Chapter

19 Fungi

Hygrophorus *fungi emerge from the decaying leaves of a forest floor. Fungi have a unique mode of nutrition, in which they secrete enzymes to break down the organic material of other organisms.*

Chapter Inquiry Classifying

1. Examine the samples of living things provided by your teacher and separate them into two groups.
2. Describe the single outstanding characteristic that determined into which group each specimen fell.
3. Hypothesize as to how each group is able to obtain its food.

Connect to the Main Ideas

All fungi are heterotrophic organisms, meaning that they live on compounds produced from other organisms. What other modes of nutrition have you already studied? Why do you think several exist?

CHAPTER PREVIEW

Main Ideas

In this chapter, you will learn how fungi obtain food. You will also examine the structural and reproductive characteristics that distinguish the five different phyla of fungi. You will learn about symbiotic relationships of fungi and some of the diseases that fungi cause.

Reading Strategy

Formulating Questions Before reading this chapter, list as many kinds of fungi as you can think of, along with the places where they are found. Formulate questions such as: How does each obtain energy? How does it reproduce? Is it beneficial or harmful? Write down your answers to these questions as you read.

Journal Activity

Biology and Your World Beer, breads, some cheeses, and certain diseases are all produced by fungi. Describe what a day in your life would be like if fungi did not exist.

19–1 The Fungi

Guide For Reading

- What are fungi?
- What are some characteristics of each of the five phyla of fungi?
- How do fungi obtain food?
- How do fungi reproduce?

For many of us, the most common encounters with **fungi** (FUHN-jigh; singular: fungus) are unwanted ones: molds spoil our fruits and breads, mildew weakens our fabrics, and athlete's foot attacks our skin. In tropical areas, more than 50 percent of the food that is produced is spoiled by fungi before it can be eaten. And in temperate regions, trees such as the elm die of a fungal disease known as Dutch elm disease.

For reasons such as these, when we think of fungi, we think of death and decay. Fungi, however, are among the most interesting organisms in the living world. Not only do they help shape the natural environment, they also provide us with food—and in so doing, they display some remarkable and exotic lifestyles.

Characteristics of Fungi

Fungi are eukaryotic heterotrophs. You will recall from Chapter 17 that heterotrophs depend on other organisms for food. Many fungi are saprophytes, or organisms that obtain food from decaying organic matter. Others are parasites, which are organisms that live directly on the body of a plant or animal host and in so doing harm that organism. Still other fungi are symbionts, or organisms that live in close association with an organism of another species.

Figure 19–1 *All fungi are heterotrophs, or organisms that obtain food from organic compounds produced by other organisms. Many of these heterotrophs, such as the bracket fungi shown here, live as saprophytes, decomposing dead matter.*

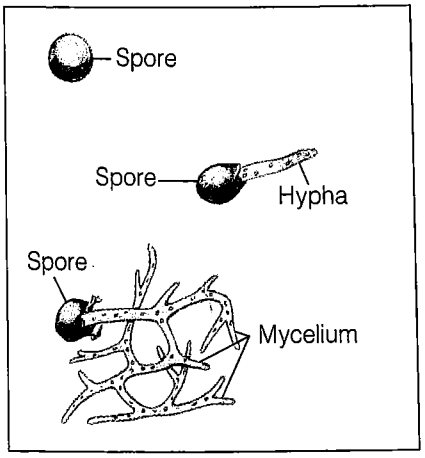


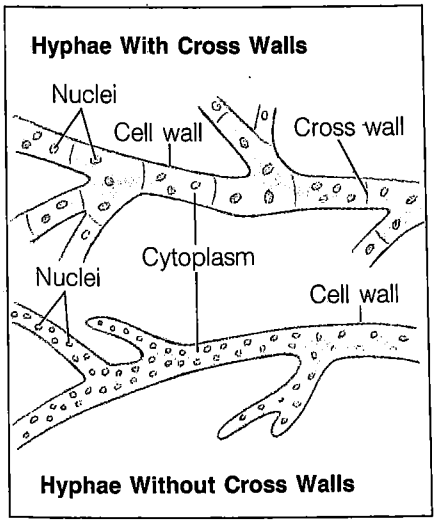
Figure 19–2 *A fungus develops from a spore that grows into a threadlike hypha. The hypha grows rapidly and branches until it resembles a tangled mass of threads called a mycelium.*

Fungi do not ingest their food. Instead, they absorb it through their cell walls and cell membranes. Fungi release digestive enzymes into their environment. The enzymes break down leaves, fruit, or other organic material into simple molecules, which then diffuse across the cell walls and cell membranes. This method of obtaining food makes fungi very important in nature: They produce powerful digestive enzymes that speed the breakdown of dead organisms, helping to recycle nutrients and essential chemicals. Together with the bacteria, fungi are the major **decomposers,** or organisms of decay.

