"Mushrooms in brine, for winter eating...."

– A. S. Pushkin, Eugene Onegin

What does it MEAN?

Fungi at the Boundaries of Science, Politics, and Nationality

by Kem Luther

Figure 1. A Southern Vancouver Island forest scene

Yesterday's rain came down in heavy bursts, ending one of the driest summers in the records of southern Vancouver Island. This morning I have hiked into a coastal forest a few kilometers from my rural home.

On the way to the top of the hill I push through bushes laden with the bounty of late summer: salal berries, huckleberries, blackberries. Red-breasted nuthatches, recently come down from their inland nesting areas, make the woods ring with their nasal taunts. Near the top of the hill I plop down on a bed of tree moss and lean back against the fallen bole of a forest giant.

The scene in front of me is dominated by a stand of Douglas-fir. What I'm looking for in the forest today is the intersection between two kingdoms. One of these kingdoms, Kingdom Plantae, is represented by the trees. The second one, Kingdom Fungi, is seen mostly by its effects. Of the two kingdoms, the fungi have received the short end of the attention stick. Just a century ago the fungi were viewed as peculiar sorts of plants. If they were covered at all in biology curriculums, they were relegated to small, week-long sections of botany courses. With the revolution in plant systematics that began in the second half of the twentieth century, the fungi were moved into their own kingdom, one parallel to the plants and animals and bacteria. As a kingdom, fungi are closer, say biochemists, to the animals than to the plants–the cell walls of fungi contain chitin rather than cellulose, the same chitin that stiffens the exoskeletons of insects. But making a separate nomenclatural kingdom out of the fungi, which range from single-celled creatures such as yeasts and some of the chytrids, to medium-complexity organisms such as molds, to the more differentiated macrofungi that we call mushrooms, has not raised them far above the obscurity imposed by centuries of neglect. My view of the scene in front of me this morning is still largely phytocentric, focused on members of the plant kingdom.

A more mycocentric view would make the fungi full partners with the plants and animals in this ecosystem. A month from now mushrooms will begin to dot the ground between the trunks of this copse and the fungi will be more front and center than they are today. The mushrooms, though, are just the fruiting bodies[1] of the higher fungi. The real fungus is a matrix of invisible threads called "hyphae." I'm sitting on a pillow of these invisible hyphae now. The pillow extends several feet below me, perhaps down to the granite that forms the base of this hill. I play a mental game, subtracting the minerals and plants and bacteria and thinking about what I would see if the fungi became as real to my eyes as they are to my thoughts. A gossamer, polychrome world fills my imagination. The outlines of the trees are still there, sketched in lines so fine that I cannot focus on the edges. Between me and the rock below are the channels in the fuzzy hyphal matrix that are occupied by plant roots. A pointillist haze of fine dust, fungal spores waiting their chance to bud and grow, fills the spaces between the hyphae.

We can think about the plants and the fungi as two large systems of regularity. Because these systems have their own rules, they can be studied in isolation. Plant biologists can ramble on for a long time and not mention fungi. Mycology textbooks sometimes give short shrift to vascular plants. But since the roots of the plants occupy the same region as the fungi and interact with them, somewhere we must have a boundary layer, a place where the regularities of these large systems chafe against each other, a place of flux where the rules change.

The best place to begin looking for the boundary layer between plants and fungi is in the symbiotic associations between members of the two kingdoms. During the hundreds of millions of years they have evolved together, plants and fungi have set up deep partnerships. The one that most people seem to be aware of is the one that assigns fungi the role of saprophytes[2]. Fungal hyphae decompose dead plants and animals and extract energy and nutrients from this dead matter to carry on their lives. As partnerships go, saprophytism is less than intimate. The plant has to die before the fungus can digest it. Plants and fungi are partners in this relationship in the same way that a legator and legatee are joined by an economic bond. To the fungal rotters, trees are rich, unknown uncles that leave them a fortune in energy and nutrients when they die.

As significant as saprophytism is in the story of plant and fungal partnerships, it is far from being the whole story. Many of the fungi maintain a closer symbiosis with the plants around them. We can see the footprints of this symbiosis by following the trail of solar energy. Almost all vascular plants get the energy they need to live and grow directly from the sun. Their cells contain light-absorbing compounds such as chlorophyll that are able to split hydrogen atoms from water molecules and join this hydrogen with carbon dioxide to cook up the sugars and other carbon compounds that are the basic building blocks of plants. Fungi, which do not have the ability to turn sunlight into energy and building materials, connect with the roots of vascular plants and tap into the plants' supply of carbon. The plants that live in symbiosis with fungal partners, it turns out, are generous with their carbon, tithing and even double-tithing their net production to support their associates. In return for this treasure of energy and building materials the symbiotic fungi enlarge the rhizospheres of the plants, exposing the plants to sources of water and nutrients they could never reach on their own. Suzanne Simard at the University of British Columbia has calculated that fungi expand the surface area of some root systems sixty-fold. The minute fungal hyphae, wedging into spaces too small for root hairs to reach, shuffle a steady supply of water and nutrients–phosphorus and nitrogen in particular–to the host plant. To acquire these valuable goods, enzymes in the fungal hyphae plunder the biological deposits of the nutrients in the duff and soil. Fungi can even use hydraulic action and acids to break down the soil's composite minerals. In their relentless search for nutrients, some fungi have resorted to predation. A soil ecologist discovered in 2001 that springtails, which often feed on fungi, dropped dead when they fed on *Laccaria bicolor,* a companion of local conifers. The *Laccaria* mycelium absorbed the nitrogen from the dead insects and passed it along to the conifers.

