Erin Welsh	Just a quick content warning here, the firsthand account does include a description of the death of a dog. And so if you would like to skip that, you can fast forward around 5 or 6 minutes.
Diana	Hi, my name is Diana and I had a beautiful 6 month old Bernese Mountain Dog puppy named Donato which means gift in Italian. And he was that; he was gorgeous. In the summer of I think it was 2010, I was at a friend's house in August in Carmel Valley, California. It was hot, the middle of the summer, not a time that you would think there'd be mushrooms. So we were swimming in the pool and he was running around having a blast. And he didn't come when I called. I went up and looked for him and I found him in the garden with what looked like was an inverted mushroom growing into the ground. I couldn't figure out what the heck it was. Little did I know that this cup-like thing in the ground was the volva of a death cap mushroom. About 4 hours later he threw up but he was still running around and active and I didn't think much of it because he was a puppy. But in the middle of the night he continued throwing up and had major diarrhea and he was in obvious pain.
	So I rushed him to the emergency vet in Carmel Valley at 5 am. And in 2010 vets weren't really that aware of mushroom toxicity as they are today. Also it was a bit of a perfect storm in some ways because my high-level vets that were in the Bay Area were moving their offices, so I had to stay with this small country emergency vet. Though I brought the shards of the mushroom to the vets, they disregarded them and they gave him some anti-nausea medication and ran a liver test initially and it was slightly elevated but they just said oh, he'll get better. They kept him to watch him and he was not improving. I could tell he wasn't and I pushed for another liver test and they kept putting it off and putting it off. And finally late that night they did it again and his values were off the charts.
	We transferred Donato at that point to a larger and high-level vet hospital and though they tried everything, they couldn't save him. I was devastated. I mean absolutely devastated. Had I known what I know now, he might have had a chance. Now, yes, I can identify a death cap mushroom in an instant. I would have induced vomiting immediately after seeing that inverted cup in the ground. And today, vets, they have a quick and easy way to test for amatoxin poisoning developed by Candace Bever. And also I recognize that though the summer is not a time that you think of mushrooms, when people water their gardens and create a really nice warm environment underneath their oak trees, you can have death cap mushrooms in the midst of summer. So since that horrible day, it's become Donato's legacy and my mission to spread the warning about the danger of mushroom toxicity. I started a blog, Mushrooms 911, I've handed out over 80,000 mushroom alert cards, and I'm helping Candace and others to promote the AMATOXtest. I hope everybody stays safe out there and watches their yard, mushrooms come up quickly.
TPWKY	(This Podcast Will Kill You intro theme)
Erin Allmann Updyke	Oof.
Erin Welsh	Yeah.
Erin Allmann Updyke	Yeah.
Erin Welsh	That is absolutely heartbreaking.
Erin Allmann Updyke	It is. Thank you so much for taking the time to share your story with us, for having to relive that, and also for all the work that you're doing and trying to raise awareness and advocacy. We really, really appreciate it.

Erin Welsh	Yeah, we truly do. Thank you. Hi, I'm Erin Welsh.
Erin Allmann Updyke	And I'm Erin Allmann Updyke.
Erin Welsh	And this is This Podcast Will Kill You.
Erin Allmann Updyke	And today we're talking about mushrooms. Though not just any mushroom.
Erin Welsh	Right. This is our first foray into poisonous mushrooms.
Erin Allmann Updyke	It is. And it definitely won't be our last.
Erin Welsh	Nope.
Erin Allmann Updyke	Because if there is anything that I got very interested in, it is how many different toxins there are in so many different mushrooms.
Erin Welsh	Yes. And like why? Great question.
Erin Allmann Updyke	Great question.
Erin Welsh	Yeah. I think this is going to be a really interesting episode. I am really excited to learn about the biology of this toxin, like what it does.
Erin Allmann Updyke	It's terrifying.
Erin Welsh	Yeah.
Erin Allmann Updyke	It's scary, yeah.
Erin Welsh	It's truly so scary. And it's just bizarre to put that along with the ecology and the evolutionary aspect.
Erin Allmann Updyke	That's the question I have.
Erin Welsh	Yeah.
Erin Allmann Updyke	That's what I want to hear about, Erin, because I was like not reading that and then I was like sorry, why does this toxin exist?
Erin Welsh	Yeah.
Erin Allmann Updyke	What is it doing for this mushroom?
Erin Welsh	I know.
Erin Allmann Updyke	That's my big question.
Erin Welsh	Well I do know I guess.

Erin Allmann Updyke	Okay, I hope you do. Because I wanna know.
Erin Welsh	We'll find out.
Erin Allmann Updyke	Okay.
Erin Welsh	But before we can do any of that, it is quarantini time.
Erin Allmann Updyke	Quarantini time.
Erin Welsh	Erin, what are we drinking this week?
Erin Allmann Updyke	We're drinking The Deadliest Dose.
Erin Welsh	I mean it kind of is. It's like one of the deadliest toxins on the planet, yeah.
Erin Allmann Updyke	Yeah, yeah. As far as I know.
Erin Welsh	Yeah.
Erin Allmann Updyke	I mean I guess I didn't look up all deadly toxins but like as far as mushrooms goes, it's for sure up there.
Erin Welsh	It might be up there.
Erin Allmann Updyke	Yeah.
Erin Welsh	And in the deadliest dose, the quarantini and placeborita is not deadly, it is delicious.
Erin Allmann Updyke	It is.
Erin Welsh	It has vodka, it has cucumber juice. How fun is that?
Erin Allmann Updyke	Cucumber.
Erin Welsh	It has lime juice, simple syrup, and elderflower liqueur.
Erin Allmann Updyke	Kind of like a little gimlet but with elderflower.
Erin Welsh	Yeah.
Erin Allmann Updyke	Ugh, so good. You'll find the full recipe for that quarantini as well as the non-alcoholic and equally delicious placeborita on our website thispodcastwillkillyou.com and on our social media. Are you following us yet on social media? We're on Instagram, we're on TikTok.
Erin Welsh	We are. Yeah, we are all over social media.
Erin Allmann Updyke	The internet.

