

You're listening to Fungi Town and this is Episode 17: Nematodes Beware!

[Fungi Town theme music]

[0:00:15]

Welcome to Fungi Town, where we lure with lollipops, nurture natives, and round up roundworms. I'm your host and mayor of Fungi Town, Jen Parrilli. Today, we're going to speak with Dr. Greg Thorn from the University of Western Ontario about fungi that have evolved to trap and digest nematodes.

[0:00:33]

Before we begin the episode, I have a couple of mayoral announcements. First, I want to thank all of the Fungi Town citizens who have been patient while the show was on hiatus. Due to some unforeseen events, Fungi Town was forced to relocate over the holidays. The show is now coming to you from its new home near San Antonio, Texas! Also, the "Saltshaker of Death" episode I promised last time has been postponed. I hope you'll enjoy today's guest and learning about carnivorous fungi!

[0:01:02]

Today's episode focuses on nematode-eating fungi, but that might not seem very significant unless we know what a nematode is in the first place. Nematodes are animals, very, very small animals. According to the [University of Nebraska at Lincoln](#), they are the most numerous multicellular animals on the planet. There are around 20,000 described species of nematode, and probably many more that have yet to be discovered. One handful of soil from your backyard is likely to have thousands of these little worm-like creatures living in it and they are everywhere in the world where there's water. They're pretty simple creatures, resembling the shape of an earthworm and lacking dedicated circulatory and respiratory systems.

But they do have mouths and many of them are parasites that infect plants, insects, or animals. About 44% of them are animal parasites - which includes human pathogens. Nematodes cause all kinds of nasty-looking infections with unpronounceable names. But, if nasty-looking, unpronounceable things are your jam, I've included a link in the show notes for a list of nematode-caused human diseases. Ick.

They can also cause serious problems with plants. About 15% of nematodes are plant pathogens. They infect beets, wheat, and other important crops, feeding on roots, stems, leaves, flowers, and seeds. A 1987 estimate by Sasser and Freckman said that nematodes caused \$77 billion worth of damage a year, worldwide. And that was in 1987.

The rest of the nematodes eat things like bacteria, protozoans, and yes, even fungi. So, maybe the fungi are taking their revenge. After the break, we'll find out how beneficial fungi like oyster mushrooms use nematodes as a food source.

[0:02:58] **Break:**

I am truly thankful to the guests who visit Fungi Town. Despite busy schedules, they take the time to share their expertise and enthusiasm with us. So I like to show my appreciation by sending them a hand-written thank you card. Even though we live in an age of instant connectivity, it feels pretty special to get a surprise in the mailbox, something you can hold and touch, something the sender put care into. But, sappy, mass-produced grocery store greeting cards are *not* for me. That's why I order all of my notecards from Haley at Lichen Landscapes.com. Each card features a gorgeous, hand-drawn illustration of a different lichen. The cards come in packs of four different designs and are blank inside so you can customize your message. Not only can you find a variety of cards at Lichen Landscapes.com, but you can also order Haley's beautiful lichen prints. They're a great way to show your fungi love. You can get 10% off of your entire order when you enter the promo code "FungiTown." Not only will you save 10% for yourself, you'll also be giving back to the podcast because a percentage of your order will go to support the show. So get on over to Lichen Landscapes.com and discover your new favorite design! So what are you waiting for?

[0:04:13]

Welcome back. Before the break, we learned a little about nematodes and the problems they can cause. But some familiar fungi have adapted to turn these little monsters into meals. To get more information, I called on one of our neighbors to the north.

[0:04:27]

I'm Greg Thorn, and I'm a mycologist in the Department of Biology at University of Western Ontario, in London, Ontario.

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And what is your current research?

GT: I'm looking at the Ecology of fungi in a very broad sense, particularly soil fungi. And one of the things that we're working on right now is the communities of soil fungi and how they are affected by agriculture. In other words, what does agriculture do to their diversity and their composition as communities? And also conversely what do fungi do to the agricultural crops and what members of the community may actually be affecting the yield of crops. And so might we tweak, if we wanted to increase yield, without applying a whole lot of fertilizer or pesticides.

