Discipline Courses-I
Semester-II
Paper III: Mycology and Phytopathology
Unit-V
Lesson: Basidiomycota
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Chapter: Basidiomycota

Introduction

The Basidiomycota contains about 30,000 described species, which is approximately 37% of true Fungi. They include the rusts, smuts, mushrooms, polypores, bracket fungi, puffballs, stinkhorns, etc. Rust (*Puccinia graminis*) and smut (*Ustilago* spp.) cause disease of crop plants and are responsible for serious economic losses. Mushrooms like *Agaricus brunnescens, A.campestris, Volvariella volvacea* etc. are extremely nutritious and are eaten across the world. However Some like *Amanita phalloides, A. verna* etc. are poisonous. Bracket fungi like *Polyporus betulinus P. squamosus* etc. are known parasites of forest trees while some like *P. umbellatus, P.frondosus* are edible.

Figure: A. Rust of wheat; **B.** Smut; **C.** *Amanita muscaria* **D.-E.** *Polypores squamosus*- bracket fungi. **F.** Puff ball- *Lycoperdon pyriforme* **G.** Stinkhorn mushroom - *Phallus rubicundus*

Source:http://upload.wikimedia.org/wikipedia/commons/d/d4/Wheat_leaf_rust_on_wheat.jpg , http://farm5.staticflickr.com/4113/5072178380_e1cc31d54f_o.jpg , http://upload.wikimedia.org/wikipedia/commons/3/32/Amanita_muscaria_3_vliegenzwammen_op_rij.jpg, http://2.bp.blogspot.com/_6GTgPFqKOYk/SuoAX0lWfuI/AAAAAAAAOa0/9Xpkju4CcU8/s400/2009-10-29+Galloway+Park.jpg, http://upload.wikimedia.org/wikipedia/commons/thumb/3/36/Polyporus_squamosus_Molter.jpg/1280px-Polyporus_squamosus_Molter.jpg

http://guildwoodvillagemushrooms.blogspot.in/2009/10/polypores-multicolour-bracket-fungi-or.html, http://farm1.static.flickr.com/90/245227172_bde49b12e8_m.jpg

Ecology

The fungi belonging to the Basidiomycota are mostly terrestrial although a few are marine. The members are important saprophytes, plant pathogens, and, animal pathogens.

Among the saprophytes are the degradative fungi which obtain nutrition from dead decaying organic matter thus breaking down wood and leaf litter thereby also recycling minerals like organic Nitrogen and Phosphorus. Some of these fungi form ectomycorrhiza as symbiotic association with roots of vascular plants. Here, they improve the mineral uptake of the host, while obtaining sugars from their partners.

As pathogenic fungi , they can attack both plants and animals. Plant pathogenic fungi include the rusts and smuts, pathogens of forest trees and soil pathogens of crop plants. They also destroy wood products like timber, railway track ties, poles etc. The same fungi are however also used as decaying agents for cellulose and lignin; as pulping and bleaching agents in Paper Industry!! Animal pathogens are less important, although *Filobasidiella (Cryptococcus) neoformans* can be a serious threat to immunocompromised people.

There are also members which are edible, hallucinogenic and toxigenic fungi. Some are eaten directly for e.g. Mushrooms are eaten in many countries. Of these *Agaricus bisporus*, is by far the most well known, however in the recent times other species have also become appealing to the gastronomes, namely the Shiitake mushroom (*Lentinula edodes*), the oyster mushroom (*Pleurotus* spp.)

Some members produce toxins for e.g. *Amanita phalloides {(death cap)* produces the toxin phalloidin}; *Psilocybe (magic mushroom), Amanita muscaria (fly agaric).*Species of *Psilocybe* are now being cultivated for the hallucinogen it produces.The Basidiomycetous yeast *Phaffia* produces a red pigment astaxanthin, (which is used to add color to farmed salmon). Some wood-decaying Basidiomycota produce certain enzymes that have potential applications in paper production and bioremediation i.e. the decontamination of polluted environments with the help of biological agents.

Characteristic features

The Characteristic features are:

- The group includes both saprophytic and parasitic species.
- Presence of well developed branched septate mycelium having simple or **dolipore septum**.
- Motile spores are absent. The primary mycelial cells contain one nucleus (monokaryotic) while the secondary mycelial cells contain two nuclei (dikaryotic). The secondary mycelia may organize to form the fruit body often called the tertiary mycelium.
- The cell wall is mainly composed of chitin and glucans
- Vegetative reproduction takes place by budding and fragmentation.
- Asexual reproduction takes place by conidia, oidia and chlamydospores. This is lacking in the higher taxa of this group.
- Sex organs are absent. During sexual reproduction a dikaryotic cell is formed by somatogamy, spermatization or by Buller's phenomenon. Karyogamy results in formation of a diploid nucleus in the baisidium mother cell. Four haploid spores are formed by meiosis.

- The basidiomycetes produce complicated fruiting bodies called the basidiocarps. These bear the reproductive structures called **basidia** (sing. basidium).
- The basidium typically bears four spores-basidiospores, exogenously each usually at the tip of a stalk - sterigma.
- Basidium are of two types: Holobasidium (aseptate) e.g. *Agaricus*; and Phragmobasidium (Septate) as seen in *Puccinia, Ustilago.*
- **Clamp connections** are hyphal outgrowths that are formed during reproduction and are unique to Basidiomycota.