We have, then, two large, stable systems of life, the vascular plants and the fungi, rubbing against each other. Between them is a no man's land, a boundary layer where the rules of life as a vascular plant and the rules of fungal existence reach a compromise. I lean over and turn up a patch of ground next to me. Yesterday's heavy rain has not penetrated far–I'm soon clawing through a lace of dry roots. I pull up a clump of soil and focus a hand lens on it. Here are the telltale signs of the boundary layer: blunt lateral plant rootlets covered with what looks like tightly-wound gauze bandages. I put my nose into the hole I have dug. The smells of mold and mushroom fill my senses.

Over 90% of vascular plant species, we now know, live in symbiosis with mycorrhizal ("mushroom/root") fungi. In the forest before me there are two important types of mycorrhizal relationships. The oldest of these connections between host plants and fungi are the ones that mycologists call "arbuscular mycorrhizas" (AMs), named for arbuscules, the tree-like branchings of the fungal hyphae inside the root cells of the plant. Spores that are typical of AM fungi appear in Silurian

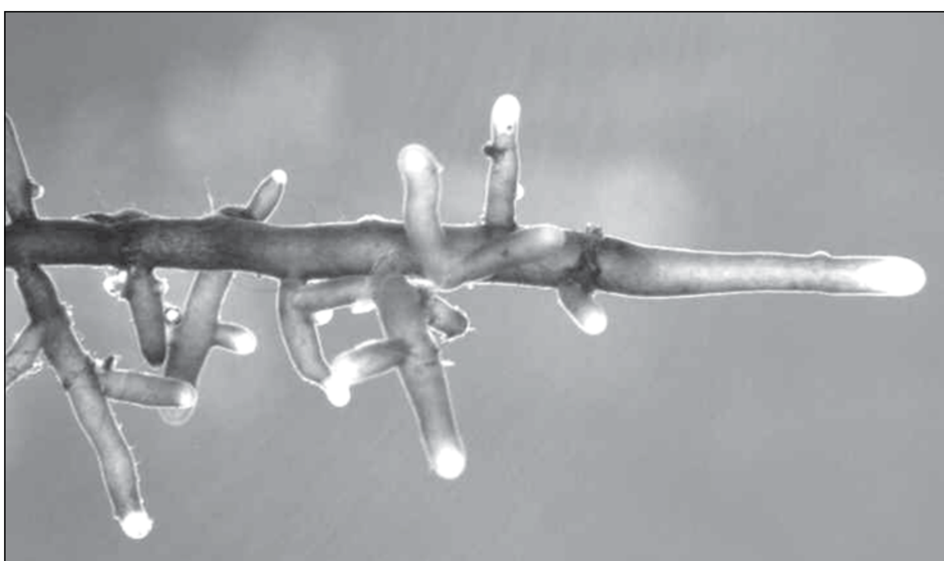

Figure 2. Fungal mantles on the root tip and lateral roots of a western hemlock. Photograph by Marty Kranabetter

fossils laid down 440 million years ago. Could a fungal association have enabled photosynthetic water plants to make their first steps onto the soil-free land? The lichenized fungus eking a living off a bare rock near me suggests the idea has some merit. I don't see any vascular plants nibbling on the stone.

For the most part the primitive AM fungi, because they reproduce asexually and do not form fruiting bodies, pass unnoticed to all but botanists and mycologists. They are, however, extremely common: two thirds of all known species of land plants accept AM symbiosis with a member of this phylum. It may be that all land plants have the genetic disposition to form a partnership with AM fungi. The species of plants that don't allow AM connections may have rejected, somewhere in their evolutionary careers, the deep code of this symbiosis.

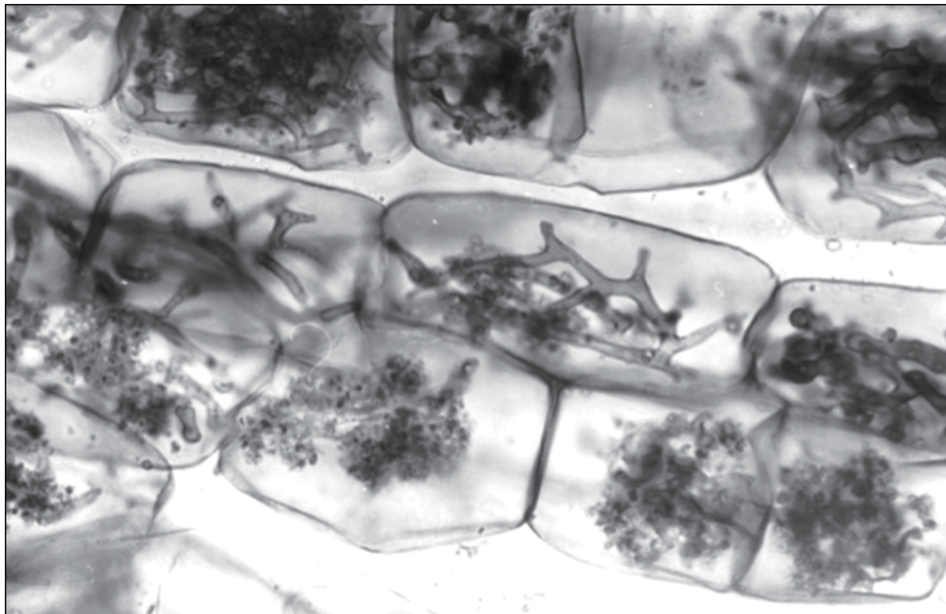

Figure 3. The hyphal coils and arbuscules of an arbuscular mycorrhiza in the cells of a ginseng root.