[0:05:17]

I don't think I've ever seen a nematode. They're kind of worm-shaped and really small?

GT: Yeah, they are very small. Or at least most of the nematodes we're talking about are very small. The biggest of them would be about a millimeter long. And 1/100th of a millimeter in diameter. So about the diameter of your hair, but in little wee millimeter or half-millimeter long bits. So you can imagine they're not really easy to see with the naked eye. And they're clear, they're colorless. So, under a dissecting microscope you can see them swimming around, but it does take some magnification to actually see these guys.

[0:06:01]

If I go out to my backyard and take a scoop of soil am I likely to find some nematodes if I put them under a microscope?

GT: Yeah. So what you could do is you could take a Petri dish with just water agar in it and sprinkle some soil on it like that and the nematodes would come out of their soil and start swimming around. And if you're patient you can actually watch some of them get trapped by the fungi that are in the soil. So your garden soil very likely has nematode-trapping fungi in it as well. And so that's an exercise that we do in our lab. We actually bait the plates with some extra nematodes, so we put the nematodes on the plate and then the students sprinkle a little bit of soil from their garden, or wherever they get it on their way to class, and after a couple of weeks we find that the nematodes have essentially baited out from the soil the nematode-trapping fungi.

[0:07:01]

Tell me more about the - I'm not sure if I'm pronouncing this right - the Nematophagous...

GT: Nematophagous.

Tell me more about nematophagous fungi. They actually trap and eat nematodes, right?

GT: Right, so some of them trap them. And you might call them predators in that sense, because one mycelium of the fungus - all the network of fine, microscopic threads in the soil or rotting wood, wherever it's growing - produce actual traps. So that when a nematode passes through the trap or over the trap if it's a sticky one, the nematode is caught and then gradually penetrated and digested. And then its nutrients are passed through the mycelial network to allow that network to continue growing and perhaps reproducing. So one mycelium can trap many many, thousands even, of nematodes. So it's very much like a predator. Other nematode-eating fungi, or nematophagous fungi catch one nematode at a time. And they do this by either sticking to them, using an adhesive spore, or getting swallowed by the nematode, or some other mechanisms which are really very fancy. But one way or the other one nematode swims away and then is colonized from inside by this new parasite, you might say. And it's not really a parasite, it's more like the parasitoids that entomologists talk about, where mama wasp lays an egg in a caterpillar. The caterpillar grows but meanwhile so does the baby wasp. And eventually the baby wasp eats the whole caterpillar and out pops not a butterfly, but an adult wasp. Same with the fungi. They eat the whole nematode, and so instead of laying eggs or

more baby nematodes the nematode body is entirely taken up by the fungus, and it grows out and produces more spores, which go off and catch more nematodes.

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When you're talking about traps, I think I've seen some that are sort of like a circle, and then they swell up when the nematode crawls through them?

GT: Right, those are called constricting rings. Those are probably the most famous kind of traps because they are really dramatic. And so the BBC, for instance, has some really nice footage of that under the microscope. And so the nematode passes through what looks like a hoop. But when it touches the inside of the hoop, the cells actually inflate and constrict around the body of the nematode, so that it is literally physically caught. Other ring traps don't inflate like that and they're the so-called non-constricting rings, and they're just adhesive. So the nematode swims off with what looks like a series of collars of little rings around its neck, you might say (nematodes don't really have necks, but that's okay). And then one of those rings will actually germinate and penetrate through the body of the nematode and colonize it that way. But the constricting rings are intended to hang on to the nematode where it gets caught, and then if the nematode rips it off the mycelium, because it's a big, strong nematode, well then it acts like a dispersive spore. So it actually penetrates the nematode after all, and the nematode dies in the end anyway.

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And then there are sticky traps, too, you said?

