TPWKY	This is Exactly Right.
Winifred Frick	Hi, I'm Dr. Winifred Frick and I started studying white-nose syndrome when I was a postdoc and I'd been interested in population ecology and conservation biology of bats but had not worked on hibernating bats. And I got introduced to the topic of white-nose syndrome by Dr. Tom Kunz who is really the godfather of bat biology in North America and he was a professor at Boston University. And he invited me to be a postdoc with him and I went to visit him in the summer of 2009 and he had basically been studying little brown bats in Massachusetts and New Hampshire for decades really, like had a whole system of a set of maternity colonies which is where females come to raise their pup, that he had trained graduate students and also had a field camp with undergraduate students. So this was his system and really these bat colonies were part of his life and his study system and really like old friends.
	So this was the summer of 2009 and so it was really early on in the WNS epizootic and we went on a tour, he took me on the tour of all these maternity colonies and every time we would show up, instead of being thousands of bats chattering and these are like in old barns and attics and things and you should've been able to hear little chitters and chatters of the females doing their social calls while raising their pups, it was just silence and there were no bats there. And we would get to the next site and it would be the same thing and it was just so heartbreaking and I could see on Tom's face just the loss of these bats that he knew and had this long term relationship and that they were gone.
	And a couple years later I was working in Virginia and doing underground surveys there and it was sort of a similar thing where we would go underground with Rick Reynolds who's the state biologist in Virginia to these sites that he knew and he knew all the bats that should be in there are we'd get in there and the main cavern where there should have been thousands of bats was just empty. And it was that same look of just kind of disbelief and a sense of personal loss for these folks who had a relationship with these sites and with these bats and seeing them just be gone.
TPWKY	(This Podcast Will Kill You intro theme)
Erin Welsh	Wow. I just can't imagine the devastation.
Erin Allmann Updyke	I know, it's so horrific.
Erin Welsh	You just heard from Dr. Winifred Frick and we are very excited because this is not the only time in the episode that you will hear from her, she actually was kind enough to spare some of her time to chat with us about white-nose syndrome.
Erin Allmann Updyke	Yes.
Erin Welsh	Which is the topic of today's episode of This Podcast Will Kill You. Hi, I'm Erin Welsh.
Erin Allmann Updyke	And I'm Erin Allmann Updyke.
Erin Welsh	And we did that completely backwards. (laughs)
Erin Allmann Updyke	I love it actually that was fun. It's fun to do things a different way sometimes.

Erin Welsh	I know, I was like I don't know where we're going anymore with this. It's great. But we know where we're going with the topic of today's episode which as we mentioned, white-nose syndrome, it is a wildlife disease.
Erin Allmann Updyke	Yeah.
Erin Welsh	It's one of our first this season.
Erin Allmann Updyke	I think it is our first one this season, yep.
Erin Welsh	Yeah.
Erin Allmann Updyke	We've only done a few in our history thus far so I'm excited about this one.
Erin Welsh	Right. Wildlife exclusive. Yeah, yeah.
Erin Allmann Updyke	Yeah.
Erin Welsh	But I'm very excited because this is the kind of thing where in grad school we learned about this as a developing issue and it still is very much developing.
Erin Allmann Updyke	Right. I know. I remember hearing a lot about it back in like 2013 when I first started grad school and I feel like I haven't been hearing about it as much lately and so it was really great to do a nice deep dive. And I learned so much that I never knew. Like all I knew was oh, the bats are dying.
Erin Welsh	Yeah, exactly. It was really cool to do this deep dive and I'm really excited to hear what you have to say.
Erin Allmann Updyke	Ooh, I'm excited to hear what you have to say and I'm also excited Erin, like you mentioned, to speak with Dr. Winifred Frick who is incredible and a true expert on white-nose syndrome and bats.
Erin Welsh	Yes, yeah.
Erin Allmann Updyke	So very exciting.
Erin Welsh	But before we get into all of that, we have some business to take care of.
Erin Allmann Updyke	the most important business: it's quarantini time!
Erin Welsh	It's quarantini time. What are we drinking this week?
Erin Allmann Updyke	We're drinking Wingin' It.
Erin Welsh	Wingin' It. Because as we sat down to record we kind of realized that we had forgotten to name this quarantini.
Erin Allmann Updyke	We forgot. It's fine, we wung it.

Erin Welsh	We wung it. Yeah. I like the name though.
Erin Allmann Updyke	I love it, it's perfect.
Erin Welsh	And I also like what's in the quarantini which is-
Erin Allmann Updyke	Tequila of course because Erin tell us why we had to choose tequila.
Erin Welsh	Because without bats, tequila wouldn't exist.
Erin Allmann Updyke	It wouldn't exist.
Erin Welsh	Bats pollinate the agave plant which is what is used to make tequila. So bats are crucial.
Erin Allmann Updyke	Crucial for tequila.
Erin Welsh	Yeah.
Erin Allmann Updyke	But it's not just tequila, you know we spiced it up a little bit, added some peach green tea, some orange liqueur, some lemon juice, it's like really quite tasty and refreshing.
Erin Welsh	Yeah, super refreshing. And the most important thing about this and I don't know if it actually adds that much to the flavor, it might detract, but you rim the glass in powdered sugar for white-nose syndrome. And we will post the full recipe for this quarantini as well as the nonalcoholic placeborita on our website thispodcastwillkillyou.com as well as on all of our social media channels.
Erin Allmann Updyke	All right, other business that we always have to mention. We have a really great website, thispodcastwillkillyou.com. On it you can find a link to our Goodreads list, our bookshop.org affiliate account, our music by Bloodmobile, transcripts of every episode, nonalcoholic episodes, all of our merch. Oh my gosh, there's just so much, go check out our website.
Erin Welsh	Yeah, I think that about covers it. So can we learn about white-nose now?
Erin Allmann Updyke	I would love to. Let's take a quick break and then dive into the biology.
TPWKY	(transition theme)
Erin Allmann Updyke	So white-nose syndrome, sometimes in the literature also called white-nose disease but we're gonna call it white-nose syndrome. This is a disease of hibernating bats that is caused by a fungus named Pseudogymnoascus destructans, it's a very appropriate name.
Erin Welsh	Oh yeah. I think I just call it Pd cause I saw that 'pseudo' and was like I'll attempt that once if I have to but that's it.