AM fungi can colonize new plants with phenomenal speed. Transplant a new seedling into a location inhabited by the right fungus, and hyphae several centimeters away will immediately start to grow toward it. Within two days of contact the AM fungus will form its first structures on the exterior wall of the plant's root. In less than two weeks after contact the new plant will be colonized and fungal arbuscules will have taken up residence inside the root cells, turning the AM fungus and its host plant into an almost indissoluble organic unit.

AMs are the mycorrhizas of agricultural plants and species-rich ecosystems. A typical AM event would involve a crop growing on lush prairie soil or a fast-growing tree in the tropics. When we think of the mycorrhizal associations of plants in the Pacific Northwest, the ones we call "ectomycorrhizas" (EMs)[3] command more attention. EM associations are much more recent than their AM counterparts. EMs may have arisen in the early Carboniferous, a mere 130 million years ago. Fewer than 5% of plant species form EM connections, but their importance is multiplied by the type of plants and the amount of the earth's surface occupied by these plants. Trees in the pine, oak/beech, birch/alder and willow families—the kinds of trees that predominate in the Pacific Northwest—seem to prefer EM connections over the more common AM partnerships.

To the biologist, three features signal an EM colonized plant. The first is a mantle, a sheath of hyphae, around sections of the plant root. These are the gauze bandages I saw on the root tips that I pulled from the soil. In some cases EM fungi envelop almost all of the root tips of the trees that are their symbiotic partners, replacing the root hairs the plants would employ in the absence of fungal liaisons. The second feature of an EM colonized plant is something botanists call a "Hartig net," an extension of the fungus into areas between the cell walls of the root. To see this net we need to look at a thin section of the root under a compound microscope. The third feature of EM colonized plants is a network of hyphae that extends from the mantles into the soil around the roots. A single kilogram of soil from a forest like this may contain 200 kilometers of fungal strands.

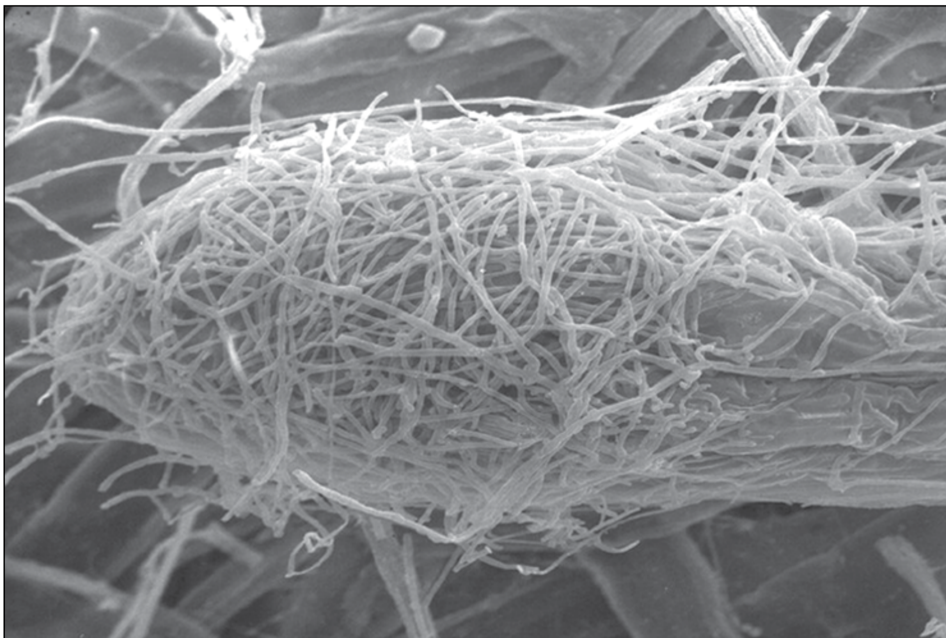

Figure 4. A scanning electron microscope image of an alder root tip that has been colonized by poison pax, an EM mushroom. The picture shows the mantle and some of the hyphae reaching out into the surrounding soil.

Even when we haven't got the laboratory equipment we need to detect the three main features of EM colonization, we can still be fairly certain, for at least two or three months of each year, that we are in the presence of EM connections. The fungi that make EM connections produce many of our most familiar mushrooms. When we happen on boletes, corts, chanterelles, fiberheads, hedgehogs, russulas, trichs, and amanitas growing around our local trees and bushes, chances are good that the fungi have EM associations with nearby plants. Over its geographic range a given species of tree may cohabit with thousands of fungal species, and a single tree, botanists have found, can support ten or more different EM associations at the same time. The Douglas-firs in the forest around me are especially promiscuous when it comes to choosing fungal partners.

Thinking about host plants and their EM or AM fungi as a single unit is a revolutionary idea. But research over the last twenty-five years hints at an even more radical concept. We know that a given mycorrhizal fungus may colonize several plants in the same area, even plants of different species. We have also discovered that the hyphae of compatible mycorrhizas readily fuse into a single, interconnected mesh. These complex meshes that connect several plants into a nutrient network are called "common mycorrhizal networks" (CMNs). Radioactive tagging demonstrates carbon compounds from one photosynthesizing plant are shunted along the interconnected hyphal strands of a CMN. The carbon made by one tree can end up in the root systems, and even in the shoots, of another plant.

We can see evidence of ectomycorrhizal CMNs in our Vancouver Island forests. When a tree that is part of a CMN is cut off a meter above the root, it doesn't always die. It can persist as a living stump, begging crumbs of sugars and nutrients from the fungal mesh it once supported. Other clues to the presence of CMNs are the herbaceous plants that do not make their own chlorophyll. Several varieties of local plants–indian pipe, pinesap, and the various coralroot orchids–are not, as we once believed, saprophytes living off the decaying duff of the forest floor. Their roots form mycorrhizal partnerships with russulas and other fungi that are part of CMNs. The carbon and nutrients these plants require are derived from their CMN partners.