Erin Welsh	So check us out. Do you know what else is on the internet? Our website.
Erin Allmann Updyke	Our website, it's there.
Erin Welsh	Thispodcastwillkillyou.com.
Erin Allmann Updyke	Dot com, the internet.
Erin Welsh	Surprisingly enough that is the name, that is the URL. And on our website you can find all sorts of things from transcripts to our show notes; you can find links to bookshop.org affiliate account, our Goodreads list, music by Bloodmobile.
Erin Allmann Updyke	The incredible merch we have.
Erin Welsh	Merch!
Erin Allmann Updyke	Like the shirt that Erin is wearing.
Erin Welsh	I love this shirt so much.
Erin Allmann Updyke	It's so good.
Erin Welsh	This design is like one of my favorites. The rat queen. She steals my heart.
Erin Allmann Updyke	She's so cute.
Erin Welsh	And other things. Patreon, a contact us form, a link to a firsthand account form.
Erin Allmann Updyke	There's a lot.
Erin Welsh	There's a lot of good stuff.
Erin Allmann Updyke	Check it out.
Erin Welsh	So check it out.
Erin Allmann Updyke	Yeah, do that.
Erin Welsh	All right.
Erin Allmann Updyke	Shall we get into this mushroom, Erin?
Erin Welsh	I think we should.
Erin Allmann Updyke	Okay.
Erin Welsh	Let's take a quick break and then begin.

TPWKY	(transition theme)
Erin Allmann Updyke	I know you'll get into this more, Erin, but there are well over 50,000 species of mushroom across the globe.
Erin Welsh	I won't be getting into mushroom diversity.
Erin Allmann Updyke	Okay great. Good. Because let me tell you, there are over 50,000 species of mushroom across the globe.
Erin Welsh	Excellent.
Erin Allmann Updyke	Many of these are still unclassified, unnamed. At least 350 of them have been identified as edible mushrooms and around 1000 are poisonous. Of all of these poisonous mushrooms, there's a really wide variety of different toxins that they produce, each of which has different effects on our bodies. And yet none of them are quite as deadly as the subject of today's episode, Amanita phalloides.
Erin Welsh	Quick question.
Erin Allmann Updyke	Okay. Love it when we start off this way.
Erin Welsh	Okay. When you say that there are 1000 species that are classified as poisonous or have toxins that can be harmful-
Erin Allmann Updyke	Yeah.
Erin Welsh	Is that to humans or mammals specifically or is that like...?
Erin Allmann Updyke	That's a great question. I think that is from a human context.
Erin Welsh	Okay, okay.
Erin Allmann Updyke	But I don't know for sure.
Erin Welsh	That makes sense, yeah.
Erin Allmann Updyke	It was like a review paper.
Erin Welsh	Right. I mean if it's like edible vs poisonous, yeah.
Erin Allmann Updyke	Right.
Erin Welsh	I could see that being for humans.
Erin Allmann Updyke	Anthropocentric. Okay?
Erin Welsh	Yeah.

Erin Allmann Updyke	Amanita phalloides or the death cap mushroom, I want to paint us a picture here because I don't know, most people probably aren't that into mushrooms.
Erin Welsh	I think you might be wrong about that.
Erin Allmann Updyke	Well look I probably am. I'm not that into mushrooms, so I needed to paint myself a picture of what we're talking about here. And as far as mushrooms go, I feel like when I first looked at the pictures of Amanita phalloides it looked pretty innocuous. It was like a mushroom-looking mushroom. Like draw a picture of a mushroom, kid. You're going to get something that looks a lot like Amanita. So it has this very kind of gently domed cap with this wide brim.
Erin Welsh	Okay.
Erin Allmann Updyke	And it looks a lot like the mushrooms in Fantasia with maybe a less pointy dome. Do you remember those dancing mushrooms in Fantasia?
Erin Welsh	Which music or which act? Like what else was going on with the mushrooms?
Erin Allmann Updyke	I don't remember.
Erin Welsh	I only remember like the dino one very strongly and the pegasus ones.
Erin Allmann Updyke	I only remember the mushroom one and then the dancing brooms.
Erin Welsh	Wow.
Erin Allmann Updyke	And I don't know if that was the same skit or not.
Erin Welsh	Okay.
Erin Allmann Updyke	No? Okay well then think of the toad mushroom in Super Mario Brothers. Toad?
Erin Welsh	Oh yeah, okay, Toad. Sure.
Erin Allmann Updyke	Okay, Toad. Let's do that. So Toad is a red with white dot mushroom, that is also an Amanita species, Amanita muscaria.
Erin Welsh	Okay.
Erin Allmann Updyke	So Amanita phalloides looks kind of similar to Toad except that the cap, instead of being red with white dots, is this light kind of yellowy-green, almost metallic-looking, like very smooth cap. They can be quite large, so we're talking the cap is like between 5-15 centimeters in diameter which is like 2-6 inches across, so pretty good size.
Erin Welsh	Wow.

Erin Allmann Updyke	And then on the underside, of course mushrooms have gills, and in the case of Amanita phalloides they're white, pure white gills. And then underneath on their little stalk or stem, which I learned in mycology is called a stipe, just to be fancy. Along this stipe, they have a frilly little like mini skirt that hangs down just below the cap. And their stipe, their stem is pretty beefy-looking compared to some other species of Amanita, so they're like a little thicker. And they can be pretty long, like 3-5 inches tall coming out from the ground. It's a white stem but with some little olivey kind of scaly bits that you might see on there. And then just below, like buried just beneath the earth where this mushroom is coming out but often visible if you were to pull this mushroom all the way out, they have this wider swollen sock sack-looking situation that hangs down. It's called a volva. Not a vulva but a volva.
Erin Welsh	V-O-L-V-A.
Erin Allmann Updyke	V-O-L-V-A.
Erin Welsh	Okay.
Erin Allmann Updyke	It looks almost like, I don't know, like a really fragile eggshell that the mushroom is like growing out of.
Erin Welsh	Okay.
Erin Allmann Updyke	And that is kind of what it is because when these mushrooms come out of the soil, they first come out in what's called this universal veil and then the mushroom kind of pokes out of it. All Amanita species do this. And so on the red and white, I'm getting a little too detailed, Erin, but sorry-
Erin Welsh	I'm loving it.
Erin Allmann Updyke	The red and white mushrooms, the white little dots-
Erin Welsh	Yeah.
Erin Allmann Updyke	Are remnants of that universal veil.
Erin Welsh	Oh how fun.
Erin Allmann Updyke	Isn't that cute?
Erin Welsh	Yeah.
Erin Allmann Updyke	And so other species of Amanita have maybe like a big chunk of it kind of left on top of the cap.
Erin Welsh	Okay.
Erin Allmann Updyke	Amanita phalloides doesn't have any left on the top, the frilly skirt that hangs down on the stipe is part of it, and then it has this eggshell sack at the bottom.
Erin Welsh	Okay.