GT: Yeah, so quite a few of them are just like little lollipops and the nematode comes up, and some of them actually try to lick these lollipops because they must have some sort of attractive odor or flavor. And so the nematode puts its mouth around it and then finds that it's stuck. Others just simply stick to the skin of the nematode as it's passing by. And the chemistry of the glue has been investigated in some of these fungi. There's an actual chemical bond that's specific between the glue of the fungus trap and the skin of the nematode. A kind of lectin-carbohydrate bonding.

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So I read that some of the fungi only make these traps when they're near nematodes, when they live in an environment where there are nematodes. What do these fungi do when they don't have that food source?

GT: Well, most of the nematode-trapping fungi are both nematode eaters and decay organisms. So for instance, the ones with the constricting rings and the non-constricting rings, the *Arthrobotrys* type of nematode trapper, they actually are litter decomposers. So they're growing through rotting logs or rotting leaves, or in the soil digesting plant litter. And presumably the nematodes are an additional source of nitrogen for these fungi because nitrogen is in either low supply or very heavily competed for in the environments where they live. So like a carnivorous plant, these fungi have evolved adaptations to get their extra nitrogen from a special source not available to other fungi that they compete with.

[0:12:29]

Well, the plants in the soil are using nitrogen, too, right?

GT: Yes, of course. So yeah, in soil there's proportionately lots and lots of nitrogen but there's also millions or even billions of organisms that are competing for it. And so these guys have a special way of getting their nitrogen.

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So how does the fungus know - the constricting trap, how does it know that there's a nematode in there? What triggers it to constrict?

GT: It does seem to be a physical stimulus. And it can be mimicked with a very steady hand. George Barron, who I studied with for my Master's Degree, had a very steady hand, and under the microscope he actually stimulated these constricting rings to constrict around a glass needle. So it didn't have to be a nematode, but something that was small enough to get in the space and touch it, or stimulate it with a little bit of heat would cause the ring to constrict.

[0:13:28]

Okay, so it can sense the nematode through heat?

GT: Possibly through heat or more likely through just the sensation, the touch of the nematode passing through the inside.

[0:13:41]

Is that kind of like the little hairs inside a Venus fly trap that trigger it to close?

GT: Exactly, yeah. So there's some kind of a physical stimulus, a touch sensitivity on the hairs of the Venus fly trap, or in this case on the ring. And then of course it sets up a whole physiological cascade of things that have to happen for the cells to inflate.

[0:14:06]

Cool. And they fill with water?

GT: Yeah, presumably the rest of the mycelium has lots of water, and the ring must have a very high osmotic - osmoticum - it must have a lot of salt solutes in there, salts or proteins or whatever in solution. And so when it's triggered, it lets the water in and the cell swells up. I mean that's a hypothesis but it sounds good, anyway.

It's very dramatic.

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Are the relationships species-specific, or can a fungus catch different types of nematodes?

GT: Most of them are very general. So, most nematode-trapping fungi catch many different kinds of nematodes. But there are a few species that have been found to be at least genus-specific or kind of group-specific, so they don't eat every nematode. But they eat just a few. And they're of course a little less common, or a little less commonly seen.

[0:15:07]

That's pretty cool. A very interesting evolution. In your lab, it looks like your lab uses *Pleurotus ostreatus*.

GT: Yeah, so *Pleurotus ostreatus* is the common oyster mushroom that people may know from the grocery store, and it turns out that it's a very active nematode-eater. And its story is a little different. Of course it's a mushroom, not an ascomycete. And it's a very, very good wood rotter, and because it was an edible mushroom it's been known for centuries. But this part of its life cycle, that it eats nematodes, wasn't known until the 1980s. So that was kind of one of the fun things that we discovered when I was working with George Barron, that if you grow it in a Petri dish culture with no extra nutrients, so we just grow them on water agar, and then after it's grown out a while you add some nematodes. Lo and behold it produces these little toxin droplets that immobilize the nematodes. The nematode bumps into the toxin droplets and after a while it stops swimming. And then the hyphae of the *Pleurotus* actually grow towards the mouth of the nematode, while it's still living, and down its throat, and then digests it from the inside out.