The existence of CMNs is one of those paradigm-busting ideas that threaten to overturn the way we think about the natural world. When a forest ecologist told the late Donella Meadows, one of the authors of *Limits to Growth* and the founder of the Sustainability Institute, about CMNs, the revelation stopped her in her tracks. "The trees pass stuff around?" she asked, "What does that MEAN?"

We have only begun to put an answer to Meadows's question. At a minimum, CMNs threaten to overturn our notions of evolutionary competition, ecological dynamics, and forest management. But the study of CMNs may carry us much further in coming decades. The rules for a new understanding of forest systems, such as the one I'm in now, are not found in the ancient habits of vascular plants or fungi. They are coded in the boundary layer where the two come together.

I think of this new perspective as a mycocentric one because the invisible fungi of these forests have not received the attention they deserve. But reaching a balance in our appreciation of these two kingdoms will just be a beginning, taking us to a place where we see the outlines of a larger picture that is neither phytocentric nor mycocentric. It is

Figure 5. Two living stumps of Douglas fir enjoy the meals provided by a neighboring tree through a common mycorrhizal network.

the *partnership* between the EM fungi and the vascular plants that manages a significant part of the forest budget, sharing out the limited resources, deciding who thrives and who dies. To really comprehend what is going on we will have to shift to a view that sees the forest and not just the trees, a view that sees the vascular plants and mycorrhizal fungi as a single organic entity.

I lever myself from my seat of moss and shift my weight to legs gone stiff from the long sit. In a month or so the fungi will put out their mushrooms and we will have a better sense of the partnerships that make this forest work.

The mushroom perched on a bed of moss is soggy from a week of steady November rain. A third of it has been eaten by slugs. I dig it up and peer under the cap. The violet and brown gills hint that it might be a cort, but the cortina ring, the remnant of a diaphanous veil usually plastered against the upper stem, is faint. What else could it be? A blewit? I pass the gills under my nose. They lack the fruity smell of blewit gills. Definitely a cort, I decide, the first large cort we have seen this morning.

Oluna is down the hill, twenty paces away. I wade through a dense patch of Oregon grape and show her the mushroom. She takes it from me and turns it over once, twice in her hands. "Yes," she says, "a cortinarius," the middle syllable of the word taking on the open "ar" sound of her native Czech. I wait for an explanation, expecting a Socratic tutorial showing what I should have noticed about the mushroom and revealing, at the end of a chain of iron logic, the name of the species. She is patient with my poor memory and generous with her lessons, but I have to wonder: does she really imagine that my brain could be trained to work like hers? Oluna knows mushrooms the way a pathologist knows diseases–in a few seconds her mind makes and rejects more hypotheses than I could conjure in an hour. This time, though, I don't see the wry smile that precedes one of her tutorials. The specimen I've handed her, either because of its rarity or because it is damaged, defies field identification. To decide which of the thousand species of cortinarius I have found, Oluna will need a microscope, some chemical reagents, and access to specialized monographs. She may even have to send part of the mushroom away for DNA analysis. For every hour Oluna spends in the field collecting specimens she spends another three hours in her lab dissecting, drying, and sketching the samples. She sighs and fishes in her bag for a piece of wax paper to wrap the mushroom.

The botanist Hans Roemer and I have joined Adolf and Oluna Ceska to sniff out mushrooms today on the south face of Victoria's Observatory Hill. Oluna has been doing fungal surveys on the hill for the last five years. The seventy-odd hectares of this enclave of ravines, rock balds, creek beds, and Douglas fir forest is a government property managed by the Herzberg Institute of Astrophysics. At the top of the 200-meter hill are a pair of telescopes, one of which was, for a few brief months in the early part of the twentieth century, the largest telescope in the world. The telescopes are still used, though these days the library, dorms, meeting rooms, and public education displays surrounding the observatories attract more people than the instruments themselves. The buildings on these grounds are one type of development that botanists do not object to. The presence on this hill of one science–astronomy–opens a door to other sciences. The mantle of federal protection with its restrictions on commercial development makes Observatory Hill an important locale for researching the natural systems of southern Vancouver Island. Hans and other botanists have studied the vascular plants on the property. Adolf and Oluna know they can return year after year to study the mushrooms here without worrying about armies of backhoes ripping up the beds of fungal hyphae.

Oluna's surveys of Observatory Hill have turned up more than 1000 different species of mushroom. Her study is one of only a handful of long-term, science-based inventories of the mushrooms at a single site. One conclusion that has emerged from these long-term studies is that short-term inventories are misleading. In a five-year study a third or more of the mushroom recorded in a given year will be sightings not found in any other year. What triggers the dormancy cycles of the fruiting bodies and spores is not well known. Oluna has been able to find some correlation between mycorrhizal mushrooms and moisture patterns, but much mystery remains. Because of these sighting inconsistencies, no one knows the real extent of the genetic treasure that presses back against my steps today. To make estimates of the number of fungal species, botanists use a six-to-one rule: for every vascular plant species, they say, we should expect about six fungal species. Hans tells me that Observatory Hill hosts about two hundred species of vascular plants. If the rule holds, Oluna's site inventory may one day put names to about 1200 species of mushrooms.

Figure 6. Oluna Ceska on a Vancouver Island mushroom foray.

I met Adolf and Oluna about the time they began their Observatory Hill study, when I showed up at a meeting of the local mushroom club. Mushroom clubs are meeting places for people with many different agendas. A number of the members will be people who like to eat wild mushrooms. Others will enjoy photographing mushrooms. Some, especially those with field naturalist backgrounds, will have an interest in identifying mushrooms. It didn't take long, after I joined the Victoria club, to find out that we had more than a half dozen members who could put a name to most of the local mushrooms. Adolf and Oluna, though, were in a class by themselves, the experts to whom the other club experts deferred. Any foray that mentioned their names would attract dozens of people. Oluna's passion for learning more about mushrooms and her willingness to share what she knows seems to draw others to her.