Except for yeasts, which are unicellular, the body of a typical fungus is made up of many tiny filaments tangled together into a thick mass called a **mycelium** (migh-SEE-lee-uhm). The individual filaments are called **hyphae** (HIGH-fee; singular: hypha). In many fungi, the hyphae are divided by cross walls into cells containing one or more nuclei. See Figure 19–3. The cell walls of most hyphae are made up of chitin, a complex carbohydrate that is also found in the external skeleton of insects. The cell walls of other hyphae contain cellulose, the complex carbohydrate that makes up the cell walls in plants. The mycelium, or tangled mass of hyphae, is well suited to absorbing food because it permits a larger surface area to come in contact with the food source.

Most fungi reproduce both asexually and sexually. Asexual reproduction occurs either by the production of spores or by the fragmentation of the hyphae (each fragment becomes a new fungus). In some fungi, spores are produced in structures called **sporangia** (spoh-RAN-jee-uh; singular: sporangium). Sporangia are found at the tops of specialized hyphae called **sporangiophores.**

Figure 19–3 *Some hyphae are divided by cross walls that contain one or more nuclei. Other hyphae are coenocytic, meaning they lack cross walls.*



In many fungi, sexual reproduction involves two different mating types. One mating type is referred to as + (plus) and the other is referred to as − (minus). When the hyphae of opposite mating types meet, each hypha forms a **gametangium** (gam-uh-TAN-jee-uhm), or gamete-forming structure. Then the two gametangia fuse, and some of the nuclei pair and join to form zygote nuclei.

During the greater part of their life cycle, the nuclei of most fungi are haploid (N). Diploid (2N) nuclei form during sexual reproduction. Shortly after the nuclei fuse, meiosis (reduction division) occurs and produces haploid nuclei that dominate the remainder of the life cycle of fungi.

Fungi are classified according to their methods of reproduction and their basic structure. At one time fungi were classified either in the kingdom Plantae or in the kingdom Protista. Today, fungi are placed in their own kingdom, the Fungi.

We have divided the kingdom Fungi into five phyla: Oomycota, Zygomycota, Ascomycota, Basidiomycota, and Deuteromycota. Notice that the name of each phylum ends in *-mycota.* This suffix is derived from the Greek word for mushroom, which is *mykes. Mykes* is also the root for mycelium.

Oomycota—Protistlike Fungi

Because the fungi in the phylum Oomycota (oh-oh-migh-KOHT-ah) are so closely related to the plantlike protists, many scientists include them as one of the phyla within the kingdom Protista. Members of this phylum, called oomycetes, commonly form a white fuzz on aquarium fish or on organic matter sitting in water. Although oomycetes are commonly known as "water molds," a few are able to grow on land under damp, humid conditions. Even though these fungi are not common on land, they do cause a number of serious diseases among crop plants, including potato blight. We will consider these diseases when we examine how fungi fit into the environment.

The cell walls of oomycetes are made of cellulose. It is through these thin cell walls that the water molds absorb food. Oomycetes are the only fungi that produce motile spores. These spores swim through water and raindrops to new sources of food. The hyphae of oomycetes lack cross walls. As a result, the hyphae are multinucleate (have many nuclei).

The life cycle of a water mold is shown in **Figure 19–4**. Notice the two types of reproduction that can occur: asexual and sexual. In asexual reproduction, portions of the hyphae develop into sporangia (spore cases). Each sporangium produces flagellated spores that swim away from the sporangium in search of food. When food is found, the spores develop into hyphae, which grow into new organisms.

Figure 19–4 *The water mold, an oomycete, reproduces both asexually and sexually. During asexual reproduction, flagellated spores are produced by the diploid (2N) mycelium. These spores grow into new mycelia. During sexual reproduction, the male gamete fuses with the female gamete.*

