INTRODUCTION

MUSHROOMS AND HUMANS: PAST, PRESENT, AND FUTURE

Mushrooms as we know them today evolved at least 120 million years ago—well before the time of the dinosaurs—and they have been part of our lives for as long as humans have existed. One of our closest living relatives, the mountain gorilla, is a passionate mushroom eater. The earliest record of humans eating mushrooms comes from a burial site in Europe from about 18,700 years ago, and the oldest record of mushroom cultivation by humans dates from about 600 CE in China. In Europe, button mushrooms (*Agaricus bisporus*) were first propagated in quarries and caves in France around 1650, on composted horse manure. The practice of fungiculture has developed rapidly since pure culture laboratory techniques were developed around the turn of the 20th century; these lab techniques require a high level of sanitary measures that are not easily achieved at home on a low budget. But things have changed, and it is now easier than ever to grow your own mushrooms. The proliferation of information-sharing via online forums has decomposed many of the barriers to DIY mushroom cultivation. Widely dispersed communities of home-scale cultivators have developed simple technologies (aka *teks*) to facilitate growing mushrooms at home.

◀ Gathering mushrooms is an age-old practice. JA SCHINDLER

▶ Uma Echo Kirouac Arevalo enjoys the aroma of her harvest of pink oysters. WILLOUGHBY AREVALO

Certainly, people grow mushrooms for many different reasons. They are well loved as food, and most cultivated mushrooms are grown for this purpose. Practically all species of edible mushrooms have medicinal properties, as do many species that are inedible due to their texture or flavor. People are becoming increasingly aware of the health benefits that can be gained by consuming mushrooms regularly, including immune support, cancer prevention and treatment, and more. Incorporating mushroom cultivation with other forms of agriculture provides opportunities to build soil, cycle "waste" products, increase biodiversity, and boost ecological resiliency. And the application of cultivated mushroom mycelium into polluted land has been increasingly studied and implemented in *bioremediation*—the practice of engaging living agents to break down or remove toxins from soil, air, and water. Fungi produce unique enzymes capable of degrading some of the most toxic chemicals that humans have created into benign molecules. Fungi invented these enzymes about 299 million years ago to break down *lignin*, the rigid, durable component of wood that had recently (in an evolutionary time frame) been invented by plants, the buildup of which was choking out their ecosystems. Many DIY mycologists envision a near future in which fungi, with the help of humans, invent enzymes for decomposing the vast accumulation of plastics that we have created. And, of course, mushrooms are a pleasure to the senses. They offer us forms, textures, aromas, and flavors that remind us of other beauties while being uniquely their own.

A BIT ABOUT ME AND MY APPROACH TO MUSHROOM CULTIVATION

My love for fungi came long before I began growing them. I grew up in the humid coastal redwood ecosystem in Northern California, where mushrooms are abundant and diverse. I was fascinated by age four. I read as many mushroom books as I could get my hands on, and often brought specimens home to study. By age 13, my supportive—but not mycologically savvy—parents trusted my skills

enough to let me cook and eat the edible mushrooms I was able to confidently identify. At Humboldt State University, I was finally able to study mycology formally, though I majored in art, and it was then that foraged mushrooms became a significant part of my diet.

After reading *Mycelium Running* by Paul Stamets, I realized that my relationship with mushrooms was not very reciprocal. I studied mushrooms. I hunted mushrooms. I ate mushrooms. And in doing so, I objectified mushrooms. So, I made a conscious effort to give back to the fungi that I loved so much—by learning how to grow them and teaching my peers about them. I began by teaching a mycology workshop at a skillshare at a punk house in my town, and I soon began leading educational forays in the woods.

I approached Mike Egan, the mushroom grower at my farmer's market and asked him for a job doing inoculations. Three days later I arrived at Mycality Mushrooms, freshly showered and ready to work in the lab. Through my training with Mike, I learned the ins and outs of commercial gourmet mushroom production. Amazingly, despite my lack of cultivation experience, Mike trusted me to perform the most sensitive and technical part of the cultivation process. With my enthusiasm and his support, we expanded the number of species his farm was producing from four to over a dozen. While my main task at the farm was inoculating the fruiting substrates with grain spawn, I got the chance to try my hand at just about every step of the cultivation process.

During my two-year stint working at Mycality, I began touring the West Coast to teach workshops, and I had the opportunity to present at the 2012 Radical Mycology Convergence in Port Townsend, Washington. I had never experienced anything like this gathering of mushroom nerds, activists, cultivators, and visionaries. I found myself instantly enmeshed in a dynamic community of sharing and mutual support — reflective of the interspecies communities of symbiotic fungi. It was through this network that I began to learn about home-scale mushroom cultivation practices.

Less than a year later, I followed the love of my life to Vancouver, Canada, where we moved into a tiny cabin in a wild garden behind a chaotic but charming clown house. I found myself starting over in mushroom cultivation, with 100 square feet of shared living space, no mushroom cultures, no lab, no job, and very little equipment. I slowly adapted to my new constraints and built up a simple but effective cultivation setup that allows me to grow a modest amount of mushrooms for my family to enjoy.

