Welcome to the fungus lab on-line!

One of the things that you are not supposed to yell in a crowded room is, “There is a fungus among us”! People do not like fungi, especially athletes. (People who do like fungi and study them are called mycologists). Usually all we want to know about a fungus is what is it and how do you kill it.

However, there is more to fungi than an itch between your toes.

Remember Kingdoms?

The fungi are one of the 5 kingdoms of life, meaning that they are fundamentally different from the life in the other kingdoms.

The kingdoms are:

- Plantae - multicellular eukaryotes that carry out photosynthesis

- Fungi - mostly multicellular eukaryotes that absorb nutrients after decomposing organic matter, examples: molds and mushrooms

Kingdoms continued

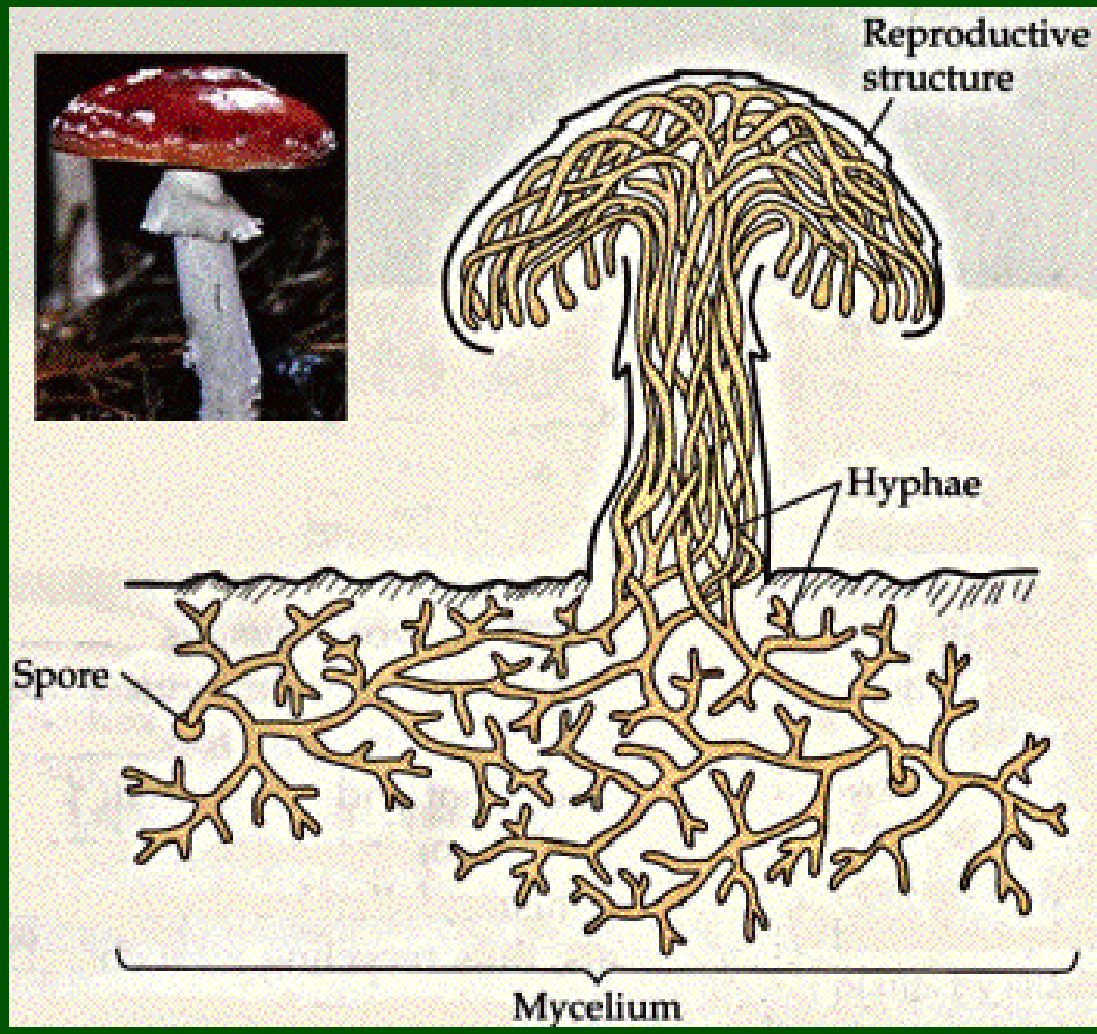
- Animalia - multicellular eukaryotes that ingest other organisms
- Monera - prokaryotic organisms, examples: bacteria and blue-green algae
- Protista - unicellular eukaryotes and simple multicellular organisms, examples: protists, euglenas, and diatoms

Since this is the FUNGUS lab lets talk fungi.

Fungi are eukaryotic, have chitinous cell walls, are generally multicellular, and are heterotrophic. In general, they spend most of their life cycle as haploid individuals.

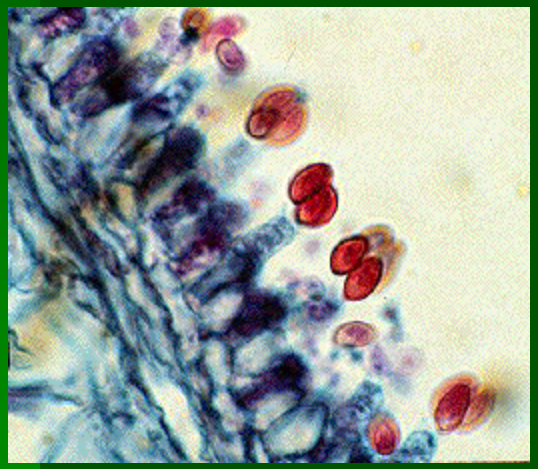
Hyphae

The vegetative (non-reproductive) part of a fungus(except for yeasts), called the **hyphae**, is composed of filamentous strands of cells. Collectively a mass of hyphae is referred to as the **mycelium**. The mycelium of a fungus can be quite extensive, although it is not usually seen by the casual observer.

