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Introduction

In Southwest China's Yunnan Province, high on the Tibetan Plateau, you can climb a hillside at dawn during the late summer and early fall, and looking down, although the night is ending rather than beginning, it will seem as if stars are coming out in the valley below.

They are flashlights, carried by villagers walking up into the mountains to hunt for matsutake mushrooms. People collect all morning and return home when the dealers arrive at a village market or drive along the roads, buying from mushroom hunters as they go. These dealers will, in turn, sell their matsutake to other dealers, until eventually the mushrooms reach Japan, where they are highly valued.

The mushrooms are carried in shoulder satchels, often hand fashioned from bags once used for fertilizer or pig food, the durable everyday sack of rural China. When hunters find a prize specimen, they wrap it in a layer of thin plastic film or snap off the tip of a rhododendron branch and wrap grass around the mushroom, securing it to the branch and cinching it snugly, like a swaddled baby. The mushrooms are carefully cushioned in these satchels, as they can be easily damaged during the long hike across steep terrain.

Over the season, millions of these mushrooms travel from forests to villages, to local buying centers and bulking stations and then onward to Japan. Because of their delicacy and their great appeal to insects, such a journey must be made within forty-eight hours, for the insects within the stalk and the cap are already starting to eat them.

—Revised field notes from Yunnan Province

This book reveals a world that is far more lively, far more unexpectedly propelled by multispecies relations than the human-centered world that most of us learned about in school. Since the 1980s, in both popular and

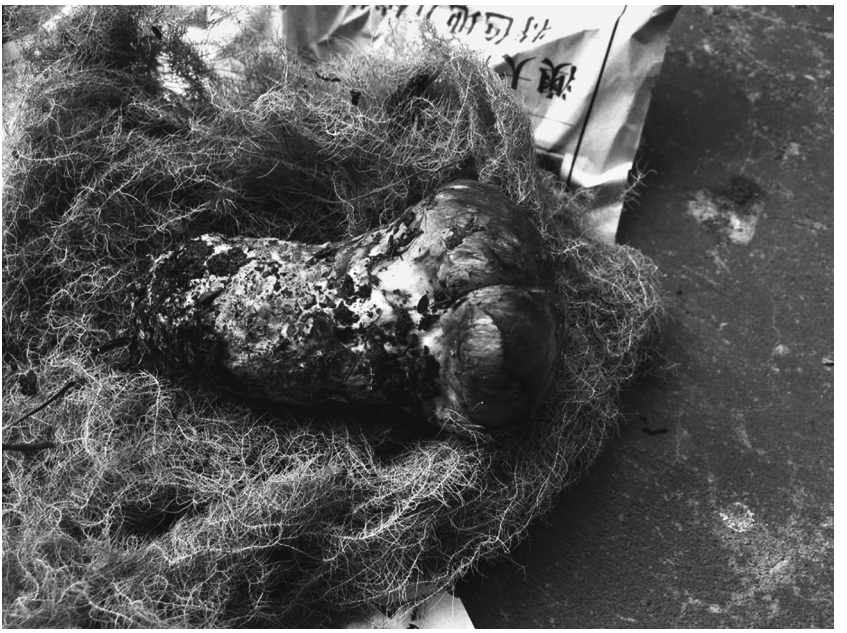

FIGURE I.1. Young matsutake cushioned in lichen and wrapped in paper. Found in the mountains outside of Gyalthang, in Yunnan's main Tibetan area. Photo by Michael J. Hathaway.

academic literature, there has been an explosion of interest in lives "beyond the human." Many people now actively learn about and debate whether animals possess rights, have capacities to feel pain, or imagine the future.[1] Yet most of this intellectual energy has been focused on the lives of our fellow mammals with familiar bodies and behaviors. Many of these studies take a "sameness approach," showing how other animals are similar to humans.[2] This book, in contrast, takes us beyond the animal realm to explore a place barely known to most people, the inner realm of fungi and how they participate in making the world around them via their relations to microbes, other fungi, plants, and animals. Even when I describe social worlds in which human mushroom hunters in China could be regarded as the main actors—seeking out matsutake and bringing them to lucrative markets (fig. I.1)—I also show how the mushroom's own behaviors shape these human actions in ways that are

rarely considered. All told, most matsutake appear and disappear without ever entering into human markets, yet they nonetheless shape landscapes and, hence, human lives, in powerful ways.

The book tells some stories of how the kingdom of fungi has shaped our planet in powerful ways, and it asks how we might imagine a different history of Earth. I tell tales of the intimate relations between fungi and other beings that many have not heard before but that nevertheless deeply influence our lives. Although I first turned to anthropologists and biologists to help me understand how other organisms might be understood as actors (i.e., as having the capacity *to act* rather than simply react), I quickly discovered that there are, as well, a growing number of other people—including fiction writers, historians, and social scientists, among others—who are no longer satisfied imagining a world where humans are the only beings that seem to act.[3] They write novels that acknowledge other species' lives and create histories in which humans are not the only actors that matter, with all other species relegated to the background as merely potential resources, commodities, or threats to human world-making ventures. They consider social lives as not just limited to the social lives of humans. Although such challenges to human-centered accounts of the world might seem new, they are not at all; indeed, a sense of society that includes other beings has long been common and remains strong in most parts of the world, despite the strong tendencies in Western thinking to view humans as exceptional beings.

Biologists are one group of people who are explicitly interested in the lives of nonhuman organisms, and they have produced much of the intimate knowledge we have about these beings. Science, as we understand it today, as a formalized and very particular way of thinking about and describing the world, is relatively new. It was only in 1833 that the term "scientist" was coined, while the older term "natural philosophers" slowly lost favor. In the 1860s, Charles Darwin's radical theories, which argue for our common kinship with other beings, were sometimes described as a way to bridge what was known as the "Great Divide," meaning the gulf that separates humans and other animals. The Great Divide is a form of "human exceptionalism," the notion that humans are categorically distinct from all other animals. Another related concept, the "Great

Chain of Being," asserted that humans not only are different from other animals but are better: smarter and more powerful. This concept ranked all beings, from God to angels, humans to animals, and plants to minerals, along a hierarchical scale (lords above peasants, lions above zebras, gold above lead, and so forth). Given this, Darwin's theories encountered great resistance, especially from the Christian Church; nevertheless, in time these theories reigned supreme among scientists.