Mycelium

Alexopoulos described the somatic structures of this Division in 1952. The mycelium is made up of network of well-developed hyphae, which penetrate into the substratum and absorb nutrition. The hyphae are microscopic as a single unit but they can be seen by naked eye in mass. The hyphae have regular cross-walls i.e. they are septate. The mycelium is usually white, bright yellow or orange in color and often spreads in a circular manner. In some forms a number of hyphae join together to form thick strands of mycelium or aggregates of vegetative hyphae, such as **Rhizomorphs** (root like) or **Mycelial Cords** (shoestring like) or **Sclerotia**. Rhizomorphs are parallel strands growing together but enveloped in a sheath or cortex and behaving as a single unit or tissue. They are often confused with old roots in morphology. The outer part is dark in color and made up of thick walled cells e.g. *Armillaria* (honey fungus). Mycelial cords are formed by hyphae lying parallel to one another. They do not show pigmentation e.g. Ectomycorrhizal fungi- *Phallus impudicus*. Sclerotia are adaptive, perennating structures seen in some forms. They may be loose aggregations or tightly packed differentiated structures formed from colored hyphae packed with food reserves.

The mycelium shows three distinct stages of development. These three stages are the **primary, secondary** and **tertiary** mycelia. The germinating basidiospore produces a thin hypha called the germ tube which develops into a mycelium called the primary mycelium. It may be multinucleate at first, but soon septae are formed which divide the mycelium into uninucleate cells.

At the time of reproduction, the protoplasts of two uninucleate cells of the primary mycelium fuse. However only the protoplasts of the two cells fuse without nuclear fusion, i.e. plasmogamy occurs without karyogamy. Thus a dikaryotic condition begins when a single cell with two nuclei of different mating types is formed. This phase is the dominant phase of the life cycle in most Basidiomycota.Such a cell is called a **dikaryon.** The secondary mycelium originates from this dikaryon.

A dikaryotic mycelium arises from the dikaryotic cell. A special mechanism is required to ensure that sister nuclei arising from the conjugate division of the two nuclei are segregated properly in the two daughter cells. This mechanism functions through special hyphal structures called **clamp connections**. When a dikaryotic cell divides, a short hypha called the clamp connection, arises between the two nuclei a and b and curves towards mycelium forming a hook like structure. The nuclei now divide simultaneously, one pair in the main axis of the hypha, and the other pair towards the clamp, it's spindle becomes oriented obliquely so that one daughter nucleus b forms in the clamp connection and the other b' near the other end of the cell. Simultaneously, the clamp completes its curvature and its free end connects with the cell. The cell wall dissolves at this point connecting the cell with the clamp connection. Thus the clamp forms a bridge and it's through this that one of the daughter nuclei (nucleus b) passes to the other end of the cell and reaches one of the daughter nuclei a of the other spindle. A septum forms to cut off the clamp at the point of its origin and another septum forms in the cell vertically under the bridge to divide the cell into two daughter cells with nuclei a and b in one daughter cell and nuclei a'and b' in the other. This reestablishes the dikaryotic condition and develops dikaryotic mycelium from dikaryotic cell.

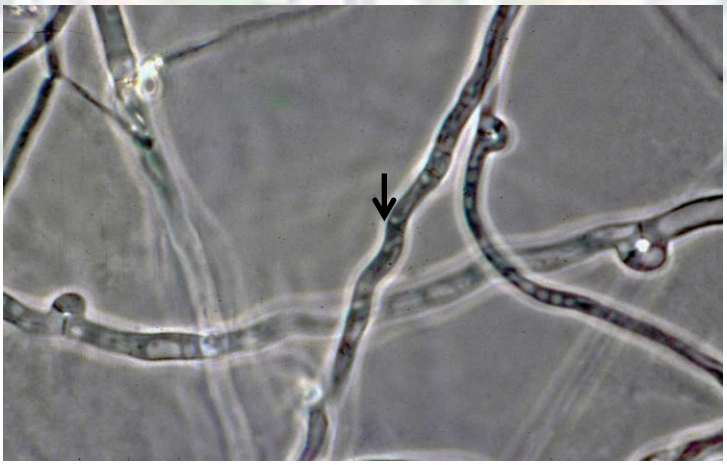


Figure: Clamp connections in Basidiomycetes

Source: https://atrium.lib.uoguelph.ca/xmlui/handle/10214/6926

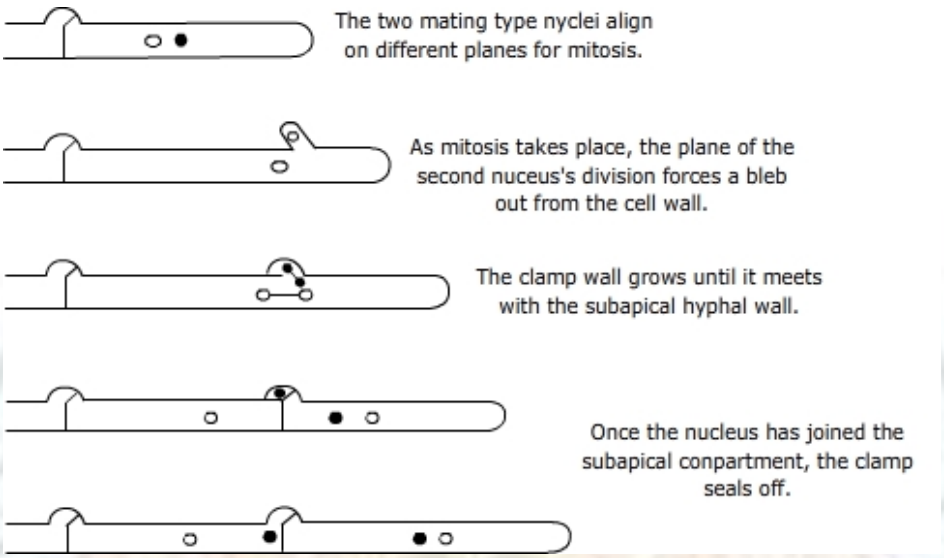


Figure: Diagrammatic representation of nuclear events that occur in clamp connection formation that ensures the maintenance of the dikaryotic condition in some basidiomycetes.