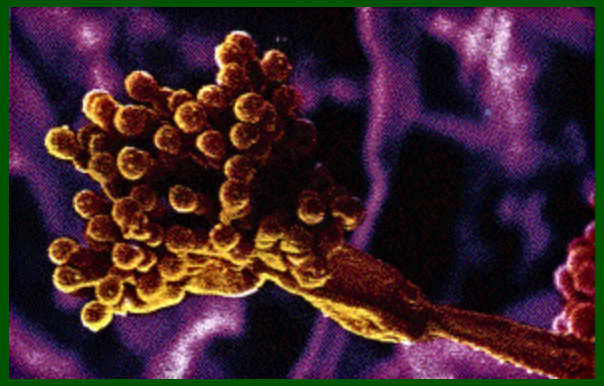


Sample sporangia

The reproductive structure of the fungus consists of mycelia modified to form **sporangia** (spore bearing structures). The different classes of fungi are organized based on the type of spore bearing structure they produce.



Basidium



Conidia

Fungi are important

Fungi form an integral part of any ecosystem and have an enormous importance to humans directly both economically and medically. Next are some of the important economic, medical, and ecological roles that fungi play.

Ecological roles

Saprophytes (Decomposers, Recyclers)

Saprobic fungi absorb nutrients from nonliving organic material, such as fallen logs, animal corpses, or the wastes of live organisms, and in the process, the fungi decompose this material.

Parasites

Parasitic fungi absorb nutrients from the cells of living hosts. Many of these fungi, such as certain species which infect human lungs, are pathogenic.

Ecological roles

Symbiotic(mutualism)

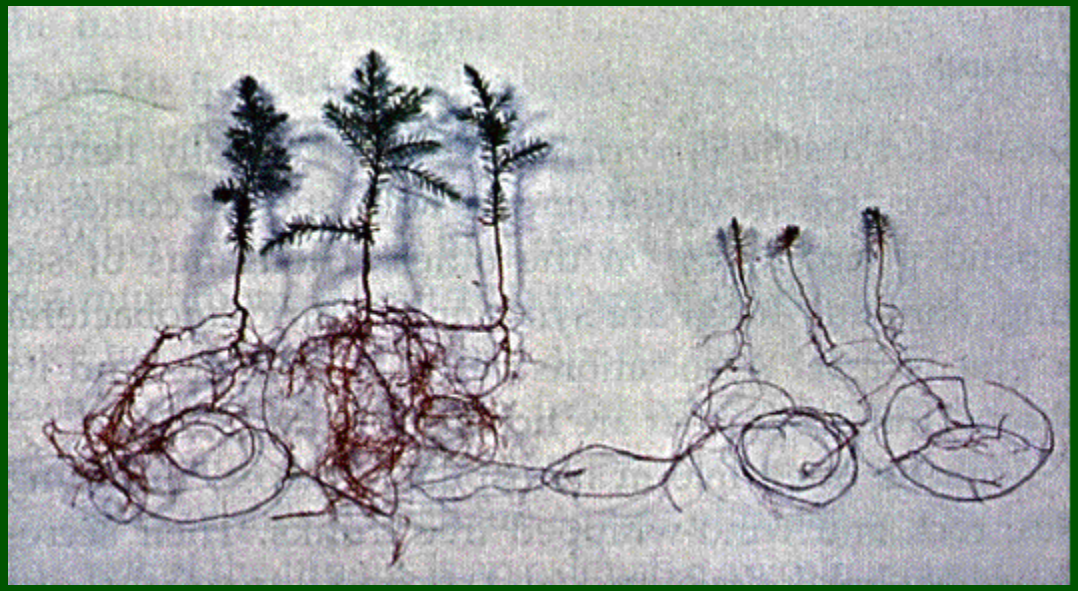
mycorrhizae (fungal roots)

Fungi form what are called mycorrhizal associations with the roots of over 90% of the existing plant families today. The fungus supplies the plant with an increased surface area for water absorption. Additionally, the fungus is very efficient at absorbing the essential plant nutrient phosphorous. In return, the plants supply the fungus with a ready carbohydrate source with products from photosynthesis. Because these mycorrhizae help trees obtain nutrients from the soil and grow at a faster rate, foresters make sure the tree roots are exposed to the fungus before they are planted.

Ecological roles

Symbiotic(mutualism)

mycorrhizae (fungal roots)



These are six-week old hemlock seedlings grown in soil with fungi and without. Most conifers will not survive without mychorrizae.

Ecological roles

Symbiotic(mutualism)

lichens

Fungi, usually a sac fungi, also form symbiotic associations with algae, usually a green algae, to form lichens. The alga provides the fungus with carbohydrates and the fungus gives the alga protection in potentially harsh environments. Lichens can live on bare rock or in poor soil, and they are able to survive great temperature extremes and dryness in all areas of the world. Lichens have been used as indicator species, as some of them are very sensitive to increases in pollution.

Answer the questions about lichens found at the end of your worksheet with the material on these next few slides:

Ecological roles

Symbiotic(mutualism)

lichens

Lichens, such as reindeer moss, also form part of the basis of the food chain in the arctic tundra. Lichens are the first colonizers to grow on barren terrain such as bare rock, volcanic ash, or burned-over forests. They help prepare the soil for other plants by penetrating the substrate with hyphae from the fungi component of the lichen and chemically breaking down the rock or ash into usable soil.

There are three types of lichen, classified on the basis of structure or shape.

Ecological roles

Symbiotic(mutualism)

lichens

Crustose is a flat lichen that clings tightly to a tree trunk, rock, or other host. It looks like the host has been spray painted with paint. Pale Shield is a common variety found on trees.

Ecological roles

Symbiotic(mutualism)

lichens

Foliose is leaf-like though still relatively flat. The edges are curled up and ruffled. These are the most common form of lichen and usually occur on rocks

Fruticose is a branched or stem-like variety. These lichens have an erect, often branched body form and may occur on trees and soil as well as rocks. Reindeer moss is actually a fruticose lichen, not a moss. British soldier, with its characteristic red-capped stalks, is another fruticose lichen.

Ecological roles

Symbiotic(mutualism)
lichens

These are fruticose lichens.

Medicinal roles

Diseases

Many fungi are responsible for causing both minor and serious diseases in humans. Some of the diseases you are probably familiar with include athletes foot, jock itch, yeast infections, ringworm, and various allergies. More serious diseases are Cryptococcosis which affects the central nervous system, and Aspergillosis which affects the lungs and brain.

athletes foot

Antibiotics

Several antibiotics are produced by fungi; one you are all familiar with is penicillin.

Medicinal roles

Wild mushrooms

Additionally, there are several wild mushroom species which can induce hallucinations, illness, or death. Perhaps the most well known of these is a mushroom known as the Death Cap Mushroom. This particular mushroom is fatal if eaten. (Although there are several delicious edible wild mushrooms such as the morel, NEVER eat anything that has not been identified by a knowledgeable mycologist!)