Like all forms of knowledge, our understandings of biology and its categories were shaped by the social conventions in which they were formed. For instance, the biological sciences still use terms invented in eighteenth-century Europe that depict the world as mirroring the dominant political structure of that time: as "kingdoms" of plants, animals, or fungi.

Another concept from this time, which once seemed unassailable but is now increasingly debated, is that of "species."[4] Previously, scientists held that organisms belonged to the same species if they could mate and produce offspring that in turn could produce offspring; the most frequent example given in biology books was that while a horse and a donkey could reproduce, their offspring, a mule, is sterile, thus demonstrating that a horse is a different species than a donkey. Such a "test" may work fairly well for large mammals. This definition, however, has now been challenged as we have come to understand that much of the biological diversity of life is microscopic. We now know that microbes can share genetics with each other "horizontally," that is, not only "vertically" from parent to child but from sibling to sibling and even between organisms that are considered different species.

Even the term "animal" serves to reinforce a sense of human exceptionalism when it is used to describe all animals *apart from* humans. There are some recent alternatives that remind us that we, too, are animals, but these often rely on unwieldy phrases such as "nonhuman animals," "other-than-human animals," or "other animals." In this book, I use the term "nonhumans," even though I dislike language that continues to perpetuate human exceptionalism. Others are trying to create new words to manage this "lexical gap in the English language."[5] One example is "anymal," a nonanthropocentric term to describe *any*

animal other than one's own species. Thus, from the point of view of a garter snake, a blue jay is an anymal.[6] I could have used the term "anymal" in this book, but I am often talking about nonhumans that are members of other kingdoms, such as plants and fungi.

While this may seem to be merely a matter of semantics, animal rights advocates such as Kenneth Shapiro have been insightful critics of such linguistic distinctions between humans and animals as a kind of "categorical error" that creates a "subordinate and inferior status for nonhuman animals."[7] To repeat these errors, then, is to reinscribe this Great Divide—a divide that I believe has had and continues to have disastrous consequences.

The strength of the conviction that humans stand alone, in that they alone have minds, is in part a legacy of ideas enshrined by René Descartes (1596–1650) and others during the Enlightenment.[8] They argued that the best way to understand how nature works is via a mechanistic model—and indeed, the most prominent metaphor of the time was a complex yet familiar machine: the clock—consisting of hundreds of tiny parts that function in predictable ways. Descartes and his allies argued that animals were like small machines: their actions were predictable responses to external stimuli.

This view was not totally dominant, however, even within Europe. Charles Darwin, for example, conducted experiments in which he approached other organisms such as worms as lively beings who possessed forms of mysterious intelligence and who learned from their experiences.[9] Nonetheless, an increasing number of scientists began to use a mechanistic framework.[10] In a long battle that took place over centuries, two groups began to emerge. One group saw organisms as agentive, *self-making* machines (and indeed, the word "organism" refers to the idea that the animal was self-organized as opposed to being a "mere machine"). The other group saw organisms as more passive, as subject to their environment. By the 1930s, however, this battle had basically been won by the more passive-minded group, later termed the "neo-Darwinists."[11] Today, nearly a century later, the conceptual framework of the field of biology continues to be almost exclusively a mechanistic one. Although in everyday life, many biologists appreciate

the organisms they work with as lively beings, the constraints on scientific writing tend to produce accounts described in mechanistic terms. As Eileen Crist shows, standard biological texts use mechanistic language to portray "animals as objects . . . [who] appear blind to the meaning and significance of their activities and interactions. . . . Behavior comes through as something that happens to an animal, rather than an active accomplishment."[12]

This mechanistic understanding has been incredibly productive for scientific discovery in several ways. For example, viewing animals as machine-like meant that they were perceived as not feeling pain or possessing rights; hence, moral questions could be disregarded, and a wide array of experiments—from limb amputation to vivisection—could be carried out on them. The goal of a mechanistic view is to discover the mechanisms of life, the relations of cause and effect. In fact the term "the mechanism" is a common way to describe such connections. The main query of a mechanistic framework is always, at base, *What is the mechanism?* This question, while useful in many cases, also excludes many other lines of inquiry by, on the one hand, assuming a mechanism both exists and controls each relation, and, on the other, by assuming that the question of a mechanism is in and of itself the most important question.

Yet, as I will show, like all frameworks, a mechanist model also constrains the kinds of questions asked, the experiments designed, and the conclusions drawn. Experimenting with a livelier framework enables different inquiries and new understandings.

Indeed, a number of scientists are now challenging some of these precepts, suggesting potential problems with mechanistic approaches and arguing that nonhuman animals (as well as plants and other organisms) engage their surroundings in a dynamic way. They are also questioning the notion of human exceptionalism. Many claims have been made, such as the claim that only humans can use tools, feel pain, imagine the future and their own death, and communicate through language. I was imbued with this belief system whether or not I wanted to be, and even when I had a sense that it wasn't always right, I had neither the vocabulary nor examples to challenge it. Only recently, as I explain in

chapter 3, have I learned how certain language conventions work to continuously de-animate the world, drawing a strict demarcation between humans and other species and in turn rendering most of the nonhuman world passive.

Other scientists, rather than assuming a Great Divide, are now arguing that many animals do, indeed, use tools, feel pain, and communicate in sophisticated ways. It is no longer shocking news for a scientist to argue that elephants have emotions, that bees communicate through intricate dances in the hive, or that dogs mediate the emotional lives of their owners.[13] Biologists, who once insisted on the machine-like quality of animals, are now revealing in intimate detail the fantastic abilities of our fellow animals. In tandem, my own thinking is enriched and beholden to a number of scholars in the social sciences and humanities who have taken a keen interest in the more-than-human world.[14] Together, their work helps show us how the "social" is never that of humans alone. These are exciting times.

This book brings us from the more common focus on animal lives to a focus on organisms far less familiar—fungi. In it, I aim to show you that our very world has been made possible by the daily actions of trillions of fungi that have shaped our planet for almost a billion years. The discipline of biology, deeply shaped by a particular European legacy, has tended to be animal centric, and this orientation has markedly limited our ability to notice, understand, or appreciate the great diversity of nonanimal forms of life, or to imagine how organisms such as fungi have influenced animals and ecosystems, how they are part of world-making dynamics.

