Giant Porcino Mushroom. Photo by Monica 'Mo' Wilde, 2013.

MY FUNGAL MANIFESTO

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I am six years old. It's July 1971 and the rain has finally stopped. I am walking among wild blueberry bushes that are knee high, but my thick long wools socks protect my legs in spite of my short zouave pants. Above me are towering larches and spruces, and in front of me the Dolomite peaks seem to race one another towards the sky. I can't help staring at the mountains, even if I know I am supposed to look at the ground where I am stepping. The scary stories of kids, who, bitten by venomous vipers, had to be driven hours along the sinuous Schener canyon to the closest emergency room are vivid in my mind. I realize that I have been letting my guard down, just for one minute. It is, after all, a glorious day in an even more glorious setting. All of us, children and adults alike are on a mushroom foray, the first one of countless in my life which I clearly remember. As my eyes keep following clouds in the sky, a cold and somewhat slimy creature touches my left leg, right where the sock had slipped down exposing my bare skin. I am a short boy and the creature reaches the half point between my ankle and my knee. Frozen in terror, I imagine a viper that is lifting its head up and is ready to strike or wrap itself around my leg. I don't move at all; in fact, I stop breathing in an attempt not to further disturb the snake and – most importantly – I keep my eyes closed. After all, everybody knows that if you do not see "it" – whatever "it" may be – you do not have to worry about "it". I scream for help. When I open my eyes and look down, I recognize the chocolate-colored convex cap of a porcino mushroom, it is large and my foot had barely spared it. It is resting against my leg. I scream again, this time for joy and as a call for everybody to come and witness my triumph.

My family is around me and everybody is complementing my discovery. More than one member in our party says this is likely to be the largest specimen of the entire foray. My father takes out his pocketknife and cuts the mushroom off the ground rather than ripping or pulling it. "You have to cut it, so you do not damage its *roots* and then the next year another one can grow," he says. The porcino ends up in a basket as my dad emphasizes that "the fungal spores have to fall back on the ground to seed more mushrooms". However, the mushroom does not stay in the basket very long, because, as we double back to return to our village of 300 souls, I pick it out of the basket and hold it in my hands all the way, so that villagers and tourists alike may admire my wonderous catch. In fact, my first catch ever!

Residents of the Southern Alps know almost all mushrooms that grow in their valleys, differently from our neighbors to the North who are more "selective" and do not bother to learn the names of mushrooms, except for the few ones they eat. We know I am carrying a "*brisa*" in my hand, i.e. a mushroom that in the local language is equivalent to *Boletus edulis* and "porcino" in Italian, but we decide to go to the office of the mushroom expert, a lanky guy named Secco. In Italy, every township must have one such expert by law. We basically want to show off and make sure the entire village knows a six-year-old boy has found such a large mushroom. In procession, one by one, we enter his office, really the restaurant and bar his family owns in the center of the village. I am last and I am still carrying the trophy in my hands. Secco stands up and claps when he sees the mushroom, in a professorial and judge-like manner he states it is a "*brisa*" and that it is healthy, i.e. without the ubiquitous maggots found in older specimens. He goes to the back with the mushroom causing me an instant separation anxiety. Luckily, a few moments later, he comes back with scales which will proclaim officially the *brisa* weighs 780 grams.

While one could define the event narrated above as a mycological adventure, and in part it *was* a mycological adventure, in reality this was more of a culinary adventure. The only goal of these forays was and still is to procure fresh ingredients to prepare a vast range of delicious traditional dishes. I will admit that in my professional life as a mycologist and plant pathologist (even if often less knowledgeable than my colleagues who would often pick on me for not being up to speed with current fungal nomenclature) I always felt a huge connection with the fungi as if that mushroom cap touching my skin on that day had shared with me the inside story of all fungi, one that is made up of the hundreds of plants and mushrooms connected by the mycelial network. More importantly, it revealed the joint history of fungi and of all other organisms (including humans) that was specific to my valley, the Primiero. This valley, now easily reachable from the fertile plains of Northern Italy through an endless sequence of tunnels, was isolated for thousands of years. It was the only valley where a dialect of the Venetian language was and is still spoken within the County of Tyrol, together with German. I grew up thinking of fungi in the context of Primiero: for instance some woodlands are rich in one or a few mushroom species, and if the recipe calls for that specific mushroom, that is where you have to go. The same was true for ancient pastures and areas that had been logged, e.g. the amount and diversity of fungi depended on the specific history of each site. Although we did not use mushrooms for medicinal purposes, I grew up knowing that certain fungi could cause diseases and others could cure them. So it is not surprising to me that when Ötzi, the iceman, was found in a glacier just a few valleys away from mine, he was carrying mushrooms in his bag to be used for medicinal purposes.