Erin Allmann Updyke	Okay? So that's to paint a picture, Google Image search also. And I know we'll both probably talk a little bit more about the distribution and range but to continue to set the stage, this mushroom, what it is is the reproductive part of a fungus. So it's also called the fruiting body. And it's just the part of this fungus that's visible above ground. But beneath every mushroom there's a lot more to the fungal organism than meets our little eye. And in the case of the death cap, this mushroom is one part of what's called an ectomycorrhizal fungus which is a fancy way of saying that this fungus makes its home via a symbiotic relationship with the roots of a bunch of different tree species. So in order to grow it has to have certain tree species around it that it makes its home with. So while it's native to Europe, this mushroom has spread to essentially the entire globe with the exception of Antarctica. It's in Australia, South America, Africa, Asia, North America, everywhere.
Erin Welsh	Yeah.
Erin Allmann Updyke	And it is the most deadly mushroom to humans that we know of. There are 3 main toxins or like classes of toxins that are present in Amanita phalloides. There are amatoxins, phallotoxins, and virotoxins. But today we're only going to focus on one of these, and that is the amatoxins. The reason is that the phallotoxins and the virotoxins, while they exist and they are toxic to cells in vitro to various degrees, they're mostly not absorbed by our guts and so they don't really contribute to the toxicity of these mushrooms, at least in humans.
Erin Welsh	Okay.
Erin Allmann Updyke	So we're just talking today about amatoxins. This is a group of toxins, they're called, like in terms of what their chemical structure is, they're like a little ball of a protein. They're called cyclic octapeptides because they're 8 amino acids and they form two little rings. And because of the shape of these toxins, they're pretty heat stable. So they're not degraded very substantially in the process of, say, cooking or drying them.
Erin Welsh	Drying, yep.
Erin Allmann Updyke	And there's a wide variety of amatoxins, it's not just one. But the primary one that is especially deadly in death cap mushrooms at really high concentrations is called alpha-amanitin. I think that's how you say it. And let me tell you how deadly this particular toxin is. The lethal dose for humans can be as low as 0.1 mg per kilogram of body weight.
Erin Welsh	It's wild.
Erin Allmann Updyke	It is wild. So that means 6-8 mg of this toxin, which is like that's how much, I don't know, a teaspoon of salt weighs, like between 5-10 mg depending on the brand.
Erin Welsh	Okay.
Erin Allmann Updyke	So we're talking about like a teaspoon can kill a grown adult human that weighs between 60-80 kg which is 130-180 pounds.
Erin Welsh	And how much is in a mushroom?

Erin Allmann Updyke	I knew you were going to ask how much is in a mushroom. It can vary of course and just like with other plants that we've talked about, it's going to depend if we're talking about the cap, the gills, the stalk, etc. But on the low end, the average estimate is about 0.2 mg per gram of mushroom tissue. And a whole mushroom of this species might weigh like 100 g. So that's like 20 mg in an entire mushroom. 20 mg, that's more than double what it would take to kill a human being.
Erin Welsh	Yeah. So a half a mushroom is sufficient.
Erin Allmann Updyke	A half a mushroom.
Erin Welsh	Wow.
Erin Allmann Updyke	I know. It's terrifying. Now Amanita phalloides is by no means the only mushroom that makes this toxin or any of the other amatoxins because there are others that are very deadly as well. There are lots of other species in this genus that do and some of them have equally terrifying names like the destroying angel-
Erin Welsh	Yeah.
Erin Allmann Updyke	Or the springtime destroying angel. And there are also a couple of other genera too, Galerina and Lepiota. I might be pronouncing those wrong. And all of these can sometimes look very similar to and be confused for edible mushrooms or psychogenic mushrooms. So it's very easy to confuse both the death cap mushroom and other similarly toxic mushrooms for things that you might want to ingest. So then the question is what is this toxin actually doing to our bodies? Like why is it so deadly? This protein it turns out blocks transcription.
Erin Welsh	That's not a good thing.
Erin Allmann Updyke	It's not a good thing. And for anyone who's like I'm sorry, that's too technical of a biology term. Let me tell you what that means. It means that it blocks the process by which our cells are making proteins. So our cells, like their job, our job of our cells is to make proteins to be able to do, I don't know, life. And so this toxin blocks a fundamental step in the process that all of our cells have to be able to do. And when that happens, our cells stop being able to metabolize and that then sends out signals that induce apoptosis or programmed cell death. So this toxin doesn't, it is called a cytotoxic toxin, like that's the classification of it, but it's not super directly killing cells. It kills our cells by making them non-functional and then our body kills off those non-functional cells.
Erin Welsh	Wow.
Erin Allmann Updyke	Yeah. And it does this irreversibly. So it irreversibly binds to a protein that blocks transcription and makes it non-functional.
Erin Welsh	Can I ask what that protein is?
Erin Allmann Updyke	It's RNA polymerase II.
Erin Welsh	Okay.
Erin Allmann Updyke	If you really want details.