Source: Author

All the fungi that form clamp connections are members of the Basidiomycota, but not all members of the Basidiomycota produce clamp connections.

A characteristic ultrastructural feature of the septae of these fungi is the "**Dolipore Septum**" (Dolipore word comes from Dolium= barrel, cask, large jar). The fungi have septa that have a central pore. In some it has a thickened septal wall near the pore, giving a barrel shape to the pore. This is called the Dolipore septum. The septum often has a membranous overarch formed by endoplasmic reticulum called **Septal Pore Cap** (S.P.C.) or **Parenthosome** (parenthesis= round bracket). In some forms i.e. with holobasidia the S.P.C may be perforated, in others i.e. with heterobasidia it may not be .The pore often shows blockages which are temporary in occurrence. The function of the septum is to allow transport of metabolites and even organelles, and, on the other hand, to maintain cell integrity as and when required. It also cuts off damaged portions of the hypha.

Figure: Dolipore septum (arrow)

Source: http://www.mycolog.com/chapter5a.htm

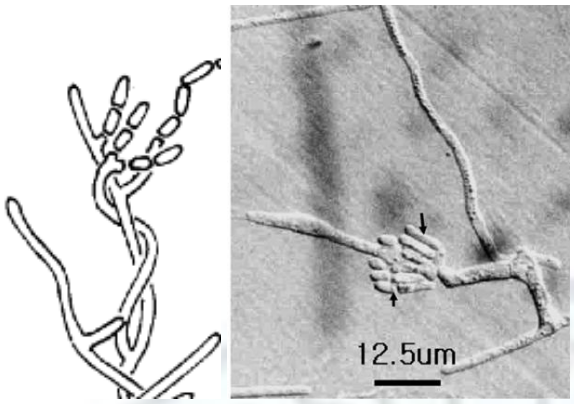
View diagrammatic image:
http://tolweb.org/tolarchive/20531/20030922/tree/ToLimages/Fig4_small.jpg

Reproduction

Asexual reproduction

Asexual reproduction takes place by a number of methods.

1) **Oidia**: They are also called Arthroconidia. They are uninucleate, unicellular, cylindrical structures formed at the tip of short, erect, branched or unbranched hyphae called oidiophores. They may develop on monokaryotic or dikaryotic mycelium. They may be dry and disperse by air currents e.g. *Flammulina velutipes* or they may be wet, in clusters and disperse by insects or water e.g. *Coprinus cinereus*.



A **B**

Figure: Arthroconidia (oidia) of **A.** *Flammulina velutipes* **B.** *Coprinous cinereus*
Source: http://synapse.koreamed.org/ArticleImage/0184MB/mb-32-164-g008-l.jpg

They germinate by forming 1 or more germ tubes and give rise to new mycelium. They can also function as spermatizing agents.

2) **Conidia**: Conidia develop at the tip of erect branches called conidiophores. They may be formed singly, successively or in groups. They may be unicellular or multicellullar, dry or wet. They may develop on monokaryotic or dikaryotic mycelium. They are of various sizes and shapes.
3) **Chlamydospores**: They are perennating spores, which can give rise to new mycelium when favorable conditions return. They may terminal or intercalary in position. A cell increases in size , stores cytoplasm, secretes a thick wall which is often dark in color and becomes a chlamydospore. It is released when the adjacent cells collapse.

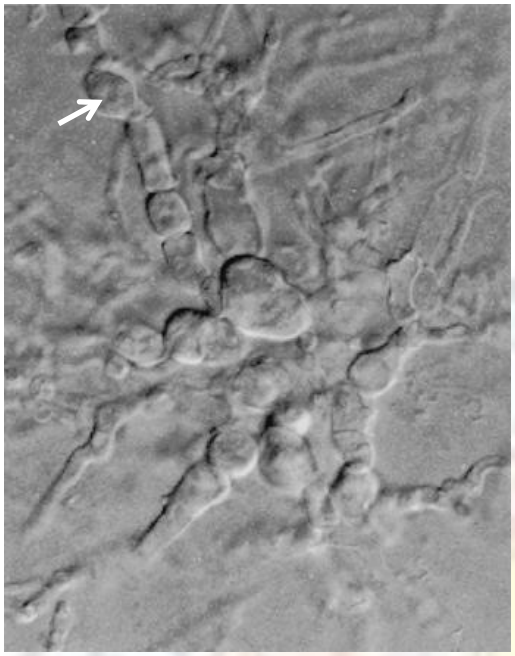


Figure: Young chlamydospores of *Coprinus cinereus*

Source:http://mmbr.asm.org/content/64/2/316.figures-only?related-urls=yes&legid=mmbr;64/2/316

Sexual reproduction

The process of sexual reproduction can be divided into three events i.e. **plasmogamy, karyogamy** and **meiosis**.

