15 *Years of Harvard in Chile*

Lights on the South

Stories by Paula Molina

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CHAPTER 8
INVISIBLE LIVES IN THE DUSKY FOREST

Donald Pfister, Harvard Asa Gray Professor of Systematic Botany and Curator of the Farlow Herbarium, followed the path of a scientific expedition that 100 years ago arrived at the windy doors of the Strait of Magellan, and recognized there the microscopic diversity of a unique place, once connected to a lost land.

Our conversation takes place at the Farlow Library and Herbarium, surrounded by an international collection of more than a million specimens of fungi, algae, bryophytes and diatoms. The frail imprint of these specimens, descendants of some of the oldest organisms on the planet, is trapped here in samples, slides, drawings, manuscripts and field documents.

"My introduction into Chile, I guess, as a place to begin, and it was in a kind of odd way, I began reading the diary that had been given to us by the family of Roland Thaxter. He was a mycologist; he studied fungi. In fact, we're sitting here in this library, and this library is here because of his work establishing this institution."

The academic I am speaking to is Donald Pfister, Harvard Asa Gray Professor of Systematic Botany and Curator of the Farlow. He goes back to 1905 to begin the story that led him to Chile.

"I am a mycologist, I study fungi, and this collection here in Harvard specializes in literature and specimens of fungi, lichens, mosses and algae. I handle the specimens and study them, and I'm responsible for them as a steward of the collections. But when I first came here, to Harvard, I became very interested in one of the botanists who had been here, Roland Thaxter."

Born in Massachusetts, son of a lawyer and a poet, Thaxter was a distinguished botanist, mycologist and entomologist who "spent over forty faithful years in building up his beloved science of mycology," quoting the words written in his Biographical Memoir for the National Academy of Science. He was named full professor at Harvard in 1901 and, "for a man of a retiring nature, he received as many honors as usually come to famous botanists," the document continues. And so it was. At different points of his life, Thaxter was named President of the American Mycological Society, elected to the American Academy of Arts and Sciences and appointed foreign member of the Russian Mycological Society, among many other designations. Several fungi and lichens are named after him, as well as the genus Thaxteria.

Described as "an extensive traveler," Thaxter began one of his most audacious field works in 1905: a trip to Chile. He was inspired by the extraordinary scientific expedition of Charles Darwin, who visited Patagonia, Tierra del Fuego, and other parts of the South American country during his five years as the naturalist on board the British vessel "Beagle."

Pfister says that when Thaxter left for South America, "he was pretty much prepared for a year in the field. One of his specialties was to look at a particular group of fungi that occur on insects (laboulbeniales), and part of what he was doing was collecting these insects, looking for the fungi. He really started that whole field of investigation of these insect parasites. He was also kind of sent on a mission by William Gilson Farlow, founder of this institution, to collect seaweeds. So, he was ready."

He took the maritime route from North America to England and then across the Atlantic, "with stops in the Azores and so forth," details Pfister. He could have crossed Panama by rail, but he was afraid of smallpox. "He ended up in Buenos Aires, where he had contact with mycologist Carlos Spegazzini, who was kind of the reigning botanist of South America. Thaxter spent time there, mostly collecting insects and working with Spegazzini. He left on a steamship and went down the Atlantic coast to Punta Arenas."

Located on the northern edge of the Strait of Magellan, just 76 miles north of Cape Horn, Punta Arenas (roughly translated to "Sandy Point" in English) is one of the southernmost cities in Chile, South America and the world.

"He writes very wonderfully about the time he spent there," recalls Pfister, "He fell in love with Punta Arenas, in a way. He said it was the most productive time and the best place that he had been to in South America."

In his "Notes on Chilean fungi," published in 1910 in the Botanical Gazette, Thaxter writes: "During the months of February and March 1906, it was my good fortune to pass six weeks of the Antarctic summer and early autumn in the town of Punta Arenas, on the Straits of Magellan."

"These months being in many respects the most favorable for botanizing in this cold and wind-swept region," continues Thaxter, "I had an excellent opportunity to become acquainted with its fungus flora, which was much richer and more varied than might have been expected, in view of the comparatively scanty phanerogamic flora and the general severity of the climate."