I practice and teach contemporary, low-tech methods of mushroom cultivation. These were developed in part by the online mushroom community and introduced to me by *Radical Mycology* author Peter McCoy and others I met at the Convergence. These methods make it easier than ever for people to grow mushrooms at home with less dedicated space, less specialized equipment, and less infrastructure cost.

▲ Me at age 14 with my mom, Lauraine Alden, our friend Marco Gruber, and the day's pick of chanterelles. ELSA EVANS

My personal tendency is toward a fairly loose cultivation practice, similar to how I play music by ear, improvise, and cook mostly without adhering strictly to recipes or precise measurements. I implement minimal environmental controls and situate my mushroom gardens in the microclimates that already exist. I opt for scrappy salvaged materials over sleek purchased ones. As a hobbyist, educator, laborer, artist, and parent, I cultivate when I can, rather than on a strict schedule. My hope is that this book will provide you with the basic skills, information, and strategies needed to build your own cultivation practice—one suited to your own personality, living situation, and intentions. Through my ever-evolving relationship with fungi, both cultivated and wild, I have learned great lessons about reciprocity, and the fungi have also led me into many nurturing relationships with other *mycophilic* (mushroom-loving) humans. I see cultivated mushrooms as companions, friends, and members of my personal ecosystem—my interspecies community—and I of theirs. So, while the book is called *DIY [Do It Yourself] Mushroom Cultivation,* the truth is that we *Do It Together.*

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MUSHROOM BASICS

▶ The features of a mushroom's anatomy. CARMEN ELISABETH

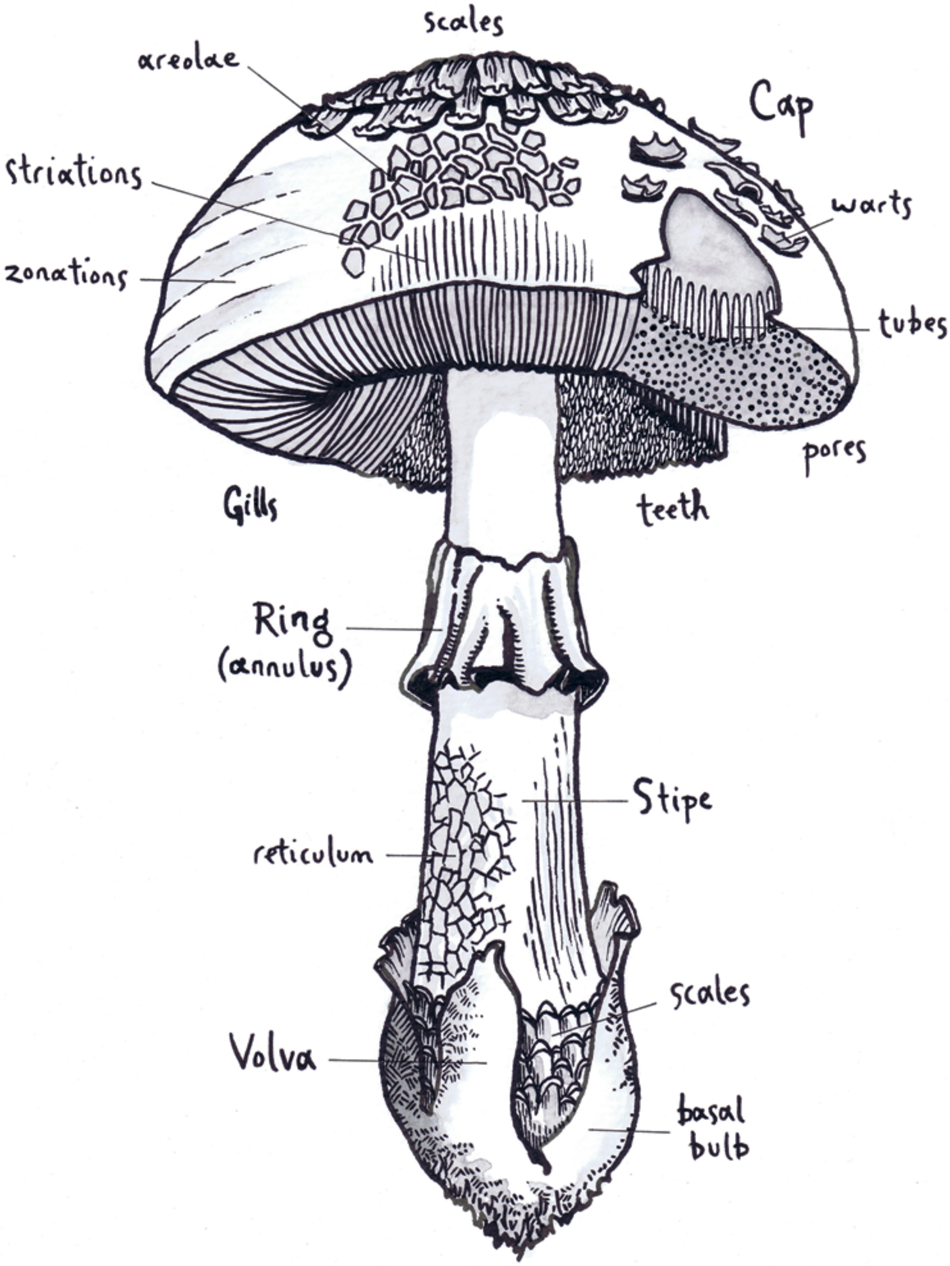
WHAT ARE MUSHROOMS?