Erin Allmann Updyke	Yeah. Called Pd for short. It used to be called Geomyces destructans but it's a different genus. Anyways, Pd for short. And I know that Erin you're gonna talk about the discovery of this fungus and this fungal infection but suffice to say it is a very recent discovery and has since been the cause of mass fatalities among hibernating bats in North America. This fungus is what's called a psychrophilic fungus which means it's cold-loving so it grows at temperatures generally between 10 and 15 degrees Celsius and it really maxes out at like 20 Celsius, so it can't really grow above that.
Erin Welsh	Right.
Erin Allmann Updyke	Which for those of us in the U.S. is like 50 to 68 degrees Fahrenheit. And that aspect is really important but I'm just gonna put a pin in it for now and we'll talk more about it later. So white-nose syndrome was first noticed and named - I hope I'm not stepping on your toes, Erin - in a picture because this fungus literally grows on the skin of the muzzles, which are the tiny little bat noses, as well as their ears and wings. And it looks like a little white fluffy Santa Claus beard kind of.
Erin Welsh	Yeah.
Erin Allmann Updyke	Right?
Erin Welsh	Yeah.
Erin Allmann Updyke	Yeah. At least one paper described it as, quote: "the delicate exuberant white filaments that obscure the muzzle."
Erin Welsh	Wow that's like such a cute description for such a horribly devastating fungus.
Erin Allmann Updyke	Isn't it? I know! I know, it makes it sound really adorable. It's not. On the wings where it also can grow it looks kind of like a tacky white film almost. But it also can present a lot more subtly with just kind of a loss of... You know how bat wings are kind of a little bit shiny looking? So infected bat wings can kind of just be a little less shiny or maybe just have small little tears in them that you wouldn't necessarily see unless you were looking very closely. And like we mentioned, as fluffy and cute as it might look in some pictures, this fungus is nothing of the sort. It's a lot more sinister, it doesn't just grow on the fur or on the fur where you see it.
	Histologically if you look at the skin underneath a microscope, what you'll see are these fungal hyphae which we've talked about this season earlier in our coccidioidomycosis episode. It's the tree-like branching fungal form and so if you look under the microscope you'll see these little tree-like fungal structures that invade the epidermis, the skin of the bat, and form these little cup-like erosions, these little ulcers that erode down into the underlying connective tissue. These fungal hyphae will invade and essentially can like replace hair follicles, they can invade sebaceous and apocrine glands, so these are glands on skin like we have them too that secrete oils and sweat and things like that around the muzzle. And on the tips of these hyphae are one of the things that can distinguish them from other species of fungus. They have these conidia, which are spores, the reproductive structures of fungus, and they're little curvy little nugs. They kind of remind me of a malaria parasite without the tail.
Erin Welsh	Okay, yeah.
Erin Allmann Updyke	I feel like that's what they look like under the microscope, kind of like a little boomerang shape.

Erin Welsh	Right, right.
Erin Allmann Updyke	Okay. So bats who are infected with white-nose syndrome during hibernation, these are hibernating bats that are infected, by the end of their hibernation season they generally appear very, very emaciated, they're starving and very often they'll die. Infection intensity in affected hibernacula, which is a new word I got to learn-
Erin Welsh	I noted that in mine too! I was like I love this word. (laughs)
Erin Allmann Updyke	Hibernacula is like where bats hibernate, like their caves and things. Infection intensity often reaches 100% by the end of a winter hibernation season. But actual mortality rates vary greatly by species which we'll talk a lot more about.
Erin Welsh	Right.
Erin Allmann Updyke	So that's like the fungus and the symptoms. Like we've covered a lot of ground in a short amount of time. And we now know that the end result is massive, massive die-offs of hibernating bat species. So the question that I want to get at in more detail in this biology section is how in the heck does this happen? Like why are bats so susceptible to this pathogen? What bats are we even talking about? Because the thing is these skin lesions that I just explained, like it's just a mold that grows on the wings and the nose, that doesn't sound that pathologic but that's just what you see. It doesn't explain how these bats end up emaciated and dead. Right. So to understand that there's two main questions that I'm gonna try and answer. One is why these bats are susceptible to the fungus to begin with and the second is what's going on within this infection that causes these dramatic effects. So first to answer the question of why these bats are susceptible. We'll focus on the biggest piece of the puzzle and that is that white-nose syndrome is a disease of hibernating bats.
Erin Welsh	Right.
Erin Allmann Updyke	So we get to talk about hibernation, Erin.
Erin Welsh	Which is very thrilling because-
Erin Allmann Updyke	It really is.
Erin Welsh	I similarly to you went on a bit of a deep dive into the evolution of hibernation and as I was putting my notes together I was like I don't know where to put this so I'm just gonna put it in parentheses somewhere.
Erin Allmann Updyke	In the fun fact section. (laughs)
Erin Welsh	Yeah, exactly. My gosh, the history section I'm just gonna be sprinkling some fun facts in there because it's such a short history, so anyway.
Erin Allmann Updyke	I love it.
Erin Welsh	I'm excited.
Erin Allmann Updyke	I'm excited too. Let's talk about what hibernation actually is because I think a lot of us probably don't really know, right?

Erin Welsh	Yes.
Erin Allmann Updyke	You'll think of like a bear that eats a lot and then goes into a cave and hibernates. What does that mean? All right. So during times of scarce food supply, aka usually winter, some endothermic animals, so like birds, mammals, not lizards and snakes, animals that control our own body temperature internally, that process requires quite a lot of energy. So one way that some endothermic animals cope with this food scarcity is by entering a state called torpor. I'm learning so many new words, it's so fun.
Erin Welsh	(laughs)
Erin Allmann Updyke	And torpor is when these animals can decrease their metabolic demands substantially. Often body temperature drops substantially and then heart and respiratory rates drop, energy expenditure massively drops. So animals can then survive these periods of very, very low food supply just by living off of their stored fat essentially. These torpor phases can last anywhere from 6-40 days depending on the species and hibernation makes up these torpor periods interspersed with a few hours or maybe up to 24 hours of quote "arousal" periods where the animal often will bring their body temperature back up to normal or just move around, be a little bit more aroused than during torpor. But this is important, during these torpor phases, especially small mammals that hibernate, body temperature can drop as low as 10 degrees Celsius or lower. That's 50 degrees Fahrenheit.
Erin Welsh	It's amazing.
Erin Allmann Updyke	That is so not normal for most mammals.
Erin Welsh	Well it's also interesting... Well anyway, I'll get into the evolution of it later but... (laughs)
Erin Allmann Updyke	(laughs) Oh I love it. It's really, really fascinating. So just to kind of put that in context, like what range are we talking about? Human body temperature we know is like 36 Celsius, 97-98 Fahrenheit. Little brown myotis, little brown bats, normally their roosts are around 100 Fahrenheit, 38 C although I've seen some studies that say their body temperature can hop all the way to 53 Celsius, 129 Fahrenheit.
Erin Welsh	Dang! What?
Erin Allmann Updyke	So they can be really hot and happy but during hibernation their body temperature drops down to within a couple degrees of their hibernacula where they're hibernating which is usually between 2-10 degrees Celsius.
Erin Welsh	Right, which is right in the range of little old Pd.
Erin Allmann Updyke	Oh, say that again Erin. (laughs)
Erin Welsh	Perfect setting.

Erin Allmann Updyke	Perfect setting for Pd. Okay. So that's hibernation, torpor, etc. So how does that altogether make bats so susceptible? You already said strike one, right, that that is the perfect temperature for Pd to grow, it is the temperature at which that fungus is most happy, all right. Strike one. Strike two, in addition to the depression of a lot of different metabolic features like respiratory rate and heart rate there's also a lot of evidence that among many animals overall immune response is drastically lessened during hibernation. And this makes sense because most bacteria and other pathogens can't replicate very well at low temperatures.
Erin Welsh	Right, yeah.
Erin Allmann Updyke	So in general, animals that have been studied during hibernation have up to a 90% reduction in circulating white blood cells. 90%.
Erin Welsh	I think I also remember reading somewhere that the hibernation, basically the rabies virus goes quiescent, like it'll just stop during hibernation.
Erin Allmann Updyke	That is fascinating. Like just stops replicating entirely.
Erin Welsh	That's what I remember reading, this is like where I'm putting a 'citation needed' to myself to go back and check. But I think I remember reading that, yeah.
Erin Allmann Updyke	I mean yeah, it makes sense that it would just persist but not still be replicating.
Erin Welsh	Right, it's like actually, you know, cryogenesis.
Erin Allmann Updyke	Right, yeah. Oh my gosh, so much interesting work about hibernation. It's a totally separate tangent, but...
Erin Welsh	(laughs)
Erin Allmann Updyke	So while these animals hibernate, even though there are periods of arousal, during that time you do see white blood cell counts rise but even during those arousal periods during hibernation, those white blood cell counts don't tend to rise back to summertime normothermic levels. So that's strike two, right. Strike one, we're in the perfect temperature zone. Strike two, we already have a depressed immune system. Strike three though is the clincher. White-nose syndrome affects the status of hibernation itself and that is how it has the devastating effects on these bats that we see.
Erin Welsh	Right.
Erin Allmann Updyke	So now we can answer that second question, how does this skin infection, what seems to be just a skin infection, cause emaciation, starvation, and death? Spoiler alert, we don't fully know the mechanisms of this but there's a lot of hypotheses and there's a lot of support for some of these. So I'll kind of go through what we know so far. First of all, bats that are infected with white-nose syndrome arouse a lot more frequently during torpor than uninfected bats. During these arousal periods, their body temperatures also increase to a greater degree than uninfected bats. Both of these things, more frequent arousals and body temperatures shifting at a greater rate likely lead to an increase in metabolic demand. And the thing is we don't fully understand exactly why it is that these bats are arousing more frequently when they're infected with white-nose syndrome but it's thought that it's very likely due to an increase in water loss.