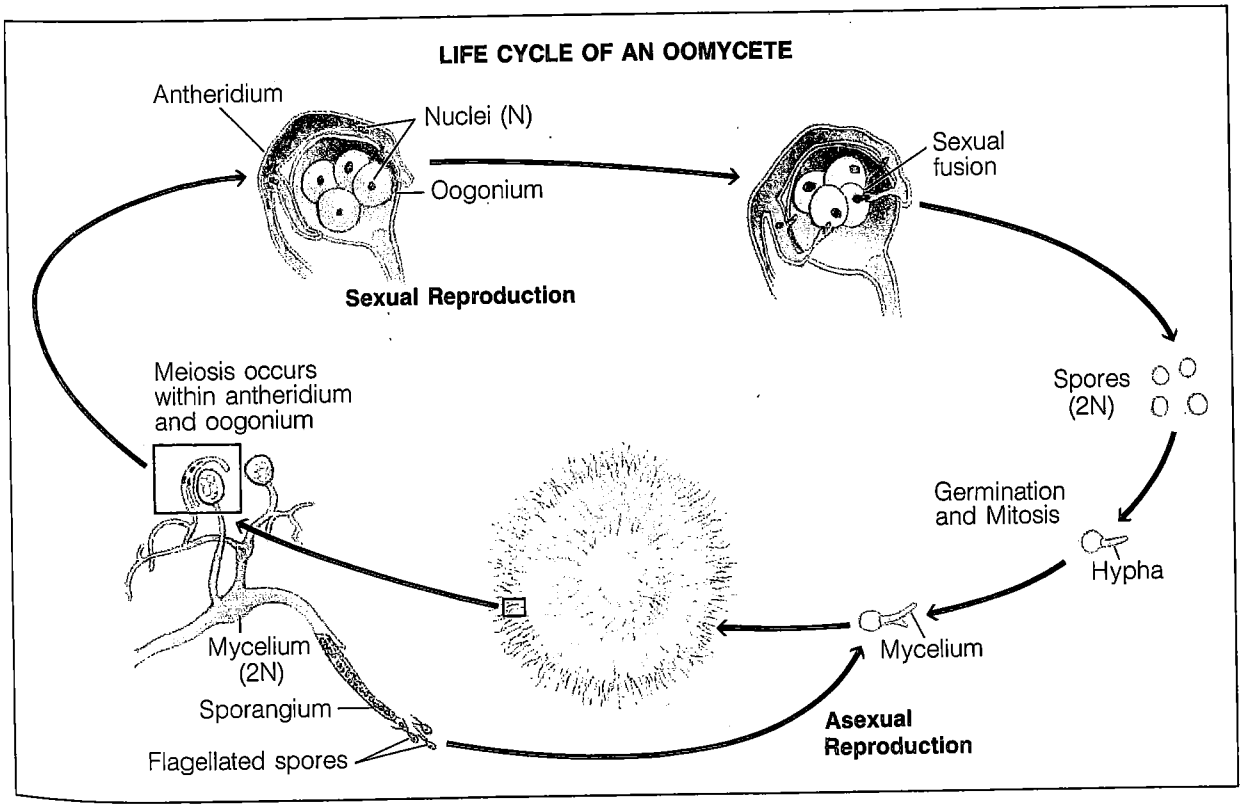


Figure 19–5 *The black bread mold* Rhizopus stolonifer, *a zygomycete, is commonly found growing on bread. The round black-colored structures at the top of the threadlike hyphae are the sporangia, or spore cases.*

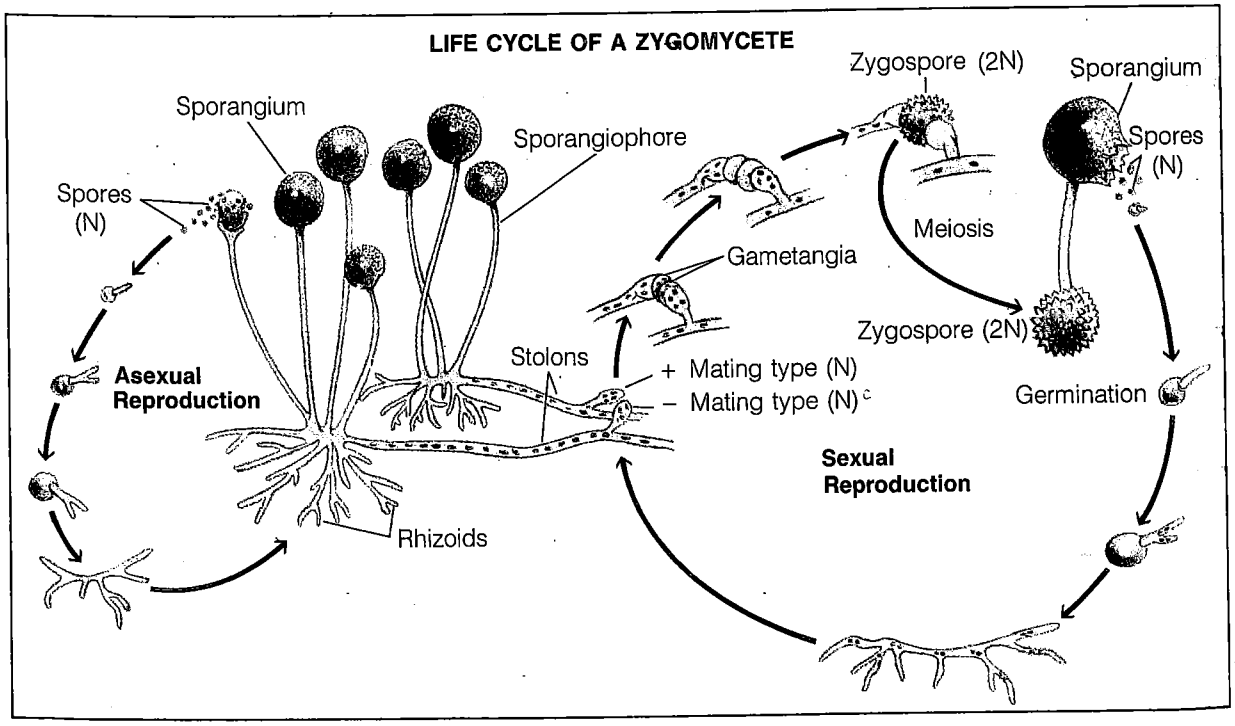
Sexual reproduction takes place in specialized structures that are formed by the hyphae. One of these structures, called the antheridium (an-thuh-RIHD-ee-uhm), produces sperm cells (male gametes). The other structure, called the oogonium, produces egg cells (female gametes). Fertilization occurs within the oogonium and, like spores, the zygotes that form develop into new organisms.