"Freezing temperatures were not uncommon and it was not unusual in the morning to see the green beech forest on the hills to the west of the town loaded with snow. The small pools, in the localities where I collected, were often frozen over as late as the middle of the forenoon, while icicles might be seen hanging from flowers and grass growing on the dripping south slopes of the ravine which led to my usual collecting ground," Thaxter narrates.

It is the diversity of fungi blossoming under this harsh weather conditions what impressed the botanist at the beginning of the 20th century. "That a heavy forest of often very large trees should develop under such climatic conditions as having been described, is surprising; but that beneath its shade a considerable flora of the more fragile and perishable forms of fungi should develop, is even more difficult to understand."

It was reading these notes, more than a hundred years later, that Professor Pfister realized "this was a wonderful part of the world," as he describes. "I'd done fieldwork in other parts of South America, but not southern South America, and never Chile. But also, having reviewed and looked at this diary that is very, very highly detailed, I realized that there were fungi that

Thaxter collected that are right here in this collection here and that had never been fully studied. I began to dig those out and work through them, and realized that many of them were not even described."

Thaxter ended his trip abruptly in 1906 when he was called home. His oldest son was seriously ill. During his following years at Harvard, the professor focused back on his founding work on laboulbeniales, the order of fungi that grows on insects. His Chilean trip was the subject of a talk at the Botanical Society of America, which he presided in 1909, and the subject of his somewhat brief "Notes of Chilean fungi." At the time of his death in 1932, it was clear that "much of the material he collected" – notes Pfister – on South America, was still not thoroughly studied, as it is mentioned in his biographical memoir.

"Thaxter travelled to South America studying the fungi that he was particularly interested in, which were insect parasites," explains Donald Pfister. This also explains the time he spent in Buenos Aires, since; at that time the Italian born botanist Spegazzini was "the only other person in the whole world who was studying these specific fungi. "He kind of wanted to know what was going on," adds the professor.

During that same period, Harvard was also building up its fungi collection, so Thaxter also collected fungi in general. More than a century after later, Pfister noted with surprise that some of those still undescribed species were very rare. "I hadn't seen anything quite like them before: they were unique kinds of fungi for me to look at and experience."

Like Thaxter, Pfister headed south.

Beauty, mystery, discovery

"When we talk about fungi, we're talking about a kingdom, in the same way, that we talk about green plants on land, or animals running through the forest. This is a kingdom," asserts Professor Pfister.´

The fungi kingdom is still a mostly unknown scientific territory in which scientists enter hoping to find a tiny unexplored part of our world. And their options for finding something new are, indeed, very high.

"We haven't even done 10 percent of the work of describing fungal diversity," assures the professor. "We've described just about 85 to 90 thousand of these organisms, but the estimates about the number of fungi in the planet are derived from the number of plants and animals. We know more or less how many plants there are, and we have some estimates about how many animals there are. We have some idea about how many fungi there would be associated

with any one plant, and it's about a ratio of three fungi to one plant. So, if there are 350,000 vascular plants or plants, then three times that would give us some estimates of the total number of fungi".

"But we also know that there are more fungi associated with insects, fungi that are living on dead organic material...If you take these factors and put them together, the estimates are well over a million, a million and a half species of fungi in the world. So it means that there's the possibility to find something new everywhere, practically. And along our lives, even in an area like this, where there've been mycologists collecting in the field for a hundred and fifty years, or two hundred years, I can go out and begin to look carefully, and I can find things that nobody has identified or characterized."

Pfister remembers his earliest days as an undergraduate and the thrill of discovery when he collected his first specimen: "a beautiful bright red fungus, one of these cup fungi." He also remembers his disappointment when he saw it described in detail on a field guide. Pfister persisted, starting a 40-year career in mycology.

"Part of this intrigue is to know that you can go and study and look and that you, unlike me as an undergraduate, are going to go out and find something new and different. We are still in this really infant stage of development of the topic."

Discovery is one of the most attractive aspects of mycology. Beauty is another one. "I'm fascinated by these little organisms. I was always taken by how beautiful they are. Just the idea that you got these perfect productions in nature," he says.

By the late eighteenth century the first books dedicated exclusively to fungi began to appear. They were generally quite descriptive. "Many of them were beautifully illustrated because that was what you had: a picture of a mushroom and its color and its size and so forth," Pfister describes.