[0:16:28]

So you can actually watch this happen?

GT: Absolutely, yeah. And if you're patient, you can watch it on the microscope stage itself. Over the course of a few hours, you can see the nematode stop moving and then the fungus hyphae approaching and then eating the nematode.

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It sounds like the oyster mushroom isn't the only fungus that feeds on nematodes.

GT: Right, so when we started looking at it as a broader phenomenon we tested quite a number of different mushrooms or different kinds of basidiomycetes. And we found that relatively few - and in our time only members of the genus *Pleurotus* and a very closely related related genus called *Hohenbuehelia* - eat nematodes. And it turns out that those two genera are sisters; very closely related evolutionarily. And then a little bit after our studies, some researchers in Taiwan discovered a different, quite unrelated group of mushroom fungi that also eat nematodes by a different mechanism. But yeah, it's not a widespread phenomenon, but it's not limited to just one species or a few. It's probably dozens or even hundreds of species that are eating nematodes in the mushroom group. And several hundred more in the ascomycetes.

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These nematodes are in trouble.

GT: Well that's the thing, there's so many millions of nematodes. So in a square meter of nice prairie soil, you could get tens of millions of nematodes. So they're out there in huge numbers, and they've been around for millions and millions of years. So yeah, the fungi have figured that out and many of them have chosen that as a source of their nutrition.

[0:18:16]

I live in - obviously, I live in the US in sort of a temperate climate. The fungi and the nematodes - are they sort of world wide, or do they only occur in specific climate areas? What kind of ecology?

GT: They are quite broad in their distribution, and there was an Irish researcher who had some money for a trip, I guess, and went to the Antarctic. And they've been detected in Antarctica. They've been detected on every continent that mycologists have looked for them. But I would say they're particularly abundant in the temperate areas, in temperate deciduous forests, temperate grasslands, they're probably about as abundant and diverse in those habitats as anywhere in the world.

[0:19:03]

I noticed that you have some links to biodiversity gardening on your website. Can you explain a little bit about what biodiversity gardening is and what role nematodes might have in the garden?

GT: Sure. So, biodiversity gardening is the concept that we humans have taken over so much of the earth, and converted it to a very homogeneous habitat; lawns, and a lot of imported non-native species that we plant in our yards. And if instead you have a biodiversity garden you would plant the species that grow in your part of the world, and that form the food base for a lot of the organisms that used to live there, that maybe now are much less common than they used to be; all the insects that depend on certain species of plants, and then the birds that depend on those insects for food. So in our own house, we've planted about 100-150 species of native plants. And with those come some of the really cool caterpillars, the caterpillar of the giant swallowtail that only feeds on one species of shrub in our habitat. And that in southern Ontario is quite rare. So the moment we planted it on our front yard, we had the giant swallowtail caterpillar that summer. And so nematodes would benefit from that increased diversity as well, because rather than having a kind of sterile lawn, with just one or a few species of grass, and lots of pesticides and fertilizer and things that affect their abundance, well, you've now got a more natural ecosystem with lots of different kinds of plants, lots of decaying leaf litter, and so it's a much richer microbial habitat as well as plant habitat.

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And so when you are planting more native plants in your yard and different types of plants, that brings the nematodes? And then the fungi come in, too?

GT: Yeah, you could speculate that. We certainly haven't done any studies on that, but you would certainly expect that a more natural, diverse environment would have more habitats for

different kinds of nematodes and also for different kinds of nematode-trapping fungi. Most people would do biodiversity gardening because they like birds and birds need insects. And so if you feed the insects; if you provide the plants that are necessary for them as pollinators and as host plants for rearing their caterpillars or their young, then you'll have more birds that feed on those insects. And so most people think of biodiversity gardening for the big organisms that we are more familiar with. Personally, I think biodiversity gardening has a lot of potential at the small end of the scale, too, for things like nematodes or fungi and even bacteria, if anyone cared about those.