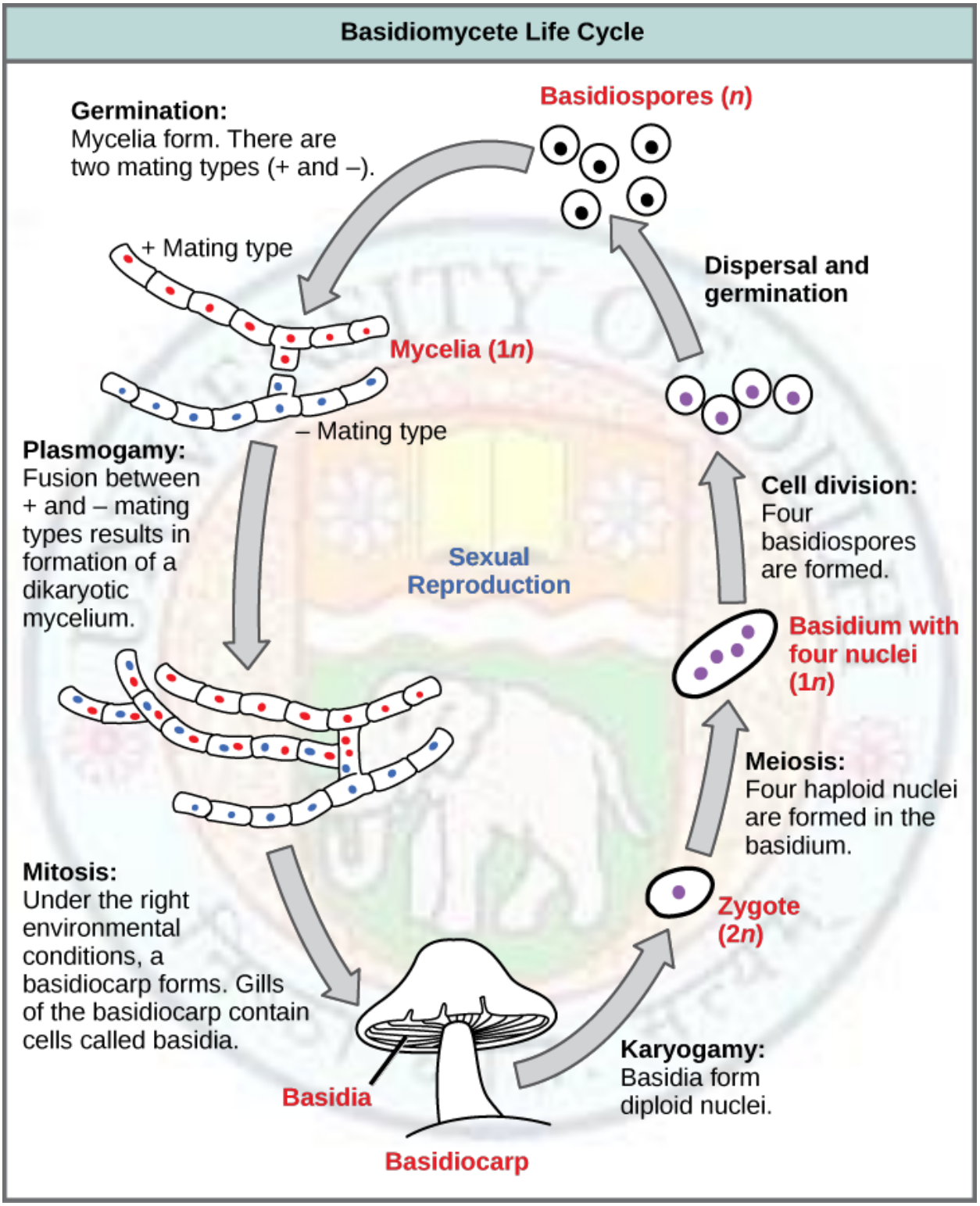


Figure: Life cycle of a typical basidiomycete. The haploid basidiospores germinate to form monokaryotic primary mycelium. The mycelia of different mating types (in heterothallic species) combine to form the dikaryotic secondary mycelium. The secondary mycelium

forms a basidiocarp- the fruiting body. The basidiocarp contain the cells called basidia where fusion takes place forming diploid nuclei that undergo meiosis to form four haploid basidiospores therby completing the life cycle.

Source: http://cnx.org/content/m44625/latest/

In the Basidiomycetes, like the Ascomycetes, these three events do not occur in succession as in the lower fungi. Plasmogamy is not immediately followed by karyogamy and meiosis. This causes there to be a stage where the" fusion cell "contains cytoplasm of both the parents and two nuclei. Since the two nuclei are of different origins this cell is called **dikaryotic** and not binucleate. In the Ascomycetes, this is a short lived stage, but in the Basidiomycetes it is long lasting, forming not just a dikaryotic cell but a dikaryotic mycelium.

Plasmogamy usually occurs early in the life cycle and forms the dikaryotic mycelium (secondary mycelium), which spreads and forms the tertiary mycelium or the fruiting body. Plasmogamy occurs by fusion between any two cells of compatible strains i.e. **Somatogamy** in most members. The fusing cells maybe vegetative cells of two hyphae of opposite strains, two basidiospores of opposite strains; a germinating basidiospore and a haploid cell of a basidium etc. However in the Rust fungi it occurs by **Spermatization i.e.** fusion of a spermatium or oidium and a cell of a primary mycelium of opposite strains.

The members of Basidiomycetes may be **Homothallic** (10%) or **Heterothallic** (90%). Heterothallism may be coded by a single gene pair or two or more. It is then called **unifactorial** or **bifactorial,** or **multiple allelic** type of heterothallism.

The tertiary mycelium occurs as complex, specialized tissue and forms the Basidiocarp or the fruiting body. The pathogenic rusts, smuts, and yeasts do not form the basidiocarps, but other members do. The basidiocarps may be microscopic or macroscopic, ranging in size from a few millimeters to several feet in diameter. They also vary in texture from spongy to leathery, papery, gelatinous, woody, corky etc.