Erin Welsh	I actually do, yeah.
Erin Allmann Updyke	Yeah. RNA polymerase II.
Erin Welsh	Okay.
Erin Allmann Updyke	So that's pretty bad.
Erin Welsh	Yeah. It's like not only does it just shut it down, it shuts it down and then marks it for destruction.
Erin Allmann Updyke	Permanently. Exactly, exactly. And because this is a really small protein toxin, it can and does travel via our bloodstream after it's absorbed in our GI tract to pretty much anywhere in our body. And we do not have any enzymes, any machinery to inactivate this toxin. We do not metabolize it. We don't break it down into something less harmful. All that our bodies can do is try and get rid of it and we do that via our kidneys. So our kidneys filter it out and they do, bless our glomeruli, a phenomenal job of it. But they sustain some pretty significant damage in the process. And they can't filter all of it out. So when we ingest this toxin, it gets absorbed really rapidly through our gut wall into our bloodstream, like within a couple of hours it's at peak concentration. And within a few days, about 75-85% of it is filtered out through our kidneys. But the rest of it goes to our liver. And our hepatocytes or our liver cells are some of the main sites of damage. And part of this is because what happens is that this toxin can be sequestered into our gallbladder.
Erin Welsh	Ooh.
Erin Allmann Updyke	So a quick... I know you probably have questions but a quick anatomy lesson before that. Your gallbladder is this separate organ that's like a storage bag that sits in almost like a little pocket nook in your liver and it holds bile, which is a juice that your liver makes and your liver has to secrete into your intestines to help it digest fat. But it's stored in your gallbladder. So your liver makes it, pooches it into your gallbladder, your gallbladder holds it and then squeezes to release that bile into your intestine when you need it. So as this toxin makes its way into our liver, it hitches a ride kind of on our bile and then hangs out in our gallbladder. And then every time a person eats a meal or just like exists because your gallbladder is still secreting, this toxin can be squirted out into your intestine, be reabsorbed, find its way back into the liver and cause more damage, be re-sequestered into the gallbladder, be re-secreted, etc, etc, etc, in a process that's called enterohepatic recirculation.
Erin Welsh	Oh my god. So it just hangs out. It can just keep doing its thing over and over.
Erin Allmann Updyke	Over and over again.
Erin Welsh	And little do you know, you feel really bad, you barf, you poop, whatever. And then you're like oh I'm starting to feel better, I'm going to eat some more. And it's there.
Erin Allmann Updyke	And it's there.
Erin Welsh	Hiding in your gallbladder.
Erin Allmann Updyke	Exactly.

Erin Welsh	That is, I hate to anthropomorphize, sinister.
Erin Allmann Updyke	But yeah. It is, it is.
Erin Welsh	But I will, yeah.
TPWKY	(transition theme)
Erin Allmann Updyke	And so that, Erin, you kind of bring up the good point of then what does this actually look like in terms of the symptoms? What do we see then, this toxin we know is causing this damage, what does it look like?
Erin Welsh	Yeah.
Erin Allmann Updyke	It's really, really awful. The symptoms of death cap poisoning, of amatoxin poisoning, follow a three phase course. Four phases really because the first phase is usually called this latent period. And the latent period is that a lot of times we think of if something is going to be toxic when you ingest it, you're going to feel those effects right away, right. You eat bad potato salad, you start barfing from that Staph. aureus toxin right away. But not the case with amatoxins. The latent phase is anywhere from 6-24 or more hours before phase two or the symptomatic phase starts. So after a period of several hours, people will start having first a gastrointestinal phase. And this is really intense vomiting, abdominal pain, diarrhea. And this diarrhea can be so severe that it's often described as cholera-like.
Erin Welsh	Oh my god.
Erin Allmann Updyke	Which is a throwback all the way to season one. So if you don't remember, cholera causes such frequent and like purely liquid, it's described as rice water stool, such severe diarrhea that people die of dehydration very rapidly. And that is a possibility here. So people can have such severe diarrhea that they go into hypovolemic shock from how much liquid they're losing. Their blood sugar can dip really low because it's not just doing this to your GI tract, it's again affecting your liver and so it affects your glycogen stores which can then cause you to have really low blood sugar. And this GI phase can last for usually like a couple of days, so 1-2 days. But it's very easy at this point to entirely miss the fact that this came from a mushroom poisoning, right. Because there was a delay between when you ate that mushroom, if you even knew what you were eating, and when you had symptoms. And this is nonspecific. It could look like so many other acute gastrointestinal illnesses.
Erin Welsh	Okay, I have a quick question about sort of like the timing of symptoms showing up.
Erin Allmann Updyke	Yeah.
Erin Welsh	It's not like a dose response thing.
Erin Allmann Updyke	Correct.
Erin Welsh	Okay. So then is there any relationship between the structure of the toxin, whether it's like protein or something else, and how quickly those symptoms emerge? Or is it primarily about sort of the target of those toxins?

Erin Allmann Updyke	It's a really good question. I really, really tried to understand and find an answer to the question of like why exactly is there such a delay in the symptoms. And I still don't really understand. Because this toxin, it's a small protein toxin, most toxins are proteins. It's absorbed very rapidly from our GI tract, so you can detect it in the blood within a number of hours and then like I said, pretty quickly our kidneys start excreting it, right? They're working really hard and they're excreting a lot of it within that first couple of days. From everything that I've read, it seems like this toxin, it's damaging cells in our liver, in our kidney, and in our GI tract. But because of the fact that it is pausing transcription, blocking our cells from doing their job, and then causing damage where those cells are essentially dying and killing themselves from apoptosis, it's not like an immediate effect if that makes sense.
Erin Welsh	Right.
Erin Allmann Updyke	So it takes some time. And then on top of that, as we'll see as this continues to progress, the whole enterohepatic recirculation starts to happen that really ends up kicking the crap out of the liver.
Erin Welsh	Yeah.
Erin Allmann Updyke	It still doesn't in my view at least like very satisfactorily answer that question of why exactly is it such a long delay? Because it can sometimes be like 24 hours, 48 hours. Some of that probably does have to do with the dose, right. The more that you're exposed to, probably the earlier on that you'll have symptoms. But it's still going to be at least 6 hours delayed usually.
Erin Welsh	Okay.
Erin Allmann Updyke	So it's just I guess how long it takes for you to start seeing the damage to your cells.
Erin Welsh	Yeah.
Erin Allmann Updyke	And then after that you enter this phase that is very scary because it's a false recovery phase. And that is where these abdominal symptoms start to subside but the damage is really only just beginning because that toxin is continuing to attack the liver. And this then manifests as really highly elevated liver enzymes, so your liver cells are literally just bursting open and leaching out their contents. And within 3-5 days of first ingesting these mushrooms you'll enter phase four which is fulminant liver failure. So enzymes that are supposed to be contained in your liver are now circulating throughout your bloodstream. Your liver essentially just isn't working. And as we've talked about before on this podcast, your liver, it's a very important organ and when it stops working it means that you can't make clotting factors, so you can't clot your blood, so you'll start bleeding internally. As this continues to recirculate, you start to see additional damage to your kidneys. You'll see severe metabolic derangements which means your electrolytes aren't normal, your liver is just non-functional. And without treatment, and in a lot of cases when it progresses to this point the only treatment is liver transplant, then death is almost certain which can sometimes be anywhere from 6-10 days after that mushroom was initially consumed.
Erin Welsh	Wow.
Erin Allmann Updyke	Yeah. For dogs, as we heard in our firsthand account, and dogs, we don't have great numbers on how much more commonly they're affected but certainly they're much more likely to be eating mushrooms in a forest than a human; the process is very similar but it tends to happen on a much more rapid time scale. So we're talking about all of this happening within a period of a couple of days rather than a week or more.