While people on forays crowd around Oluna and ply her with questions, Adolf and I often wander ahead of the groups to scout out some of the less common mushrooms. Sometimes the discussions that Adolf and I have on these reconnaissance trips wander away from fungal topics. We talk about the experiences that have brought us to where we are. Even today, with just the four of us, Adolf and I seem to need breaks from foraging that Oluna and Hans do not. Adolf tells me that he and Oluna came to British Columbia in 1969, slipping between the fingers of the Communist regime that re-established control over Czechoslovakia in the wake of Alexander Dubcek's brief stint as leader of a reformist government. Adolf grew up in a Czech home that was politically incorrect. He also had limited access to the secondary school system. By the early 1960s, however, he and Oluna met and married - both having completed the equivalent of a master's degree at Prague's Charles University, Adolf working on vegetation ecology and Oluna on fungi. Oluna took a job as a laboratory scientist for a Czech corporation and Adolf started work on his doctorate in plant ecology. About this time a biologist on sabbatical from the University of Victoria showed up in Prague. The biologist was on the lookout for students who could be drawn into research circles in British Columbia. He snagged Hans Roemer on that trip and later sent a request to the Botanical Institute of Czechoslovak Academy of Sciences that ended up in Adolf's hands. Adolf and Oluna negotiated a two-year stay at the University of Victoria, but the euphoria of the short Prague Spring persuaded them to delay the trip. The delay nearly cancelled their trip. They boarded their flight to Canada a month before the Russian-controlled government sealed the borders.

The Ceska's connections with their homeland began to unravel once they arrived in Canada. At the end of their second year in British Columbia they applied to the Czech government for an extension into a third year. Their request was denied. When their visas expired, they were faced with choices that seemed to have only disadvantages. They had not made financial arrangements to stay in Canada for an extended period. But an immediate return to Czechoslovakia also had drawbacks–conditions in their homeland seemed increasingly inhospitable. They pondered the problem, wrote letters, took counsel. Finally they decided to stay in Canada, even though it forced them into the limbo of illegal immigrancy. Their failure to return earned them, as they feared, sentences to prison terms in Czechoslovakia. Canada, in the meantime, took no immediate action to deport them, and after a few years they were able to apply for Canadian citizenship under a round of amnesty provisions.

Adolf had little hope of finishing the degree he had started at the Botanical Institute. Soon after they arrived in Canada, Oluna accepted employment as a research associate with the University of Victoria, a job she would keep for the next twenty-five years. Using Oluna's small salary as their financial base, Adolf started on another Ph. D. program at the University of Victoria. After completing his degree in 1978, he continued studying the wetland vascular plants he had researched for his doctoral thesis, taking on private contracts to do vegetation surveys. In 1981 he accepted a position at the Royal BC Museum as Curator of Botany. Field trips that Adolf made in his new job would add 35,000 specimens to the museum's herbarium and he would author and review a large number of chapters for provincial botany publications. In the last years before his nominal retirement he moved over to the BC Ministry of the Environment. At the Ministry he focused on inventories of rare Vancouver Island plants.

Oluna, meanwhile, was pulled away from her initial interest in fungi by the demands of her research job. She studied chemical compounds and metabolic pathways in agricultural plants and authored a series of journal articles on taste-and smell-producing molecules. She also honed her skills as a botanical illustrator. In her spare time Oluna

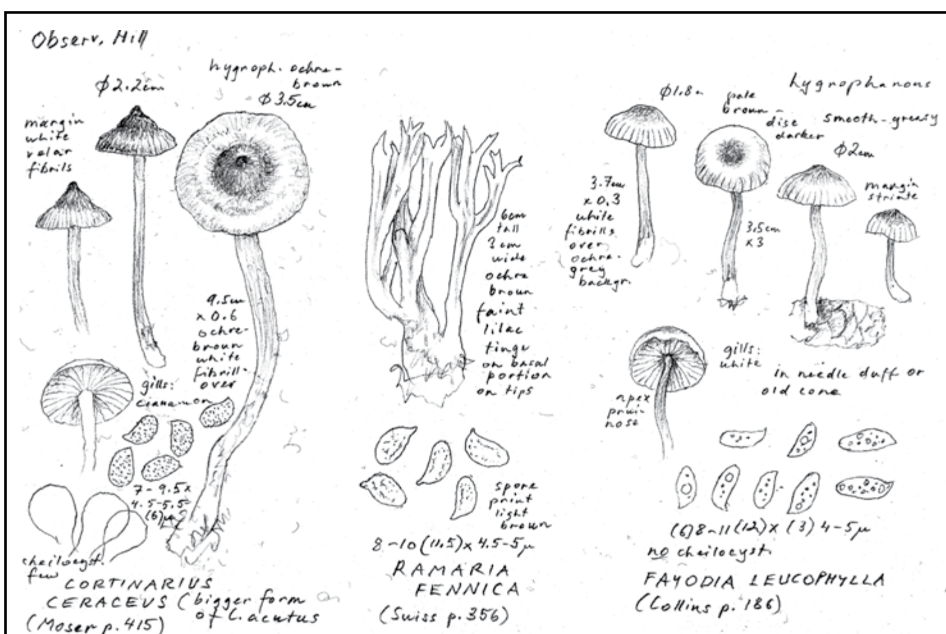

Figure 7. A page from Oluna Ceska's Observatory Hill sketchbook.

helped Adolf with his expanding work on vascular plants. Only in the mid 1990s was she able to pick up the threads of her earlier work on fungi. When Adolf retired, he found his own interests wandering to the fungal associates of the vascular plants that had occupied so much of his professional life. This time Oluna took the research lead and Adolf became her assistant.