Erin Welsh	Oh, okay.
Erin Allmann Updyke	Right? So even though this is called white-nose syndrome because of the white fluffy mold on the muzzle, it turns out that the major player in terms of infected area is actually the wings. So wings in a bat, besides being absolutely gorgeous, ugh the structure is so, so cool.
Erin Welsh	I know, I know.
Erin Allmann Updyke	But besides that, they're also a lot more than just skin, they're a lot more than just a bat's mode of transportation, they're a very physiologically active structure. They're involved in gas exchange, they're involved in fluid balance. And so it's thought that fungal damage in the wings leads to an increase in evaporative water loss which then leads to dehydration, fluid losses, electrolyte imbalances, and then increased arousal because of this water loss. Which then that increase in arousal leads to an increase in overall metabolic demand which then leads to eventual starvation and death.
Erin Welsh	Right, yeah.
Erin Allmann Updyke	There are other potential mechanisms at play, there's a lot of hormone changes that are seen with white-nose syndrome infection, there are behavioral changes that are deemed sickness behavior where bats that are infected are more likely to hibernate differently, like off to the side and alone instead of clustering.
Erin Welsh	Which is interesting in itself because of like transmission.
Erin Allmann Updyke	Exactly, right. And so it's thought too that is this somehow a protective behavior for the bat where they're trying to not get more infected from others who might be around them kind of a thing? There's a lot of kind of behavioral research on it. But they also, when they do arouse even though they arouse more frequently their behavior is different when they're aroused, they have reduced activity, they appear sick when they do arouse. And it's not really clear whether this is what exactly is kind of the cause of this but we do know kind of this overall picture that this infection leads to an increase in arousal, increased metabolic rate, premature fat depletion, starvation, and death in a lot of species of bat.
Erin Welsh	In a lot of species.
Erin Allmann Updyke	But not in every species.
Erin Welsh	But not.
Erin Allmann Updyke	And that is where this story gets so interesting and so complicated. So in North America where white-nose syndrome is a problem, at least as of today, 12 bat species have been found to be susceptible to white-nose syndrome and at least 6 other species have been found colonized with the fungus but without any real signs of disease or impacts on their population densities. And way back in our chytrid episode we talked with Dr. Taegan McMahon about how this is also true in amphibians. Some species of amphibians seem to be very tolerant of the chytrid fungus while others are really massively impacted, right? And the same is true of white-nose syndrome.

	So while we can say right off the bat that of course it has to be hibernating bats, like hibernation is a big part of susceptibility and not all bat species hibernate, although a lot do. In North America more than half of the 47 species of bat rely on hibernation to get through the winter. But it's not just that because the fungus responsible for white-nose syndrome has been found kind of all over Europe as well as the northern reached of Asia. And not only does it exist in caves and hibernacula but also on bats and it also causes a very similar white fluffy moldy beard but no disease, no white-nose syndrome.
Erin Welsh	Right.
Erin Allmann Updyke	Just white noses. So the question of what make some bat species very susceptible and some bat species not so susceptible is still a very open question. But there's a lot of people really trying to do the work to figure out what is the difference not only between the bat species in Europe and Asia that are very tolerant of this infection but also even in populations in the Americas that have survived infection, that have resisted this infection. There's a lot of potential theories out there. There's things like the specific microhabitats of hibernacula and little itty bitty differences between bat species in like the temperature of their hibernacula. There's a lot of cool work on the specifics of the physiology of torpor, so like how deep is your torpor or exactly what temperature do you get down to, things like that.
Erin Welsh	In my head is now 'How Deep Is Your Love' but 'How Deep Is Your Torpor'.
Erin Allmann Updyke	(laughs) That's really good.
Erin Welsh	Just FYI.
Erin Allmann Updyke	And that's our title. That's really funny. And also differences in immune response to kind of get at how are these different bat species reacting to this infection? Are they fighting it off? Are they just existing with it? Etc. But what's so interesting is that there's also some studies from bats in Europe that suggest that the infection doesn't result in as much tissue damage because the fungal hyphae don't invade as deeply into the connective tissue, so literally doesn't cause as much damage to the wings. But the fungus does invade around the muzzle and it's not a difference in the fungus itself because Pd strains from Europe are just as virulent in North American bats as Pd strains from here.
Erin Welsh	Right.
Erin Allmann Updyke	So it's really interesting and there's a lot of like very open questions still as to what are these real mechanisms of tolerance and resistance in these bat species. Cause if we can get at that then we can know more about maybe how to help protect other species.
Erin Welsh	It's really interesting because I think that like it once again shows how little we know not just about our own immune system but the immune systems of animals.
Erin Allmann Updyke	Oh my god. Right! What the heck? It's fascinating.
Erin Welsh	Yeah.
Erin Allmann Updyke	Yeah.

Erin Welsh	And I feel like one of the most exciting things about this, I mean it's like horribly devastating but I think that it's really exciting because this is all happening right now. Like there are studies going on right now to answer these questions.
Erin Allmann Updyke	Yeah. Speaking of studies going on right now to answer these questions, I think one of the biggest questions is like what can we actually do about this?
Erin Welsh	Right.
Erin Allmann Updyke	And we'll talk a lot more about that in the current events section with our expert, Dr. Winifred Frick. But I do wanna just mention that people are doing so many different things to try and prevent the spread of this fungal pathogen. So there are groups that are working on vaccines, oral virally vectored vaccines that are actually not dissimilar to the Johnson & Johnson and AstraZeneca COVID vaccines that are using a raccoon pox virus that expresses some proteins from this fungus.
Erin Welsh	Ooh interesting.
Erin Allmann Updyke	Yeah it's very interesting, it seems to induce an immune response, so that's very promising.
Erin Welsh	How practical is the logistics of the distribution?
Erin Allmann Updyke	That's I think the biggest thing is the practicality of it. People are also working on the application of probiotic bacterial treatments using bacteria that we use for other agricultural applications to help suppress fungal growth. Also the use of UV lights at the entrances.
Erin Welsh	Oh yeah, I saw that!
Erin Allmann Updyke	Isn't that so interesting? It turns out that this fungus has a mutation in its DNA that makes it highly susceptible to UV light which is why it only grows inside of caves on bats living inside of caves. So people have thought if we put UV lights at the entrances and exits of hibernacula, that'll kill fungal spores on the bats as they fly in and out. What?
Erin Welsh	Yeah, yeah.
Erin Allmann Updyke	So there's a lot of potential, I think there's a lot of creativity in how people are trying to tackle this massive problem that is devastating North American bat populations and has been for over a decade.
Erin Welsh	Yeah.
Erin Allmann Updyke	So yeah, that's the biology. I didn't let you ask any questions, Erin. (laughs)
Erin Welsh	I feel like you covered a lot of ground and I think that the unusual thing about this particular topic is that because it is so new, we probably read all of the same papers.
Erin Allmann Updyke	Oh I'm sure, yeah.
Erin Welsh	Because like the literature's only at most like 14 years old.