Erin Welsh	But the symptoms still take 6 hours to show up.
Erin Allmann Updyke	Not necessarily 6 but they still are delayed by a number of hours usually.
Erin Welsh	Okay.
Erin Allmann Updyke	Yeah. So yeah, that's the kind of full on course of this.
Erin Welsh	It's awful.
Erin Allmann Updyke	It really is. And I can't underscore just how severe it is. Like if this progresses to the point of liver fulminant, liver failure, there isn't anything you can do except liver transplant.
Erin Welsh	Yeah.
Erin Allmann Updyke	Because it has irreversibly killed so many of your liver cells at that point. There are things that can be done before it gets to that point and so early identification is incredibly important, like knowing that this is amatoxin poisoning is super important. And while we don't have all that much in the way of highly specific treatments, like we don't have an antidote, there is a lot that we can do in terms of supportive care. And so that includes really aggressive IV hydration because that is trying to help your kidneys flush out as much of this toxin as it can while also protecting the kidneys from damage from the toxin. And then there's some really interesting medicines that we use, some of which don't have a lot of data but are still used because they're easier medicines to get and some of which have more data but at least in the US are not approved by the FDA for use, so they're hard to come by.
Erin Welsh	Okay.
Erin Allmann Updyke	But the idea behind all these medicines is to help protect the liver and block the toxin from entering liver cells.
Erin Welsh	Got it.
Erin Allmann Updyke	So one of the big medicines that's used actually comes from milk thistle, the milk thistle plant.
Erin Welsh	Yeah.
Erin Allmann Updyke	It's called silibinin, I think, is the compound.
Erin Welsh	Okay.
Erin Allmann Updyke	And basically it binds to something on our liver cells that then blocks the toxin from entering. So if too much of that toxin has already entered and damaged your cells, then it might not be that helpful. But because we know that that recirculation process means that more and more toxin is being introduced to your liver cells like over and over and over again, this can basically stop it from ever getting into the cells. In the US this medicine is not licensed for use but there was a big clinical trial of it and so through that clinical trial a lot of people did get access to it and it seems like, I don't know, maybe it will be approved sometime soon. But it is used really widely throughout Europe.

Erin Welsh	Okay.
Erin Allmann Updyke	And then there's a few other medicines like penicillin or N-acetyl cysteine or Nac that are used with a similar theoretical effect but the data just isn't as strong that they're actually that helpful.
Erin Welsh	Penicillin.
Erin Allmann Updyke	I know, penicillin G, IV penicillin, yeah.
Erin Welsh	Okay.
Erin Allmann Updyke	It's thought that it maybe helps. Again, the data is not great on that.
Erin Welsh	Right, right.
Erin Allmann Updyke	But it's like let's do something, right.
Erin Welsh	Yeah, sure. And I imagine too that there's not... Like you said, it's hard to come by clinical data because there are fortunately relatively few cases of this.
Erin Allmann Updyke	Exactly.
Erin Welsh	Yeah.
Erin Allmann Updyke	This is fortunately still rare which means that it's hard to do large clinical trials which is a good thing.
Erin Welsh	Right. Right, right.
Erin Allmann Updyke	But yeah. And then other than that, then treatment also focuses on stopping that gallbladder from contracting and dumping out more of that toxin. So sometimes even people will put a tube into the gallbladder to drain the bile.
Erin Welsh	Okay.
Erin Allmann Updyke	Or use a medicine that helps just like stop contraction overall and not let people eat for a number of days to really just kind of slow that whole process down.
Erin Welsh	Question.
Erin Allmann Updyke	Answer.
Erin Welsh	A lot of people have had their gallbladders removed. Do we know anything about amatoxin poisoning in people with their gallbladders removed?
Erin Allmann Updyke	I do not but what an interesting question. No, I didn't see anything about that.
Erin Welsh	Okay.

Erin Allmann Updyke	Probably because the numbers again are like... It would be an epidemiological retrospective study.
Erin Welsh	Yeah.
Erin Allmann Updyke	That's a really interesting thing to try and look at, like the clinical course of people who are post gallbladder removal and then unfortunately exposed vs not. What an interesting...
Erin Welsh	Yeah.
Erin Allmann Updyke	I did not see that anywhere.
Erin Welsh	I mean I would love to do an episode on the gallbladder.
Erin Allmann Updyke	I know. We said that very recently, Erin.
Erin Welsh	I know. But when? When did we say it? I was just thinking this sounds familiar to me.
Erin Allmann Updyke	I don't know, I don't remember. But yes we will.
Erin Welsh	I think it was when I asked you to describe all the parts of the digestive system.
Erin Allmann Updyke	Well that was norovirus.
Erin Welsh	Oh maybe not then, I don't know.
Erin Allmann Updyke	Maybe it was... I don't know. Someone listening is going to be like you guys, it was so obvious.
Erin Welsh	We've recorded a lot recently, okay. It's hard to keep them all straight.
Erin Allmann Updyke	I know, I know. The gallbladder is really interesting. But yeah, that's a great question whether... I mean theoretically yeah, it should be you would get less of that enterohepatic recirculation so theoretically that should be protective.
Erin Welsh	Okay.
Erin Allmann Updyke	Does it mean that you're not going to get sick? No. But should it be protective against liver failure potentially? Theoretically.
Erin Welsh	Interesting.
Erin Allmann Updyke	Yeah.
Erin Welsh	Okay.
Erin Allmann Updyke	But that is the terrifying amatoxins present in Amanita phalloides or the death cap mushroom. Erin?