Zygomycota—Common Molds

Fungi that belong to the phylum Zygomycota (zigh-goh-migh-KOHT-uh) are called zygomycetes and are terrestrial organisms. During sexual reproduction, they form a thick-walled zygote known as a **zygospore.** The hyphae of zygomycetes lack cross walls although there are cross walls present that isolate the reproductive structures from the rest of the hypha. We have all had some experiences—most often unpleasant ones—with members of this phylum. These common molds are the molds that grow on meat, cheese, and bread.

An example of a zygomycete is the black bread mold *Rhizopus stolonifer.* You can grow this mold yourself by exposing a slice of freshly baked bread (not the processed kind) to some airborne dust. Then keep the bread from drying out by putting it in a covered container and placing it in a warm spot.

Figure 19–6 *Sexual reproduction in black bread mold occurs when two hyphae from different mating types fuse, forming gametangia. The gametangia develop into a zygospore, which grows into new hyphae that form sporangia. Asexual reproduction occurs when the spores are discharged from the sporangia.*



In a few days, if you use a magnifying glass to examine the fuzz that grows on the warm bread you will see tangles of delicate hyphae, or mycelia. Actually, you would be seeing more than one kind of hypha. The rootlike hyphae that penetrate the surface of the slice of bread are called **rhizoids.** Rhizoids anchor the fungus to the bread (much as roots anchor a plant), release digestive enzymes, and absorb digested organic material. The stemlike hyphae that run along the surface of the bread are called **stolons.** And the hyphae that push up into the air are the sporangiophores, which form sporangia at their tips.

During asexual reproduction, sporangia produce spores. A single sporangium may contain as many as 40,000 spores. When fully developed, the sporangium opens, scattering the spores to the wind. Under proper conditions of warmth and moisture, the spores germinate, producing new masses of hyphae.

Sexual reproduction occurs in bread molds and other zygomycetes when two hyphae from different mating types come together, forming gametangia (gamete-producing structures). Haploid gametes are produced in the gametangia. Gametes of one mating type fuse with gametes of the opposite mating type, forming diploid (2N) nuclei. A thick wall develops around the nuclei, producing a zygospore. The tough, resistant zygospore may remain dormant for months. Eventually, when conditions become favorable, the zygospore germinates, undergoes meiosis, and develops into a hypha. The hypha then forms a sporangium and releases spores. Each spore can develop into a new mycelium.

In zygomycetes, as in other organisms, the main function of a sexual reproductive process is to produce new combinations of genetic information. The sexual reproductive process is an effective way to maintain genetic diversity in a species.

