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Ohio Mushroom Society

The Mushroom Log

MISSOURI RESEARCHERS SHARE LESSONS FROM HUMONGOUS FUNGUS

by Karina Zaiets

Columbia Missourian, Dec. 8, 2018

COLUMBIA, Mo. - It was discovered nearly three decades ago. At the time, it was thought to be heavier than a blue whale, bigger than 23 football fields, and more than 1,500 years old. The news of its discovery appeared in almost all the major media outlets and even made David Letterman's Top 10 list.

In July 2018, in a preprint paper posted on *bioRxiv*, scientists studying it announced that the so-called "humongous fungus," an individual of *Armillaria gallica* that lives in a forest in the Upper Peninsula of Michigan, is actually four times bigger and around one and a half times older than previously thought.

It's not just that it's so big and old. It's also about what "H.F.", as retired University of Missouri professor Johann Bruhn refers to it, can teach us. Bruhn has studied the *Armillaria* species for around 40 years as a research associate professor at Michigan Technological University first, and then at MU.

Fungal Characteristics in General

In the autumn, if it's not too dry, mushrooms pop up near a tree or grow from the stem. A person looking at one may think that there is nothing more to it. But that's not the case. A mushroom is just a piece of the puzzle—the "tip of the iceberg," so to speak, of a fungus.

The main "body" of most fungi—the part we don't usually see—is called the mycelium. One example is a fibrous or cottony growth that appears on fruit as it rots. Mycelium is composed of microscopic filaments called hyphae that look like tiny threads woven together, and in forests it mostly stays underground or within species.

So it lives unseen, until the time when it has enough nutrients and the weather is right for development of fruiting structures: mushrooms. As the mycelium exhausts nutrients from one food source, it grows outward seeking new ones. It usually expands as a ring that is known as a fairy circle. That's how separate mushrooms a couple of feet away may actually belong to the same fungus.

Characteristics of the Genus *Armillaria*

General

Fungi belonging to genus *Armillaria* act primarily as decomposers of roots of trees that are already under stress, as well as their stumps and fallen stems. Infected roots are no longer able to absorb water or nutrients, and so the tree gradually dies. By killing and decomposing stressed trees, the fungus makes room and nutrients available to healthier trees, thus serving as a sort of "gatekeeper."

Wood decayed by these species is white, and often spongy and wet. The mycelium of *Armillaria* is bioluminescent, especially in actively decaying wood. The bright white glow can be seen from a considerable distance and is commonly known as a fox fire. From one victim to the next, the fungus spreads by long black cords called rhizomorphs that develop from mycelium. These bootlace-like strands can travel great distances in search of a tree to infect and may form an extensive network. Shielded underground and in decaying wood, rhizomorphs are protected from high temperatures and drought.

Armillaria gallica

Mushrooms produced by *Armillaria gallica* have a pinkish-brown to reddish-brown cap and usually grow in late summer or during the fall. They are edible, but have to be cooked.

Armillaria gallica lives throughout much of forested North America, including in Missouri. Here, it may reveal to scientists how climate change could weaken even the most resilient trees. This could have implications for Missouri's economy and wildlife.
"So the average person walking through the woods would see clumps of mushrooms here, and they're separated by quite a distance often," Bruhn said. "And they think of it as being a small discrete organism with individual representatives scattered through the woods. And what we found was that, in fact, the Armillaria individuals in the forest floor are older than the trees. They're larger than the trees and they have incredible longevity."
One of the reasons for that longevity is its low rate of mutation. That, potentially, could improve understanding of the human genome and such diseases as cancer.

History of Discovery

The discovery of the "humongous fungus" was a side product of a U.S. Navy effort called Project ELF.