Figure: Fruiting bodies of A. *Agaricus*; B. *Boletus edulis ;* C. *Geastrum (*Earth stars*)*; D.*Cyathus* (birds,s nest).

Source: http://www.mykoweb.com/photography/galleryL.html, http://en.wikipedia.org/wiki/File:Boletus_edulis_EtgHollande_041031_091.jpg http://archive.bio.ed.ac.uk/jdeacon/microbes/basidio.htm

For more images visit: http://www.mykoweb.com/photography/galleryL.html

Within the basidiocarps are the basidia which are the fertile terminal cells of dikaryotic hyphae. Some basidia are exposed in the basidiocarp, but in some forms the basidia remain hidden in the basidiocarp releasing their spores only after the degeneration of the basidiocarp.The basidia are present in a layer called the hymenium.

The basidia are the site of karyogamy and meiosis; resulting in the formation of four haploid, uninucleate basidiospores.The basidiospores are extruded out of the tip of basidia through the sterigmata.

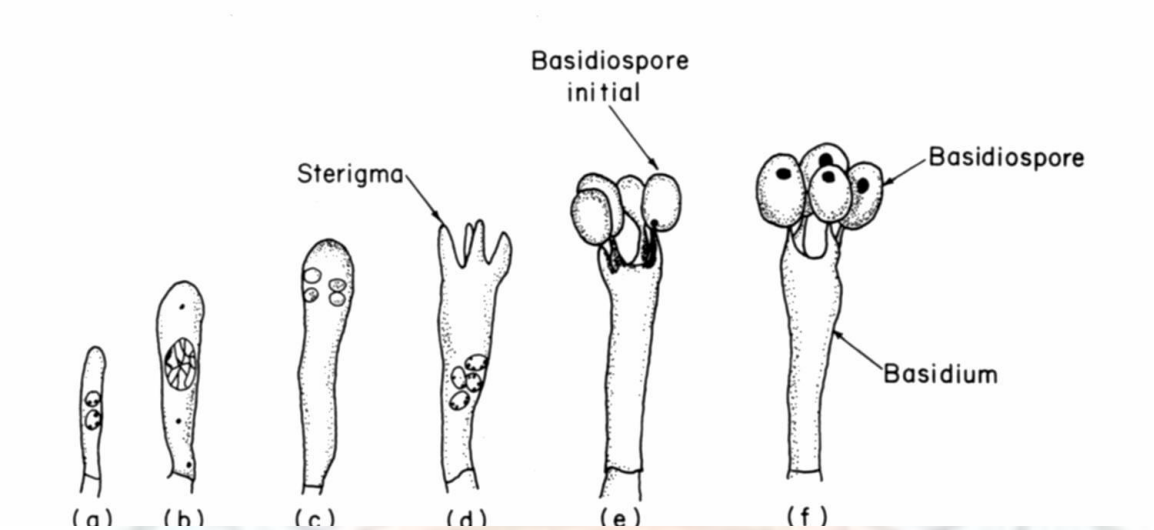
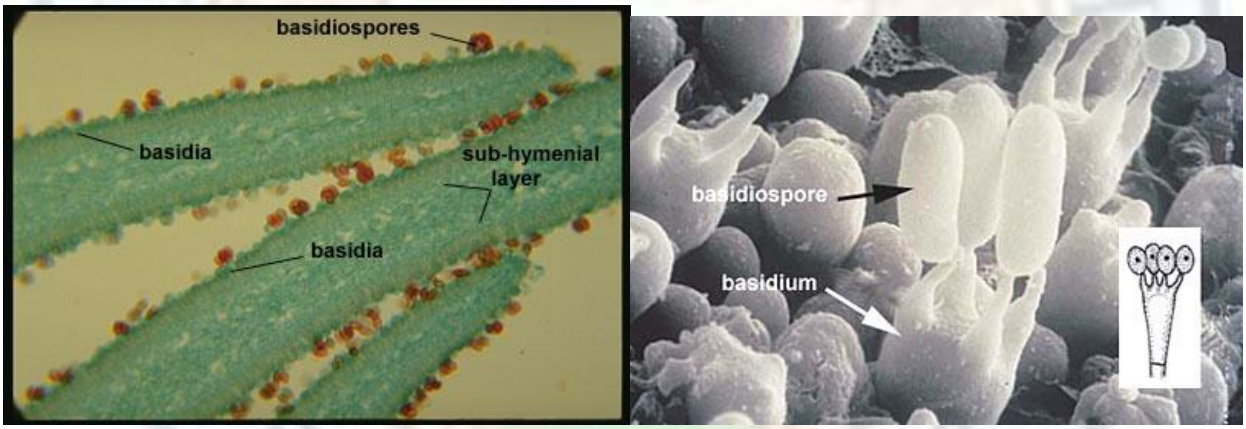


Figure: Development of a typical basidium (a) young dikaryotic basidium (b) diploid basidium; (c) basidium with four nuclei resulting from meiosis; (d) basidium after development of sterigmata ; (e) migration of nuclei into basidiospore initia; (f) mature basidium with basidiospores.



A **B**

Figure: A.Section of the gill showing the basidia and the basidiospores. ; **B.** SEM of basidium bearing the basisdiospores

Source: http://www2.puc.edu/Faculty/Gilbert_Muth/phot0087.jpg(dispalyed with permission), http://www.apsnet.org/edcenter/illglossary/Pages/A-D.aspx

There are two types of basidia :

- the unicellular, aseptate, **holobasidium** as seen in mushrooms, and the septate
- **phragmobasidium** or heterobasidium (where the septae may be vertical or transverse) For example ,the rusts in the order *Uredinales* have four-celled basidia that are transversely septate; some jelly fungi in the order Tremellales have four-celled basidia that are cruciately septate.

