



Mushroom Basics

Fungi: A Kingdom of Its Own

As we go about our lives here on Earth, we seldom think about the natural world and what it provides us, let alone about the significant value and role that mushrooms and other fungi play in providing us with the clean, healthy ecosystems from which we derive our food, shelter, clothing, and other life necessities. Scientists have developed a classification system for all living things. Depending on which classification system you subscribe to, there are five to eight kingdoms of life on Earth (Table 2.1). Although scientists may disagree on the number of divisions, they all feature Fungi as a major division. Kingdoms are the second highest classification of life (beneath domains) and describe some of the most basic divisions, for example, animals vs. plants.

The five major kingdoms (Whittaker, 1969) are:

Plantae: includes eukaryotic (cells contain a nucleus of genetic material and other organelles, all enclosed in membranes) organisms that are multicellular and are usually characterized by photosynthesis and sexual reproduction, and is always its own kingdom within all classifications to date.

Animalia: includes eukaryotic organisms that rely in some way on other organisms for nourishment, and is always its own kingdom within all classifications to date.

Fungi: includes eukaryotic, non-photosynthetic organisms distinguished by unique cellular wall structures, primarily the presence of

TABLE 2.1. The Kingdoms

Five Kingdoms	Six Kingdoms	Seven Kingdoms	Eight Kingdoms
Monera	Eubacteria	Eubacteria	Eubacteria
	Archaeobacteria	Archaeobacteria	Archaeobacteria
Protista	Protista	Protozoa	Archezoa
			Protozoa
		Chromista	Chromista
Plantae	Plantae	Plantae	Plantae
<i>Fungi</i>	<i>Fungi</i>	<i>Fungi</i>	<i>Fungi</i>
Animalia	Animalia	Animalia	Animalia

chitin rather than cellulose, and is comprised of mushrooms, yeasts, and molds, and is always its own kingdom within all classifications to date.

Monera: includes all bacteria, which are single-celled, prokaryotic (cells do not have a distinguished nuclear membrane) organisms, and is sometimes broken into two kingdoms, usually Eubacteria and Archaeobacteria (Woese, 1977).

Protista: a catch-all (not plants, animals, fungi, or bacteria), diverse kingdom of eukaryotic organisms with a simple cellular structure; it has been divided into two or three separate kingdoms by some biologists (Cavalier-Smith, 1993 and 1998).



Fungus Fact: The largest single organism in the world is thought to be a honey fungus that spans 2.4 miles (3.8 km) within the Blue Mountains of Oregon.

Mushrooms are a small group of species that exist within the Fungi Kingdom. Although the term “mushroom” is not a biological classification at any level, it is used loosely to describe fungi that have a visible fruiting body, which includes a stem and a cap with either gills or pores on the underside that produce reproductive spores. Within ecosystems, the primary role of fungi is decomposition, but they serve a variety of other functions as well. We cultivate mushrooms that are different spe-

cies (boletes, stropharia), but can also be sub-species or varieties of the same species that go by different variety names.

Many species and a wide variety of mushrooms exist. Let us start with the ones you're probably most familiar with: white button, crimini, and portobello. These mushrooms are actually the same species, *Agaricus bisporus*. In most grocery stores, your fresh mushroom selection is limited to *A. bisporus* because its production has been industrialized. The large tan version of this mushroom was a waste product at one time. It wasn't until the 1980s and early 1990s that mushroom growers started to market this variety as the now-ubiquitous portobello. The two of us set out on our mushroom-growing path because we felt *Agaricus* mushrooms are not that tasty and are often not as nutritious as other mushrooms. Plus, they must be grown on manure compost, and they can contain hydrazines, which are cancer-causing chemicals (FC&A Publishing, 2004). We now wild-collect mushrooms and grow gourmet and medicinal mushrooms that feed on plant cellulose, rather than manure compost. This is foundational to our mushroom journey and, therefore, the contents of *Mycelial Mayhem*.

Mushroom Structure and Life Cycle

The word “mushroom” most often refers to the *fruiting body*, the visible part of the organism, with the *stipe*, which is like its stem, and the *pileus*, or cap, which sprouts first as a small *pin* (technically called the *primordium*), which looks like a tiny bump bubbling up from the parent *mycelium*.

