Across Centuries and Continents

an interview with Bob Blanchette (part 2)

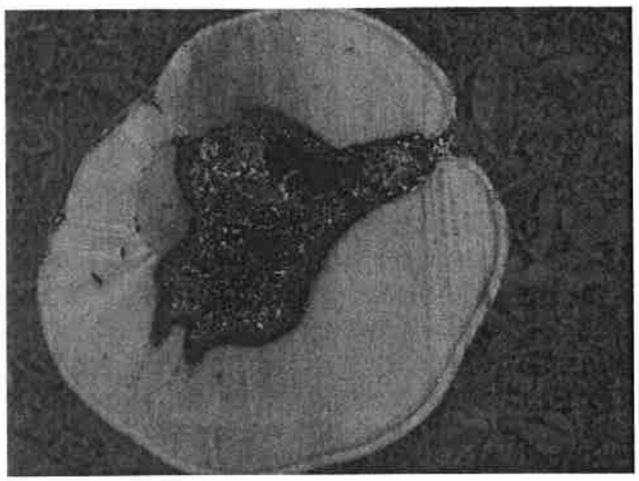
Leon Shernoff: Okay. Why don't we go to agarwood?

Bob Blanchette: Okay. Agarwood is a very interesting tree resin that occurs in a tropical rainforest tree in Asia called *Aquilaria.* Thousands of years ago, people found that the inside of these trees produced a resin: a discolored, resin-filled wood that had a magnificent aroma. People *really* sought after this for use as incense, essential oil and for traditional medicine. It is rare to find in native forests and many people indicate that the resinous wood is worth its weight in gold. So if somebody finds this, they can get enough funds to support them for many years. People do not know which trees have this, and historically they have cut trees indiscriminately looking for it. It is often found in the very oldest trees.

Maybe one in a hundred, or two hundred trees would have it. Over the centuries, and millennia, they have cut these rare old growth trees from India, all the way through Myanmar, Thailand into Viet Nam. So today, it is an endangered tree: very few of these old trees are left because of this indiscriminate cutting to get the very valuable resin. I was involved with a project to see what induced this resin, why it is only found in old growth trees, and could it be produced in young trees sustainably.

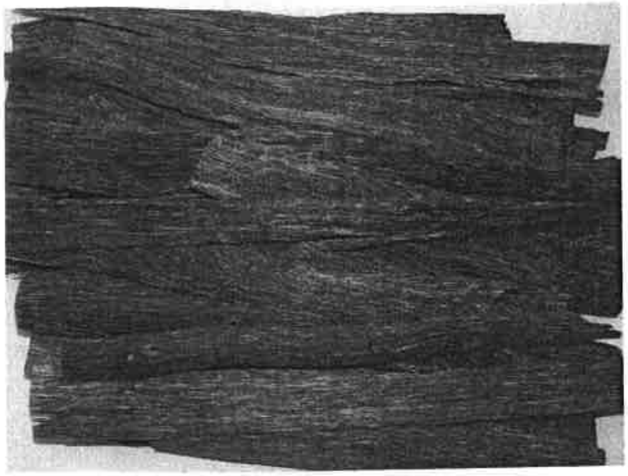
We found that the resin is produced as a nonspecific host response to fungal invasion. When you have wounds from wind storms, wood borers or any other break that lets in the local wood decay fungi, the trees produce reaction wood. And as they get older there may form thick areas of reaction wood and resin. The reaction wood produced by this tree is what has these magnificent aromatic properties.

We worked for many years looking at ways that could induce this resin in young trees. First of all, we had to find mother trees, collect seed, and get these trees growing in plantations. And then start experiments. After studying a few of the old growth trees that still remained in remote mountainous areas of Viet Nam, we found that fungi entering wounds appear to incite resin formation. We isolated fungi and put different species into these trees to see if we could induce the resin. And indeed we did and it was possible to produce it in young trees..



▲ Cross-section of cultivated *Aquilaria* tree, showing development of wounded, resinous wood. All photos courtesy Bob Blanchette

If you have a tree that's growing in the tropics, after five to six years it will be about ten to fifteen centimeters or so in diameter. So you have a nice sized tree. It is possible to treat these trees and produce a resin similar to what is produced in the old trees. The aroma and chemical properties of the resin is similar to the properties of resin found in the old growth trees. So we have been able to cultivate the agarwood and have a new sustainable source of the resin which is now available.