Mushrooms are the fruiting bodies of *mycelium,* a network of threadlike cells that is the vegetative body of the fungus. I think of mushrooms as temples of sex: ornate and highly organized structures that emerge from (and of) mycelium to create and disperse spores—the analog of our eggs and sperm. Mushrooms arise only when conditions are conducive and when the mycelium recognizes sexual reproduction as a priority for the devotion of energy and resources. Once their spores have been dispersed, the fruiting body withers.

Mycelium can persist in its substrate as long as it has adequate resources and is not attacked, eaten, or otherwise destroyed. Depending on the circumstances and species, this can be as short as months or as long as millennia. Meanwhile, most types of mushrooms are evanescent—some emerge, sporulate, and decay within hours. More last a number of days to weeks, and some live for months, years, or even decades.

Taxonomy and Classification of Mushrooms

Fungi are a large and diverse group of organisms that are classified separately from plants, animals, bacteria, and protists, forming their own kingdom. Mushroom-forming fungi exist in two of the seven broad divisions (phyla) of fungi: the Ascomycetes and the Basidiomycetes.


scales
areolae
Cap
striations
warts
zonations
tubes
pores
Gills
teeth
Ring
(annulus)
Stipe
reticulum
scales
Volva
basal
bulb

▲ Ascomycetes CARMEN ELISABETH

Ascomycota, the sac fungi, is a very large and diverse group that includes some mushrooms; however, most Ascomycetes take forms other than mushrooms. The group includes many unicellular yeasts, including *Saccharomyces cerevisiae,* the species we have to thank for bread, beer, and wine. Many are molds such as *Penicillium, Aspergillus,* and *Fusarium.*

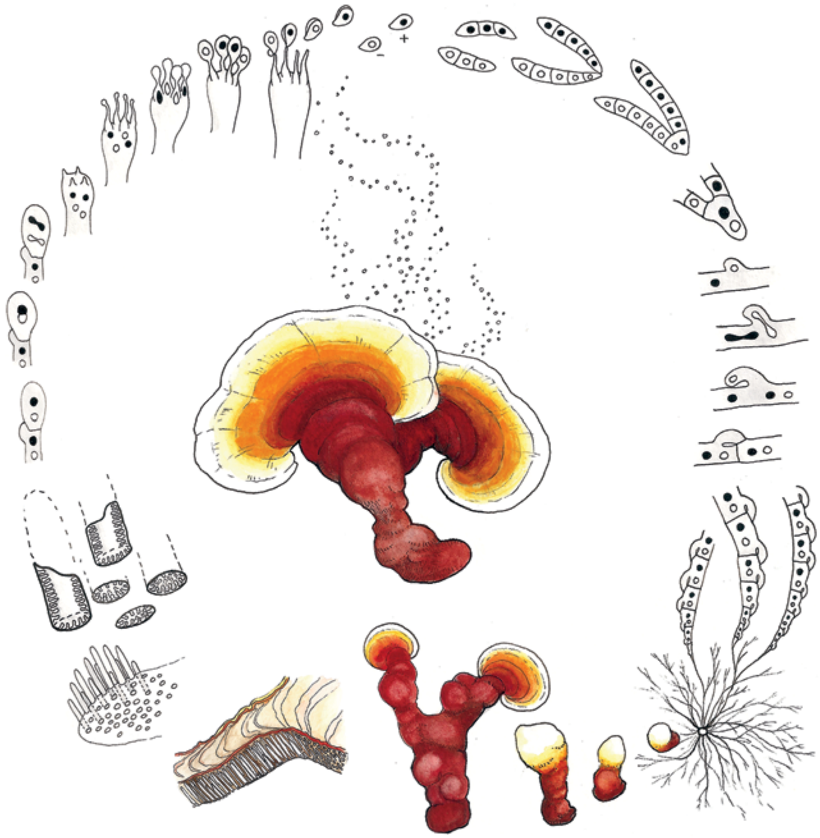
Common Name	Human	Caterpillar Fungus	Shiitake
Kingdom	Animalia	Fungi	Fungi
Phylum	Chordata	Ascomycota	Basidiomycota
Class	Mammalia	Sordariomycetes	Agaricomycetes
Order	Primates	Hypocreales	Agaricales
Family	Hominidae	Cordycipitaceae	Marasmiaceae
Genus	Homo	Cordyceps	Lentinula
Species	sapiens	militaris	edodes
Binomial	*Homo sapiens*	*Cordyceps militaris*	*Lentinula edodes*

While humans have succeeded in cultivating some of the edible and medicinal Ascomycete mushrooms such as morels (*Morchella* spp.), caterpillar fungus (*Cordyceps militaris*), and some truffles (*Tuber* spp.), most of these require advanced techniques, so they will not be the focus of this book. Although many of the techniques presented here can be applied to the cultivation of their mycelium, advanced techniques are required for fruiting them.