What are fungi? Biologically they compose an extraordinarily diverse realm, and most are microscopic. Within a European context, fungi

were often thought to be "strange plants."[15] It was only as recently as 1969 that fungi were recognized by scientists as a separate kingdom from plants, and yet the institutional structures are so deeply entrenched that now, even more than fifty years later, almost all professional mycologists were trained in a botany department.

Let me provide you with a brief sketch of fungal lives. They are diverse and superlative in a number of ways. Although many fungi are microscopic, it's possible to walk up the steep hills of Oregon's Blue Mountains for hours and still be traveling on the body of one of the world's largest known living organisms, an *Armillaria* fungus also known as a honey mushroom. Over its vast life, possibly more than two thousand years, this fungus has created a mycelial network extending over two thousand acres (eight hundred hectares). Although they seem not to move (except by mysteriously appearing overnight), hidden within their bodies is the capacity for unbelievable movement: many fungi shoot out spores with incredible acceleration, far greater than astronauts face in a rocket ship. But, because they are so tiny, they face a lot of air resistance, and thus attain speeds of only up to seventy miles per hour (113 kilometers per hour), a nonetheless impressive mark that ties with that of the cheetah, the world's fastest land animal.[16]

Fungi are like animals in several ways, for indeed we are both within the larger category I mentioned earlier: opisthokonts. This means we each need to consume other organisms to survive (rather than being able to photosynthesize like plants or eat chemicals like some bacteria). Moreover, we both breathe in oxygen and exhale carbon dioxide. Some fungi eat live animals, hunting them with snare traps and sticky nets. Many form intimate relations with animals, traveling within or on their bodies, including our own. Some fungi live within insects that transport them to new locations inside of trees, where the insects lay eggs; the fungi grow so that when the eggs hatch the young insects are surrounded by food—fungi-digested wood that is nutritionally enhanced.

While most fungi are microscopic, others are so massive you could seek shelter under them in a rainstorm (fig. I.2). The microscopic fungi are all around us, and many of them we intentionally eat with gusto: yeast that transforms wheat into bread, barley into beer, and grapes into

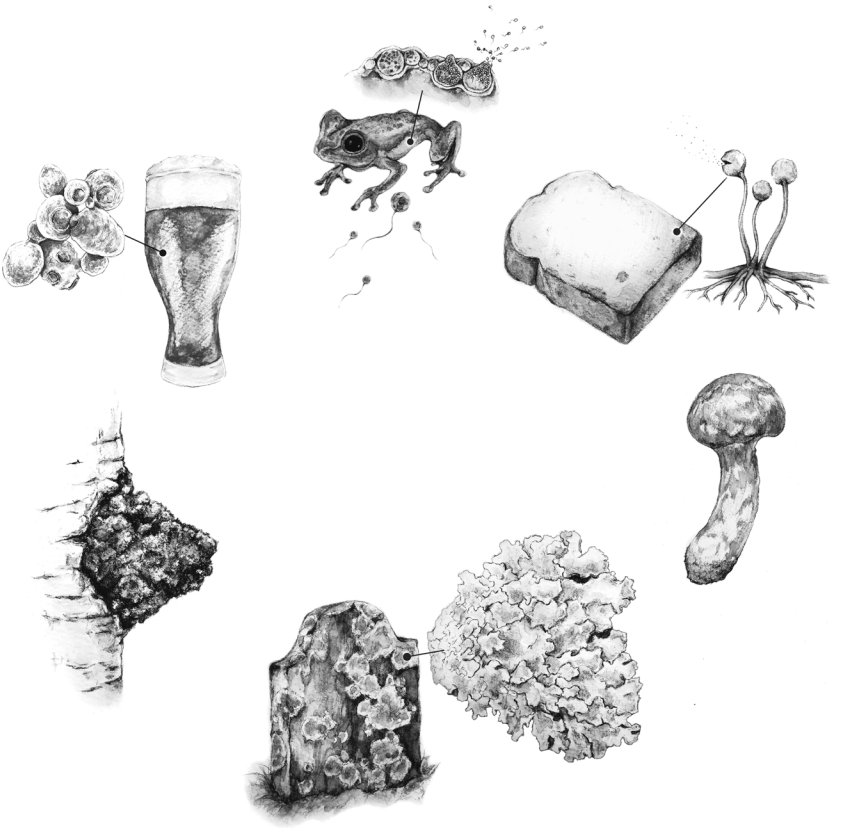

FIGURE I.2. A range of fungal forms, not to scale. From top left: beer with yeast; chytrid spores swimming after frogs; mold growing on bread and sporulating; matsutake; lichens growing on a tombstone; chaga growing on birch. Image by Saki Murotani.

wine. Fungi, thus, bring bread into being, but they can also take it away from us, as many people keep bread until blue mold appears in ever expanding circles. If you look closely, lovely stalks appear as the mold starts to produce spores to find new homes. Other molds seem to appear overnight: a blemish on an orange's skin expands and slowly liquifies its insides. Some fungi last for centuries or more. Next time you're at a cemetery, study the lichens growing on tombstones, as mycologist Anne Pringle does. While the stones represent human death, they may offer lichens a site for potential immortality.[17]

Likely the world's most common representation of a fungus is the classic *Amanita muscaria* found in the book *Alice in Wonderland* and the video game *Super Mario*, with its distinctive red cap with white flecks. Many large mushrooms appear in the autumn, popping out of the ground in a range of colors and shapes; some call them the "jewels of the forest," or "flowers of the fall." Some look like a dead person's fingers poking through the earth. When they get large, they can become incredibly charismatic: one giant cluster of *Tricholoma giganteum* mushrooms in Yunnan attracted more than 130,000 visitors in just a few days, many of whom threw money at them.[18]

To human noses, mushrooms emit a bewildering range of smells, but relatively few people have experienced their diversity of odors. The "classic mushroomy smell" of the most popular mushroom in the West (*Agaricus*) is only the beginning:

> *Lactarius hibbardae* smells like coconuts, many *Inocybe* species have a spermatic odor, *Cortinarius vulpinus* has the odor of a sow in heat; *Trametes suaveolens* and the aniseseed polypore (*Haploporus odorus*) have the odor of anise; chanterelles smell like peaches or apricots; *Amanita citrina* smells like raw potatoes; *Cortinarius paleaceus* smells like geraniums; *Mycena alcalina* smells like Clorox bleach and *Russula xeromphalina* smells like cooked crab.[19]

We know little about what effects these smells have on other species: who can detect them, who finds them attractive, and who finds them repellent? We recently learned that some insects may be attracted to glowing fungi, and other fungi possess skin with stunning ultraviolet colors, invisible to humans but likely capturing the attention of other beings.