"By early in the eighteenth century we began to get lists and catalogs of fungi, and those were all kinds of studies of diversity, based on morphology and how would they look like. Very little was understood in many ways about the reproduction of fungi and how they developed. But by the mid-eighteenth century, people were beginning to gain understanding about spores and some things about reproduction. All of this, of course, was discovered without knowing about genetics or modern biology."

When Louis Pasteur ruled out the theory of spontaneous generation, the study of fungus moved into the laboratory, from growing fungus on plates to sequencing their genomes. "These days we continue those two lines: doing biodiversity studies and going out in the field. Collecting the organisms themselves and bringing them into the lab where we manipulate

them, extract their DNA and make sequence comparisons". There is discovery and beauty in the world of fungi. There is also, "a little bit of mystery," Pfister says. "One of the amazing things for me about fungi," he says, "is that one can go out into the forest and look and collect and develop a whole new set of eyes for the natural world. Sometimes you feel like one day the fungus is there and the next day it is gone. Or you thought you didn't see it yesterday and it's there today. And this makes them seem like they are almost mystical: they come, and they go. So, when you are in the field looking for fungi, it's almost like a treasure hunt. As you're out, looking, you're developing a way to see and perceive the world. And you don't know what to expect. When we go back to an area where someone has collected a fungus previously, you may say, 'well, what are the chances of finding it?' But when you do find something new, it's just a fantastic sense that you're connecting yourself with the history of a place."

In their sudden, sometimes unexpected appearance, it seems as if fungi, and life, came out of nowhere. "Spores are everywhere; even in the most unlikely spots you can find or isolate fungi. When I teach about plants, sometimes I reflect about when we were ancients, five hundred years ago or more, what a miracle a seed would be. This thing that you plant and get the whole plant. It's a miracle. All that's packaged in it, it's all there. We can describe it very technically now, but if you put yourself in this ancient mind of not knowing any biology in the technical sense, here it is, this little thing: it's going to be a plant. It's amazing. It's the same idea with fungi. We know that they produce spores, we know that we can take the spores, germinate them, we can grow them up in the lab, but think about these observations from the perspective of an untrained mind. This room is full of spores. If I put out a piece of bread on the table, it will grow fungi. We can explain how now, but if you let yourself go, it appears to be miraculous."

The importance of an earth tooth

Unlike Thaxter, who sailed weeks to get to Punta Arenas, professor Pfister traveled from Massachusetts to the southern Chilean city in just a couple of days. Still, he had the feeling of being in a remote, unique place.

"I tend to approach things in a kind of historical context as well as a biological one. The historical part of it is that you can't go there without thinking about those early ship passages and what it was like in those days. These days you can fly into Punta Arenas, and it's windy, or raining, or whatever it is, but it's not like coming in a ship. Back then, that was the only way you could get there, knowing that you were separated from the rest of the world by months. These days you're in contact, and you're able to do emails and phone calls, but, for me, the landscape is still so special."

Pfister describes the landscape around Punta Arenas. "Because of the geology, you got these

very dramatic peaks and valleys. You got glaciers, ice, and snow and the windswept trees that are so characteristic of that part of the world. There's a kind of immediacy about the place. You feel the weather; you see the effects of climate on the landscape; you are connected to it in a certain way."

Charles Darwin wrote about "the dusky forest" around Punta Arenas. Elizabeth Agassiz, naturalist, educator and founder of Radcliffe College, traveled with her husband – geologist Louis Agassiz – from the Caribbean to the end tip of South America. In 1872, she wrote about leaving Punta Arenas, after staying several days: "It is the only settlement in the Strait of Magellan, and lies midway between the Atlantic and Pacific Oceans. Its position marks a sudden and decided change in the general aspect of the region, the shores in the eastern portion of the straits being open and low, and the passages between them wide as compared with those of the western portion. I like to remember that afternoon. To me it was full of vague anticipation, for we were on the threshold of the region where we had been taught to believe, mountains rise sharply up from narrow ocean channels, and glaciers dip into the sea; where the scenery at once delights and stimulates the imagination, suggesting more than it reveals. The weather was beautiful, a mellow autumn day with a reminiscence of summer in its genial warmth. The cleft summit of Mount Sarmiento was clear against the sky, and its snowfields swept over by alternate light and shadow, seemed full of soft undulations. Cloven peaks are, by the way, a common feature of mountains in the Strait of Magellan, as we afterward found."