The phylum Basidiomycota, the club fungi, includes the great majority of mushrooms, such as all the mushrooms with gills, pores, or teeth, and most of the jelly and coral fungi. Nearly all the mushrooms that are grown by humans are in this group, so we will focus on their life cycle and biology.

A Generalized Basidiomycete Mushroom Life Cycle

Spores (center and 12 o'clock) are miniscule propagules. Like sperm and eggs, spores are *haploid,* containing only half a set of genes (and they lack an embryo, which seeds have). Unlike sperm



The life cycle of reishi (*Ganoderma lucidum*). Bold terms follow the image, clockwise from top. CARMEN ELISABETH

Basidiomycetes CARMEN ELISABETH

and eggs, spores can begin to grow without being fertilized by one another.

Germination (12:30) occurs when a spore finds itself in conditions that will support its growth: i.e., the right water, food, air, and temperature. The spore then pushes out a threadlike cell called a *hypha* (plural: *hyphae*), which grows longer and branches, forming permeable cross-walls (septa) to control the flow of cell contents. A mass of hyphae is referred to as *mycelium*. As this mycelium grows, it exudes pheromones for communication with other fungi. These pheromones, similar to those of humans and other animals, call out

Most cultivation books use the term *colonization* rather than *myceliation*, likely a relic of the coincidence of developments in biology with the expansion of European peoples across much of the world. But I don't want to valorize the history of colonization and the continuing subjugation and oppression of indigenous peoples and the land upon which they live, nor do I want to alienate folks whose cultures and land have been colonized. We must shift our way of speaking.

chemically to potential mates. When a compatible mate is sensed—the pheromone fitting lock-in-key into the receptor—**attraction (1 o'clock)** is established, and the two mycelia grow toward each other.

Fusion (2 o'clock) occurs when the two mycelia meet and become one mycelium. Their **nuclei migrate (3 o'clock)** into the mycelium of each other, until each cell contains one nucleus from each parent spore. This **dikaryotic (two-nuclei) phase (3:30)**, which is fleeting in our species (the brief moment when the sperm and egg fuse), forms most of the mushroom life cycle. In cultivation, this genetically unique, mated mycelium is referred to as a *strain*.

Myceliation (vegetative growth, 4 o'clock) continues as the mycelium exudes enzymes to break down molecules in its *substrate* (the material it lives in and eats) and absorbs the components it needs to build more hyphae and grow. Its immune system produces extracellular antibiotics, antioxidants, and other chemicals to protect itself from viruses, bacteria, other fungi,*mycophagous* (fungus-eating) invertebrates, and oxidative stress.

Once sufficient energy is accumulated, and when environmental conditions are right, the mycelium is finally capable of producing mushrooms. They begin as dense **hyphal knots (4:30)**, which then differentiate into **primordia (5 o'clock)**, also called *pins* or *pinheads* by some cultivators. The **mushrooms develop (6 o'clock)** as the mycelium pumps the primordia full of nutrient-rich cell fluids, causing stalks to elongate and caps to expand (center).

As the **fertile undersurface (gills, teeth, tubes, etc.) matures (6:30–8 o'clock)**, waves of the sexual cells called **basidia (9 o'clock)** develop on its surface. Within each *basidium,* the two nuclei fuse. Their **genes combine, and they divide (10 o'clock)** into four new nuclei (10:30), each with a unique half-set of genes. These nuclei migrate to the outside of the **mature basidia (11 o'clock)**. Dosed with just enough nutrients to fuel the initial germination, these new *spores* are liberated by **ballistospory (11:30)**. Once in the open air, they are carried on the breeze, hopefully landing on fertile substrate near compatible mates. Because relatively few spores will live to

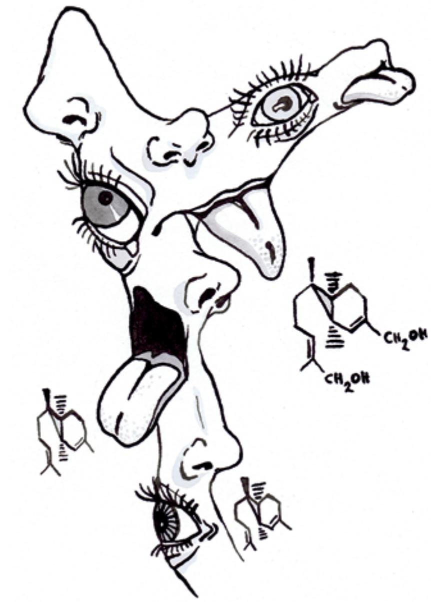
Which came first? The (chicken of the woods) mushroom or the spore? CARMEN ELISABETH

complete their life cycle, each mushroom may produce millions to trillions of spores.