In the 1990s, with the fall of the communist regimes in Eastern Europe and the emergence of the new Czech Republic, Adolf and Oluna returned to visit family and friends they had left behind in the 1960s. They were finally able to look at the files accumulated during the legal proceedings leading to their prison sentences. Like many who had fled Iron Curtain countries in the postwar decades, they found accusations in their files from family members and from people they had known as friends in their earlier life.

Adolf and I rejoin Hans and Oluna to work the upper part of the slope. At lunchtime the four of us turn and head down the hill to the pull-off where we left our cars. Oluna's list for the day notes about a hundred species of mushrooms. Samples of about half of them are in her collection bag. She's well on the way to breaking the hundred new species mark for the sixth year in a row.

Hans Roemer and the Ceskas have more in common than their professional interests. They are also united by a shared history. The three of them were recruited to come to Canada by the same botanist. They have, Adolf claims, a family connection–Hans and a husband of one of Adolf's cousins both descend from a Melchior Roemer who died of plague during the Thirty Years War. Listening to their accented English reminds me there is a third way their histories intertwine. Both Hans and the Ceskas bring a continental perspective to their work in botany and mycology.

To learn more about this continental European perspective, I've arranged to meet Adolf, Oluna, and Hans at the My-Chosen Café, a restaurant in Metchosin, the small community where I live. The café, frequented by visitors from nearby Victoria, is usually crowded. On this rainy December afternoon most of the dining rooms are empty. I nab a table beside an open fireplace. By the time Hans, Oluna, and Adolf show up, my damp clothes are steaming.

Adolf has explained on our forays how he and Oluna ended up in Canada, but I don't know much about Hans. While we wait for the staff to take our order, I ask Hans how he came to leave his native Germany. His move to Canada, he says, was a direct result of the way Europeans did plant ecology. He studied landscape ecology at the Technical University of Hanover where one of his teachers was Reinhold Tüxen. Tüxen had been one of the earliest students of Josias Braun-Blanquet, the founder of the European discipline of plant sociology. Hans became familiar with the methods and techniques of the Braun-Blanquet school while working at Tüxen's private research institute during university breaks. One of the international visitors to this institute, Marc Bell of the University of Victoria, arrived with the offer of a research assistantship for a European student who could bring to Canada the botanical skill taught in the European schools. Hans finished his master's degree at Hanover and moved to Victoria to do a Ph.D. in plant ecology. At the end of his degree Hans, wanting to continue his research on North American ecological issues, stayed on in Canada.

The Braun-Blanquet school that Hans is talking about is not a splinter movement. By the middle of the twentieth century the school had become the dominant force in European plant ecology. Comparisons have been made between the significance of Braun-Blanquet's work and the revolutions in botany triggered by Darwin and Linnaeus. But the earthquake that shook and confused the botanical landscape of Europe didn't rattle the whole globe. While the Europeans were busy uniting around the ideas laid out in Braun-Blanquet's 1928 *Pflanzensoziologie* (published in English as *Plant Sociology* in 1932), North American botanists were exploring alternate frameworks for the study of plant communities. It's easy to see, in hindsight, why an approach to botany that used metaphors drawn from the social sphere would make little headway in the United States. In the postwar American culture of the 1940s and 1950s any academic discourse that seemed sympathetic to European socialism became a target of political suspicion. Canadian botany, though, turned a friendlier face toward the European system. A number of the ecologists here embraced the Braun-Blanquet methods, using them alongside the techniques they had borrowed from the Americans. Hybridization of this sort is almost a Canadian trademark. We measure our distances in metric kilometers and our weight in avoirdupois pounds. Some of our words are spelled the British way, some the American way. We have melded a European system of socialized medicine with an entrepreneurial sector modeled on the United States. Studying Canadian plant communities using a blend of European and North American techniques is another seed from the same pod.

In recent decades the Braun-Blanquet school has divided into subschools, but all the schools share a core technique. A botanist planning to study a given region with this method marks out a plot and does a relevé, a shorthand summary of all the plant species that occur within the plot. The researcher notes on the relevé the coverage, growth patterns, and relative health of the plants in the plot. A similar relevé is done for several plots in a region and the various relevés are combined into a table with species listed in the left column and plot names in the column headers. Then the rows and columns of the table are re-ordered to give prominence to the plants that are diagnostic species for the various plots. Diagnostic species are plants that are neither uncommon (occurring rarely or not at all in most plots) nor common (occurring frequently in all plots). The diagnostic species are drawn, when appropriate, from the various vegetation layers–upper canopy trees, mid-level shrubs, and ground-hugging forbs and grasses. The vegetation type for a plot then becomes some version of the names of one or two of the plot's diagnostic species. Plots that have the same vegetation types can be lumped together to define regions with a common ecosystem.

