walled structure known as a winter sporangium. It is 25-75 μm in diameter and contains 200-300 spores. Sporangia clustered into thin-walled soruses. The motile life stage, zoospore is about 0.5 μm in diameter and has one posterior flagellum. causes the potato wart disease or black Scab. It also infects some other plants of the *Solanum* genus, though potato is the only cultivated.

General characteristics of the order Blastocladials:

1. Members of the Blastocladiales are order is chiefly occur saprophytically in water or soil. Some inhabit plant or animal debris .However, Coelomomyces is an obligate parasite of mosquito larvae and other invertebrates.
2. The thallus is eucarpic in all the Blastocladiales except Coelomomyces where a naked plasmodium like thallus is present.
3. The cell wall in a majority of Blastocladiales consists of chitin however; proteins, glucans, and ash also reported in the wall of some genera.
4. All Blastocladiales produce thick -walled resting sporangia with pitted wall.
5. The zoospores are posteriorly uniflagellate.
6. The sexual reproduction is isogamous in some and anisogamous in other investigated species. However, in many species sexual reproduction has not observed.
7. The gametes, if present are uniflagellate.
8. Blastocladiales show different types of life -cycle patterns.

Important genera include *Allomyces, Blastocladiella,* and *Blastocladiopsis.*

The family Blastocladiaceae includes four genera of these *Allomyces* is the best known Genus *Allomyces*

Occurrence:

The genus *Allomyces* is worldwide in distribution. It has reported chiefly in tropical or warm countries. The genus comprises five species. Of these *A. arbusculus, A. macrogynous* and *A. javanicus* are important. Al the species are saprophytic soil dwellers and found in the wet soil and they usually isolated by boiling water sample or water sample to which soil sample has added with a sterile hemp or sesame seeds [3].

Thallus structure and life cycle in *Allomyces*

The thallus in all the species is hyphal. It is filamentous and consists of richly branched, multinucleate hyphae. The mycelium attached to the substratum by a tuft of delicate but well formed, branched rhizoidal hyphae constituting the rhizoidal system. From the latter arises a single, stout hypha forming the lower trunk-like portion and numerous side branches, usually dichotomously branched on which the reproductive organs formed. The hyphae are multinucleate and non- septate. However, they appear to be septate. The pseudosepta are the ring-like thickenings of wall material formed at each dichotomy. The wall consists chiefly of chitin, glucan and ash. *Allomyces* in its life cycle exhibits distinct alternation of generations a significant feature that sets these fungi (Blastocladiales) a part from all other fungi. Since the two alternating individuals (gametothallus and sporothallus) in the life cycle are morphologically similar, the alternation of generations in *Allomyces* is termed isomorphic. The vegetative thalli in *Allomyces* are of two types,

a) Gametothalli (Haploid)
b) Sporothalli (Diploid)

In the vegetative phase, these two are indistinguishable. Towards maturity, the gametothalli bear gametangia and sporothalli produce sporangia. Thus, the two types of thalli distinguished only when they begin to form the reproductive organs.

1. Gametothallus

Reaching a certain stage of maturity, the gametothallus produces more or less globose gametangia in pairs or in short chains. The male and female gametangia alternate with each other (Figure 31B).

(i) Female gametangium: It is grey or hyaline and may be borne above the male gametangium *(A. arbusculvm)* or below it *(A.macrogynous).* The multinucleate gametangial contents undergo progressive cleavage to form uninucleate uniflagellate, opisthocont female gametes which are about double the size of the male gametes (Figure 31C).

(ii) Male gametangium: It is smaller than the female gametangium and is orange or red in colour. The colour is due to the presence of carotenoid pigment in the cytoplasm.

Life cycle of *Allomyces* sp

1. The two kinds of gametes released in to the water. They escape singly through one or more pores in the wall of their respective gametangia. The discharged female gametes secrete asexual hormone called sirenin, which serves to attract the male gametes towards them. The male and the female gametes copulate in pairs; pairing of anisoplanogametes, soon followed by fusion of the male and female protoplasts called as plasmogamy.
2. The fusion of male and female nuclei known as karyogamy follows plasmogamy to form zygote.
3. The motilembi-flagellate zygote formed by the fusion of two uniflagellate, opisthocont anisoplano- gametes moves sluggishly for 5 to 10 minutes. It then comes to rest, retracts the flagella, rounds up and secretes a wall around it.
4. Germmation of Zygote: The zygote immediately germinates. At the time of germination,

the zygote puts out a slender basal germ tube, which grows, and branches to form the rhizoidal system. The body of the zygote enlarges and elongates in the opposite direction to form the thick, trunk like hyphal tube that grows vigorously branches successively dichotomously to produce the diploid sporothallus.

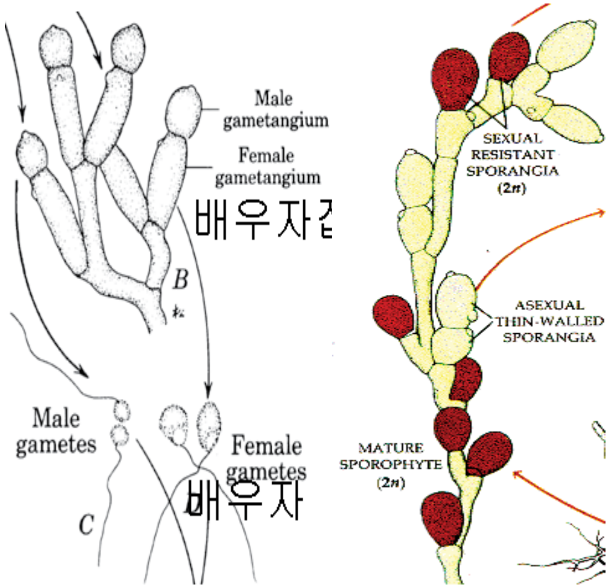

Figure 31: Gametothallus with male and female gametangial, B: male and femal gametes, mature sporophyte.

2. Sporothallus:

It is concerned with asexual reproduction. At maturity, it produces two types of sporangia (Figure 32):

(i) The thin-walled mitosporangia;

(ii) The thick-walled resting or resistant sporangia

Both types of sporangia are borne on the same thallus. They may form singly or in catenate series on the tips of the ultimate dichotomies.

i) Mitosporangium:

The multinucleate tip of the ultimate hyphal branch swells. The inflated portion separated from the parent hyphal by a basal transverse wall to function as a young mitosporangium. They later increase in size during further development. There is also increase in the number of nuclei by mitosis. The mature mitosporangium iscolorless and thin-wailed- The sporangial contents are then divided by progressive cleavage into uninucleate daughter protoplasts by in warding furrowing of the plasma membrane. Each uninucleate daughter protoplast metamorphoses into a diploid, uniflagellate, opisthocont zoospore known as the mitozoospore. The zoospores escape through pores, one or more in number developed in the sporangial wall. The discharged mitozoospore swims about for a while, comes to rest, retracts the flagellated, rounds up and secretes a wall. The encysted zoospore germinates immediately.

Germination of mitozoospore

The germinating mitozoospore first puts out a slender basal germ tube which forms the rhizoidal system- The main body of zoospore then grows into a thicker germ tube which elongates in the opposite direction and branches repeatedly to produce the dichotomously branches repeatedly to produce the dichotomously branched part of the diploid sporothallus. The diploid mitozoospores thus serve to reduplicate the sporophyte generation. They play no role in phenomenon of alternation of generations.

(ii) Meiosporagium:

The early development o meiosporangia is similar to that of the mitosporangia- There is, however, formation of a thick, pitted wall internal to an original sporangia wall in addition. The mature meiosporangia are thus thick-wall; and pitted, reddish brown in color. The multinucleate sporangia contents undergo a resting period of 2-6 weeks or even more prior to the cleavage of the protoplast into zoospores; hence the name resting or resistant sporangia. After the resting period, there is increase in the number of nuclei. The nuclear division, however, is meiotic Meiosis is followed by cleavage of the sporangial contents into uninucleate uniflagellate, opisthocont zoospores which are haploid and slightly smaller than the mitozoospores. They knew as meiozoospores or gonozoospores. The wall of the mature meiosporangiurn cracks and the meiozoospores escape in the water. In the swim about for a while, then come- to rest, retract their flagellum and round off. Each quiescent meiozoospore secretes a wall around it and then germinates immediately in the same way as the mitozoospore but produces an alternate haploid plant in life cycle called the gametothallus and not the sporothallus. The meiozoospores or gonozoospores thus play an important role in the phenomenon of alternation of generations in the life cycle *of Allomyces.*

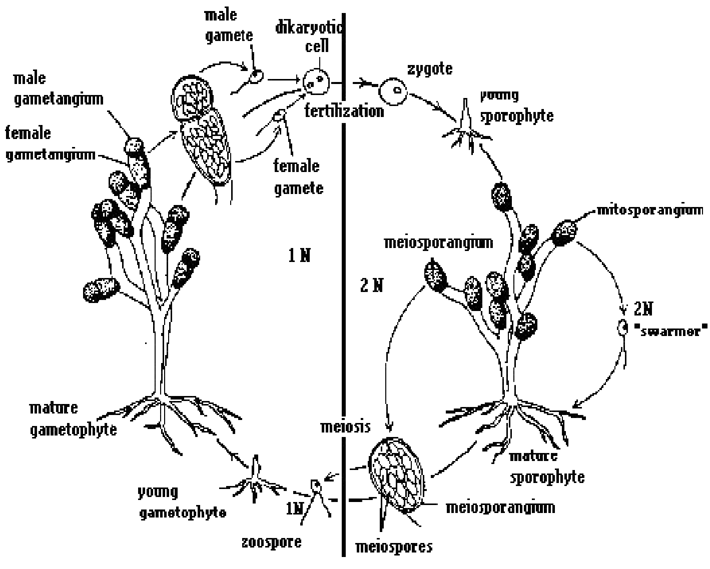

Figure 32: Allomyces sp. life cycle.

Class Plasmodiophormycetes

General characteristics:

1. Members are obligate endoparasites, attacking many plants of economic importance like cabbage and potato. Some species also attack many aquatic pteridophytes (*Isoetes*), angiosperms (*Juncus*), some algae (*Vaucheria*) as well as some fungi (*Saprolegnia* and *Pythium*).
2. The infection results into the hypertrophy (abnormal enlargement of host cells and hyperplasia (abnormal multiplication of host cells) in the host. Disruption in the vascular elements of the host results into the general stunting.

3. A characteristic Cruciform-type of nuclear division found only in Plasmodiophoromycetes and in no other fungi.
4. The life cycle includes two distinct plasmodial phases.
5. The plasmodium is parasitic with in the cell of the host plant.
6. Biflagellate zoospores contain flagella of unequal lengths .the flagella are anterior and of whiplash type.
7. The first plasmodial phase of the life cycle is a zoosporangial plasmodium.
8. The second plasmodial phase gives rise to resting spores.
9. The wall of the resting spores contains either chitin or cellulose.
10. In some species, sexual fusion observed before the development of resting spore plasmodium.

Plasmodiophoromycetes contain only one order (Plasmodiophorales) and one family (Plasmodiophoraceae).e.g. *Plasmodiophora brassicae.*

Plasmodiophora brassicae:

Occurrence:

Plasmodiophora brassicae is an obligate endoparasite on the roots of Cruciferaceous plants, attacking both cultivated as well as wild members. It causes diseases like club root or finger and toe disease of brassicae. The disease is of universal occurrence common attacked plants include cabbage, raps, mustard, turnip, etc.

Division: Zygomycotina

Division Zygomycotina includes the fungi that do not have motile cells or zoospores during any stage of their life cycle, and the perfect state spores are present in the form of thick-walled resting spores, called zygospores- of the two classes: Zygomycetes, Trichomycetes.

Under Zygomycotina, Zygomycetes includes mainly saprobe members. In parasitic members of Zygomycetes, the mycelium is immersing in the host tissue.

Members of Trichomycetes remain attached to the cuticle or digestive tract of arthropods or gut of earthworms, and their mycelium is not immersing in the host tissues. Zygomycetes and Trichomycetes studied here.

General characteristics of the Zygomycetes:

a. The majority of the members are saprobe- Some occur on dung, showing coprophllous nature, and some members attack other fungi- A few Zygomycetes are weak parasites, attacking plants and animals.
b. Most Zygomycetes produce a well-developed and branched mycelium, consisting of coarse, grey or white, coenocytes hyphen. A few members, however, contain a highly reduced mycelium, having septa at definite intervals.
c. Cells contain all typical cellular organdies including mitochondria, nuclei, ribosomes, lipid granules and endoplasmic reticulum.
d. Cell wall is mainly composed of chitosan-chitin.
e. Centrioles are absent.
f. Motile cells or zoospores are absent.
g. Asexual reproduction takes place by non-motile sporangiospores, called aplanospores. They produce in very large number within the sporangia.
h. Some reproduce by chlamydospores and a few by oidia.
i. Many Zygcmycetes reproduce by ‘modified sporangial units functioning as conidia or by true conidia’.
j. In mucorales appendaged sporangiospores are also formed Sporangiospores and appendaged sporangiospores develop in sporangia, merosporangia, and sporangiola or also as one-spared sporangia or conidia in Mucorales.

k. Sexual reproduction takes place by gametangial fusion. Two fusing gametangia may arise from the same mycelium or from different mycelia.
l. Gametangial fusion results the production of a thick-walled resting spore, called zygospore. The zygospore develops within a zygosporangium.
m. Zygospore remains surrounded by a very fuck wall, which is highly resistant to desiccation and other unfavorable factors. This wall pigmented and sculptured in many species.
n. The time of germination of me, zygospore a hypha emerges and bears a terminal sporangium. It believed that the meiosis occurs during germination.
o. Regarding me, primitive Mucorales require nutrition in Zygomycetes, no vitamins or growth factors. Only inorganic nitrogen with minerals and sugars are required. Higher forms like *Pilobolus* require growth factors such as ferrichrome (Coprogen). Entomophthorales require complex nutrition medium.

Classification:

The classification of Zygomycetes is not been settled yet. However, the majority of the workers divide Zygomycetes into three orders:

(i) Mucorales
(ii) Entomophthorales and
(iii) Zoopagales

However, Heseltine and Ellis (1973) also mentioned that 'possibly a fourth order, Endogonales, should also recognize, but Benjamin (1979) divided Zygomycetes into following seven orders, and Alexopoulos and Mims (1979) have also followed the same classification, except in the order Harpellales:

a. Mucorales
b. Dimargaritales
c. Kickxellales
d. Endogonales
e. Entomophthorates
f. Zoopagles
g. Harpellales

Recently Webster (1980) mentioned that Zygomycetes comprise only two Orders:

i. Mucorales
ii. Entomophthorales

Order: Mucorales

Mucorales divided into the following families:

I. Mucoraceas
II. Pilobolaceae
III. Kickxellaceae
IV. Endogonaceae
V. Thamnidiaceae
VI. Mortierellaceae
VII. Choanephoraceae
VIII. Piptocephalidaceae
IX. Cunninghamellaceae

Family: Mucoraceae

Mucoraceae is the largest family of 'the order, containing 20 genera, its common genera is *Mucor, Rhizopus, Absidia, Phycomyces, Adtnomvcor* and *Circadian.*

Example 1: ***Rhizopus***

Heseltine and Ellis (1973) recognized at least 120 species and varieties of these, *R. stolonifer.* (syn. *R. nigricans}* is most common, and considered as a type species representing the genus. Some details, largely *of R. stolonifer* given here.

Occurrence:

**Rhizopus stolonifer* occurs very frequently on bread, and is therefore commonly called "bread mould'.

*It is so frequent a contaminant of laboratory culture of bacteria and fungi that it considered as weed of laboratory.

**Rhizopus* occur world wide in soil, decaying fruits, dung and vegetation, *R. stolonifer* behaves parasitically, causing rot of sweet potato or fruit rot of apple, strawberry and tomato.

*Some *Rhizopus* species cause 'mucormycosis' in domestic animals and a few reported from human lesions.

*Almost all *Rhizopus* species occur saprophytically.

Laboratory culture and vegetative structures:

Since almost all *Rhizopus* species are saprophytes, the fungus can grow on dead organic materials such as bread and butter by keeping them in dark and damp atmosphere. By first exposing a moistened piece of bread in a Petri-dish for about 24 hr at room temperature, and then covering it for a few days. *Rhizopus* appears in the form of white tuft of mycelium.

Young mycelium of *R. stolonifer* consists of many well-branched, white, tubular or filamentous hyphae which are multinucleate and without cross walls, i.e. coenocytic (Figure 33).

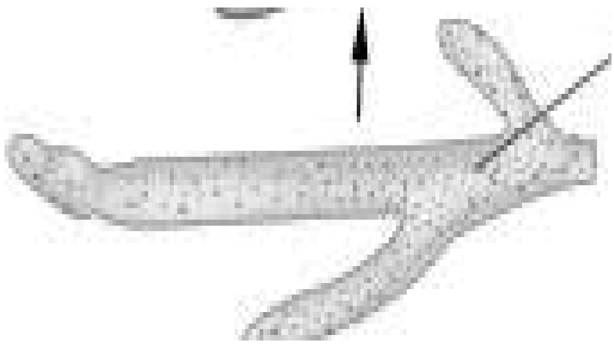

Figure 33: Coenocytic hypha of *Rhizopus*.

All hyphae are more or less a like and provide a cottony appearance when young, but later on; the mycelium soon enters the reproductive phase and becomes differentiated into three different types of hyphae (Figure 34):

A) Rhizoids
B) Stolons
C) Sporangiophores

Rhizoids are the repeatedly branched hyphae that penetrate the substratum. From each node of the stolen, they arise in the form of a cluster towards lower side. They absorb water and nourishment from the substratum. Rhizoids, sometimes called holdfast.

Stolons are the hyphae that grow horizontally above the substratum for some distance and then bend down into the substratum. The part bending down functions as a node and forms a tuft of rhizoids- The hyphae of the stolen are therefore aerial and unbranched.

Sporangiophores are the erect, aerial, unbranched and negatively geotropic hyphae, which grown upward in tufts at the point where the stolons form rhizoids. They are reproductive in function. Each sporangiophore bears a terminal sporangium. Certain enzymes secreted by the rhizoidal hyphae. These enzymes convert starch into soluble carbohydrates and readily absorbed by the fungus. Utilization of some inorganic and organic nitrogenous compounds also helps *Rhizopus* in synthesizing some proteins.

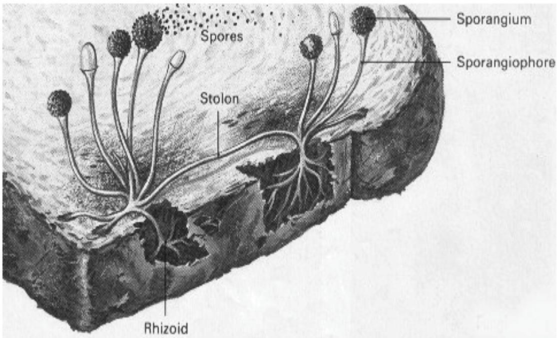

Figure 34: Vegetative structures of *Rhizopus.*

Reproduction:

A) Asexual reproduction

It takes place generally by the formation of sporangiospores and rarely by chlamydospores.

Sporangium and sporangiospores:

These are unicellular, multinucleate, non-motile spores, produced in round black bodies, called sporangia (Figure 35). Because of their non-motile nature, they also called aplanospores; a sporangium develops singly and terminally on the sporangiophore. The sporangiophores are erect phototropic structures, which develop in tufts from the mycelium. At a stage when a number of such pin-head-like black-coloured sporangia are present. The entire mycelium appears blackish and hence a popular name black-mold given to the fungus.

Development of sporangium starts by the:

1. Swelling the tip of the sporangiophore into a knob-like vesicle
2. The cytoplasm along with many nuclei from the sporangiophore flows into the swollen vesicle. This increases the size of the vesicle. The swollen portion represents the young sporangium.
3. The protoplasmic contents of the young sporangium soon becomes differentiated into two zones, i.e. outer peripheral multinucleate dense region, and the central less dense region with comparatively fewer nuclei. A layer of vacuoles separates two portions.
4. Fusion and flattening of these vacuoles results in the formation of cleft between the two zones. The wall secreted in this region of cleft. This wall thus finally differentiates outer sporangiferous zone and central columella in the young sporangium.
5. The columella therefore remains in continuity with that of the proplast of sporangiophore. Cleavage in the peripheral sporangiferous zone results in the formation of many multinucleate segments.
6. These segments secrete wall around each of them and metamorphose into unicellular, globose or oval, multinucieate, non-motile sporangiospores, called aplanospores. Germination of spore starts under favorable conditions. A spore germinates by producing a germ tube that develops into a fluffy, well-branched, white, aerial mycelium.

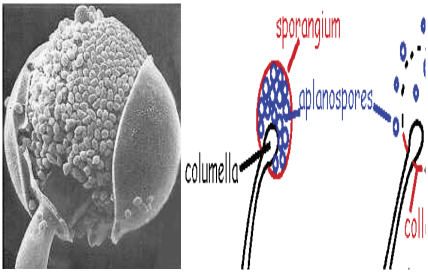

Figure 35: Sporangium contains hundreds of non-motile, asexual spores within a delicate outer membrane called a peridium.

Chlamydospores:

Formation of chlamydospores is rare in *R .stolonifer.* They produced only in the old mycelia. At the time of chlamydospore formation, the mature hyphae become transversely septate. Some intercalary cells of this multicultural mycelium are surrounded by thick walls (Figure 36), contain sufficient reserve food, and represent chlamydospores. These are very resistant to unfavorable conditions. On return of the favorable conditions, they germinate by producing fresh hyphae.

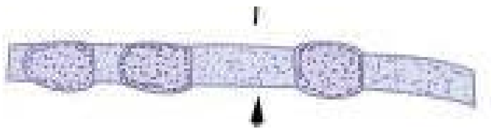

Figure 36: Chlamydospores formation.

B) Sexual reproduction:

Rhizopus reproduces sexually by the process of conjugation, which results in the formation of zygospores (Figure 37). A majority of the species, including *R. stolonifer,* are heterothallic. However, species such as *R. sexualis* are homothallic.

In the heterothallic species, the zygospores formed only when two compatible strains of different mating types mated together. These two named compatible strains of Mucoraceae as (+) and (-) strains because it could not be made possible to designate them male and female, mainly because of the very close external similarity between both of them. In the homothallic species, the zygospores formed in the mycelium derived from a single sporangiospore.

Sexual reproduction in *R. stolonifer*

In this heterothallic species, the two fusing mycelia belong to two different mating types. One belongs to (+) (plus) strain and the other to (-) (minus) strain. Sexual reproduction (Figure 37) takes place only when a (+) strain hypha and a (-) strain hypha meet each other. At the time of the sexual reproduction, two compatible hyphae attracted towards each other. These special hyphae, which are capable of developing into, progametangia, are called zygophores.

According to Burgeff (1924) and Mesland et al. (1974), following three reactions take place in the members of Mucorales when two-compatible strains approach each other:

1. Telemorphotic reaction: It involves the initiation of club-shaped, aerial zygophore formation. According to Gooday (1973, 1974) and Van den Ende (1976) the zygophores in both the strains (+ and -) are induced by trisporic acids B and C. These trisporic acids are

produced when cultures of the (+) and (-) strains are in continuous diffusion contact with each other on the media.

2. Zygotropic reaction: Under this reaction the zygophores of (+ and -) mating partners are directed to grow towards each other. According to Banbury (1955), the zygophores of opposite strains show a mutual attraction, whereas that of the simil ar strains shows mutual repulsion.

3. Thigmotropic reaction: It controls the stages occurring after the contact of zygophores. The stages like gametangial fusion and septation are under control by thigmotropic reaction.

Under zygotropic reaction, the zygophores of opposite strains approach towards each other and from each develops a copulation branch. The two copulating branches called as progametangia.

The progametangia of opposite strains adhere together by their tips. They begin to enlarge because of the flow of the cytoplasm and nuclei into them. Owing to the enlarged size of the progametangia, the zygophores pushed apart. The tip of each progametangium is soon cut by a septum. The small terminal cell so formed called a gametangium whereas the long tubular part called a suspensor. The gametangium is densely granular multinucleate protoplast, whereas the suspensor has a more vacuolated protoplast. The protoplasm of each gametangium constitutes the aplanongmete. The size of both the gametangia and the number of nuclei are increase. The gametangia of the fusing pairs are generally equal in size, but they may also be unequal. A large pore develops in the adjoining wall of the two gametangia, which allows both the gametangia protoplasts (aplanogametes) to fuse and form a zygospore. A thick, black, warty wall surrounds the zygospore soon. The zygospore wall made up of two layers, of which the outer dark, thick and many layer called exine, and the inner: thin layer called as inline. The zygospores undergo a resting period of about week to 5-9 months. Meiosis takes place only at the time of zygospore germinatation, i.e. after the resting period is over .Therefore the zygospore is the only diploid structure in the life cycle. Segregation of strains takes place during meiosis.

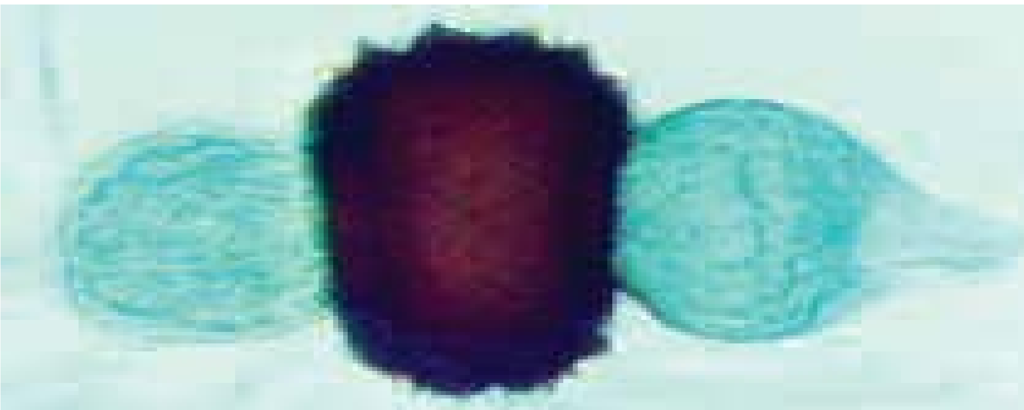

Figure 37: Zygospore formation.