▲ Resinous *Aquilaria* wood after harvest, .

LS: And you have working plantations now.

BB: There are plantations and we've been working mostly in Viet Nam. A lot of people have asked me about the aroma of agarwood. It has an earthy fragrance that is very pleasant. It's a wonderful aroma. It has traditionally been used by Buddhists during meditation and prayer and Muslims use it in rituals and to help connect spiritually. The essential oil made from the resin is also widely used as a perfume. Cultivated agarwood from the Viet Nam plantations is being sold by ScentedMountain.com in the United States. This is a company we started to help the Vietnamese farmers sell their new product.

LS: And does it need specific fungi? Do some work better than others?

BB: It looks fairly nonspecific. We were worried that it might need one particular fungus. And if you were to try to use this in different countries, you wouldn't be able to because you'd be bringing in foreign fungi. But it does appear that you can simply treat trees to get the natural population of fungi established inside it. You wound the trees, provide nutrients, and then the natural microflora comes in and does its job and the resin forms from the the tree's natural defense responses.

LS: I remember seeing that you also did some work on fungi from these sunken Greek warships,

BB: We did. We have been looking at waterlogged wood from several different ships. Some were Roman warships, off the coast of Sicily, that were they sunk about 200 BC. The ship wood was under sediments in the sea and we looked at the degradation of the woods. In this environment with not much oxygen, it's mainly bacterial degradation.

We've also looked at some other ships; we've looked at wood from the USS Monitor, the famous ironclad warship from the Civil War, and characterized the decay present, as well as a number of other ships.

But with the Roman warships, an interesting aspect with their construction is that they had a ram, and the ships were designed with this ram in the front that was used in battling other ships. The oarsmen would go as fast as they could to ram into the enemy ships. That was their main method of attack. In addition to studying the degradation present, we also were looking at what type of wood was used in those ships

The wood used for most of the ship was oak. But the wood used for those rams was made out of elm. They used a very strong wood for the ramming.

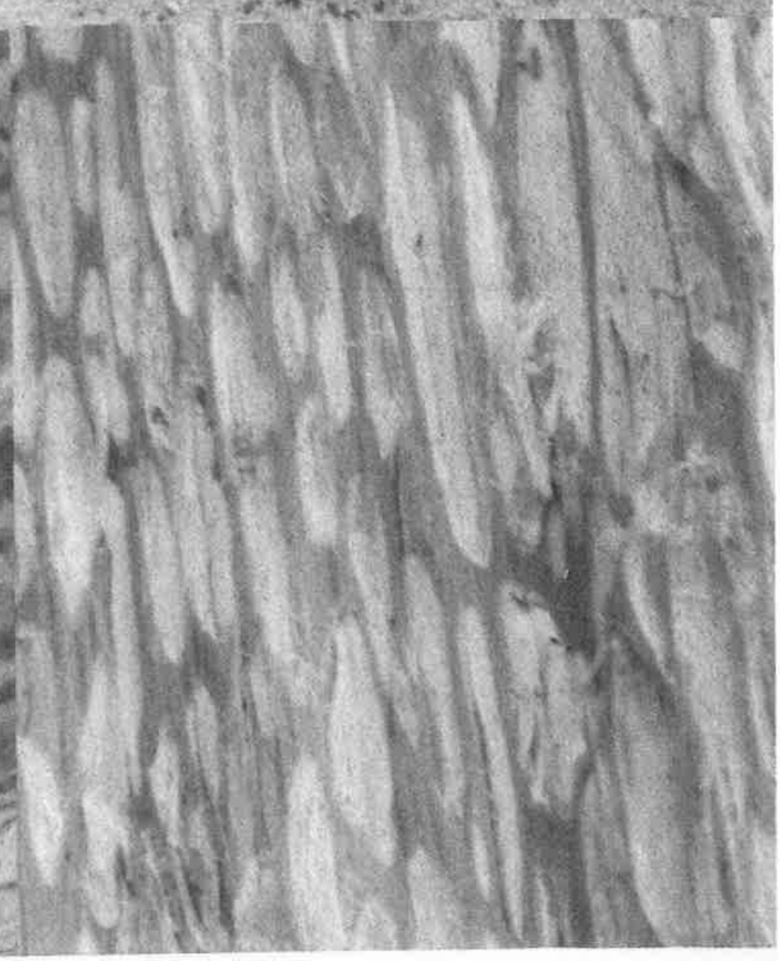
LS: Neat. Now I've been looking past you in your office. And it looks like you have some conks on your desk back there.