Erin Welsh	Terrifying is right.
Erin Allmann Updyke	Why? Why? Why on earth does a little mushroom growing on tree roots in the forest need to have a toxin that can kill us so easily at such high concentrations in its tissue?
Erin Welsh	I mean you know what we always say, that's a great question. Do I know? Let's find out after this break.
Erin Allmann Updyke	I can't wait.
TPWKY	(transition theme)
Erin Welsh	Erin, I swear that one of these days my search history for this podcast is going to put me on some kind of watchlist. If I'm not already on one. To illustrate, I'm going to read you a really long quote that I came across when doing research for this episode.
Erin Allmann Updyke	Can't wait.
Erin Welsh	Ready? Quote: "For murderers, there is only-"
Erin Allmann Updyke	I'm sorry.
Erin Welsh	I'm telling you, this was published in an academic journal, let me just say that.
Erin Allmann Updyke	Okay, keep going. I'm sorry for interrupting.
Erin Welsh	"For murderers, there is only one kind of mushroom worth considering."
Erin Allmann Updyke	Oh my god.
Erin Welsh	"Amanita phalloides. From the murderer's point of view, the deadly Amanita suffers from one shortcoming. An occasional victim, after days or weeks or even months of shattering illness, slowly recovers and returns to circulation."
Erin Allmann Updyke	Oh my god.
Erin Welsh	"True, he is only a frail replica of his former self but he is alive and has foiled the murderer's coup."
Erin Allmann Updyke	What journal, Erin?
Erin Welsh	Oh there's more. Can I?
Erin Allmann Updyke	Yeah. Sorry, sorry.
Erin Welsh	I need you to know this.
Erin Allmann Updyke	Okay.

Erin Welsh	"On the other hand, if the murderer also hates his victim and if success attends his undertaking, his worst instincts and hopes will have been more than satisfied by the slow progress and horrible suffering that attend the victim's downward course into the grave."
Erin Allmann Updyke	Oh my god.
Erin Welsh	"The symptoms of poisoning by the deadly Amanitas are distinctive, dramatic, and terrifying." And there's more. I'm just gonna keep going.
Erin Allmann Updyke	Keep going, keep going.
Erin Welsh	"Nothing arouses suspicion as the greedy diner consumes his fateful dish, nor does he suspect anything for many hours thereafter. The victim goes about his affairs blissfully unaware that the fingers of death are entwining him. Perhaps he speaks with relish of the mushrooms he has eaten and may ask for another helping of the same kind at the next meal. If they have been served to him intentionally, his murderer standing by eyes him with wicked and dissembled solicitude, alert for the inevitable moment. Of a sudden, the victim is gripped by appalling abdominal distress followed by vomiting and diarrhea. Neither emetics nor purgatives can help him now, for his system has absorbed the venom during the long period of silent invasion." End quote.
Erin Allmann Updyke	What? I need to know-
Erin Welsh	Okay. So like I said, it's from an academic publication, not a murder mystery novel, not a handbook on how to murder someone with mushrooms, although it kind of reads like that.
Erin Allmann Updyke	Right. It's from How to Get Away with Murder.
Erin Welsh	Yeah.
Erin Allmann Updyke	Sorry, that's not-
Erin Welsh	Best worst show. Yep.
Erin Allmann Updyke	Yeah.
Erin Welsh	It's from a 1972 article in Harvard's Botanical Museum leaflets titled 'The Death of Claudius or Mushrooms for Murderers' by R. Gordon Wasson.
Erin Allmann Updyke	Oh my god. Harvard? Okay.
Erin Welsh	Yeah.
Erin Allmann Updyke	Okay, 70s though tracks.
Erin Welsh	70s, sure. Yeah.
Erin Allmann Updyke	I also just want to say, I'm sorry I'm just interrupting here, researching this episode has made me... I will now never not ask someone with diarrhea have you eaten mushrooms?

Erin Welsh	Yeah. Well in California, I mean I guess Southern California-
Erin Allmann Updyke	Southern California less. But I've never asked someone that.
Erin Welsh	Yep.
Erin Allmann Updyke	I ask always like have you eaten anything new or different? Have you traveled anywhere?
Erin Welsh	Right.
Erin Allmann Updyke	Like I ask about food exposures obviously but never have I specifically asked mushrooms. I ask picnics, I don't ask mushrooms. And now I will always be asking about mushrooms.
Erin Welsh	Yeah. Well especially because I feel like if you have eaten mushrooms before and you may not think that you're eating something new or different when in fact it is a new and different species-
Erin Allmann Updyke	Right.
Erin Welsh	Most deadly. Yeah.
Erin Allmann Updyke	I have fear.
Erin Welsh	Yeah, I empathize. I feel similarly. Yep.
Erin Allmann Updyke	Okay but keep going, Erin.
Erin Welsh	Okay. So this article by Wasson is not meant to offer a murderer's perspective on deadly mushrooms.
Erin Allmann Updyke	Okay.
Erin Welsh	Maybe. But rather seemingly to go through one of the most famous instances of mushroom murders in history, that of the Roman Emperor Claudius I.
Erin Allmann Updyke	What?
Erin Welsh	Yep. Which is one of the many historical poisonings that contributes to the lore and notoriety surrounding this fungus. So what I want to do today is first take us through that lore, like what historical deaths have been attributed to this mushroom, and then go into the very real threat that they pose today as they continue their spread, before trying to get at the center of the question, why?
Erin Allmann Updyke	Why?
Erin Welsh	Why do these mushrooms, as you asked, possess this extremely deadly quality? Does it serve an evolutionary purpose?
Erin Allmann Updyke	Does it?