Germination of zygospore starts by the development of a lateral crack in its wall .The inner thin inline comes out in the form of a hypha-like germ tube, which also called promycelium. The early divisions are meiotic, resulting into a number of haploid nuclei in the protoplasm of germinating zygospore. The young germ tube functions as a sporangiophore and develops a germ sporangium at its tip.

The germ sporangia of *R. stolonifer* contain either all (+) or all (-) spores, or a mixture of both. These spores germinate to form fresh mycelium (Figure 38).

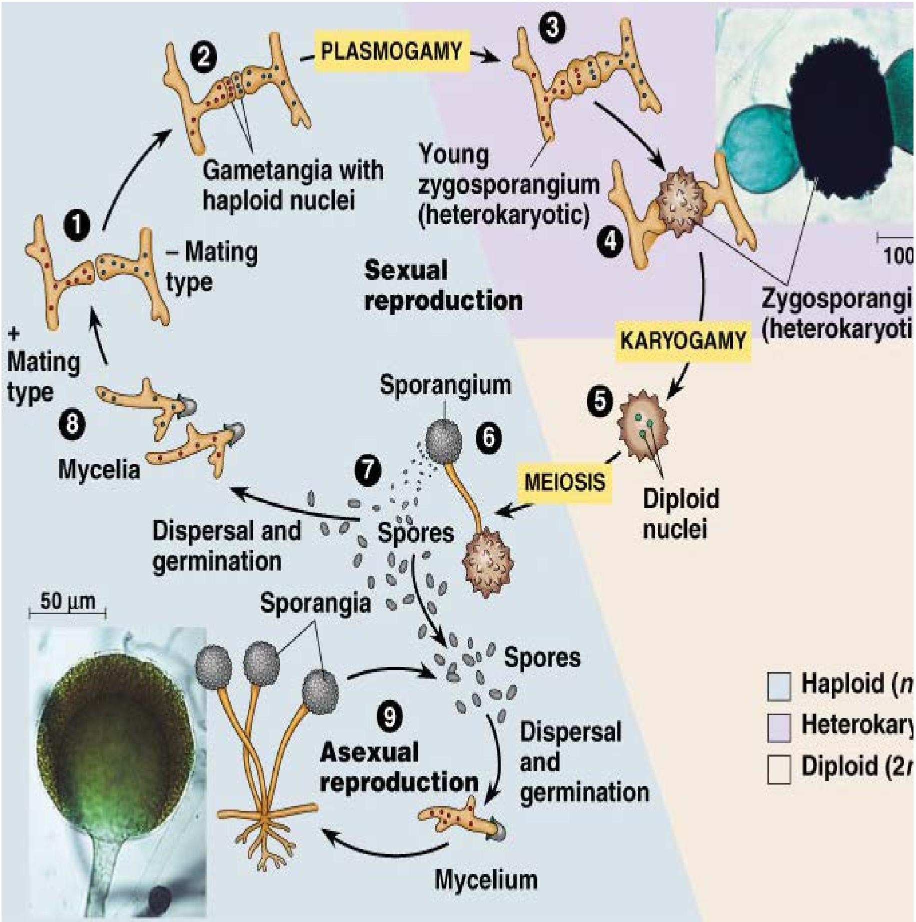

Figure 38: Life cycle in *Rhizopus sexualis.*

Example 2: *Mucor*

Mucor (Figure 39) resembles with *Rhizopus* in almost all major characteristics, except that of following differences (Table 1):

	Rhizopus	*Mucor*
1	Rhizoids (absorptive hyphae) or holdfasts are present.	Rhizoids or holdfasts are generally absent, or less specialized.
2	Stolons are present.	Stolons are absent, and thus there is no differentiation of stolons and holdfast in mycelium
3	Rhizoids mainly absorbs the food material	Food mainly absorbed by the entire mycelia surface
4	Sporangiophores develop in well-organized groups mainly against the rhizoidal hyphae	Sporangiophores arise singly, and not in groups
5	Spores remain adhered to columella and not easily disseminated	Spores easily blown away by wind

Table 1: Diffeences between *Rhizopus and Mucor*

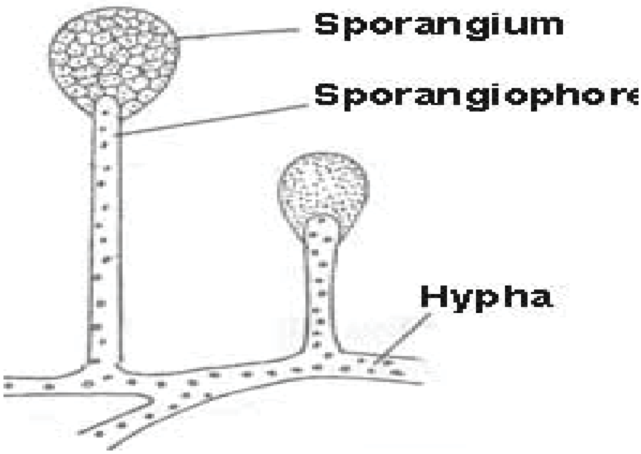

Figure 39: Vegetative structures of *Mucor* sp.

Heterothallism in Mucorales

A condition shown by heterothallic species called heterothallism. What are then heterothallic species? Alexopoulos and Mims (1979) mentioned that there are two versions about a heterothallic species. According to one version, a species consisting of self-incompatible or self-sterile individuals, which for sexual reproduction require the union of two compatible thalli (mating types), is called heterothallic. According to another version a species in which the sexes are segregate in separate thalli, therefore two different thalli are required for sexual reproduction called as heterothallic.

Thus it is a condition where the thalli of a single species are morphological similar but physiologically different. Physiologically the mycelia are unisexual, but there is no apparent distinction between the male and female mycelia. They differ only in their sexual behaviors. Such a condition of sexual incompatibility in fungi was firs observed in Mucorales by an American geneticist. Heterothallic species contains two physiologically' and sexually different strains or races. Such races when grown apart produce only asexual bodies or sporangia. However, when they are allow to come in contact they fuse and form zygospores along the line of their union. These different strains are (+) (plus) and (-) (minus). Of course, morphologically (+) and strains are indistinguishable, but often the (+) strain shows more vigorous growth than (-) strain, and the gametangia of the former (+) strain are larger than of latter strain. Some workers are, however, of the opinion that this difference in gametangial

Size is not because of any difference of sex but because of available nutrients.

Family: Pilobolaceae

Distinguishing characteristics:

1. Only three genera (Pilobolus, Pilaira and Utharomyces) are included in Pilobolaceae and all of them always found growing on dung of herbivorous animals.
2. Sporangia of al members contain dark-coloured, persistent walls.
3. Many spores are present in a sporangium.
4. Sporangiophores are large, elongate and phototrophic, i.e., grow towards sunlight.
5. At the base of the vegetative mycelium, some swollen structures called trophocysts found except in *Pilaira*.

6. In *Pilobolus,* the Sporangiophores are swollen. Its sporangia always shot off the sporangiophore.
7. All members are heterothallic

Example: *Pilobolus*

Pilobolus is a coproophilous fungus (Figure 40), i.e. found on the dung of many herbivorous animals, especially on horse dung. Some of its common species are *P.crystallinus, P. kleinii*, P. longipes. The mycelium consists of short, coarse hyphae, branched, aseptate, and multinucleate, the swollen parts or trophocysts appear yellow because of the presence of carotene.

Other examples of Mucorales:

***Syncephalestrum* sp**

The genus *Syncephalastrum* (Figure 40) characterised by:

1. The formation of cylindrical merosporangia on a terminal swelling of the sporangiophore
2. Sporangiospores arrange in a single row within the merosporangia. *Syncephalastrum racemosum* is the type species of the genus and a potential human pathogen; however, well-documented cases are lacking. It is found mainly from soil and dung in tropical and subtropical regions. It can also be a difficult laboratory aerial contaminant.
3. The sporangiophore and merosporangia of *Syncephalastrum* species may also be mistaken for an *Aspergillus* species, if the isolate is does not look carefully. Colonies are very fast growing, cottony to fluffy, white to light grey, becoming dark grey with the development of sporangia.
4. Sporangiophores are erect, stolon-like, often producing adventitious rhizoids, and show sympodial branching (racemose branching) producing curved lateral branches.
5. The main stalk and branches form terminal, globose to ovoid vesicles, which bear finger-like merosporangia directly over their entire surface.
6. At maturity, merosporangia are thin-walled, evanescent and contain 5-10 globose to ovoid, smooth-walled sporangiospores (merospores).

***Thamnidium* sp**

Thamnidium is a genus in the order Mucorales of the Zygomycetes. It has a tall sporangiophore bearing a 'Mucor-type' sporangium (with a columella) at its tip (Figure 40). Laterally on the sporangiophore, it produces a series of dichotomous branches with the ultimate tips bearing sporangioles (tiny sporangia) each containing a few spores (sporangiospores) and lacking a columella.

Cunninghamella *sp*

The genus *Cunninghamella* (Figure 40) characterized by:

1. White to grey, rapidly growing colonies, producing erect, straight, branching sporangiophores
2. The sporangiophores end in globose or pyriform-shaped vesicles from which several one-celled, globose to ovoid, echinulate or smooth-walled develop on swollen denticles
3. Chlamydoconidia and zygospores may also be present
4. *Cunninghamella* species are mainly soil fungi of the Mediterranean and subtropical zones, and less commonly in temperate regions
5. The genus now contains seven species, with *C. bertholletiae* the only species known to cause disease in man and animals

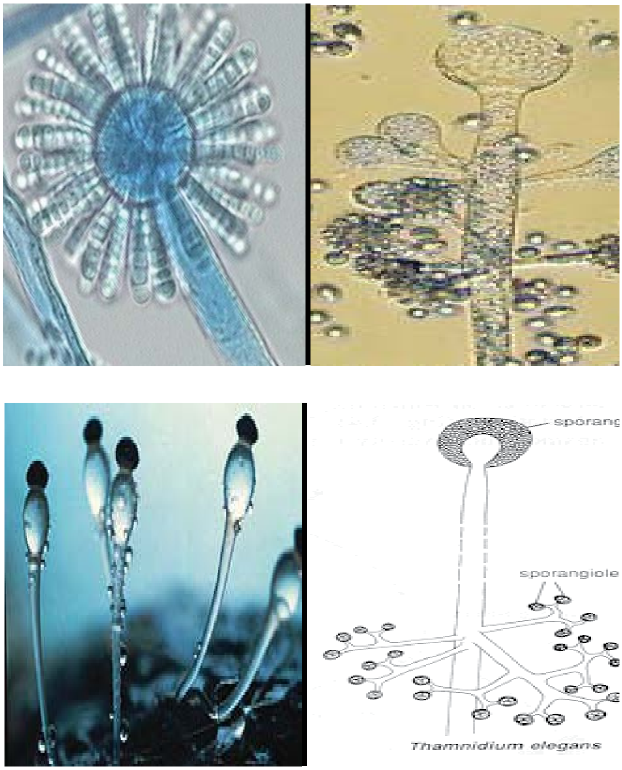

Figure 40: *Syncephalestrum, Cunninghamella, Pilobolus, and Thamnidium* respectively from higher.

Importance of Mucorales

1. Some species of mucorales caused soft rot of sweet potato, strawberry and many other fruits.
2. *Rhizopus* is a common spoiling agent of bread.
3. Some species used in the production of organic acids such as lactic acid, succinic acid, citric acid and fumaric acid.
4. Many oriental foods like temph and sufe are prepared from species of *Actinomucor* and *Rhizopus*.
5. Carotene compounds produced from species of *Blakeslea*.
6. *Rhizopus stolonifer* used in biotransformation of cortisone manufacture.
7. Many species causes mucoromycoses such as *Mucor* and *Absidia.*
8. Members of family Piptocephalidaceae of Mucorales occur parasitically on other fungi, and primarily on other Mucorales. Such fungi, which occur on other fungi, called mycoparasites.
9. Some produce highly active antibiotics against several types of bacteria e.g., from *Absidia.*

2) Order Entomophthorales: As the name implies, these fungi often attack insects. *Entomophthora muscae* infects, and eventually kills, houseflies. Dying flies, their bodies riddled by the fungus, usually crawl into exposed situations.

3) Order Zoopagales: Parasites of fungi, nematodes, amoeba etc, and many taxa produce merospongia (sporangia that break up at maturity, looking rather like the thallic-arthric conidia of some ascomycetes and basidiomycetes).

4) Order Kickxellales (Named after a mycologist called Kickx). Members of this order are atypical of the *Zygomycetes* in that they often have regularly septate hyphae. Their teleomorphs are unremarkable, but they develop some of the most complex anamorphs known e.g: *Coemansia mojavensis* [4].

Class Trichomycetes

These classes contain 4 orders, 7 families, 52 genera, about 210 species. This eccentric group of fungi live almost exclusively attached to the lining of the guts of living arthropods, Trichomycetes are common in herbivorous or detritivorous arthropods, but rare in predaceous species. A single species of trichomycete can usually inhabit several related host species. They often seem to be commensals, doing little or no harm to their hosts: sometimes they may even be associated with faster growth of their hosts. At least one species, *Smittium morbosum*, causes the death of mosquito larvae. The mycelia are very limited in extent and may be branched or unbranched depending on the species (Figure 41). The Class contains four Orders. Three of them are *Asellariales*, *Eccrinales* and *Harpellales* and closely related, and seem to have common ancestry. The fourth, the *Amoebidiales*, is an outlier. These fungi found attached to the gut lining of insects, crustacea and millipedes. M.M. White, a Canadian doing graduate studies at Kansas, has recently published the first report of a new genus of *Harpellales* in isopod Crustacea, of Trichomycetes in *Trichoptera* (Caddisflies), and of *Eccrinales* in *Plecoptera* (Stone flies). These discoveries indicate that there is much to be learning about the taxonomy and host range of this group.

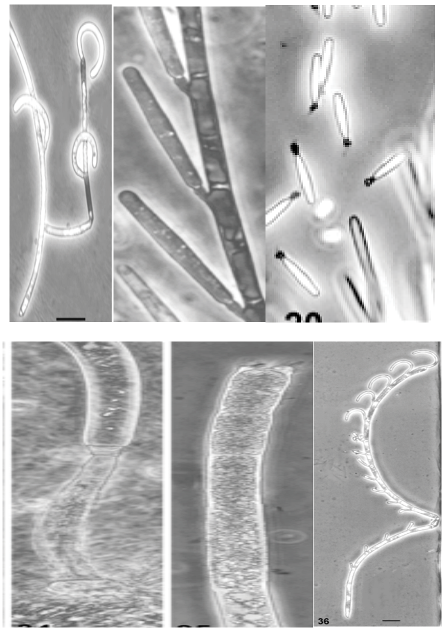

Figure 41: Different forms of Trichomycetes thalli.

Division: Ascomycota
Subdivision: Ascomycotina
Class: Ascomycetes

The subdivision Ascomycotina is equivalent to class Ascomycetes of the older classifications. Ascomycotina includes only such fungi in which the zygospores are absent and the perfect-state spores are the ascosporic. The Ascomycetes and the Basidiomycetes commonly called "higher fungi". Ascomycetes is the largest class of fungi, including more…than 15,000 species. Some of the commonly-known Ascomycetes are yeasts, black molds, green molds, powdery-mildews and morels- The characteristic ascosporic are present in a sac-like body, called accuse and therefore these fungi are called "sac fungi" (Gr. ciskos = sac).

General characteristics

1. Ascomycetes occur in almost all climatic conditions, and in a wide variety of habitats, i.e. in soil, on dung (coprophilous), in marine, as well as fresh water, as saprophytes of animal and plant remains, and as parasites on plants as well as animals. Micah of most parasitic species grows within the host tissue, but powdery mildews grow superficially upon the host showing ectoparasitic nature. Few Ascomycetes are entirely hypogeal, i.e. grow and develop only underground.
2. The mycelium is well developed, profusely branched and septate. Each segment the hyphen contains several nuclei. However, yeasts are single-celled organisms.
3. In each septum or cross wall of the mycelium there is present a simple central pore.
4. The chief distinguishing character of all Ascomycetes is the presence of a sac-like body, called ascus (pi. asci). It contains sexually produced spores, called ascospores.
5. The ascosporic are formed after karyogamy and meiosis. In an ascus, the number of ascospores is usually eight. However, in soroe species their number may vary from one to over 1000 in an ascus.
6. The ascospores are always endogenous in origin, and called perfect-state spores.
7. The asci usually grouped to form a definite type of multicellular fruiting body called ascocarp. The ascocarps remain enveloped in a sheath of sterile hyphae.
8. The ascocarps are either cup or saucer-shaped (apothecium, e.g. Discomycetes), flask-shaped (perithecium, e.g. Pyrenomycetes), or ovoid, spherical and indehiscent cleistothecium, e.g. many Plectomycetes).
9. Any type of flagellate cells is completely absent in the life cycle of all Ascomycetes.
10. Asexual reproduction takes place by the imperfect Stage, present in the form of non-motile, exogenously produced spores, and called conidia. The conidia develop on special reproductive hyphae called conidiophores. In some members, the asexual reproduction is by means of pycniospores, oidia or chlamydospores.

Reproduction:

The life cycle of an ascomycete, in general, consists of two reproductive stages that include- asexual stage and sexual stage:

Asexual stage often called the imperfect stage. Sexual stage designated as the perfect stage.

The asexual stage however, predominates with asexual spores forming the chief means of dispersal of the fungus. The sexual or perfect stage occurs only under particular conditions or at a particular season.

sexual reproduction by the following:

1. Conidia: The conidia are exogenously produced, non-motile, deciduous asexual spores. They are thus exposed or unprotected and are abstricted singly or successively from the free, distal end of a special, short, erect, fertile hypha called conidiophores. The conidiophores (Figure 42) may be branched or unbranched, unicellular or multicellular. Each ultimate branch bears a cluster of bottle-shaped structures called sterigmata each of which produces a long chain of conidia. Generally, conidia are multinucleate. Upon germination, each conidium gives rise to a germ tube, which grows into a mycelium.

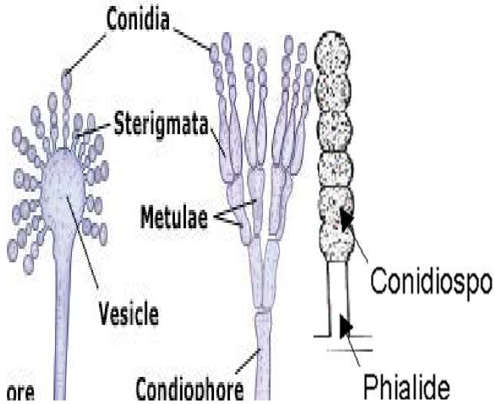

Figure 42: Unbranched, branched conidiophore, chain of conidiospores.

2. Oidia: In some Ascomycetes the hyphae do not form spores in succession at their free ends- Instead the septate hyphae may undergo additional septation and break up or fragment under proper conditions into their component cells. These single-ceiled fragments behave as asexual spores called oidia. The oidia formed throughout the length of a hypha. They do not seem to be reproductive structures in the same sense as conidia- oidia).

3. Chlamydospore: Any cell in the mycelium may lose water, accumulate granular, reserve materials and develop around it a thick wall to become a chlamydospore. The chlamydospores may be terminal or intercalary in position and may form singly or in short catenae series. With the onset of conditions favorable for vegetative growth, the Chimayo spores germinate, each producing a new mycelium.

Asexual reproduction by vegetative methods:

(i) Fragmentation: In this method, there is separation former mycelium of hyphae or segments of hyphae called the fragments. The fragments may consist of one or more living cells. By repeated cell division and apical growth, each fragment produces a new mycelium.

(ii) Fission: The Ascomycetes with a unicellular thallus such as fission yeasts usually multiply by this method. It is a kind of ceil division. The division is transverse. The mother cell elongates. The nucleus divides into two. The daughter nuclei move apart. Mean while a ring-like in growth of the wall material appears at 'the wall in the middle) of the cell. It grows, inwards covered in front by the plasma membrane. Finally, it meets in the center stretching across the cell forming a complete partition called the septum. The septum thickens and then splits into two layers, one for leach daughter cell before they separate (Figure 43).

(iii) Budding: *Saccharomyces* (baker's yeast) under normal conditions reproduces by this method only. At the time of budding, the cell protoplast covered by the cell wall bulges out in the form of a small protuberance at or near one pole of the yeast cell. The protuberance gradually increases in size and called the bud. Meanwhile the nucleus of the parent cell along with the vacuole divides. One of the daughter nuclei migrates into the enlarging bud. The bud grows and become consented at the base. Eventually the opening between the bud and yeast cell closes, double wall forms and the two cells become physiologically distinct. They subsequently separate from each other leading independent life (Figure 43).

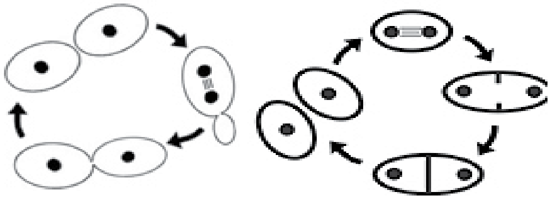

Figure 43: Asexual reproduction by budding and fission.

Sexual reproduction:

The eucarpic mycelium in Ascomycetes, which produced conidia, enters the sexual or perfect phase under particular conditions or at a particular season usually late fall or early spring. It is either homothallic or heterothallic and sexual reproduction it is gammas heterogamous. The copulation branches in some of the lower Ascomycetes do not show any distinction and are similar. However, in the higher Ascomycetes they undergo functional and morphological differentiation to form male and female sex organs. The male sex organ called an antheriditini and the female ascogonium- The initial step in sexual reproduction always aims at the fusion of two protoplasts, which brings the two compatible nuclei close together in the same cell. This processes called plasmogamy. Therefore, first study the common methods, which the Ascomycetes employ to achieve plasmogamy (Figure 44).

1. Gametangial copulation:

In some of the lower Ascomycetes (Hemiascomycetjdae) such as *Eremascus,* the copulation branches are indistinguishable from each other and sexual reproduction described as isogamous. They arise in pairs as small, vertical protuberances, one from each of the two adjoining cells of the same hypha (homothallic) near the separating septum.

Each sexual branch receives nucleus from the parent cell and separated from the latter by a wall appearing at its base. The two sexual branches grow side by side and eventually their tips, which may call gametangia, become apposed to each other. After a time the two gametangia fuse. The intervening walls disappears other region of contact. The union of the two protoplasts which known as plasmogamy, is then brought about by gametangial copulation. The two nuclei soon unite in the fused region of the protuberance. The fusion cell with a diploid nucleus of the zygote enlarges and becomes transformed directly into an ascus. Karyogamy (fusion of the two nuclei) takes place immediately after plasmogamy. Then meiosis takes place to form ascospores.

2. Hologamy:

It is a kind of gametangial copulation in which fusion takes place between two mature somatic cells and functioning as gametangia, no gametes formed in this case. In the unicellular yeasts (e.g. *Schizosaccharomyces oclosporus),* the mature haploid somatic cells directly function as gametangia. They fuse in pairs, nucleus with nucleus and cytoplasm with cytoplasm. The resultant fusion cell, which has a diploid nucleus, called the zygote. It directly functions as an ascus mother cell.

3. Gametangial contact or gametangy:

Two simitar gametangia come together, touch at their tips or coil around each other and fuse two nuclei in the fusion cell. Which come from two different gametangia, fuse, resulting into a diploid cell that functions as an ascus? The diploid nucleus divides meiotically to form haploid ascosperes. Gametangial copulation occurs in many Heimascomycetidae. Morphologically differentiated gametangia produced by many higher Ascomycetes. The male gametangium called antheridium and the female as ascogomuin, a pore develops at the point of contact of antheridium and ascogonium. Through this pore, male nucleus passes from the antheridium into the ascogonium. Sometime the ascogunium contains tubular receptive process, called trichogyne, through which it receives the male nucleus. No fertilization tube has formed.

4. Autogamy:

In *Penicillium vermiculalum,* the antheridial tip simply touches the ascogonium, and this mere touch stimulates the ascogonial nuclei to arrange themselves in functional pairs or dikaryon. Here antheridia remain non-functional. Such a phenomenon of pairing of nucleic of the same gametangium called autogamy, in some Ascomycetes, the andieridia not formed at all.

5. Spermatization:

The male sex cells are present in the form of minute, spherical, uninucleate bodies, called spermatia. In some species, the spermatia develop in pycnidium-like bodies called spermogonia, whereas in others they develop at the tip of special reproductive hyphae called spermatiophores. Ascogonia in such species are well developed. The spermatia are detached from the parent hyphae, and carried away up to trichogyne or other receptive part of the ascogonium through wind, water or insects. The spermatium empties its contents in the receptive female organ. This fusion between spermatium and female receptive organ called Spermatization. Sometimes minute conidia (microconidia) and oidia also function as spermatia. Instead of germinating into a mycelium, they attach on female receptive organ of ascogonium, empty the contents there in, and bring about Spermatization.

6. Somatogamy:

In some higher Ascomycetes, fusion takes place between the somatic hyphae or two compatible mycelia. The nuclei of one migrate to the other, and reach up to the ascogonia through septal perforations. In such cases neither antheridia nor spermatia formed.

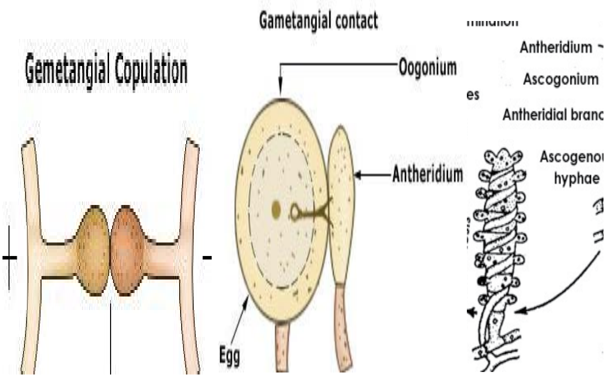

Figure 44: Gametangial contact Isogamous, Anisogamous, Autogamy.

