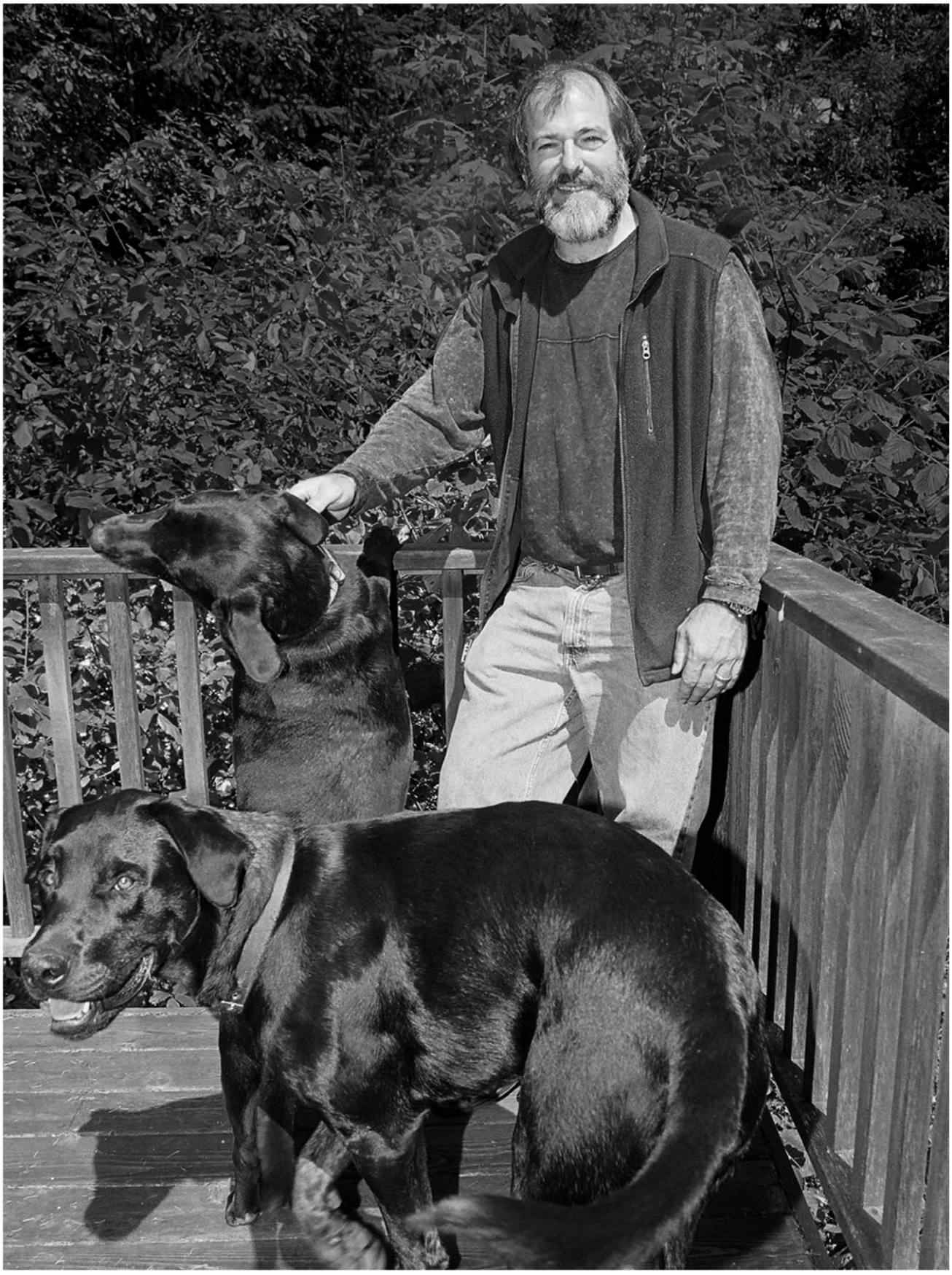

Paul Stamets

Can Mushrooms Help Save The World?

Interview by Bonnie J. Horrigan | Photography by David J. Horrigan

Paul Stamets, founder and director of Fungi Perfecti, LLC., and director of the Fungi Perfecti Research Laboratories (www.fungi.com), has been a mycologist and mushroom enthusiast for more than 30 years. A pioneer in the cultivation of edible and medicinal mushrooms, he is credited with the discovery of four new mushroom species. Stamets is the author of five books on mushroom cultivation, use, and identification, including *MycoMedicinals: An Informational Treatise on Mushrooms; Psilocybin Mushrooms of the World; Growing Gourmet and Medicinal Mushrooms; Mushroom Cultivator; Psilocybe Mushrooms & Their Allies*; and his most recent one *Mycelium Running: How Mushrooms Can Help Save the World*.

Stamets holds a vision of a deeply interconnected world environment and firmly believes that a greater knowledge of fungi can solve many of the world's pollution problems as well as some of the world's health problems. He has a strong interest in saving the old growth forests of the Pacific Northwest where many ancient species of mushrooms can be found. A dedicated explorer with a passion to preserve, protect, and clone as many ancestral strains of mushrooms as possible, he was the 1998 recipient of the Collective Heritage Institute's Bioneers Award and the 1999 recipient of the Founder of a New Northwest Award from the Pacific Rim Association of Resource Conservation and Development Councils.

EXPLORE interviewed Stamets at his home and mushroom farms near Seattle, Washington, in the summer of 2005.

Shown here on the porch of his yurt, Paul Stamets is one the world's most foremost mycologists. "I believe mushrooms can help save the world," he says.

EXPLORE: I am sitting here in your library admiring your collection of mushroom stones, these decorative statues that look almost like mushroom people. Tell me about them.