But, let's back up to the beginning of the life cycle, the germination of a mushroom's *spores*, which are like a mushroom's seeds. When the spores are released from a fungi's fruiting body, usually from underneath the cap, they germinate, and start to form threads of cells, called *hyphae*. Hyphae continue to



FIGURE 2.1. Oyster mushrooms primordia (pins) starting to form fruiting bodies (stipe and pileus).

grow and branch out, forming mycelium. Mycelium is a network of cells that spreads like a plant's roots within the organism's growth medium, usually soil, manure or various types of plant material such as

straw or woody substrates. From the mycelium, the pins arise from cells that gather and push outward and upward. These form the fruiting bodies, usually comprised of the stipe and the cap. Spores mature within the fruiting body, usually beneath the cap, and are released when ready.

When we exhibit at shows or teach classes, Dave usually wears a black t-shirt that has the mushroom life cycle on it. All he has to do is point at the shirt when he wants to explain the process of a mushroom's life cycle.

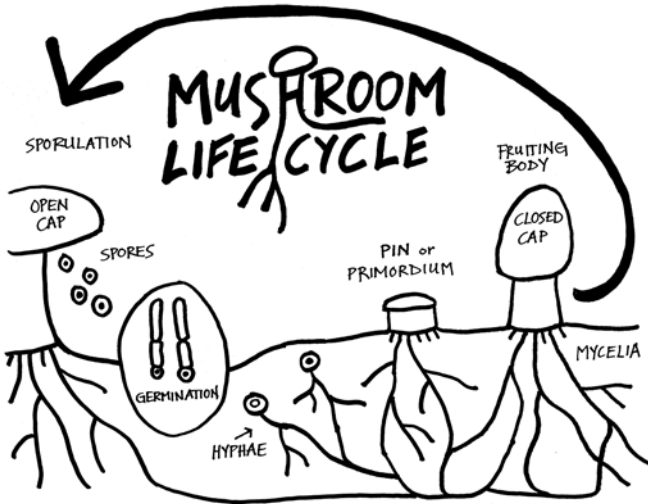


FIGURE 2.2. Lifecycle of fungi.

Relevance of the Life Cycle to Cultivation and Harvest

Here, we'll cover the basics of mushroom growth and their successful cultivation and harvest; we'll expand on this information in Chapter 3. A good understanding of mushroom properties and life cycle will help you have cultivation success, capitalize in various ways on these features during cultivation, and think more broadly of the inherent wisdom of the mushroom life cycle, which can (somewhat surprisingly) benefit your business perspectives as well. As Paul Stamets and J. S. Chilton explain in *The Mushroom Cultivator* (1983), you, the cultivator and harvester, interact with all stages of the mushroom's life cycle and therefore need to know how to facilitate the cycle, usually with the goal of producing as many mushrooms as possible, as frequently as possible. Unfortunately, successfully creating a healthy growth environment for say, oyster mushroom mycelia, can also create an excellent home for green mold and other invaders. So you will need to learn how to tip the scales

in favor of the mushroom you are trying to grow. In the case of the oyster, you do this by pasteurizing your straw, keeping everything as clean as possible, and not getting too much water into the production bags—because oysters require less water for their life cycle than green mold.

If you provide just the right environment for your mushrooms, you will literally see the fruits of your labors. The first thing you'll see will be healthy *mycelia* colonizing your growing medium. The figure here shows an Italian oyster “production bag” completely populated with oyster mycelium, which appear in the photo as solid white. Understanding what a mushroom looks like at its various stages is important. You need to know when it is releasing its spores so you can collect them at the right time, and you'll want to recognize stages to help with the timing of your harvest. For example, some mushrooms, like wine cap stropharia, become bitter-tasting when their caps open and start to produce spores.

Cultivating mushrooms is as exciting and fun as gardening or any other effort in which we shepherd our own food creation. We are not so much the masters of the processes but the caretakers of these ageless cycles of life. Much like picking tomatoes at the height of perfection, you will want to know the perfect time to pick your mushrooms. You want to pick for optimal taste and shelf life. Every mushroom and every strain is a little different. For example, *hericium* (lion's mane) is very different from shiitake in its structure. One of the most often wild-collected mushrooms is *Coprinus comatus*, known as “shaggy mane,” “lawyers wig,” or “inky caps.” These edible mushrooms will go from a scaly whitish beauty to an oily black mess of spores in a couple of days. For optimal taste and before they turn oily, “ya gotta get her before she lifts



FIGURE 2.3. Mycelium throughout the bag produces plenty of Italian oysters.

her skirt,” in other words, before the veil is broken and the spores start to mature.

With our cultivated mushrooms, these same processes play out, so as a cultivator, you will need to know when to pick, when to compost, and when to allow the full process to play out. Often, we allow wine cap stropharia to play out so that it will sporulate, continuing its life



FIGURE 2.4. Wine caps harvested at the right time.