BB: Oh, yes. I have a lots of them. I also have some fungal masks.

LS: Yeah, I thought I was seeing that. And it looks like there's some *Ganoderma* next to them.

BB: I do have many *Ganoderma*. I have some *Ganoderma* with long stipes and many large ones. I've been involved

▲ Ritual mask from the Pacific Northwest, made from *Laricifomes officinalis*. See p. 62.



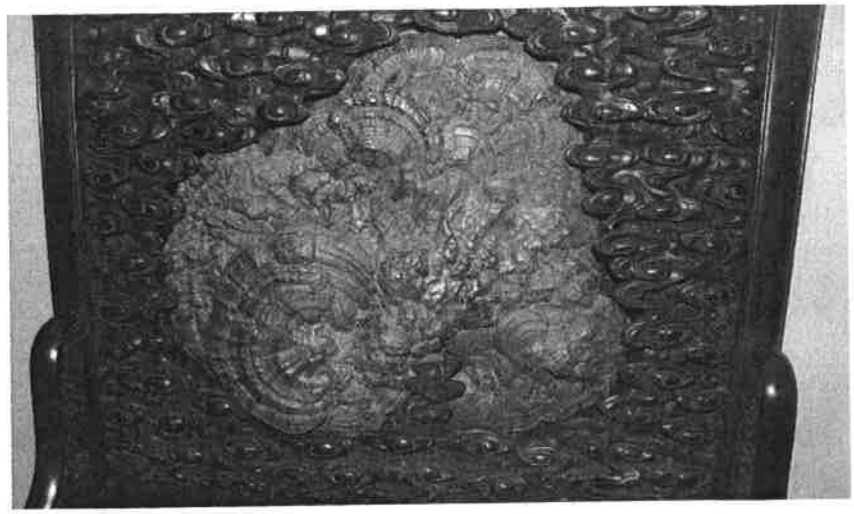
Top left: A painted wooden coffin being excavated at Abydos, Egypt.
Top right: Wooden statues in a tomb at Abydos with decay so extensive that they disintegrate if lifted. Investigations on the decay present and consolidant testing has helped find methods to conserve the wood.
Lower right: An especially flamboyant large *Ganoderma.*
Lower left; Light micrograph of soft rot in ancient cedar wood from one of the Old Kingdom wooden statues viewed under a light microscope. Wood cell walls are filled with cavities (spiraling lines in the photo) caused by soft rot fungi.
Lower center: White pocket rot in wood. The white pockets in the decayed wood are free of lignin and consist primarily of cellulose. The mechanisms these fungi use for delignification are of great interest for possible use in bioprocessing technologies such as biopulping of wood, biobleaching and lignin removal of woody plants for ethanol production.

with a lot of ethnomycological studies. In these studies I have been working with various museums to identify fungi in their collections. These studies started as I was on decay projects involving historic wooden cultural properties and historic structures.

There are many natural history and art museums that have lots of fungi in their collections. Back 100 years or more ago, there were many collectors from natural history museums, and also ethnologists who would collect cultural materials and bring them into the museums, so they often have detailed collection notes with them. Many of these objects were made of fungi and I have worked for many years trying to find more information about how these fungi have been used. It's really quite incredible how many have been found and identified.

There are some fungi that were considered to be very sacred. Agarikon, *Laricifomes officinalis*, is one of these that I have right here in my office. The fruiting bodies of this polypore can get to be very old. This one here is probably 50 or 60 years old, but others I have seen are 100+ years old. As you know, Agarikon has a long history of use as traditional medicine. It has been used in Europe and also by Indigenous People of North America. We know from museum collections that shamans in the Pacific Northwest – and there were many of them that did this – would carve the big Agarikon fruiting bodies into spirit figures, and then use them in rituals to designed to help cure the sick this in addition to administering the fungus as a medicine.