PAUL STAMETS: There's been a continuum of interest in mushrooms throughout history within many different cultures, and, culturally speaking, something becomes important sacramentally, not for one reason but for a multiple of reasons. So the purposes of the mushroom stones are multidimensional.

There are several hypothesizes. One is that these stones could represent the coat of arms of a family, handed down from parent to child. Another is that the stones were used to invoke rain because mushrooms appear after it rains. Their purpose could also be linked to the medicinal use of mushrooms. For instance, in Oaxaca, Mexico, a very famous woman shaman named Maria Sabina (1894-1985), who was a devout Catholic but also an Oaxacan Indian, used the sacred (*Psilocybe*) mushrooms to diagnose illness. People with a physical or mental illness would come to her to participate in the healing ceremony known as a *velada*. During the ceremony, Maria would ingest these *Psilocybe* mushrooms to "open the gates of her mind." Then she would recommend a treatment. Historically, many other species mushrooms have also been ingested as medicines. These practices date back more than 10,000 years.

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These particular mushroom stones were uncovered in Meso-America–in Guatemala and in southern Mexico– by farmers plowing their fields. They are very rare. We know one of them is more than 2,000 years of age. I have six mushroom stones, but I am just a temporary custodian. I put them out today because they tie the ancient and the new medicines together.

EXPLORE: They are beautiful. Let's talk about your belief in the interconnectedness of all things and what mushrooms do for the environment?

STAMETS:: The bottom line is that mushrooms generate soil. They are the grand molecular decomposers in nature and the grand recyclers of the dead, whether they are plants, animals, bacteria, or protozoa.

First, mushrooms reproduce through microscopic spores. When conditions (moisture, temperature, and nutrients) are right, these spores germinate into threads of cells called *hyphae.* As each *hypha* grows, it forms a connection with other *hyphae* to create a mycelial mat, which then gathers nutrients and moisture from the environment. The actual mushrooms are formed by this mycelium, which looks like cobwebs. You can see mycelium by going out into your backyard and picking up a piece of wood on the ground. Mycelium is everywhere. The mycelium channels nutrients to form the mushrooms, and it also infuses the trees and plants, which have fungal associates. In fact, you can no longer define a plant without its fungal allies. Plants do not exist in absence of fungi.

There are four categories of mushrooms. Mycorrhizal symbiotic fungi, such as the matsutake, form mutually beneficial relationships with plants. The plants have access to nutrients from the mycelium, and the mushrooms have access to plant-secreted sugars. Endophytes are benevolent fungi that partner with many plants and enhance the plants ability to absorb nutrients and stave off infections and parasitizing insects. Then there are saprophytes, which are the decomposers and which I grow a lot of, and the fourth category is the parasitic fungi, which are predators that endanger the host's health. But they all play essential roles in the ecosystem.

To put it in perspective, about 12,000 years ago at the end of the great ice age, when the glaciers were receding, the ice scraped away most of the topsoil and flushed it into the oceans. The Cascade and Olympic mountains were barren of soil. But small lenses of soil survived, and plant communities began to grow. The plants grew, climaxed, and died. The fungi rotted those plants, and the soil became a little bit deeper, and the lens of soil a little bit larger. So after many repeated life cycles, soil depth greatly increased. It is through the activity of these fungi, decomposing plants and other tissues, that soil is generated.

Generally speaking, the richer and deeper the soil, the more it can support biodiversity. So these fungi actually lead the way in increasing biodiversity by fortifying a nutritional habitat, ie, soil, in which they also have a self-interest. Because mushrooms feed upon the debris fields of plants, affecting subsequent microbial populations, they are the immunomodulators in nature. We have an immune system in our own body, and environments have their own immune systems as well. Mushrooms are the bridge between the two.

"The antibiotic defenses that fungi have developed are exquisitely useful to us in fighting bacterial infections."

In a single gram of soil, there can be several hundred billion microbes. In a single cubic inch, there can be more than eight miles of mycelium. I believe that mycelium is earth's natural Internet. Mycelia is the nutritional and information sharing platform, and it is the basis and the construct of the food web. The food web is totally dependant upon these fungal fabrics. The fortitude of an ecosystem to respond to a catastrophic event–whether it's a mundane catastrophe such as the building of a house or road, or a chemical disaster caused by humans, or a natural disaster like a hurricane or a tornado– depends on these mats. The fungi rise up very quickly and bring back the nutrients into the food chain through decomposition. So it's through the biodiversity of these fungi that we have life on this planet today.

EXPLORE: How many different types of mushrooms are there?

STAMETS: We estimate between one and two million species of fungi in the total kingdom, and, of those, around 10% (or 150,000) are mushrooms. Some of my friends in DNA research, when looking at fungi, believe that we have vastly underestimated the genome. They think there may be as many as 10 to 30 million species of fungi in the entire kingdom. But we've only identified about 14,000 species of mushrooms so far, which means our ignorance of species diversity exceeds our knowledge by at least one order of magnitude.

Four hundred and sixty-five million years ago, we shared a common ancestry with fungi. We split paths when life hit the beach. We went the overland route and in order to protect ourselves from loss of moisture, we developed a callous skin of cells, which was multicellular. Our proto-ancestors digested nutrients within, basically forming a stomach around the food source, secreting enzymes and acids, and digesting the food within that cavity. The fungi chose the underground route. They retained their filament as a one-cell-thick structure and digested nutrients externally to the cells. They produced the acids and enzymes, which broke down the plant material, and then, through semipermeable membranes, they drew in the nutrients that were essential for life.