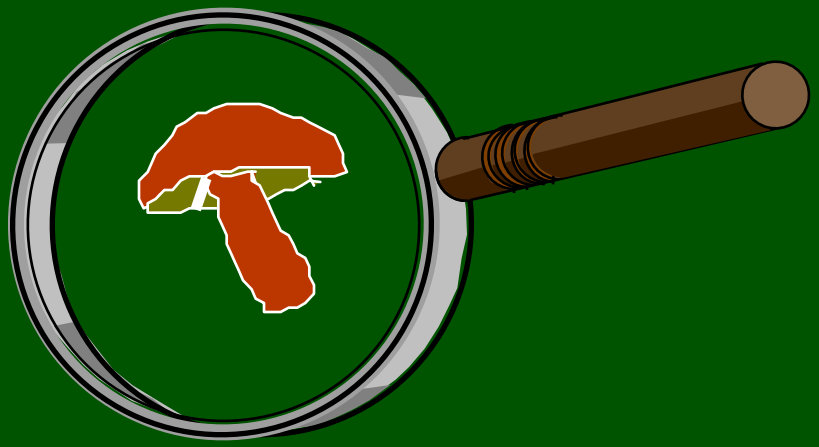
Amanita muscaria

Economic roles

Beer, wine, bread: these are all the result of fungi. Yeast, a single celled fungus undergoes fermentation. In the case of beer and wine the alcohol produced by fermentation is the desired product, in the case of bread, the CO_2 is desired.

The "blue" in Bleu Cheese, and its characteristic flavor, is the result of the fungus Penicillium roquefortii. Brie and Camembert are also flavored by fungi.

Now that we know what fungi are; lets look more closely at them.



How would you classify or group different kinds of fungi?

- by slimy, squishy, or stinky?
- by color?
- by taste? (not advisable!)
- Mycologists, being the kinky people that they are, classify fungi by their sexual orientation. That is, whether the fungi are asexual or sexual and also by what structures they do it with.

Fungi classification cont.

In this lab we will look at four divisions of fungi.

- Zygomycetes--sexual (uses a zygosporangium) and asexual reproduction
- Ascomycetes--sac fungi, sexual reproduction with an ascus
- Deuteromycetes--imperfect fungi, no known sexual stage or asexual stage of Ascomycetes
- Basidiomycetes--club fungi, sexual reproduction with a basidium

Fungi classification cont.

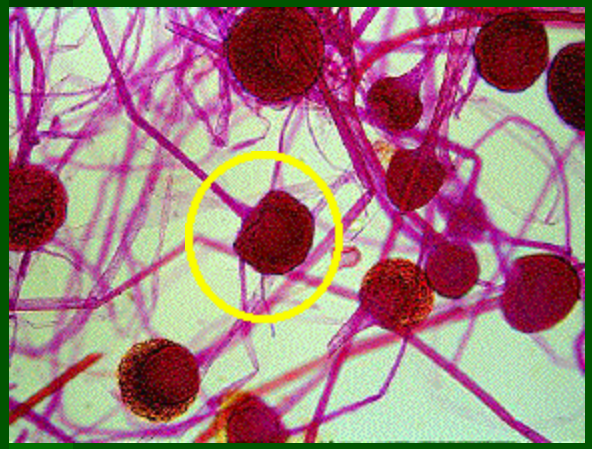
We are not going to make you learn the water molds (fisheries students should read about them in your textbook). You deserve a break today.

Now that we know where fungi fit into realm of life, the roles they play in our lives, and how to classify them lets move on and take a closer look at different divisions of fungi.

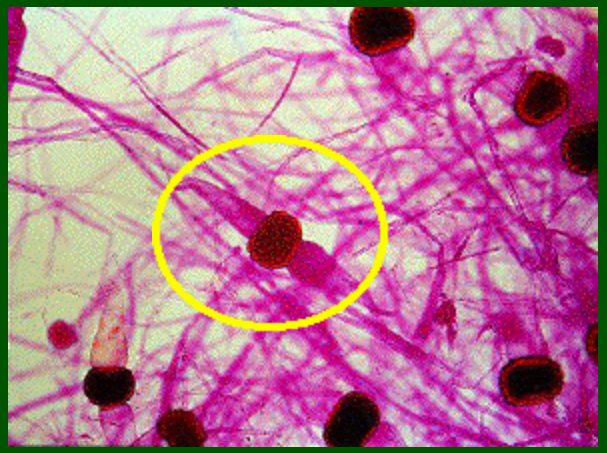
Zygomycetes: "bread molds", Pilobolus, and others

The fungi of this group (about 600 species) produce distinctive thick-walled reproductive structures. Theses are called **zygosporangia**. Many species are saprobes that live in soil, on decaying plant matter, or on food that is being stored. Others are parasites on insects, including the common housefly. Like most fungi generally, the members of this group rely mostly on asexual reproduction. When they reproduce sexually, their zygotes develop a thick wall and so become zygosporangia, which give rise to stalked, spore-producing structures upon germination.

Zygomycetes



This is the asexual reproductive structure called the sporangium. It will give rise to stalked, spore-producing structures upon germination.



This is the sexual reproductive structure called the zygosporangium. This also produces a spore-forming structure.

Zygomycetes

Rhizopus, the black bread mold.

The black bread mold is a notorious spoiler of baked goods, and is still an occasional household pest despite the addition of preservatives to most processed foods.

Winds have dispersed the spores of this species about everywhere, including the North Pole. This is not a very precise way to disperse spores, but Rhizopus releases the tiny cells in great numbers.

A species of Rhizopus is used to ferment cakes of soybeans into a tasty product called tempeh.

Zygomycetes

Pilobolus

This saprophyte on animal dung is able to aim its spores.

Zygomycetes

Pilobolus cont.