By the time Hans arrived in Canada, botanists on the West Coast had already started using the Braun-Blanquet methods to divvy up British Columbia into distinct ecosystems. The person responsible for bringing the European methods to Western Canada was, more than anyone else, another displaced Czech. Vladimir J. Krajina rose to a prominence in his native Czechoslovakia, becoming a docent in botany at Charles University in the 1930s and taking on various administrative positions. When the Nazis overran Czechoslovakia and closed its universities, Krajina joined the Czech resistance movement. He managed to pass along to colleagues in England, via a clandestine radio link, thousands of messages about German activities. Eventually arrested by the Nazis and sentenced to death, he was saved by the sudden end to the war. After the war Krajina was promoted to full professor at Charles University and he became active in the new Czech political parties. As the Secretary-General of a party that opposed the Communists, his position became increasingly untenable when the USSR tightened its hold on Czechoslovakia. Krajina fled Czechoslovakia in 1948 and moved to British Columbia in 1949. In the 1950s he climbed the same academic ladder in Canada that he had scaled in Czechoslovakia in the 1930s. Over the next thirty years Krajina and his students at the University of British Columbia would use the plant associations defined by the Braun-Blanquet methods to organize the ecosystems of the Canadian West Coast.[4]

Hans became one of Krajina's students, completing a postdoc under him and working closely with him on provincial projects in the 1970s and early 1980s. I ask Adolf and Oluna if they also knew Krajina. "Of course," says Adolf. "The community of Czech botanists in BC is small. But we were kept at a distance. It wasn't until much later, during Krajina's last years, that we learned the reason. Krajina believed that we had been sent over by the Czech communists to spy on him! We had been in Canada almost a decade before we were able to have an open discussion."

Hans tells us about some of the field studies he did with Krajina to help organize British Columbia's network of ecological reserves. These reserves, now numbering about 150, were established by the BC government in the 1970s as ecosystem banks, repositories of the rare and unique, the living and nonliving. No commercial development is permitted in the reserves and individuals and groups use them only for educational and scientific purposes. For many years Hans was employed as the plant ecologist and botanist of the province's ecological reserve program. Krajina's goal was to set aside about 1% of BC land in the new ecological reserves, a goal he fell short of by a factor of five. Today the reserves exist in an underfunded limbo, orphaned by several changes of provincial regimes. They are currently managed by BC Parks, even though they are not provincial parks. Hans and others who have been involved in the creation and extension of the reserves over the last four decades, worry about the political retreat from the lofty principles behind the founding of BC's network of ecological reserves. The reserves continue to be protected, however, a testimony to one of the world's most profound pairings of science and conservation, a hybrid produced by mating the older academic traditions of Europe with the wildness of the Canadian West.

The waitress arrives and we sort out drinks and food. I ask Hans, Adolf, and Oluna if mushrooms were important to them when they were growing up. "To a certain degree everyone in Europe is interested in mushrooms," says Oluna. "You have to take into account," Hans says, "that we grew up when times were hard, the years just after the war. I would go out with my mother and my sister walking through the fields and forests between the villages to gather food. We would pick mushrooms and steal the odd turnip or potato from the fields. When things got really bad, we would beg. In German we called it "hamstering," which means gathering–it's the same word that gives us the English term for a hamster. We would go up to farmhouses and knock on the door. The adults would stay in the background while we kids asked if the farmer could spare a potato or two. If we were feeling really bold, we would ask for an egg." "You can see the contrast between Canadian attitudes and European attitudes," says Adolf, "when you compare an English writer like Shakespeare to a continental writer like Pushkin. Shakespeare hardly mentions mushrooms. In Pushkin's writings the women sit around a table preparing mushrooms." The Pushkin reference surprises me. The North Americans I have known who read Pushkin were literature majors. "*You* know Pushkin's works?" "I had to take a lot of Russian when I was in Czechoslovakia. Seventeen years of it. I keep a Russian copy of the Pushkin poem 'Copper Rider' by my bed to read when I can't fall asleep. Knocks me right out."

Adolf's comment about Shakespeare and Pushkin calls attention to a divide in European folkways that runs along the English Channel. The Europeans that most Canadians and Americans count as their ancestors, the ones who lived in England, Scotland, Ireland, and Wales, were notorious mycophobes. To the inhabitants of the British Isles, mushrooms were "toadstools" that played almost no role in cuisine or medicine. A classic exposition of the British attitudes toward fungi is found in William King's *A Journey to London* (1699). "The diet of Londoners," King writes, "consists mostly of bread and meat.... [W]hereas we have a great deal of Cabbage, and but a little bit of Meat, they will have Monstrous pieces of Beef..., with but a few Carrets, that stand at a distance as if they were fright'd; nay I have seen a thing they call a Sir-Loin, without any herbs at all, so immense, that a French Footman could scarce set it upon the table." King asked a friend what mushrooms Londoners had for sale in the markets. "I was absolutely astonish'd to find, as that for Champignons and Moriglio's [morels], they were as great strangers to 'em as if they had been bred in Japan."[5] The continental food traditions King noted in the eighteenth century were reinforced in the nineteenth and twentieth centuries by the privations of the European wars. Wild mushrooms often supplemented meager supplies of domestic crops. Today crowds of Europeans, especially those in central and eastern regions, head out on summer forays to enjoy the sight of mushrooms and to collect baskets of fungal edibles. Unlike the markets in Britain and North America, which until recently offered the public only one Model-T mushroom,[6] markets in Europe continue to sell a range of seasonal fungi. When the people of the British Isles settled the U. S. and Canada, they brought their mycophobic attitudes with them.

"Does this difference in British and European folkways have any effect on the way European academics handle mushrooms?" I ask the three botanists. "I think so," says Adolf. "In general Europe has a healthier relationship between professional and amateur science. Many who have no formal connection to universities are able to work at the cutting edge of research." The conversation around the table veers off into the exceptions, the North Americans that Hans and the Ceskas have worked with who contributed to science without benefit of academic credentials. As I listen to this litany of names and stories, I become aware how the European context from which these three have emerged enables them to cultivate and encourage a people's science. Amateurs with an interest in the natural systems of Southern Vancouver Island belong to a number of interlinked societies and clubs that are focused on mushrooms, botany, birds, hiking, and native plants. Hans and the Ceskas have contributed their expertise to almost all of these amateur groups. This populist connection was probably not a conscious choice on their part. They didn't decide when they came to Canada that they wanted to hobnob with amateurs–they brought with them from Europe a perspective on science that already included linkages between formal and informal science.