Of course, this is back in the seventeen, eighteen hundreds and nobody really had a very good understanding of what caused disease in those days. But it's interesting that they selected a fungus to use that we now know has medicinal properties. Shamans would also use masks of Agarikon in their rituals. There's one in the Canadian Museum of Natural History up in Ottawa that was used by Native Americans in the Pacific Northwest coast during an eclipse and also in various other rituals.



▲ Large *Ganoderma* set in a carved wooden panel, collection of the Qianlong emperor.

In indigenous villages of Nepal – especially in the Himalayas – they would also use fungal masks; and once again, they selected fungi that had medicinal properties. In this region they used laccate *Ganoderma*. They would use these in rituals and their ceremonies to help ward off evil spirits to control sickness. I have a few very old ones here in my office – these are made from *Ganoderma*. And it's interesting that they selected a fungus that we now recognize as having medicinal properties.

I have some *Ganoderma* with very long stipes. This is one here. If you look at some of the old Chinese paintings, you often will find Emperors and other revered people holding a *Ganoderma*. Of course, *Ganoderma* in China has been used for a very long time in traditional medicine, but it's also a symbol of longevity, it's also a symbol of good luck and good health. And a *Ganoderma* with a long stipe has been thought to likely give you a longer life with greater health benefits and more good luck. .

LS: When I got my masters, I had a roommate from Taiwan, and his father would make a cordial out of *Ganoderma*: he'd soak them in alcohol. And he very much felt that the active principle was in the shiny surface. So he wanted long stems with very little interior.

BB: That's very interesting. This is something that has been passed down for generations. They certainly have been used for long, long periods of time in China. I found some interesting information about *Ganoderma* while working on another decay project of historic buildings in the Forbidden City in China. On this project, I had the opportunity to see some of the collections that they had from the Qianlong Emperor, who reigned during the 1700s. He used to go on expeditions to collect *Ganoderma*.

LS: The Qianlong emperor was a fascinating guy. He had these matchlock rifles: You have this big long rifle. And there is gunpowder in an open pan. And what happens when you pull the trigger is they have a piece of fungal amadou which is smoldering at the end and you pull the trigger and it tips that forward so that it ignites the powder in the pan. It's an amazing piece of craftsmanship.

BB: He certainly seemed to be an amazing person. He would collect these big *Ganoderma* and put them into very beautiful carved cabinets. He would then display them in his palace. [see photo facing page]

For the Emperor, *Ganoderma* was also an important symbol. He liked just having them around since they were thought to have benefits of bringing good luck and keeping you healthy.

Back to the *Ganoderma* with long stipes, they're quite rare to find so often craftsmen would carve *Ganoderma* with long stipes out of wood. These, even today, are often presented, for instance, at a wedding. The couple will give gifts to one another, including a gift like a long-stemmed *Ganoderma* as a symbol for good luck and longevity and good health. [Bob is holding one of these in the photo at the top of p. 56]

LS: Wow, and that it looks like that carved *Ganoderma*… has some smaller *Ganoderma* carved on it.

BB: Yes, there's not only a long stipe, but other *Ganoderma* are carved along it too. It's really ornamental! And some are very simple. So there's a range of very simple ones to much more ornate; but they all have the same meaning of good luck and good health and long life.

LS: Very cool. And I saw at one point you were working on ancient Egyptian wooden statues. [see photos p. 60]

BB: I have worked on several different Egyptian projects. Some were with conservators at the Metropolitan Museum of Art in New York investigating decay that occurred in wooden objects from different tombs. Just this past year we published information on some of the oldest wooden objects found at excavations in Abydos in Egypt. This work was with archaeologists and conservators from the University of Michigan, the Smithsonian and the Boston Museum of Fine Art.

The wooden objects were from an Old Kingdom site where some of the first pharaohs were buried. This site belonged to Weni the elder who was the governor of Upper Egypt and dates to about four thousand years ago. Other important people were also buried all around the site.

This was a time where the burials were below ground. They had mud brick, buried into the ground, and this was all excavated. They found a lot of wooden objects, and many were severely degraded – they were so degraded that the archaeologists feared that they would just break apart into fragments if moved. So we studied their current condition and the type of decay that occurred in these wooden objects – and what type of conservation procedures could be used to help consolidate them so they could be moved to the lab, studied and further treated so they could be presented in the museum.