Fungal sexuality has often been an enigma, and for many years, fungi were seen by European researchers as a kind of mysterious plant. While technically called a "fruiting body," a mushroom is not a fruit that contains seeds. It is closer to a flower that contains pollen yet is very different as well. Like a flower, a mushroom is a sex organ. Plant flowers disperse pollen, which can be carried by wind, rain, insect, or animal, and when these grains land on the receptive part of a flower's ovary (sometimes

called a stigma), the pollen germinates, creating a long tube that then ejects sperm into the ovary; if the sperm and ovary fuse, they create a seed. In fungi, on the other hand, spores do not immediately seek a companion of a different "mating type." Historically, European systems of understanding often assumed that there were two mating types in the world, what we often call "the sexes," a supposedly universal division between female and male, construed as opposites. Study of the sex lives of fungi (and bacteria), however, helped foster a new understanding of diverse mating types. Through the work of two female mycologists—Elsie Wakefield, who directed the world's largest mycological department at Kew Gardens in England, and Cardy Raper, who worked at Harvard—breakthroughs were made in understanding fungal sex and the proliferation of mating types. They discovered that spores are choosy about which spore they will mate with and will not fuse with those of the same type. Although some fungi have a few mating types, others can have tens, hundreds, or even thousands. One kind of shelf fungus boasts more than twenty-three thousand mating types, a mind-boggling notion, as many humans still puzzle over reckoning with any more than two genders. Such profligacy means that when these spores germinate, say on a new tree, the chances that they will find spores of a different type are greater than 99 percent.[20]

Yet the aboveground mushroom is just a tip of a fungal iceberg. Underground, the structure of a fungus is formed by many filaments, called hyphae, that grow together in a mycelium. Just one cell thick, hyphae extend through the soil column in search of water and nutrients. Some fungi are saprobic, meaning they eat dead matter such as fallen leaves and wood, breaking it down into soil and food for other organisms. Some fungi are symbiotic, meaning they make intimate relations with other living organisms, in a wide array of dynamics, from mutualism to parasitism. One form of mutualism—the connections between fungi and plant roots in what is called a mycorrhizal relationship—has become one of the planet's most fundamental relationships, because fungi are critical to the flourishing of nearly 95 percent of the plants around us. I will explain this more in detail in chapter 2, but basically fungi are able to gather water and soil nutrients, which they exchange

for photosynthetic sugars created by their plant partners. Thus, almost every plant is part of an underground fungal network.

Fungi deviate from the usual dichotomy of plant and animal; fungi are the "third *F*"—what some call the "funga," alongside flora and fauna. Their ways of living diverge significantly from other organisms; for example, some fungi make symbiotic connections with species in other kingdoms, while others produce a prodigious diversity of sexes. Some fungi may have a potentially unlimited life span, for they do not possess what scientists call "preprogrammed cell death"; that is, although they get older, they don't, as we commonly understand it, "get old." To acknowledge fungi's seeming strangeness, according to animal and plant logics, can help us queer the field of biology, revealing a radically different view of life.

Within mainstream Western education, fungi have been largely ignored, sometimes described as the "forgotten kingdom." They have tremendous powers over our lives, and yet most accounts of the world leave them out entirely. Even in the late 1990s, botanists argued that plants were often underappreciated compared to animals and came up with estimates that of all living things on Earth, plants made up 99 percent of living biomass.[21] This figure, however, was derived from a "two kingdom view of life" that excluded fungi.

Newer studies of the weight of the living world are more likely to consider fungi. New estimates suggest that they weigh more than humans and all other animals on the planet combined.[22] Even biology textbooks tend to give them short shrift, vastly understating how fungi are shaping the world. Such neglect even influences our main models of climate change, to our detriment, given that mycologist Jennifer Talbot recently revealed that while all the major climate change predictions completely ignore fungi, they are likely the most important actors in determining how carbon moves through soils—a source of carbon ten times more important than all land-based human processes.[23]

Fungi have been such influential world-makers in part because of their success in learning how to live in diverse habitats, from high mountaintops to the ocean deep. Even in one small area, such as between your

toes, scientists have found more than forty species of fungi that have made a home.[24] They have spread throughout the entire planet by water, land, and air, including places such as the ice fields of Antarctica, where plants cannot survive.[25] Recently, fungi were found deep underground, within the igneous oceanic crust itself, previously thought to be without life.[26] Their lightweight spores, designed to be airborne, allow fungi to traverse vast distances in space. Although we tend to think of fungi as stationary, like how we understand plants as rooted in place, fungal spores can move over space, flying high in the jet stream, crossing oceans, and jumping continents.[27] In general, though, mushrooms move by spore or mycelia with plants, expanding or shrinking their territories slowly in relation to climatic changes, moving ahead of or behind glaciers. They have been thriving on the planet for so long that many have moved around the world riding on tectonic plates.

Each kind of fungi has its own particular history of global movement, the study of which is called "mycogeography." Let's consider one possible map of the matsutake diaspora over tens of millions of years, which contains a sense of matsutake's movement. Whereas most maps convey an impression of spatial fixity and temporal stability, this one offers a dynamic representation (fig. I.3). The map was developed by Britt Bunyard in 2013, and it portrays three different species, each represented in a different shade (some of these species were later subdivided, in 2017).[28] Notice how the lightest path shows this particular species traveling across the vast Atlantic Ocean, which gives a sense of matsutake's long-distance travels, though as I explain in chapter 4, when these journeys happened, so long ago, the arrangement of the continents was very different than it is now, so perhaps the Atlantic Ocean did not yet exist.

