*Sulfur tuft (*Laetiporus conifericola*).*

Unidentified mushroom species.

CONTENTS

Coprinellus *sp.*

FROM TOP LEFT TO BOTTOM RIGHT *Mushroom species unknown;* Clathrus *sp. (© Taylor Lockwood);* Hygrocybe conica*;* Clathrus *sp. (© Taylor Lockwood);* Fistulina hepatica*;* Omphalotus olearius*; Mushroom species unknown; Microstoma protractum; Chanterelle;* Laetiporus sulphureus*; Mushroom species unknown;* Aleuria aurantia.

INTRODUCTION

PAUL STAMETS

PAUL STAMETS is the preeminent mycologist in the United States. He has discovered several new species of mushrooms, pioneered countless new techniques, published several best-selling books, and won numerous awards.

Mushrooms are mysterious.

They come out of nowhere suddenly, with their splendid forms and colors, and just as quickly, go away. Mushrooms' startling appearances and enigmatic disappearances have made them forbidden fruits for thousands of years. Only a few of the cognoscente—the shamans, the witches, the priests, and the wise herbalists—have gained a glimmer of the knowledge mushrooms possess.

Why?

It is natural to fear what is powerful yet unknown. Some mushrooms can kill you. Some can heal you. Many can feed you. A few can send you on a spiritual journey. Their sudden rise and retreat back into the underground of nature make them difficult to study. We have longer periods of contact with animals and plants and we usually know which ones can help or hurt us. Mushrooms are not like that. They slip into our landscape and exit shortly thereafter. The memory fades quickly, and we wonder what we saw.

Mushrooms are the fruit bodies of a nearly invisible network of mycelium, the cellular fabric beneath each footstep we take on the ground. Reach down and move a stick or a log, and you will see a vast array of fuzzy, cobwebby cells emanating everywhere. That's mycelium, the network of fungal cells that permeates all landscapes. It is the foundation of the food web. It holds all life together. Yet these vast underground networks, which can achieve the largest masses of any organism in the world and can cover thousands of acres, hide in plain sight; silent but sentient and always working tirelessly to create the soils that sustain life.

Over thousands of years we have accumulated a large body of knowledge when it comes to edibles. Starvation is a good motivator for finding novel foods. Our ancestors quickly learned

that some mushrooms are not only nutritious but delicious. Mushrooms provide protein and vitamins, and they can strengthen our immune systems. They have been critical in our species' struggle for survival.

Many elderly people share joyous memories of going with their parents and grandparents on family trips into the forest to pick mushrooms. They have experienced that eureka moment of discovery and understand the challenges of identifying edibles and the danger of misidentifying toxic species. They know the reward and joy of a delicious meal foraged by their family from the natural world around them. All this can create meaningful memories that bond families across generations. Many mushroom patches are kept as family secrets, only shared with future generations. This is what the mushroom experience does—it grows on you. It is like a mycelial thread through time, a bridge from our ancestors to us and to our descendants in the future.

It is the multiplicity of benefits, I think, that makes mushrooms so attractive to those who learn their uses. One theme that pervades indigenous cultures: It is the substances that are utilitarian, that help humans survive, that are threaded into the cultural fabric.

Though much of our ancestral knowledge about mushrooms has been lost to history, a lot of knowledge is being scientifically validated as we begin to study fungi in clinical contexts. Penicillin, made from *Penicillium*, began the era of antibiotics and has saved millions of lives. An endophytic fungus, *Taxomyces andreanae* was discovered to synthesize taxol, which can treat certain types of cancers. I personally discovered that extracts from *Fomitopsis officinalis* protect against the family of viruses that includes smallpox. Fungi often have antimicrobial properties, they can support the immune system, and they can prevent or heal viral diseases. They can do so much, and yet, we have only really begun to discover the endless possibilities that the fungal world holds when it comes to improving human health.

Many edible mushrooms are both delicious and good for you. However, most mushrooms, though they're not poisonous, do not taste good. What is deemed inedible by one culture is sometimes a delicacy in another. The poisonous *Amanita muscaria* is called fly agaric. Long before the invention of window screens, pre-Europeans chopped up fly agaric mushrooms and placed the pieces in bowls of souring milk on windowsills to attract and kill flies.

Not a good mushroom to consume? You may think that, but in Asia and elsewhere, foragers discovered that if you boil fly agaric mushrooms in water and rinse them three or more times, the water-soluble toxins are removed, thus rendering the mushrooms edible without ill effects. The berserkers of Viking lore reportedly consumed this mushroom before battle, and in the ensuing frenzy, they became quasi-robotic killers, as the mushrooms can induce uncontrollable repetitive motions and allow the person to ignore pain.

In Siberia, shamans would ingest *Amanita muscaria*. They eventually discovered that reindeer would consume their pee by eating the yellow snow. The Siberians used that knowledge to lasso and corral the stoned reindeer with ease. It's incredible that just one variety of mushroom can poison flies, herd reindeer, weaponize humans, and feed people (if prepared properly).