Ascomycota—Sac Fungi

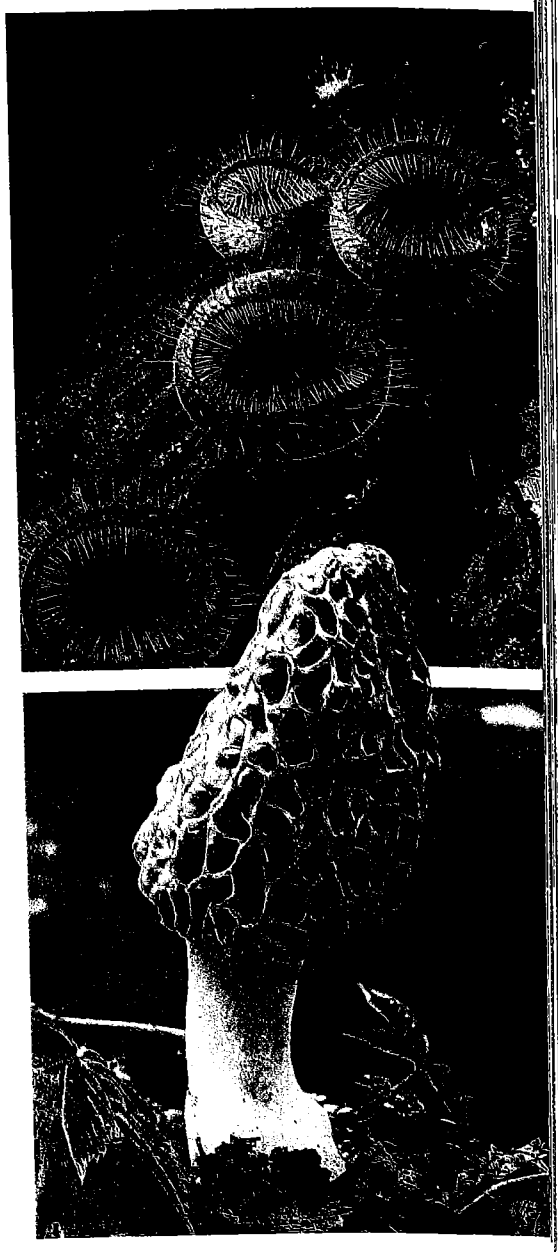
The phylum Ascomycota (as-kuh-migh-KOHT-uh) is the largest phylum of the kingdom Fungi. There are more than 30,000 species of ascomycetes, as members of this phylum are called. The nuclei in the hyphae of ascomycetes are separated by cross walls so that individual cells do exist within the organism. In the cross walls, however, there are tiny openings through which the cytoplasm and the nuclei can move. Some ascomycetes, such as the morels, are large enough to be visible when they grow above the ground. Others, such as yeasts, are microscopic.

The life cycle of an ascomycete usually includes both asexual and sexual reproduction. Asexual spores are formed at the tip of specialized hyphae called **conidiophores** (koh-NIHD-ee-uh-forz). Because these spores are very fine, they are called **conidia** (koh-NIHD-ee-uh; singular: conidium) from the Greek word *konis*, which means dust.

Quick Lab

To reinforce the **Main Idea** of reproduction in fungi, perform the Quick Lab activity called Observing a Bread Mold on p. 1093.

Figure 19–7 *Ascomycetes are the largest phylum of fungi, containing 30,000 species. Among the ascomycetes are the common morel (bottom) and a type of cup fungus (top).*



Sexual reproduction in ascomycetes involves the formation of an **ascus,** or tiny sac. The ascomycetes are named for this reproductive structure. In most ascomycetes, sexual reproduction occurs between two different mating types (+ and −), which produce gametangia. The gametangia grow together to allow the haploid (N) nuclei to fuse. The cell that results from this fusion begins to develop into a structure that forms the ascus. See Figure 19–8. At first the cell has two nuclei, indicating that the nuclei of the two mating types do not fuse right away. When fusion does eventually occur, a diploid (2N) zygote is formed. The fusion is quickly followed by meiosis, producing 4 haploid cells. In most ascomycetes, meiosis is followed by a round (or two) of mitosis, so that 8 or 16 cells are found within the ascus. The cells produced within the ascus are known as **ascospores.** Like conidia, ascospores are capable of growing into new organisms.

The fruiting bodies of ascomycetes can be spectacular. A fruiting body is the part of the fungus that you see above the ground. It contains the spore-producing structures. The morel is an edible ascomycete in which the fruiting body bearing the asci has become the largest visible part of the organism.

The yeasts, which are unicellular, are one of the most interesting groups of ascomycetes. Most of their reproduction is asexual and takes place by mitosis and by budding. Budding is the formation of a smaller cell from a larger one.