Even as we view this map of matsutake's travels, it's important to keep in mind that the global spread and distribution of matsutake was by no means assured in advance; each encounter was dynamic, and how each unfolded was not a foregone conclusion. Rather, their expansion into new lands—and unfamiliar ecosystems—meant that there were many encounters with organisms that were new to them. Matsutake became involved in a whole suite of relations: some were able to connect with

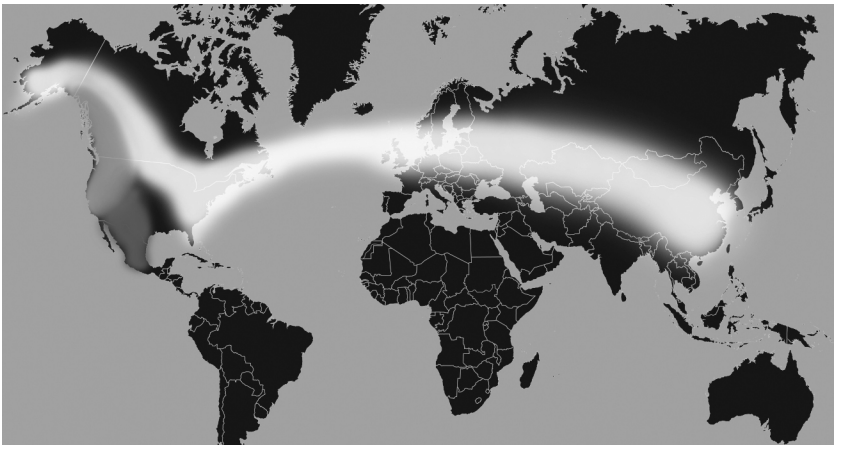

FIGURE 1.3. A map showing the possible spread of matsutake species. With kind permission from Andreas Voitk.

certain unfamiliar trees, were parasitized by some plants that could detect their underground mycelia, and were eaten by other fungi and animals. It should be noted that organisms that tried to eat the newly arrived matsutake had to experiment. Although some fungi have strong flavors that either attract or repel, some seem edible but contain toxins that take days to bring death—and yet somehow this knowledge spread, albeit imperfectly.[29]

I wanted to understand how such relations emerge, but it is rare to find scientific accounts of mushrooms as dynamic organisms. The cases that are most likely to show fungi as dynamic are those that label them "invasive," when they kill plants or animals or objects we care about, such as the fungi that kill bats or frogs, those that attack human crops, or the fungi (dry rot and others) that devastate wooden ships and homes. In almost every other case, scientific accounts portray fungi as relatively passive, as already adapted to their environment—in short, as mechanistic organisms in a mechanistic world. Many scientific accounts portray fungal life as a mere series of chemical reactions, each triggered by a certain stimulus. And still, despite these reductive portrayals, scientists fall in love with fungi, experiencing their charisma while spending long

hours peering into microscopes or digging down into the forest duff to observe their mycelial networks.[30]

Working with my anthropologist colleagues in the Matsutake Worlds Research Group, I had initially envisioned this book as a more conventional anthropological account in which people were the only actors, but something happened along the way. In part, I became fascinated on my trips to Southwest China by the ways that two neighboring ethnic groups of people, Tibetan and Yi, were committing themselves to the trade in this valuable mushroom.

On the eastern edge of the Chinese Himalayas, previously poor and poorly treated rural villagers of two different ethnic groups transformed their lives with mushroom wealth, but in notably different ways. Their encounters with matsutake brought about rapid social changes that went beyond a mere infusion of wealth. I was originally interested in what people *did* with matsutake and, more specifically, how it was a commodity that people *used* to make social worlds. I was more familiar with the social role of labor in making money, but less so with the idea that different kinds of labor made different kinds of wealth. For example, I was intrigued when Tibetans told me that "matsutake money" was not the same as "yak money." I found this quite interesting, but it was two particular interactions over the course of my research that expanded my interests into the capacity of the mushroom itself, beyond its role as a commodity in a human-made world, and helped me to start imagining the various ways that it, too, could be understood as a world-maker.

At a lecture in Texas four years ago, someone asked me if it was possible for Chinese pickers to pick every single matsutake, so that there would be none left. I replied that the life cycle of matsutake was starkly different from the "animal model" most biologists used to predict sustainable levels of harvest.[31] For example, picking a mushroom is not like

killing a deer or a salmon because the mushroom is not the entire organism. As I explain above, mushrooms contain not seeds but spores, and I offered the audience member the most common analogy to describe the whole fungus as being like an apple tree: the mushroom is the aboveground apple, and the root-like group of hyphae is the belowground tree. Picking apples once a year doesn't reduce the crop the next year; that is, it doesn't affect the tree's sustainability.

I had given these answers before, but this was the most extreme version of the question I had ever gotten. It made me realize that the vast majority of matsutake would never be picked by people because they grow over such a vast area, on steep and challenging terrain, and often hidden under leaves. Pondering my answer led me to this question: How might I understand the lives of the many mushrooms that never become part of human commodity chains?

A second encounter compelled me down another path of understanding how matsutake *themselves* are world-makers. My first main introduction to this idea came from some ethnic Yi matsutake-hunting families who described insects as savvy and active agents who were hunters of mushrooms, like themselves. I joined these matsutake hunters on morning hunts and to evening concerts of lively music with exuberant crowds and tipsy musicians. They described how certain matsutake-hunting insects could detect the mushrooms by studying the actions of other insects who were also able to find hidden matsutake. In other words, they were describing these insects, such as the fungus gnat (*Sciaridae*) or click beetle (*Elateridae*), as actively perceiving and reflecting on the world. I had never imagined that insects might study the actions of other insects that were neither prey nor predator. The Yi matsutake hunters carried out experiments to see how these insect matsutake hunters engaged the world, which I describe in chapter 5. This understanding of insects as capable, intelligent, and able to learn felt very different from how I had been taught to understand them, that is, as purely instinctual or as animals without brains.