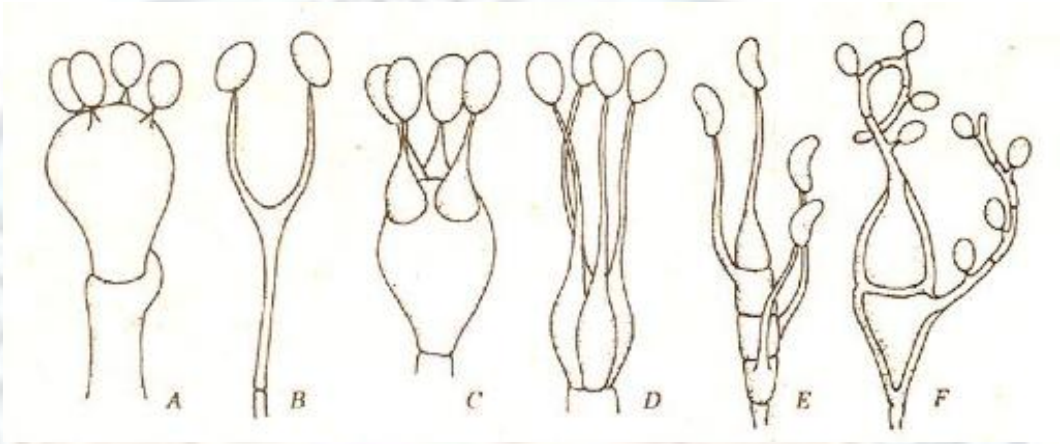


Figure: Diagrammatic representation of various types of basidia. A. Typical basidium; B. Tuning fork basidium of *Dacrymyces;* C. Basidium of *Tremella;* E. Basidium of *Auricularia;* F. Basidium of *Puccinia*.

Source:http://nsdl.niscair.res.in/bitstream/123456789/178/1/Fungi-II+revised+formatted.pdf

Depending on the nuclear events the basidia have been divided into three parts: a) **Probasidium** - where karyogamy takes place; b) **Metabasidium** - where meiosis takes place; and, c) **Sterigmata** which is the part of basidium between metabasidium and basidiospore.

The Holobasidium is club shaped and can be further divided into two types;i) Chiasto basidium where the spindle fibres are oriented perpendicular to the long axis of the basidium. ii) Stichobasidium where the spindle fibers are oriented parallel to the long axis of the basidium but at different levels.

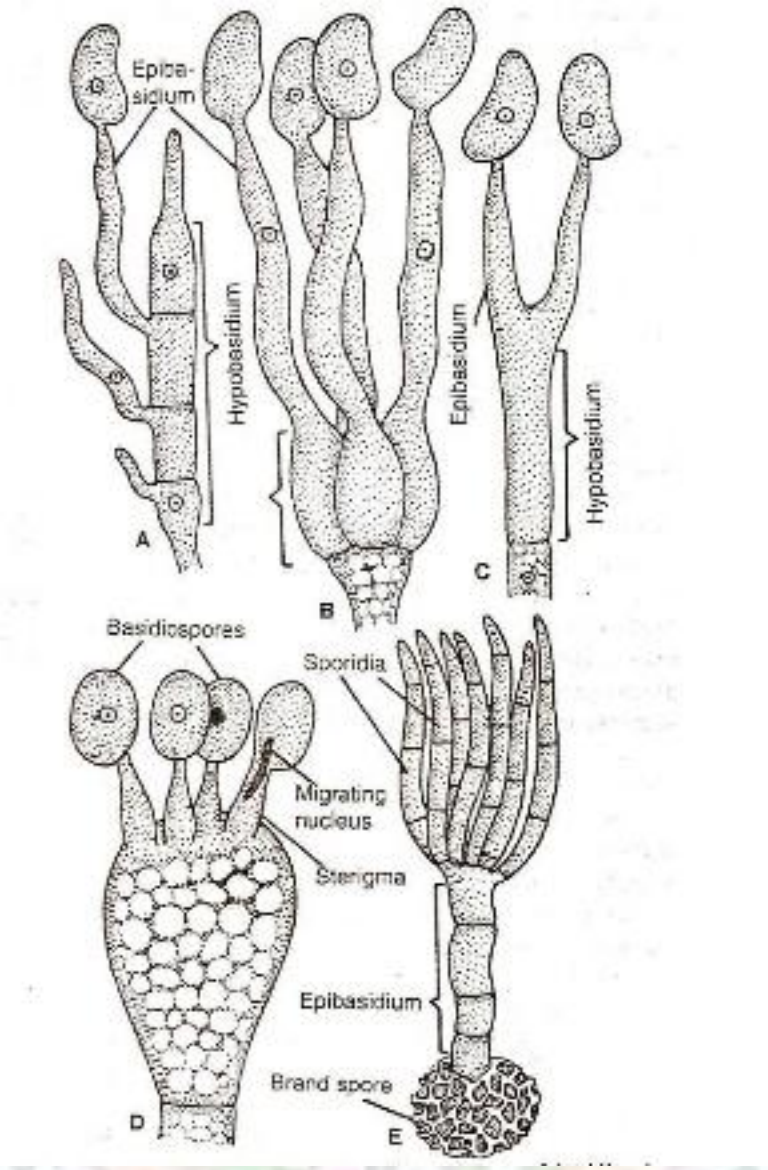
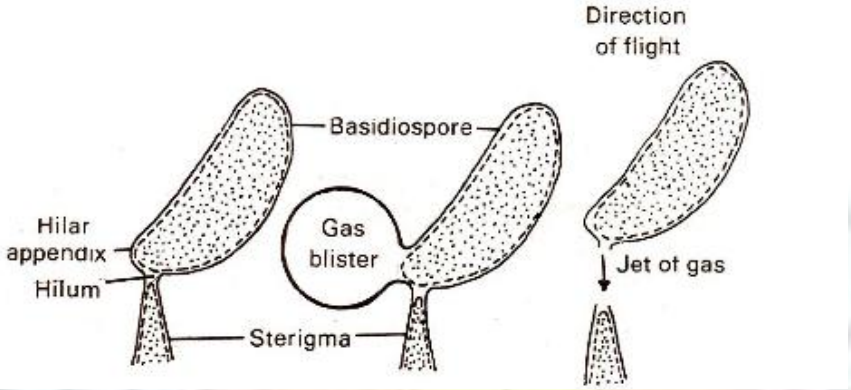