Erin Welsh	For now, back to Claudius.
Erin Allmann Updyke	Okay.
Erin Welsh	Claudius was an unlikely emperor. Even though he was born in 10 BCE into the ruling family of the Roman Empire, he was not close in line of succession and the circumstances of his birth, he was born at 32 weeks in 10 BCE-
Erin Allmann Updyke	Oh wow.
Erin Welsh	Right? Okay.
Erin Allmann Updyke	Yeah. I mean how accurate was dating back then though? I don't know.
Erin Welsh	I don't know. I do feel like for some reason, I don't know why I got this idea but I feel like his life is pretty well documented.
Erin Allmann Updyke	Yeah. It's just fascinating that like 32... That's very specific.
Erin Welsh	Right. How did they date the first-
Erin Allmann Updyke	How did they date pregnancies?
Erin Welsh	Sure.
Erin Allmann Updyke	That's what I mean, yeah.
Erin Welsh	Yeah, yeah, yeah.
Erin Allmann Updyke	How did they date pregnancies? Yeah, yeah. Anyways, doesn't matter.
Erin Welsh	Anyways. But he also had poor health during childhood.
Erin Allmann Updyke	Okay.
Erin Welsh	Which included a limp, a movement disorder, and quote unquote "disfigurement", whatever that meant. And these things led most people, including Claudius himself, to believe that he would spend most of his life behind the scenes. Which is what he did, becoming a historian and a politician until a series of chaotic, despotic events and assassinations made him emperor in 41 CE at the age of 51.
Erin Allmann Updyke	Okay.
Erin Welsh	Skipping over his time as emperor, you can read more about that in books and Wikipedia, and jumping instead to his death at the age of 64 in 54 CE-
Erin Allmann Updyke	Okay.

Erin Welsh	As told in the form of a modern medical case report. This is great. Okay. Quote: "Case presentation. In October, a 64-year-old man developed postprandial abdominal pain and vomiting. He had been feeling well until passing out during a banquet at which he had consumed a large quantity of wine and food. One dish that was composed of mushrooms was a longtime favorite. On regaining consciousness shortly thereafter, he complained of severe abdominal pain. He vomited and felt somewhat better. A physician induced additional vomiting by placing a feather in the back of the patient's throat."
Erin Allmann Updyke	Interesting.
Erin Welsh	Yeah, not great. Sounds absolutely horrible. "Shortly thereafter the patient's condition deteriorated. He became confused and exhibited signs of unremitting abdominal pain and fecal incontinence. He died 12 hours after the onset of his illness." End quote. Many writers both modern and ancient have attributed Claudius's death to Amanita phalloides, the death cap mushroom, allegedly sneaked onto his plate by his fourth wife Agrippina who wanted to make sure that her son Nero, Claudius's stepson, would succeed as emperor rather than Claudius's other son Britannicus from a previous marriage.
Erin Allmann Updyke	Oh my gosh.
Erin Welsh	I know, it's so dramatic. Now was it actually murder? Could be. There's motive, there's opportunity, there's knowledge of the deadly power of death cap mushrooms which I find fascinating. The symptoms match for the most part, kind of.
Erin Allmann Updyke	Yeah.
Erin Welsh	The account written closest to his death describes it as murder, open and shut. But there are some holes in this theory. Most of the accusations of murder came out years after Claudius died and are kind of just repeating rumors. Like where does this source actually come from? Depending on the source, the timeline doesn't really fit. Like did he get sick at the banquet right after eating mushrooms and then die shortly after?
Erin Allmann Updyke	Right.
Erin Welsh	Or was it a while after he ate them that he started having these symptoms?
Erin Allmann Updyke	Right. And like death in 12 hours, that's pretty...
Erin Welsh	It's pretty-
Erin Allmann Updyke	It's pretty rapid, yeah.
Erin Welsh	Yeah. And finally I'll just say that one common way to discredit powerful women back in the day was to call them a poisoner. Today it's trainwreck, in Ancient Rome it was poisoner. In any case we probably aren't going to ever fully resolve whether Claudius was assassinated via mushrooms or died of cardiovascular disease, which is another hypothesis.
Erin Allmann Updyke	Okay.
Erin Welsh	Yeah. Or just like something else.

Erin Allmann Updyke	Yeah, like some other... I'm not convinced it was Amanita by the description that was in that case report.
Erin Welsh	I know. I mean 12 hours.
Erin Allmann Updyke	But I'm not a historian.
Erin Welsh	The other thing though is that another account of Agrippina's son Nero saying oh yeah, my mom killed him, like all these sorts of things.
Erin Allmann Updyke	Right.
Erin Welsh	So it's like...
Erin Allmann Updyke	I don't know. We weren't there.
Erin Welsh	Who was?
Erin Allmann Updyke	Who was?
Erin Welsh	But the influence that Claudius's death has had on death cap mushroom lore is indisputable.
Erin Allmann Updyke	Wow, I love that.
Erin Welsh	I know. Any paper that's like the history of death cap mushrooms, it's like Claudius.
Erin Allmann Updyke	Okay.
Erin Welsh	And he's not the only one. As the author of that murder article puts it, this is what I'm calling it, quote, "Mycologists are prone to exaggerate the importance of mushroom poisonings in history. In their writings, we repeatedly find a list of eminent persons who have died allegedly from eating poisonous mushrooms, a list that they copy from each other without verification."
Erin Allmann Updyke	Oh my gosh, such shade.
Erin Welsh	I know. So rather than making the same mistake, I'm just going to go through a few more famous cases that seem to be more or less like they have more support, I guess I'll say that.
Erin Allmann Updyke	Okay. Love that.
Erin Welsh	Starting with another Roman emperor, the Holy Roman Emperor Charles VI.
Erin Allmann Updyke	Okay.
Erin Welsh	Quote: "On the 10th of October 1740 at night, his complaint was increased by indigestion, occasioned by a dish of mushrooms stewed in oil of which he ate voraciously." End quote. Ten days later he died and his death as the last male Habsburg of Royal Austrian dynasty set off a continent-wide war, the War of the Austrian Succession, when Charles's daughter Maria Teresa said she had the right to succeed her father but some countries wouldn't accept her. As a woman.