Back in Vancouver, I read deeply on the topic of insect-mushroom relations and came across an intriguing term: "biosemiotics." It seemed to resonate with Yi sensibilities. In graduate school, I had learned about

"semiotics," the creation and interpretation of human-made signs as a form of communication, including writing, speech, body language, and so forth. I had not heard that there were researchers exploring the semiotics of other organisms in an expanded field called "biosemiotics." I had heard a few stories of animal communication such as how the alarm calls of vervet monkeys distinguish between various threats—from a snake, eagle, or leopard;[32] but biosemioticians were exploring many organisms in varied and sophisticated ways. Even though I could imagine that mushrooms might send out signals to other mushrooms (as I had read that maple trees send chemical alarm messages to other trees when attacked by insects), I realized I held a relatively impoverished view of the possibilities of fungal communication.[33]

Biosemiotic accounts helped reorient my point of view in two fundamental ways. First, I had previously assumed that such reactions were merely automatic reflexes, based on the mechanistic language of Western science that asserts that certain responses are triggered by particular stimuli. In contrast, biosemiotics introduced me to the notion that organisms exercise discretion and choice in how they respond. Second, I was surprised to learn that mushrooms not only produce forms of chemical communication; they also *interpret* others' communication. Initially I had assumed that communication was a simple case of cause and effect, in which a particular situation (such as an insect attack) would trigger the automatic release of a corresponding chemical. In turn, others of the same species would be triggered by perceiving that corresponding chemical. Such chemical messages, however, are not just one-to-one, where each situation is matched with a corresponding chemical. Rather, the receiver needs to interpret these messages. I wasn't as surprised that mammals have this interpretative ability, but I didn't imagine mushrooms could also engage the world in this way. I realized, to my chagrin, that in regarding mushrooms as relatively passive organisms, I was more subject than I had thought to some of the mechanistic frameworks that imagined other living beings as machines reacting to their environment. These two chance encounters exemplify how we are remade through our interactions with others and led me to dig deeper into the lifeworld of matsutake and other fungi.

I increasingly became aware that matsutake were not just a pawn of human economic projects; rather, and much more radically, they were carrying out their own life projects. Through these two encounters, my research project turned from being a human-centered account—in which humans are the only world-makers, who use other organisms as objects to accomplish their human worlds—to an account of how matsutake seek out other species to make their own worlds. This book explores how the actions of matsutake themselves—as living, breathing organisms interacting with other fungi and other organisms—literally make the forest and knit it together. My initial fascination with this one fungus grew into an interest in the whole kingdom and in the ways that fungi have shaped the planet.

Agency, Ontology, Actant

Above, I have used the concept of world-making to show how matsutake literally and actively make the world. The notion of world-making allows us to think in more nuanced ways about a related concept: *agency*. Within mainstream Western understandings, agency is often defined as *intentional action*[34]—the corollary being that only humans carry out intentional actions and thus that *agency* is exclusively a human domain. *Intentionality*, in turn, typically presumes an autonomous individual whose actions are consciously willed.[35] That said, I wish to sidestep debates about intentionality, because I am interested in how actions create worldly effects rather than the internal motivation for such actions.

Some scholars of nonhumans argue that the concept of agency is too historically burdened and anthropocentric to use beyond a human context.[36] But I contend that the notion of agency has too powerful a grip on the imagination, and on the fundamental structure of scientific thought, to confine it to humans. Inventing a separate term to describe nonhuman agency merely reinforces the idea that only humans have agency, thereby supporting a belief in human exceptionalism. In contrast, I am interested in finding ways to think about agency that include but also extend beyond humans.

Over the past few decades, various thinkers have introduced concepts that help us understand agency in new and different ways. The French intellectual Bruno Latour is the most well-known thinker and promoter of the influential framework of Actor Network Theory, which relies most notably on the concept of the "actant."[37] With this term, Latour meant to dissolve the distinction between humans and nonhumans (whereby actors can be *only* humans), arguing that we should see humans as just one actant among many.[38] Likewise, American political scientist Jane Bennett's notion of "vibrant matter" suggests a kind of neo-animism that recognizes the ways that nonhuman and nonliving things may possess something like agency in the world.[39] Some describe Bennett's work as having changed the dominant Western understanding of things as a passive backdrop for human affairs into an understanding of things as active protagonists in and of themselves.[40] I find Bennett's work exciting and inspiring; it argues that mainstream political theory largely views the world as consisting of dead matter, as a collection of objects that can be manipulated for human purposes. In contrast, she argues that the agency of things often exceeds human intentions, not only in episodic crises, such when a giant electrical grid fails, but in the comings and goings of everyday life, when piles of leaves clog street drains.

Compared to the terms offered by Latour or Bennett, one of the main advantages of the term *world-making* is that it inspires our curiosity into the particular qualities, properties, and lifeways of specific living beings. Whereas Latour's and Bennett's understandings tend to flatten agency, so that all things are equally actants or forms of vibrant matter, world-making inquires into the particulars—the diverse and specific agencies—of various organisms. For instance, African elephants' world-making will be totally different from the world-making of termites they share lands with, or even substantially different from that of their closer kin, the Asian elephants.

World-making as a concept appeals to me in part because it challenges the notion of human exceptionalism and can accommodate all organisms insofar as it explores how particular beings act in the world and create relationships with others. In contrast to the Enlightenment

perspective that only humans deliberately make worlds, I argue that all organisms—be they plant, animal, fungus, bacteria, or otherwise—are world-makers, even if their world-making occurs in ways that differ radically from each other (including from humans). The German philosopher Martin Heidegger stated that only humans make worlds, that animals are poor in world, and rocks have no world.[41] Although I appreciate that he does not make an absolute distinction between humans and other animals, I disagree with his assumption that all other animals are poor in world. If we avoid the assumption that other animals are not as sophisticated as humans, new areas for biological research suddenly open up. What kinds of new questions can be asked? What else can be noticed? For example, later I will pose the questions: How might a matsutake-loving fly observe and learn from other insects when searching for mushrooms? How might fungi themselves learn or gain skills throughout their lifetime?

My understanding of the term "world-making" draws on several earlier, related terms that have been used within cultural studies and anthropology. In these fields, world-making has sometimes been used to discuss the practices and perspectives of particular cultural groups. In cultural studies, Lauren Berlant and Michael Warner provide an example that I found helpful to my thinking, describing what they call "queer world-making" as efforts to build convivial networks and create amenable spaces within homophobic cities.[42] In anthropology, the closest term is often "cosmologies" or "ontologies" (which, unlike in cultural studies, typically refer to a group of people with its own distinct language), where each group is understood as living in its own world. As Anna Tsing argues, studies of cosmologies or ontologies have most often used these terms to mean a *mental* conceptual space, whereas the notion of world-making also includes physical activities and emphasizes the active making of a place, rather than assuming that it is always already there.[43] People have asked me if I will write this book in an ontological way, that is, from matsutake's point of view or "how mushrooms think." Although I am interested in this topic, I do not presume to have any such insights on it, nor have I seen any scientific studies claiming such knowledge. Instead, I am interested in understanding how matsutake *act* in the world.