FIGURE 2.5. Wine caps fully open, left to spread spores.

cycle and fostering future grow beds. Because of the fast growth of the fruiting body, though, we sometimes accidentally allowed it to play out. But that’s ok, because we know this will strengthen the beds and augment our garden soil. When eating or picking to sell wine caps, we harvest the fruiting body when the gills are white and the caps were still somewhat closed and burgundy in color. This is important because taste is optimal before sporulation starts. This demonstrates the importance of not only knowing a mushroom’s life cycle, but also what each of your mushrooms looks like at various stages in the cycle.

The fruiting body is what we sell, and therefore what we are known for. The average customer is not interested in the mycelial structure or timing; they just want to see fresh and beautiful mushrooms. So, let’s start the discussion with varieties that have the “classic” look of the mushroom fruiting body: shiitake, pioppino, and wine cap stropharia.

Where the mycelium breaks from the ground, log, or substrate, is called the base. Next is the stipe or stalk. A stipe can be solid or hollow (as is the case with morels). Some call this the stem. If there is a “netting” look on the stipe, this is called *reticulum*. (Many



FIGURE 2.6. Shiitake grow block, showing various stages of growth and parts.

boletes have this on their stipe.) If there is a ring around the stipe, of tattered or papery appearance, this is the *annulus* and is where the cap's veil was attached to the stipe. You will see an annulus on stropharia, shiitake, and pioppino, too. The “cap” of the mushroom is known as the pileus. On the underside of the pileus, the *hymenium* exists in the forms of *gills*, technically called *lamellae*, *tubes*, or *pores*. (Shiitake, stropharia, pioppino, oyster, and nameko all have gills, while boletes have pores.) For the best harvest of your cultivated mushrooms, you want to collect



FIGURE 2.7. Wine cap annulus.



FIGURE 2.8. Shiitake's hymenium, in the form of gills (lamellae).

your mushrooms right before or as soon as possible after the cap's veil breaks from the stipe. This happens prior to sporulation, which compromises most mushrooms' taste. Once the veil breaks, the caps tend to flatten out to facilitate spore release. Harvesting at this time also gives your mushroom a longer shelf life. However, we once had a customer who liked shiitake fully flattened out!

But mushrooms are all different. With oysters, you do not have the luxury of looking to see the veil breaking. You have to watch them and learn when to pick them. Oyster caps will also begin to flatten out as the mushrooms begin to release their spores. The best way to know when to pick oysters is to watch the caps. The mushroom caps will drop a "dust"—the spores—on their neighbor below. This means that sporulation has begun. Once you start to see any spores on any of the caps in an oyster cluster, pick them! It will only be a matter of hours or a day or two before every cap is covered in spores and the taste will be compromised. Oysters are notorious producers of copious spores.

With hericium (lion's mane), you will watch the top of the mushroom more than anything else. A small ball will push out of your wood or from the substrate, and soon it will grow "teeth." Once the top of hericium begins to turn brown or becomes discolored, it is time to harvest the mushroom.

Maitake will "frond out," meaning it will have plates or leaves that will be slightly upright at first but will flatten out. We always try to pick



FIGURE 2.9. Lion's mane ball ready for harvest.

our cultivated maitake just when the fronds begin the flattening process. In the wild, we grab them any way we can, or we watch and wait for the flattening process. If we see a maitake we want to pick, we mark it and then watch the weather. If a drencher rain storm is coming, we pick it. If very hot weather or severe uptick in temperature is on the horizon, we pick the mushroom. If a hard freeze or snow event is coming, we grab it. Otherwise, we allow it to run its course to the flattening stage.



FIGURE 2.10. Maitake fruiting, primordia (*left*) and fruiting body formation (*right*).



FIGURE 2.11. Maitake fruits, fully “fronded out” and ready to eat.

Facilitating Growth and Reproduction

Most beginning mushroom growers purchase spawn from a supplier. Spawn is a mixture of materials that contains all of the necessary ingredients to facilitate mycelial growth and, eventually, mushrooms. Ingredients include an initial growth medium or food for mycelia, usually a grain. Mycelia has usually already started to spread within the grain upon purchase of spawn. Once received, the grower distributes the spawn within more growth media, such as wood chips, straw, or wood. Knowing what a mushroom’s mycelia looks like will help you recognize good mycelial growth as well as growth that deviates from that, which can indicate an invasion of some other fungus that is enjoying your growth medium and may outcompete your mushroom.

If you decide to move into the production of mycelia from spores, with all of the laboratory equipment and knowledge necessary, you will need to know how to recognize sporulation so that you can collect spores. You’ll then facilitate their growth within a sterilized medium, usually agar in a Petri dish. To recognize sporulation with the naked eye, look for the cap of the mushroom to start opening or spreading out laterally, exposing the gills or pores underneath so that the spores contained within can be more easily released.