Erin Allmann Updyke	Right, yeah.
Erin Welsh	Mostly like 13 years old, so.
Erin Allmann Updyke	Okay well take us through that 13 year history Erin, would ya?
Erin Welsh	(laughs) I will, okay. Let's take a quick break first.
TPWKY	(transition theme)
Erin Welsh	In the late winter of 2007, biologists from the New York State Department of Environmental Conservation set out to visit some caves near Albany, New York for just a routine survey of the hibernating bats that were there in the area. You know, things like how many bats are there? What caves are they in? Where are they in the caves? How the hibernation seems to be going, you know that sort of thing. And one of the things they were looking out for of course is whether there was anything unusual that seemed to be going on with the bats. And I'm sure that the biologists conducting this survey expected it to be no different from the countless other surveys that they had done in previous years. But the scene that greeted them when they first entered the caves and turned on their headlamps was unlike anything that they had ever seen before.
	Maybe the biologists knew something was up during their approach to the caves when a few bats flew shakily out of the cave's entrance into the snowy landscape when instead they should be snugly hibernating inside. Or maybe the bodies of a few dead bats that dotted the ground a few steps outside of the cave's entrance gave them some indication as to what they might find on the inside. But I'm sure nothing could've prepared them for the scene that awaited them inside the cave. Absolutely piles and piles of dead bats on the floor of the cave. Others moving around, seeming to look for food despite the fact that this was deep in hibernation season and that there were no insects in the cold landscape for the bats to eat. And when the biologists moved on to other caves in the area, they learned that unfortunately this was no fluke. At at least three more of the caves where they surveyed they saw similar devastation with mounds of dead bats on the ground and more flying in the winter sun where they would not find any food but rather would be easy pickings for birds of prey.
Erin Allmann Updyke	I really can't even imagine how horrific a scene that must have been.
Erin Welsh	No. So in one of the books I read or in one of the chapters of the books I read, there's a picture of it that is-
Erin Allmann Updyke	Yeah. I saw that picture.
Erin Welsh	You saw that?
Erin Allmann Updyke	Yeah.
Erin Welsh	I mean we read all the same stuff.
Erin Allmann Updyke	We saw the same stuff. Yeah, it was really, really awful. Especially cause before that I had only seen individual bats with white-nose.

Erin Welsh	Right. I mean like just to give you some idea, in those four caves biologists estimated that between 8000-10,000 bats had died as a result of whatever was making them wake up from hibernation prematurely. But at that time they didn't know what it could. Was it infectious disease? Was it some sort of pesticide? Was it habitat disturbance by humans? At the time that these first bat die-offs were recognized, the world was no stranger to massive unexpected wildlife or plant losses. Colony collapse disorder in bees, chytrid in frogs, Tasmanian devil facial tumor disease, even the chestnut blight among many other things. By the way a lot of those are fungus, not all of them but a lot of them
Erin Allmann Updyke	Yeah, fungus among us.
Erin Welsh	Yeah, interesting. And each one of these enormous mortality events illustrated just how interconnected the world is not just in observing the cascades within an ecosystem but also in highlighting the roles that humans play, both as perpetrators of disturbance or as disseminators of infectious agents but also as victims themselves. Things don't happen in a vacuum as we are very fond of saying on this podcast and the role that any organism plays in an ecosystem is never negligible. And the impact of a lost species or at least the loss of a population can have on an ecosystem can be very difficult to predict. And if anything these mortality events have highlighted how wildlife or ecosystem conservation isn't just some altruistic venture to preserve the charismatic megafauna of our planet, it's necessary for our own survival.
	So the discovery of thousands upon thousands of dead bats in some caves outside of Albany was not just this tragedy that took place somewhere in New York, it rang some very big alarm bells across the globe. As we've talked about before on this podcast, bats are often unfairly scapegoated as pests, as bringers of disease, as whatever. But what is often not talked about enough is the absolutely integral role they play in the ecosystem and our economy and of course our health. There are over 1400 species of bats worldwide.
Erin Allmann Updyke	I was hoping you were gonna list these numbers cause I get so excited hearing about how many bat species there are.
Erin Welsh	(laughs) Press 1 to subscribe to bat facts.
Erin Allmann Updyke	(laughs)
Erin Welsh	There's gonna be a lot of them, here we go. These bat species occupy nearly every environment that you can think of and they display an incredible diversity in body size, in food preferences, in hibernation activity, in lifespans, social behavior, and so much more. And I wanna give a shout out also to the amazing bat researchers who taught me so much about bats at STRI, Smithsonian Tropical Research Institute in Panama.
Erin Allmann Updyke	I know, it's very thrilling. I had a line that I didn't say in my little writing here, I was like, 'We're not bat biologists but we have a lot of friends who are!' (laughs)
Erin Welsh	We do, I was just gonna say you heard someone on the podcast before, Alex Trillo who provided a firsthand account for Dengue.
Erin Allmann Updyke	Yeah!
Erin Welsh	Yeah, there are so many amazing bat researchers that I have encountered. I mean I still remember my very first year in Panama back in 2013 learning from a presentation by Rachel Page that there are more bat species on Barro Colorado Island, at least 74 species which is this kind of smallish island in the Panama Canal, than there are in all of North America.

Erin Allmann Updyke	Yeah. Like what?
Erin Welsh	It's so cool!
Erin Allmann Updyke	Do you know what I learned researching this episode? There are no about species in North America that are also in Europe. What?
Erin Welsh	Oh that's interesting.
Erin Allmann Updyke	Isn't it?
Erin Welsh	Did you know that some bats are incredibly long-lived?
Erin Allmann Updyke	No!
Erin Welsh	Like some live over 30 years.
Erin Allmann Updyke	What? 30 years?
Erin Welsh	Yeah. I think like at least six species live over 30 years and the oldest recorded bat lived 41 years.
Erin Allmann Updyke	Stop it, that's adorable.
Erin Welsh	I know. (laughs)
Erin Allmann Updyke	Did you know that the little brown bats are so little they're only like 5-7 grams?
Erin Welsh	They're so cute.
Erin Allmann Updyke	They're so cute.
Erin Welsh	And hold on, I also looked up the etymology of the little brown bat and I gotta find out what it is real quick.
Erin Allmann Updyke	I love this.
Erin Welsh	Okay so the etymology of the little brown bat, which the species name is Myotis lucifugus, 'lucifugus' means it's from the Latin 'light' and 'to flee', so it's like a little light fleer, like to flee the light.
Erin Allmann Updyke	Oh that's so cute.
Erin Welsh	Very cute. What are some other bat facts? There are some more bat facts but I also want to shout out a Kentucky fact which is that Mammoth Cave in Kentucky is the world's longest cave system with more than 400 miles of documented caves and probably much more extensive. It's also the only national park in Kentucky and it was also hit by white-nose starting in 2014. Bringing it back.