Compatibility

Compatibility actually means fusing capability, or sexual nature of the mycelia.
According to this, Ascomycetes fall into two distinct groups:

Homothallic species:

Where all individuals are able to form asci themselves, i.e. without the aid of other mycelium they are therefore self-compatible or self-fertile. The mycelium in homothallic species considered bisexual.

Heterothallic species:

Where two compatible individuals mated before asci formed. Therefore, the mycelium in these species is unisexual. Alternatively, it may also say that sexually it is self-sterile, and for sexual reproduction, it requires the aid of another compatible mycelium of a different mating type. The two compatible mycelia may be named (+) and (-) strain mycelia. There can therefore be a fusion only between a (+) ascogonium and (-) antheridium, or a (-} ascogonium and (+) antheridium. This phenomenon called heterothallism.

Ascus Development

Ascus develops after fertilization by: Direct or Indirect method

(i) Direct development of ascus (Figure 45):

In lower Ascomycetes, plasmogamy followed immediately by karyogamy, resulting in the formation or a diploid nucleus. The cell containing this diploid nucleus develops directly into an ascus. This nucleus divides first meiotically and then by ordinar/y divisions, resulting into eight haploid nuclei, which change into same number of ascospores.

(ii) Indirect development of ascus (Figure 46):

In higher Ascomycetes, the ascus development is indirect, the two gametangial (antheridium and ascogonium) contact with each other. The male nuclei from the antheredium pass through the trichogyne into the ascogonium, and get themselves paired with the female nuclei present there in. However, there is no fusion of male and female nuclei at this stage. These paired nuclei called dikaryons. At this stage, when many dikaryons are present in the ascogonium, the wall of ascogonium gives rise to many papilla-like outgrowths, which develop into short ascogenous hyphae. The paired nuclei or dikaryons migrate into these ascogenous hyphae. Young ascogenous hyphae are aseptate but later on, they become multicellular and profusely branched. Only rarely, they are unbranched. Ascogenous hyphae remain intertwined with one another. A majority of their cells are binucleate. Of these two nuclei of the cells of ascogenous hyphae one is of antheridial origin and the other is of ascogonium origin. The asci develop at the tips of ascogenous hyphae. The terminal cell of each ascogenous hypha contains two nuclei. It recurves and forms a crozier or hook. Both the nuclei of crozier divide simultaneously to form four nuclei. Wall forms in such a way that a uniucleate tip cell, binucleate penultimate cell and a uninucleate basal cell formed. Binucleate penultimate cell become the ascus mother cell. It enlarges and develops into an ascus. The two nuclei of this ascus mother cell fuse and form a diploid nucleus. This diploid nucleus divides first meioticaliy and then ordinarily or mitotically, forming four haploid nuclei. One more mitotic division results in the formation of eight haploid nuclei. All these nuclei surrounded by some cytoplasmic contents and change into eight ascospores.

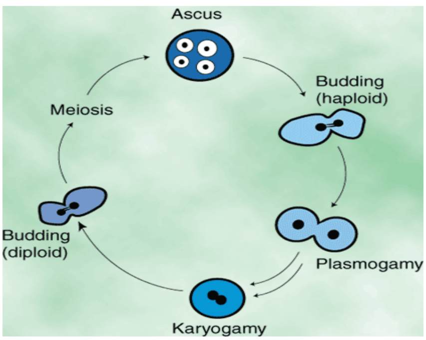

Figure 45: Direct development of ascus.

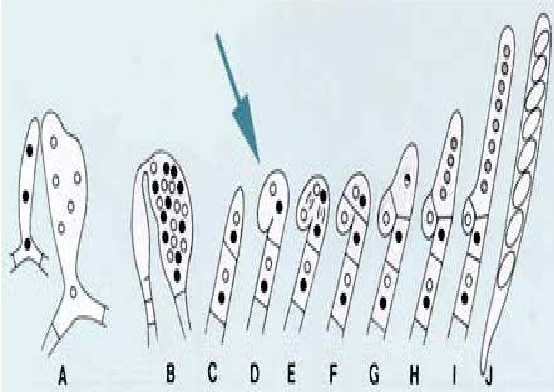

Figure 46: Indirect development of ascus.

Asci and Ascospores

An ascus (plural asci) is the sexual spore-bearing cell produced in ascomycete fungi. Asci are different in shape (Figure 47) may be elongated, oval, globose, club-shaped, cylindrical or even tubular. The arrangement of ascospores in an ascus is also variable. They may arrange in umseriate, biseriate, fasciculate or irregular manner. On average, asci normally contain eight ascospores, produced by a meiotic cell division followed, in most species, by a mitotic cell division. However, asci in some genera or species can number one (e.g. *Monosporascus cannonballus*), two, four, or multiples of four. In a few cases, the ascospores can bud off conidia that may fill the asci (e.g. *Tympanis*) with hundreds of conidia, or the ascospores may fragment, e.g. some *Cordyceps*, also filling the asci with smaller cells. Ascospores are nonmotile, usually single celled, but not infrequently may be septate, and in some cases septate in multiple planes. Mitotic divisions within the developing spores populate each resulting cell in septate ascospores with nuclei. In many cases the asci formed in a regular layer, the hymenium, in a fruiting body that is visible to the naked eye, here called an ascocarp or *ascoma*. In other cases, such as single-celled yeasts, no such structures found. In rare cases asci of some genera can regularly develop inside older discharged asci one after another, e.g. Dipodascus. Asci normally release their spores by bursting at the tip, but they may also digest themselves passively releasing the ascospores either in a liquid or as a dry powder.

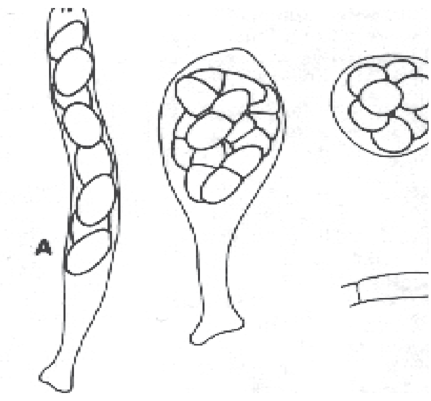

Figure 47: Three forms of asci: cylindrical, clavate, and spherical.

The form of the ascus, the capsule that contains the sexual spores, is important for classification of the Ascomycota.

There are four basic types of ascus

A unitunicate-operculate ascus has a “lid”, the Operculum, which breaks open when the spores ripen and in this way sets them free. Unitunicate-operculate asci only occur in those ascocarps, which have apothecia, for instance the morels. ‘Unitunicate’ means ‘single-walled (Figure 48).

Instead of an operculum, a unitunicate-inoperculate ascus has an elastic ring that functions like a pressure valve. On ripening, it briefly expands and so lets the spores shoot out. This type appears both in apothecia and in perithecia; an example is the illustrated *Hypomyces chrysospermus* (Figure 48).

A bitunicate ascus enclosed in a double wall. This consists of a thin brittle outer shell and a thick elastic inner wall. When the spores are ripe, the shell splits open so that the inner wall can take up water. Consequently, this begins to extend with its spores until it protrudes above the rest of the ascocarp so that the spores can escape into free air without obstructed by the bulk of the fruiting body. Bitunicate asci occur only in pseudothecia and found only in the classes Dothideomycetes and Chaetothyriomycetes (which formerly united in the old class Loculoascomycetes). Examples: *Venturia inaequalis* (apple scab) and *Guignardia aesculi* (Brown Leaf Mold of Horse Chestnut) (Figure 48)

Prototunicate asci are mostly spherical in shape and they have no active dispersal mechanism at all. The ripe ascus wall simply dissolves so that the spores can escape, or it is broken open by other influences such as animals. Asci of this type can be found both in perithecia and in cleistothecia, for instance with Dutch elm disease (Ophiostoma). This is something of a catchall term for cases that do not fit into the other three-ascus types, and they probably belong to several independent groups that evolved separately from unitunicate asci (Figure 48).

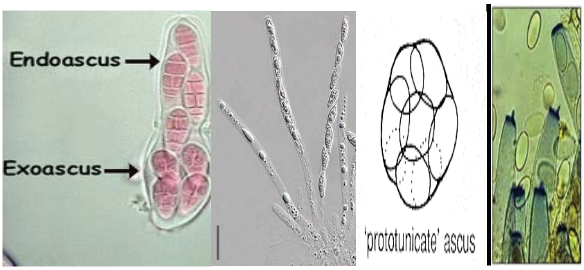

Figure 48: Bitunicate ascus, Unitunicate-inoperculate, Prototunicate, and Unitunicate-operculate.

Ascocarps

In a majority of the Ascornycetes, except yeasts and some related fungi of Endomycetales, the asci remain enclosed by many sterile hyphae. The ascogonium, ascogenous hyphae, asci, ascospores, paraphyses and the enveloping sheath or peridium in ascomycetes (Figure 49) remain grouped together in the form of a fruiting body or fructification, called ascocarp.

Main types of Ascocarps:

The following four-niain types of ascocarps met with in Ascomycotina (Figure 50):

1. Cleistoihecium: Globose fruiting body with no special opening to the outside the asci arranged irregularly within them. When mature the cleistothecia burst open to release their asci and ascospores as in Erysiphaies, Eurotiales.

2. Apoihecium*:* A saucer-or cup-shaped fruiting body, as in Helotiales and Pezizales
3. Perithecium: A flask-shaped fruiting body- opening with an ostiole or pore, and its asci areuninmicate, as in Pyrenomycetes
4. Pseudothecium: A perithecium with bitunicate asci, as in Loculoascomyceles, Some call pseudothecium as ascostroma.

Along with the asci, a majority of the ascocarps also contain several types of sterile threads.

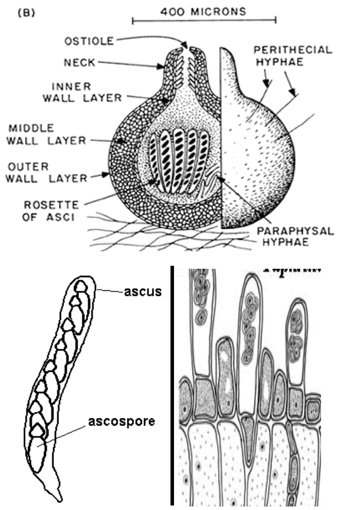

Figure 49: Internal structure of *Perithecium* ascocarp, Ascus with ascospores, naked asci.

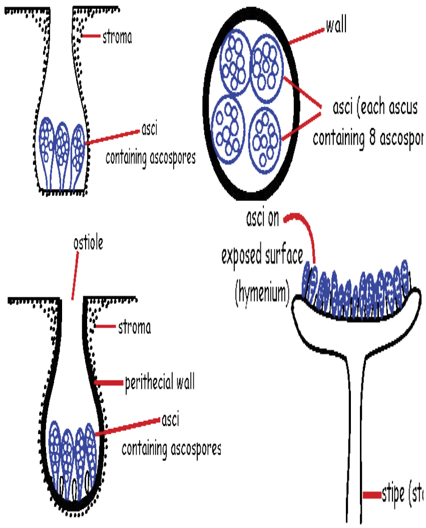

Figure 50: *Ascoearps Pseudothecium Cleistoihecium (high) Perithecium: Apoihecium* (low).

Economic importance of ascomycetes:

Some Ascomycetes are of tremendous importance to man. Some examples of their detrimental are nature mentioned below:

1. Species of *Aspergillus* and *Penicillium* cause great damage to food, and to some common goods such as leather. Chaetomium destroys the fabrics containing cellulose.

2. They attack many crop plants, as well as timber and ornamental plants, causing diseases such as powdery mildew, apple scab, foot rot of cereals and chestnut blight.

3. They cause many diseases of domestic animals as well as man. "Aspergillosis" is causes by *Aspergillus fumigatus, A. flavus* and *A, Niger.*

4. *Claviceps purpurea* contains the sclerotia with many such alkaloids that, if consumed, are deadly to animals and human beings. On the contrary, it used as a medicinal drug. Some of the beneficial aspects of Ascomycetes mentioned below:

- Many yeast species well known for their fermenting activities in brewing and baking industries.
- Antibiotics, such as penicillin, are prepared from *Penicillium notatum* and *P.chrysogenum.*
- Ascomyceious members prepare many industrial products, such as citric acid, oxalic acid, gluconic acid, vitamins and glycerol.
- Some of the morels and truffles are edible.
- Some Ascomycetes used as a source of protein for human consumption.

Classification of Ascomycotina:

The main criteria of the classification of Ascomycotina have been:

(i) type of structure of ascus
(ii) type of ascocarp,
(iii) ascocarp centrum and
(iv) Ail ascogenou; and conidial stages of the organisms.

Owing to the absence of fossil evidence and lack of our present knowledge regarding the developmental stages of this large group, the statement made by Alexopoulos and Mim (1979) about the taxonomy of Ascomycotina appears quite convincing. They mentioned that k is no exaggeration to

Say that no two specialists agree completely on the classification of this large group fungus. Therefore, the most recent system of classification will considered.

According to Alexopoules and Mims (1979), the class Ascomycetes, is subdivided into the following

Subclasses:

1- Hemiascomycetidae
2- Plectomycetidae
3- Hymenoascomycetidae
4- Labouibeniomycefidae
5- Loculoascomycetidae

Subclass Hemiascomycetidae

The Hemiascomycetidae includes the simplest Ascomycetes that some mycologists consider primitive and others degenerate. They have very simple structure. Sexual reproduction takes place by the conjugation of two cells (gametangia) which in some species are alike (Eremascus) and in others unlike (Dipodascus). The fusion cell be directly transformed into an ascus or grows out to produce an ascus.

Characteristics of this subclass are-

1. The mycelium either poorly developed or lacking
2. Absence of ascogenous hyphae
3. Complete absence of ascocarps
4. Direct development of asci without the intervention of acogenous hyphae
5. Asci borne directly on the mycelium or formed from specialized ascogenous cell

Classification:

The subclass includes about 250 species assigned to nearly 59 general, placed under the following two orders:

Order (1): **Taphrinales** characterised by the:

1. Presence of a true mycelium
2. The asci developed from special, binucleate ascogenous cells derived from the binucleate mycelium and not from the zygote.
3. The asci lie in a palisade-like layer parallel to one another but without any enclosing sheath or peridium.
4. No fruit body is thus organized.
5. There are about six genera with 125 species in this order. The best-known species of this order is Ascomyces (*Taphrina deformans).* It causes a disease of the peach plant know as peach leaves curl.

Taphrina

Taphrina occur on a wide variety of hosts, including some economically important species; best known of these is *Taphrina deformans* (Figure 51). They cause peach and almond leaf curl disease that produces obvious symptoms on the leaves and may lead to complete defoliation of the host tree.

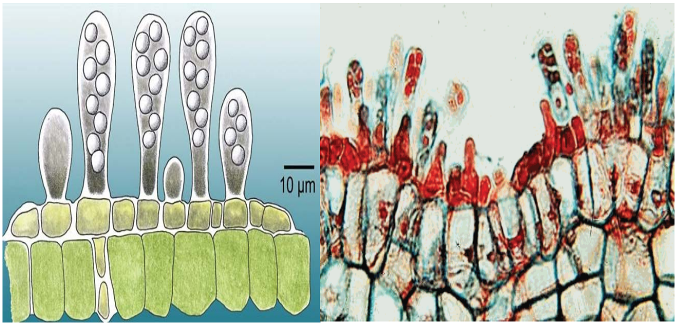

Figure 51: *Taphrina deformans.*

2. Order Endomyctales (Saccharomycetales) characterised by the:

1. The asci develop directly from the fusion cell (zysgote) or sometimes parthenogenetically.
2. The zygote formed by the fusion of the protoplasts of two gametangia or two ascospores or two haploid vegetative cells.
3. The plasmogamy immediately followed by karyogamy so that there is no dikaryophase in the life cycle.
4. The order includes about 140 species that placed under 45 genera. Some of these are saprophvtic and others parasitic.
5. The thallus greatly reduced, often to a single cell.
6. Asexual reproduction is by budding, production of conidia, or mycelial fragmentation.
7. Cell wall polysaccharides, primarily mannans and B-1,3 and B-1,6 glucans as well as reduced amounts of chitin, localized primarily in bud scars.
8. The order includes three families. Dipodascaceae, Endomycetaceae, Spermophthoraceae and Saccharomycetaceae

Saccharomycetaceae

1. Have a predominantly unicellular thallus that may produce pseudomycelium,
2. Reproduce asexually primarily by multilateral budding.
3. Produce ascospores in a free ascus that originates from a zygote or parthogenetically from a single somatic cell.

The best-known member of the family is *Saccharomyces cerevisiae*.

Saccharomyces Cerevisiae

Saccharomyces cerevisiae commonly employed in bread making and beer brewing. Therefore, it known as called the brewer's or baker's yeast.

Yeast culture

A culture of yeast can be prepared in the laboratory by placing a piece of yeast cake or a few- grain of dried yeast in a solution of molasses and water or sugar solution. The yeast cells will multiply rapidly in any well-aerated, nutrient solution containing adequate amount of sugar. Millions of yeast cells will be available for study a day or so.

Thallus structure nutrition in yeast

The yeast cell (Figure 52) appears hyaine in colour, consists of a single minute oval or spherical cell. Like other fungi, the yeasts lack chlorophyll. They are thus heterotrophic in of nutrition. They obtain ready-made food from an external source by usually as saprophytes. The brewer's yeast obtains nutrition in the form of sugars in solution. It gets it from the substratum on which it grows such as the ripe fruits, fruit juices, sugar solutions or crushed moistened grains. The elements required are carbon, hydrogen, oxygen, nitrogen, phosphorus, sulphur, magnesium, iron, zinc, manganese, copper and molybdenum. The metallic elements function as enzyme activators or as components of enzymes, it traces. Carbon secured chiefly from sugars or starch. In addition, certain -like growth factor is also essential for growth. It called as "bios". It is active in extremely low concentrations. Yeast cells secrete enzymes on the substratum. These enzymes are collectively zymase. The zymase changes me starch or complex sugars present in the medium into simpler sugars. The latter diffuse into the endoplasm through the thin cell membrane. A small percentage of the absorbed sugar used as food. When yeast grows in aerated nutrient medium, the rest of them completely oxidized in normal respiration. The reaction shown by the overall equation

$C_6H_{12}O_6 + 6O_2$ $6CO_2 + 6H_2O$ + energy

In such a solution, the yeast multiplies rapidly. In the absence, or poor supply of oxygen the yeast multiply slowly, the major portion of sugar converted into carbon dioxide and ethyl alcohol within the cytoplasm.

The products of this reaction (CO_2 and C_2H_5OH) diffuse out, through the cell into the surrounding liquid. The breakdown of carbohydrates (starch and sugars) by yeast into carbon dioxide and alcohol in the absence of oxygen called alcohlic fermentation**.** This process is utilised in the production of industrial alcohol, in wine making, in brewing and in bread making. The energy released during processes utilized by the cell in carrying out the vital functions.

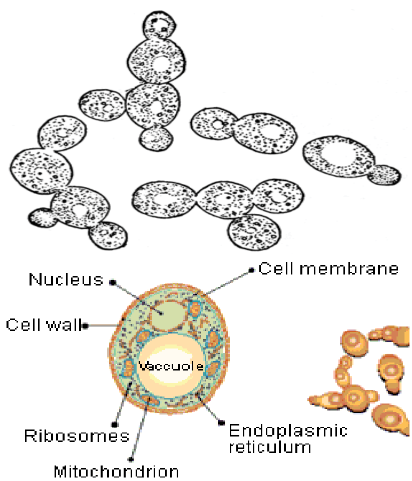

Figure 52: Diagram showing a yeast cell.

Reproduction

Yeasts reproduce both asexually as well as sexually.

I. Asexual Reproduction

Most of the yeasts multiply asexually by vegetative method called budding. A few undergo fission. *Saccharomyces* normally reproduce by budding. At the time of budding a small portion of the cell wall, at or near one pole of the yeast cell softens and thins. The protoplast in this region, covered by the thin softened». membrane, bulges out in the form of an outgrowth or protuberance. The protuberance gradually increases in size. It known as the bud- The nucleus of the parent yeast cell divides and with it the vacuole as the bud is forming, some believe that the nuclear division is amitotic. Others consider it mitotic. One of these daughter nuclei migrates into the enlarging bud. The bud grows and becomes constricted at the base. The cytoplasm of the bud and mother cell remains continuous for some time. Eventually the opening between the two cells closes; a double cross wall forms and the two cells become physiologically distinct and may separate leaving a scar on both cells. After the daughter cell, a scar with a convex surface remains on the mother cell. The daughter cell as well retains a corresponding concave birth scar. The detached bud or yeast ceil grows and again starts budding. A new bud arises on the surface of the parent cell at the opposite end to the first and not known as the same area, this known as bipolar budding. In the presence of abundant food supply, process of budding quickened. It becomes so rapid that the buds often produce new buds before separation from the mother cell. The process repealed in this way a large number of buds formed without being detached from one another.

These results in the formation of branched or unbranched chain of cells constituting the pseudomycelium there may be as many as 64 connected cells in the Pseudomycelial mass. The cells in the chain or pseudomycelium loosely joined. Soon the chains break, the constituent cells are separated from each other (Figure 53).

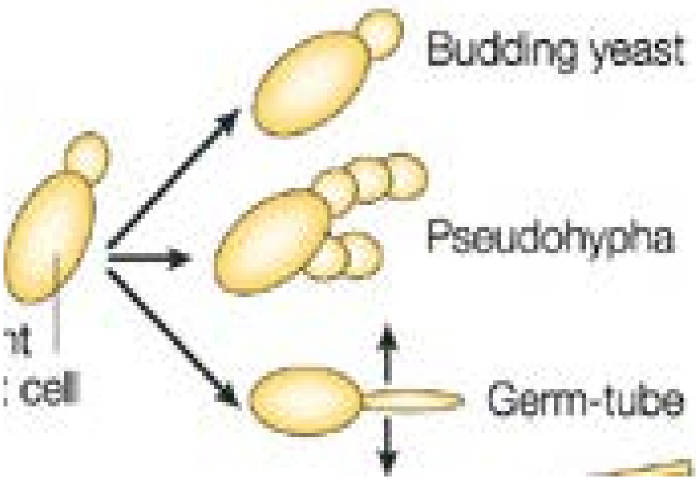

Figure 53: Budding in yeast.

Fission

Vegetative reproduction by fission reported but it occurs in some other yeast and not in *Saccharomyces* (budding yeasts). Therefore, they called the fission yeasts for this reason. The division is transverse. The mother cell elongates and the nucleus divides into two. The daughter nuclei move apart .Meanwhile a ring-like outgrowth appears at the wall of the yeast cell in the middle Covered in front by the cytoplasm it grows inward towards the center of the cell. Finally, it stretches across the cell forming complete partition called the septum. The septum thickens and then two layers, one for each daughter before they separate. Budding is common when compared to fission (Figure 54).

Sexual Reproduction

Recent investigations have shown that like other Ascomycetes the formation of ascospores in yeasts is contingent upon a sexual process of course no sex organs like antheridia and oogonia produced. Instead, the sexual process is extremely simplified. Ii consists of three phenomenon characteristic of the sexual process, namely, plasmogamoy (sexual fission), karyogamy (fusion of two nuclei) and meiosis**.**

In brewers or baker's yeasts *(Saccharomyces),* there are two kinds of somatic cells Figure 55.

(i) Dwarf strain yeast Cells

They are small haploid yeast cells, which are spherical in shape. Normally they multiply by budding. Under certain conditions, they resort to sexual fusions. Dwarf strain yeast cells belong to two mating. Types (A and a) or (+ and-} strainsThese function as gametangia.

Plasmogamy takes piece by gametangial copulation, between the plus and minus strain gametangia to form a large fusion cell with two nuclei (one of plus strain and the other of minus strain) lying side by side to form a dikaryon. The two nuclei of the dikaryon finally fuse. The fusion of the two nuclei constitutes karyogamy and it is equivalents to fertilizations process. The diploid fusion nucleus is called a synchrony and the ceil containing it is a zygote. Dwarf strain yeast cells thus represent the haplophase in the life cycle.

(ii) "Large strain" yeast cells

They are diploid and larger than Dwarf strain yeast cells. 'They are ellipsoidal in shape. These large diploid cells are employed industrial processes. In fact the large strain' yeast cells are the zygotes formed because of sexual fusion, two haploid yeast cells (dwarf strain) of opposite strains. The zygotes under favorable conditions multiply by budding to increase the number of diploid somatic cells of large strain of yeast under conditions unsuitable for continued vegetative growth (shortage of water,, food, and low temperature) the large strain' somatic cells yeast directly function as asci and produce ascospores. The ascus is spherical in shape. The diploid nucleus of the ascus mother cell undergoes meiosis. The resultant four daughter nuclei are thus haploid. Two of these are of plus strain and the other minus strain. Each of these accumulates a little of cytoplasm around it and secretes a wall to become organised into an ascospores The asci rupture with the onset of conditions favorable for growth- The ascospores swell and press against the wall of the ascus. Owing to pressure from within the ascus wall ruptures and the haploid ascospores released. They are globose in form. On liberation the ascospores germinate, each produces a small round somatic cell of dwarf Strain.

The dwarf strain somatic cells are of two mating types. They reproduce vegetatively by budding for a time. These vegetative cells are the potential gametangia. It is worth noting that in this yeast both haplophase and diplophase are equal importance. They perpetuated by budding.

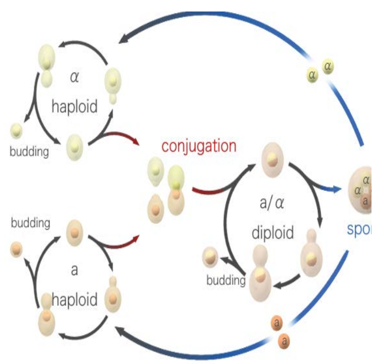

Figure 55: Sexual reproduction in yeast.