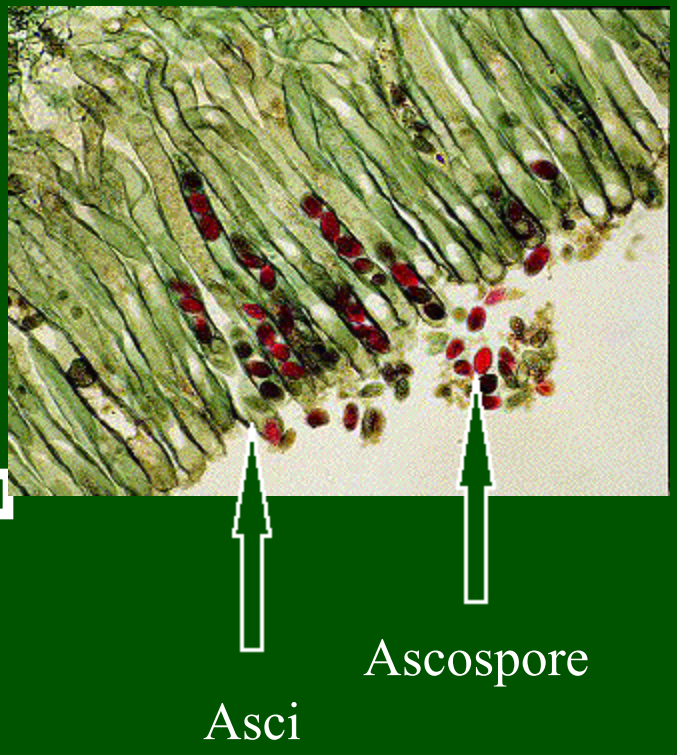
Pilobolus bends its sporangium bearing device toward light, a direction where grass is likely to be growing. The whole sporangium is then shot off on an explosive burst of cytoplasm(under pressure) out the end of the hypha, sometimes carrying the sporangium as far as 2 m - a remarkable feat, considering that the stalk is only 5 to 10 mm tall! Why this adaptation? It disperses the spores away from the mass of dung and onto surrounding grass, which will be eaten by a herbivore such as a cow. The asexual life cycle is completed when the animal scatters the spores in feces.

Ascomycetes: "yeasts", morels, truffles, sac or cup fungi

Over 60,000 species of ascomycetes have been described from a wide variety of habitats. They range in size and complexity from unicellular yeasts to morels and truffles. All produce haploid sexual spores in pouchlike cells called **asci** (singular, ascus).

Ascomycetes

This is a morel. Inside the pits are several asci with their ascospores.



Ascomycetes

Some of the most devastating plant pathogens are ascomycetes, such as ergot which attack cultivated cereals. Ascomycetes are also the cause of chestnut tree blight and Dutch elm disease, resulting in the death of most of the chestnut and elm trees that dominated the forests of much of the United States; especially the Southern Appalachians. A great many other ascomycetes are important saprobes, and about half the species in this division live with algae in the symbiotic association called lichens. (Remember them?)

Ascomycetes

Morels and truffles form mycorrhizae (remember what they are?) with plants. Speaking of truffles, you could get rich with them. Trained dogs (used to be pigs, but the pigs ate the truffles) are used to to sniff out truffles, which grow underground. Truffles are now cultivated commercially on the roots of inoculated trees in France. Even so, these fungi remain one of the most expensive luxury foods ($600 a pound).

Ascomycetes

Some of the yeasts are members of this group. Yeasts occur naturally in liquid or moist habitats, like the nectar of flowers and on fruits and leaves. One commercially important yeast, Saccharomyces cervisiae produces the carbon dioxide that leavens bread and the ethanol in wine, beer, and other alcoholic beverages. Most often yeasts reproduce asexually by dividing or budding. Some yeasts can reproduce sexually by forming an ascus or a basidium and are then classified as Ascomycetes or Basidiomycetes.

Ascomycetes

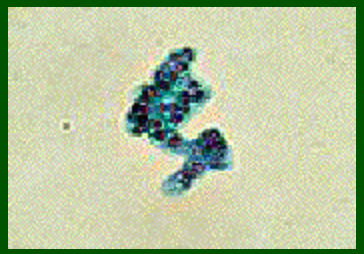
This is a fermentation tube. Baking yeast is placed into the tube along with warm water and some sugar as a carbohydrate source.

The fermentation equation is:

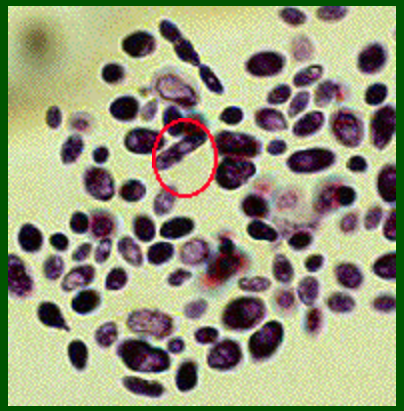
glucose $\longrightarrow$ carbon dioxide + alcohol

Ascomycetes

These are microscope slides of yeast.



Sorry this picture is so fuzzy. Look at the little dark red balls. These are the ascospores. The yeast itself forms the ascus.



These are budding yeasts. They are going to split into two parts.

Ascomycetes

Some yeasts cause problems for humans. A pink yeast, Rhodotorula, grows on shower curtains and other moist surfaces in our homes. Another well known yeast is Candida, one of the normal inhabitants of moist human tissues, such as the vaginal lining. Candida can become pathogenic by growing too rapidly and releasing harmful substances. This can occur, for example, with an environmental change, such as a pH change, or when the immune system of the human host is compromised (by AIDS for instance). It is also the cause of moniliusis, a fairly common vaginal infection in females who take birth control pills.

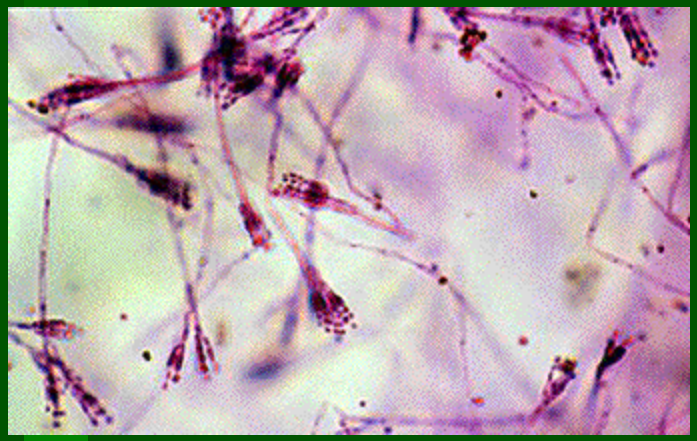
Deuteromycetes: "blue-green" molds and others --the "virgin" fungi

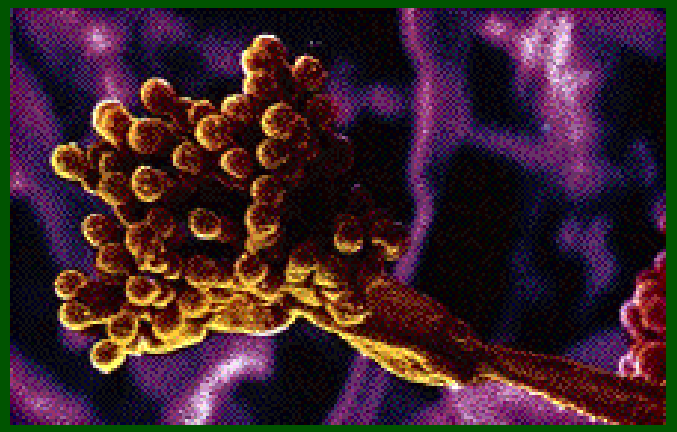
These are fungi that have no sexual stage; they are said to be "imperfect". When researchers do discover a sexual phase for one of the species, they assign it to a recognized group - the sac fungi or club fungi most often.