Queering the Fungal Queendom

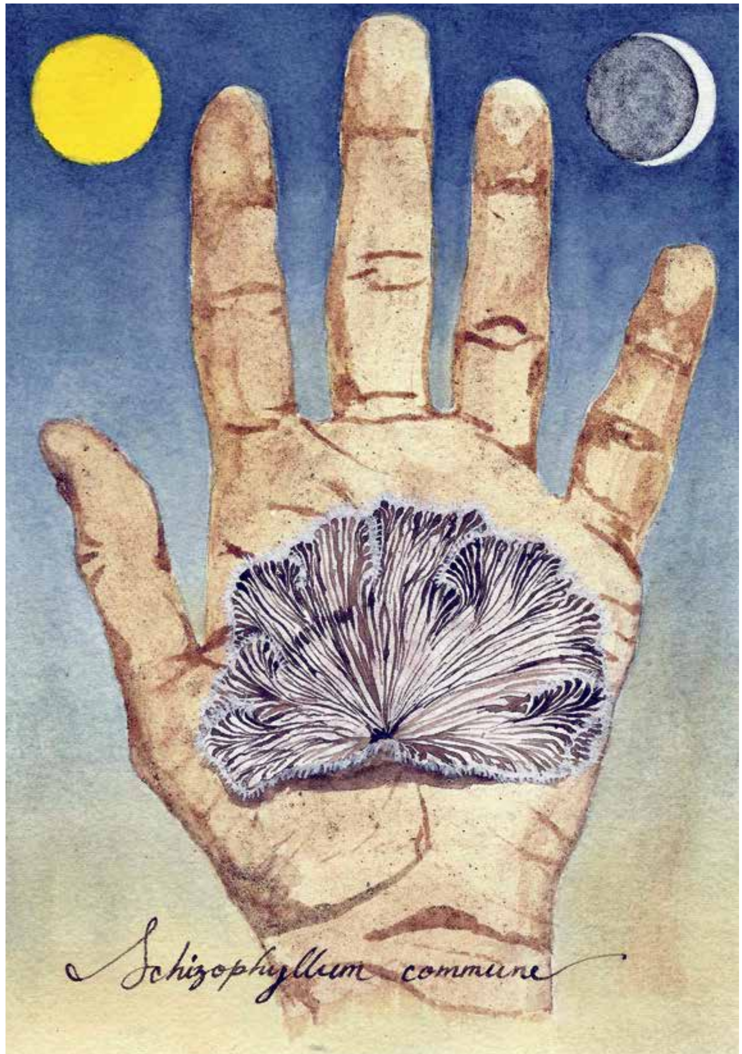
I've just described how most mushrooms live and reproduce, but there are many exceptions. While most species' spores must breed with another spore (*heterothallic*) as shown in the illustration, about 10% of mushroom species' spores are self-fertile (*homothallic*). Often, more than one factor determines *mating type* (what we think of as "sex"), meaning that many mushroom species have more than two mating types. The extreme example is the split gill fungus *Schizophyllum commune*. It has 23,328 mating types, each compatible with 99.98% of the others. This has given it remarkable adaptability.

While aerial spore dispersal (ballistospory) is the norm, some mushrooms have evolved internal spore production and alternative spore dispersal strategies that involve animals, raindrops, or other agents. These are called the *gasteroid* fungi, because they make their spores inside stomach-like structures. Wait. Do you know of any other beings that make their reproductive units in stomach-like structures? I think we should call these species the *uteroid* fungi. Several uteroid mushrooms are cultivated, including some truffles and stinkhorns.