This is why the antibiotics we derive from fungi are so potent against bacteria. We actually share about 30% of our genes with fungi, and we benefit from the antibiotics because we have the same microbial enemies as the mushrooms–*E. coli, Staphylococcus*, *Streptococcus*, *Listeria monocytogenes*, etc. These are all microbes that parasitize mushrooms. They also parasitize us. So the antibiotic defenses that fungi have developed are also exquisitely useful to us in fighting bacterial infection. But if you have a fungal infection, as is the problem with AIDS patients, the antifungal agents are very toxic to humans because our ancestry is more common with fungi than with bacteria.

EXPLORE: What is the state of the art in medicines derived from mushrooms?

Stamets holds a bottle of the extract from the living mycelium of Agarikon (*Fomitopsis officinalis*) that was submitted to the US Department of Defense BioShield program, which, when they had finished testing over 200 samples, was one of the six that proved to be active against ortho poxes.

STAMETS: For antibiotics, there is calvacin, which has been isolated from the puffball (*Calvatia gigantea*) mushroom. There is armillaric acid, isolated from honey mushroom (*Amillaria mellea*). There is sparassol, which comes from the cauliflower mushroom (*Sparassis crispa*), and campestrin, which comes from the meadow mushroom (*Agaricus campestris*). These are all known antibiotics derived from mushrooms. But these were discovered largely in the 1950s and 1960s.

What happened was, when the pharmaceutical industry looked at the yields within fermentation vessels of mushroom mycelium versus mold mycelium–penicillin molds produced more of these compounds faster than the mushrooms–the industry steered away from the mushroom-based antibiotics and concentrated on the mold fungi. Well, 99% of *Staphylococcus aureus* are now resistant to penicillin. It used to be 99% of *Staphylococcus aureus* were sensitive to penicillin, a fact that had a major influence on our winning WW II.

Here is a great story. In 1942, in response to a call for Americans to send in their mold fruit, a lady in Peoria, Illinois, sent a moldy cantaloupe to a US Defense Department hospital laboratory. Her cantaloupe gave rise to the most potent strain of *Penicillium chrysogenum* heretofore seen. It produced 200 times more penicillin than any other strain in their library. The Germans and the Japanese did not have penicillin, but the Americans and British did. This had a huge influence on the economies and infrastructures of these two countries because there was one type of battle wound for which the fatality rate was about 80%, largely due to infection. With penicillin, the mortality rate dropped to less than 10%.

Now, this mushroom I am holding is an extremely rare species. It grows only in the old growth forests of Washington State, Oregon, and British Columbia. The Latin name for it is *Fomitopsis officinalis*. Dioscorides first described this mushroom in 65 AD in the first *Materia Medica* as a treatment against consumption. In ancient times, it was called *Agarikon*, and it was known to the ancient Greek natural philosophers and the medieval herbalists, both of whom used it for a variety of ailments. The Haida people of the Haida Gwaii, also known as the Queen Charlotte Islands of British Columbia, also used this mushroom to stave off diseases "from the spirit world." Since the old growth forests have been cut in Europe and elsewhere, this mushroom is on the edge of extinction in Europe, and you are not legally allowed to collect it. But we still have it in our old growth forests.

The US Department of Defense BioShield BioDefense program contacted me about four years ago because of the threat of bioterrorism subsequent to the anthrax attacks. Their number one concern regarding a terrorist attack in this country was not about airplanes or nuclear bombs; it was about weaponized viruses. As terrible as it sounds, a nuclear blast in Boston will cause billions of dollars worth of damage, but it is not a contagion. It's localized. A smallpox outbreak, however, would be devastating. Pox knows no borders, and an outbreak would have international implications. So I cloned the Agarikon mushroom from the underside, developed cultures, made liquid extracts using a proprietary methodology that I had developed for growing the mycelium, and then submitted over 200 samples to the US Department of Defense. Of the more than 200,000 samples submitted to the BioShield program, only six proved to be highly effective against ortho poxes, including cowpox and Vaccinia. The top six were recommended to the Centers for Disease Control and Prevention (CDC) for the potential development of antipox medicines, and two of the six were my strains from the Agarikon mushroom. We have just received confirmation that some of these mushroom extracts are active against a variant of the smallpox virus, Variola. In essence, we now have confirmed activity against three pox viruses. We hope this species will provide broad antiviral activity, but the jury is still out. Note that these are in vitro tests, and the jump from test tube results to mammals is a vast one, medically speaking.

There is no treatment for pox. A number of vaccines have been developed, but the immunocompromised population is in danger of having adverse reactions from these vaccines. And there is no treatment right now for fighting pox subsequent to infection. Thirty percent of us with European backgrounds who are susceptible to the virus would die; 30% would become blinded; and 30% to 40% would survive but would have horrific scars.

For the Native peoples, it is far worse. Those of us with European ancestors have a history of herding cows, chickens, and pigs. *Vaccinia* was first found as a way of vaccinating humans because the milkmaids would get blisters from cowpox known as *molluscum contagiosum*. Then a medical doctor in the 1800s discovered

that the ladies with cowpox were immune from small pox. That's because in our hundreds, if not thousands, of years of herding these animals, we were exposed to pox viruses that wouldn't kill us but which enabled our immune system to devise a defense. However, Native Indians in North America do not have that history and are susceptible at a rate of 90 plus percent because they don't have a natural immune defense system in their genes. So here is where our current exploration of mushrooms could literally save millions of lives.

EXPLORE: I have this image in my mind of a mushroom with an "S" on its chest–"Here I've come to save the day." But you are saying it could be true; that it *is* true.

PAUL: Yes. I first got the test results of my submissions when the BioShield Program sent them to me by mistake. As I was flipping through the pages, I found the word "active" as a test result and then another "active" and then another. I was very excited, so I called the person in charge of my samples at the BioShield program and said, "Did you see these results?" He said, "What results?" So I told him that they had just been delivered by Federal Express from the NIH.

