

Fungi

Note - Many of the photographs below are linked to larger photographs. Click on a photographs if you wish to view an enlargement.

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Nutrition

Fungi (kingdom Fungi) are *heterotrophs*. They cannot manufacture their own food as photosynthetic organisms can.

Most species of fungi are *saprotrophic*; they decompose dead matter. Many are *parasitic*; they obtain nutrients from living organisms.

Fungi are the principle decomposers in every ecosystem. They can break down most organic compounds including lignin, a compound that is a major component of wood and is very difficult to break down or digest.

Some species are parasites and others are mutualistic.

They have extracellular digestion by secreting enzymes into environment and absorbing the nutrients produced.

Fungi store their food as glycogen (like animals). Plants and green algae store their food as starch.

Structure

Yeasts are single-celled but most fungal species are multicellular.

Multicellular fungi are composed of filaments called *hyphae* (singular: hypha).

Hyphae may contain internal crosswalls, called *septa*, that divide the hyphae into separate cells. *Coenocytic* hyphae lack septa. The septa of many species have pores, allowing cytoplasm to flow freely from one cell to the next. Cytoplasmic movement within the hypha provides a means to transport of materials.

The hyphae may be branched. A mass of hyphae that is not a reproductive structure is called a *mycelium*.

Fungi have cell walls (like plants) but the cell walls are composed of *chitin*, which is what arthropod (insects, crayfish, etc.) exoskeletons are composed of. The cell walls of plants and some protists are composed of cellulose.

The hyphae of some symbiotic fungi become specialized for penetrating the cells of the host. These

hyphae are called *haustoria*.

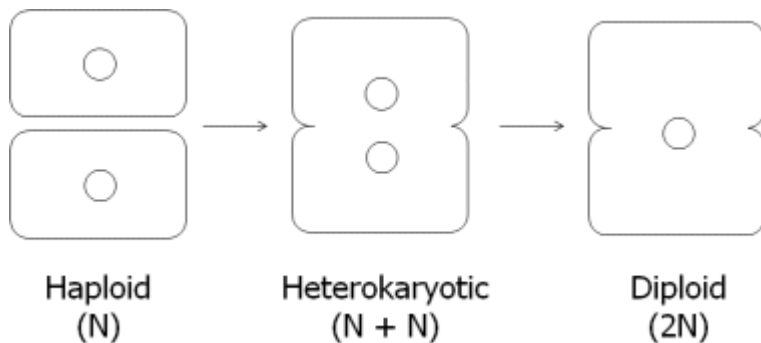
Most fungi do not have flagella in any phase of their life cycle. They move toward food by growing toward it.

Reproduction

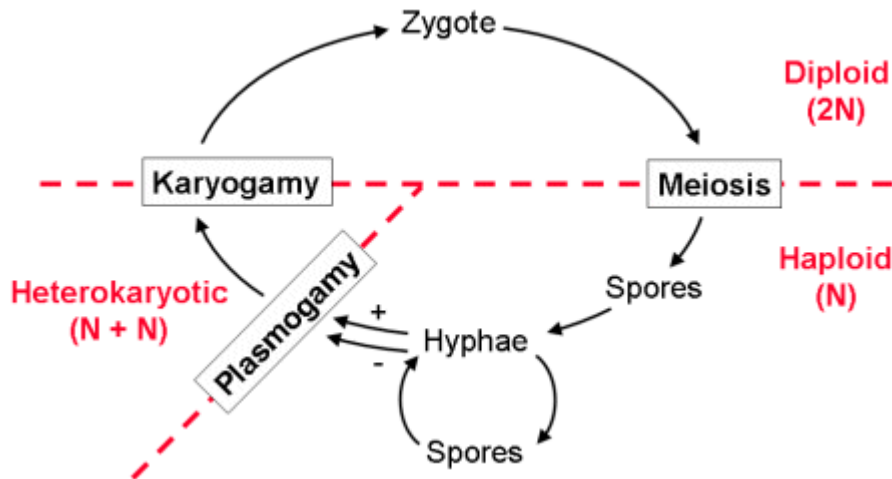
Fungi are categorized into phyla (divisions) based on the type of structures produced during sexual reproduction.

Some fungal species have not been classified into phyla based on evolutionary relationships because they do not have a sexual phase or because details regarding their sexual reproduction are unknown. They are placed in a separate group called Deuteromycota. When details concerning their evolutionary relationships become available, they are reclassified into one of the other phyla.