Much more knowledge than this is needed to successfully grow mushrooms from spore to cap, so see Chapter 3 for more information and the technical resources you will need to succeed. Still, recognizing when a mushroom cap is in its pre-sporulation phase is important for any grower, as this is the best time to harvest for freshness and optimal taste. The signs vary by mushroom, and some produce spores a lot faster than others, so learning what the mushroom looks like in various phases is important.

Beyond producing mushrooms, knowing about the structures and life cycle can help you on other fronts as well. For example, wine cap stropharia can serve as a great companion within a vegetable garden. The mycelial mat that forms within the straw on the ground can hold important moisture in the soil, providing water for adjacent plants. The fruited wine cap bodies that are not harvested in time to eat (which can be numerous since they are fast growing) can provide much-needed nutrients to your soil as they quickly degrade on the ground.

A mushroom's mycelial mat can serve a variety of purposes. Mycelium can be used as a dietary supplement because the structural and chemical properties of mycelium can mirror that of the fruiting body. Many times, it is not the fruiting bodies, but the mycelia that are the raw materials of mushroom supplements because mass-producing an ongoing mycelium source can be more reliable than the short-lived fruiting body.

Fungi in Our Ecosystems

In ecosystems, everything is connected, interdependent. So, it is logical that the species that make up one of the five kingdoms of life play many important roles, filling *niches*, as they are known in ecology. Most people know that mushrooms are the master decomposers in nature, filling a large portion of this huge niche so that we don't have too much "stuff" build up in nature, like fallen leaves, trees, and other organic matter. Mushrooms feed on this organic matter, cycling nutrients back into the ground upon their demise. But, as if they don't do enough as decomposers, fungi also serve other roles in nature. An example of mu-

tualism (mutually beneficial relationships), mycorrhizal fungi facilitate plant growth by providing essential nutrients to a plant's roots, while receiving sugars from the plant. According to Gary Lincoff (2015), fungi also form other mutualistic relationships with plants, such as by occupying plant tissues (becoming *endophytes*) and potentially contributing to their functions. They also contribute to soil ecology and provide the "network" of underground mycelia so important in the exchange of resources. It's the underground Internet, so to speak. So, fungi contribute both to the healthy existence of plants and the breakdown of excess plant material.

Fungi can also cause system disturbances, as seen with the ergot fungus; commonly known as St. Anthony's fire, it caused widespread illness and rye crop devastation in Europe during the Middle Ages. Another example is Dutch elm disease, an infection caused by sac fungi (transported by the elm bark beetle) that has all but wiped out the American elm tree from North America. It's important to note that this is a case of non-native invasion; the disease was brought from Asia to North America and Europe, where elm trees did not have resistance to the disease.

Though we still have much to learn about all these interactions, we already know enough to determine that fungi are vital to the existence of life on Earth, despite the examples of disturbance. Through the years, much more attention has been given to the negatives of fungi in our world. *Mycelial Mayhem* focuses on the many positive roles fungi play and how to incorporate them into our lives.

Mushroom Life Cycle and Ecology as Teacher

This book is organized into sections paralleling the mushroom life cycle because it's a great analogy for the journey of mushroom cultivation. The mushroom life cycle can be a process that reminds you of the important stages in your new mushroom business. The genesis of your business requires the basic ingredients of desire and "seed" resources to begin, just as the mushroom requires spores coming together to form hyphae and then mycelia. Once you have the basics germinating

together, you need to prepare for a fruitful business by learning, growing, and branching out your foundation, the hyphae. Developing a game plan is required for a fruitful business, as you need all of the energy, food, and resources you can muster. This is your mycelial growth stage. Once you have a solid foundation, you can produce great results, the fruits of your labors. But, you must always keep an eye on your foundation for challenges and obstacles that might set the stage for competition to take over. Sporulation signifies sharing or spreading of your mushrooms and your fungi passion and knowledge, whether you're simply sharing with friends and family or growing a successful mushroom business.

There are things to learn from fungi's roles in ecosystems. We know they form mutually beneficial relationships, ones that benefit both participating parties. Can you participate in similar mutualism? Can you barter your mushrooms for organic straw? Can you form two-way partnerships with other organic farming businesses, such as working with a beekeeper to co-package and sell reishi tea kits that include reishi, honey, and other ingredients? In highly evolved natural ecosystems, collaboration happens all of the time, more than originally thought, perhaps even more so than competition. Collaboration is the way of the future. We are wise if we look to nature—including the world of fungi—for inspiration and applications to human society.