Alternation of Generations in *S. cerevisiae* (Figure 56)

The "large strain" yeast cells represent the diplophase or sporophyte phase. Besides reproducing by a vegetative method of budding they under contain conditions directly function as asci. Each ascus produces four haploid ascospores. These ascospores normally germinate to produce the haploid ''dwarf strain" of yeast, which represents the haplophase or gametophyte phase. The gametophyte cells bear no sex organs. Under certain conditions, they themselves function as gametangia. The protoplasts function as gametes. The gametangia resort to conjugation and fuse to form the diploid zygote. The zygote by budding gives rise to the "large strain" diploid yeast cells representing the diplophase. It is evident from the account that the life cycle of yeast consists of two distinct phases, the sporophyte phase or diplophase and the gametophyte phase or haplophase. The former consists of the "large strain" dipole cell (zygote) and the asci. The latter (gametophyte phase) consists of the ascospores and the "dwarf strain" yeast cells- These two phases alternate in a single life cycle- Both the phases are perpetuated by budding. Sometimes the gametophyte stage reduced. The haploid cells conjugate to form large strain' yeast cells. In such cases, the haploid ascospores are the only gametophyte structures in the life cycle. *Saccharomycodes ludwigii* is an example of this type.

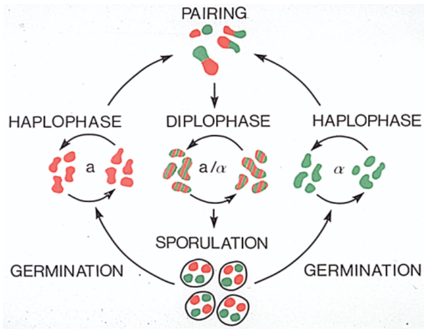

Figure 56: Graphic illustrating Alternation of Generations in yeast.

Schizosaccharomycetales

Characteristics of Schizosaccharomycetales

1. Several characters distinguished these species from the yeasts of the Saccharomycetales including their method of cell division and cell wall polysaccharides.
2. After nuclear division, the cell elongates and a wall produced between the daughter nuclei. The new wall material apparently originates from the area between the cell wall and plasma membrane abutting the original cell wall. It develops as an annulus with inward growth until the new daughter cells are completly partitioned. Parts of the devoloping wall thicken during their formation, and eventually separate in a middle translucent layer leaving scars at the ends of the new cells.
3. Although low levels of chitin may be present in fission yeasts compared to the true yeasts, they also differ in other wall polysaccharides, particularly mannan structure and the presence of several unique major structural polysaccharides.

Schizosaccharomyces, the fission yeasts, have been isolated from slime fluxes, honey, fruit, and fruit products, habitats that also are common to a number of the Endomycetales.

Economic Importance of *S. cerevisiae* and other yeast species

1. They play an important role in brewing and baking industry.

2. They form alcoholic beverages under anaerobic conditions. *S. cerevisiae* plays an important role in brewing industry.
3. This species also play an important role in baking industry by forming carbon dioxide and alcohol.
4. They also used as vitamin rich food.
5. They also spoil foodstuffs.
6. They play a vital role in formation of silk.
7. Some of the species like *Candida albicans; Cryptococcus* and *Torula* attack human beings and lead to thrush and inflammation of genital organs.

Subclass: Plectomycetidae

General characteristics

1. The mycelium is well-developed branched and septate
2. Many members show degeneration of sex oranges especially of male gametangium.
3. The mycelium forms well- defined fruiting bodies or ascocarps.
4. Asci develop from ascogenous hyphae which are typically dikaryotic .the asci are typically 8-spored.
5. In a majority of the members, the ascocarp is of cleisothecium type but some also have berithecium, apotheium or ascostroma.
6. Paraphyses are absent in the fruiting bodies.
7. Under this subclass, five order from which Eurotiales.

Order Eurotiales

General characteristics

1. Members are primary saprobic, but may be parasitic on plants as well as animals.
2. They occur in soil as well as develop on wood,dung,textiles,feathers ,horns,etc.and are responsible for the decomposition of many organic materials.
3. Members are thermophilic or thermotolerant.
4. Majority of the members are homothallic, and only a few are heterothalic.
5. Usually the ascogonia remain free on the mycelium in the early stages. Later on, they get surrounded hyphae and develop into ascoarp.
6. Ascocars are small, spherical, generally sessile and non-ostiolate.
7. Paraphyses are absent in ascocarps.
8. The asci are globose, sessile, thin-walled, and quickly evanescent and typically contain eight ascspores.
9. The asci distributed irregularly throughout the centrum of the ascocarp.
10. Asci lack pore or operculum.
11. Ascospores are unicellular, variously ornamented, and not bear germ pores or germ slits.

The genera of *Aspergillus* and *Penicillium* taxonomically placed in the Euroticeae family of the class Plectomycetes in Ascomycotina. Since sexual stages of some of the species identified, the genera of *Aspergillus* and *Penicillium* studied in the sub division of ascomycotina. However, they extensively reproduce asexually through conidia and in fact, in many species sexual stage is absent or unidentified.

Example (1) *Aspergillus*

Somatic structure

The mycelium consists of many branched, septate and interwoven mass of hyphae. Each cell has surrounded by a thin wall, and contains many nuclei distributed in the granular cytoplasm. Mitochondria, endoplasmic reticulum and ribosomes are present in the cytoblasm of mycelial cells. A simple central pore is present in each septum (Figure 57).

Asexual reproduction

Asexual reproduction in *aspergillus* sp by formation of conidiospores as following:

a) The somatic hypha develop the many erect hyphae (long, aseptate and unbranched) called conidiophores.
b) The conidiophore terminates into a globular or bulbous head, called vesicle. The vesicle is multinucleate, and from its entire surface develops a layers of strigmata (one or two layers) the former layer is called primary strigmata while the other called secondary strigmata.
c) At the tip of the mature strigmata develop many small, globose, unicellular, and unicleate or multinucleate bodies called conidia.

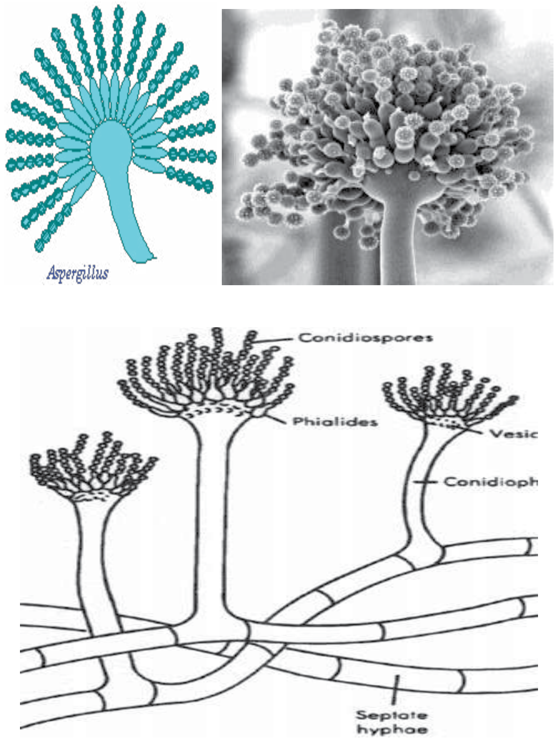

Figure 57: Conidiospores and strigmata in *Aspergillus* sp.

Sexual reproduction:

Sexual reproduction by sex organs called antheridium and ascogonium.

Description of ascogonium

It develops on the mycelium in the form of a septate, loosely coild, female hyphal branch, and called archicarp. Young archicarp differentiated into a lower multicellular stalk, middle unicellular ascogonium and the terminal unicellular trichogyne. The trichogyne elongated and produced by the ascogonium for the reception of the male gamete. All cells of archicarp are multinucleate.

Description of antheridium

It develops in the forme of male branch. The male branch also called pollinodium, the male branch coms close to the trichogyne and cuts a unicellular antheridium at its tip. The lower part called stalk. The anthridium is multinucleate.

Steps of sexual reproduction

Anthridium tip encounters the terminal part of trichogyne, the walls between them dissolve, and the contents of the antheridium mix with that of the trichogyne (plasmogamy).

The haploid nuclei in the ascogonium come to lie in pairs. The unicellular ascogonium divides into binucleate cell produces an outgrowth called ascogenous hypha. The two nuclei of each ascogenous hypha divide, making the latter a multinucleate body again. Ascogenous hypha now becomes septet and developing asci, the diploid nucleus divides by meiosis into four haploid nuclei, each of which divides mitotically giving 8 haploid nuclei. Each nucleus surrounds by the cytoplasm and develops into an ascospore. At this stage, many sterile hyphae grow up from the base of the archicarp. These hyphae enclose the asci from all sides to form cleistothecium fruiting body (Figure 58).

Economic importance of *Aspergillus*:

1. *Aspergillus niger, A .flavus* and many other species spoil almost all foodstuffs
2. *A.flavus* produces a violent toxin called aflatoxin.
3. Condia of various *Aspergillus* species are very common in the air, and hence they contaminate the laboratory cultures very commonly.
4. Many species grow on leather and cloths fabrics even in slight humid conditions and reduce their commercial value.
5. Many diseases aspergillosis caused in humans and animals by several species, including *A.terreus A.flavus, A.niger* and *A.fumigatus*.
6. Many plant diseases caused by species of *Aspergillus*.
7. *Aspergillus* species used in various industries, especially in the production of citric acid, gluconic acid and many other similar products.
8. *Aspergillus* species are also used in the commercial production of some enzyme
9. Some antibiotics have also been isolated from the cultures of *Aspergillus*.
10. *Aspergillus* also used for bioassay of soil for trace elements, such as copper.

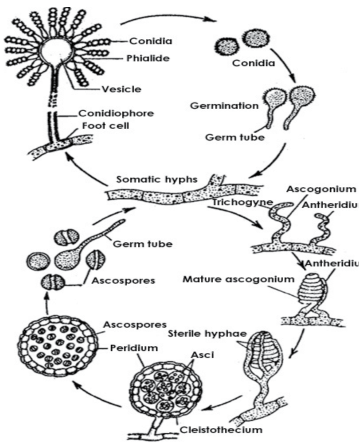

Figure 58: Life cycle of *Aspergillus* sp.

Example (2) *Penicillium* (Figure 59)

Penicillium species occur on Citrus and other fruits, cheese and other foods. The mycelium is well branched, and consists of many septate hyphae, conidiophores are develops from the hyphae, the conidia developing on the erect conidiophores. The conidiophores develop from any hyphal cell but not from specialized foot cell as in *Aspergillus* sp. The conidiophores are branched but unbranched in few species, *Penicillium* characterized by the presence of primary and secondary strigmata.

Asexual reproduction

The conidia dispersed by wind. On getting the suitable conditions of moisture and temperature, each conidium swells and germinates by producing a germ tube. The latter becomes septate and develops into the mycelium.

Sexual reproduction

The sexual reproduction take place between the female organ ascogonium and the male organ antheridium, where the ascogonium elongates and its nucleus divides several times to produce as many 64 nuclei. Simultaneously, the antheridium coils spirally around the ascogonium. The antheridium tip touches the ascogonium at one point, and the wall between them dissolved.

The antheridial nucleus migrates into the ascogonium, the ascogonium septeted into binucleate cells function as ascogenous hypha, which contains two nuclei (one from ascogonium and the other from antheridium). The two nuclei fused to form the diploid nucleus in the young ascus mother cell, and the zygotic nucleus might have passed through meiosis to form eight ascospores in each ascus. Many sterile hyphae develop and enclose the young asci from all sides and the fruiting body is formed (Figure 60).

Economic importance of *Penicillium*

1. Several species of *Penicillium* play a central role in the production of cheese and of various meat products.
2. *Penicillium roqueforti* are the molds on Camembert, Brie, Roquefort and many other cheeses.
3. *Penicillium nalgiovense* used to improve the taste of sausages and hams and to prevent colonization by other moulds and bacteria.
4. Species of *Penicillium* serve in the production of a number of biotechnologally-produced enzymes and other macromolecules, such as gluconic, citric and tartaric acids, as well as several pectinases, lipase, amylases, cellulases and proteases.
5. Most importantly, they are the source of major antibiotics, particularly penicillin and griseofulvin.
6. Some species causes animal and human diseases.

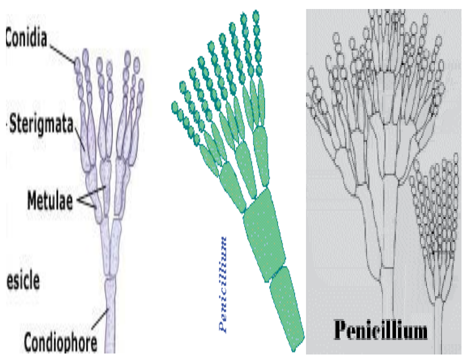

Figure 59: *Penicillium* sp.

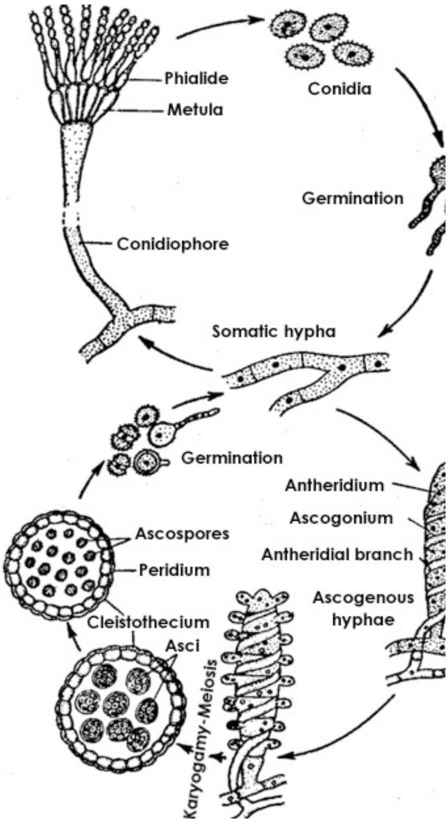

Figure 60: Life cycle of *Penicillium* sp.

Sub class: Hymenoascomycetidae

Based on the gross morphology of the ascocarp, the hymenoascomycetidae comprises numerous species, which are under two groups, namely, pyrenomycetes and discomycetes.

Pyrenomycetes

General characteristics

1. It occurs on wide variety of habitats, such as dung, decaying stems and leaves and soil, and some occur as plant pathogens.
2. The asci are unitunicate, and clup-shaped or cylindrical and remain arranged in a hymenial layer.
3. Usually the asci are persistent, but they may also be evanescent.
4. Majority of them develop ascocarp of a perithecium, however, some member's contain cleistothecial type of fruiting body.
5. The perithecium usually containing an apical opening called ostiole.
6. The perithecium either occur singly or remain clustered together, on or within a stroma.
7. The ascocarp remains surrounded by a definite peripheral wall called peridium.
8. Sterile filaments called paraphyses may also be present among the asci. Such filaments are absent in the Plectomycetes.
9. Paraphyses grow into the central cavity become enlarge and provide a space where the asci and ascospores will develop.

10. Ascospores often forcibly ejected from the ascus and perithecium when mature.
11. Species in this series may produce perithecia directly on their substrate or in a stroma.

Classification Pyrenomycetes

Pyrenomycetes classified into orders Erysiphales, Meliolales, Coronphorales, and Sphaeriales.

Orders Erysiphales

General characteristics

1. It occurs as obligate parasites on plants.
2. They produce enormous number of conidia, which appear as white powdary coating the surface of the host.
3. The mycelium is superficial, well-develop, branched, septate and contains shortuninucleate cells.
4. Asexual reproduction by conidiospore developed on short conidiophore.
5. The conidiophores develop singly and at right angle to the host surface.
6. The conidia are uninucleate, oval, and thin-walled and contain numerous vacuoles of water.
7. Sexual reproduction by antheridia, ascogonia or by vegetative cells acts as gametes.
8. Theyproducefruitingbody(cleistothecium)whichenvelopedbypseudoparenchymatous peridium made up of 6-10 layers.
9. The mature cleistothecia bear some characteristic appendages (Figure 61), of four different types: a) myceloid, resembling the somatic hyphae, e.g. Erysiphe. b) Circinoid or hooked with curled tips, e.g. *Uncinula.* c) Dichotomously branched tips, e.g. *Microsphaera*, d) with bulbous base, e.g.*Phyllactinia* (Figure 61).

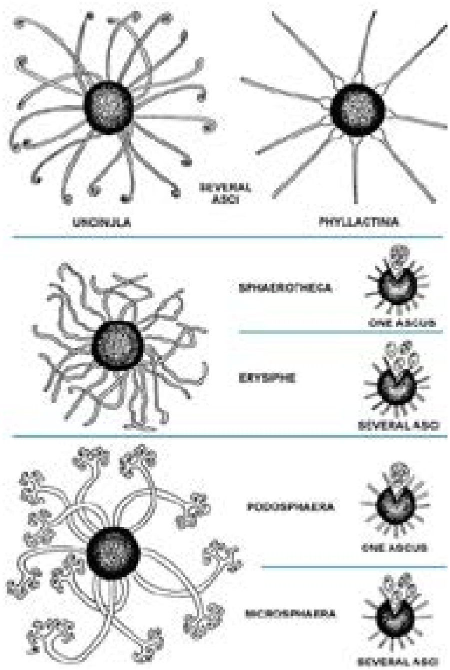

Figure 61: Types of cleistothecium appendages.

Erysiphe is a genus of fungi in the Erysiphaceae family. It obligate ectoparasitic the mycelium grows superficially on the host epidermal cells. It forms long chain of conidiospores on short conidiophore reproduce asexually by conidiospores, and sexually by gametes antheridium and ascogonium. Many of the species in this genus are plant pathogens, which cause powdery mildew (Figure 62).

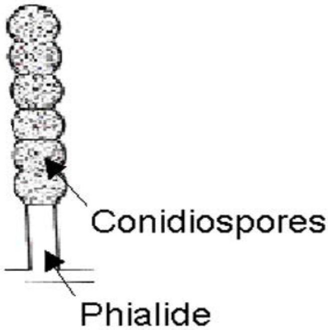

Figure 62: Erysiphe showing long chin of conidiospores.

Family Clavicipitaceae

Clavicipitaceae is a family of fungi within the order Hypocreales. It consists of 43 genera and 321 species common species *Claviceps purpurea.*

Ergot forms a dark, compact, fungal mass called a sclerotium where the grain would normally develop. One or several of these pellets like sclerotia can see in an infected grain spike, typically extending out from the bracts (glumes). When separated from the grain spike, the sclerotia superficially resemble rat droppings (rat pellets). The sclerotia are the source of the potent alkaloids in *Claviceps purpurea*. In late spring, when rye plants are in bloom, the over wintering sclerotia from the previous year's crop produce stalked ascocarps resembling microscopic fungal fruiting bodies. The head of each ascocarp contains many embedded perithecia. The perithecia contain numerous sacs like asci, each with eight ascospores. The ascospores infect the young, developing grains (ovaries) of rye plants, eventually replacing them with purplish-black sclerotia (Figure 63).

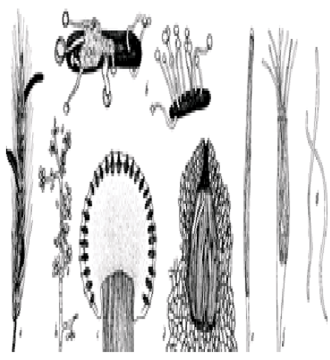

Figure 63: Claviceps purpurea the ergot fungus. A) Sclerotia (ergots) protruding from a head of rye; b) two germinated sclerotia with a number of perithecial stromata; c) longitudinal section through a perithecial stroma showing numerous embedded perithecia around the outer margin; d) section through a perithecium showing numerous asci; e) ascus with eight ascospores; f) ruptured ascus discharging ascospores; g) two ascospores; h) conidia produced on mycelium.

Significance of *Claviceps*

1. Many of its members produce alkaloids toxic to animals and humans
2. Consumption of grains or seeds contaminated with the fruiting structure of this fungus, the ergot sclerotium, can cause ergotism in humans and other mammals.
3. The ergot sclerotium contains high concentrations (up to 2% of dry mass) of the alkaloid ergotamine, consisting of a tripeptide-derived cyclol-lactam ring connected via amide linkage to a lysergic acid (ergoline) moiety, and other alkaloids of the ergoline group that are biosynthesized by the fungus.
4. Ergot alkaloids have a wide range of biological activities including effects on circulation and neurotransmission.
5. The alkaloid ergotamine used extensively to relieve migraine headaches through the constriction of blood vessels.
6. Ergot can cause a direct yield loss in proportion to the number of kernels infected.
7. These alkaloids are useful in pregnancy and labour to promote expulsion of the foetus as artificial abortion.
8. The ergot alkaloids also utilized in controlling uterine haemorrhage (bleeding) after childbirth.

Discomycetes

The series Discomycetes characterized by the formation of an ascocarp called an apothecium. Typically, an apothecium is cup-shaped, which is why Discomycetes sometimes called "cup fungi". However, the shape of the apothecium is quite variable. Whatever their shape may be, the asci form a hymenium that entirely exposed at maturity**.** The asci are unitunicate and forcibly eject the ascospores. Paraphyses are generally present in apothecia.

General characteristics

1. Members are either terrestrial, coprophilous, saprophytes or parasites.
2. Most members lack conidiophores and conidia.
3. All non- lichen- forming Discomycetes have unitunicate asci.
4. Colour of the apothecia may be yellow, red, brown, or even black. Some are even hyaline.
5. The fruiting bodies of some members are underground (hypogean) and in other members are above the ground (epigean).
6. Members show progressive reduction in their sexuality. The antheridia and ascogonia are both functional in some members while in the other the antheridia are non-functional, in other the antheridia are totally absence.
7. The ascospores in all discomycetes except tuberales ejected forcibly through different types of apical opening.

Classification of Discomycetes

It classified in to-

1. Epigean Discomycetes (Fruiting bodies above the ground)

   Order: Pezizales

2. Hypogean Discomycetes (Fruiting bodies under the ground)

   Order: Tuberales

Order: Pezizales

General characteristics

1. Found on wood, dung, soil and plant debris.
2. The asci open by a lid or operculum.
3. The fruiting body varies in size from less than 1 mm to 15 mm in diameter.
4. Some of members are ediple, whereas others are poisonous.
5. The order contains 16 families, 199 genera, and 1683 species.
6. It contains a number of species of economic importance, such as morels, the black and white truffles, and the desert truffles.

7. The Pezizales are saprobic, mycorrhizal, or parasitic on plants.
8. The ascospores are single-celled, bipolar symmetrical, and usually bilaterally symmetrical, ranging from roughly spherical to ellipsoidal to occasionally fusoid.

Family Pezizaceae includes fungi that form their spores in a sac-like ascus. These fungi reproduce by fission rather than budding and this subdivision includes almost all the ascus fungi that have fruiting bodies visible to the naked eye.

Peziza

Peziza is large genus of saprophytic cup fungi that grow on the ground, rotting wood, or dung. Most members of this genus are of unknown edibility and are difficult to identify as separate species without use of microscopy. Mycelium consists of a dense network of hyphae. The hyphae are branched and eptate their fruiting body is above ground.

The Apothecium

An apothecium consists of three parts shown in Figure 64.

Hymenium- is the layer of asci that lines the surface or hollow part of the disc, cup, saddle, or other variously shaped structures; it is made up of club-shaped or cylindrical asci, usually with paraphyses among them; paraphyses may be as long as the asci, longer, or somewhat shorter. In some apothecia, the tips of the paraphyses may be branched, and the tips of the branches united above the asci to form a layer called the epithecium.

Hypothecium- is a thin layer of interwoven hyphae located immediately below the hymenium.

Excipulum- is the apothecium proper (i.e., the fleshy part of the ascocarp that supports the hypothecium and hymenium); the excipulum as consisting of two parts, the ectal excipulum, which is the outer layer of the apothecium, and the medullary excipulum, which is the inner portion.

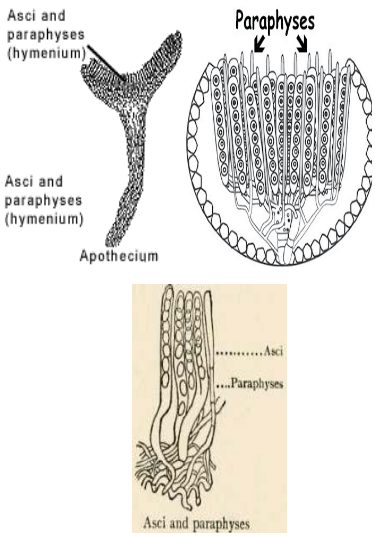

Figure 64: Apothecium structures.

Reproduction in *Peziza*

Ascospores (Figure 65 (1)) agerminate and develop into mycelia (Figure 65 (2)). At this stage, these mycelia can produce more mycelia, and then produce conidia, which can produce more conidia and eventually spores. This repetitive cycle is the asexual cycle. Some mycelia as they age form two kinds of gametangia, the female organ, ascogonium (Figure 65 (3)) and the male organ, antheridium (Figure 65 (3)). The antheridium attaches itself to the ascogonium by means of a receptive hyphal branch, known as the trichogyne (Figure 65 (4)) and transfers its nuclei to it (Figure 65 (5)). This process, which called plasmogamy (the transfer of protoplasm and nuclei, which do not fuse), stimulates the ascogonium to produce binucleate hyphae (Figure 65 (6)). The binucleate hyphae, known as dikarya become septate (Figure 65 (7)) and bend at the tip to form a hook cell (Figure 65 (a)). The nuclei in the hook cell (Figure 65 (a)) divide (Figure 65 (b)) and form septa. The septated entity forms three cells (Figure 65 (c)), a uninucleate basal cell, a uninucleate apical cell and a binucleate ascus mother cell. The nuclei in the ascus mother cell fuse (karyogamy) (Figure 65 (d)). The resulting zygote nucleus in the young ascus is the only diploid nucleus in the entire life cycle of the filamentous Ascomycetes. Meiosis then takes place and forms a tetrad of nuclei followed by mitosis. This last division is necessary for the development of a mature ascus with ascospores (see green letter “E”). The process described here, A - E, takes place in the fruiting body indicated in the top flow chart as red circle 8 (Figure 65).