So an important aspect of the work was the conservation of the objects but of course I was interested in what fungi had caused the decay and how these desert fungi are able to attack the wood.

These desert environments are an extreme environment, and extreme environments exclude the normal white and brown rot fungi. Instead, in these dry deserts soft rot fungi can dominate. When they grow in the wood they can cause a lot of damage to the secondary walls of the of the wood.

In this case, the ancient wood had such advanced stages of decay that the wood, if moved, would just break into tiny fragments. So knowing the micromorphological condition of the wood, conservators tested different consolidants to see what would work best to give it that needed stability.

And as I mentioned, we had a publication of the fungi that we isolated from that study that was came out recently and another that reports the methods to conserve and consolidate the wooden objects so that it can be preserved long into the future.

LS: So I'm hearing you say that these are soft rotters, but they are different ones from the polar fungi found in the huts in Antarctica?.

BB: Yes. In the desert environment *Chaetomium* was present and other Ascomycota. After long periods of time, with just small amounts of intermittent moisture, many of species of Ascomycota can cause soft rot in wood.

LS: And I've remembered something that flitted through my mind a few minutes ago, and I meant to ask: You were saying that the soft rot in those polar huts is different from the white rot and brown rots that are sort of the standard rots that we learn about first in our textbooks.

And we've sort of it, it seems to me – and again, maybe I'm wrong and you can straighten me out – that

Persimmon Venison and Oyster Mushrooms

by Diowli Dave Lewis

½ pound or so of fresh Oyster mushrooms, sliced
1 cup of persimmon pulp
4 tablespoons butter
1½ pounds venison back strap
1 cup of crumbled dried Black Trumpets

Slice the venison 1/2-inch thick and cut into bite-sized pieces. Melt 2 tablespoons of butter in a small frying pan and sauté the venison over low heat for just a minute or so, then set aside. Melt two more tablespoons of butter in the pan, add trumpets, one cup of water and sauté the Oyster mushrooms over low heat until all the liquid is absorbed. Add the venison and persimmon pulp to the mushrooms and stir until thoroughly mixed.

Mushroom

we've gone through this progression in understanding of rot. When I started out, I was told that in brown rot, the fungi are eating the cellulose and leaving the lignin; and white rots are eating the lignin and leaving the cellulose. But recent more recent work has shown that they're always eating the cellulose; it's just a question of how they extract it.

The [standard story now is that the] white rots came first and they're sort of primitive: they just blow the cell walls apart, so the lignin is actually destroyed; then the fungi eat most of the cellulose but some is left behind so you get this white rot. And then the brown-rotters evolved and they sort of unzip the cell walls to get at the cellulose and then they zip it right back up again, so you have this brown leftover wood with lots of lignin in it. So it was a very simple set of concepts: just two kinds of rot.

But I saw that you had another paper where you talked about... I think of it as different phenotypes of white rot: they present physically in a different way. And is this because all white rots come from the same evolutionary tree and that tree is older and it's had more time to spread out and take different forms? Or do they have different evolutionary origins? What's the current understanding of that sort of thing?

BB: Well, first, for the white rot fungi... there's thousands of them. And there isn't just one or two enzymes responsible for the wood decay. We know that these white rot fungi can attack all wood components, even lignin.

And there's many, many mechanisms that they use – many different enzymes and nonenzymatic processes. This huge, diverse group of white rotters have very a great variety of degradative systems in operation.

Some of them can be very selective at attacking lignin and hemicellulose and leave cellulose behind. These are the white pocket rot fungi. It's kind of amazing that they are not attacking cellulose, the material that you would think would be degraded first. Instead, they attack the recalcitrant lignin. There are others that simultaneously attack cellulose with lignin and some are real odd balls and we have been calling them "gray rots."

LS: So when you say attack, are they actually eating the products of the degradation of the lignin?

BB: Yes, they definitely are degrading it. Those that are selective for lignin degradation also remove hemicellulose which is bound together with lignin. And yes, some of these white pocket rots are not attacking the cellulose and this is left behind. The fungi that can do this are very good biological pulping agents: removing lignin from wood in these pockets. The cellulose is left behind, and you can see (bottom of p. 60) these very distinct white areas in wood where it's just pure cellulose like you'd find in white paper. There is a lot of interest in trying to figure out exactly how these fungi do this so new bioprocessing technologies can be realized.