The fungus in the petri dish did not photograph very well, so a big clue is that it is Penicillium.

Deuteromycetes

Since deuteromycetes do not have a sexual stage they must reproduce asexually. This is accomplished with a structure called a **conidia**. These are Penicillium conidia:





Deuteromycetes

Humans have found many commercial uses for deuteromycetes. Imperfect fungi are sources of antibiotics; pharmaceutical companies grow these molds in large liquid cultures, then extract the antibiotics. Penicillin is produced by some species of Penicillium. Other Penicillium species are important fermenters on the surfaces of blue cheese, Brie, and Camembert and produce the unusual colors and flavors we associate with each type of cheese. Roquefort is a goat milk cheese that has been incubated in certain caves in the Roquefort region of France, where the wild Penicillium roquefortii is allowed to "infect" the cheese naturally. The imperfect mold Tolypocladium inflatum is the commercial source of cyclosporine, used as a drug to help prevent rejection of foreign organs in transplant patients. Aspergillus is used to produce the citric acid that imparts a lemon flavor to candies and soft drinks. It also is used in the manufacture of soy sauce (the fungus ferments the soybeans used to make the sauce).

Deuteromycetes

One of the most interesting deuteromycetes is Arthrobotrys, a predatory fungus of nematodes (roundworms). The hyphae of the fungus form nooselike rings that swell rapidly with incoming water when stimulated (rubbed). The increased turgor pressure shrinks the "hole" in the noose and captures the nematode. Once it is trapped, the fungus produces additional hyphae that penetrate the body of the nematode, release digestive enzymes, and then digest and absorb its contents.

Basidiomycetes: "mushrooms", shelf fungi, conks

You are probably familiar with some of the 25,000 or so species of club fungi. Members of this group include the mushrooms, shelf fungi, coral fungi, stinkhorns, and puffballs. 10,000 of these are mushrooms. Some club fungi are saprobes that are important decomposers of plant debris. Many form mycorrhizae in association with the roots of forest trees, conifers especially. Others, including the rust and smut fungi are parasitic fungi that attack grains, resulting in great economic loss and necessitating expensive control measures. Some species are edible; in fact, cultivation of the common mushroom (Agaricus brunnescens) is a multimillion-dollar business.

Basidiomycetes

Here are several different types of basidiomycetes:

Basidiomycetes

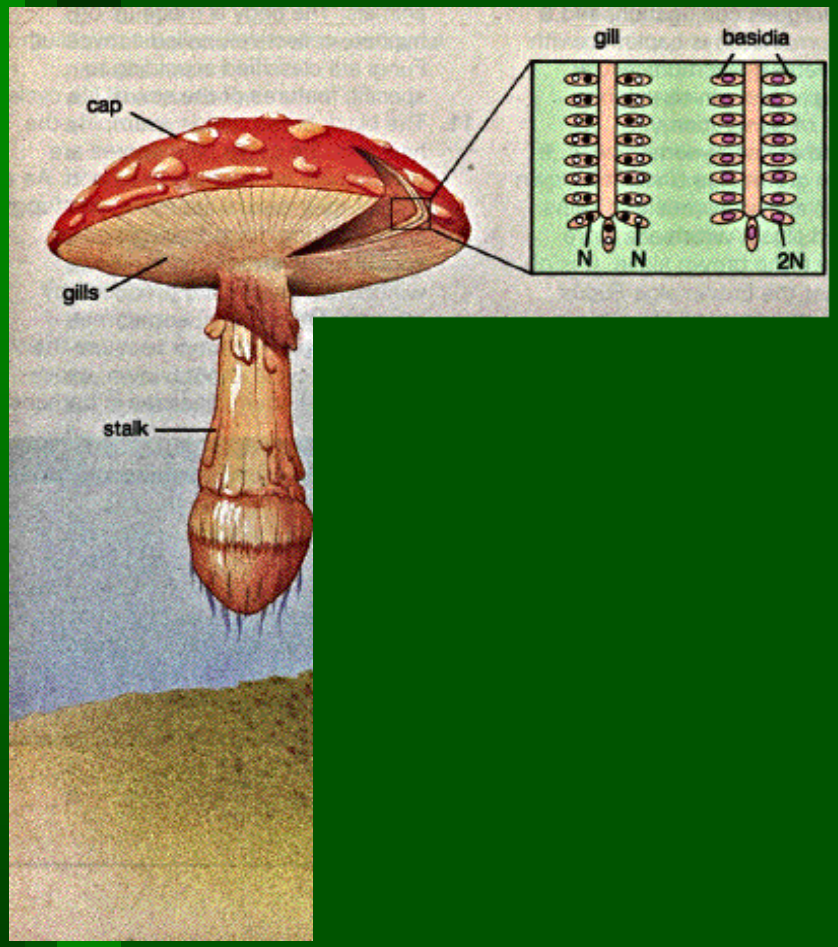
Some species of mushrooms have hallucinogenic or deadly effects. Remember: “There are old mushroom hunters and bold mushroom hunters, but no old, bold mushroom hunters”.

Basidiomycetes

The spore-producing cells of club fungi are called basidia (singular, basidium). They usually are club-shaped, and they always bear the sexual spores on their outer surface. The club-shaped cells typically develop on a short-lived reproductive structure the **basidiocarp**. The part of the fungus that is visible above the ground or on the surface of a log is the basidiocarp. The living mycelium is buried in the soil or decaying wood.

Each mushroom is a short-lived basidiocarp consisting of a stalk and a cap. Its spore-producing cells occur on the sides of gills, which are sheets of tissue in the cap. The rest of the fungus is an extensive mycelium.