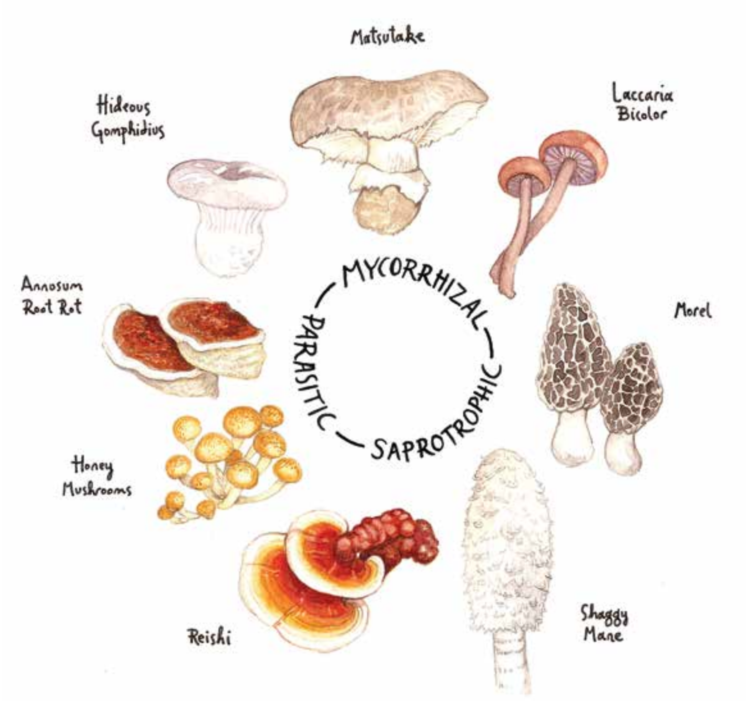


On the surface of the hyphae are sensory receptor molecules—similar to those we use to see, smell, and taste—some of which receive pheromone signals from potential mates. CARMEN ELISABETH

Two water droplets condense on each spore and grow until they converge. The sudden shift in balance hurls the spore into the air at up to 25,000 g's. This is the fastest acceleration known in nature. Being so tiny, air drag causes the spores to decelerate rapidly too, slowing to a freefall as soon as they're off the wall of basidia. CARMEN ELISABETH



▲ Split gill's sexual diversity has helped it become one of the most common mushrooms in the world. It has been widely cultivated for genetic studies, though it is not commonly grown as food or medicine despite being edible and medicinal. WILLOUGHBY AREVALO



◀ Clockwise from top: Matsutake (*Tricholoma magnivelare*) is mycorrhizal. *Laccaria bicolor* decomposes animal carcasses and hunts microscopic springtail animals, giving the nitrogen to their mycorrhizal tree partners. Morels (*Morchella* spp.) can be saprotrophic and/or mycorrhizal, and potentially weakly parasitic, switching over time. Shaggy manes (*Coprinus comatus*) are saprotrophic, but they also trap and eat nematodes. Reishi (*Ganoderma* spp.) are usually saprotrophic but will act as facultative (weak) parasites on an already compromised tree. Honey mushrooms (*Armillaria* spp.) are aggressive parasites but will act as saprotrophs after host death, or as needed to travel. Annosum root rot fungus (*Heterobasidion* spp.) is parasitic but keeps eating its host after death. Hideous gomphidius (*Gomphidius glutinosus*) is parasitic of mycorrhizal *Suillus* mushroom mycelium.

CARMEN ELISABETH

MUSHROOMS IN ECOSYSTEMS

Mushrooms and their mycelium play a variety of crucial roles in land-based ecology, with mushroom species evolved to fill niches in nearly every ecosystem on Earth. There are three main categories into which mushrooms are grouped based on their nutritional mode (energy source). However, many mushrooms can play more than one role, so I like to think of the nutritional mode as a spectrum on which there are three nodes: mycorrhizal, saprotrophic, and parasitic. Each of these is described below.

Many fungi have co-evolved with other organisms over millions of years to live in mutualist symbioses (*sym*=together/*biosis*=way of living) such as *mycorrhizae* and *endophytes* (fungi growing inside plants), and lichens. These symbiotic fungi get carbon (sugars) from their photosynthetic partners (plants, algae, and cyanobacteria), and most provide mineral nutrients, water, and/or protection in return. Many fungi are are symbiotic with bacteria; most of these

The scientific names of mushrooms are constantly changing as molecular phylogenetic analysis reveals unexpected relationships. This causes a lot of confusion for mushroom people. I use the most current names at the time of writing, but when that's different from the best known name, I include the synonym in parentheses.

▲ Honey mushrooms fruit prolifically from trees they have killed. "Let us therefore trust the eternal Spirit which destroys and annihilates only because it is the unfathomable and eternal source of all life. The passion for destruction is a creative passion, too!"

MIKHAIL BAKUNIN Russian political philosopher, anarchist, and atheist, 1842 WILLOUGHBY AREVALO

relationships are not well understood by science. When we cultivate mushrooms, especially at home, we enter a mutualist relationship with fungi, exchanging substrate, shelter, and more for food, medicine, and beautiful companions.

Mycorrhizal Fungi (*mykes*=fungus/*rhiza*=root)

Mycorrhizal fungi engulf and infiltrate plant root tips, exchanging essential minerals and water for photosynthesized carbohydrates. There are several types of mycorrhizae that do not form mushrooms and one that does, the *ectomycorrhizae*. Many attempts have been made to cultivate ectomycorrhizal mushrooms such as chanterelles, matsutakes, boletes, and truffles; results have been inconsistent, at best. While some of the techniques offered in this book may apply to the culturing and spawn production of certain mycorrhizal species, the topics of establishing a symbiosis and fruiting mycorrhizal mushrooms are beyond the scope of this book. The arbuscular mycorrhizal fungi (AMF, or *endomycorrhizae*) do not form mushrooms but are known for their generous support of most species of land plants, including the majority of garden and farm crops. While AMF can be grown fairly easily on a small scale and low budget, this, too, is beyond the scope of this book.