In general, the life cycle involves the fusion of hyphae from two individuals, forming a mycelium that contains haploid nuclei of both individuals. The fusion of hyphae is called *plasmogamy*. The fused hyphae containing haploid nuclei from two individuals is *heterokaryotic*. In some cases, plasmogamy results in cells with one nucleus from each individual. This condition is called *dikaryotic*. Eventually, two nuclei that originated from different individuals fuse to form a diploid zygote. Meiosis then produces either four haploid nuclei or four haploid cells.



The diagram below shows the generalized life cycle of fungi.



Spores are reproductive cells that are dispersed by wind. They are capable of germinating and producing a new mycelium.

Ecology: Some Important Symbiotic Relationships

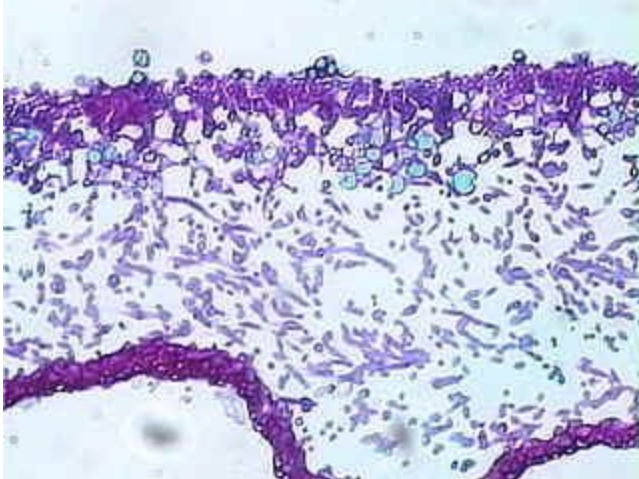
Lichens

Lichens are structures made up of two different species: 1) a fungus and 2) either a cyanobacterium or a green algae.

The photosynthetic cells are contained within the middle layer.

The photosynthetic cells provide photosynthesis for the lichen. It was thought that the relationship was mutualistic because the fungus prevented the algal cells from desiccation. Recent evidence indicates that the photosynthetic cells may grow faster when separated from the fungus. Perhaps the fungus is parasitizing the photosynthetic cells.

Below: Lichen thallus (cross-section) X 200. The algal cells are a lighter color. They are surrounded by and held in place by fungal hyphae.



Reproduction is asexual. Fragments are produced that contain fungal hyphae and photosynthetic cells.

Lichens derive most of their water and minerals from rainwater and air. This allows them to survive on bare rock, tree trunks, inhospitable places.

Below: Lichens growing on a rock.



Below: Lichens growing on trees.



Lichens are so efficient at absorbing nutrients from the air that they can be used to monitor air quality because some kinds do not survive in polluted air.

They play an important ecological role: breaking down rocks and starting the process of soil formation.

Mycorrhizae

A *mycorrhiza* is a mutualistic relationship between a fungus and a plant root.

The fungus functions like a root by growing into the soil and absorbing nutrients for the plant. 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.

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.

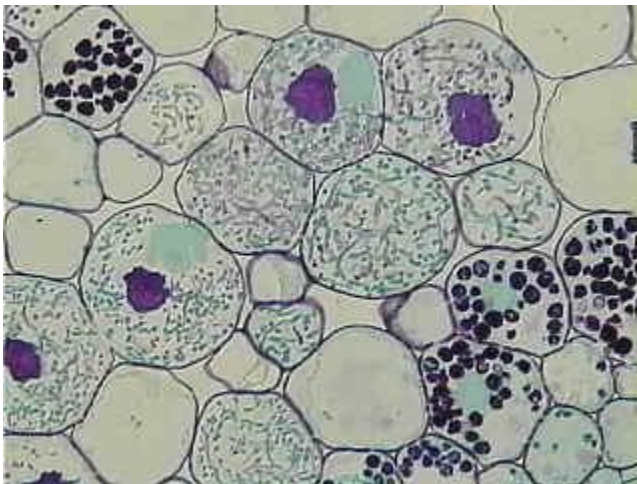
Ectomycorrhizal fungi have been described as the "dominant nutrient-gathering organs in most temperate forest ecosystems" because nearly every tree in temperate and northern forests form these associations with fungi.