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Are nematodes, as a gardener, your friend or your enemy?

GT: They're both. So most of the nematodes that my fungi are feeding on are probably friendly nematodes in the sense that they're eating bacteria. And so what those free-living nematodes, or bacterial-feeding nematodes are doing is just cycling the nutrients and making them more available to plants. Unfortunately, amongst the many thousands, or perhaps even a million species of nematodes - no one knows how many nematodes there are - there are lots of plant-parasitic nematodes. Nematodes that will eat the roots of your crop plants, distort the shape of your carrots, do all sorts of nasty things to your tomatoes. So having nematode-trapping fungi in your garden, because you've got more nematodes as a whole, could actually help control the number of pathogenic nematodes that you don't want.

[0:23:13]

It's time for de-funked, a segment where I debunk fungi myths and misconceptions. The Atlantic recently published an article titled, "When Tulips Kill." It's a great article and you can find a link to it in the show notes for this episode. But it got me thinking about fungicides - chemicals designed to kill fungi. Although I'll dive deeper into this topic in a later episode, I wanted to chat with Dr. Thorn about why fungicides are dangerous not just to the fungi, but potentially to us humans as well.

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Are there any myths or misconceptions about fungi that you'd like to help clear up?

GT: Well, I think it's now pretty well established, and so it's made it to textbooks that fungi are not plants. And I still like beating on that, because a lot of my students, even though they, you know, they grew up very recently here in a fairly well-educated part of the world, they still think they're plants because they don't move and they have seeds. And evolutionarily that's so far from the truth; that fungi are much closer to animals and indeed that's why when you get a really pervasive fungal infection, the chemical that you take to treat the fungal infection just about kills you because we're pretty closely related.

[0:24:37]

I was just reading an article about fungi that are becoming resistant to fungicides, medically. And - I think this was in the Netherlands - and they found out that these fungi were becoming resistant because of agriculture; because they were being sprayed with chemicals in

agriculture and in gardening and they became resistant to these chemicals. And a lot of the same chemicals were used in medicine to treat fungal infections. And so there's growing concern that - sort of like with the antibacterial resistance.

GT: Right. That is going to be a growing area. And if we keep relying on a very narrow spectrum of antifungals it's no surprise that fungi that we keep treating with the same thing time and time again are going to come up with mutations to resist that. And if we do it in agriculture, which as you say is very broad spread, one of those resistant fungi is going to come out of that environment and may be our next major pathogen.

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Yeah, I think that fungicides are not as controlled in agriculture as they are in medical environments. So I think that they can spray a bunch of stuff outside that they - if they were treating a patient with it, it would have to go through different protocols.

GT: Well, I think it's...I really can't comment on the regulation, but certainly the surface area that gets covered with agricultural pesticides is very, very large. So you're treating lots and lots of - the population of fungi that you're treating is huge. So the likelihood of there being one or two mutants out there that are then selected by this fungicide are quite high.

[0:26:53]

Would you like to hear your music on an episode of Fungi Town? Just email your .mp3 to fungitownpod@gmail.com to get your de-funked theme in the next episode of the show!

[0:27:04]

That wraps up episode 17 of Fungi Town. Thanks to Dr. Greg Thorn and the Mycological Society of America's Student Section.

[0:27:12]

Fungi Town is written, edited, and produced by me - Jen Parrilli and hosted by Podbean. The theme song is by Athens band Shehehe. You can find all of their awesome songs on their BandCamp page at Shehehe.bandcamp.com. Episodes of Fungi Town are released roughly every other week. Be sure to subscribe so you don't miss the next episode, where we'll interview our second round of Fungus Olympics contestants. You can join the conversation and share your fungi photos with Fungi Town on Facebook, Instagram, and Twitter @fungitownpod. Check out Fungi Town's YouTube page for exciting extra features. If you like this podcast, please subscribe and leave me a review on iTunes. This goes a long way toward helping more people find their way to Fungi Town. Thanks for listening!