Erin Allmann Updyke	Bringing it back.
Erin Welsh	Okay. Bringing it back but also I'm not done with bat facts.
Erin Allmann Updyke	Okay good.
Erin Welsh	Articles about colony collapse disorder in bees often talk about the number of foods that would be lost to us without pee pollination. But did you know that there are also many foods that bats pollinate?
Erin Allmann Updyke	I did but tell all our listeners. (laughs)
Erin Welsh	Bananas, avocados, mangoes are among over 300 fruit species that depend on bats for pollination and many others rely on bats to help spread their seeds like figs and cacao. And bats also play a hugely important and often overlooked role in agriculture through insect control.
Erin Allmann Updyke	Yeah. Pest management.
Erin Welsh	Pest management.
Erin Allmann Updyke	We should pay them.
Erin Welsh	I know. (laughs) I read an analysis from 2011 that estimated that bats provide insect suppression services to commercial agriculture in the U.S. that is valued at on average 22.9 billion dollars per year.
Erin Allmann Updyke	That's billion with a 'B'?
Erin Welsh	Yeah, that's a lot.
Erin Allmann Updyke	That's a lot.
Erin Welsh	And if you've listened to some of our COVID episodes before, you know how we've talked about the importance of bat conservation for preventing spillover events. And we'll get into more of that later in our episode with our amazing guest but the bottom line is that these bat deaths in New York would have far reaching consequences. What exactly those consequences would look like or how intense they would be depended of course on what on earth was responsible for the deaths. And once that was figured out then the scope of the problem could be estimated and a plan for mitigating the spread could be developed.
	When the biologists had stepped into those caves, they noticed something striking about the dead bats that lay in piles on the cave floor. Not just the sheer number of them but also that many seemed to have this fuzzy white growth that was covering their nose and some had patches like on their wings or torn wings. And it looked like it could be a type of fungus that could be the source of all of this death but how would you even go about figuring that out? The identification was not necessarily an easy one because the places where these bats hibernate, the hibernacula, are chock full of fungi and probably most of them not fully characterized or never even isolated before.
Erin Allmann Updyke	Yeah that's a good point.

Erin Welsh	And so culturing any one swab, even if that swab was directly from the muzzle of a bat is likely to get you a lot of different fungal species. How do you know that you have the right one or the one that is causing the disease? Essentially you follow Koch's postulates. Number one, you have to find the pathogen in just the disease but not the healthy individuals. Number two, you have to be able to culture the pathogen from an isolate collected from a diseased individual. Number three, you have to be able to take that cultured pathogen and inoculate a healthy individual with it and then have disease result. And number four, you have to be able to then re-isolate that pathogen from that inoculated individual and culture it.
Erin Allmann Updyke	It was pretty exciting to read papers that did those things.
Erin Welsh	Yes.
Erin Allmann Updyke	I never get to read those papers. (laughs)
Erin Welsh	(laughs) Yeah and so that's exactly what they did. So they actually tested this with these hibernating little brown bats. And so finally then pretty soon after, it's not really a finally type of moment, they had the culprit which as you mentioned first was Geomyces destructans now it's P. destructans or Pd. The fungus that was causing this growth, Pd, hadn't been described previously but as you mentioned it did appear to be related to other fungal species that are also cold-loving and in the group it seems that some are pathogenic but to plants and not to animals. So it seems that this one is the only one in the group in one of the papers I read-
Erin Allmann Updyke	So far.
Erin Welsh	So far, right, that is pathogenic to animals. Okay so now that researchers had nailed down the pathogen responsible for this massive bat mortality, what were the next steps? Well one was to figure out just how bad this was. Was it only those four caves outside Albany or were there bats dying all over the country or all over the world? Understanding the current distribution of this fungus would help characterize the scope but it's also just a snapshot. You know, what's happening here at this moment in time. With mortality rates in the 90% range, understanding how this pathogen spread and where it came from was crucially important. White-nose syndrome as it came to be known was an emerging infectious disease but an emerging infectious disease can be newly emerging, as in it's existed there before but a recent mutation or change in the environment has led it to increased transmission in a way to make it more lethal or something like that. Or it's brand new, introduced into a naïve host population that has no evolutionary history with it. So why is it so important to make this distinction between whether a pathogen is introduced or re-emerging?
Erin Allmann Updyke	Yeah.
Erin Welsh	And it's important for predicting how it's going to behave and in how we try to control it. For instance, if the North American Pd had been around for a long time in North America and a new mutation had led to these die-offs, then introducing it to Europe for example like somewhere it didn't exist could be devastating for bat species there who were presumably naïve to that strain of the pathogen or the pathogen itself. But if instead it was introduced from let's say Europe to North America, that could tell us about how the European bat species cope with this fungus. And in terms of management, understanding whether a pathogen is introduced or has existed before is also super important. So if the pathogen had been present in North America before then management practices might focus on the factors that influence the virulence of the pathogen because you're not going to control its spread, there's nothing you can do to control its spread because it presumably already has spread.

Erin Allmann Updyke	Right, right.
Erin Welsh	But if it was new then management techniques focus mainly on controlling the agents that spread the disease. But in the case of white-nose that would mean controlling the bats themselves which is all but impossible.
Erin Allmann Updyke	Yeah.
Erin Welsh	Okay. So there are many different ways to test whether Pd was introduced into the U.S. from somewhere else or whether it had just evolved to be more deadly and I'm not going to go into all these different ways but I will list the results or the evidence that points towards this being a newly introduced pathogen into North America.
Erin Allmann Updyke	Excellent.
Erin Welsh	And I'm taking these points from a Nature paper by Zukal et al 2016 by the way, just to give credit where credit's due. Even though we will shout out all of our sources at the end. Okay so number one, none of the fungal communities associated with the North American bats and the places that they Hibernate, the hibernacula, are closely related to Pd. Number two, the isolates of Pd in North America seem to be all clonal from one single genotype suggesting-
Erin Allmann Updyke	Whoa!
Erin Welsh	Yeah. Suggesting one introduction.
Erin Allmann Updyke	Wow.
Erin Welsh	So if it had been here awhile, if it was something that had changed recently, we would see a lot more diversity.
Erin Allmann Updyke	Right.
Erin Welsh	Number three, since the first known instance in North America which as you mentioned was actually traced back to 2006 in a photo of bats with white-nose, the distribution of white-nose syndrome has followed a very clear invasion path. And there's one exception to that, so asterisk. Number four, Pd has been found in many European and some Asian countries as you mentioned including on bats but without the super high mortality that we see here. Number five, experimental infection of North American bats with Pd samples from Europe leads to disease or death. And number six, there's additional evidence that goes into like the fungal biology of it so basically like there's the existence of different mating types of the fungus in Europe compared to just one in North America.
Erin Allmann Updyke	What? That's cool.
Erin Welsh	Yeah, it suggests an introduction.
Erin Allmann Updyke	Right.