Parasitic Fungi: Those Who Eat at Another's Table

Rather than inhabiting plant tissues and giving back like the mycorrhizals do, the *parasites* take energy from their host plant without any direct reciprocation. However harsh as this may seem, parasitic fungi can enhance their ecosystems. They help to drive succession by killing weak trees, which opens up the forest canopy, creates new habitat niches for amimals, fungi, and plants, and provides selective pressure toward the evolution of more resilient tree species. Some parasites kill their hosts and continue to eat them after they die, while others depend on their host's survival and do not kill. Parasitic mushrooms are not often cultivated, as many people are wary of their power and potential for destruction, but some are cultivated and applied as biological controls for invasive plants.

Saprotrophic Fungi (*sapro=rot/troph=eating*)

Saprotrophic fungi are Earth's great decomposers, working together with invertebrates and bacteria to break down the world's dead plant matter and convert it into smaller molecules, carbon dioxide, and water that can be recomposed into other forms of life. In so doing, they connect the cycle of life and death. They play a huge role in building soil, breaking hard-to-digest woody biomass into bite-sized pieces for invertebrates and bacteria to break down further. Because of the simplicity of preparing and feeding dead plant matter (called *substrate)* to the mycelium, these mushrooms comprise the vast majority of mushroom species cultivated, and they will be the focus of this book.

Saprotrophic fungi thrive in a wide spectrum of environmental niches, ranging from wood, to leaves, to humus. Some species are very particular in their substrate needs, while others are generalists and can eat a wide range of substrates. For example, wild brick tops (*Hypholoma sublateritium*) grow almost exclusively on oak and chestnut stumps, while oysters (*Pleurotus* species) grow naturally on a wide variety of woods and have been successfully cultivated on over 200 types of agricultural and forestry wastes.

Within a particular piece of wood, there is a succession of different decomposers: *primary decomposers* are parasitic or aggressive saprotrophic mushroom species that eat their fill before leaving it to the *secondary decomposers,* which eat partially degraded wood. Eventually, the rotten wood is transformed to humus, which is inhabited and eaten by the *tertiary decomposers*. At each step in the process, the components in the wood are broken into smaller and smaller molecules until they are ready to be taken back up into plants, usually with the help of mycorrhizal fungi. Most of the wood-rotters that are commonly cultivated are primary decomposers,

▲ Spontaneous fruiting of *Lenzites cf. elegans* from a crude-oil-soaked log in the Ecuadorean Amazon rainforest. Amisacho and CoRenewal are two non-profits collaborating with each other and with fungi, bacteria, plants, and humans to bioremediate the numerous oil pits left throughout the region by Chevron/Texaco.
MAYA ELSON

preferring fresh wood that has not been inhabited and eaten by other fungi. These fungi are the focus of this book. The cultivated species that are naturally found on the ground growing on non-woody substrates such as leaf litter, compost, manure, or humus are mostly classified as tertiary decomposers. For example, blewits (*Clitocybe nuda)* are tertiary decomposers that eat leaf litter in the wild but can be grown on straw that has already been partially eaten by oysters.

SAPROTROPHIC MUSHROOM NICHES

Wood-Rotting Fungi

The wood-rotting fungi, whether saprotrophic or parasitic, are also classified by the type of rot that they produce. Wood is made up of a matrix of stringy, fibrous cellulose and hemicellulose running longitudinally through rigid, brittle, and porous lignin.

The *brown-rotters* are able to work around the hard-to-degrade lignin and eat away the cellulose and hemicellulose, leaving behind a blocky, crumbly brown rot. These porous blocks of residual lignin can remain in soil for many years, increasing the soil's water and air retention as well as its *cation exchange capacity*—the ability for the upper layers of the soil to hang onto nutrients rather than letting them be washed away into the groundwater—allowing plants greater access to these nutrients.

Relatively few brown-rotters are cultivated. These include chicken of the woods (*Laetiporus* spp.), birch polypore (Femitopsis betulina [*Piptoporus betulinus*]*)*, shimeji, and elm oyster (*Hypsizygus* spp.).

Most cultivated mushrooms are *white-rotters*. They give the wood a pulpy, bleached-out appearance by degrading the lignin in order to access the cellulose and hemicellulose within the matrix. The powerful enzymes produced by the white-rotters to degrade lignin have the ability to degrade petroleum hydrocarbons and other toxic chemicals.

Litter and Compost Decomposers

Some fungi eat litter (in the sense of leaves, twigs, humus, and other smaller plant particles), and some of these fungi may also be able to eat human-made litter, such as paper products and certain agricultural wastes, including used substrates from the cultivation of other mushrooms. Some mushrooms are very substrate specific, such as those small mushrooms that grow exclusively on the cones of a certain tree species. These mushrooms are also feeding on lignocellulose, though in an easier form to digest than wood. They often rely on a microbially rich ecosystem in which to thrive, and some are weak or slow-growing in pure culture. Therefore, most of these grow better in gardens or other more natural settings, rather than in containers indoors. Some of the cultivated members of the group are button mushrooms and other *Agaricus* species, shaggy manes (*Coprinus comatus)*, parasols (*Macrolepiota procera* and *Chlorophyllum* spp.), blewits (*Clitocybe nuda,)* and paddy straw mushroom (*Volvariella volvacea)*.