Fungi are an indispensable part of the forest ecosystem. While they are technically microbes, both macrofungi and microfungi can be visible, even if just barely so in the case of the microfungi. I emphasize “can”, because often they are not visible at all. More importantly, unlike bacteria they share some distribution traits that are more comparable to those found in plants. Most fungi are territorial and when they occupy a specific niche, they actively exclude other fungi that may compete for the same resources. They do this chemically by producing antifungal compounds at the edges of their territory, and physically by creating barriers made up of impervious substances such as melanin. They will maintain a hold on the physical space they occupy until the substrate provides the type of nutrition they require, after which they may allow for succession by other fungi. They are masters of managing resources in the physical space they occupy. The mycelial network generated by ectomycorrhizal fungi is well known, but there are even larger networks, such as those caused by root rot fungi. In these cases, networks can span several miles, often with a single individual genotype making up the vast majority of the network.

Mycelial networks are not static, mostly because they follow the spatial distribution of the resources the fungi need. As a resource diminishes in one location, so does the mycelial network in such location, and vice versa. The connection with the territory they inhabit is complex in forest fungi and it is driven by the environment, by the age of the overstory, the structure of the forest and the diversity of the plants. However fungi themselves modify their territory and often make it more suitable for fungal colonization. This process can be selected through long-lasting evolutionary histories or may have been generated through rapid evolution associated with disturbance.

In order to minimize genetic inbreeding, many fungi must mate before they can exploit the resources of a substrate. This occurs between two germinating spores that carry different mating alleles. Only after mating are these fungi stable and competitive. The opposite is true: if they do not mate, single spores are unstable and uncompetitive after germination. This is a huge challenge for the dispersal of certain groups of fungi, because the vast majority of spores that remain “single” fail to establish a mycelium. Once a mycelium is established, though, fungi can favor further colonization by fungi, both of the same and other species. This can happen directly or indirectly. For instance, the Matsutake mushroom creates mycelial networks that facilitate the germination of individual spores that land on them through a process called di-mon mating. The end result is a useful diversification of the genetic pool. An example of indirect fungal intervention is that of *Heterobasidion*, a fungus that, by causing a root and butt rot of infected fir trees, causes physiological stress in neighboring trees whose roots are interconnected with those of the infected tree. This physiological stress allows for *Heterobasidion* spores that have long been lodged in the wood to germinate and start their own pathogenic phase.

The two examples above appear to be processes that have been selected during co-evolution among forest organisms. There is a third example of establishment facilitation of fungi by fungi that is the result of an introduction. It has been shown that when the Eurasian native fungus *Heterobasidion annosum* become sympatric with the introduced North American *Heterobasidion irregulare*, the latter species alone dramatically increases its sporulation rate. Thus, the presence of the native species enhances the dispersal potential of the introduced species, rather than fencing it off. Of course, there are many cases in which one fungal species that arrives first will prevent the establishment of a species that arrives second. One notable case is that of the fungus *Phlebiopsis gigantea* that will prevent infection of freshly cut stumps by *Heterobasidion* species. The backpack sprayer you may have seen in the installation “We shall by morning inherit the Earth”, may be used to facilitate such process by spraying *Phlebiopsis gigantea* spores on stumps as they are cut to prevent stump infection by *Heterobasidion* spores.