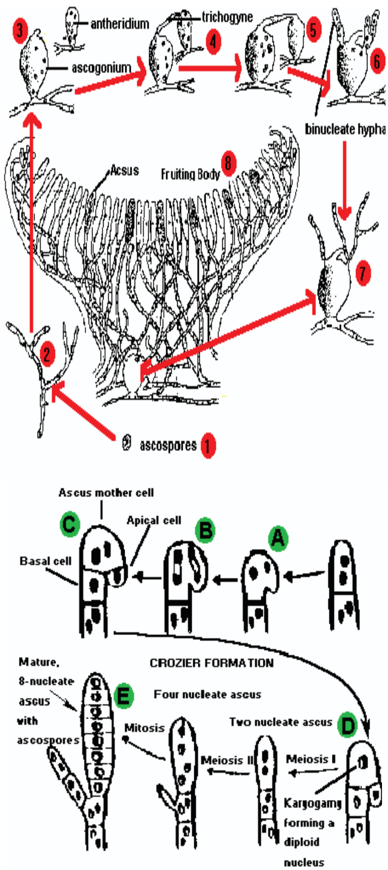

Figure 65: Life cycle of *Peziza*.

Morchellaceae

The Morchellaceae is a family of ascomycete fungi. The best-known members are the highly regarded and commercially picked true morels of the genus *Morchella*, the thimble morels of the genus *Verpa*, and a genus of cup-shaped fungi *Disciotis*. By ascocarp morphology, the three genera of Morchellaceae differentiated. *Morchella* species have an ascocarp with a sponge-like pileus, with a hollow stipe and pileus. *Verpa* species have a cup-like or thimble-shaped, smooth or wrinkled pileus above a hollow stipe. *Disciotis* has a cup-like pileus with vein-like hymenial folds and a small or nonexistent stipe. The ascospores are ellipsoid, smooth, and usually hyaline.

Example *Morchella*

The fruit bodies of the *Morchella* are highly polymorphic in appearance, exhibiting variations in shape, color and size; this has contributed to uncertainties regarding taxonomy. *Morchella elata* as example of this species in Figure 66 containing, fruiting bodies are hollow, and usually 5 to 10 cm tall, with an ovoid or conical head. The stipe (often swollen at the base) is 4 to 10 cm tall by 1.5 to 5 cm thick. *M.elata* characterized by the production of brown or reddish-purple, elongated, cylindrical, slightly pointed globular, longitudinal pits. *M.elata* distinguished from the other black morels by smooth, white stalks in younger specimens, by steel-gray colors in the ridges and pits of the pileus, and by the production of spores larger than those of *M.angusticeps* did. The spore deposit is cream-colored. This is an edible species, although like other morels, some individuals may be allergic.

Figure 66: *Morchella.*

Order: Tuberales

General characteristics

1. Tuberales commonly called as truffles.
2. They form underground fruiting bodies.
3. Some speacies occur in the form of mycorrhizal association with many trees.
4. The fruiting bodies containing a special flavour and emit strong smell.
5. The ascoarps remain closed in most of species.
6. The asci are spherical to clavate and do not contain lid or operculum.
7. The ascospores are colourless or brown and contain cyanophillic marking.
8. The number of ascospores in the ascus is usually eight, but the asci with fewer spores often seen within the same ascocarp.

Example*: Tuber*

The origin of the word truffle appears to be the Latin term tuber, meaning “lump”, which became tufer The asci, produced in a highly convoluted hymenium, are rounded and thin-walled, with no trace of an operculum or other shooting mechanism, and usually contain only 1-3 spores. The ascospores of truffles have complex, highly ornamented walls. They come in two basic patterns – spiny and lacunose (Figure 67).

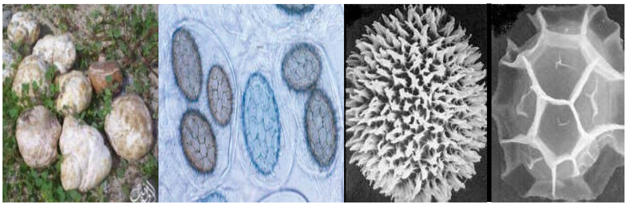

Figure 67: *Tuber* ascocarps, Asci contain only 1-3 spores, spiny *ascospore* and lacunose *ascospore* from left to right.

Reproduction

The sexual reproduction by somatogamy, two uninucleate cells fuse and bring about the binucleate condition, from the binucleate fusion cell develop many ascogenous hyphae. The tip of each ascogenous hypha becomes recurved to form crosiers. The penultimate binucleate cell of the ascogenous hypha functions as a young ascus. Its both the nuclei unite and the fusion nucleus divides miotically and then mitotically to giving 8 daughter nuclei. Out from which, only 2-5 remain functional and mature into ascospores the remaining nuclei degenerate. Then the ascocarps envelop the asci. On the other hand, asexuall reproduction very few take place by conidia (Figure 68).

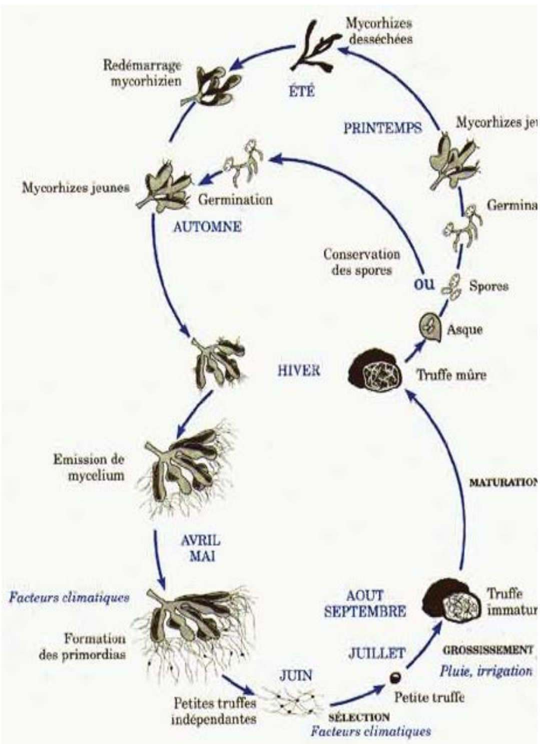

Figure 68: Life cycle of *Tuber*.

Basidiomycotina

Basidiomycota is a major division (or phyla) of the kingdom Fungi, About 30,000 described species are placed within Basidiomycota, or about 37 percent of all described species of fungi. Basidiomycetes compose a class of fungi containing many important plant pathogens and important litter decomposing fungi. This group also contains many ectomycorrhizal fungi of trees as well as delectable mushrooms for the cook. The mycorrhizal relationship is a symbiosis that benefits both trees and fungi.

General characteristics

1. The members are terrestrial and saprophytic or parasitic Basidiomycetes range from being facultative parasites (e.g. can live some of their life as saprophytes) to obligate parasites (rusts and smuts).
2. Basidiomycetes confined to only living host plants in nature.
3. The mycelium is well developed, branched and septate, and differentiated into primary, secondary or tertiary.
4. Most Basidiomycetes formed clamp connection.
5. Dolipore septa are present in most genera.
6. Cell wall in majority of basidiomycetes consists of chitin and glucans with 1,3 linked and 1,6 linked B- D – glucosyl units.
7. No specialized sex organs formed in basidiomycetes, plasmogamy takes place by somatogamy or spermatization.
8. Basidiomycetes reproduce sexually by basidiospores borne on basidia. Some basidiomycetes reproduce asexually by spores that sometimes called conidia. Both spores can infect plants. Some wood rotting basidiomycetes also can produce root-like strands of hyphae called rhizomorphs that can infect roots. The basidium is septated or non-septated.
9. Usually four basidiospores develop on basidium.
10. Basidiomycetes are harmful as well as useful. Their attack foods and ornamental plants, cause many different diseases including seedling diseases, wood rots, root and stem rots, seed diseases (smuts) and rusts on the other hand it used as humans foods.

Types of Basidiomycetes mycelium

1. Primary mycelium: It germinates from basidiospore. It consist of uninucleate cells and therefore called homokarion, although, the first stage of the primary mycelium may be multinucleate but then septa formation divides it into uninucleate cells (Figure 69).
2. Secondary mycelium: It develops from the fusion of two uninucleate cells of primary mycelium; the process of confertion of primary mycelium into secondary mycelium called as dicariotization or dipodization shown in Figure 70. The basidia formed from binucleate cells of secondary mycelium.
3. Tertiary mycelium: The secondary mycelium in some higher basidiomycetes organized into complex tissues to develop sporophores or basidiocarps, this stage known as tertiary mycelium.

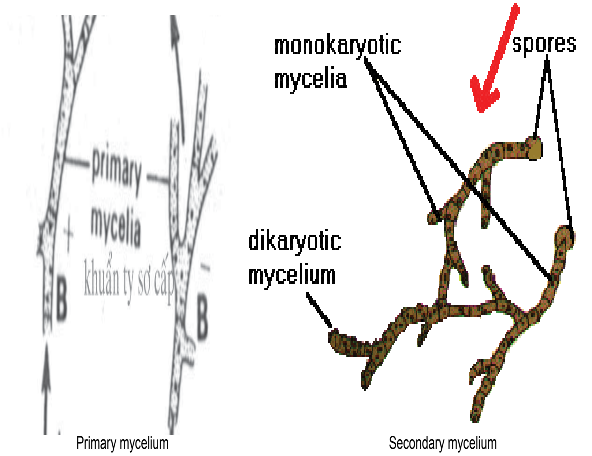

Figure 69: Types of basidiomycets mycelium.

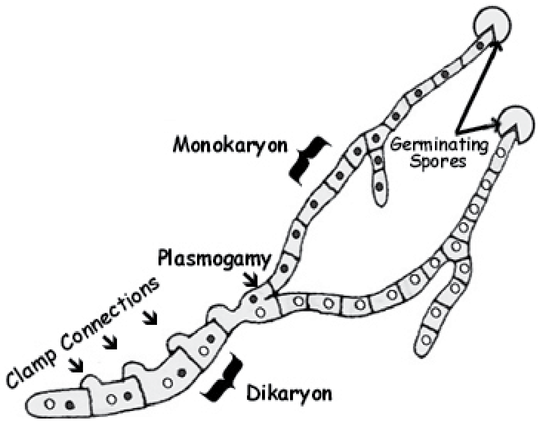

Figure 70: Dikaryon formation resulting from fusion of a pair of compatible monokaryons. Clamp connects may be or may not be present.

Clamp connection

A bridge-like hyphal connection involved in maintaining the dikaryotic condition, stages of clamp connection (Figure 71):

a. Terminal cell of hypha, growth only takes place at hyphal tips

b. Hyphal tip elongating

c. Synchronous division of nuclei and the beginning of hyphal branch will become the clamp connection. One nucleus (b) migrates into the new clamp.

Septum forms at base of the clamp trapping nucleus b. Nuclei a' and b' migrate to the hyphal tip, while nucleus migrates away from the tip

Septum forms below clamp forming new cell at hyphal tip. Fusion of the clamp to the adjacent cell releases nucleus b to the adjacent cell. Now both the terminal and subterminal are binucleate, each with a compatible pair of nuclei.

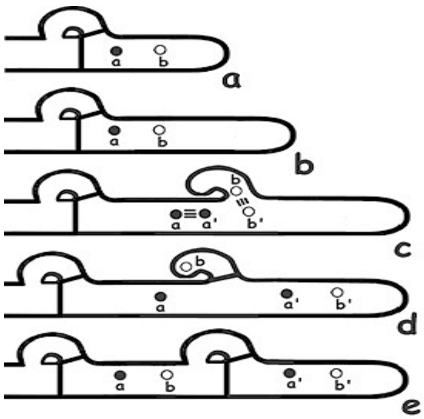

Figure 71: Formation of a clampconnection on hypha of a basidiomycete.

Basidium and basidiospres

Basidium is the cell in which karyogamy (nuclear fusion) and_meiosis occur, and on which haploid basidiospores formed. The basidium produces four basidiospores, borne on the tips of little prongs which project from the apex, and which called as sterigmata. Conidia, are produced if an asexual stage is present. Basidia divided into two types depending on whether they are septate holobasidia (a single-celled basidium), and phragomobasidia (a basidium that is divided into more than one cell by transverse or longitudinal setpa) (Figure 72 and 73).

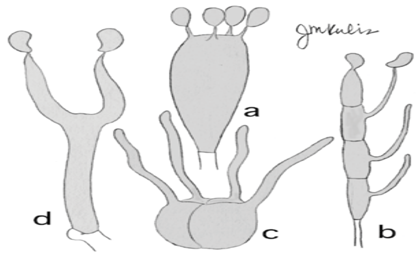

Figure 72: Different forms of holobasidia and phragmobasidia.

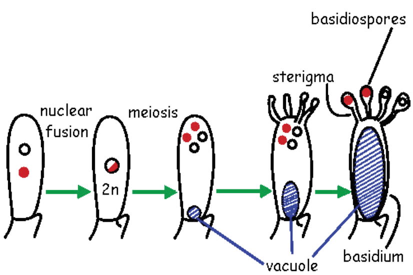

Figure 73: Basidiospres formation.

Importance of basidiomycetes

Basidiomycota are very important for the ecosystem and for humans:

Ecologically**:**

They are vital for decaying dead organic matter, including wood and leaf litter, and thus vital for the carbon cycle . Some also form important symbiotic relationships, such as mycorrhizal associations with the roots of a plant, whereby the fungus receives carbohydrates from the plant's photosynthesis and the plant gains the mycelium's very large surface area to absorb water and mineral nutrients from the soil. Ants cultivate some.

For humans:

Some Basidiomycota are a source of food. On the other hand, they also will decompose living wood tissue and thus can damage the wood in homes and other buildings, and the rusts and smuts are parasitic on plants and cause diseases of important agricultural crops, such as wheat. Some cause human and animal diseases.

Common Life cycle of basidiomycetes

1. Haploid basidiospores germinate to produce haploid mycelium (primary mycelium). In some species, the primary mycelium contains one nucleus in each compartment, in others; there may be multiple uclei/compartment – also called monokaryon since it contains nuclei of one genotype. At the same time the primary mycelium, exhibits limited growth.
2. Plasmogamy occurs shortly after basidiospore germination to primary mycelium, Plasmogamy occurs between two compatible hyphae (somatogamy) – no specialized sex cells.
3. Plasmogamy initiates dikaryotic phase or the secondary mycelium (dikaryon). After plasmogamy, nuclei migrate into monokaryotic cells to establish dikaryotic condition.
4. As mycelium grows, nuclei divide conjugately to maintain dikaryotic condition in cells. Dolipore septum prevents nuclear migration so that each compartment contains two nuclei; pore is 0.1-0.2 µm in diameter. Under certain conditions (e.g. after plasmogamy), dolipore septum breaks down to allow nuclear migration.

Many Basidiomycetes also form clamp connections (formation is reminiscent of crozier formation in Ascomycota) (Figure 74 and 75).

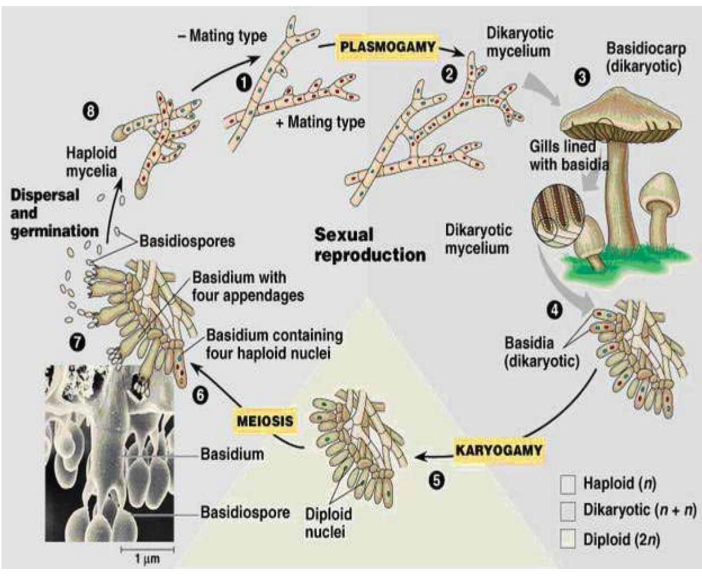

Figure 74: Life cycle of basidiomycetes.

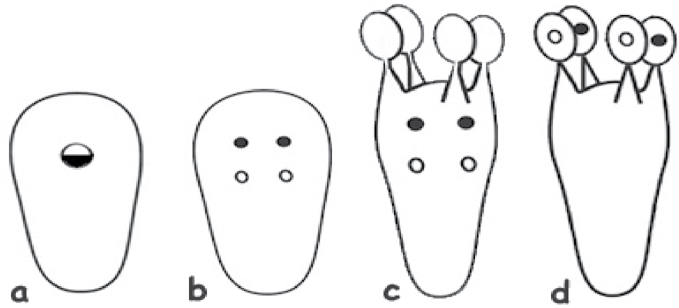

Figure 75: The zygote a. is the only diploid stage. Four nucleate stages after meiosis b. Formation of basidiospores, but nuclei have not migrated into spore's c. nuclear migration into basidiospores d. clamp connections.

Basidiomycota Classification

Classification of fungi belonging to the Basidiomycota, based upon the presence or absence of fruiting bodies (Basidiocarps) and the type of basidiocarp formed. Basidiocarps are amongst the most familiar of fungal structures, including toadstools, brackets and puffballs. However, the Basidiomycota also contains many species that produce microscopic sporulating structures, i.e. micro-fungi.

Classification of fungi belonging to the Basidiomycota according to Alexopouos and Mims 1979: Basidiomycotina classified into class basidiomycetes that divided into three sub-classes

1- Holobasidiomycetidae 2- Phragmobasidiomycetidae 3- Teliomycetidae

Sub-classe: Teliomycetidae

General characteristics:

1. The mycelium is well developed and septate, but the septa lack dolipores.
2. Members lack basidiocarps. They possess thick- walled, binucleate resting spores, called teliospores.
3. Fusion of two nuclei takes place within the teliospores.
4. Members of this sub-class include rusts and smuts, which are parasitic on many plants.
5. Teliospore germinates to short germ tube, called promycelium.
6. The diploid nucleus moves into promycelium where meiosis takes place and haploid basidiospores formed.
7. The basidiospores formed on promycelium and typically four in rusts, but in smuts, the number is large.
8. Strigmata-like outgrowths are present on the promycelium only in rusts. They are absent in smuts.
9. The uredinales and ustilaginales are two important orders of plant-pathogenic fungi belonging to the Teliomycetidae.

The class divided into three main groups of significance to gardeners (Table 2):

1. Ustilaginales

1. Spores typically dark (giving them the common name of smut fungi).
2. Mycelium is septated, well developed, thick walled and intercellular with no specialized haustoria.
3. A basidium and basidiospores produced on germination, asexual spores not produced in smuts.

4. All members of this group are parasitic.*Ustilago maydis* -Zea mays smut, *Urocystis cepulae* - onion smut.
5. Clamp connection also seen in the mycelium of many species.
6. Represented by over 1100 species and occur parasitically in more than 75 families of angiosperms.
7. The cells of dicaryotic mycelium are binucleate, which round off to form thick walled resting spore which called smut spores or chlamydospores.
8. Teliospores are usually blackish, brownish or yellowish.
9. No strigmata formed.
10. The smuts reproduce asexually by the formation of conidia, which develop from uni-nucleate as well as binucleate mycelium.
11. Budding is also very common in the basidiospores and conidia in smut.

2. Uredinales

1. All members of this group are parasitic of vascular plants, ferns and connifers.
2. Life cycles are very complex frequently involving two hosts, in which case the fungus is to be heteroecious.
3. Both asexual and sexual spores are produced, the basidium resulting from the germination of a dark, thick walled, one or many-celled teleutospore.
4. The spores, borne in groups on leaf or stem surfaces are often orange coloured giving the group the name rust fungi.
5. Urediniomycetes develop no basidiocarp, karyogamy occurs in a thick-walled resting spore (teliospore), and meiosis occurs upon germination of teliospore.
6. They have simple septal pores without membrane caps and disc-like spindle pole bodies. Except for a few species, the basidia are transversally septate.
7. Mannose is the major cell wall carbohydrate, glucose, fucose and rhamnose are the less prevalent neutral sugars and xylose is not present.
8. Rust fungi that have all five spores called as macrocyclic rust. Those with less than five stages called as microcyclic rusts. Microcylic rusts often just produce teliospores and basidiospores.
9. Macrocyclic rusts that infect a single host called as autoecious. Others require two hosts called as heteroecious. Example: Uromycetes fabae - bean rust, Puccinia graminis- wheat rust

Uredinales (rusts)	Ustilaginales (smuts)
1. Teliospores terminal	1. Teliospores intercalary
2. Basidiospores 4, discharged from sterigmata.	2. Basidiospores variable in number, not on sterigmata, not discharged.
3. Spermagonia produce dikaryotic stage.	3. No spermagonia dikaryotic stage arises from fusion of any two compatible cells.
4. Clamp connections absent.	4. Clamp connections common.
5. Many species require two hosts for complete life cycle.	5. Never requires two hosts.
6. Most species unculturable on artificial media	6. Most species readily culturable
7. Infections usually localized.	7. Infections usually systemic
8. Teliospores in telial sori, usually on stems or leaves	8. Teliospores replace host host organs, usually ovaries and anthers.
9. Attack ferns, gymnosperms, or angiosperms	9. Attack only angiosperms

Table 2: Differences between rust and smut fungi.

Sub-classes: Holobasidiomycetidae

General characteristics:

1. Member grows in varied habitats such as forest litter, grassland, on dung, on sand dunes and a few even on termite mounds.
2. Most of them are saprophytes. Some are important plant parasites and good many wood destroying fungi.
3. Presence of simple unseptate, typically club- shaped or cylindrical basidium bears generally four, sometimes one, two or eight basidiospores.
4. Commonly the basidia arranged in a regular fertile layer, the hymenium that extends over the surface of basidiocarp.
5. Basidiospores are borne singly at the tips of small stalk called sterigmata.

The basidia arranged in a layer known as a hymenium that is, fully exposed at maturity.

Sub-classes: Holobasidiomycetidae

Order: Agaricales

General characteristics:

1. The order Agaricales, also known as gilled mushrooms (for their distinctive gills), or euagarics, contains some of the most familiar types of mushrooms. The order has about 4,000 species, or one quarter of all known homobasidiomycetes. They range from the ubiquitous button mushroom to the deadly Amanita virosa and the hallucinogenic fly agaric to the bioluminescent jack-o-lantern mushroom.
2. All are terrestrial; their habitats include all types of woodland and grassland, varying largely from one species to another.
3. Basidiocarps of the agarics are typically fleshy, with a stipe, often called a stem or stalk, a pileus (or cap) and lamellae (or gills), where basidiospores are stored. This is indeed the stereotyped structure of what we would call a mushroom or toadstool.
4. The agarics' life cycle is very much representative of the basiodiomycetes. Clamp connections are present in the dikaryons of several species, but that is not always the case.

Order: Agaricales

Family: Agaricaceae
Family: Bolbitiaceae
Family: Clavariaceae
Family: Coprinaceae
Family: Cortinariaceae
Family: Entolomataceae
Family: Hydnangiaceae
Family: Lycoperdaceae
Family: Marasmiaceae
Family: Nidulariaceae
Family: Pleurotaceae
Family: Pluteaceae
Family: Schizophyllaceae
Family: Strophariaceae

Family: Agaricaceae

Agaricus

Agaricus is a large and important genus of mushrooms containing both edible and poisonous species, with possibly over 300 members worldwide. The genus includes the common ("button") mushroom (*Agaricus bisporus*) and the field mushroom (*Agaricus campestris*), the dominant cultivated mushrooms of the West.

Members of *Agaricus* are characterized by having a fleshy cap or pileus, (Figure 76) from the underside of which grow a number of radiating plates or gills on which are produced the naked spores. They are distinguished from other members of their family, Agaricaceae, by their chocolate-brown spores. Members of *Agaricus* also have a stem or stipe, which elevates the pileus above the object on which the mushroom grows, and a partial veil, which protects the developing gills and later forms a ring or annulus (ring like structure sometimes found on the stipe of a mushroom). The annulus represents the remaining part of the partial veil, after it has ruptured to expose the gills or other spore-producing surface. An annulus may be thick and membranous, or it may be cobweb-like. The latter type of annulus is referred to as a cortina) on the stalk.

The Basidiocarp

Stipe

A stipe refers to the stem or stalk-like feature supporting the cap of a mushroom. Like all tissues of the mushroom other than the hymenium, the stipe is composed of sterile hyphal tissue. In many instances, however, the fertile hymenium extends down the stipe some distance. Fungi that have stipes called as stipitate.

Pileus

The pileus is the technical name for the cap, or cap-like part, of a basidiocarp or ascocarp (fungal fruiting body) that supports a spore-bearing surface, the hymenium. The hymenium (hymenophore) may consist of lamellae, tubes, or teeth, on the underside of the pileus. A pileus is characteristic of agarics, boletes, some polypores, tooth fungi, and some ascomycetes. Pilei can be of various shapes, and the shape can change over the course of the developmental cycle of a fungus. The most familiar pileus shape is hemispherical or convex (Figure 77,78 & 79).

Structure of gills

The gill exhibited a comples structure of interwoven hyphae, which are more closely compacted. In transverse section of the gill, we can make out the following regions:

Trama:

It is the innermost or central part of the gill between the two hymenial surfaces, the hyphae in this region anastomos and is irregularly interwoven. They run more or less longitudinally. The cell contains fewer nuclei than the cells of the hyphae constituting the stipe and the pileus.

Subhymenium or Hypothecium:

The hyphae constituting the trama give off short lateral branches. The latter curves outwards towards the two surface of the gill where they form a more closely compacted tissue of small-inflated cells with still fewer nuclei (2 or 3 per cell).

Hymenium or Thecium:

On the surface of subhymenium, covering both sides of the gill fertile layer called hymenium. It consists of a closely packed palisade – like layer of clup-shaped cells. They are called the basidia (terminal elongated cells of the same hyphae which constitueted the trama and the subhymenium, non-septated). Interspersed between the basidia, are the sterile hyphae called paraphyses or cysidia. Each basidium bears four basidiospores at the free end. They are elevated on shrt stalks, the sterigmata.