Figure: Different types of basidia: A. Stichobasidial type; B. Chiastobasidial type; C. Tuning fork type; D. Holobasidium; E. Stichobasidium type with a terminal cluster of septate sickle shaped sporidia

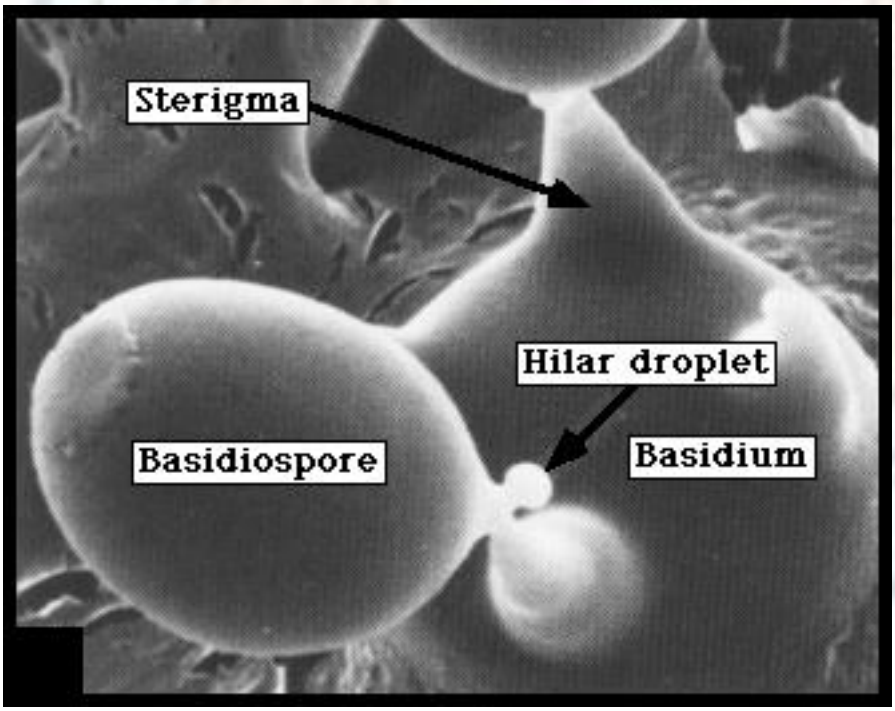
Source:http://nsdl.niscair.res.in/bitstream/123456789/178/1/Fungi-II+revised+formatted.pdf

Basidiospores are small, unicellular, haploid structures. They are variable in shape, color, size, and surface marking. They are obliquely attached to the sterigmata tip. A drop of liquid called the Buller's drop forms at the base of the spore, at the junction with the sterigma. The basidiospore is also covered with a film of liquid. When the hilar droplet fuses with a

film of liquid on the surface of the spore a shift in the mass occurs causing a rapid or explosive discharge of the spore from the sterigma. This mechanism is called "surface tension catapult" and it results in spore discharge with a force of about 25,000 g.



The production of spores which are discharged forcibly from the sterigma is called Ballistospory and such spores are called Ballistospores. Ballistospores may be produced during sexual or asexual reproduction, by basidia, hyphae, yeast cells, or even other ballistospores. Ballistospory is seen in fungi that disseminate their spores in the air.



Source: http://tolweb.org/tree/ToLimages/hilarappendix2.gif

Figure: Diagrammatic sketch of the possible mechanism of basidiospore discharge (Moore, 1966).Source:http://nsdl.niscair.res.in/bitstream/123456789/178/1/Fungi-II+revised+formatted.pdf