Basidiomycetes life cycle

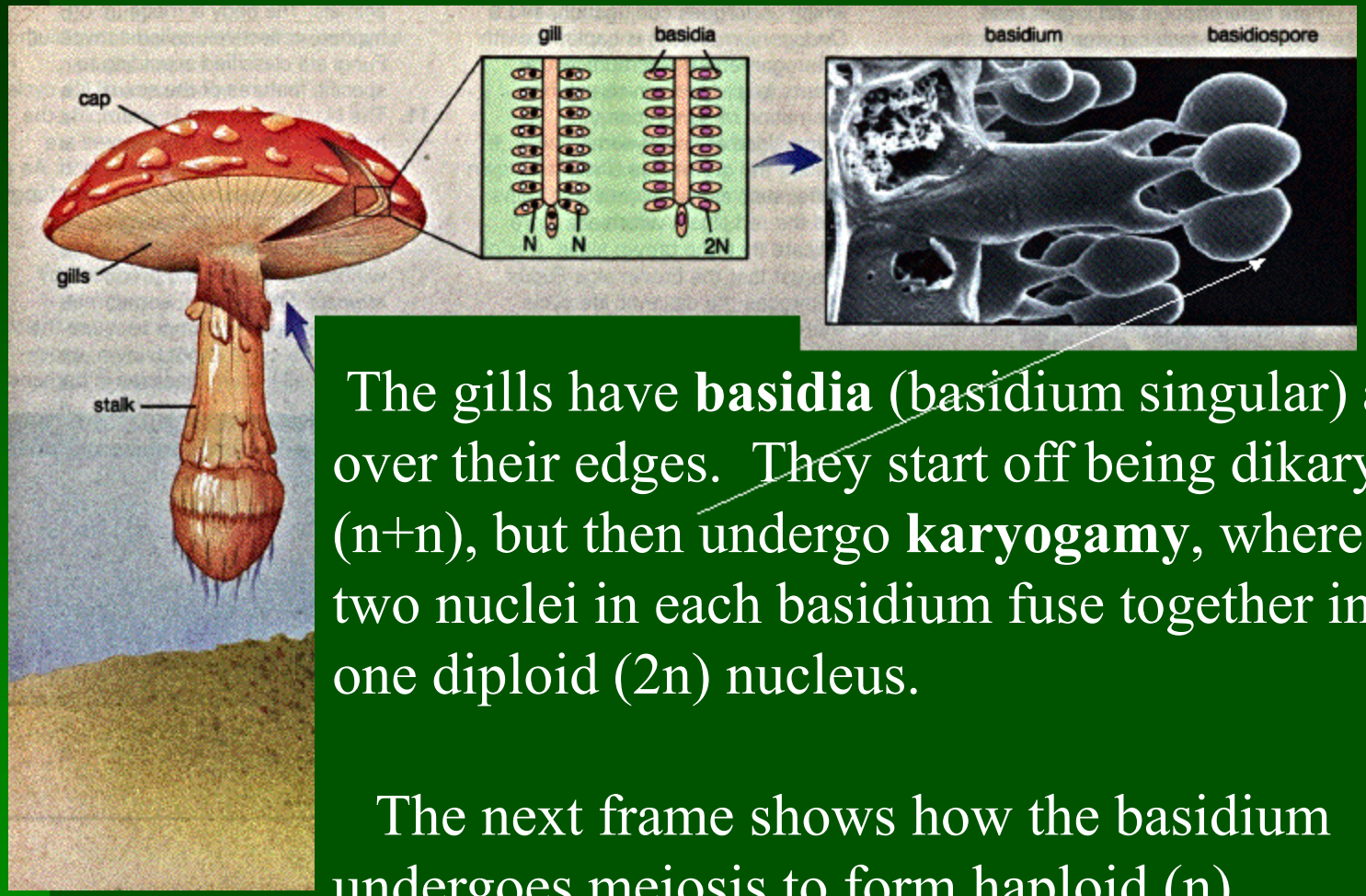


These are the basic parts of the mushroom. Remember that the mushroom is a fruiting body or **basidiocarp**. It is **dikaryotic**, meaning that it is made up of cells that have two nuclei each (n+n).

One other part of the mushroom that is not in this picture is the mycelium. You remember it of course!

The next frame shows what is on the gills of a mushroom.

Basidiomycetes life cycle



The gills have **basidia** (basidium singular) all over their edges. They start off being dikaryotic (n+n), but then undergo **karyogamy**, where the two nuclei in each basidium fuse together into one diploid (2n) nucleus.