He said, "You are not supposed to get those results!" So I said, "No problem, I'll photocopy them and send them to you."–which he took in great humor.

I have to say, the people I've worked with in the BioShield BioDefense program are of such extraordinary high quality that it makes me feel more patriotic as an American. We may disagree with our politicians, but the infrastructure of our government is something that has matured over the years. These people are brilliant, and their hearts and souls are in the right place.

The genome of these fungi has enormous potential for fighting disease, and the fact that we have an old growth forest, and Osama Bin Laden does not, means that the old growth forests are essential to our national defense. In the context of the expense of a smallpox outbreak, if this mushroom can prevent or cure pox infections, from a monetary point of view, it exceeds the value of timber in the old growth forest. So I think future generations will look back in time and think that the economic rules that we used to measure the value of the old growth forests were incredibly biologically provincial, almost Neanderthal.

Our genome is part of our national heritage. We have a responsibility to give that genome intact to our descendants. The big questions is: What happens when we loose so much biodiversity? One analogy is rivets coming out of an airplane. How many rivets can come out of an airplane before you have a catastrophic failure? Similarly, we have this genome that is untapped. If we lose the species, then we may have lost an opportunity of finding cures for any of the pox viruses, bird flu viruses, HIV, and other diseases.

Our research in the discovery of novel antiviral medicines from these polypore mushrooms that grow in the old growth forests underscores that these indigenous mushrooms are not only essential for our national defense today but hold promise from protecting us from man-made or natural viral epidemics in the future.

"The genome of these fungi has enormous potential for fighting disease."

EXPLORE: You are showing me a mushroom extract. What is it?

STAMETS: This is the extract of the living mycelium of Agarikon (*Fomitopsis officinalis*). This is the very strain that has proved to be active against pox viruses. I cloned the mushroom that I showed you earlier by taking a tissue sample that I put it into a petri dish. I purified the strain, and then took a series of steps that ultimately ended up as this, which is the medicine. This beautiful amber fluid is so active against pox viruses that the same concentrations used in the BioShield programs when compared to pharmaceutical drugs were within the same window of concentration of activity. That has drawn a lot of attention within the BioShield program because whatever is in this extract is extremely potent.

You see, when you boil Agarikon to make a hot water extract, which is the traditional Chinese medicine method, the extact has no activity against pox viruses. That's because it's the living mycelium–not the heat-treated mycelium–that is effective. Also, most antiviral products are harmed by heat. So while my methods for deriving compounds from the mushrooms are nontraditional, they work. I have filed multiple patents on Agarikon and two other species against pox and HIV. HIV uses RNA and pox uses DNA, but both of these envelope viruses use CD4s, the protein membrane receptor sites on the human cell wall membrane. The viruses scavenge or steal this protein from the human cell wall membrane and envelope or encapsulate the virus in the membrane. This tricks the human cell because the human cell recognizes it as its own protein, and the virus enters into the cell.

Our initial studies support the theory that whatever is active in this living mycelium of this mushroom blocks CD4 and prevents that CD4 gate to open. More importantly, it can be used postinfection because it kills the virus without harming the healthy cells.

We have recently signed a contract with the federally funded National Center for Natural Products Research (NCNPR) at the University of Mississippi to fractionate this extract in order to find out which fraction has the activity. They understand that, in the effort of breaking apart a natural substance, you can fractionate it until all its components are inactive. So the question is where between the natural extract and a single molecule do you have the most potent activity? There may well be a synergistic blend of intermediate macromolecules that combine to give you the most activity. Being sensitive to this, we are creating 20 plus fractions at a time. We break them down from there. It will be very interesting, and time will tell. But presently, in this natural form, we know that this extract is active in vitro. So then we will go to fractionations, and then we will go to ex vivo and in vivo studies.

EXPLORE: I heard you named a mushroom after Dr. Andrew Weil.

STAMETS: Yes. I accuse him of culturing me, like I culture fungi from the forest. He has an intuitive and deep belief in the medicinal properties of mushrooms, in how mushrooms aid the ability of the immune system to resist diseases, including cancer and microbes. Andy empowered me through his friendship and referrals to oth-

ers exploring the medicinal properties of mushrooms, so I named a species of mushroom after him. It's called *Psilocybe weilii.* It's a *psilocybe* magic mushroom. The greatest tribute one can give to another person is to name a species after them. You never name it after yourself. So in this way, I've given Andy a tidbit of immortality—his species will survive him. It grows in Georgia, and they've actually found a vast fruiting of it in front of Newt Gingrich's office. I think these mushrooms have a poetic sense of humor. They like to make fun of humans—especially humans who are uncomfortable with their properties.

EXPLORE: I so agree. I think that, in a certain way, all life forms, mushrooms included, are conscious beings.

STAMETS: Yes, nature is intelligent, and I believe that the mycelium is an intelligent network. I wrote an article that was published in *Whole Earth Review* about 10 years ago stating that I believed that mycelium was the earth's natural Internet and that the invention of the computer Internet is really a repetition of a previously proven biological model. The computer Internet is patterned after the same archetype as the mushroom mycelium. You could shoot a hole in mycelium and not harm it. It just regrows. Just like you can't disrupt the whole Internet from any one specific point. Mycelia are neurological synapses of nature, and, if mushrooms have evolved for as long as we've evolved, why wouldn't they be intelligent? Humans have this pompous, biologically provincial attitude that we are intelligent, and nature is not. But nature gave us our intelligence, so why wouldn't the mother be as intelligent as the children?

EXPLORE: You have a mushroom that is of the same species that was found with the Ice Man, correct?