Figure 76: Different forms of basidiocarps.

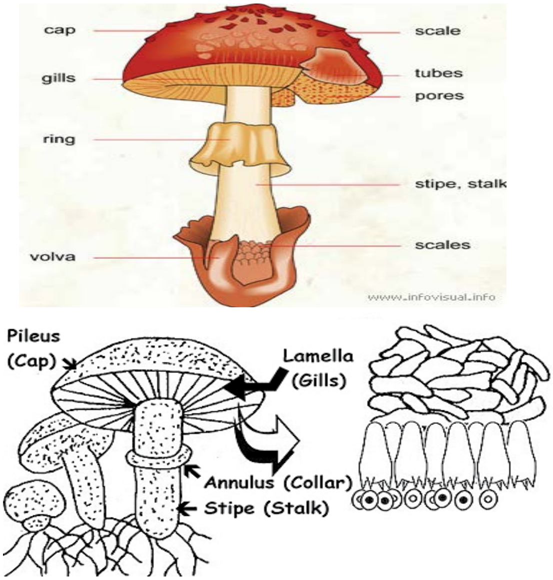

Figure 77: Basidiocarp of Agaricus sp.

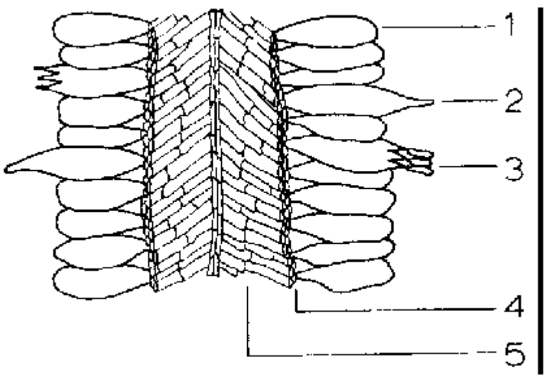

Figure 78: Longitudinal section through the bolete hymenophore1, Basidium 2, Hymenial cystidium 3, Basidium with sterigmata and basidiospores4, Subhymenium, 5, Bilateral trama showing central strand and divergent hyphae.

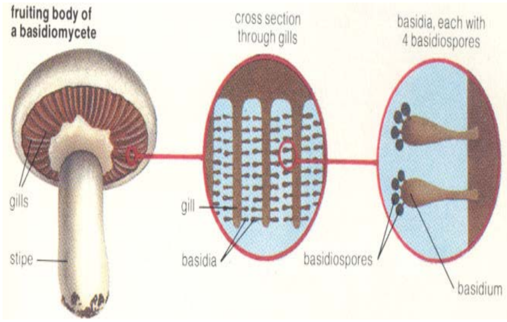

Figure 79: Section in Agaricus gill.

Life cycle of *Agaricus bisporus* (Sexual reproduction)

Mycelial Growth Stage

1. *Agaricus bisporus* life cycle begins with basidiospores (Figure 80). Each basidiospore has a germ pore, a circular indentation in one end of the spore. From this pore, a haploid strand called a hypha will grow (primary mycelium) and the hypha will grow, branching to form mycelium, a web of cells beneath the surface of the ground.

Hypha Growth Stage

2. The hypha is haploid, meaning they have exactly half of the chromosomes necessary to form a mushroom. When two genetically compatible hypha come in contact, the cell walls of each hypha dissolve and fuse together (Plasmogamy), combining their genetic material into one cell (Karogamy). From then on, any growth from these cells will also contain two nuclei, and will be dikaryotic, having a full set of chromosomes. These cells continue to form mycelium (Secondary mycelium). This mycelium, however, is now capable of forming the fruiting bodies that we commonly call mushrooms.

Fruit Body Stage

3. Most mushroom species, including *A. bisporus*, will take many weeks to grow fruiting bodies. Immediately before fruiting bodies develop, nuclei within the dikaryotic cells begin to replicate in large numbers. Then the cells will divide rapidly to forming the fruiting bodies. As they grow, they will erupt from the growth medium as a bud, eventually forming a mushroom. This is typically the stage in the life cycle of *A.bisporus* when they harvested for human consumption.

Basidia Development Stage

4. As the mushroom matures, it will develop a stem and cap. Under the cap, gills will form. As the gill matures, bubble-like cells called basidia will grow in the gill slits. These cells have two nuclei. These nuclei will eventually merge to form a single diploid nucleus. This will then reproduce through meiosis to form four haploid daughter cells.

Spore Development Stage

5. Projections called sterigmatae will then develop. The nuclei within the daughter cells will then migrate through this growth and form four spores at the tip. The spores wait at the end of the sterigmata until they physically dislodged. The spores are then released from the mushroom, falling to the ground or substrate to begin the life cycle again (Figure 80,81).

Asexual reproduction

Asexual reproduction in the field mushroom reported to multiplay by the formation of chlamydospores and conidia.

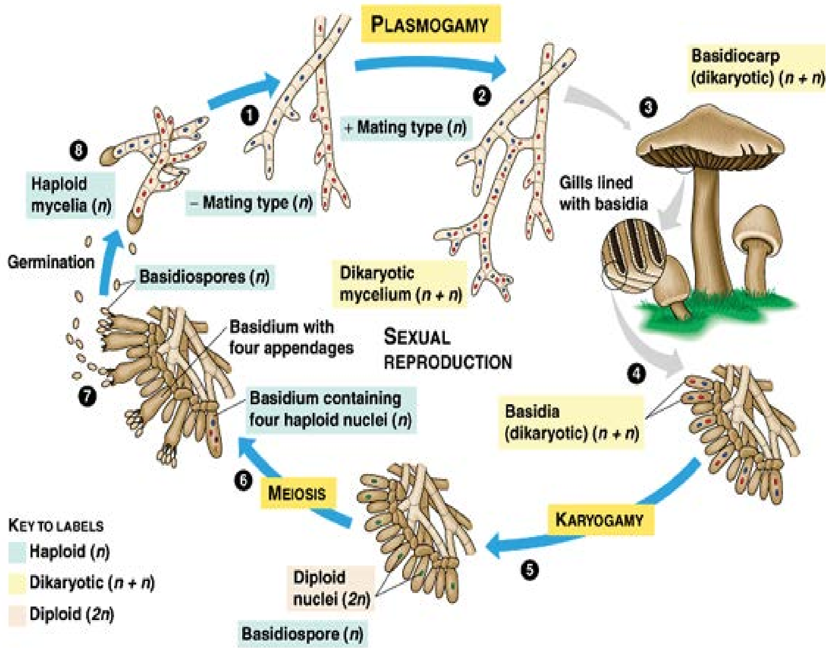

Figure 80: Sexual life cycle of *Agaricus sp.*

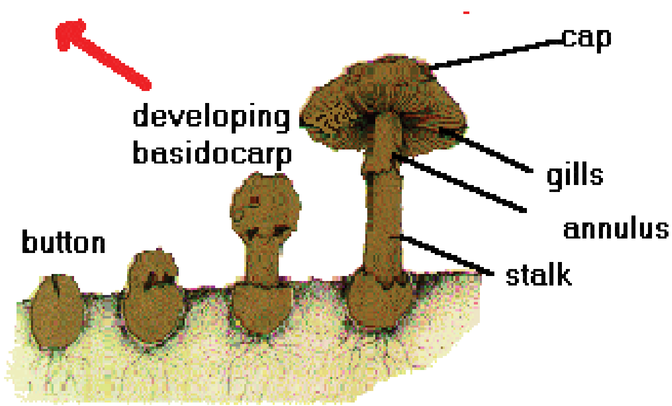

Figure 81: Besidocarp developing.

Family**: Pleurotaceae**

Pleurotaceae is a family of small to medium sized mushrooms, which have white spores. Members of Pleurotaceae can be mistaken for members of Omphalotaceae. Perhaps the best-known member is the oyster mushroom (*Pleurotus ostreatus*).

Many species in the genera *Pleurotus* and *Hohenbuehelia* are nematophagous, that is, they derive nutrition by consuming nematodes. This made possible by hyphae that may have adhesive knobs that attach to passing nematodes and secrete nematotoxic compounds.

Oyster mushroom or *Pleurotus ostreatus*

Pleurotus is a genus of gilled mushrooms, which includes one of the most widely eaten mushrooms, the oyster mushroom (Figure 82).

Like all other basidiomycetes, it distinguished by having clamp connections along its hyphal length.

The mushroom has a cap spanning 5-25 cm broad, fan or oyster-shaped; Natural specimens range from white to gray or tan to dark-brown; margin inrolled when young, smooth and often somewhat lobed or wavy. Flesh white, firm, varies in thickness due to stipe arrangement. The gills of the mushroom are white to cream, descend stalk if present, if so stipe off-center with lateral attachment to wood. The spore print of the mushroom is white to lilac-gray, best viewed on dark background. The mushroom's stipe is often absent. When present it is short and thick. The taste of the mushroom is, described as mild with a mild odor of anise.

Habitat

The Oyster Mushroom is widespread in temperate and subtropical forests throughout the world. A saprotroph, that acts as a primary decomposer on wood, especially deciduous, particularly beech.

The mushroom usually is not fussy where it grows, however it does not like to grow near stinging nettles. This is probably due to the high acidity of the nettles. The oyster mushroom is also one of the few known carnivorous mushrooms. Its mycelia can kill and digest nematode, which can believe to be a way in which the mushroom obtains nitrogen.

Figure 82: *Pleurotus ostreatus.*

Polyporales

Polyporales (earlier known as *Aphyllophorales*) are important decomposers of wood. They are basidiomycetes that lack soft gills (lamellae), but are also hymenomycetes as are boletes and agarics. This assemblage of fungi is polyphyletic. Polyporales have a smooth hymenophore, or have pores such as the boletes, or teeth, or irregular gills. Major groups are the polypores and various coral fungi.

Famly Polyporaceae

The Polyporaceae are a family of bracket fungi belonging to the Basidiomycota. The flesh of their fruiting bodies varies from soft (as in the case of the Dryad's Saddle illustrated) to very tough. Most members of this family have their hymenium (fertile layer) in vertical pores on the underside of the caps, but some of them have gills (e.g. *Panus*) or gill-like structures (such as *Daedaleopsis*, whose elongated pores form a corky labyrinth). Many species are brackets, but others have a definite stipe - for example: *Polyporus badius*.

Polyporus

Polyporus is a genus of fungi in the Polyporaceae family. It is a genus used for the production of single cell proteins, sources of mixed protein extracted from pure or mixed cultures of algae, yeasts, fungi or bacteria (grown on agricultural wastes) used as a substitute for protein-rich foods, in human and animal feeds.

This mushroom commonly attached to dead logs or stumps at one point with a thick stem. Generally, the fruiting body is 8–30 cm (3–12 in) across and up to 10 cm (4 in) thick. The body can be yellow to brown and has "squamules" or scales on its upper side. On the underside, one can see the pores that are characteristic of the genus *Polyporus*, which will produce a white spore print if laid onto a sheet of paper. They can found alone, in clusters of two or three, or forming shelves. Young specimens are soft but toughen with age. It is particularly common on dead elm and found on living maple trees (Figure 83).

Distribution and habitat

This organism is common and widespread, found east of the Rocky Mountains in the United States and over much of Europe. It commonly fruits in the spring, occasionally during autumn, and rarely during other seasons. Many mushroom hunters will stumble upon this when looking for morels during the spring as both have similar fruiting times, and this fungus can grow to a noticeable size of up to 60 cm (2 feet) across. It plays an important role in woodland ecosystems by decomposing wood, usually elm, but is occasionally a parasite on living trees. It is especially interesting as it can digest lignin [5].

Figure 83: *Polyporus.*

Commercial production of mushrooms

The following are the steps in mushroom production- a cycle that takes about 15 weeks (time varies by species) from start to finish (Figure 84).

1. Choosing a growing medium
2. Pasteurizing or sterilizing the medium

3. Seeding the beds with spawn (material from mature mushrooms grown on sterile media)
4. Maintaining optimal temperature, moisture, and other conditions for mycelium growth and the conditions that favor fruiting (This is the most challenging step)
5. Harvesting, packaging, and selling the mushrooms
6. Cleaning the facility and beginning again

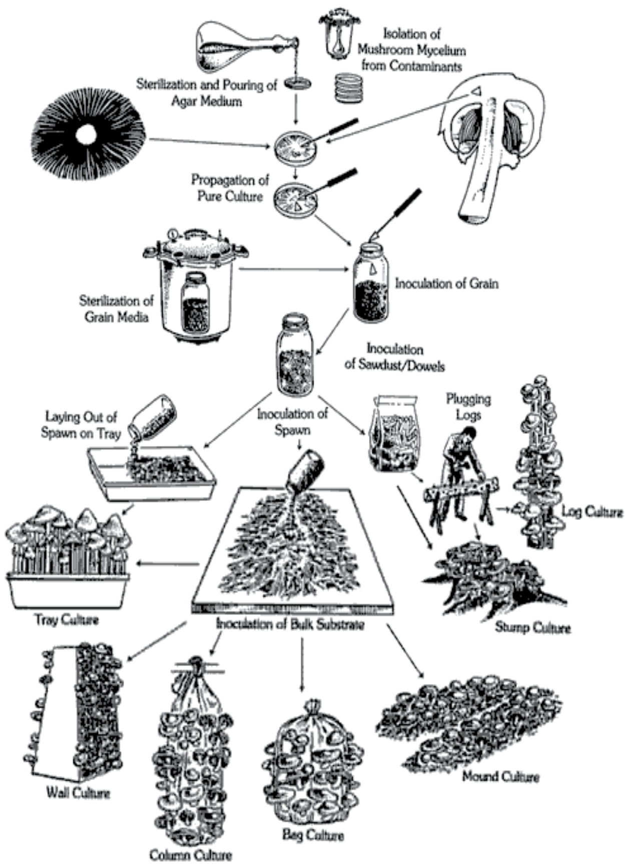

Figure 84: Steps of mushroom production.

In order to destroy any fungal and/or bacterial competitors or contaminants, the substrate on which the mushrooms will grow and develop their fruit bodies are to be sterilize or pasteurize in hot water.

To produce spawn, inoculate a pasteurized medium, usually grains, with the sterile culture of a particular mushroom species. After the culture has grown throughout the medium, it called as spawn. Generaly, producing spawn requires exacting laboratory procedures.

Several mushroom suppliers sell many kinds of spawn, and the starting mushroom farmer should take advantage of this selection in early trials to estimate which species grow best on available substrates. Eventually, learning to produce spawn might minimize your cost of production. Evaluate this possibility only after you have mastered the later stages of cultivation.

While the mycelium is growing-and until it fully occupies the substrate-, the mushroom farmer typically manipulates the growing environment to induce mycelial development. The atmospheric conditions are then changed to initiate "pinheads," and then to complete fruiting. For example, in oyster mushroom production under closely controlled conditions, the grower lowers the temperature and the CO_2 in the grow room to initiate fruiting. Each species has specific requirements for its stages of development.

When you can cut the time between harvests, annual production increases. Short cycles are what the large-scale commercial producers aim for, constantly looking for ways to increase efficiency. You face this competition if you plan to sell your product on the wholesale market.

Mushroom cultivation advantages:

1. Reduce the environmental pollutions "how": Wastes such as agricultural wastes such as straws, largely burnt by the farmers, which causes environmental pollution. However, these raw materials can actually used for the cultivation of mushrooms. This kind of bioconversion exercise can greatly minimize environmental pollution.
2. Mushroom cultivation can be a labour intensive activity. Therefore, it will serve as means of generating employment, particularly for rural women and youths in order to raise their social status. It will also provide additional work for the farmers during winter months when the farming schedule is light.
3. Mushroom cultivation is a cash crop. The harvested fruiting bodies can be sold in local markets for additional family income or exported for an important source of foreign exchange that will definitely improve the economic standards of the people.
4. It will provide the people with an additional vegetable of high quality, and enrich the diet with high quality proteins, minerals and vitamins, which can be of direct benefit to the human health and fitness. The extractable bioactive compounds from medicinal mushrooms would enhance human's immune systems and improve their quality of life.
5. Some warm mushrooms, e.g. *Volvariella volvacea* (Straw mushrooms) and *Pleurotus* (Oyster mushrooms) are relatively fast growing organisms and harvested in 3 to 4 weeks after spawning. It is a short return agricultural business and can be of immediate benefit to the community.

Divition: Deuteromycota

Subdivition: Deuteromycotina

Class Fungi imperfect

The Fungi imperfecti or imperfect fungi, also known as Deuteromycota are fungi which do not fit into the commonly established taxonomic classifications of fungi that are based on biological species concepts or morphological characteristics of sexual structures because their sexual form of reproduction has never been observed; hence the name "imperfect fungi." Only their asexual form of reproduction is known, meaning that this group of fungus produces their spores asexually. Many fungi once placed in this group have since been found with fruiting bodies and been renamed and placed elsewhere - although sometimes the name of the imperfect stage is retained for convenience. For example, the snow mould of turf, *Fusarium nivale,* is the imperfect (infertile) stage of the Ascomycete *Calonectria graminicola.*The correct name is that of the rare fertile form but the better-known name of the commoner, imperfect, form is still used.

General characteristic

1. It represented by over 15000 species, majority of which are terrestrial
2. Majority of which are saprobes or weak parasites, causing a number of plant diseases as well as animal diseases

3. A large and varied group with septate hyphae in which no fertile (sexual or "perfect") stage is known
4. Asexual reproduction by spores called conidia
5. The conidia are non-motile structures, which develop exogenousaly on the conidiophores
6. The conidia produced either directly on the conidiophores or in some special types of fruiting bodiessuch as synnemata, acervuli, sporodochia or pycnidia
7. The mycelium is usually intercellularor intracellular and each cell contains many nuclei

Types of Conidiophore Formation

1- Simple, unbranched conidiophores:

Some species form conidia on single, unbranched hyphae (conidiophores) (Figure 85). E.g. *Geotrichum candidum*

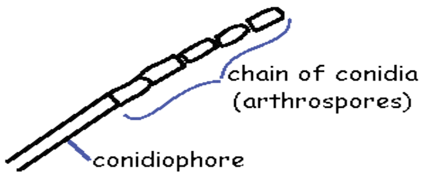

Figure 85: Simple and unbranched conidiophore.

2- Branched conidiophores:

Example of a branching pattern of conidiophores bearing clusters of conidia at their tips (Figure 86). E.g. *Trichoderma viride*

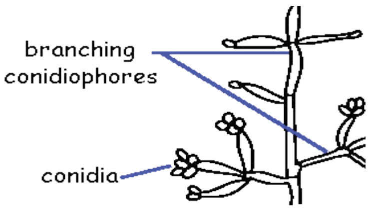

Figure 86: Branched conidiophore.

3- Coremium:

1. Conidiophores are aggregated together to form a vertical stalk-like coremium
2. At the top of the coremium, the conidiophores branch and conidia develop at the tips of the branches (Figure 87). E.g. *Penicillium claviforme*

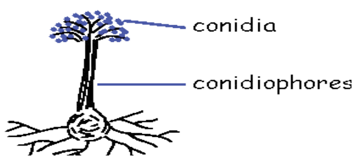

Figure 87: Coremium.

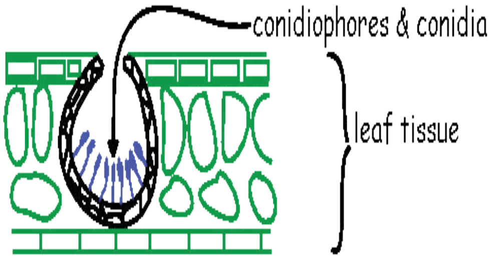

Figure 88: Pycnidium.

4-Pycnidium:

Pycnidium is a flask-shaped structure with conidiophores developing from cells of the pycnidial wall (Figure 88). E.g. *Phoma* species

5-Acervulus:

- Acervulus is a flat, open pad of short conidiophores growing side-by-side.
- The conidiophores develop from the underlying mass of somatic hyphae (Figure 89).
- E.g. *Colletotrichum* species

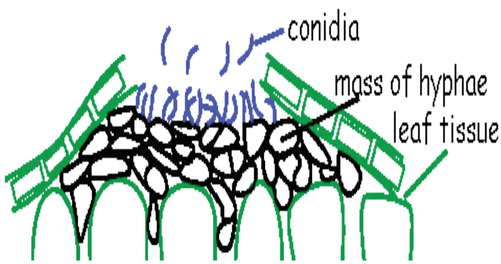

Figure 89: Acervulus.

6-Sporodochium:

Sporodochium is a cushion-shaped mass of short conidiophores (Figure 90).
E.g. *Epicoccum* species

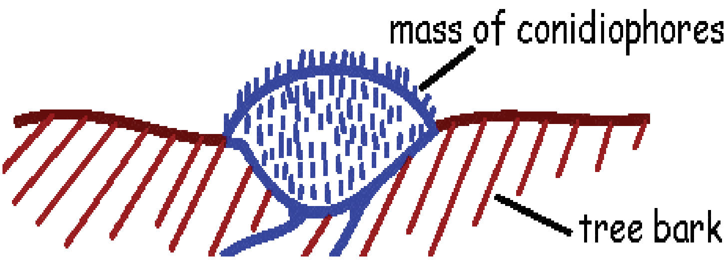

Figure 90: Sporodochium.

Deuteromycotina classified according to shape, size septation, colour and ornamentation of conidia their development (thallicand blastic types), morphology and ontogeny of conidiophores, as well as aggregation in the form of definite fruiting bodies (synnemata, acervuli, sporodochia or pycnidia).

Deuteromycotina contained Form class:

1. Blastomycetes True mycelium is absent or poorly developed; plant body is yeast like and shows budding.
2. Hyphomycetes: True mycelium is present, budding cells are absent, mycelium is either sterile or bears spores on sporophores, which never aggregated in pycnidia or acervuli.
3. Coelomycetes: True mycelium is present, budding cells are absent spores aggregated in in pycnidia or acervuli.

Form – Sub class Hyphomycetidae

General characteristics:

1- A majority of the members are either saprophytes or parasites.

2- Mycelium is septated and branched.

3- Reproduction is by conidia or by fragmentation.

4- Conidia are either dry or slimy.

5- Any member produces neither pycnidia nor acervuli.

There are two order of Form – Sub class Hyphomycetidae of importance to gardeners

Order (1) Moniliales and Order (2) Agromycetales:

1. Order Moniliales - Conidia borne freely on short branches of the hyphae, majority of them are saprophytes or parasites, divided into the following form- families:

1. Moniliaceae, conidiophores separate from one another or absent. Spores and mycelium are hyaline or light coloured, e.g *Monilia*.
2. Dematiaceae, spores and mycelium are dark coloured, e.g. *Alternaria, cercospora, Curvularia* and *Pyricularia*.
3. Tuberculariaceae, Conidia and conidiophores are develop in sporodochium e.g. Fusarium.
4. Stilbellaceae, Conidia and conidiophores are developing in Synnemata, e.g. *Graphium*.

Form- class Coelomycetes including sub- class Coelomycetidae which characterized by

1- It is saprophytes or parasites on vascular plants.

2- The budding cells are absent.

3- Conidia and conidiophores, aggregated in pycnidia or acervuli.

4- The conidia are unicellular, deciduous and hyaline or pigmented.

5- The thallus is eucarpic, mycelial and septated.

6- It classified into form order

A) Melancoliales: Conidiophores grouped into pustules or acervuli. Conidia usually in tendrils embedded in mucilage.

Example: *Colletotrichum lindemuthianum* - anthracnose of French beans

B) Sphaeropsidales: Conidiophores contained within flask shaped pycnidia, which in parasitic species to be embedded in the host tissues and conidia in mucilagenous tendrils.

Examples: *Septoria appi-graveolentis* - leaf spot of celery

Ascochyta pisi- leaf and pod spot of peas

Alternaria

1. *Alternaria* species are known as major plant pathogens
2. They are also common allergens in humans, growing indoors and causing hay fever orhypersensitivity reactions that sometimes lead to asthma
3. They readily cause opportunistic infections in immunocompromised people such as AIDS patients
4. There are 299 species in the genus
5. They are ubiquitous in the environment and are a natural part of fungal flora almost everywhere
6. They are normal agents of decay and decomposition
7. The spores are airborne and found in the soil and water, as well as in indoors and on objects
8. The club-shaped spores are single or form long chains
9. They can grow thick colonies, which are usually black or gray
10. Mycelium consists of light brown, selnder, profusely branched, septate hyphae

Reproduction in *Alternaria*

It reproduced by conidiospores, which develops as an apical bud from the uppermost cell of the conidiophore. The young conidium divided by transverse septa, which develop by annular ingrowths. In the center of each septum is present a pore that allows the conduction of cytoplasm in between cells of the conidium. Later on, some of cells divide by longitudinal septa. Usually the tip cell of a conidium also shows budding, and the ultimate result is the formation of chain of conidia, resulting in the branching of the spore chain. The plugging of the spore of the basal conidium stops the further extention of the conidial chain. The conidium disseminated readily by wind. In the presence of moisture and suitable temperature, a conidium germinates by producing five to ten germs tubes (Figure 91).

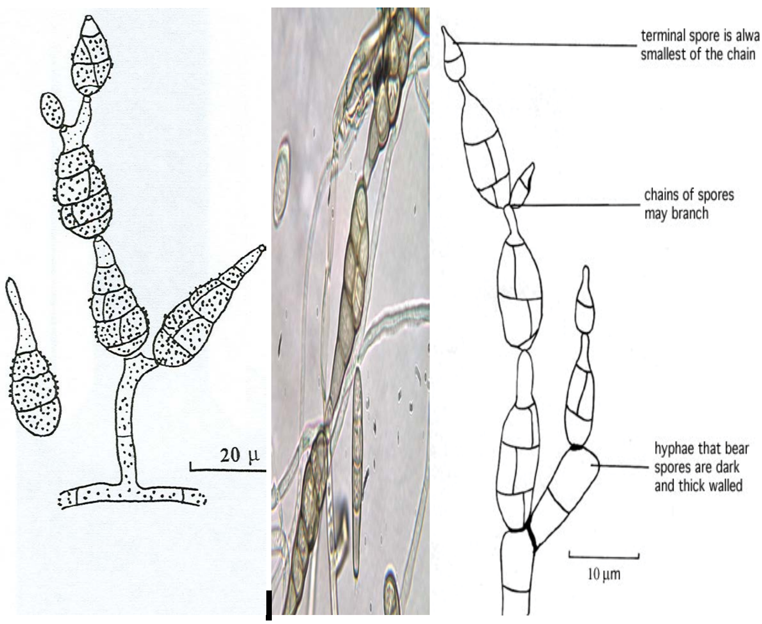

Figure 91: Vegetative structure of Alternaria.