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 type of haustorium called an ***arbuscule***, which aids in the transfer of nutrients between the two species.

Fungal hyphae can be 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 are found in eighty percent of all terrestrial plants.



Phylum: Chytridiomycota (Chytrids)

Fungi in the phylum Chytridiomycota are called Chytrids.

DNA evidence indicates that this group may have been the first fungi to evolve.

These fungi live mostly in water and soil.

Unlike other fungi, the spores (called zoospores) have flagella. These are the only fungi with flagellated cells.

Phylum: Zygomycota

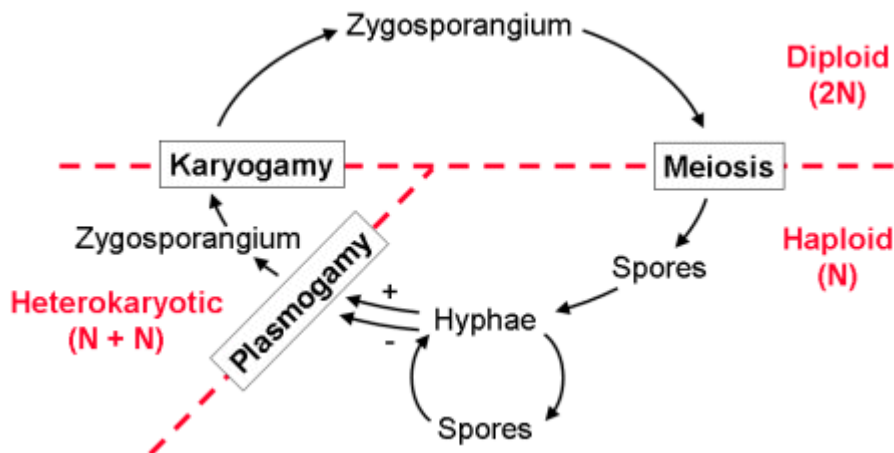
Fungi in the phylum Zygomycota are called zygomycetes.

The zygomycetes are terrestrial. They are usually saprotrophs but there are some parasites.

The hyphae are coenocytic (they lack septa). Septa are found only in the reproductive structures.

Reproduction in Zygomycota

Fusion of two hyphae leads to the formation of a **zygosporangium**, a thick-walled structure that is capable of surviving environmental extremes. Before karyogamy, the zygosporangium contains many haploid nuclei. After karyogamy, it contains many diploid nuclei.

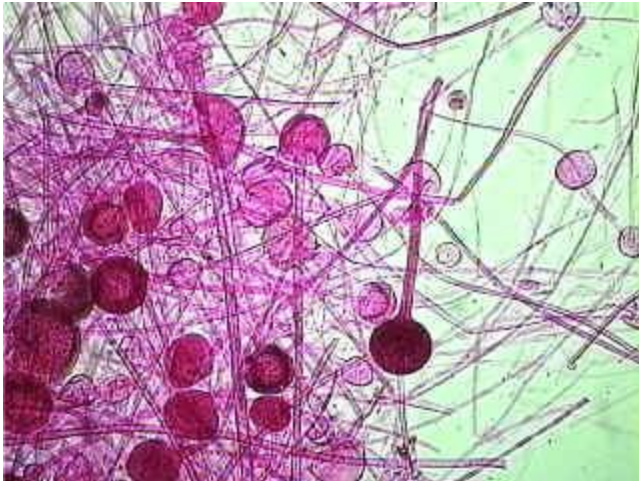


Example: *Rhizopus* (black bread mold)

Asexual reproduction involves mycelia producing sporangia that produce haploid spores by mitosis. The spores produce new mycelia.

When environmental conditions deteriorate, sexual reproduction may occur. Hyphae from opposite mating types produce structures that contain several haploid nuclei. Fusion of two of these structures from opposite mating types results in a heterokaryotic **zygosporangium**. A thick-walled develops that protects the zygosporangium until environmental conditions become favorable. When conditions are favorable, nuclear fusion (karyogamy) occurs within the zygosporangium producing diploid nuclei. This is followed by meiosis. The zygosporangium then germinates to produce a sporangium which releases haploid spores.

Rhizopus Sporangia X 40. Click on the image to view an enlargement.



Rhizopus Zygosporangia X 40. Click on the image to view an enlargement.



Phylum: Glomeromycota

Glomeromycetes are an ecologically important group because they form arbuscular mycorrhizae.