STAMETS: Yes, this mushroom is called *Fomes fomentarius* or *Amadou.* It was found with the 5,300 year-old Ice Man, who was discovered in 1991 on the border of Austria and Italy. Amadou mushrooms actually allowed for the portability of fire. You can hollow this mushroom out, put embers of a fire in it, and the fire will smolder for days, allowing it to be transported over distances. If a clan could not keep fire alive, the clan would die, so these mushrooms were absolutely instrumental to human survival as a source of punk, and they allowed for the migration of humans into Europe from Africa.

When you boil and then pound this mushroom, it separates into a highly flammable fabric that can be made into garments. In addition, this mushroom also revolutionized warfare because, although the Chinese invented gunpowder, Europeans invented guns. Flint, which throws sparks in many different directions, needed to be paired with something flammable, so they used the wood conk mushroom as punk (a preparation used to ignite gunpowder in more primitive weapons). It is the oldest known biologically manipulated product ever found associated with prehistoric humans. The oldest human site that has been discovered is from around 12,000 BC. In that settlement, they found this mushroom. So if it wasn't for *Fomes fomentarius*, a lot of us wouldn't be here today.

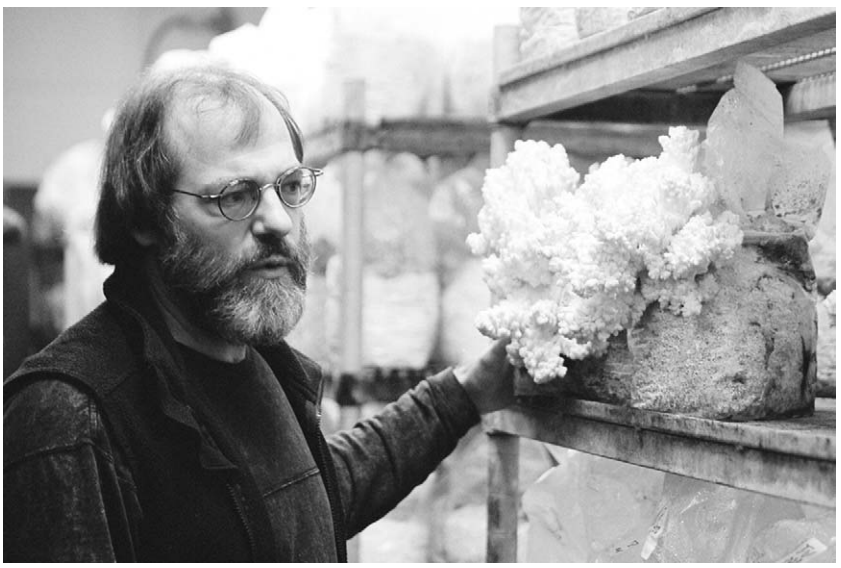
EXPLORE: Tell me about some of the other mushrooms here in your laboratory.

STAMETS: This is a *Hericium abietis* mushroom, commonly called the conifer coral mushroom. It forms on the undersides of downed conifers and produces a brown rot on the trees it decomposes. This mushroom has a novel nerve growth stimulant factor that causes brain neurons to regrow. The Japanese medical researcher, Dr. Kawagishi, has identified *erinacines*, named after the closely related *Hericium erinaceus*, which are NGF compounds that cause brain neurons and myelin (essential material in muscles fibers) to regrow on the nerves. So the folkloric reputation is that it imparts intelligence.

EXPLORE: Okay, I can't help but notice that there are frogs on the floor.

STAMETS: Yes. We don't use any pesticides. The frogs eat flies. So the main control in our grow room are these tree frogs. We've had several herpatologists tell us that this is a very good reflection of how clean and nontoxic our environment is because the skin of the frogs have extremely sensitive membranes. If there were any type of contagion or if toxins were present, the frogs would be our first indicator of that toxicity. They are our unsung heroes, an invaluable asset to our company, and a good parable for joining with nature to find environmentally benign solutions to pest problems.

The wonderful thing about mushrooms is that they are the most elegant displays of art in nature. Here is a Pink Oyster mushroom or *Pleurotus djamor*, and this is a Golden Oyster mushroom or *Pleurotus citrinopileatus.* They will be twice as large by tomorrow. They grow very quickly. We have been funded by the NIH for a clinical study at the San Francisco General Hospital with Dr. Donald Abrams. Oyster mushrooms contain a compound that helps remodulate liver function. The problem with protease inhibitors being



Standing in one of his laboratories, Stamets explains that, "The wonderful thing about mushrooms is that they are the most elegant displays of art in nature."

taken by AIDS patients is that there is a hyperaccumulation of LDL cholesterol, so many of the AIDS patients have circulatory problems and heart disease, and, as a result of bad circulation, they get fungal infections. The protease inhibitors, even though they are keeping the virus in check, damage the liver. Our NIH study is in its second year, and we are using oyster mushrooms as an adjunct therapy for treating HIV patients.

This is *Agaricus brasiliensis*, which is very popular in Japan as an anticancer treatment. The old name is *Agaricus blazei*. But it produces beta-1,6-glucans and beta-1,3-glucans, which are polysaccharides currently being studied for immunopotentiation. The beta-glucans promote natural killer cells, which are selectively cytotoxic to tumor cells.

This is *Ganoderma lucidim*, which is the best-known medicinal mushroom in the world. It is also called *Reishi*, which is Japanese for "divine," or *ling chi* in China. It has strong antiinflammatory and antimicrobial properties. It functions as a biological response modifier and activates natural killer cells.

EXPLORE: What are they growing in?

STAMETS: We use sawdust. These mushrooms are wood decomposers primarily. The mycelium then produces or fruits the mushroom.

EXPLORE: So the growing bags are essentially filled with wood chips, sawdust, moisture (water), and some spores? And in the process of decomposing the wood, they create the food that enables them to grow?