Some of these selective lignin degraders produce big white pockets, such as the white mottled rots, and a few of these fungi under the right conditions can cause a delignification of a whole log.

We see this in some of the temperate rain forests on the Pacific coast. I've seen this in Oregon and also down in Chile. In *Nothofagus* in Chile, there are some *Ganoderma* there that grow inside these trees and cause extensive delignification: this results in logs with huge amounts of cellulose left behind.

Back many years ago, the farmers in Chile would split open these logs to feed to their cattle: the cellulose left behind was very digestible since the lignin is gone.

So we have a whole range of these selective lignin degraders that will delignify wood selectively in small spots, or in bigger, mottled areas or even some in very large zones.

We also have some white rot fungi that grow fast, they grow right inside the cells [that is, not breaking apart the cell walls]. They're after the simple sugars, and they can actually tolerate resins and other protective chemicals.

As they colonize, they also cause wood decay. Many of these pioneer species can cause serious decay problems and hazardous conditions in trees. We are currently working on a project of the fungi associated with the emerald ash borer – an invasive exotic insect. Pioneer white rot fungi come in fast with the borer and lots of decay in the ash trees making them hazardous within a very short time after borer attack starts.

There are just so many different kinds of ways that fungi can attack wood. The brown cubical rot that you see in the forest is usually very high in lignin – the cellulose has been removed. These brown rot fungi can depolymerize cellulose early in the decay process. Since cellulose gives the wood binding power, once the polymer is cut up, you have a tremendous loss of strength. So the brown rots also cause hazardous conditions in trees and a lot of problems in buildings because of the strength losses from the decay.

LS: So what I'm getting is that the white rot thing involves a whole suite of enzymes and decay processes. And I'm wondering whether this is a sort of swarm of capabilities? Are these all things that sort of co-evolved in one... genetic horde, that advanced together? Or are these different processes thought to be the result of different evolutionary lineages?

BB: As these fungi evolved, they changed. Some of them have lost some of these enzymes and in others they are retained but they're not active and have to be induced – likely by substrate or environmental factors.

LS: Now, my understanding is that our first land fungi were lichens. Plants colonized land with their help, and at a certain point much later, the wood decay ability developed. What is the thought on what was going on back then?

BB: Well, we know that land plants did evolve before the lignin-degrading fungi did – maybe 80, 90 million years before. Then about 290 million years ago, the first white rot fungi evolved. And it's thought that there was a lot of plant material around before then, and maybe there was even some degradation by other Ascomycota. But there's no evidence of the lignin peroxidases or class two peroxidases involved with lignin degradation until the white rotters appears.

And maybe this resulted in the coal formation period: there is a time period right about 300 million years ago, that we have these very large accumulations of coal. And coal, of course, has a botanical origin. It's made from plants. Coal formation has occurred throughout the ancient past, but during this period a huge amount of coal formed. The process of coal formation, of course, involves lots of time and pressure and this changes the plant material and produces coal.

Now, it's very suggestive that this period of peak coal formation occurred just before fungi developed their lignin-degrading enzymes.

LS: Now what you made me think of was this phenomenon where sometimes we get these ancient organisms, for instance lichens, and then newer organisms evolve and come in and crowd them out in the more hospitable environments.

But in the extreme environments, the newer organisms don't bother with them, so we end up with these cryptogamic crusts and so on that have been there... basically forever. And I was wondering , does it look like something like that has been happening here?

Chanterelle Bacon

by Anna McHugh

1) Parboil fresh mushrooms for 3 minutes

2) Allow to dry thoroughly, slice thin

3) Toss mushrooms with oil and salt

4) Roast at 350 degrees for 30-40 minutes, flipping after 20 minutes. Make sure they get crisp, but not burned.

5) Toss with a little maple syrup, garlic powder, black pepper, and a few drops of liquid smoke. I also used a little MSG because it's awesome.

6) Devour

It's based on a recipe by Kenji Alt-Lopez, who i think is now with NYT, but I modified it substantially for chanterelles. It works great with king trumpets too – no parboil required. Anyhow by all means feel free to use whatever you wish!