Thaxter writes a lot about the environmental degradation that had been going on in the area, a century ago, a consequence of ranching and sheep raising. "Many of the forests were cut and burnt. The landscape was quite desolate. The forests were gone. Today around Punta Arenas, there is a lot of open pasture land where you can see the trunks of trees. And I think many of those tree trunks were probably there when Thaxter was here, a hundred years before," says Pfister.

Pfister arrived in Punta Arenas as leader of a trip organized by the Harvard Alumni Association and the Museum of Natural History. The trajectory of the trip was a lake crossing, from the Chilean city of Puerto Montt to Bariloche, in Argentina, and also included a visit to Punta Arenas. In the same year, Pfister got funding to make several trips to some of the localities were Thaxter had collected specimens. He worked in collaboration with Matthew Smith, a postdoctoral fellow at Harvard at that time. The primary areas for collecting were southern and central Chile. Pfister and Smith determined the locations, seasonality and plant associates of some of the species gathered by Thaxter.

"The primary locations where we recollected were Punta Arenas, the lakes region of Chile and around the Osorno town and the volcano. We were able to go back and look at some of these areas where Thaxter had collected fungi and, much to my surprise, we were able to, a hundred years later, go back to some of these locations and find some of these undescribed,

elusive fungi that he had collected. That was unusual for us because many of these areas have been highly disturbed, the trees cut and so forth, but we were back to areas that have been more or less restored or that were coming back after a lot of land use changes."

Smith – now curator of the Fungal Herbarium at the University of Florida – accompanied Pfister on two trips to Chile. "Matt was very interested in looking at the fungi that grow on the roots of trees, and there, the southern beech also known as the Nothofagus tree."

In 1850, the name Nothofagus was coined from two Greek terms: nothus, meaning 'false,' and fagus, meaning 'edible,' referred to the beech of the tree. More than 30 species of trees and shrubs are part of the Nothofagus group, including Chilean coihues, lengas, ñirres and raulíes, which cover the hills toward the snow lines in the Andes Mountains. They were a natural resource in the early days of settlement in Chile and were used for building and fuel.

"The Nothofagus forest can be large and impressive as you walk through it, very park-like. The trees give a wonderful appearance to the landscape, and Darwin, when he was on the voyage of the Beagle, described it as the dusky forest, because they are kind of a gray-green," Pfister details.

There is something more about Nothofagus. In 1873, the English Naturalist Joseph Dalton Hooker, who sailed from Tasmania to Tierra del Fuego on board of one of the last great scientific expeditions of the nineteenth century, raised the idea that the similarity between the flora of the different continents in the Southern Hemisphere was proof of their common origin.

"There is this idea that there was a big continent, Gondwana, a land that broke apart. South America, Australia and Antarctica were part of the southern part of that land," explains Pfister. "Today, Nothofagus only occur in South America, Australia, New Zealand and New Guinea. But if we go back and look at fossil records, we can find fossil pollen of Nothofagus in Antarctica, and this has to do with the geological history of the Southern Hemisphere."

Fungi like the ones Thaxter collected in Chile could tell part of the history of this gigantic, ancient mass of land.

"In his three months in Punta Arenas, Thaxter went out into the field almost every day. He collected fungi and insects with their parasites, algae. But in the Nothofagus forest, he saw something that looked like a tooth coming from the ground. He had no idea what it was, but he gave it the nickname of Geodon, or 'earth tooth.'"

The Geodon, described in 1979 as underwoodia singeri, is a mycorrhizal fungus, which means it lives in a symbiotic relationship with the tree.

"As many woody plants, Nothofagus has this biological feature that is mycorrhizal. But the fungi that are with the Nothofagus also have a similar Southern Hemisphere distribution. So, about this Geodon, there are two species in southern South America, and there are at least two, I think, in Australia of the same genus of fungus and in the same association with Nothofagus. In doing these studies, part of what you're thinking about is what is the bigger implication. The bigger implication here is that we are looking now at this southern breech broad distribution in the Southern Hemisphere and thinking about what it is, how did this get established, how are they perpetuated. What can it tell us about the evolution of the organisms over time in these distinctive habitats and what can it tell us about this distribution of these? Did they ride the continents or did they get distributed through the air or the sea? We are still working on the similarities of the flora and then asking these questions about it."