The work began in 1982. The plan was to build miles-long antennae and bury their ends in the ground in Wisconsin and Upper Michigan. The antennae would send signals of extremely low frequency through bedrock to underwater craft around the world. The U.S. Navy conceived the project because it was having a problem: to receive an order, a submarine had to trail a buoy or buoyant antenna near the surface. Doing this made it easily detectable. The solution was to use the unique property of the radio waves: the lower their frequency, the more deeply they can penetrate the sea.
"So what they concluded was that they could send a very simple message through the water out to sea saying, 'Come to the surface to get new instructions' or 'Stay on the present course,'" Bruhn said. "Then the submarines wouldn't have to resurface so often or they wouldn't have to resurface at all." The public was concerned about possible environmental impact, so the Navy established an elaborate environmental monitoring program to assess the effect of the electrical signals on wildlife, trees,

etc. Bruhn was one of the participating scientists.

Environmental Impact Study

“So what we concluded was that what we had to do was we had to establish small plantations of a fast-growing tree species that was very genetically homogeneous so that all the trees would be the same age,” Bruhn told the Columbia Missourian. That would enable scientists to measure the trees and build a better statistical model of the effects of the electrical fields on their growth.

The researchers cut patches of mixed hardwood/conifer forest and planted red pines. As he expected, Bruhn soon noticed that two species of Armillaria were killing trees in the research plantations.
“The pine pathogen was focused on the pines, but there was this other species that came eventually known as the ‘humongous fungus’ that was decomposing the hardwood stumps,” Bruhn said.

He observed that the Armillaria species seemed to occupy enormous territory. He wanted to understand how many individual organisms of each species were involved, and how they were spatially distributed in the forest. He dug up the dead seedlings and cut a window through the bark to expose the fungus growing underneath, then sampled a piece of the fungus and grew it in culture. Then he mapped where the seedlings had been growing. Over about eight years, he ended up with a collection of hundreds of mapped cultures of the Armillaria species.

Discovery It was One Species

“One of the interesting things for me is that I cut the back of my finger, and I’ve got 10 stitches in it and the skin is going to grow back together because the skin on one side of the cut recognizes the skin on the other side of the cut as being compatible,” Bruhn said. “Well, this mushroom can do the same thing.”
When two cultures put in a Petri dish belong to the same genetic individual they will grow together without leaving a sign that they were once separated. In distinct individuals, there would be a dark brown line between them. But to prove that different samples came from the same individual some molecular tests had to be done.
So Bruhn asked his friend Jim Anderson from the University of Toronto to help. Anderson had the necessary expertise in molecular biology and had a graduate student, Myron Smith, who just happened to be looking for a graduate project to work on.

Original Study Results

They analyzed the samples, studied the rate at which the rhizomorphs (long black cords specific to Armillaria and related species that develop from mycelium—the main “body” of most fungi) grow, and published a paper with the results in Nature in 1992. At that time, they determined that it occupied at least 37 acres, weighed more than 100 tons, and by conservative estimates was more than 1,500 years old. Soon, it got the name “humongous fungus.” The researchers were sure it was even larger than that. Starting in 2015, they took samples annually, mapped them, did compatibility tests to determine if they had reached the limit, and extended the geographic area of the study. "We could hardly believe that it was as big as it turned out to be and we can only handle so many samples in the laboratory each year," Bruhn said. "This is a large perimeter to be making collections."

Updated Results

This year, they reached the edge. It turned out the humongous fungus weighed more than 400 tons and is more than 2,500 years old.

"We say 2,500 years, but that's a conservative guess. (It) could be almost as old as the forest that replaced the glaciers," Bruhn said. "What we wanted to understand was how the individual could get so large and so old and still retain its identity. For a human being, we would eventually contract cancer or something. People don't live to 2,500 years old. We wouldn't look like much."

The team also wanted to understand where it originated. Typically, fungi start from a single point and grow outward in a radial pattern, but obstacles and the development of new food bases would cause them to change direction. By gathering the samples and analyzing the number of mutations, researchers understood more about both the longevity and the growth of the humongous fungus.

"It's a great follow-up on the work that they did quite a long time ago," said Thomas Volk, professor of biology at the University of Wisconsin-La Crosse. "The methods are much more sophisticated now, and I think they have been able to glean a lot more interesting information from the current study."