STAMETS: Yes. We inoculate in the laboratory, and, after they produce the mushrooms, we throw them into a compost pile, essentially feeding this "spent substrate" to the resident worms because, after they climax, they become food for other organisms. Our compost piles are all made from this material. Once the mushrooms have fruited and we have thrown the sawdust into the piles, the red worms digest what's left. That's how we make soil. We actually supply several organic farms with soil from these compost piles because it is certified organic. Then the organic farms bring us vegetables in exchange.

So mushrooms are the soil magicians. They are the grand molecular disassemblers. The whole basis of health in the environment is soil. Soil depletion causes famine; it causes the food web to collapse, which then makes people more susceptible to disease. So these fungi are absolutely critical to the health of the ecosystem. And we need to think multigenerationally downstream.

EXPLORE: I've heard you mention that before. What is the concept of seven generations?

STAMETS: The Native American concept is that, with every activity that you are engaged in, you should have a long-term view of thinking seven generations downstream. What is the influence of your activities on the next seven generations? It's not what you make in this lifetime; it's what you contribute to the whole program.

"The Native American concept is that you should have a long-term view of thinking seven generations ahead—so what is the influence of your activities on the next seven generations?"

EXPLORE: You have a new book coming out, I understand.

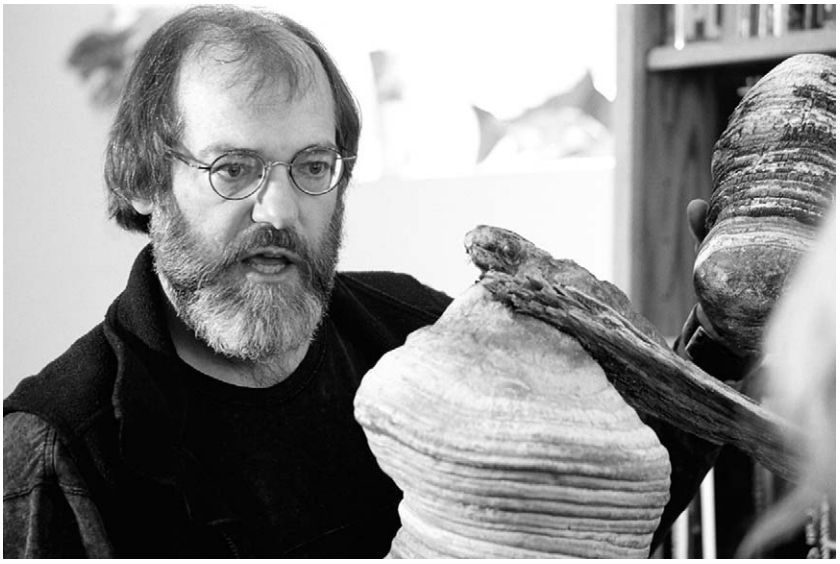
STAMETS: Yes, the book just came out! It's called *Mycelium Running: How Mushrooms Can Help Save the World*. It is about mycorestoration, which has four components. There is mycofiltration—the use of mycelium to filter sediments and silts as well as microbes and pollutants. That ties into mycoremediation, the use of mycelium to break down toxic waste. We have done a lot of research on that and have some excellent examples of how mushrooms can break down diesel and petroleum-based contaminants in the environment. Then there is mycogardening and mycoforestry, which are tied together. It's about the companion cultivation of fungi with plants using mycorrhizal, endophytic, and saprophytic mushroom species. The constellation of species that grows around the roots of plants is part of the host defense system of the environment. And finally, mycopesticides, which are an environmentally benign method of controlling insects.

So the book is basically how to use mycelium and mushrooms as allies for helping the health of people and the planet. As I stated, I believe that we have immune systems, and that habitats have immune systems. The fungi keep these immune systems in balance, both externally and internally.

As we all know, diseases spring from the environment. Look at the flu viruses coming from China. I just came from China, and I can sum up Shanghai as committing ecological suicide. Shanghai's environment is increasingly more polluted—a sign of the times to come. It's a highly technologically advanced city, but it is an economic engine out of control, and it is marginalizing human health issues as well as causing stratification in the Chinese society. It is an example, frankly, of what we do not want to become.

Mushrooms can concentrate heavy metals. This is a huge issue, and part of my research is the remediation of the environment contaminated with heavy metals by different methods through the hyper accumulation of metals in mushrooms. There is a mushroom called *Gomphidius glutinosus* that can hyper accumulate cesium 137, which is a byproduct of nuclear fission, 10,000 times the background contamination. Now, there's good news and bad news. The good news: Why do these mushrooms hyper accumulate heavy metals? It may be the immune defense of the ecosystems. These mushrooms concentrate the heavy metals by denaturing or decontaminating the heavy metals in the surrounding environment and making hot spots. This way, the ecosystem can rebound, and plant communities can grow up. The mushroom is toxic, but, if it is removed, you could potentially remove the heavy metals from the environment. This is where I think we need to establish a generational system of knowledge and education in our schools. It takes one or two generations to cause the contamination and the pollution. It will take 10 or 20 generations to clean it up.

So if we could educate people who have these pollution issues about which mush-



Stamets points out the *Fomes fomentarius or* Amadou mushroom, the same species of which was found with the 5,300 year-old Ice Man, who was discovered in 1991 on the border of Austria and Italy.

rooms not to eat but to pick and remove, then we could detoxify that particular environment. The mushrooms could be taken to an incinerator, and the heavy metals could be recaptured.

The bad news is that the unsuspecting public wants to have confidence in what certified organic means and in the integrity of the food supply. The fact is that mushrooms are, as we are, a reflection of the environment in which they are born and in which they grow. If you are foraging mushrooms near a smelter, or a heavily industrialized country, then you could be in trouble. I am very concerned about the accumulation of toxic metals in medicinal mushrooms coming from polluted lands, whether those lands are New Jersey or China.