An ingredient in the evolution of cultures from ancient Europe to North America was the discovery of "magic mushrooms," particularly those containing psilocybin. Though they've been used in various contexts throughout human history, recent clinical studies in the United States and Europe show how doses of psilocin (the active ingredient in psilocybin mushrooms) help victims of trauma and terminal patients in fear of death and are even associated with a reduction in criminal tendencies.

Magic mushrooms have been ingested for millennia in Europe and Mexico. Preserving psilocybin mushrooms in honey is a practice in Mexico to this day. Before the Bavarian Beer Purity Act Law (*Reinheitsgebot*) in 1516, mushrooms had been used to spike beer. These hallucinogenic brews were part of local nature-worship practices. Some archaeobotanists suspect magic mushroom meads, fermented honey-based brews infused with magic mushrooms, figured in early European and Mesoamerican rituals.

TOP LEFT TO BOTTOM RIGHT Mucronella *sp. (© Taylor Lockwood);* Amanita muscaria*; Mushroom species unknown;* Cookeina tricholoma.

TOP Tremella fuciformis *(© Taylor Lockwood).* BOTTOM LEFT *Mycelium.* BOTTOM RIGHT *Mushroom species unknown.*

Honey, bees, and mushrooms are intimately connected. Let me explain. *Fantastic Fungi*, the book and the movie, have been a collaboration between filmmaker Louie Schwartzberg and myself for more than a decade. A few years ago, Louie completed a film on pollinators, *Wings of Life*, which includes bats, butterflies, and bees. After watching bees struggle, he grieved at seeing the greatest pollinators of all die off in massive numbers. He asked me a poignant question: "Paul, is there anything you can do to help the bees?"

Louie knew of my prior work with fungi and insects, but his question made me remember a bizarre event I'd witnessed in my garden. Back in 1984, I had two beehives. One July morning I went to water my mushroom patch. I noticed a cluster of twenty or so bees busy on the surface of my wood chips. Upon closer examination, I saw they were sipping on tiny droplets exuding from white threads of mycelium in between the woodchips. A continuous stream of

bees traversed several hundred feet, from my beehives to my garden, from dawn to dusk for forty days. The bees moved the chips—giant wooden monoliths compared to their bodies—to uncover more succulent droplet-oozing mycelium underneath. Daily, they "milked" the mycelium.

Years later, after that conversation with Louie, my memory of these observations came back in a waking dream. That morning, I began connecting the dots between the bees in my garden and my work with the Department of Defense BioDefense program. That post-9/11 project led to the discovery that several of our polypore mushroom extracts were potent at reducing the effects of potentially weaponizable viruses, such as smallpox and influenza. I wondered if these same extracts could help bees fight deadly viruses that Varroa mites inject into them, a major cause of bee colony collapse.

Upon waking, I knew what I had to do: I needed to test those extracts on bees to see if I could help them fend off debilitating viruses.

Four years later, our team, working with Washington State University and the United States Department of Agriculture, found that the extracts of mycelium of woodland polypore mushrooms reduce the bee-killing viruses. Once the bees sip our extracts, bee viral loads plummet thousands of times. Bee lifespans are extended. This paradigm-shifting technique could help us assist bees to overcome colony collapse disorder and strengthen worldwide food biosecurity. A happenstance thought-dance between an artist and a scientist spawned this historic breakthrough.

Mushrooms are food for the body and medicine for the soul. The *Fantastic Fungi* film and this book are your portals to a grander wonder. In these pages, we'll explore studies pointing to mycelium as a solution to our gravest environmental challenges, examine research that reveals mushrooms as a viable alternative to Western pharmacology, and learn about fungi's marvelous proven ability to shift consciousness. Welcome to the mushroom underground. We are all connected!

SECTION I

FOR THE PLANET

There is a feeling in this world, the pulse of eternal knowledge.

When you sense the oneness, you are with us.

We brought life to Earth.

You can't see us, but we flourish all around you.

Everywhere, in everything, and even inside you...

from your first breath, to your last...

in darkness, and in the light.

We are the oldest, and youngest.

We are the largest, and smallest.

We are the wisdom of a billion years.

We are creation.

We are resurrection.

We are condemnation and regeneration.

The "third kingdom" of fungi and mushrooms is a realm of mystery on whose secrets the future of life on Earth may depend. At a time when solutions to our

planet's most pressing challenges seem as elusive as ever, the ground beneath our feet may hold the most promising answers.

Scientists and researchers around the world, trained in universities and inspired by their passion for the planet, are discovering that underground networks of interconnected organisms are revealing a new story about the planet's ability to heal itself. The innate intelligence of these networks—the result of billions of years of evolution—has much to teach us.

In this section, experts explore how humans can utilize mushrooms to restore our planet.

TOP Leucocoprinus cepistipes. **MIDDLE** Hemitrichia *sp. (© Taylor Lockwood).* **BOTTOM** *Mycelium.*

CHAPTER 1

MYCELIUM: THE SOURCE OF LIFE

SUZANNE SIMARD

SUZANNE SIMARD is a professor of forest ecology at the University of British Columbia's Department of Forest and Conservation Sciences in Vancouver.