"Chile is so long and so narrow, it's pushed against the sea and the mountains. This causes a tremendous variation in climate and vegetation patterns, and so, when one began to look at this and think about the organisms that are there, it's a tremendous range of different kinds of habitat that the fungi can inhabit."

"When I talk about the Nothofagus, they're mostly found in central and south Chile, and that's primarily where we worked. The big similarities that we found in southern Chile with fungi are that their closest relatives are likely to be in Australia and New Zealand. And it has to do with the geology of the earth. These continents we look at now were once connected, and the vegetation, the animals, the plants have an origin in the supercontinent of Gondwana, which later began to break apart. Pangea was the big continent, the southern part of that was Gondwana, which included South America, Australia, South Africa and Antarctica. When we look at the distribution of some of the plants, we can reconstruct those distributions by looking, in the case of Nothofagus, at the pollen record. And we can see distinctive types of pollen throughout the deposits across these continents. We know that Antarctica at one point had Nothofagus growing on its lands. In different positions, different areas, but certainly Nothofagus species existed. And this connection that we see is an ancient connection that existed because of the proximity of these continents at one time."

Pfister found new, undescribed species in his trips to Chile, which he recognizes as a unique spot, not only because of its natural conditions. "Chile is the only country in the world that has legislation that includes fungi in looking at and trying to evaluate a site for development or construction. So, in many parts of the world, plants are considered, but fungi have never been considered along with these environmental parameters for development." He mentions the work of Chilean Giuliana Furci, from the Fungi Foundation, as the spirit behind this legislation. "It's a very special thing so far as conservation of fungi goes. And Chile is way far ahead of any other part of the world in doing this."

"Chileans connect to fungi in a particular way," says Pfister. "They have stories with them."

"Whether it's at a park or a restaurant or in the street when I tell people that I'm interested in studying fungi, they'll have a story about some fungus they ate, or they'll have a question about what's that fungus on the tree over there. My impression has been that Chileans are very much connected with the natural world around them, and that they have a curiosity about that world and fungi specifically. There is also a culture in southern Chile of using the fungal products. If I mention a cyttaria darwinii, fungi that forms a golf ball-like structure on the trees, the fruiting bodies are eaten and traditionally they're used in a fermented beverage. But also the wood from the tree which is deformed by the fungi is used to make furniture or bowls or other items."

This close relation to fungi is not always a constructive one. A cup fungi species, morels, are not only eaten, but also exported from Chile. "Morels are a good example of some issues in Chile about fungi and fungal harvest. These are important fungi for commerce. They're collected many times dried and sent overseas, and so forth. But the morels are thought to fruit much more frequently when there's been a burn, and one of the things that are problematic is that, because of their economic importance, there's a motivation to find the places where this occurred or to make the place more fruitful by burning the forest. This is one of the big conservation issues in southern Chile, and particularly the damage done to forests through mushroom collecting."

Fungi are vulnerable. Mycorrhizal fungi can only live if a Nothofagus tree is present. If forests are destroyed, and lands are converted to grassland, these fungi lose their environment.

"In this case, there were obviously fragments and pieces of the forest that survived and in some cases, increased after a period, so they hang on in habitats that were left and presumably extended into other habitats. But many fungi are very vulnerable to environmental change. If we think about good environmental indicators that involve fungi, it's all in the lichen. Lichen is a combination of algae and fungi, and many have been used in environmental studies to judge air quality. If you want to preserve something, you have to see them."

"Fungi fit into ecosystem balance in a couple of different ways. One way is that they are critical to nutrient cycling, because saprophytes break down organic material in ecosystems, releasing nutrients that support new growth. Another way is this idea of mycorrhizal fungi and the connection they have with plants that enhances the roots of the plant. And for good primary production, you need to have this fungus present, and you need the fungi in the nutrient cycle. It would be an odd ecosystem if you don't to have fungi."

At the southern end of the American continent, facing Antarctica, fungi grow. Pfister thinks about Chile's next steps, like building a scientific infrastructure that goes along with this legislation that protects and conserves the unique fungi on its territory. His trips and experiences in Chile give him hope.

"We think about this changing world and changing environment and so forth, but the fact that we could go back a hundred years later, to some of the same places and see what Thaxter saw a century ago, it's something quite remarkable. You know that a lot of things have happened in this part of the world, but one can still go and see things as they once were."