Under the right circumstances, yeasts also reproduce sexually. They form asci that contain ascospores. Most scientists

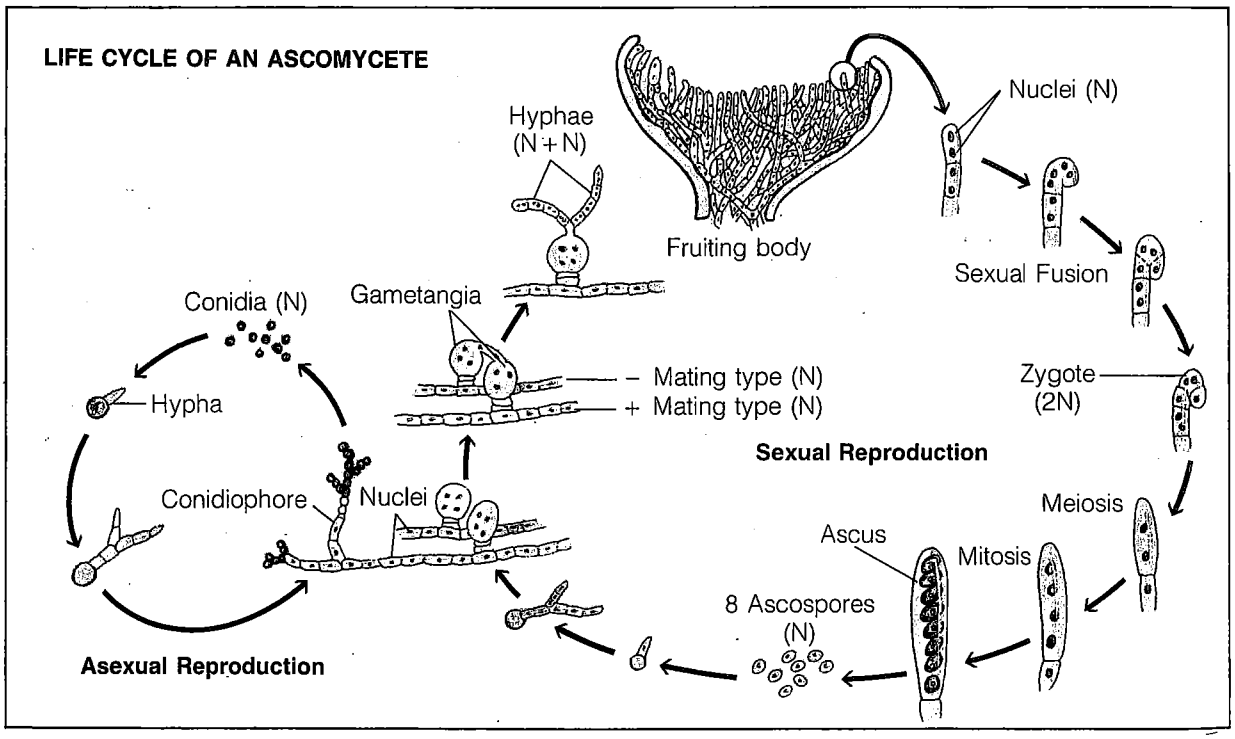


Figure 19–8 *As in most fungi, the life cycle of ascomycetes includes both asexual and sexual reproduction. During asexual reproduction, spores called conidia are formed at the tip of conidiophores, or special hyphae. During sexual reproduction, an ascus, or tiny sac that contains ascospores, forms.*

believe that yeast evolved from more complicated (and more typical) ascomycetes that lost the ability to form hyphae and became unicellular.

You might think of yeast as a lifeless dry powder used to make bread and rolls. But the dry granules actually contain ascospores, which become active in a moist environment. To see this for yourself, take a teaspoon of dry yeast and add it to about 50 milliliters of warm water that contains two teaspoons of sugar. When you examine a drop of this mixture under a microscope in about twenty minutes, you will be able to see cell division in the rapidly growing yeast cells.

Basidiomycota—Club Fungi

Most of the organisms that we call mushrooms belong to the phylum Basidiomycota (buh-sihd-ee-uh-migh-KOHT-uh) and are known as basidiomycetes. The phylum gets its name from a specialized reproductive structure that resembles a club. This spore-producing structure is called a **basidium** (buh-SIHD-ee-uhm; plural: basidia). In mushrooms, basidia are found in the cap.

Basidiomycetes undergo what is probably the most elaborate life cycle of all the fungi. A **basidiospore** germinates to produce haploid primary mycelia. The haploid primary mycelia of different mating types fuse. A secondary mycella containing two nuclei—one nucleus from each mating type—is formed. (The nuclei themselves do not fuse at this stage.)