WHAT MUSHROOMS NEED TO SURVIVE AND THRIVE

Air

Just like us, fungi consume oxygen (O_2) and produce carbon dioxide (CO_2) through their metabolism. Lacking lungs, they respire with all their mycelium on a cellular level. They are more sensitive than we are to relative levels of O_2:CO_2. Mycelial growth doesn't require as much oxygen as fruiting does, though without any access to oxygen, mycelium will cease to grow, suffocate, and die. Imagine mycelium growing through the interior of a log. There is little airspace and airflow from within the wood to the outside air, so CO_2 levels can get pretty high. When the mycelium is preparing to fruit, it grows to where there is more oxygen, at the surface of the wood, perhaps in a fissure in the bark. It senses the oxygen in the ambient air, which helps to trigger the formation of fruiting bodies. In our substrates, particle size is important; if the particles are too large, there will be big air gaps that the mycelium will have to bridge, which is energetically expensive. If the particles are too small, over-compaction and restriction of airflow causes anaerobic conditions.

Water

Water is life, and mycelium and mushrooms are mostly water, roughly 90%. Because of this and because of how they exude chemicals (sometimes called *secondary metabolites*) to surround themselves as they grow, water can be a major limiting factor for mycelial growth. Water must not only be present in a substrate, but it must also be available. Each particle of a substrate should be thoroughly moist and coated in a thin film of free water, so it can be easily utilized by the mycelium. However, if the substrate is so wet that water pools in the bottom of the vessel, then airflow will be compromised and mycelial growth along with it, favoring instead bacteria and molds. As you get to know your substrate materials, you will develop a sense for how moist they should feel.

Water quality is also an issue. Most cultivators use tap water, which in most areas is okay. The levels of chlorine (or chloramine, a non-evaporating chemical that is increasingly substituted for chlorine) in most tap water are not high enough to do major damage to our fungi, but if you are able to dechlorinate your water by simply letting it sit out uncovered overnight, that is a good practice. Chloramine can be removed from water by various chemical methods. Mineral-rich water such as spring water is great, if you have access to a source, but I do not recommend buying spring water or other bottled water for growing mushrooms unless your tap water is significantly polluted. Because many mushrooms hyperaccumulate heavy metals, water contaminated with these elements should not be used. If you filter your water for drinking, I would advise filtering your mushrooms' water as well.

Food

Like animals, fungi are *heterotrophic*—they get their energy (carbohydrates) from outside sources. Many have evolved to produce strong enzymes that can break down and get energy from tough stuff like the lignocellulose matrix of wood, and many can break down rocks and absorb the minerals. Think of the human digestive system as an outside-in variation on a theme that evolved in our common ancestors. We ingest and digest; fungi "*outgest*" and digest.

Decomposer mushrooms can be grown on a wide variety of plant-based substrates. Some species are restricted to specific types of woods, while others can eat and grow from many types of lignocellulose-rich plant matter. All dry land-plant matter contains lignocellulose.

In addition to carbohydrates, fungi need nitrogen from and for proteins, and small amounts of micronutrients such as calcium, sulfur, lipids, and vitamins. Most of the commonly used substrates supply ample amounts of these nutrients to support fruitings, but not all substrate ingredients are created equal. You could grow oyster mushrooms on logs, sawdust, or paper —all of which are wood products—but the nutrient density and quality of the substrate (and the mushrooms produced on them) decrease the farther you get from the source. Keep these nutritional needs in mind when experimenting with substrate formulation, and when in doubt, mimic the natural substrate of the mushroom.

Warmth

Mushrooms are *mesophiles,* like us; they like middle-range temperatures—few thrive in freezing cold or sweltering heat. Mycelial growth halts when it gets too cold, and mycelium can die of overheating. However, even in extreme climates, human companions of fungi can create microclimates in which mushrooms can be happy, and our living spaces are full of these niches. There is a fairly wide range of preferred temperatures for growth and fruiting for various species—between 45–100°F (7–38°C), which is about the temperature range inside a home. Each species (and even each strain) of mushroom has its own temperature preferences, so with a good collection of cultures and some forethought, one can fruit mushrooms indoors and/or outdoors year-round in nearly any climate.

Fruiting Surface

Different species have different needs for their spatial relationship to gravity and the surface from which they grow. Their shape and natural growth habit reveal these needs. Ground-dwelling mushrooms normally fruit from the top of a horizontal surface. Many wood-rotters prefer to fruit from the side of a vertical surface, but some will fruit from side, top, and even bottom surfaces of their substrate. For species like shiitake, a broad fruiting surface should be exposed to the air for mushrooms to fruit all over. For others (like oysters), small holes in the vessel allow focused fruiting in clusters, which prevents moisture loss in the substrate and facilitates harvest.