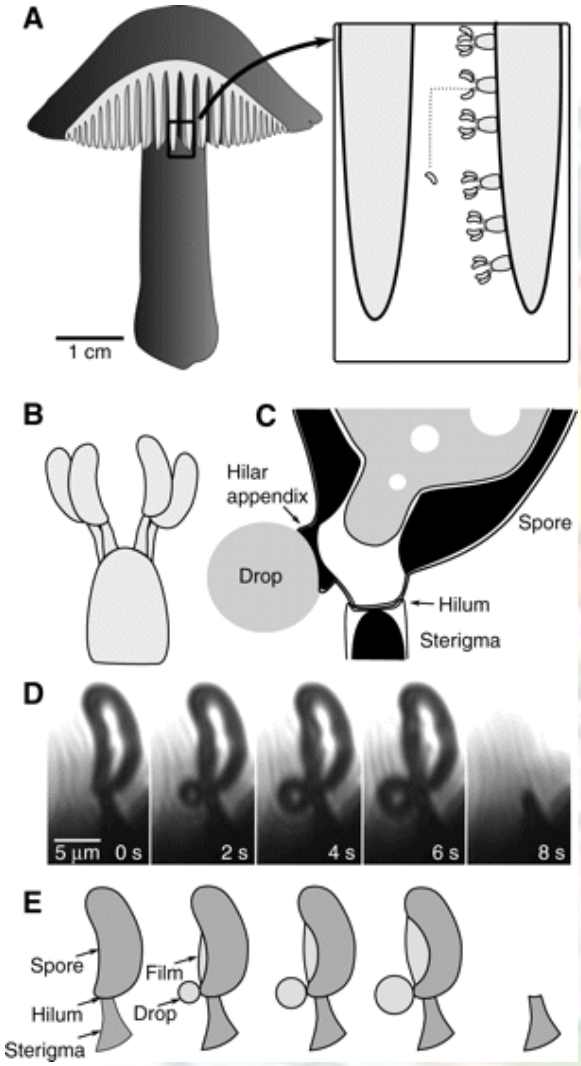


Figure: Ballistospore discharge in basidiomycetes. (A) Section of a typical mushroom cap showing the gills and the location of the spore-bearing basidia (insert). The approximate trajectory of the spore is shown as a broken line. (B) A typical basidium with four spores. (C) Structure of the lower half of the spore [based on McLaughlin et al. 1985.](D) Spore ejection in *Auricularia auricula*. In this species, spores are borne singly on the sporogenic surfaces. (E) Diagrammatic representation of the ejection in D.

For details visit: http://jeb.biologists.org/content/212/17/2835.full

Basidiospores germinate to form hyphae (filaments) or yeast cells that are typically haploid and uninucleate.

Classification

Based on the modern phylogenetic system the **Phylum Basidiomycota** is divided into 5 **classes** :

- **Homobasidiomycetes** : Fungi with holobasidia in exposed hymenium. e.g. Agarics
- **Heterobasidiomycetes** : Fungi with heterobasidia in exposed hymenium e.g. Jelly fungi
- **Urediniomycetes** : Fungi which do not form Basidiocarps, septate basidia e.g. Rust fungi
- **Ustilaginomycetes** : Smut fungi
- **Gasteromycetes** : Fungi where hymenium is not exposed.

Summary

This chapter is about Basidiomycota which constitute approximately 30% of the known fungi. They are mostly terrestrial, saprophytic, parasitic, and, symbiotic forms. Some members are edible, some poisonous, some hallucinogenic and some medicinal! They show the occurrence of three different stages of mycelia growth. The life cycle begins with the primary mycelium. Soon, though it gives rise to the secondary mycelium which is dikaryotic i.e. each cell contains two nuclei of different but compatible strains. This is the dominant phase of the life cycle, forming extensive dikaryotic mycelia. The proper separation of the two nuclei during the development of the mycelium occurs by the formation of Clamp Connections.

Reproduction occurs by asexual and sexual methods. Asexual reproduction is less frequent but when it occurs it can be by Oidia; Conidia; Chlamydospores etc. Sexual reproduction results in a fruiting body or basidiocarp in most forms. The basidiocarp forms basidia which are the site of karyogamy. The basidia may be unicellular, aseptate (then called holobasidium) or they may be septate & made up of 4 cells (then called phragmobasidium). In the phragmobasidium the septae may be transverse or vertical. Meiosis also occurs in the basidium resulting in four haploid nuclei. These nuclei are extruded out of the basidia through four sterigma in the form of basidiospores. The basidiospores germinate to form new mycelium after dispersal.

Exercises

Q1. Define the following:

Dikaryon; Primary mycelium; Secondary mycelium; Clamp connection.

Q2. What is a dolipore septum? Describe it.

Q3. How many types of Basidia can be found in the Basidiomycota?

Q4. Differentiate between a Stichobasidium and a Chiastobasidium.

Q5. What is the Buller's drop? How does it help in spore discharge?

Q6. Enumerate the different types of habitats of the Basidiomycota.

Q7. Name some examples of the following:

Edible fungi; Poisonous fungi; Pathogenic fungi; Hallucinogenic fungi

Glossary

Ballistospore: A spore that is discharged forcibly

Basidiocarp: A fruiting body that produces basidia

Basidiospore: A spore produced on the basidium after karyogamy and meiosis

Basidium: A structure which bears a fixed number of spores after karyogamy and meiosis

Chiastobasidium: A basidium in which the spindle of dividing nuclei is oriented perpendicular to the long axis of the basidium.

Clamp connection: A bridge like connection formed on secondary mycelium to maintain the dikaryotic nature of the mycelium

Dikaryon: A pair of compatible nuclei usually from different parent hyphae

Dikaryotic mycelium: A mycelium containing dikaryon

Dolipore septum: A septum with a central pore surrounded by barrel shaped swelling of wall, also covered by perforated membrane called parenthosome; characteristic of basidiomycota

Ectomycorrhiza: A mycorrhiza where fungus grows only externally not penetrating the plant body

Holobasidium: A single celled club shaped basidium

Mycelium: Mass of hyphae forming the plant body of a fungus

Phragmobasidium: A divided basidium, divisions may be horizontal or vertical

Rhizomorph: A collection of somatic hyphae to form a thick strand resembling old roots

Stichobasidium: A basidium in which the spindle of dividing nuclei is oriented parallel to the long axis of the basidium.

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Web links

http://www.mycolog.com/chapter5a.htm

http://www.apsnet.org/edcenter/illglossary/Pages/A-D.aspx