Phylum: Ascomycota (Sac Fungi)

Examples: Yeasts, molds, morels, truffles

Ascomycetes are important in digesting resistant materials such as cellulose (found in plant cell walls), lignin (found in wood), and collagen (a connective tissue found in animals). This group also includes many important plant pathogens.

Many, perhaps half of the species of ascomycota form lichens- a symbiotic relationship between a fungus and a photosynthetic cell such as a green algae or a cyanobacteria. The fungal component of most lichens is an Ascomycete.



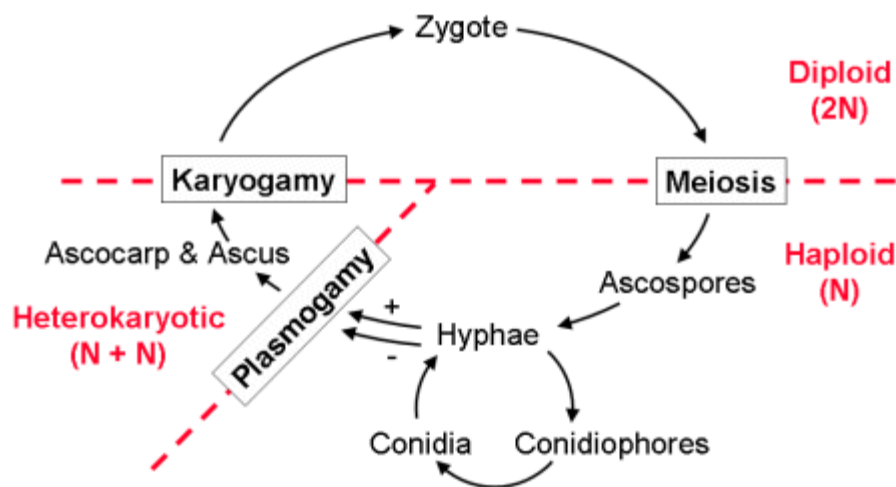
Morels (left) are sac fungi. Photo courtesy of Michael Lawliss.

Reproduction in Sac Fungi

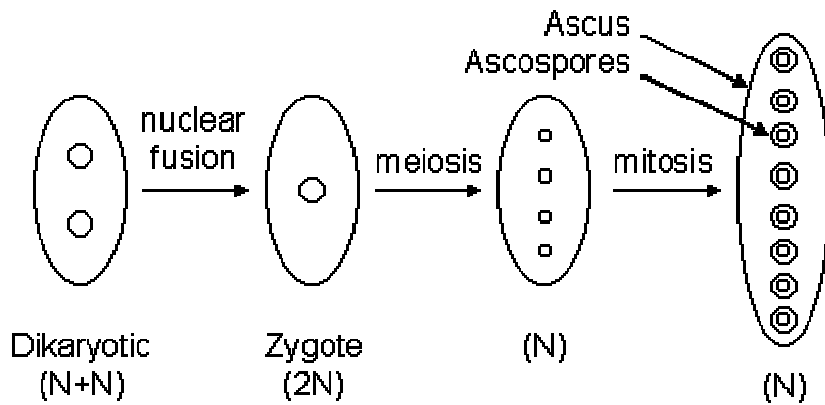
Sexual

Hyphae from opposite mating types fuse, forming a heterokaryotic structure which then produces dikaryotic hyphae.

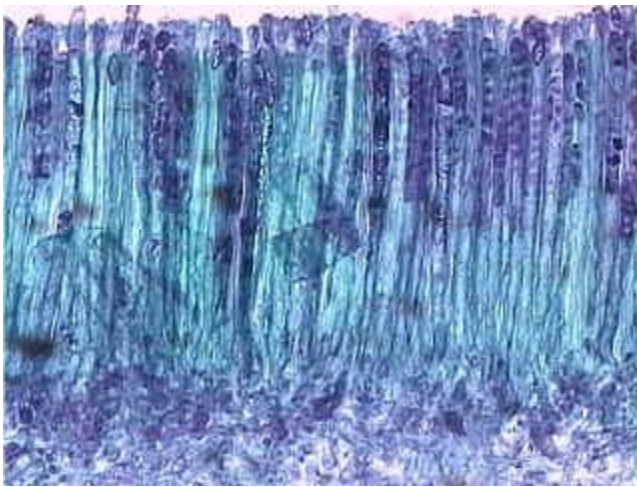
The fruiting body is called an *ascocarp*. It is composed of dikaryotic hyphae and haploid hyphae.