Erin Welsh	And so all of these bits of evidence put together, it's pretty suggestive that this fungus was introduced into North America from most papers say Eurasia. And they estimate that because of the diversity of the fungus in different sites in Europe and Asia and the fact that there appears to be either tolerance or resistance in the bats to the fungus there, it has probably existed in those places for millions of years.
Erin Allmann Updyke	I have so many thoughts.
Erin Welsh	I know. Yeah. I know I mean it's like this is such an ongoing area, it's like you can only almost dig so far down the rabbit hole in some ways or down the bat cave.
Erin Allmann Updyke	Right, exactly. Oh! That's good.
Erin Welsh	(laughs) The oldest specimen of Pd, at least that I came across, was a 1918 museum specimen of a bat that had been collected in France.
Erin Allmann Updyke	Wow, okay.
Erin Welsh	Yeah. So how did it get to North America? We still don't seem to know and it's possible that we'll never know the exact sequence of events. There are several different possibilities from the transport of an infected bat from Europe to the use of contaminated field equipment in North American caves, from tourists with contaminated clothing or shoes to maybe even I saw one paper suggest the import of European specialty cave-aged foods like some cheeses.
Erin Allmann Updyke	Wow.
Erin Welsh	Yeah, yeah. So while all this research was going on in terms of understanding where this fungus came from and how it's being spread and what are going to do about it, the pathogen continued to work, it continued to spread, it continued to kill millions and millions of bats. And that's actually the wrong tense of course because research is still going on and the pathogen is still continuing to spread. Since that first photo showing white-nose syndrome in New York from February 2006, the disease has spread to 39 U.S. states and 7 Canadian provinces. And while most of this spread is likely due to bat movement, some has been caused by humans such as when it showed up in western Washington state 1300 miles or 2100 kilometers away from the closest known contaminated site in Nebraska. And since showing up in Washington state it has continued to spread out from there. Is there a limit to the spread? Yes, there does seem to be partly because hibernation which is a key factor in the severity of disease is not as you mentioned a trait shared by all bat species. Here's my rabbit hole insertion of the evolution of hibernation.
Erin Allmann Updyke	Yes!
Erin Welsh	I wanna shout out a really interesting paper by Lazzeroni et al from 2018. And in this paper they talked about how the earliest bats which evolved sometime in the Eocene around 50-60 million years ago, they weren't necessarily hibernators, like they probably weren't hibernators but rather daily heterotherms, so they practiced this daily torpor.
Erin Allmann Updyke	What
Erin Welsh	And that is this midway between an endotherm and an ectotherm.
Erin Allmann Updyke	What?

Erin Welsh	Meaning that like with this heterothermy or daily heterothermy you can regulate their temperature themselves but also allow the surrounding environment to regulate it.
Erin Allmann Updyke	Right, oh my gosh.
Erin Welsh	So it was only later that hibernation and homeothermy evolved. And so this is also this longtime belief that the earliest mammals were homeotherms when in fact it might actually have been that they're heterotherms because that's sort of more inbetween.
Erin Allmann Updyke	It makes sense, yeah.
Erin Welsh	Yeah.
Erin Allmann Updyke	Yeah.
Erin Welsh	Like reptiles and amphibians and homeothermy.
Erin Allmann Updyke	Yeah, absolutely. And I never even thought about that as hibernation as a kind of way of doing that too. Oh my gosh, wow.
Erin Welsh	And it's so cool because all of these things too have been looked at as discrete traits but they're not, like this exists on a spectrum.
Erin Allmann Updyke	Right.
Erin Welsh	The way that like body temperature regulation is managed.
Erin Allmann Updyke	Oh my gosh. I went on a deep dive of bear hibernation and they barely even drop their body temperature, so they're able to do this amazing metabolic reduction without really reducing their body temperature very much. It was really fascinating.
Erin Welsh	And then there's like regional heterothermy. So like different body parts. I mean it's incredible, there is so much more to explore down these rabbit holes, down these bat caves. I love it. Anyway, okay. But not only do not all North American bats hibernate which would reduce their susceptibility to the fungus but also the environmental preferences of the fungus may prohibit it from establishing in some southern parts of the continent for example. So like it hasn't shown up in Florida despite showing up in nearby states for at least 7 years. But the worst may still not be over. More than half the bat specie sin the U.S. are severely declining or are endangered and other parts of the world where Pd hasn't yet spread are certainly at risk, such as Australia. Even though some bats are displaying resistance to the pathogen, population recovery will take a very long time. Because this is such a new disease, like there's not really much more to the history than this.
Erin Allmann Updyke	Yeah.
Erin Welsh	It's still being written and so I'm very excited for our guest this episode since she's one of the ones doing a lot of that writing.
Erin Allmann Updyke	Yeah.

Erin Welsh	So I will stop here so that we get to hear what the expert has to say about the ecology and status of white-nose syndrome today.
Erin Allmann Updyke	Excellent. We'll let her introduce herself right after this break.
TPWKY	(transition theme)
Winifred Frick	Yes I'm Dr. Winifred Frick and I'm the Chief Scientist at Bat Conservation International and an Associate Research Professor in ecology and evolutionary biology at the University of California Santa Cruz. At Bat Conservation International I lead our science department that's really focused on trying to use science and research to understand and solve the threats to bats and protect bats worldwide. So BCI is a nonprofit organization dedicated to ending bat extinctions worldwide. We implement endangered species interventions to try to protect critically endangered species around the world, we also work on habitat protection and restoration, and we work on research and development of scalable solutions to find conservation actions that can help bats.
Erin Allmann Updyke	Awesome, thank you so much for speaking with us, we're really excited. So we wanted to kind of start just by getting a sense for the status of white-nose syndrome in the world today. So could you kind of tell us the geographic distribution of white-nose in North America and the overall effects that we've seen on bat populations so far, like the number of species that have been impacted and maybe some numbers in terms of population declines?
Winifred Frick	Yeah, so white-nose syndrome had spread from where it was originally emerged in upstate New York across North America. It is currently in over 30 U.S. states and 7 Canadian provinces and it's actually really coast to coast. So about five years ago the disease was detected in Washington state but there's still some areas in which the pathogen that causes white-nose syndrome which is a fungus, Pseudogymnoascus destructans, has shown up and invaded certain areas but we have yet to see the manifestation of disease. But the impact the disease has had has been really severe. So it infects hibernating bat species and we have research that has just come out showing that across the range of some of these species the declines have been greater than 90% for some of our hibernating species, meaning that 9 in 10 bats that we know about have died from this disease over the past decade.
Erin Welsh	Yeah, it's hard to even I think imagine the scope of it or picture the scope of that. And so I don't have to tell you but bats are integral in any ecosystem and declines in their numbers could have very widespread and cascading effects. So could you talk about what we've seen so far in terms of the impact that these bat declines due to white-nose syndrome have had in the areas that have been hardest hit?
Winifred Frick	Yeah so here in North America and in temperate latitudes, almost all of our bats are insectivorous so bats are a voracious consumer of nocturnal insects and a lot of those insects are actually agricultural pests, it's well documented the value that bats have to farmers. In fact, bats are eating insects that otherwise farmers would have to apply pesticides for. Bats have been documented to increase crop yields in places. So one of the things that's been so intense about white-nose is that we lost really common species, species that were highly abundant right. And so we've seen a dramatic decrease in the number of bats that are out in the night sky consuming insects and performing their ecological services. It's hard to quantify that kind of impact because of just the complexity of the ways that we collect data that can kind of measure the interactions between that abundance on the landscape, insects and their impact. So at this moment there aren't studies that really demonstrate the economic impacts from the loss of bats but the logic experiment of that is true.

Erin Allmann Updyke

Yeah, that makes sense. And as you mentioned, we've seen such massive declines in bat populations but we've also seen some populations stabilize or even show I think the beginning signs of recovery maybe. So what do we know about the mechanisms of how these populations have persisted and I'm also wondering how has that been informed by what we've seen in Europe and Asia? Is there any reason for hope in this story or might we see a permanent reduction in population size?

Winifred Frick

Yeah those are great questions and what we've seen is in certain areas there seem to be colonies that seems to have stabilized although they have declined precipitously. It's easy to just kind of generalize across species and I should clarify that there's three species that have been most heavily impacted by white-nose syndrome in North America, the little brown bat, the northern long-eared bat, and the tricolored bat. And then there's a fourth species, the Indiana bat that actually was already listed as endangered in the United States and in some places that species has seen on average 80% declines in colonies but there are a few places where there still are very large colonies. And so some of the research that's been done on stabilization and maybe evidence of the starts of resistance have been on little brown bat colonies in New York where there are still a few very large colonies, although they're not as large as they once were. And so I think there's still active research going on trying to understand both the mechanisms of resistance and/or tolerance of populations persisting but still getting infected.