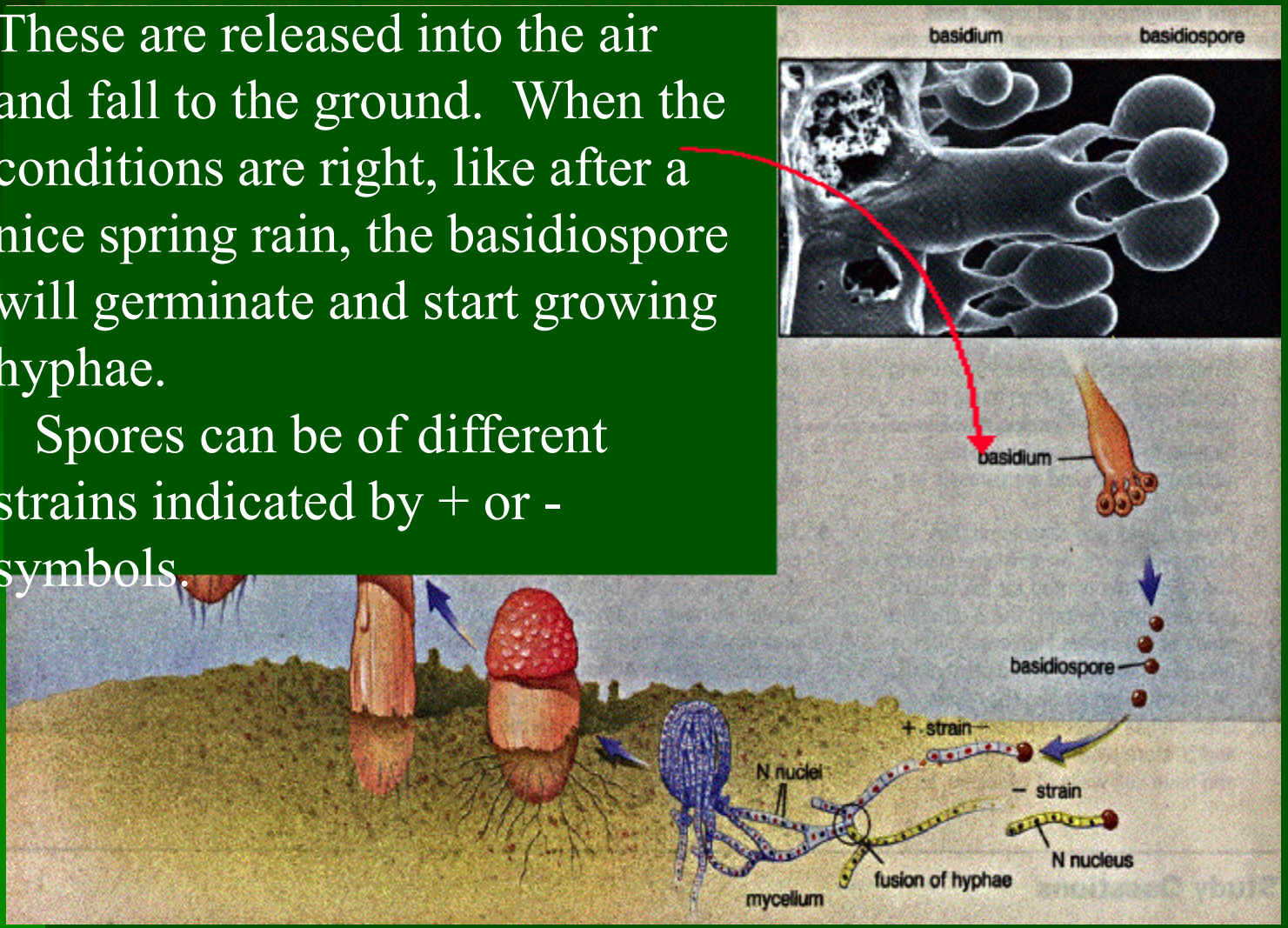
The next frame shows how the basidium undergoes meiosis to form haploid (n) basidiospores.

Basidiomycetes life cycle

Each of these is a basidiospore.

These are released into the air and fall to the ground. When the conditions are right, like after a nice spring rain, the basidiospore will germinate and start growing hyphae.

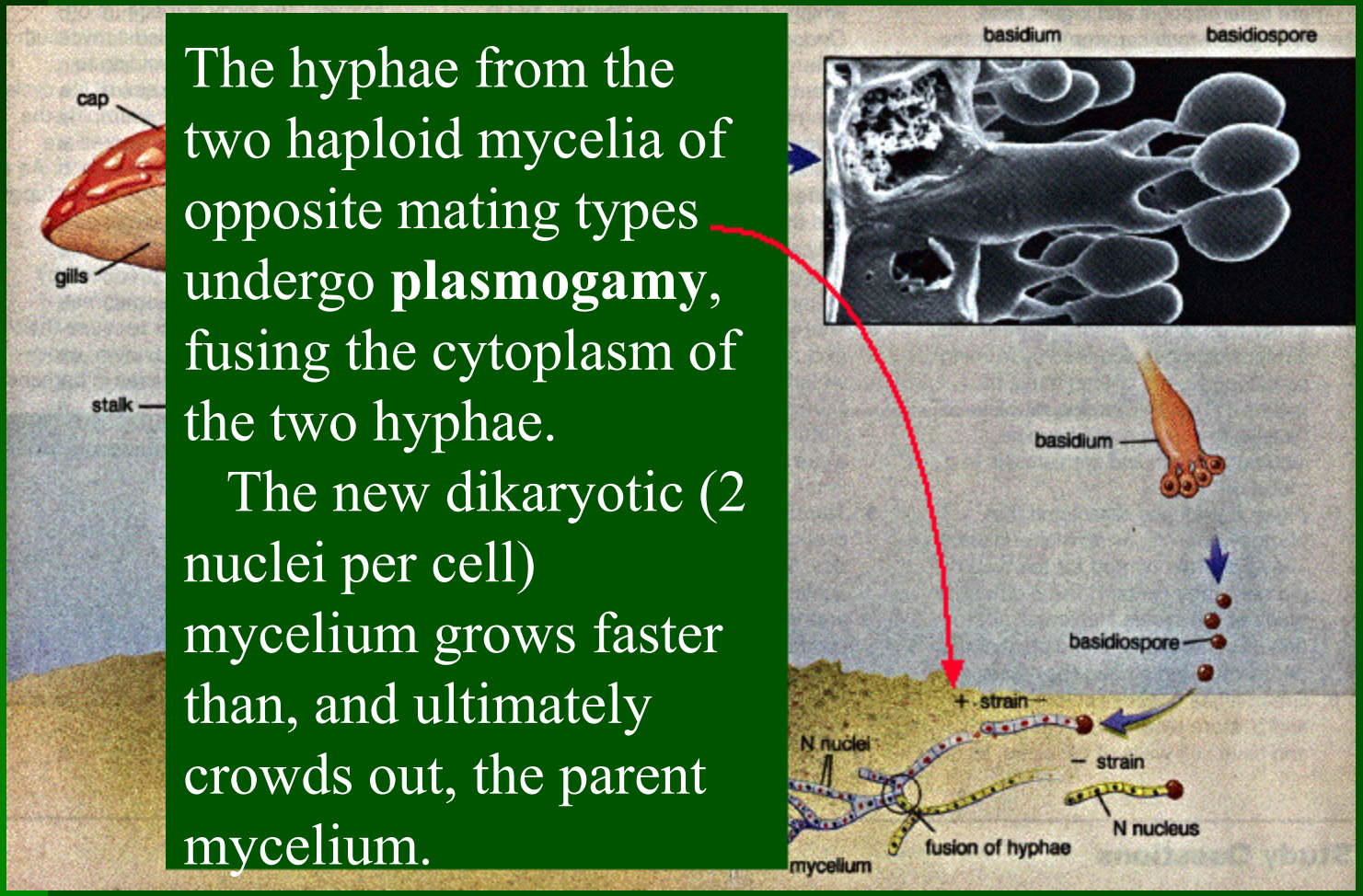
Spores can be of different strains indicated by + or - symbols.