Dikaryotic hyphae within the ascocarp produces *asci* (singular: *ascus*), sacs that are walled off from the rest of the hyphae. Nuclear fusion within an ascus will produce a diploid zygote. The zygote will undergo meiosis, followed by mitosis to produce 8 haploid *ascospores*.



Below: *Peziza* cross section X 200. Asci with ascospores can be seen in the photograph below.



Asexual

Most reproduction is by asexual spores called ***conidia***. Unlike the Zygomycetes which produce asexual spores within sporangia, conidia are produced on the ends of specialized hyphae called conidiophores.

Below: *Penicillium* Conidiophores and conidia X 400. Click on the image to view an enlargement.



Examples of Sac Fungi

Morels and truffles are gourmet delicacies.

This group includes many important plant parasites such as Dutch elm disease, chestnut blight, leaf curl fungi, and *Claviceps*.

An ergot is the hard, purple-black fungus *Claviceps purpurea*. It contains toxic alkaloids, including LSD. When infected rye is made into bread, the toxins are ingested and cause vomiting, muscle pain, feeling hot or cold, hand and foot lesions, hysteria and hallucinations. Historians believe that those that accused their neighbors of witchcraft in Salem may have been suffering from ergotism. *Claviceps* is used to stimulate uterine contractions and to treat migraine headaches.

Yeast

Yeast are single-celled members of the sac fungi.

Most reproduction is asexual; a small cell pinches off from a larger cell. This type of mitosis where a smaller and a larger cell are produced is called **budding**.

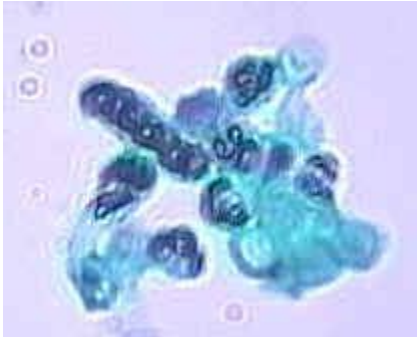
Yeast (*Saccharomyces*) budding X 1000. Click on the images to view enlargements.



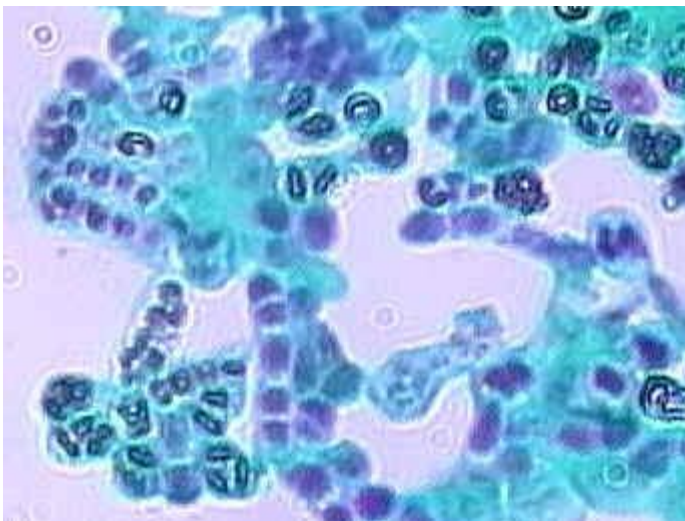
During sexual reproduction, the fusion of two cells results in the formation of an ascus.

Schizosaccharomyces octosporus X 1000

The elongated cell in the upper left part of the photograph contains ascospores.



Cells in the lower left part of the photograph contain ascospores.



Yeast are important in leavening bread by CO₂ production and in producing ethanol for alcoholic beverages.

Phylum: Basidiomycota (Club Fungi)

Some examples of basidiomycetes are mushrooms, puffballs, shelf fungi, birds nest fungi, and stinkhorns.

This group includes some serious plant diseases such as rusts and smuts.

Below: Mushrooms.



Shelf fungi are particularly important in breaking down wood.

Below: Shelf fungi.