Scholars of ontology—which briefly means a theory about the nature of being or what it means to have existence—suggest that each cultural group lives in its own world, which necessarily presents the idea of plural worlds. This idea, in turn, challenges the dominant understanding that we all live in a singular world—a *uni*-verse. To articulate this concept, several of these scholars of ontology (who I will call "ontologists") have proposed the notion of a "world of many worlds" or a "*pluri*verse."[44] They use the term *pluriverse* to challenge the hegemony of the Western scientific perspective of a singular truth that describes a singular "nature"—a universe. Their work seems to parallel one of the defining contributions of anthropology, which is, as Ruth Benedict put it in 1934, to pluralize the notion of culture. Benedict and others suggest that in contrast to the European idea of Culture, there are many different ways of being (cultures). These anthropologists helped us to recognize forms of Eurocentric thinking that permeated how other groups were evaluated and judged. Like Benedict and others, ontologists argue these other cultures should not be judged and ranked on a Eurocentric scale of more or less civilized. Yet, ontologists have sometimes criticized their fellow anthropologists for holding other cultural worlds at arm's length (dismissing them as "myths," "legends," and "beliefs") and conflating the world of their own culture as *the* world; ontologists, on the other hand, take other cultural worlds seriously in and of themselves, as fully rich worlds that are each unique.

Although I appreciate ontologists' notion of the pluriverse, I nevertheless want to expand its use from the diversity of *human* worlds to include the worlds of all beings.[45] Expanding the notion of the pluriverse to include other species seems especially apropos given that these scholars of ontology were often deeply influenced by Indigenous groups in the Andes and the Amazon, whose important philosophical understandings recognize and acknowledge how other beings are important actors.[46]

A second point of divergence is that I am leery of how some more extreme versions of ontology imagine the world as a realm of social bubbles. To put it another way, anthropologist Eric Wolf famously critiqued scholars who describe cultural encounters as if each group were like a billiard ball, preformed and solid.[47] As Tsing argues, in contrast

to thinkers who write about cosmologies or ontologies as solid forms that "collide" or "clash," the concept of world-making allows us to imagine such worlds as overlapping and intersecting.[48] I find it helpful to follow what Lieba Faier (a MWRG colleague) and Lisa Rofel describe as an encounter approach:

> Ethnographies of encounter distinguish themselves by considering how culture making occurs through everyday encounters among members of two or more groups with different cultural backgrounds and unequally positioned stakes in their relationships. The term encounter refers to engagements across difference: a chance meeting, a sensory exchange, an extended confrontation, a passionate tryst. Encounters prompt unexpected responses and improvised actions, as well as long-term negotiations with unforeseen outcomes, including both violence and love. Ethnographies of encounter focus on the cross-cultural and relational dynamics of these processes. They highlight how meanings, identities, objects, and subjectivities emerge through unequal relationships involving people and things that may at first glance be understood as distinct.[49]

Although this statement was made in relation to human-based encounters, the concept of encounter is also highly applicable to interspecies relations. As American scholar Donna Haraway puts it: "human becoming is becoming with" other species.[50] Haraway looks at human-dog relations where dog domestication was previously viewed as a one-way street: humans took a wild dog and turned it into a docile domesticate. In contrast, an encounter approach that views dogs and humans as "becoming with" encourages the further study of how dogs may affect human evolution, as well, such as shared emotional responses (including producing oxytocin) and shared viruses. Viewing domestication as a long-term encounter, a mutual transformation, means that we have to look at *both* organisms as actors. Trying to specify these ancient changes is hard if encounters do not leave physical traces; I was intrigued, for example, to learn that some people in Japan have a unique enzyme that allows them to better digest seaweed, and the theory is that this enzyme is the result of a multispecies encounter.[51] I first assumed that this en-

zyme must have emerged from human DNA but later read that it was created by bacteria in the gut microbiota. Scientists think this enzyme became part of some people's gut microbiota through a horizontal transfer of seaweed-eating bacteria a long time ago. Thus, rather than being digested in the stomach, these bacteria become part of human bodies. This is a powerful example of the physical manifestations that particular encounters can leave on the body. Although world-making is shaped by particular bodies, the outcome of encounters is uncertain. The presence of one life inflects the life of another, in complex webs of relations that are in the process of becoming.

I was reminded of these encounters when one day I found a huge chicken-of-the-woods mushroom, a bright-yellow-and-orange shelf fungus that I always found delicious. Grilling it over coals after a brief marinade, I was surprised by its intense bitterness, which I belatedly realized was because it had grown on a willow tree and had thus imbibed the tree's salicylic acid (a bitter chemical used in making aspirin); previously I had found these mushrooms growing on oak trees, and together they produced a flavor that I found delicious. Although these mushrooms had a similar shape, color, and texture, each was inflected by its encounter with other beings, in this case a tree, and became something different. In a less human-centered example, mycorrhizae are a unique structure that occurs only when fungal mycelia and plant roots find each other and decide to fuse together. Even though there are two kinds of membranes in between, I consider this a form of fusion as these connections allow for the exchange of water and many nutrients across these membranes. Mycorrhizae exist, in other words, only through encounters.

Even if one takes the plurality of worlds metaphorically rather than literally, world-making suggests that different species partake of their own significant and unique experience of living, and one can refer to each of these qualitatively different experiences as a kind of world. In this way of understanding, neighboring species experience realms that may be largely unknown to each other even as their presence shapes the other. For example, the sensorial worlds of perception and realms of interest for two species in the same place—say, for example, an African elephant and a mosquito on his or her ear—can be extremely different,

yet in other ways their lives coincide as they are briefly connected when the elephant's blood enters the mosquito's body.

When this project started to expand and I began to explore whether fungi had any active shaping effect on the world—that is, whether they possessed any kind of agency—I was hard-pressed to imagine that they could. I wondered: How did their presence matter to the world? For a while, my main answer was that they were a source of food for the animals who ate them. Even as food, however, they seemed inconsequential: low in calories, temporally fleeting, and scattered throughout the landscape. I later realized that I was thinking only about the kind of forest mushrooms I knew best and my own relationship to them, which meant the limited timescale of their aboveground lives. Breaking from these limitations, I switched my perspective to explore the role of fungi writ large, comprising more than a million species, to learn about their actions under the soil, in seawater, within the bodies of logs and the leaves of plants. My time frame shifted from a few weeks to hundreds of millions of years. In changing scale, forms of fungal agency loomed large, so much so that I soon discovered that fungi are absolutely critical to the planet as we know it.