So How Does It Live So Long?

The team found that the fungus had very few mutations, and this could be the key to understanding how it has maintained its identity for such a long time. "Cancers involve huge rates of specific mutations, and Armillaria essentially represents the opposite end of the spectrum with just almost unbelievable genetic stability," Bruhn said. "There may be a mechanism within the fungus that may be fixing mutations," Volk said, like a chemical, for example. "There is a possibility that something like that could help people to avoid mutations, and mutations are really what cause cancer." Living underground is another factor, besides genetic stability, that has contributed to its longevity.

Change in Armillaria Resistance

Even healthy trees will have rhizomorphs wrapped around their roots "just waiting for a drought or an insect or epidemic or a fire or any kind of stress factor to weaken that tree and then it [Armillaria root disease] will infect it," Bruhn said.

One of the tree species Bruhn found to be resistant to the root disease Armillaria caused was white oak. But then he took a graduate student to a research site and saw a sign of Armillaria infection in a white oak tree. "That was the first time ever that I had ever seen Armillaria doing to white oak what it's been doing to (black and scarlet oaks) for decades," Bruhn said. Simeon Wright was with Bruhn when they saw the white oak infected by

Armillaria. Now a forest health specialist with the Michigan Department of Natural Resources, Wright said warmer temperature and increased heavy rainfall events over the past 30 years in Missouri could lead to increased periods of soil being saturated. That could make it difficult for roots adapted to drier conditions to get enough oxygen. Conversely, warmer temperatures also increase drought at other times, which also damages roots. The tree becomes stressed and the Armillaria fungus can start attacking those roots. That can potentially lead to the change in the composition of the forest. “If we see white oak replaced by species that are less valuable for timber or wildlife, that certainly could have a big impact on Missouri’s economy,” Wright said.

Prophesy Fulfilled

The sight of the enduring white oak dying from the root disease brought back Bruhn’s memories of his senior year at Utah State University. He was taking a plant ecology course, and one day the professor came in and said: “You are too young to have seen this happen. You haven’t lived long enough. We’re in the early stages of being able to see what’s changing. But I guarantee you that by the time you have retired, you will have seen changes you can’t explain without including the greenhouse effect and climate change. “He was right, boy was he right, and he was brave for bringing that up in 1970,” Bruhn said.

[Note: The humongous fungus of Michigan, while large, is not the world’s largest. That distinction goes to an individual growth of Armillaria ostoyae in eastern Oregon, which covers 2,385 acres of the Malheur National Forest. This particular individual is estimated to be anywhere from 2,400 to 8,650 years old.

By another measure, the largest organism could be the 13-million-pound clonal aspen forest of Utah, which, sadly, is now dying.]

Reprinted from the Puget Sound Mycological Society via the Columbia Missourian Dec. 8, 2018

The Whiskey Fungus

By Bob Antibus

As students in Orson Miller’s lab in the 1970s we became accustomed to folks frequently showing up at the lab with an interesting array of fungal identification problems. One such incident involved a black mold growing on the siding and decks of homes in a newly established allotment. Being a fan of bourbon Orson was more than willing to check out whether the resident’s suspicions about a possible link between fungus and a nearby distillery had merit. I was reminded of the event after reading a piece in a recent issue of *Field Mycology* dealing with the “whisky fungus” in Scotland. So, what is this whisky fungus, what does it do and why is it apparently spreading in Scotland?