The conversation turns to other differences in European and North American mycology. "Several European countries," I point out, "maintain lists of threatened and endangered species of fungi. In North America such lists are uncommon." "We ran into the problem of at-risk fungi," says Adolf, "with a species of mushroom that we found on Observatory Hill last month. *Squamanita paradoxa* is a rare parasitical fungi. It has been reported from only a few sites around the world. Our discovery was the third collection of the species from the Pacific Northwest. We contacted a mycologist at the University of Washington about this mushroom. He wanted Oluna to write an article describing it. We hesitated–*Squamanita* was just one of a large number of at-risk mushrooms that our work has turned up. This made us think about doing something more extensive on rare mushrooms. I sent an email to conservation centres in several U. S. states where there were long traditions of mycology and important collections of fungal specimens and asked them if lists of at-risk fungi were available. The replies were almost all negative. New York and California, for example, had nothing. Minnesota had a tiny list with about ten species. Oregon had a list, but it was mostly concerned with truffles."

"The national lists of endangered fungi kept by Switzerland and Germany are quite large, aren't they?" I ask. "Yes," says Adolf. "If we had such lists here, chances are that they would contain many more species than the indexes of endangered vascular plants that we currently maintain." I raise the issue of the national COSEWIC (Committee on the Status of Endangered Wildlife in Canada) list. In its at-risk categories COSEWIC recognizes about 600 species. Nearly 400 items on the list are animals and the other 200 are plants. Of the plants, 90% are vascular plants, the rest are mosses and lichens. The list contains no mushrooms. "Have you tried," I ask, "to get COSEWIC to accept a mushroom?" "I offered to do this last year," Adolf says, "for *Tubaria punicea,* the Christmas mushroom that grows at the base of decaying arbutus trees. Oluna had contributed to an article on the mushroom. When I contacted COSEWIC, they said that we were welcome to submit a report on the mushroom, but they guaranteed that it wouldn't be put on the list."

Figure 8. The powdercap strangler (*Squamanita paradoxa*) discovered by the Ceskas on Observatory Hill in 2009. Picture by Adolf Ceska.

"What I can't understand," Oluna says, "is why Canada allows lichens on their list of endangered species, and not fungi. Lichens are just fungi with algal partners." "But *why* doesn't COSEWIC include fungi?" I ask. Oluna's grey-green eyes flash. "That's the question, isn't it? It's time. How long should we wait?" "I think," says Hans, "that the proportions on the current COSEWIC list reflect orders of difficulty in doing the descriptions rather than the reality of risk." "We lack good data on fungi, true," says Oluna, "but we could at least make a start. Getting something on an official list would stimulate the research we need." "Yes," Hans agrees, "it's a negative cycle." We sit and look at our drinks for a while. I'm uncomfortable with the pause, so I break the silence with a joke. This is something else I have noticed about continental Europeans–when a conversation leads to a logical dead end, many of them mark it with a longer silence than North Americans can tolerate. Perhaps Wittgenstein had this difference in mind when he uttered his famous line about silence being the only response to what cannot be spoken. His garrulous English students must have driven him to despair.

The silence is still on my mind as we leave the café and its warm fire to walk back into the cold drizzle. The boundary I wanted to explore with Hans, Adolf, and Oluna was the one between European and North American attitudes. In trying to probe this social boundary layer, however, we returned to the ecological boundary layer at the beginning of this article, the interface between Kingdom Fungi and Kingdom Plantae. Perhaps the direction of our conversation was not an accident. These two boundaries, the one between European and American science and the one between plants and fungi, may be more closely related in British Columbia than in other parts of the world. The plant-defined ecosystems that the province has marked off with the help of a European academic tradition raise questions about the meaning of the abundant fungi in these ecosystems. The fungi and their common mycorrhizal networks bind together the levels of ecosystem vegetation and glue them to the terrain that supports them, but we leave them out of our botanical equations because Braun-Blanquet assembled the pieces of his classification system at a time when we knew almost nothing about mycorrhizal networks. Somehow the new information that we are gathering about the soil fungi has to insert itself into the older picture. British Columbia has protected in one way or another about 12 million hectares, some 13% of its land, but only a handful of these hectares have been socked away to save the fungi that enrich these western lands. The mushrooms that live in the boundary layer between our soil and our plants are no less important, and many of them no less rare, than the plants and animals we now protect.

This article is a chapter from a book Kem Luther is working on about boundary layers in British Columbia ecosystems. Kem, a writer and retired university professor, lives in Victoria, BC. He is the author of *Cottonwood Roots and The Next Generation Gap.*

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(Footnotes)

1 An unfortunate phytocentric plant metaphor. We lack a popular mycological equivalent.

2 "Sapro-" refers to decay. "Saprophyte," of course, is another phytocentric term, and in this case an incorrect one, since we no longer believe that members of the plant kingdom do direct decomposition.

3 "Ecto-" because these mycorrhizas usually do not to penetrate the cell walls of the host plant. AMs are endomycorrhizas.

4 In the two decades before he died in 1993, Canada and Czechoslovakia conveyed on Krajina all the major awards they could give him. Oddly, no one has written a book-length biography.

5 Westerners knew little about Japan at the end of the seventeenth century. Mushrooms are an important element in the historical cuisine and medicinal arts of Japan. Many of the tastiest mushrooms now go by their Japanese names–shiitake, matsutake, enoki. In neighboring China over thirty kinds of mushrooms are grown or collected commercially for the markets.

6 Agaricus bisporus, the button mushroom. Crimini and portabello mushrooms are not exceptions to this one-mushroom rule–they are just varieties of the button mushroom.