I would like to do a calculation on the exportation of heavy metals through food coming from polluted lands. I think that you could actually come up with a scale or a measurement system showing what the impact is to the food chain through the exportation of contaminated foods. Heavy metals and pesticides are the norm in many environments. Most mushrooms sold in China are grown using very toxic methods. They use methyl bromide and formaldehyde because its less expensive then high steam pressure vessels, but, unfortunately, the mushrooms then capture those compounds. So we need to constantly evolve and challenge the old paradigm and make advances, and I think the medicinal mushroom industry is clearly at that stage right now where there is an enormous amount of new information.

For instance, using living mycelium as a source of novel myco-medicinals is something that we are proving, which is antithetical to the traditional Chinese method approach, which is all mushrooms must be boiled in water. We have found that ethanol extracts of mushrooms pull out constituents that are novel, that are exceptionally powerful as immunomodulators, and this is contrary to the standard thinking of many people elsewhere in the world.

Every mushroom species is a miniature pharmaceutical factory producing hundreds if not thousands of novel constituents that are new to nature and not found elsewhere. There is a commonality factor between mushrooms with certain constituents, but the species itself is defined by its architecture of novel molecules. And the molecular configuration that makes up one species signifies it and endows it with a unique cast of molecular characters that are unique to that species and not necessarily common to other ones. From these mother macromolecules, descendant compounds are released during digestion, influencing our immune systems. Intricate, but the research as it unfolds is proving to be very interesting.

EXPLORE: How does a mushroom act as an insecticide?

STAMETS: My old house, which was built in 1910, was, in our minds, a biohazard facility. It was decomposing because of a mushroom that actually rotted the underneath of the house. Then the carpenter ants came marching in after the mushroom mycelium pulped the wood and made it more succulent. So the fungi come first: the insects come second. I was trying to figure out how to get rid of carpenter ants, and I went onto the epa.gov home page and found a group of fungi called *Metarhizum*, which was target specific to pest structural insects, carpenter ants and termites, but not epidemic to beneficial insects. So the EPA was recommending these fungi for further research.

Now there are many other mycologists in the world who know a lot more about this subject than I do: I just had a unique circumstance in that we have spore-free environments. These *Metarhizum* fungi produce mold spores that look very similar to penicillin molds that you see growing on fruit. When I received some of the cultures, I was horrified that they were mold cultures. I grow mycelium that does not produce spores because I don't want spores blowing around my laboratory. So I was very chagrined to see that these cultures that I obtained were covered with mold spores. So I very quickly and in careful circumstances cultured these fungi. In playing around with them over a period of several months, I saw that there was a white fan of growth out of the green mold, which is called a sector. This is a fan of white mycelium that has no spores. So I thought, well, I'll chase that sector. I'll recall the culture from that point on the petri dish. I did that and was able to morph the strain from a mold state to a presporulating state that contained no mold, just the white fuzzy mycelium like we have with oyster and Shiiitake mushrooms.

In looking at the literature, the conventional view is that, when sectors form, the strain is going bad. It's dying. But that's a male militaristic view–more spores, more missles, more death. But everything from my experience in the martial arts says that when you get punched, if you are tense, you will get hurt. If you get punched and

you are relaxed, you absorb the energy. It is just the way of nature. This is the feminine side and the male side, the duality of yin and yang.

I recognized that the pesticide industry didn't have the yin and yang approach. The yang would be the spores; the yin would be the nonspore stage. So I grew the mycelium that had no spores out on rice. My wife, daughter, and I made a game of it. Every morning, I was vacuuming up sawdust piles because the carpenter ants were having a party at night. They were consuming my house. There was a part of the house where the wood was rotted out, and that was the avenue of escape and entrance for them. So I asked my daughter for her Barbie Doll dish, and I told her that we were going to trick the carpenter ants. I put the mycelium that I grew from the *Metarhizum* prior to sporulation down about 10 o'clock at night. Thankfully, my daughter had to use the bathroom at about one o'clock in the morning. When she walked by and looked down at the dish, there were about 30 ants all over the dish. Sure enough, the ants were swarming over the mycelium.

"Mushrooms have an ancestral intelligence—in the incredible dance with microbes, these fungal mats are able to achieve the largest masses of any organism in the world today."

Now, the problem with the commercialization of this fungus is that the spores cause repellency. The ants aren't stupid. They can smell the plague when they get near to it, just as we are repulsed by moldy bread. The insects are repulsed by a pathogen because, over millions of years, they've come to learn the repellant properties of these spores, which otherwise are contagious. And so, by delaying sporulation, I discovered the attractancy of a fungus that is otherwise pathogenic. So the workers took the *Metarhizum* mycelium and gave it to the queen.

We have now completed tests at Texas A and M University and other places, and we have found that the mycelium is so friendly that the workers present it to the queen. In one case, a fire ant queen was enthroned in the mycelium by the workers. She spread the mycelium back through the workers in the brood, and they became points of inoculation of the fragments of mycelium throughout the colony. And when the mycelium regrew, the entire colony was killed within two weeks.

We made extracts of the mycelium and found that it causes tremendous phago-stimulation. And we find that, by diluting the extract, we make it more potent. So we create attractancy and phago-stimulation, which means that we can make something be consumed, and, with the mycelium, it attracts and kills. So we have a contagion for the insects.

Now, I attached my guiding principles to this patent, which are strong environmental principles because I was very concerned that this patent could be crushed.

EXPLORE: What are the principles?