The whisky fungus was first collected and described in 1872 by Antonin Baudoin from the walls of a distillery in Cognac, France. The fungus has a long and complex history of taxonomic treatment but was until recently known as *Torula compniacensis*. This tongue twister literally means “the Torula from Cognac”. Molecular work currently places the fungus in a genus *Baudoinia* thus named after Baudoin. The fungus is only known to grow in industrialized areas around distilleries, spirit maturation and aging warehouses. It has also occasionally been reported near bakeries. It is known to occur in North American, Asia and Europe. It's likely associated with the prevalent aged spirit in these areas including: rum, bourbon, cognac, Canadian and Scotch whiskeys. Crucial to the story is that these all must be barrel aged. The fungus forms a black crusty, laminate or lichen-like growth. In fact, the growth is a biofilm containing a suite of organisms, which made pure culture isolation of the fungus difficult. Eventually it was discovered that addition of small amounts of ethanol to growth media could encourage spore germination and growth of the fungus. *Baudonia compniacensis* is the asexual stage of the fungus and is characterized by brownish barrel-shaped spores (conidia). The conidia produced on a black stroma are thick-walled with surface ornamentation and typically dry. No sexual stage of the fungus has been identified. DNA sequencing places the fungus in the Ascomycota and the Order Capnodiales. As such it is related to the sooty mold fungi that often grow on plant surfaces as epiphytes. If you have been to an OMS summer foray you may have seen another sooty mold known as the beech aphid poop-eater. This fungus, *Scorias spongiosa*, grows in black layers on leaves – especially those of American beech. The fungus uses the honeydew of the beech blight aphid *Grylloprociphilus imbricator* as a food source. The fungus starts out as a large yellowish spongy mass but eventually turns into a crusty black mass that holds ascospore producing reproductive structures. Such a mass is known by mycologists as a stroma. If you are interested in learning more about *S. spongiosa* mycologist Tom Volk's website has a nice summary of its ecology.

In areas where *Baudonia* occurs the black crust can cover any smooth surface including houses, decks, buildings, walls, fences and even trees. Growth can do serious damage to trees. I've even seen pictures of the fungus on cars in Kentucky – I wonder how often these cars were driven! Mostly the fungus appears to be an unsightly nuisance, and little is known concerning possible effects on human health.

Like other sooty molds that don't really penetrate host plant tissue the whisky fungus must find some form of carbon and nutrients deposited on its substrate. For *Baudonia* this must be ethanol or other air borne releases from a spirit producing facility. Conidia of the fungus are stimulated to germinate by ethanol and growth is enhanced in media containing 1-2% ethanol. But what the source of ethanol in nature? Keep in mind that when distilled spirits are aged in wooden barrels some of the product is lost. Distillers count on a 1-2% loss of volume of product per year. These losses concentrate the remaining product while the wood adds complex flavoring compounds. Distillers refer to escaped vapors as the "angel's share". This is likely a complex mixture that contains ethanol as well as other volatiles. Being heavier than water vapor the angel's share will condense or mix with water and condense on cooler surfaces outside a storage facility. This condensate is what fuels the growth of the *Baudonia* biofilm. As the biofilm accumulates it forms more surface to trap condensate enhancing further growth. Nitrogen fixing *Nostoc* are occasionally found in the biofilm and may provide nitrogen to the fungus, but so may various nitrogenous air pollutants. Another common name for *Baudonia* is the angel's share fungus.

Back to the question of why this fungus seems to be spreading in Scotland and what can be done about it. In the article I mentioned the authors suggest that Scottish distilleries once used aging barrels produced locally but in recent years have switched to importing barrels from bourbon and cognac producers in the United States and France. They feel the fungus has been unintentionally spread through Scotland with such imports. Alternatively, *Baudonia* may have been common but was only noticed after mycologists started a systematic study enlisting help from the general public did it show everywhere. After doing some research I found a number of lawsuits have been filed by people and businesses near distilleries and aging facilities. In some cases, the distillers have paid to have houses and buildings cleaned and repainted but there seems to be little in the way of longer-term solutions. Most solutions like installing filtration systems on production facilities would be expensive. Better zoning might prevent some problems or maybe, as the authors of the F*ield Mycology* paper suggest, people could stop drinking distilled spirits! Finally, you might be wondering if a similar fungus exists related to wine production. The answer is yes. A fungus also in the Capnodiales known as the" cellar fungus" *Zasmidium cellare* grows as a black crust on the walls of wine aging caves and cellars.