Curvular

Curvularia genus having multiseptate, darkly pigmented conidia with the middle cell enlarged on one side, so that the spore curved slightly. Many of the species are plant pathogens, but some are saprobes. This genus occurs commonly in outdoor air (Figure 92).

1- This species represented by over 30 species.
2- It occurs on rice and many other crops causing leaf spots, blights, and root rot.
3- Conidiophore is erect, macronematous and mononematous.
4- The conidia develop either spirally or in whorls on conidiophores.
5- The conidia are curved and septated transfersally, the third cell from the conidium is largest
6- Occasionally, the conidiophores develop in stromata.
7- Reproduce asexually by condiospores.

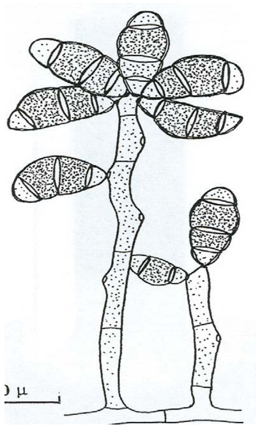

Figure 92: Vegetative structure of *Curvularia*.

Pyriculari

Pyricularia oryzae causes seious blast disease of rice, on pale brown conidiophores, producing conidia hyaline to pale olive brown, obpyriform, hilum protrudent, 17-28 x 6-9 um with 1-3 septa (Figure 93).

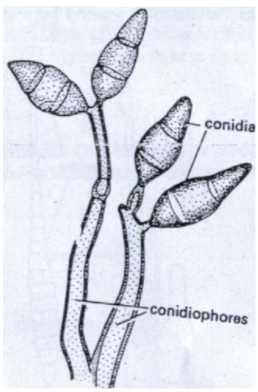

Figure 93: Vegetative structure Pyricularia.

Stachybotrys

Stachybotrys is a deuteromycete fungus in the family Dematiaceae. The most important species in this genus is Stachybotrys chartarum, formerly known as Stachybotrys atra. This species is important for a variety of reasons, most of which relate to the fact that it can produce a novel class of trichothecenes, a type of mycotoxin. (You might recall that Aflatoxin is species.).

The genus *Stachybotrys* produces a mass of sticky, single-celled ornamented conidia from phialides on each conidiophore (Figure 94 & 95). This fungus grows extremely well on substrates that are high in cellulose, particularly when those substrates are wet. This means that typical building materials, such as wood and drywall, when wet, make a good habitat for *Stachybotrys*. *Stachybotrys* is a moderately common inhabitant of moist areas in homes, and its spores can cause some possible health risks. Stachybotrys is commonly isolated in buildings with mechanical or structural defects that lead to areas of increased moisture accumulation. Stachybotryotoxicosis is the disease that results upon ingestion of the toxins produced by *Stachybotrys*. The disease is most common in horses, where they encounter the fungus and its toxins through feed and/or bedding contaminated with *Stachybotrys*.

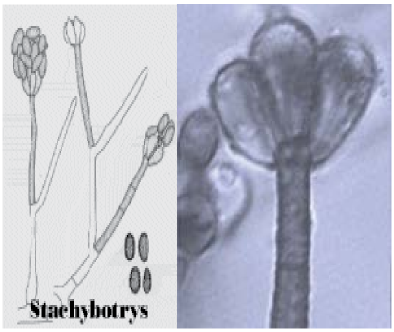

Figure 94: Vegetative structure of Stachybotrys.

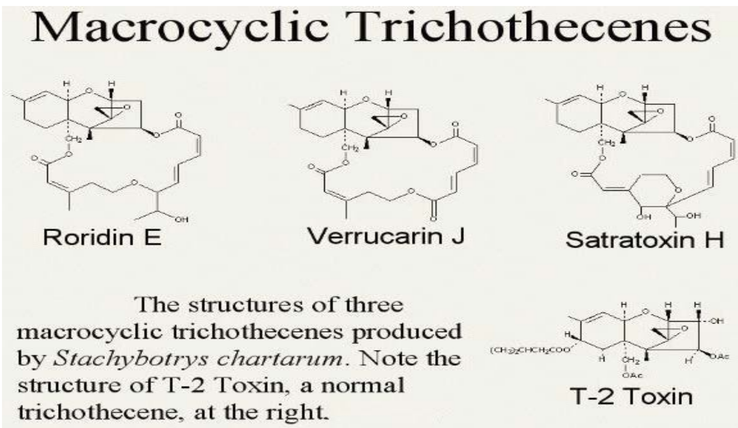

Figure 95: Structure of three macrocyclic trichothecenes produced by Stachybotrys chartarum.

Fusarium

Fusarium is a large genus of filamentous fungi (Figure 96 & 97) widely distributed in soil and in association with plants. Most species are harmless saprobes and are relatively abundant members of the soil microbial community. Many plants attacked by this genus causing wilt diseases. Some species produce mycotoxins in cereal crops that can affect human and animal health if they enter the food chain. The main toxins produced by these *Fusarium* species are fumonisins and trichothecenes.

Reproduction in *Fusarium*:

Reproduction in *Fusarium* by the asexual spores as following:

1. Macroconidia: Macroconidia (asexual spores) derived from conidium-producing cells called phialides.The phialides clustered together in cushion-shaped masses known as sporodochia. The macroconidia are hyaline, canoe-shaped spores usually with five or more septa.
2. Microconidia: Microconidia are small, usually unicellular but sometimes bicelled, spherical or oval bdies produced from simple phialides or from branched or unbranched conidiophores.
3. Chlamydospores: Chlamydospores are round or oval, thick- walled, terminal or intercalary cells of old hyphae. They develop either singly or in chains. They get detached and germinate by means of germ tubes if the condition is favourable. The chlamydospores are very durable and remain viable for along time.

Plate 1, Mycelium of *F. oxysporum*; Plate 2, Microconidia; Plate 3, Macroconidia; Plate 4, Chlamydospores.

Figure 96: Reproduction in *Fusarium.*

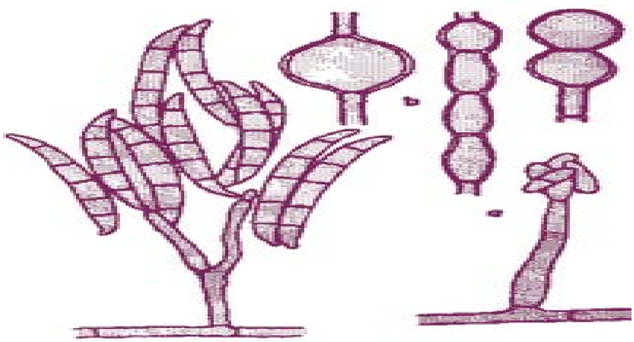

Figure 97: Conidiophore with macroconidia and chlamydospores.

Acremonium

Genus that has the spore bearing cells directly on the hypha, which bears single celled spores. Some species produce spores in a slime drop and some in dry chains. Some experts put the species that produce spores in chains in the genus *Gliomastix*. *Acremonium* spp. generally considered soil fungi, and some species can grow indoors when damp conditions are present [6].

Cladosporium

Genus characterized by darkly pigmented spores produced in chains from branched conidiophores. *Cladosporium* spores may be single celled or septate. There are many species in this genus, and several species are common in outdoor air. *Cladosporium* spp. is usually the single most abundant type of mold in outdoor air; some are also common on painted wooden surfaces and may grow indoors.

Other example of deteromycetes is showen in Figure 98.

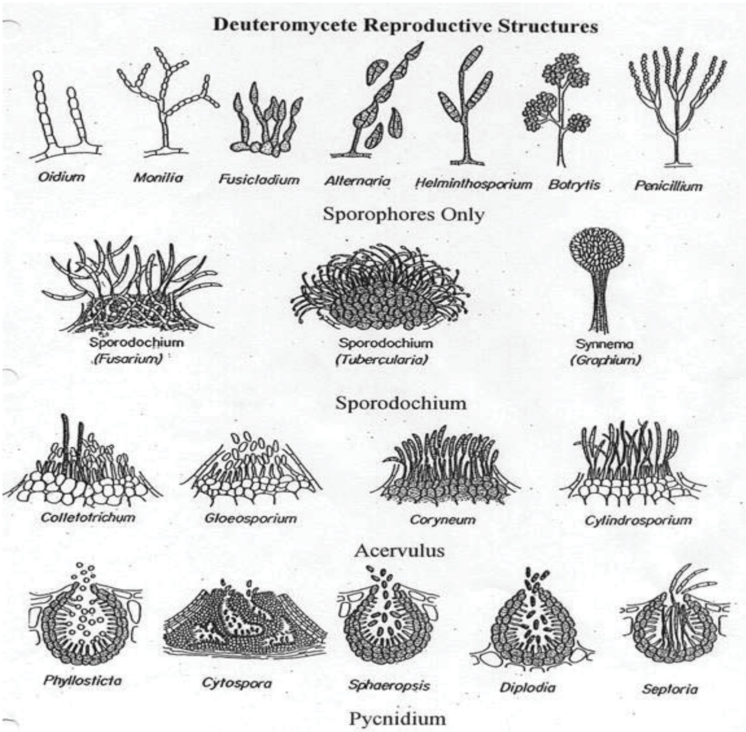

Figure 98: Structures of deuteromycetes genera.

Fungus-like protists

Division: Gymnomycota

Sub-divition: Plasmodiogymnomycotina

Class: Myxomycetes

The true slime molds, or plasmodial slime molds, containing about 500 described species. These organisms exhibit phagotrophic nutrition.

General characteristic of Myxomycetes:

1. Free-living multinucleate, naked, acellular protoplasmic mass called plasmodium represents the thallus.
2. The entire plasmodium organized in one or more plant like fruiting bodies called sporangia.
3. The somatic phase are represented by the plasmodium is the holocarpic, free living and active.
4. The spore wall differentiated into two layers, the outer of which is sculptured or spiny.
5. Spores germinate to giving biflagellte swarm cells, which function as gamets.
6. The sexual reproduction is isogamous type.

Class Myxomycetes contains 2-3 subclasses, containing much order from which Physarales, Stemonitales, and Ceratiomyxales.

Orders distinguished based on

1. Sporophore development
2. Type of sporophore produced
3. Method of spore production
4. Spore color
5. Presence or absence of special thread-like structures collectively known as capillitium (pl. capilitia; L. capillus = hair)
6. Calcium (often called "lime") content of the sporophore, and
7. Plasmodium type

Characteristic myxomycetes Spores

1. Liberated from their sporophores by wind, water and the activities of animals, including arthropods
2. Generally globose with a definite, rather thick wall, the surface of which may be smooth, punctate, spiny, warty, and reticulate or areolate relatively little information is available on the composition of the myxomycete spore wall.
3. Mature myxomycete spore typically contains a single haploid nucleus.
4. Color of the spores in mass may be pallid, yellow, rosy, purple, olivaceous, gray, deep violet, brown, or black. The pigments are dilute so that individual spores, when viewed under strong transmitted light, will not show the same color as the mass of spores; spore characteristics are extremely important in the taxonomy of myxomycetes at several taxonomic levels; size, shape and color, spore ornamentation is also important.
5. Spores of some myxomycetes appear to be exceptionally resistant to unfavorable conditions, especially prolonged periods of desiccation which few other organisms are able to withstand; some spores are capable of germinating after 75 years of storage in a herbarium .
6. Spores dispersal: spores of myxomycetes are small (4-20 μm) and are easily picked up by air currents, arthropods and other animals.

Life cycle of myxomycetes

1- Spore Germination, Myxamoeba, and Swarm Cells.

a) In nature, myxomycete spores probably germinate in rainwater.
b) When a spore germinates, one or more myxamoebae or flagellate cells known as swarm cells emerge.
c) Whether myxamoeba or swarm cells emerge from germinating spores depends to some extent on environmental conditions. If spores suspend in water, the emerging cells are often flagellate from the very beginning. Sometimes, however, a myxamoeba will issue from the spore, remain quiescent for a few minutes, and then either develop flagella and become a swarm cell or begin to divide repeatedly, resulting in

a large population of myxamoeba that may or may not be converted to swarm cells. Swarm cells themselves are not capable of division. However, they readily convert to myxamoebae following retraction of their flagella.

d) After a period of motility, the swarm cell eventually withdraws its flagella, thus changing into a myxamoeba. Myxamoebae, like swarm cells, are capable of ingesting food particles.

2- Formation of Zygotes and Plasmodia

a) Swarm cells and myxamoeba may function as gametes and in heterothallic strains; they eventually fuse in pairs (two swarm cells, two myxamoebae or possibly one of each) karyogamy takes place to form a zygote.

b) The diploid zygotic nucleus undergoes many mitotic divisions to form a multinucleate plasmodium having diploid nuclei.

3- Sporulation and Sporophores

a) Entire plasmodium of a myxomycete usually converted into one or more fruiting bodies or sporophores so that the somatic and reproductive phases seldom coexist in the same individual. Whatever happens in a plasmodium that causes it to sporulate appears to be irreversible, for once; a plasmodium reaches the fruiting stage it cannot induce to resume growth.

b) Many uninucleate haploid spores are formed, and thus the life- cycle is completed (Figure 99).

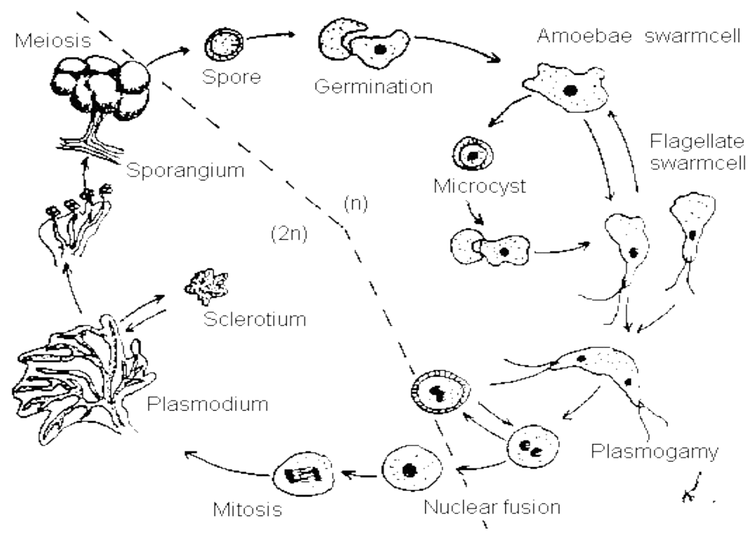

Figure 99: Life cycle of *myxomycetes.*

Basic types of plasmodia

1. **Protoplasmodium** - Microscopic throughout its existence; gives rise to only a single sporangium when it fruits.
2. **Aphanoplasmodium** - Resembles a protoplasmodium in its initial stages, but soon elongates, branches, and becomes a network of very fine, transparent strands; Stemonitales.
3. **Phaneroplasmodium** - It resembles a protoplasmodium at first; it grows larger and becomes more massive. Its protoplasm is very granular, and the plasmodium is visible even at an early stage of development. The gelified and fluid portions of the veins are easily distinguishable and the rhythmic, reversible streaming is very conspicuous.

Types of sporophores

1. Plasmodium forms numerous individual stalked or sessile sporangia. Each sporangium has a peridium of its own. There also may be a thin, cellophane-like base, the hypothallus, from which the sporangia arise; each sporangium is independent of all the others in the group.
2. Second type of sporophore is the aethalium, large, generally cushion-shaped sporophore that derived from an entire plasmodium that has not differentiated into individual sporangial units.
3. Third type of sporophore is the pseudoaethalium; in this structure, a group of sporangia is crowded together to form what appears to be a single sporophore. The individual sporangia are clearly distinguishable, however, and are by no means fused.
4. Fourth type of sporophore, the plasmodiocarp, is similar to a stalkless sporangium, but differs in that it retains, to a certain extent, the morphology of the plasmodium. In the formation of the plasmodiocarp, the protoplasm accumulates in some of the main veins of the plasmodium and develops into a sporophore that more or less retains the shape of the plasmodial venation at the time of fruiting. It is very difficult to draw the line between the sessile types of sporangia and short plasmodiocarps. These two forms actually merge into one another and might be side by side in the same group of fructifications, developed from a single plasmodium (Figure 100).

Sclerotia formation in myxomycetes

In the normal course of events, the plasmodium gives rise to sporophores. Under certain conditions, however, a phaneroplasmodium converted into an irregular, hardened mass, the sclerotium that can remain dormant for a long time, but grows out into a plasmodium again when conditions favorable for growth return.

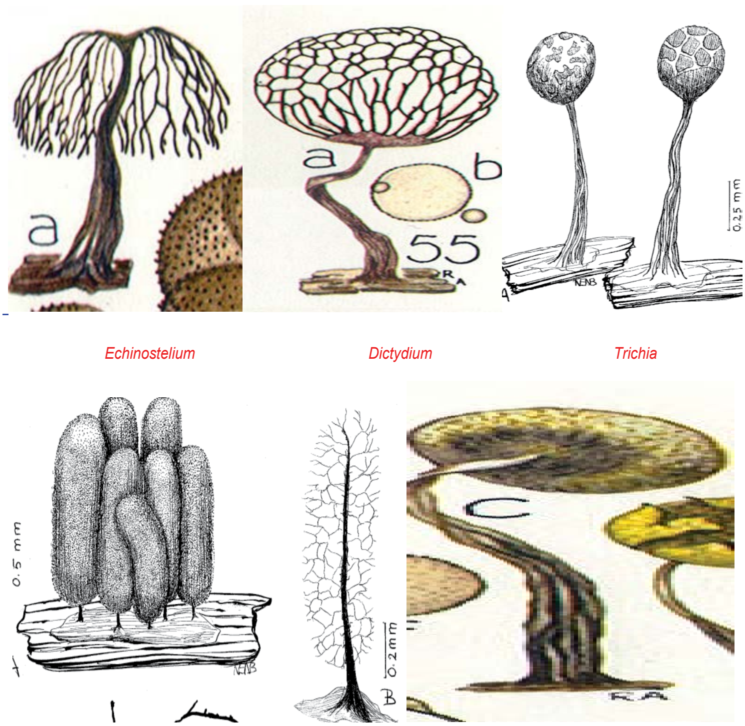

Figure 100: Types of sporophores.

Division: Oomycota

Class: Oomycetes

Oomycetes have assigned the name (water molds) by several investigators.

General characteristics of Oomycetes:

1. Although Oomycetes ocure in variety of habitats, a majority of them are aquatic fungi, and a live parasitically on algae, water molds, aquatic insects and other animals as well as plants, some higher forms grow in the soil, e.g. Some Saprolegniales and Peronosporales
2. The mycelium is well-branched, filamentous coenoytic and grown abundantly in the substratum, however, some Oomycetes are unicellular
3. The cell wall shows the presence of celloulose, which is very rare in most the other fungi.the chitin is mostly absent
4. A majority of Oomycetes are eucarpic, i.e develop reproductive bodies in some parts of the thallus
5. Zoospores are produced by almost of all Oomycetes
6. The zoospores produced inside zoosporangium
7. Many Oomycetes produce only the kind of zoospores, which germinate directly into new fungus, such species called monoplanetic and this phenomenon called as monoplanetism
8. Many Oomycetes produce non-motile asexual spores, generally at the tip or side of unbranched hyphae
9. Sexual reproduction is Oogamous-taking place by gametangial contact, and results in the formation of thick walled reting spore or oospore
10. Alexopoulos and Mims (1979) mentioned that meiosis, in all the Oomycetes
11. The life cycle in a majority of Oomycetes is haplobiontic –diploid

Classification

Although, based on their general morphology and lifestyles, this group was traditionally classified as fungi, a cladistic classification based on modern insights, supports a relatively close relationship with the photosynthetic organisms such as brown algae and diatoms, within the eukaryotic group - the heterokonts. This relationship supported by a number of observed differences in the characteristics of oomycetes and fungi. For instance, the cell walls of oomycetes are composed of cellulose rather than chitin and generally do not have septations. In addition, in the vegetative state they have diploid nuclei, whereas fungi have haploid nuclei. Oomycota spores have two flagella, while fungi spore, which retain flagella (such as the Chytridiomycetes) have only one. Oomycota and fungi have different metabolic pathways for synthesizing lysine and have a number of enzymes, which differ.

Pathogenicity

The oomycetes are economically and scientifically important because they are aggressive plant pathogens. Some species can cause disease in fish. The majority of the plant pathogenic species classified into three groups, although more exist

Saproleginales

- It was known as water molds
- Mostly saprophytes some are parasites (e.g. *S. parasitica* on salmon)
- Large diameter hyphae; profusely branched; coenocytic
- Several oospores/oogonium
- Mostly eucarpic, some holocarpic; hermaphroditic & homothallic
- Morphology of sexual stages used to delimit species
- Asexual reproduction; long cylindrical terminal zoosporangia; sporangium morphology and zoospore release are used to delimit genera
- Zoospores primary and/or secondary, mono- or dimorphic; mono-, di- or polyplanetic

Asexual reproduction:

It takes place by means of biflagellate zoospores produce din club-shaped ore pear – shaped zoosporangia develop at the tips of the hyphae.the hyphal tips are somewhat pointed as shown in the Figure 101.

The cytoplasm with nuclei get accumulated at the hyphal tips which sepreated by a septum. Cleavege of cytoplasm takes place producing uninucleate pices of cytoplasm sporangium the zoosperes are liberated by the breaking of the sporangium giving pear-shaped uninucleate with two apically flagella.one flagellum is whiplash type wheres the anthor is of tinsel type each zoospore also bear a contractile vacuole. These zoospores also called as primary zoospores.

The primary zoospores keep on swimming in the surrounding water for less than one min to over one hr in different species. After the swimming period is over the zoospores withdraw their flagella and become non-motile. The cytoplasm of each deflagellated zoospores gets surrounded by distinct firm membrane.these zoospores now undergo a resting period of 2-3 hr.After the resting period is over this encysted primary zoospores germinate to release a new secondary zoospore.

Structurally the secondary zoospore is different from that of primary zoospore. Its shape is variable and shows amoeoid changes, in general the attached flagella the primary zoospore are pear-shaped bodies having apically attached flagella.

The secondary zoospores kep on swimming for several hours, after some time they stop swimming withdraw their flagella get enclosed by a distinct firm membrane and assume almost spherical shape these encysted secondary spores may now called secondary cyst. Each secondary cyst germinates by producing a germ tube (Figure 101).

Saprolegnia and phenomenon of diplanetism:

Saprolegnia is dimorphic because it produce two types of zoospores in succession i.e, primary and secondary zoospores. The phenomenon of successive production of two types of zoospores by a single organism called diplanetism. A dimorphic species in which two swimming periods occur, called diplnetic.

Saprolegnia is diplanetic because of the presence of two sepreate motile stages in the asexual reproduction .according to Alexopoulos and mims (1979) diplanetism is the rule in *Saprolegnia*.

Sexual reproduction:

The sexual reproduction (Figure 102) is oogamous. A majority of species are homothallic or monoecious where few species are heterothallic or dioecious. Life cycle description as in the following:

1. Oogonium: Usually the oogonia are globose but in some species they are oblong .at maturity a septum separates the oogonium from the remaining vegetative hypha. The oogonia remain surrounded by a smooth thick wal, but in some species the wall may be spiny or papillate. The oogonia develop singly and terminally but rarely they also intercalary multinucleate oogonium gets cleaved into a number of uninucleate oospheres or eggs usually the oospheres are 4-10 in an oogonium but rarly they may reach up to 32. Each oospere is dark, uninucleate, and contain a single large or many small oil globules .there is no periplasm.the oogonium starts to develop by the swelling of the tip of a hyphal branch. The swollen portion ultimately becomes aspherical or globose. Many nuclei of of the hypha along some cytoplasmic contents migrate into this swollen portion, which finally gets seprated by septum. In the multinucleate swollen ooonial portion, the nuclear divisions continue for some time.accordigly meiosis takes place in the oogonium and thus the oospheres in the oognium are haploid. After some time many nuclei degenerate except those which are included in the formation of the eggs. Cleavge furrows start to develop from the central vacuole region of the oogonium and strat to radiate outwards. Many uninucleate portions thus formed and they ultimately become round and function as eggs or oospheres.

2. Antheridium: The antheridia are ultinucleate elongated and smaller than oogonia usually they develop from the some hyphal branch, which bears the oogonium, but they may also develop on a different hyphal branch of the same thallus. In S. Litoralis, the antheidial branch develops from the oogonial stalk showing androgynous condition. If the antheridia develkop on different hyphal branches, they are called diclinous. The mature antherdia becomes attach to the oognium and each of them delimited by a septum. Each antheridium is multinucleate, tubular and elongated body filled with dense cytoplasmic contents. Formation of well-organized sperms is absent in *Saprolegnia*, many haploid gamete nuclei are formed in the antheridium by meiosis.

3. Fertilization: Just before fertilization, one or more antheridia become closely, attached to the oogonial wall. At the point of contact, atube originates from the antheridium and penetrates into the oogonium. This is called fertilization tube inside the oogonium the fertilization tube may give out some smaller branches one each for each oosphere. If more than one antheridium is in contact with the oogonium, one fertilization tube approaches only one oosphere. Through the fertilization tube, the many male nuclei migrate from the anthor towards oosheres. A male nucleus enters into each oosphere, come near the female nucleus, plasmogamy and karygamy take place and a diploid zygotic nucleus is formed. A thick wall now develops a round each oosphere, thick walled oosphere having diploid zygotic nuclus (Oospore).