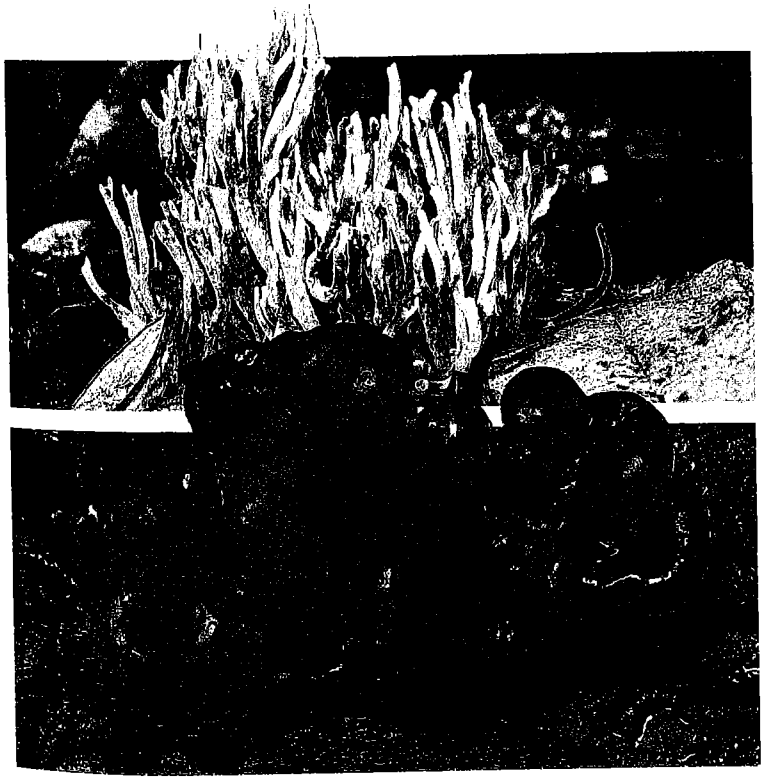


Figure 19–9 *All basidiomycetes, or club fungi, are composed of masses of hyphae. The coral fungus (top, left), shaggy mane fungus (right), and jelly fungus (bottom, left) illustrate the many different shapes that masses of hyphae can form.*

Figure 19–10 *This photograph shows the underside of a parasol mushroom. Notice the gills and the stalk. The ringlike structure on the stalk is called the annulus.*

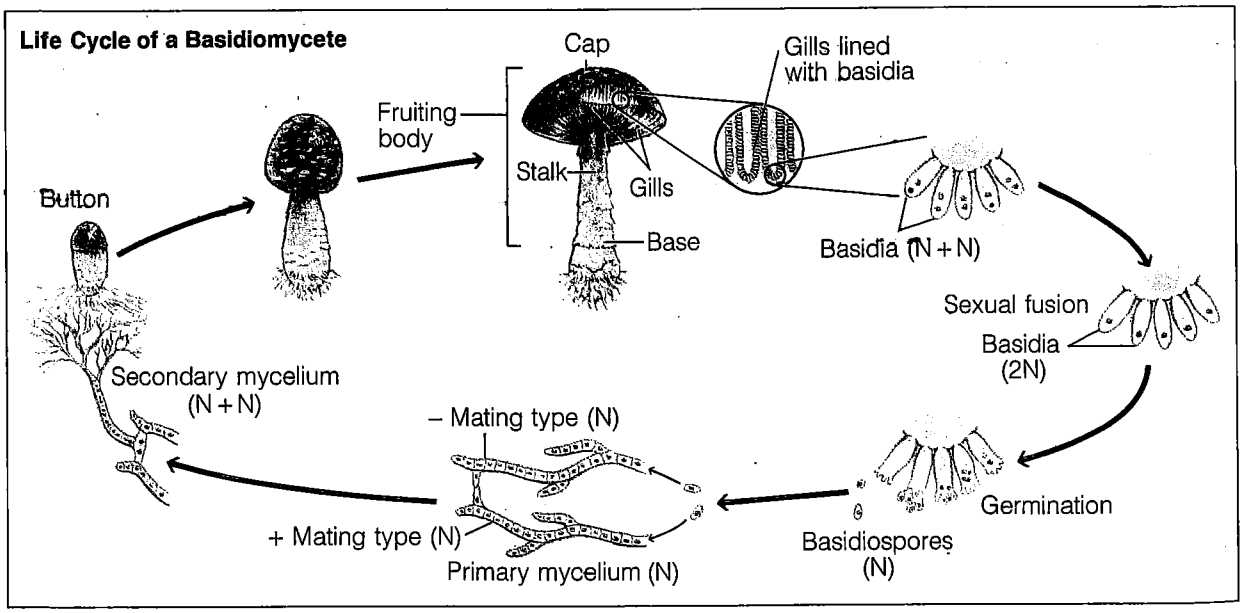
The secondary mycelia can grow in the soil for years, reaching an enormous size. (A few mycelia have been found to be hundreds of meters across, making them perhaps the largest organisms in the world!) When the right combination of moisture and nutrients occurs, a spore-producing fruiting body pushes above the ground. We recognize these fruiting bodies as mushrooms.