Mushroom

BB: Exactly. The environmental conditions dictate which fungi grow there. When you go to extreme conditions – whether it's very dry desert conditions; or it's very cold polar conditions where you have freeze-thaw occurring a lot; or even underground such as in a mine that has a lot of heavy metals – most of the fungi are excluded: they can't grow in those condition. But a few can, and they dominate there over long periods of time. They're responsible for the degradation. And it turns out that the fungi able to grow in these extreme environments are the soft rotters: unique fungi in the Ascomycota.

This is a group of fungi we really don't have a lot of information about, but it's needed. The more we can discover about their ecology and biology, the more likely we'd be able to better understand their ecological role. Also this information will help to find ways to control the ones that attack historic woods in these environments.

LS: One of the questions I submitted ahead of time was, "What are your major questions about the field? Given 20 years and unlimited funding, what would you do? Would it be to look at these environments and these sorts of fungi or..."

BB: Yes, definitely! Just in the last several years, every study that we have been involved with, we have found new, undescribed fungi. We have so many that we know little about and need to be studied.

Not only do they need to be described, we need to learn more about their biology and ecology. And like I say, there's some right here in the backyard. There are undescribed fungi in ash trees that are being attacked by the emerald ash borer; there are undescribed fungi in the Egyptian deserts; there are undescribed species in Polar Regions and it seems every place we look. With 20 years and unlimited funding, I'd bring in a power house of graduate students and work on all of them

We have a study now in the Amazon and this is really a place for high biological diversity! We're working at the Yasuni National Park in Ecuador where there are more tree species per hectare than we have in all the United States. Just in one hectare! Imagine the fungi in all those tree species! It's just incredible. I have a graduate student from Ecuador, Cristina Toapanta who has recently described 4 new species of fungi from the rainforests. These *Polyporus*-like fungi are very strange in that they produce rhizomorphs above ground. Wherever we look, there's new fungi and much more work to be done.

LS: Wow.

So I think you answered the questions that I sent in. And I think we covered the four ethnological areas that I mentioned. And let's see...

BB: The last thing I'll just mention, for the ethnomycology aspects: Just recently, we found some additional objects in two different museums, and they are examples of indigenous people using mycotextiles. It suggests that there are still many fungal objects to be found in these museums.

These are mycelial mats used by the Indigenous Native Americans over 100 years ago. It's so interesting that these are from over 100 years ago, and now we see a real big current interest in using fungal mycelial mats for a leather substitute and other biomaterials.

The mycelial mats used by the indigenous People of the Pacific Northwestern United States were produced by the Agarikon fungus *Laricifomes officinalis*. This brown rot fungus produces brown cubicle rot and cracks and crevices in the decayed old growth trees would fill with mycelium forming mats. They would just go and pull out large pieces of these fungal mats and use them.

LS: and they are they felting it or pounding it and

BB: It seems they used it right out of the tree. There's just some very big pieces that can be up to a quarter inch thick and a meter long. This information on the mycotextiles was recently published; it came out in *Mycologia*.

LS: Are these mats something unique to the *Laricifomes*? Or are there other fungi producing them too...

BB: You can find mycelial mats produced by other fungi too. Another common fungus producing them is *Fomitopsis pinicola*, the red banded polypore. You can also find them produced by white rot fungi such as *Ganoderma*.

In these old growth trees, you can find really big long pieces of these mycelial mats, some as I mentioned as long as three feet.. The ones here in Minnesota that I have seen in decaying smaller diameter trees can get maybe two or three inches long.

LS: My understanding is that the fruiting body of Inonotus obliquus can be a sort of mat underneath the bark. Is that the same sort of thing?

BB: Yes, it forms a mycelial mat under the bark once the tree dies and this turns into a poroid fruiting body. This would likely be hard to pull that off the tree. And then there's also Amadou: in the Eastern European countries, they take Fomes fomentarius, and they use the upper context of the fruiting body. This is ground up and pounded, and made into a mycelial fabric to make hats and various other items.

LS: Right. I've run an article on that, too.

BB: This type of mycotextile is relatively recent – I think that that has been used in the last several decades. Whereas the Indigenous People were using mycelial mats over a hundred years ago. And the tinder from *Fomes fomentarius* mycelium has been used for thousands of years.

LS: I think we've covered all the things that I was thinking of ahead of time. Thank you for your time. Thank you for all this.

BB: It's been great talking with you.

Mushroom