STAMETS: There are five guiding principals. The first guiding principal is that we wage no war against insects. We want them but not in our house. So we don't want to create a disease that is going to spread across the environment. As it turns out, my own house will never be invaded again because after the insects were killed, the fungus sporulated causing repellency. So no insects will enter into that environment because of the sporulation. It's a beautiful thing.

Two, the patent cannot be quashed. There are hundreds and thousands of tons of DDT and other pesticides now banned by most developed countries that are being sold off to underdeveloped countries. DDT is still used in India and China. This is a horrifying concept because, after mad cow disease was first discovered in Great Britain, they did an analysis and found DDT in the milk and in the meat. But DDT hadn't been used in England in almost 40 years. So where was it coming from? As it turns out, it was coming from grain grown in China. So I don't want this patent to be crushed by companies in order to prevent a good environmental technology from advancing forward because these companies have invested so much money in their toxic chemical inventories.

The third guiding principal is that we honor and respect the rights of native peoples. We are opposed to bio piracy. In so far as a native culture has developed a technology or has a genome that is essential to the technology, we will not exploit or be involved in bio piracy. It is far better to engage the indigenous peoples as coinventors than to exploit them. I believe in karma, and it's bad karma.

The fourth principal is to set up a nonprofit to steer off revenues that will fund these environmental friendly technologies or similar technologies, and the fifth one is to introduce these environmentally friendly technologies to developing countries where toxic chemicals are preferential due to their economic advantage. We would then motivate those markets by making this technology more economic than the toxic chemicals.

EXPLORE: What is your overall vision?

STAMETS: I want to create a paradigm shift. I believe that mushrooms can help save the world. We can do a course correction on the evolution of life on this planet and engage with the powerful fungal allies because they are the pedestal and the basis of the food web. All the research I have seen is speaking directly to that. They operate very quickly, and they have a long-term influence on rehabilitating the ecosystem.

So one of my research experiments was to break down toxic waste. Diesel-saturated soil will not permit life to rebound. But when we put oyster mushrooms into the soil, they actually fruited and hundreds and hundreds of mushrooms came out of the diesel saturated oil pile. As the mushrooms matured, they sporulated, which attracted insects. So then the insects came in and laid eggs, which became larvae, and then birds came in after the larvae. Our pile became an oasis of life in about 10 weeks. The other piles that were treated with chemicals and other remediation techniques were still neutral and lifeless.

I believe that mushrooms are gateway species. They lead to habitat restoration by steering the course of biological succes-

sionism. Once the mushrooms have done their job and denatured the toxin, they give themselves up. But the mushrooms preselect the bacterial colonies that are beneficial to the plants that give rise to the debris fields that feed the mushroom. So it's an exquisitely elaborate process wherein the mushrooms are preconditioning the environment for the benefit of the plants that the mushrooms ultimately need to sustain their own progeny. So mushrooms embody the seven generations concept.

EXPLORE: Have mushrooms evolved or are we dealing with the same species that existed 10,000 years ago?

STAMETS: Actually, mushrooms are evolving very quickly. We share common ancestry 465 million years ago. About 250 million years ago, there was a huge cataclysmic event. Some people think it was an asteroid. Others think it was the volcanoes in Siberia. But whatever the cause, the earth was shrouded in dust, and the earth's surface darkened. We know from the fossil record that 90% of life became extinct on this planet. Many suspect the earth was shrouded in darkness for many years, but then fungi surged to the forefront. They inherited the earth, and the plants that formed a mutual relationship with the mushrooms survived.

Speciation marched forward from 250 million years ago to 65 million years ago, until there was another cataclysmic event–a second asteroid hit the earth. Mass extinction again. At that point, we were little voles, by the archeological record. But the oldest mushrooms found so far are encased in amber and are *Codyceps*, and they are 100 million years old. There is another mushroom that has a stem and a cap, called *Aureofungus yaniguaensis*, that's from 90 million years ago. Mushrooms were fully intact in their forms as we know them today when we were little voles. These are ancient, ancient organisms, in many cases older than primates.

I believe that they have an ancestral intelligence because in the incredible dance with microbes, these fungal mats are able to achieve the largest masses of any organism in the world today. The largest is in eastern Oregon. It is a 2,200-acre honey mushroom mat that is only one cell thick. We have five or six cells that protect us from microbes, the mycelium has one. It is surrounded by hungry microbes, yet it can span thousands of acres in size? How does it do that? It has only achieved that through an exquisite understanding of how to dance with microbes at the microscopic level. So I think we can benefit from this innate intelligence, understanding that these mycelial mats are exquisitely sophisticated and very stealthy in their appearance because they are seemingly unsophisticated. We now know that the outer surface layers of the mycelial threads are covered with receptor sites that interplay and react to agents in the environment in a very sophisticated way.

EXPLORE: And you believe that we can all participate in helping ourselves and our environment by understanding and cultivating mushrooms?

STAMETS: Yes, by learning how to heal the environment using mycelial membranes and how to grow medicinal mushrooms, you can take a health issue that you or your family or your community has and you can customize a mosaic of medicinal mushrooms in your backyard that will target your needs relative to toxins, whether they are chemical or microbial. For instance, the Ling chi mushroom is very good for treating arthritis. It also enhances the immune system yet is an antiinflammatory. This is a seeming oxymoron because an immune response is associated with an inflammatory action. But here is the one mushroom that we know has strong antiarthritic properties and, yet, it modulates the immune system. It speaks to the fact that the definitions of inflammation aren't fully articulated by current Western medical thinking.

We are basically living upon lenses of mycelial mats, but these lenses are mosaics of multiple species infused and interlayed between and upon each other. This is the life fabric that we walk upon. This is the food web. So we have the ability to choose our fungal allies at a time when we desperately need healing. And if our environments can be made healthy then we will all benefit. Ultimately, we are a reflection of the environment.