One of the things that makes white-nose syndrome from a disease ecology perspective so pernicious is that the fungus that causes the disease can persist in the cave and mine habitats where bats are hibernating and so when the bats return to their underground refuges to hibernate, they get re-exposed to the fungus so it has an environmental reservoir, right. And so pathogens that have a environmental reservoir can have a more serious impact on populations because once you see a big decline in the number of individuals, the pathogen is still there and available to infect the remaining individuals at the site. So that's to say that we're still trying to investigate what the long term impacts will be.

There's some hope that there'll be environmental limits to the impact of the pathogen meaning that we know that the disease affects bats when they're hibernating and it takes a long time for the fungus to grow on their skin tissues and cause the physiological disruption that leads to mortality. And so in places where bats aren't hibernating for as long we may see less mortality, although we're still seeing high levels of mortality across the range of where the fungus is currently spread. What we also know is that the fungus is widespread throughout Europe and northern Asia and there bats also do get the disease, meaning the characteristic lesions but we don't see the same level of high mortality rates in those places. So it could be that those populations have evolved some kind of resistance or tolerance and there's a number of studies that have kind of tried to investigate those different mechanisms.

Erin Welsh

Mm-hmm, gotcha. And so looking maybe ahead a bit in the future, what do we know so far about how things like climate change or this increasing land use change are likely to affect the distribution of white-nose syndrome and are there any concerns for its spread beyond North America in places that are still naïve to the pathogen?

Winifred Frick

Yeah well in terms of the spread, yes there's been quite a bit of concern about other places that have temperate hibernating bats. And so there's been some surveys on it in temperate South America so in Chile and places, there's been some research trying to understand what the risk to Australian bats might be. And we first discovered that the fungus is actually widespread in Europe and that's where we assume that it had come from but then Dr. Joe Hoyt also did an extensive amount of work looking at presence of the fungus and evidence of the disease in northern Asia and actually also working with a set of collaborators through basically a very extensive survey effort to understand about the dynamics in the environment and on bats in Asia and into Europe. So I think it's very important to be monitoring in these other places and be able to act quickly if signs of the fungus get there. We know the fungus can persist on people's clothing and boots and other things so it quite possible that that's how we assume that it got here was through some human activity.

And now that the fungus and the disease are in Texas and in caves where Mexican free-tailed bats which are capable of sort of getting the fungus on them, they don't seem to be very likely to have high levels of mortality cause they don't hibernate for extensive periods of time, but they're migratory and they migrate into Mexico. So there's Mexican collaborators, Dr. Rodrigo Medellin who's working on doing surveillance for the fungus in Mexico. As you move into more tropical latitudes that's really it, in mountain areas and high elevations where you might get bats that might hibernate, bats will use torpor periodically but it's probably long term hibernation that is really the risk factor.

To go back to your question about climate change, in temperate latitudes bats are choosing underground environments that are very stable, that are thermally stable. I'm not sure how much climate change will influence underground conditions although we've looked a little bit at the relationship between surface temperatures and underground temperatures, we know that temperature and humidity affect the fungus and may also affect the hibernation energetics of the bats. But I think probably where there's the intersection between climate change and disease impacts has to do with both the extreme weather events that disrupt ecology of species in various ways, we saw huge mortality event in Texas during the big freeze this winter. So you've got these other stressors right, these other big events that cause mortality or disrupt the food base and if species are sort of at the limit in trying to persist and survive this devastating and difficult disease infection to then have the extra whammy of a big unseasonal storm that may delay spring or have some other kind of knock on affect.

Erin Allmann Updyke

Yeah, that makes sense. So kind of as you've been saying and as we talked about through the whole episode, this is a very ecologically complex pathogen. So what about other things? How do things like colony size or even social behavior, how do these kind of big picture things play into infection or extinction risk for different bat species?

Winifred Frick

Right, so a little bit about the winter ecology of hibernating bats. In most of eastern North America, our hibernating bats are aggregating in large numbers and in multispecies aggregations, meaning you've got multiple different species using the same cave or mine to hibernate. So these are really communities of bats that are in these underground spaces and there's variation in the social behavior during hibernation. There's certain species that form dense clusters where they're actually tightly packed together, most likely for thermoregulatory reasons. And then other species that are more solitary where they roost individually throughout a site.

So within one site you might see tricolored bats that are sort of dotted throughout the cave or the mine and then these dense clusters of something like an Indiana bat or a little brown bat. And what we found when we were first doing work on sort of the transmission ecology of this disease is that the sociality, whether they were in dense clusters or not, didn't seem to have a big impact on the disease. And most likely that's because of the important role that the environmental reservoir plays but there's a lot of contacts between bats and between species and these underground environments and so you can't necessarily predict the contact rates based off the roosting behavior.

Erin Welsh

Yeah, that's very interesting. And so now comes the question of well what do we do about it? And I know that there's been a lot of research on potential interventions from things like vaccines to bacterial control to using UV lights to combat white-nose syndrome. So could you walk us through what interventions have the most support or have shown the most promise and what are people doing on the ground right now to control or manage the spread of this disease?

Winifred Frick

Yeah that's a great question. So from the very beginning there's been a really earnest attempt to try to find solutions to this disease and I think it's a really powerful example of researchers and managers coming together and working together to try to solve a difficult problem. There's an active research community trying to explore different solutions. And so Tonie Rocke at the National Wildlife Health Center is working on a vaccine to see if that might help improve survival, there's been various different research in different kinds of treatments of things that you could actually spray on bats that might reduce the infection or reduce mortality from infection. And there's also then a set of research that's focused on what we call sort of environmental treatments or environmental cleaning which is ways that are focused on reducing the pathogen in the environment. You know there's different pros and cons to the different types of approaches for treatments that require actually treating the bat, you've got the difficulty of trying to access a high enough proportion of the population that could be treated.

Bats are incredibly sensitive to disturbance while they're hibernating and they're torpid, they're not metabolically active so you have to have a treatment that will work and that doesn't require lots of application and that also isn't super disruptive. And so thinking about treating the environment opens up some other kinds of opportunities cause you could potentially do it before the bats return to hibernate and knock down the pathogen load, of course that's only gonna be feasible in certain kinds of environments because if you're trying to do something that could reduce the fungus it might have non-target effects and that's not gonna be appropriate in cave ecosystems but mines that are human-made environments it might be possible, and lots of bats hibernate in mines. There's some folks that are working on trying to change the microclimate conditions underground because there's evidence that suggests that bats that are in cooler, drier hibernacula have higher survival rates and so if we can maybe make the environmental conditions in terms of the microclimate less conducive to fungal growth and better for bat hibernating energetics that that could improve survival.

At Bat Conservation International we've been involved in a number of different studies that have tried some of these different approaches over the years and currently we're working on a different type of approach that we have nicknamed our Fat Bat Project which is focused on using some underlying research that shows that bats that are still surviving in places where white-nose has been for a long time show an increase in their body condition, they basically get fatter prior to winter and then they have the fat reserves to basically withstand the infection and the metabolic costs that come with it. And so we've been looking at ways in which we can help bats fatten up before winter with the idea that increasing foraging efficiency.