The mushroom (fruiting body) begins as a mass of growing hyphae that forms a button, or thick bulge, at the soil's surface. The bulge expands with astounding speed and force, producing fully developed mushrooms overnight. This rapid growth occurs because the cytoplasm from thousands of hyphae in the soil quickly streams into the growing mushroom, enlarging it and producing a great amount of force.

When the mushroom cap opens, it exposes hundreds of tiny gills on its underside. Each gill is lined with basidia. Within a few days, the two nuclei in each basidium fuse to form a true diploid (2N) zygote cell. The diploid cells quickly undergo meiosis, forming clusters of haploid basidiospores. The basidiospores form at the edge of each basidium and, within a few hours, are ready to be scattered. Mushrooms are truly amazing reproductive structures—a single mushroom can produce as many as one billion spores!

In addition to common mushrooms, this phylum includes shelf (bracket) fungi, which grow near the surfaces of dead or decaying trees. The visible bracketlike structure that forms is actually a reproductive structure, and it too is an amazing producer of spores. Puffballs, toadstools, jelly fungi, and plant parasites known as rusts are other examples of basidiomycetes.

Figure 19–11 *The most familiar basidiomycetes are the mushrooms. The mushroom cap, which contains basidia, is made up of masses of tightly packed hyphae. Basidia are the club-shaped structures that produce the basidiospores.*



Deuteromycota—Imperfect Fungi

The phylum Deuteromycota (doo-ter-uh-migh-KOHT-uh) includes fungi that cannot be placed in any of the other phyla because their sexual reproduction has never been observed. The word imperfect is a botanical term referring to a lack of sexual reproduction; hence, the name imperfect fungi.

A great majority of the deuteromycetes (as they are also known) closely resemble ascomycetes. Others are similar to basidiomycetes. And a few are much like zygomycetes. An example of a deuteromycete that is similar to ascomycetes is *Penicillium*. *Penicillium* is a mold that frequently grows on fruit and is the source of the antibiotic penicillin. *Penicillium* forms large mycelia on the surfaces of its food source. And like ascomycetes, *Penicillium* reproduces asexually by means of conidia. Biologists believe that *Penicillium* may have developed from a type of ascomycete that lost the ability to carry out the sexual phase of its life cycle.

The deuteromycetes include some of the most infamous members of the kingdom Fungi: those that are responsible for ringworm, athlete's foot, and other skin infections that affect humans. Other deuteromycetes cause several plant diseases, including black spot of roses and early tomato blight.

Figure 19–12 Aspergillus niger, *a deuteromycete, contains spore-bearing structures called conidiophores (inset), which form at the tips of hyphae.*

Figure 19–13 *Five phyla of fungi*

Phylum	Examples	Characteristics	Reproduction	
			Asexual	**Sexual**
Oomycota (protistlike fungi)	Water molds, downy mildew, potato blight fungus	Cell walls with cellulose; coenocytic diploid hyphae	Flagellated oospores in sporangia	Fusion of gametes in gametangia resulting in oospores
Zygomycota (common molds)	*Rhizopus* (black bread mold), *Pilobolus* (a dung fungus)	Cell walls with chitin; coenocytic hyphae	Unflagellated spores in sporangiophores	Fusion of gametes in gametangia resulting in zygospores
Ascomycota (sac fungi)	Yeasts, morels, truffles, *Neurospora* (red bread mold)	Hyphae divided by perforated cross walls; short stage in which cells have two nuclei	Conidia on conidiophores	Fusion of hyphae resulting in ascospores in ascus
Basidiomycota (club fungi)	Mushrooms, puffballs, bracket fungi, rusts, jelly fungi, toadstools	Hyphae divided by perforated cross walls; long stage in which cells have two nuclei	None or conidia on conidiophores	Fusion of cells on tips of hyphae resulting in basidiospores on a basidium
Deuteromycota (imperfect fungi)	*Penicillium*, *Aspergillus*, ringworm and athlete's foot fungus, black spot on roses fungus, tomato blight fungus, cucumber scab fungus	Some resemble ascomycetes; others similar to basidiomycetes; few like zygomycetes	Conidia on conidiophores	None known