4. **Oospore** enters in the resting period, after this period is over the oogonial wall disintegrated and the oospores are liberated. Each oospore germinates to giving new mycelium.

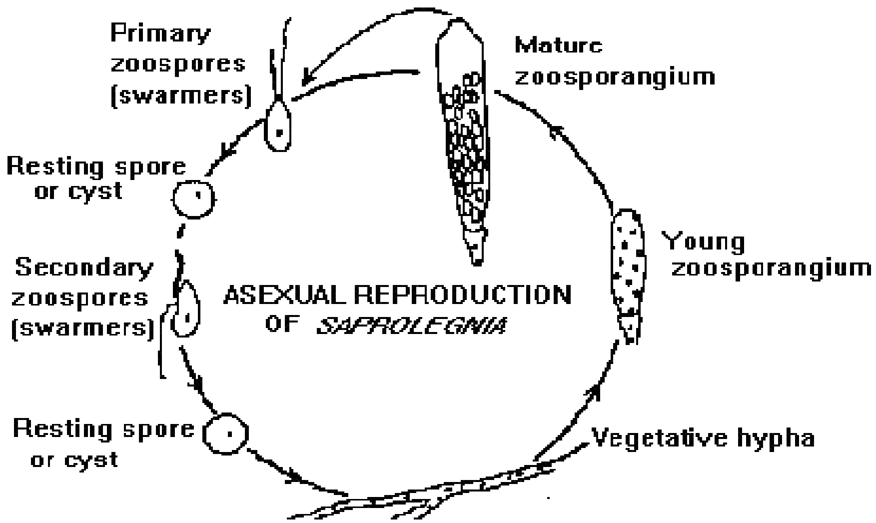

Figure 101: Asexual reproduction in *Saprolegnia*.

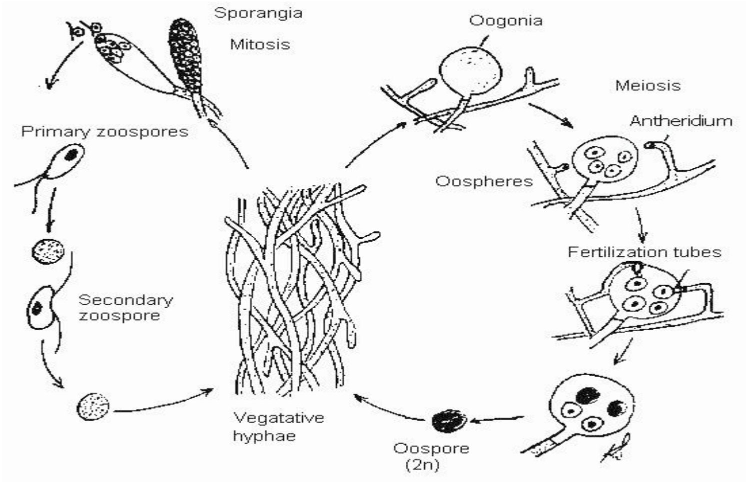

Figure 102: Sexual reproduction in Saprolegnia.

Order Peronosporales

- Considered most advanced group of Oomycetes
- Aquatic, amphibious, terrestrial, eucarpic
- Some of the most destructive pathogens
- Zoosporangia; one or few discharge pores, with or without papillae
- Zoospores only secondary
- Containing three families: 1. Pythiaceae (*Pithium*, *Phytophthora*),

  2. Peronosporaceae (*Plasmopara)* and

  3. Albuginaceae (*Albugo*)

Peronosporaceae

Family of Peronosporaceae also known as water moulds that include 17 genera, contain with more than 600 species. Most of Peronosporaceae species cause downy mildew disease of plants particularly dicots, and therefore they called as downy mildews. The closest relative of Peronosporaceae is *Phytophthora.* Peronosporaceae are obligate biotrophic plant pathogens. They parasitize their host plants as an intercellular mycelium using haustoria to penetrate the host cells. The downy mildews reproduce asexually by releasing sporangia or conidia. These collectively referred to as Conidiosporangia. Sexual reproduction takes place in this family with the formation of oospores. Some downy mildew genera have a more restricted host range fore example:

Basidiophora, Paraperonospora, Protobremia and Bremia on Asteraceae

Perofascia and Hyaloperonospora almost only on Brassicaceae

Viennotia, Graminivora, Poakatesthia, Sclerospora and Peronosclerospora on Poaceae

Plasmoverna on Ranunculaceae

On the other hand, largest genera*, Peronospora and Plasmopara*, have a very wide host range.

Pythiaceae

Pythiaceae is family of water moulds. The family includes plant pathogenic fungus-like organisms in the genus *Phytophthora* as well as serious plant and animal pathogens in the genus *Pythium.*

Phytophthora

Phytophthora (Figure 103) is a genus of plant-damaging Oomycetes (water molds), whose member species are capable of causing enormous economic losses on crops worldwide, as well as environmental damage in natural ecosystems. *Phytophthora spp.* is mostly pathogens of dicotyledons, and is relatively host-specific parasites. *Phytophthora infestans* was the infective agent of the potato blight. Albuginaceae *Ex. Albugo*

Albugo (Figure 104) is a genus of oomycetes, which are not true fungi (Eumycota), although many discussions of these organisms still treat them as a fungus. The taxonomy of this genus is incomplete, but several species are plant pathogens. *Albugo* is one of three genera currently described in the family Albuginaceae, the taxonomy of many species is still in flux. This organism causes white rust or white blister diseases in aboveground plant tissues. While these organisms affect many types of plants, the destructive aspect of infection is limited to a few agricultural crops *(Albugo candida*, White rust of several Brassicaceae) [7].

Figure 103: *Phytophthora.*

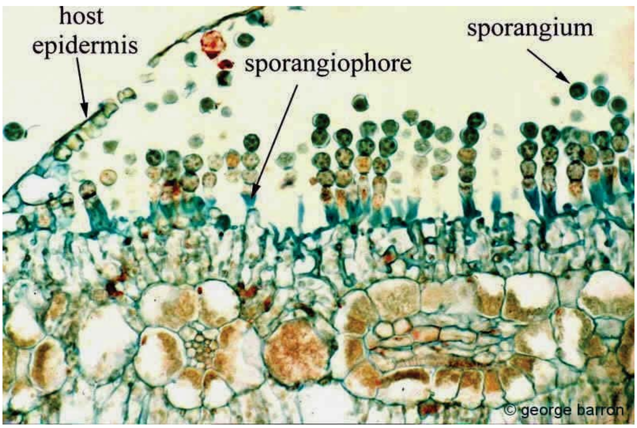

Figure 104: *Albugo.*

Symbiotic Relations between Fungi and Other Organisms

Lichens

A symbiosis between a photosynthetic organism (an alga or cyanobacterium) and a fungus (either an ascomycete or a basidiomycete) called as *lichens*. *Lichen* often lives in marginal habitat and often grows only one or two centimeters per year. Historically this symbiosis has considered an example of mutualism, where their association harms both organisms benefit and neither.

Lichens recognized as useful organisms for humans. Certain species of *lichen*, now recognized as bioindicators or biosensors of environmental pollution, other types of *lichens* been used to make natural dyes by indigenous poeople, or even to make poison-tipped arrowheads. Deu to they often live in marginal environments, lichens have had to develop chemical defenses, making them prime targets for natural antibiotic research. One estimate places half of lichen species as possessing some sort of antibiotic chemicals. Soe *lichen* is even edible, although many others are harmful if eaten, so extreme caution should use if investigating edible fungi.

Reproduction

Fungal component of *lichen* usually reproduces sexually, but *lichens* naturally dispersed in nature asexually. Sexual reproduction in lichens is similar to that of the sac fungi except ascomata produce spores continuously for many years (Figure 105).

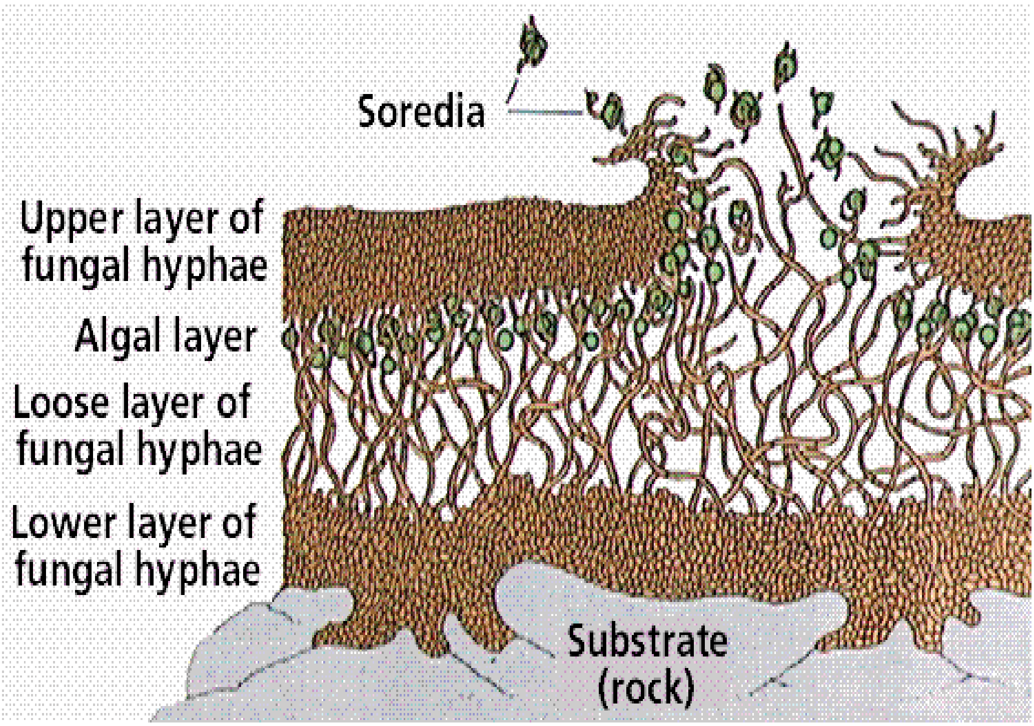

Figure 105: Structures of *lichen.*

Usually lichens grouped into three major growth forms:

Crustose: attached to or embedded in their substrate over their entire lower surface.

Foliose: contain leaf-like thalli, which often overlap.

Fruticose: may resemble miniature, upright shrubs or hang down in festoons from branches (Figure 106).

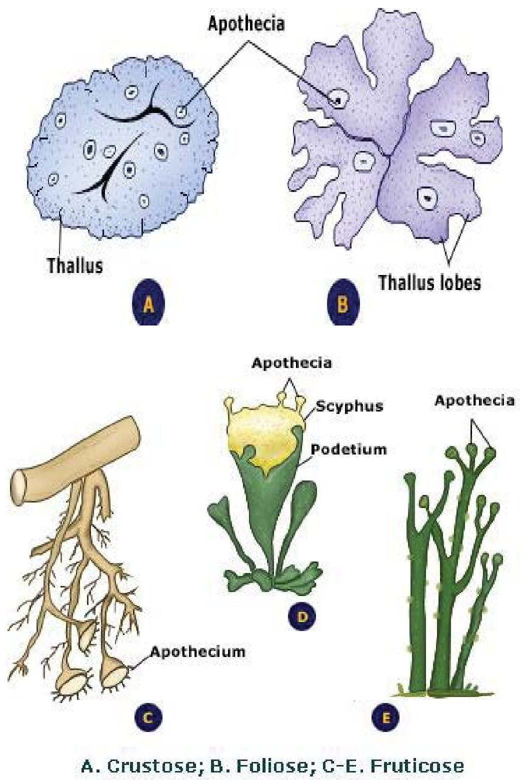

Figure 106: Growth forms of *lichen*.

Mycorrhizae

Mycorrhizas are symbiotic associations essential for one or both partners, between a fungus (specialised for life in soils and plants) and a root (or other substrate-contacting organ) of a living plant, that is primarily responsible for nutrient transfer. The plant provides the fungus with products of photosynthesis (sugar). Many plants do not do well or do not grow at all without the fungi. Approximately ninety percent of all plants develop mycorrhizae (Figure 107A & 107B).

Characteristics of mycorrhizae summarized in the following:

1. The structure and development of mycorrhizal fungus hyphae substantially altered in the presence of roots of host plants. These root-borne hyphae are distinct from hyphae, which are specialised for growth in soil.
2. The primary role of mycorrhizas is the transfer of mineral nutrients from fungus to plant. In most cases, there also is substantial transfer of metabolites from the plant to fungus.

3. All mycorrhizas have intimate contact between hyphae and plant cells in an interface where nutrient exchange occurs.
4. Mycorrhizas require synchronised plant-fungus development, since hyphae only colonise young roots.
5. Plants control the intensity of mycorrhizas by root growth, digestion of old interface hyphae in plant cells.

Ectomycorrhizal Fungi

Ectomycorrhizal fungi form a dense network of hyphae around plant roots. The hyphae may penetrate the root, but they do not penetrate the root cells. Ectomycorrhizal fungi are common in cool, northern climates.

Ectomycorrhizal fungi described as the “dominant nutrient-gathering organs in most temperate forest ecosystems” because nearly every tree in temperate and northern forests forms these associations with fungi.

Arbuscular Mycorrhizal Fungi

The hyphae of arbuscular mycorrhizal fungi (endomycorrhizal fungi) penetrate the plant root cells. The portion of hyphae within the plant cell forms a highly branched structure called an arbuscule, which aids in the transfer of nutrients between the two species.

Fungal hyphae seen in the cells of these orchid roots (below), they extend into the soil and absorb water and minerals for the plant. The plant provides the fungus with sugar.

Arbuscular mycorrhizal fungi are common in grasslands and tropical ecosystems. They found in eighty percent of all terrestrial plants.

Populations of arbuscular mycorrhizal fungi in the Glomeromycota thought to have occupied the same soil habitats for millions of years, slowly adapting to changes in site conditions. The classification of the Glomeromycota based on the structure of their soil-borne spores and DNA sequences. Accurate identification of these fungi often requires them to be isolated in cultures with host plants, to observe developmental stages, avoid the loss of diagnostic features and obtain healthy spores for DNA extraction.

Classification scheme for Glomeromycotan taxa (Table 3)

I.Archaeosporales

a Ambisporaceae
b Archaeosporaceae
c Geosiphonaceae

II.Diversisporales

a Acaulosporaceae
b Entrophosporaceae
c Diversisporaceae
d Gigasporaceae
e Pacisporaceae

III.Glomerales

a Glomeracea

IV.Paraglomerales

Paraglomeraceae

Family	Genera
Acaulosporaceae	Acaulospora, Kuklospora
Ambisporaceae	Ambispora

Archaeosporaceae	Archaeospora, Intraspora
Diversisporaceae	Diversispora
Entrophosporaceae	Entrophospora
Geosiphonaceae	Geosiphon (not a mycorrhizal fungus)
Gigasporaceae	Gigaspora, Scutellospora
Glomeraceae	Glomus (Sclerocystis)
Pacisporaceae	Pacispora
Paraglomeraceae	Paraglomus

Table 3: List of genera of Glomeromycotan families.

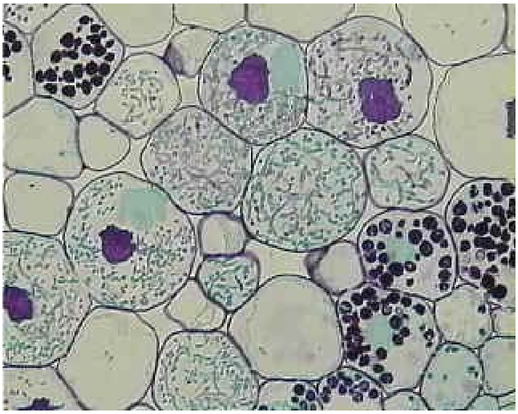

Figure 107a: Plant cells clonized with mycorrhiza.

Figure 107b: Developing arbuscule of *Glomus mosseae* in a root cell with fine branch hyphae (arrows).The trunk (T) of this arbuscule branched from an intercellular hyphae.

Endophytic Fungi

Endophytic fungi are a group of fungi, which live asymptomatically inside plant tissues. These fungi first noticed in the 1940s, but only at the turn of the 21st century was the ubiquity of these fungi fully recognised. They live like fungi *imperfecti*, much of the time, producing mostly conidial spores or simply cloning them. They are between benign parasites and true symbionts in their behaviour. Endophytic fungi become rotting agents upon the death of their host plant. Sometimes they may produce toxins in response to pests, which feed on their host's tissues. These toxins benefit the host plant. For example, there are endophytes, which make grass poisonous to grazing animals. Other endophytes, in oak leaves, ward off gall midges. In the sense that these 'endophytes' can protect their host, they are symbionts. Endophytes are low-key examples of symbiosis Endophytes belong to several fungal taxonomic groups, but most are ascomycetes. Many of the needles, cast fungi (e.g. *Phomopsis spp.* & *Lophoderma spp.*), have endophytic relatives. Even some of the leaf spot diseases (e.g. *Rhytisma spp.*) have endophytic relations. Most of the endophytes that infect pines are members of the Rhytismataceae family. Since there are rhytismataceous parasites, mycologists have wondered if endophytes are not just the old familiar parasites in dormancy mode. Genetic studies show that the rhytismataceous endophytes are not the same as their pathogenic cousins. They are members of the same genera, but they are not identical species. Endophyticity seems to be a niche different from parasitism. Possibly this mode of life developed from true parasitism [8,9].

In theory, parasites can evolve to become ever more benign to their host. If a parasite does not harm its host, it has a more secure food supply than if it weakens the host. Severe plant diseases may often be due to parasites in novel hosts. Novel hosts may lack resistance to the 'new' parasite. In the end, both host and parasite may co-evolve into an asymptomatic relationship. Probably a fungus would evolve quicker than a long-lived tree. Highly virulent strains of a parasite would have an initial advantage in its new frontier. The advantage would become a detriment after the contagion's food supply consumed. Natural selection would then favour the less virulent strains of the parasite. This co-evolution seems to have happened in many cases. Dutch elm disease (*Ceratocystis novo-ulmi*) was relatively benign in Asian elms. However, when it reached Europe and the Americas, it encountered hosts, which were not equipped to deal with the fungus. Similarly, the potato blight (*Phytophthora infestans*) is relatively harmless to the potatoes of the Andes. When potatoes were cultivated in Europe, they lost their tolerance of the fungoid. When the fungoid introduced to Ireland in the 1840s, the results were devastating. There are many other examples of diseases, which only become problems for host species, which have not co-evolved mutual tolerance.

Glossary of terms

Acervulus: A mat of hyphae bearing short conidiophores packed closey together

Achlorophyllous: lacking chlorophil

Aflatoxins: A group of carcinogenic mycotoxins produed by some species of *Aspergillus*

Agaric: Common name for any member of the order Agaricales (Basidiomycota)

Anastomosis: Fusion between hyphae

Agaric: Common name for any member of the order Agaricales (Basidiomycota)

Anastomosis: Fusion between hyphae

Antheridium (a): Male gametangium

Aplanospore: A non-motile spore

Apothecium (a): Open, cup-shaped ascocarp produced by some species belonging to Ascomycota

Arbuscules: Minute, Minute, tree-like hyphal branching structures produced within host plant cells by arbuscular mycorrhizal fungi

Arbuscular mycorrhizas: Mycorrhizas formed by fungi belonging to the Glomeromycota

Arthrospore: Asexual spore formed by the septation and fragmentation of a hypha

Ascocarp: Fruiting body of fungi belonging to the Ascomycota, bearing asci

Ascogenous hyphae (e): A dikaryotic hypha emerging from an ascogonium after fertilization, which gives rise to asci in fungi belonging to the Ascomycota

Ascogonium (a): Female gametangium in fungi of the Ascomycota, which contains cells that are fertilized during sexual reproduction

Ascospores: Sexual spores of fungi belonging to the Ascomycota, borne in asci

Ascostroma (ta): An ascocarp bearing asci directly in cavities within a compact mass of hyphae.

Ascus (i): Cell(s) containing ascospores in fungi of the Ascomycota

Asexual reproduction: Reproduction NOT involving karyogamy and meiosis

Basidiocarp: Fruiting body of fungi of the Basidiomycota, bearing basidia

Basidiospores: Sexual spores of fungi belonging to the Basidiomycota

Basidium (a): Enlarged terminal cell of a hypha, bearing basidiospores

Bioremediation: The use of microorganisms to remove or detoxify toxic or unwanted chemicals in an environment

Biotrophic: Obtaining nutrients from living host cells without killing them

Blastic conidium: Conidium arising from a yeast cell or hypha because of elongation and swelling before separation by a septum

Chemostat: Apparatus used in a continuous culture system

Chlamydospore: Thick-walled, melanized thallic conidium that develops from an existing hyphal compartment and that functions as a resting spore

Cleistothecium (a): Thick-walled, melanized thallic conidium that develops from an existing hyphal compartment and that functions as a resting spore

Cleistothecium (a): A completely closed fruiting body formed by some fungi of the Ascomycota, contating asci.

Colony: A group of individuals of the same species living in close association; for fungi, usually refers to a group of many yeast cells or a mycelium originating from a single point, cell or spore

Columella (e): A curved cross-wall extending from the tip of a sporangiophore into the sporangium

Conidiophore: A hypha-giving rise to conidia

Coremium (a): structure of agagregated hyphae bearing conidia at the tips

Dikaryon: A hyphal compartment, mycelium or fungal cell occupied by a pair or pairs of closely associated, genetically different, sexually compatible nuclei

Dolipore septum: Septum with elaborate ultrastructure, found in fungi belonging to the Basidiomycota

Encystment: Formation of a thick wall, e.g. around a zoospore after it settles and loses its flagellum (a)

Extracellular enzyme: An enzyme whose action on a substrate takes place outside the cell's protoplasm

Fairy ring: A ring of mushrooms produced at the edge of an underground mycelium

Fertilization tube: A tube originating from the male gametangium and penetrating the female gametangium; through which the male gametes (nuclei) are transferred

Fruit(ing) body: Large spore-bearing structure produced by species belonging to the Ascomycota and Basidiomycota

Gametangium (a): A structure specialized for the production of gametes during sexual reproduction

Germ-pore: A thinner area of spore wall through which a germ-tube emerges

Germ-tube: An immature hypha emerging from a spore

Heterothallism: The requirement for two compatible mating types for sexual reproduction; self-sterility

Homothallism: A second mating type is NOT required for sexual reproduction; self-fertility

Hymenium (a): The surface of a fruiting body on which sexually produced spores are borne in asci (Ascomycota) or on basidia (Basidiomycota)

Hypha (e): Filamentous structure which exhibits apical growth and which is the developmental unit of a mycelium

Isolate: A strain of a fungus brought into pure culture (i.e. isolated) from a specific environment

Jelly fungi: Term sometimes applied to the Tremellales (belonging to the Basidiomycota)

Karyogamy: The fusion of nuclei, preceding the production of sexual spores

Lichen: A symbiotic association between green or blue-green algal cells and fungal hyphae

Monokaryon: A hyphal compartment, mycelium or fungal cell occupied by nuclei of a single genotype

Mycelium (a): A branching network of hyphae

Mycobiont: The fungal component of lichen

Mycology: The study of fungi

Mycoparasite: A fungus capable of parasitising another fungus

Mycoprotein: Protein of fungal origin, particularly from mycelial species

Mycorrhiza: A symbiotic association between a plant root and fungal hyphae

Mycotoxin: A general term for a toxin produced by a fungus

Myxamoeba: An amoeboid cell, particularly of the Myxomycota

Necrotroph: A fungus that kills the cells of a living host and then utilizes those cells as a source of nutrients

Oidium (a): A form of asexual spore involved in bringing about dikaryotization in fungi belonging to the Basidiomycota

Oogonium (a): A female gametangium

Oosphere: A female gamete within an oogonium

Oospore: A diploid spore produced by species belonging to the Oomycota

Perithecium (a): A flask-shaped fruiting body produced by some species of the Ascomycota; from the neck of which asci are discharged

Photobiont: The algal component of lichen

Pileus: The cap of a mushroomk

Pycnidium (a): A hollow, flask-shaped structure lined with conidiophores bearing conidia

Quorn: The commercial trademark for a range of food products containing mycoprotein

Radial growth: Growth from the centre, e.g. of a fungal colony

Resting spore: A spore with prolonged survival potential, or a spore that is in a state of dormancy

Rhizoid: A fine filamentous structure, which grows into the substrate and anchors the cell or surface mycelium

Saprotrophic: Using dead organisms as a source of nutrients

Septum (a): A cross-wall in a hypha

Sexual reproduction: Reproduction involving karyogamy and meiosis

Sporangiophore: A hypha, which bears a sporangium

Sporangiospore: An asexual spore borne in a sporangium

Sporangium (a): A specialized cell containing sporangiospores

Sterigma (ta): A small outgrowth that supports a sporangium, a conidium or a basidiospore

Stipe: The stalk of a mushroom or toadstool

Synthesis: The creation of complex chemicals from simple ones

Thallic conidia: Conidia formed because of the septation and fragmentation of a hypha

Trehalose: An oligosaccharide from some fungi

Trichogyne: The receptive hypha formed during sexual fertilization in fungi belonging to the Ascomycota

Universal veil: A thin membrane covering certain types of young mushrooms; as the mushroom expands the veil tears and the remnants may form scales on the pileus and comprise the volva

Uredospores: Dikaryotic spores produced by rust fungi (Uredinales)

Volva: A cup at the base of the stipe of certain mushrooms; a remnant of the universal veil

Woronin body: An electron-opaque, spherical, membrane-bound proteinaceous structure found in hyphae of fungi belonging to the Ascomycota and some mitosporic species (formerly Deuteromycota), located near septa

Xerotolerant fungus: A fungus capable of growing on substrates possessing a low water potential, i.e. water activities below 0.85

Yeast: A unicellular fungus that multiplies asexually by budding or fission

Zoosporangium (a): A specialized cell in which zoospores develop, and from which they are released

Zoospore: A motile sporangiospore capable of swimming in water by means of one or more flagella

Zygospore: A spore formed following fusion of two gametangia in fungi belonging to the Zygomycota

Zygote: A diploid cell resulting from the union of two haploid cells followed by karyogamy

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