While the mycelial network allows for the significant spatial spread of many forest fungi, long distance dispersal is mostly achieved through airborne spores. One dogma that I have tried to debunk throughout my career is that these microscopic spores are everywhere, and hence all fungi are capable of long-distance dispersal. In reality, the majority of airborne fungal spores cannot remain viable for a long period of time, due to the combined effects of solar radiation, drying, predation and freezing. The territorial aspect of fungi has haunted me since I was six years old, when I already knew that all fungi were not everywhere. Matsutake populations in deeply set Himalayan valleys, separated by high mountain ranges that prevent spore dispersal, differ genetically from valley to valley, but are the same within one valley, even if the length of the valley is greater than the distance between two valleys. Mycorrhizal fungal communities are less complex in patches of trees that have survived forest fires than in neighboring forests untouched by fire. Species richness is negatively correlated with the distance between the patch of trees and the forest, and positively correlated with the size of the patch. Just recently, thanks to the ability to identify thousands of species that coexist in the same substrate, I have been able to show that the fungal microbiome (mycobiome) of tree trunks changes through space if there are gaps in the vegetation cover. Most importantly, I have shown that in many cases, as the geographic distance between populations increases so does the genetic distance. At one point that genetic distance is so large that two populations can be regarded as two different species, and they do “behave” as different species. Given that fungi are often relatively simple morphologically, these different species may look alike.

Understanding that populations of seemingly identical fungi from distant locations are different species has been a game changer, and in recent decades there has been a strong impetus to split many fungal species, once thought to be cosmopolitan, into species with regional or continental distribution. The importance of this exercise cannot be overstated. Due to our interconnected world, the Anthropocene has seen a huge jump in the introduction of non-native fungal species. Most non-native species do not survive once transported to a new environment, but some do, and some become invasive. Invasive fungal species can have innumerable negative effects on native ecosystems at societal, economic and ecological levels. Death caps in North America are a good example of a negative societal effect with regards to mycorrhizal fungi. Originally Eurasian, death caps were introduced on both coasts of North America, where their fruiting potential is substantially higher than in their native range. As a result, massive numbers of deadly death caps can be seen in North America, hence increasing the likelihood they will be collected and consumed. When non-native fungi or fungus-like organisms are pathogens, their introduction can result in massive mortality in naïve hosts, i.e. host that have never encountered such pathogenic fungi before. Mortality and rapid disease spread may occur because naïve plants have never needed to develop resistance to the newly encountered fungus. However, we are now understanding that these non-native fungi often and serendipitously encounter conditions that increase their transmission rate, independently of susceptibility of the host. In other words, we have to understand transmission and infection in order to predict mortality. This is exactly what human epidemiologists do. I will not give specific examples of non-native forest pathogens, but I will simply cite a few of the diseases they cause, such as chestnut blight, Dutch elm disease, white pine blister rust, alder decline, ash decline, colored canker of sycamore, cypress canker, and sudden oak death.

The introduction and invasiveness of forest fungi can both be driven by humans. The long-distance transport and sale of plants, plant parts (e.g. seeds or flowers) and plant products (e.g. timber or packaging wood) has led to the introductions of many dangerous non-native forest fungi. More importantly, when such introductions are associated with sales networks or commodity markets, the fungi are likely to be introduced multiple times, and ample evidence shows that the more introduction events there are, the more likely the invasion will be successful. This is the case with cypress canker disease caused by the fungus *Seiridium cardinale,* which was present on Monterey cypresses imported *en masse* from California to Southern Europe in between the two world wars; and with white pine seedlings infected by the white pine blister rust fungus (*Cronartium ribicola*), which were repeatedly sold by European nurseries to North American buyers in multiple locations. Some examples are particularly disturbing because the commodity that started the invasion is unrelated to forests or forestry activities in general. The most recent example of such an introduction is that of *Phytophthora ramorum,* a water mold (not a true fungus, but comparable to fungi in many respects) responsible for sudden oak death. It was introduced to the USA and Europe though the sale of infected ornamental plants, rather than plant stock intended for use in reforestation or afforestation projects. The intersection of different "worlds" can be extremely deleterious. In the case of sudden oak death, the ornamental industry has only taken responsibility for the disease in ornamentals, but has largely remained unresponsive to its impact in woodlands. Likewise, the industry continues to employ a business model in which plants grown in one region of the word (the US West Coast, Florida or Southern Europe) are then transported long distances and sold everywhere. If plant stock were to become infected by a non-native invasive pathogen in these winter hubs, as happened with the sudden oak death pathogen, the consequences could be devastating.