But then, too, I also wanted to learn about the specific capacities of one particular fungus, the matsutake. There was relatively little research about its specific ecological role, in part because humans' as yet unfulfilled desire to cultivate it has focused research on how it grows. Matsutake's role within the larger ecology is also complex because it grows alongside hundreds, perhaps thousands, of other fungal species, so it would be incredibly difficult to disentangle the effects of matsutake in particular within a given ecosystem. Scientists have eliminated large mammals, such as deer, from a given landscape in order to study how their absence affects other animals and plants; but to date, no scientist has attempted to eliminate matsutake from a given site to see what hap-

pens to their coinhabitants. Such a task would be formidable, as matsutake exist as underground mycelia without fruiting in many places, so their presence is not easily detectable. Likewise, their underground growth is extensive and may run deep into the soil, so it would be very difficult, nearly impossible, to remove just this one species of fungus.[52] I hope, through future experiments and by intimately working with matsutake, we can better understand its specific engagements with other beings and how it shapes the larger forest ecology.

I have gathered what ecological knowledge I could find on matsutake, and by taking a lively, world-making approach, I have emphasized how they have shaped their own experience of life, as well as the lives of many others, including people, with whom they are in intimate relations. In the spirit of encounter, I became fascinated by how this one particular fungus, the matsutake, shapes its encounters with different groups of people. Toward that aim, I traveled to Southwest China, where I had previously spent nearly three years, to see how the two main groups of matsutake hunters have made their lives together with this mushroom and other beings. Together, fungal studies and anthropological fieldwork combined to make this book possible.

Chapter 1 provides an account of the history of planetary life, with fungi in the starring role, as told through the stories of fossils and molecular DNA. I ask, What role have fungi played in turning the blue planet into the green planet, and thereby in making this larger world? This chapter explores fungi as an entire kingdom to ask how, over deep time, fungi have shaped our planet, allowing life to leave the oceans to make a living on land. In so doing, they stopped the clock on the creation of fossil fuels and played a crucial role as mediators among water, rocks, and plants.

Chapter 2 explores the ways that fungi seek each other out, along with nutrients, water, and plants, and how they engage with insects and mammals. The chapter highlights the ways that even without direct human presence, fungi negotiate and build their own networks, and it explores the range of their often-surprising capacities.

Chapter 3 shows different ways that some Western scientists have tried to explore the inner worlds of various species. I introduce the reader

to the work of the polymath Jakob von Uexküll and consider his inspiring legacy in fostering curiosity about how different animals, including insects, perceive the world and draw meaning from it. The work of Uexküll and others has been critical to creating a lively approach to engaging with other beings as fellow perceivers and interpreters of the world.

In the second half of the book, I turn to the matsutake and explore how neighboring but culturally distinct ethnic groups draw this valuable mushroom into their lives in different ways. Chapter 4 tells the story of Japan's mushroom tragedy, when matsutake nearly disappeared, and how the Japanese turned to China and elsewhere to find new supplies of matsutake. I show how Southwest China became the world's largest source of matsutake, through geological events that made matsutake lives possible on the edge of the tropics. I also look at the daily actions of hundreds of thousands of matsutake hunters and dealers who bring the mushrooms by foot, bicycle, car, truck, and bus to airports, and then fly them to Japan.

Chapter 5 moves us into Yi villages, revealing how the matsutake economy does not take a single form, even among neighboring groups. I look at how the Yi people in China's Yunnan Province learned about Japan's desire for matsutake and articulated themselves into transnational markets. I explore how the Yi learned to attune themselves to matsutake's rhythms and ways of life, including its conditions of growth, and how they share the hunt for matsutake with a range of insects. Yi are making their own worlds, using the mushrooms to do so, yet the matsutake's own particular way of life shapes how the Yi build worlds around them.

Chapter 6 is about Tibetan mushroom hunters in Yunnan Province, for whom matsutake wealth has created an unprecedented reverse diaspora. A number of Tibetans who had fled to India are now returning, in part attracted by the thriving economy generated by matsutake, which includes a housing boom of "matsutake mansions" and a resurgence in the creation of Buddhist paintings and carvings. I explore how two of the most prominent species with which Tibetans in this region have entangled their lives—yaks and matsutake—converge and diverge in challenging ways. Yaks and mushrooms are not just pliable objects of human

projects or ambitions; they each have their own demands and desires, and the worlds they cocreate are shaped by these continual encounters.

In my conclusion, I offer some thoughts on the implications of taking a world-making approach. How, for example, might this mode of inquiry challenge some of the deeply embedded human exceptionalism that is structured within English and many other languages, as well as the field of biology?

Eventually, I learned that the vast majority of matsutake are never picked by humans: they quickly rise and fall above ground, attracting a wide variety of insects, birds, and mammals to their fruiting bodies. As well, below ground, they live their mycelial lives shuttling nutrients and water between trees and the realms of soil, minerals, and water; they spend the bulk of their time slowly traveling through subterranean depths over decades, perhaps centuries, helping to determine the kinds of trees and the forest ecology that they help produce. Even for those mushrooms that are picked by people, we can see how the Japanese demand for freshness—another term for alive and still breathing[53]—means that the mushroom's ways of life continue to exert a powerful force as a range of ethnic groups rush it from forests to markets.

By using a world-making perspective, we can understand matsutake as active beings that possess capacities of perception and action; the idea of world-making also allows us to explore how these organisms seek out and create networked relationships across different kingdoms of life. As a kingdom, the worlds of fungi may go far beyond our animal-centered imagination as well as our typical scientific assumptions. It is my hope that this project, which builds on the efforts of many others, plays some role in encouraging a shift in our understanding of how we live with other beings in complex and interdependent relations. To explore how a mushroom—typically seen as possessing no capacity for awareness or choice—interprets and acts in making a world can in turn open up a greater awareness of a lively planet, where humans are far from being the only actors that matter.

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