Editorial Musings

I decided to reprint this whole article on Armillaria since it added a lot more facts to the Armillaria story than were previously known. Especially noteworthy is the fact that the rhizomorphs will sidle up to a potential victim and lurk there until environmental stresses make the tree suseptible to attack by the fungus.

Also noteworthy is the hypothesis that climate change could be the cause of the increased stresses leading to infection.

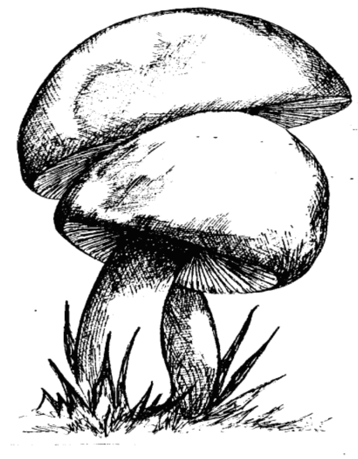
Which only goes to show how interconnected all organisms are and how a perturbation in one part of the web of life can create a chain reaction deleterious to others.

Many thanks to Bob Antibus for the article on Whiskey Fungus. By the way, whiskey has an e in the American spelling which is abssent in the British (e.g.) Scottish spelling. Just to show you, despite being retired from academe for 12 years, I can still be a pedant!! Of course we can always call it bourbon. I believe I have reprinted articles on the angel's share fungus years ago but Bob's article puts a unique spin on it. Bob teaches (taught?) Biology at Bluffton College in Bluffton, Ohio.

Deb Shankland sent me a link about the rapid spread of Amanita phalloides. If you are interested see their link at https://www.theatlantic.com/science/archive/2019/02/deadly-mushroom-arrives-canada/581602/

Calendar of Events

There are no forays yet to be announced. That awaits the Board meeting in February.
Check your most recent issue of the *Mushroom Log or* our website for more detailed information. Please plan to join us. All mini-forays are subject to cancellation. Call first to confirm.
Please bring a whistle and compass and an **RSVP to the host is mandatory** so they have cancellation flexibility.
Morel and other mini-forays, are subject to change, especially the former. Leaders will be checking the woods to



assess their progress, so you should contact them at least a week prior to the announced mini-foray for any updates.
Miniforays: (RSVP required)

Beside those listed below, other mini-forays are likely during the summer/fall.. **See later issues of the Log or the OMS website for later postings of these miniforays**.

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Articles for the next Log due March 25, 2019

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May OMS provide your name to other mushroom related businesses? Yes ____ No ____

LIABILITY RELEASE AND PROMISE NOT TO SUE:

I understand that participating in the activities of a mushroom club involves a moderate amount of risk. This includes all of the risks of being away from home, risks associated with moving about in fields and woods, risks of encountering inclement weather, risks involved in eating wild mushrooms, risks of losing personal property by theft or misplacement, and all other expected and unexpected risks, including illness or injury. While a member of the Ohio Mushroom Society; or as a non-member attending any event hosted by the Ohio Mushroom Society, I agree to assume total responsibility for my own safety and well-being; and that of any minor children under my care, and for the protection of my and their personal property. I release the Ohio Mushroom Society, its board members, club members, contractors, and any and all entities such as parks or preserves, or any private property owner who may host an Ohio Mushroom Society event, and all other persons assisting in the planning and presentation of any Ohio Mushroom Society event, from liability for any sickness, injury, or loss I or any minor children under my care may suffer during any event or as a result of attending or participating. I further promise not to file a lawsuit or make a claim against any of the persons or entities set forth above, even if they negligently cause me or my minor children injury or loss. I agree to hold the Ohio Mushroom Society harmless from any liability they may incur as a result of any damages to any property I may cause. This release and promise is part of the consideration I give in order to be a member of the Ohio Mushroom Society, or to attend any event which they host or attend, whether a member or a non-member. I understand this affects my legal rights. I intend it to apply not only to me but to anyone who may have the right to make a claim on my behalf.

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