	So bats do this thing where they go through this period of hyperphagia right before they hibernate and the most energetically intense time for female bats is when they give birth and they lactate, so they're ending the summer sort of having just gone through a really intense, energetic period. And then they've gotta rebuild and put on fat mass before being able to survive the winter, so they basically go on this feeding frenzy for a couple of weeks that we call the Fall Swarm and they just pack on the fat. And so we're trying to target that timeframe and we're building them bug buffets using UV lights to attract nocturnal insects so that they can feed near their hibernacula. And it's pilot results, we're still working it out but the pilot results look promising, we're really excited and the nice thing about it is it could point to long term solutions of helping increase habitat quality and doing things to improve the underlying prey base that could benefit bats at the target areas where they wanna improve their body condition before hibernation.
	That is so cool. Bug buffets. (laughs)
Erin Allmann Updyke	I love it!
Winifred Frick	They nicknamed the project as Fat Bats at the Bug Buffet. (laughs)
	Yes, that's incredible.
Erin Allmann Updyke	That's so cute, I also just love picturing bats like getting extra chunky before going into hibernation.
Winifred Frick	Chunky bats are the best, they put all their fat on their butts and they're so chub chub. Yeah.
	(laughs) Oh my gosh.
Erin Allmann Updyke	(laughs) Love it. So speaking of how adorable bats are, I'm sure you are aware how bad of a rap they often get unfairly in popular culture and I think it's probably in part because they do have these associations with a lot of pathogens that can potentially spillover into humans including of course coronaviruses. And I saw at least one paper with some evidence that bats that were infected with white-nose syndrome actually had higher viral loads of some coronaviruses. So could you talk about bat diseases like white-nose syndrome and how the health of bats can be actually directly related to human health in the context of bat conservation?
Winifred Frick	Sure. It's important to underscore that we still don't know how the virus that causes COVID-19 got into the human population. What we do know is that bats can be ancestral hosts for coronaviruses, so they carry closely related SARS-like betacoronaviruses although the closely related virus to SARS-CoV-2 probably diverged 40 or 50 years ago and so there's still a lot of investigation as to how the virus that causes COVID-19 got into the human population. One of the things that's fascinating though is that bats are kind of like superheroes when we think about their immune systems, they are capable of carrying a bunch of different viruses and don't appear to get sick from them.
	And so there's lots for us to learn in terms of the what sort of superpowers bats have in terms of their immune systems and I think that was one of the reasons why white-nose syndrome was so shocking and upsetting is that there aren't that many diseases that we've seen really negatively impact bat populations in this sort of way. There's a lot of research about bats and disease but from all the viral research it's more about how well they can sustain viral infections and not be pathogenic, right. But white-nose is caused by a fungal pathogen and we've certainly seen other kinds of fungal pathogens decimate wildlife like the chytrid fungus in amphibians.

	I think one of the big lessons that we have learned from the COVID pandemic is just how understanding ecological integrity and protecting wildlife and protecting ecological systems is part of global human health. There's a growing body of evidence that shows that it's a disruption and degradation of ecological systems that increase the chance for spillover and that's true across the board, not specific to bats and so I think it's really important that we recognize and understand the ways that we can predict and prevent spillover events through conservation and protection of intact natural ecosystems.
Erin Welsh	Mm-hmm. Yeah, absolutely. And so white-nose is obviously one enormous threat to bats in North America and I was wondering if you could speak more generally about some of the other biggest threats to bats both in North America and maybe globally as well. And what can we do to sort of combat those threats?
Winifred Frick	Yeah so we recently did a review of the global threats to bats and what we find is that... So bats are an incredibly diverse order, right, they're the second-most diverse order of mammals with over 1400 different species and a lot of that biodiversity occurs in tropical latitudes. So iconically we think about bats roosting in caves but actually about 40% of bat populations are cave roosting but many, many species live in forest environments, in fact many of our cave roosting species also depend on forests for foraging and habitat. And so the top number threat globally to bats is habitat destruction through deforestation, right, and then land conversion from agriculture. So land use, the intense impact that we have on the planet in terms of just habitat destruction and degradation.
	Globally other threats include hunting, unsustainable hunting, so bats are hunted in parts of Asia and parts of Africa and if those hunting practices are done in a way that are unsustainable, we've seen certain species actually get hunted to extinction. And then here in North America and really sort of growing around the world, one of the major threats that's been identified is that impact of land energy. So unfortunately when turbines kill bats and kill large numbers of bats and so trying to determine ways in which we can support renewable energy in ways that does not cause biodiversity loss is really important. And luckily there's really great research that shows that there are things that we can do, we can actually prevent the turbines from spinning at low wind speeds during the seasonal migration and that dramatically reduces the amount of fatality. Getting some of those solutions adopted and part of standard practice remains a challenge.
	So lastly too, we know climate change is also an impact so increase of severe storms, roost disturbance is another threat. So going back to thinking about our bats that roost in caves, they can be really vulnerable to people coming in and either disrupting them on purpose cause they are trying to like harvest guano or do other things or not being aware that they're disrupting those populations. So in terms of what people can do, it's wonderful when people share just how valuable and important bats are, you can also support groups that are working on bat conservation. And then I like to also promote that anything you can do to lower your footprint on the planet helps bats, so things you can do to lower your carbon footprint or another thing is that we're sharing the planet with other creatures and if we can lower the type of impact we have, that benefits bats too.
TPWKY	(transition theme)
Erin Welsh	Well that was just fantastic.
Erin Allmann Updyke	I am still fangirling.
Erin Welsh	Absolutely.

Erin Allmann Updyke	I really, really... Thank you so much Dr. Frick for taking the time to speak with us, I have never gotten to speak with someone that I've read so many of their papers except maybe Peter Hotez, like that's this kind of moment.
Erin Welsh	I was just about to say maybe Peter Hotez. (laughs) Anyway that was absolutely wonderful, thank you so very much. Well should we go right to sources?
Erin Allmann Updyke	We certainly should.
Erin Welsh	So I shouted out a couple in the history section but I will shout out just a couple more that I thought were super great. So there's an entire book called 'Bats in the Anthropocene' that is great not just for information about white-nose but about other ways in which bats have been affected by humans and so on and so forth. And then I also want to shout out a very, very recent paper form March of 2021 by Hoyt et al called 'Ecology and impacts of white-nose syndrome on bats'. Tons of great info there. And also I have a bunch more sources, I'll post it on the website.
Erin Allmann Updyke	Excellent. I wanna mention that the white-nose syndrome in bats chapter from that book was written by none other than our guest, Dr. Winifred Frick along with several other authors.
Erin Welsh	So thrilling.
Erin Allmann Updyke	So thrilling. I also want to give a shout out to the whitenosesyndrome.org website which is coordinated by the U.S. Fish and Wildlife Service. Not only does it have a ton of very digestible information, they also have a RefWorks page that has links to over 500 peer-reviewed articles on white-nose syndrome and related things. So it's far more comprehensive, I opened so many papers that I didn't even get to from that RefWorks site but I will also post all of the papers that I actually did use for this biology section on our website like Erin mentioned, thispodcastwillkillyou.com. You can find the sources for this episode and every single one of our episodes.
Erin Welsh	Yes. Well thank you again to our wonderful guest for taking the time to chat with us about white-nose syndrome.
Erin Allmann Updyke	Yeah. And thank you to Bloodmobile for providing the music for this episode and every single one of our episodes.
Erin Welsh	And thank you to the Exactly Right network of whom we are a very proud member.
Erin Allmann Updyke	And thank you to you, listeners, we hope you enjoyed this animal episode.
Erin Welsh	Yeah! Thanks for listening.
Erin Allmann Updyke	Yeah.
Erin Welsh	Well until next time, wash your hands.
Erin Allmann Updyke	You filthy animals.