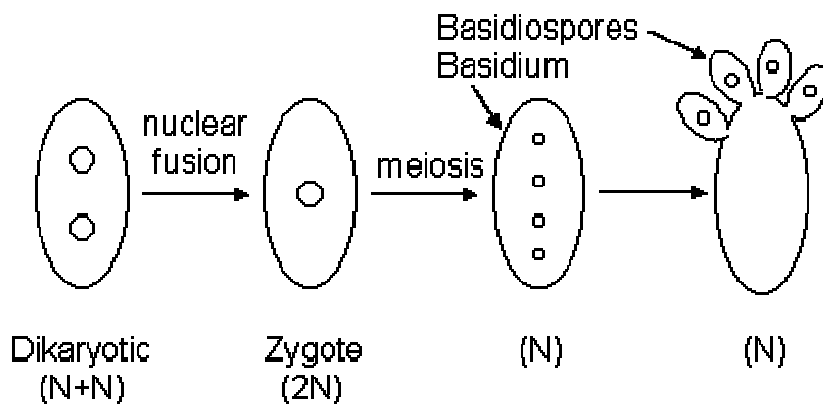
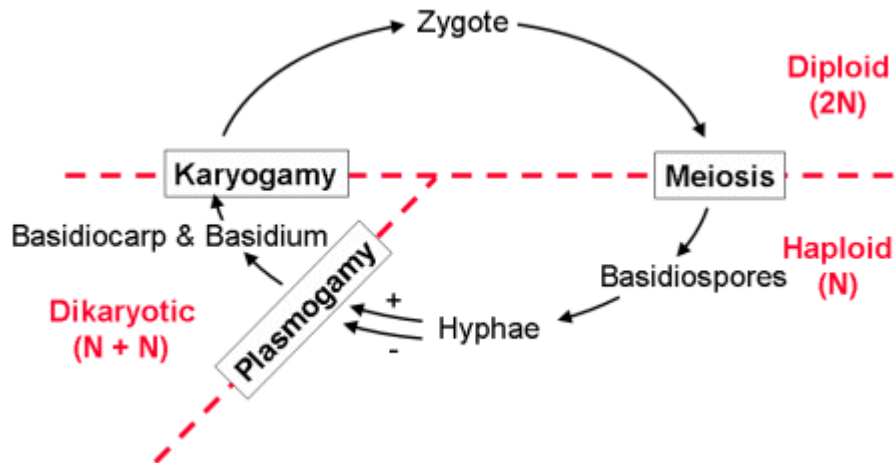


Reproduction in Club Fungi

Asexual reproduction is rare.

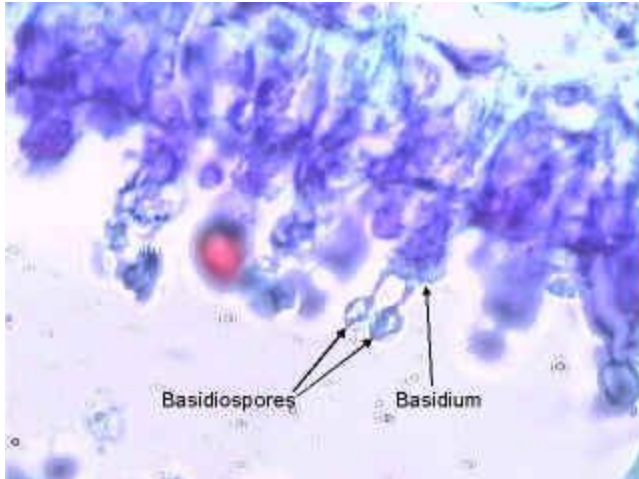
The fruiting bodies are called *basidiocarps*. This is the visible "mushroom".

Spores, called *basidiospores* are produced on *basidia* within the basidiocarps. In mushrooms, the basidia are located along the gills on the underside of the cap. In the photograph below, a portion of the cap of this mushroom has been broken away to reveal the gills.



In ascomycota (sac fungi, see previous section), the ascospores were enclosed in an ascus. In basidiomycota, the basidiospores are not enclosed. Compare the diagrams of a basidium with basidiospores above with that of an ascus with ascospores seen earlier.

Below: Basidia and basidiospores X 1000.



Basidiospores germinate to produce monokaryotic (haploid, one nucleus per cell) hyphae. Mushrooms are composed of dikaryotic hyphae which are formed when hyphae fuse. Dikaryotic nuclei within the basidium fuse to produce a zygote and meiosis then produces basidiospores.

Below: Puffballs are club fungi. They produce basidiospores as described above.