Humans can also facilitate invasiveness through the way they manage ecosystems. Two examples come to mind. Although several California oak species are most likely to be killed by the sudden oak death pathogen, they are not infectious. California bay laurels are in fact responsible for spreading the disease to oaks. California bay laurels do not die when infected, hence they can be long lived “super spreaders” of the disease. Because of fire exclusion and of cattle grazing, California bay laurels have tripled their presence and distribution in the last decades resulting in laurel-rich woodlands where oak infection is rampant. Curtailing bay density , as we would do with mosquito populations in a malaria-ridden area, is now an option that needs to be considered, if we want to reduce oak mortality. The second example is that of *Heterobasidion* root disease. *Heterobasidion* is a rare occurrence in primary forests, but stumps and stem wounds caused by logging greatly increase its presence because its spores can easily infect freshly-cut stumps and wounds. The increase in disease can be so extreme that entire forest stands can become unproductive and unusable for recreation, as trees infected by *Heterobasidion* can easily fail.

I am 60 years old, sitting in a laboratory in a beautiful Italianate building on the U.C. Berkeley campus, and I have been asked to write a manifesto. Instead I am writing a personal history intertwined with relevant fungal facts. In this state-of-the-art laboratory, I designed and am still running a program for detecting tree pathogens using DNA probes. The world’s first government-mandated DNA-based assay was that for *Phytophthora ramorum*, the causal agent of sudden oak death. This assay, designed in my lab at Berkeley, became mandatory for certain ornamental plants starting in 2004. This PCR test was conceptually identical to the one used for COVID that became mandatory more than 15 years later. For once, forest pathology was ahead of the times. Certainly, sensitive DNA tests can help us prevent the introduction of invasive non-native fungi, but they are costly and they need to be matched by extensive and accurate sampling schemes. How are we to test a shipment of 500,000 seedlings? Unlike in 2004, DNA tests are easily available now, but we need to figure out how to best detect pathogens in traded plants. Trained dogs, chemical signatures, imaging at different wavelengths are all options currently on the table.

However, I am 60 years old, and it is younger folks who can develop the new technologies. I am in my office and thanks to so-called next generation sequencing, I am analyzing the genomes of *Heterobasidion* isolates from the region around Rome, where the North American species *Heterobasidion irregulare,* introduced by the US military during World War II, now coexists with the native *Heterobasidion annosum*. Years ago, we had figured out that the two species were hybridizing (i.e. individuals of the two species were mating and having progeny) every time they met. What I am finding out now is different: there are individuals that genetically clearly belong to the native species *Heterobasidion annosum,* but contain a handful of genes that belong to the North American species *Heterobasidion irregulare*. These genes are responsible for higher rates of sporulation and of wood decay, hence it is no surprise these individuals are as aggressive as the other American individuals and much more aggressive than their European counterparts. Those few genes are enough to increase the overall aggressiveness of *Heterobasidion annosum*. It is not surprising that, like fungi, fungal *genes* are also territorial, and when introgressed, i.e. moved, from one species to another, have significant consequences. In Europe, we now have to look out for both the non-native *Heterobasidion* species and the non-native *Heterobasidion* genes in the native species.

I stop completely, just as I did when the porcino mushroom touched my leg. Like a river, the endless sequence of DNA nucleotides flows into me through the computer screen. Millions of years of fungal evolution are shared with me, along with oh-so-many secrets, hidden just as they were in that underground mycelial network connected to the famous porcino I once touched. I was six years old…

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This manifesto is part of *FUNGI: Anarchist Designers*. This exhibition, curated by anthropologist Anna Tsing and architect-artist Feifei Zhou, presents fungi as radical designers in a world beyond human control. On show at the Nieuwe Instituut from 21 November 2025 to 9 August 2026. With the support of het Cultuurfonds, Mondriaan Fonds, Graham Foundation and Iona Stichting.