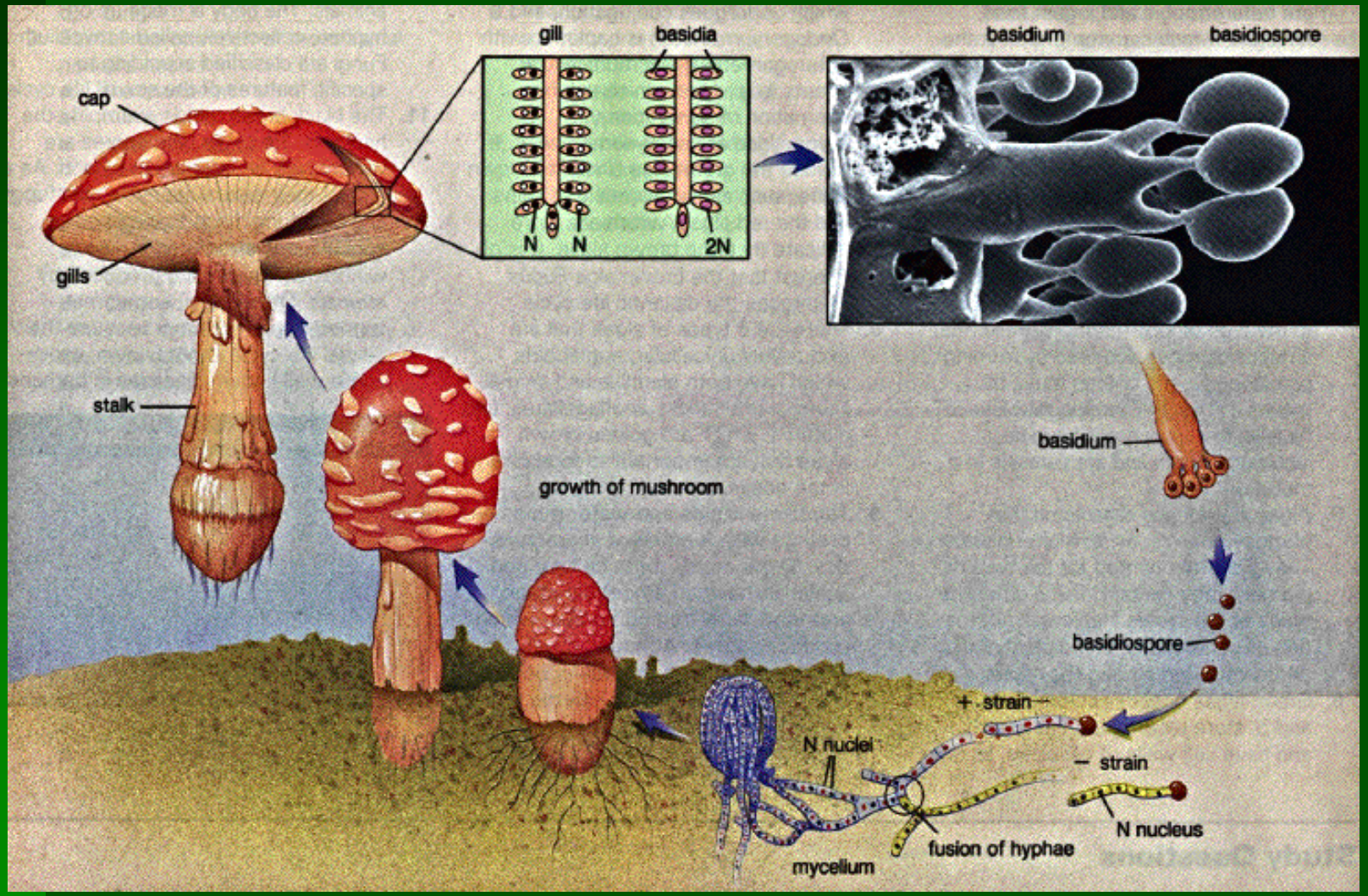
Basidiomycetes life cycle

The hyphae from the two haploid mycelia of opposite mating types undergo **plasmogamy**, fusing the cytoplasm of the two hyphae.

The new dikaryotic (2 nuclei per cell) mycelium grows faster than, and ultimately crowds out, the parent mycelium.



Basidiomycetes life cycle



Basidiomycetes

Astreus

Wet

Dry

When placed in water Astreus swells up, becoming plump and flexiable. When dried out it is shrunken, hard, and crispy.

Basidiomycetes

One last tidbit about mushrooms: a ring of mushrooms, popularly called a fairy ring, may appear on a lawn overnight. These are not planted by fairies or UFO's, but are a natural, though strange phenomena. These mushrooms are saprobes on dead plant material, not parasites on living grass. Although the grass in the center of the ring is normal, after a few days the grass near the ring is stunted and the grass just outside the garland of mushrooms is especially lush.

As the underground mycelium grows outward, its center portion and the mushrooms around it die because the mycelium has consumed all the available nutrients.

Basidiomycetes

As the underground mycelium grows outward, its center portion and the mushrooms around it die because the mycelium has consumed all the available nutrients. The grass beneath the mushrooms is stunted because it cannot compete for minerals with the active mycelium. But fungal enzymes diffuse ahead of the advancing mycelium, and the grass there is fertilized by the minerals that become available. The fairy ring slowly increases in diameter as the mycelium advances at a rate of about 30 cm per year.

Some giant fairy rings may be centuries old. This perennial nature of basidiomycete mycelia was recently highlighted by the discovery, in Michigan, of a genetically uniform mycelium of the honey mushroom, Armillaria bulbosa, which occupies about 37 acres, weighs more than 100 tons, and may be more than 1500 years old.

Dung Garden

The dung garden unfortunately did not photograph very well. A pity, because I know you wanted to see pictures of fungus growing on rotting horse poop balls. Use your imagination and the information you have already learned to answer the last two questions for this station.

All right, you got some info; now lets see what you can do with it!

1. Acid rain can potentially kill all the fungi in a forest. What would that do to the forest ecosystem? Describe all the possible effects.
2. Many fungi produce antibiotics, such as penicillin, that are valuable as medicine, but of what value are the antibiotics to the fungus?

More Questions

3. Many fungi and lichens in the United States are threatened with extinction due to destruction of habitats. Should they come under legal protection by their inclusion on lists of endangered species? Defend your answer.
4. How have fungi made life more expensive for us? Think of ways they have affected you in your everyday life.

We hope that this lab helped you to go beyond just memorizing some facts about fungi so that you can appreciate the varied roles fungi play in our world and understand how fungi relate to the rest of biology.