What goes on beneath a forest floor is just as interesting—and just as important—as what goes on above it. A vibrant network of nearly microscopic threads is recycling air, soil, and water in a continuous cycle of balance and replenishment. Survival depends not on the fittest, but on the collective.

Imagine a log that was once was a tree. Maybe it died of old age or became infected by a disease and fell over. When it did, fungi spread into the log from the earth below and started decomposing it. These fungi are part of a vast network of underground vegetation called mycelium, composed of very tiny, cobweb-like threads of organic life called hyphae. All along the thousands of miles of mycelium occupying this one big log, the mycelium uses the fungi to send out enzymes and organic acids that break down the lignin in the wood's cell walls that gives the wood its structure and strength.

In the process of decaying, the wood releases its nutrients. Those nutrients become available to other organisms in the food web, including the fungus, which distributes the nutrients through the mycelium. After many challenges, these networks come to the surface and form mushrooms, the reproductive structures of fungi. Mushrooms are literally "the tip of the iceberg." When we see mushrooms, there's actually a vast network of mycelium hidden in the ground beneath them. Only about 10 percent of all fungi produce mushrooms. But when you pick a mushroom, you stand upon a vast, hidden network of fungal mycelium that literally extends underneath every footstep you take. These networks are the foundation of life. They create the soils that nourish all life on land. Without fungi, we do not have soil. Without soil, there is no life.

Without this metamorphic process, the planet would choke. Forests would be miles deep in organic decay. The only reason we can walk around in most woods is because thousands of species of fungi are decaying all of the organic detritus on the forest floor, recycling the dead material and beginning the renewal of life.

Once the log starts to decay and release nutrients, other organisms such as mites and nematodes move in and start eating the fungus, small bits of leftover wood, and other organic material, which they ultimately excrete. Some of that ends up in the nutrient cycle, and then other critters like springtails or spiders come along and eat the nematodes, and then other creatures eat the springtails and spiders, and so it goes up the food chain to larger and larger organisms. Even mushrooms become food for squirrels, and eventually something will eat the squirrel—maybe a bird, maybe a bear—and it's all linked back to that original wood-decomposing fungus. When each organism reaches the end of its life, it returns to the soil and continues replenishing the cycle.

In all ecosystems, death and decay are the fundamental beginning of life. If a forest never went through this process, it couldn't regenerate. It would crowd near big trees, leaving few gaps for young ones. The big trees would suck up the light, water, and nutrients. Decay organisms like fungi are crucial for that process of regeneration. They are the building blocks of the ecosystem, the fundamental starting place for how a forest grows.

MOTHER TREES AND THEIR FUNGAL PARTNERS

Forests are incredibly complex places with trees of many different sizes and compositions, depending on the type of forest. There are little trees coming up in the understory, and then there are the parents, the big trees that provide the seeds for the forest's continued diversity and generational health. We call the biggest and the oldest of these trees Mother Trees because they are connected below ground to all the other trees around them—their community—by what we call a mycorrhizal fungus.

A mycorrhizal fungus is a special kind of organism that forms a symbiotic relationship with the tree. It wraps its fungal body around soil particles, extracting nutrients and water that it then brings to the roots of the tree. In return for this precious nourishment, the tree obliges the fungus by providing it with the sugars that the fungus needs to survive. These sugars are infused with carbon that the tree has accumulated through photosynthesis.

Climate change is the result of an accumulation of greenhouse gasses in the atmosphere, and carbon dioxide (CO_2) is the biggest culprit. Carbon dioxide is also what plants

photosynthesize. They put that carbon in different places, such as their leaves and trunks, but we now know that 70 percent or more of that carbon actually ends up below ground.[1] It's first stored in the cell walls of plants until it's traded for nutrients via these root exchanges with mycorrhizal fungi. Once the carbon has been absorbed by these fungi, it can stay underground for thousands of years. And surprisingly, when mycelium dies, it also locks in the carbon for extended periods of time, building a carbon reserve for the future.

These mycorrhizal fungi form a network of threads that bond with the roots of other trees in the neighborhood and connect them all, no matter the species, like underground telephone wires. The biggest and oldest trees—the Mother Trees—have the largest root systems and the most root tips intertwined with these fungi, and they therefore connect with more trees.

We often think of kin selection or kin recognition as an animal behavior, but our research is showing that these Mother Trees also recognize their own kin—their seedling offspring—through these mycorrhizal networks and communicate with each other through carbon.[2] Carbon is their universal language. The stronger trees support the weaker ones by regulating the flow of carbon between them. If a Mother Tree knows there are pests around and her offspring is in danger, she'll increase their competitive environment. A good example is the *Leucaena leucocephala* (commonly known as the white leaf tree or river tamarind, among other names) that is native to southern Mexico and northern Central America. When it senses a competing species, it releases a chemical into the soil that stops the competitor's growth. It's a magical thing and it could not happen without the fungi.

TOP LEFT AND RIGHT *An edible, parasitic mushroom usually found in Patagonia, southern Chile, and Argentina* (Cyttaria harioti). BOTTOM *Turkey tail* (Trametes versicolor).

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