Erin Allmann Updyke	Right.
Erin Welsh	Yeah.
Erin Allmann Updyke	Wow.
Erin Welsh	It's interesting to me that no one suggests that he was murdered.
Erin Allmann Updyke	Murdered.
Erin Welsh	But more just that he ate a bad batch.
Erin Allmann Updyke	The wrong mushrooms.
Erin Welsh	Right.
Erin Allmann Updyke	Yeah.
Erin Welsh	Mistaken mushroom identity, yeah. And I'm no War of the Austrian Succession historian. I was kind of planning on reading a book about it and then I was like what are you doing? You don't have the time for this. But it seems like a big deal from what I gathered.
Erin Allmann Updyke	Yeah, yeah.
Erin Welsh	As Voltaire put it, quote, "A pot of mushrooms changed the history of Europe." End quote.
Erin Allmann Updyke	Wow.
Erin Welsh	Yeah.
Erin Allmann Updyke	Okay. Big deal.
Erin Welsh	Big deal. The next murder by mushroom story I'm going to tell comes to us from France in the early 20th century. A man named Gerard, together with his wife and mistress-
Erin Allmann Updyke	Love it.
Erin Welsh	They dreamt up a really quite sinister insurance fraud scheme. So he would befriend wealthy individuals or couples and then take out insurance policies in their names with either himself or his wife or mistress posing as the future victim on the policy.
Erin Allmann Updyke	Oh wow.
Erin Welsh	So then he would invite them over to dinner and serve them death cap mushrooms. He also apparently tried with anthrax and typhoid, but Amanita phalloides was his favorite.
Erin Allmann Updyke	Fave.

Erin Welsh	His preferred method.
Erin Allmann Updyke	Okay, yeah.
Erin Welsh	When his victims died he would collect on the policy. So he would show up. I mean this was like the early 1900s.
Erin Allmann Updyke	Okay.
Erin Welsh	So he would just like show up.
Erin Allmann Updyke	You could just do that, I guess.
Erin Welsh	Yeah.
Erin Allmann Updyke	Yeah.
Erin Welsh	Yeah.
Erin Allmann Updyke	I don't know insurance history.
Erin Welsh	Things didn't always go as planned.
Erin Allmann Updyke	Okay.
Erin Welsh	He didn't collect the mushrooms himself but instead hired a local guy named Theo.
Erin Allmann Updyke	Okay.
Erin Welsh	Theo wasn't the greatest mycologist and sometimes collected non-toxic lookalikes.
Erin Allmann Updyke	Okay.
Erin Welsh	So Gerard's victims just went away well fed instead of poisoned. But eventually Gerard's greed proved to be his downfall. He took out four insurance policies on one woman, he collected on three of them successfully but the fourth launched an investigation and the whole grizzly story came out.
Erin Allmann Updyke	Oh my god.
Erin Welsh	Gerard, his wife, and his mistress were all arrested but Gerard himself died of tuberculosis before confessing and he maintained his innocence until his last breath.
Erin Allmann Updyke	Wow. Okay, dark.
Erin Welsh	Dark. Okay, one more last dark one-
Erin Allmann Updyke	Okay.

Erin Welsh	That I'm going to mention briefly because so many of you out there would not forgive me for skipping this one. And I think at least a handful of you have reached out and mentioned this.
Erin Allmann Updyke	Okay.
Erin Welsh	And this is the 2023 death cap poisonings in Australia. This is a very quick version of this story because I'm sure there are true crime podcasts that have covered it. In July 2023, a woman named Erin Patterson invited her ex-in-laws over for lunch. This is her ex-husband's parents, Gail and Don, and his mom's sister and her husband, Heather and Ian. And she fed them beef Wellington. The next day all four guests, but not Erin, went to the hospital with GI distress. And over the following week three of the four, Gail, Don, and Heather died.
Erin Allmann Updyke	Oh my god.
Erin Welsh	Ian recovered but only after weeks. And tests revealed death cap mushrooms as the cause of their death. And a few months later Erin Patterson was charged with 3 counts of murder and 5 counts of attempted murder which included times over the previous years when her ex-husband got really sick of suspected food poisonings. So he was actually supposed to be at that lunch but he canceled last minute.
Erin Allmann Updyke	Wow.
Erin Welsh	As of the time of this recording, the last update is that Erin pled not guilty I think in May 2024 and the case is going to the Supreme Court of Victoria. And there's lots more out there on this case if you'd like to read more. The food dehydrator that she threw away after the lunch, her kids also eating the beef Wellington with the mushrooms scraped aside. Yeah. But we're not a true crime podcast, so that's where I'm going to leave things.
Erin Allmann Updyke	Oh my gosh. Awful though.
Erin Welsh	Awful, awful. And these famous or infamous mushroom poisonings may make up most of the headlines for death caps but they represent only a small proportion of all of the deaths or illnesses caused by these mushrooms. For Agrippina to use this as her murder weapon, she had to have known that their consumption was deadly. Which means of course that people had eaten them and gotten sick or worse for centuries. As Gerard's mushroom picker Theo was collecting the wrong kind of mushroom, i.e. the non-toxic kind-
Erin Allmann Updyke	Right, the opposite of what you would normally call the wrong kind.
Erin Welsh	Other people were making the opposite mistake and bringing home death caps for their evening meal. In fact the same year that Gerard was arrested, 31 schoolchildren in Poland died after eating a meal containing Amanita phalloides that had been served at school.
Erin Allmann Updyke	At school, ugh.
Erin Welsh	Isn't that absolutely-
Erin Allmann Updyke	Devastating.
Erin Welsh	Awful.

Erin Allmann Updyke	So sad.
Erin Welsh	Accidental ingestion of Amanita phalloides has always been a hazard for mushroom foragers in the areas where this mushroom grows naturally. And it turns out that area is growing. The death cap mushroom's natural range is in Europe, as you mentioned, but in the early decades of the 20th century, around the 1920s or 1930s, it was introduced to California. Not intentionally but it likely hitchhiked in soil or ornamental trees or shrubs brought over from Europe which were then planted. The oldest Amanita phalloides specimens are from 1938 and 1945 and come from Monterey County and Berkeley. Since their accidental introduction, the mushrooms have actually seemed to really take to the California habitat and have successfully established populations in natural environments, gradually expanding their range with a corresponding increase in accidental poisoning cases. And California isn't the only place we've seen Amanita phalloides find its footing. As this deadly mushroom expands its distribution, there has been a pressing need to get better at treating people and animals who have ingested them. And we've really made strides as far as that goes. I mean it's not perfect but we really have made strides.
Erin Allmann Updyke	Yeah, major.
Erin Welsh	Major. In the early 20th century, mortality rates from amatoxin poisonings were upwards of 60%-70%.
Erin Allmann Updyke	God.
Erin Welsh	With the introduction of fluid replacement therapy and better supportive care, that dropped to 30% and it's even lower today.
Erin Allmann Updyke	It is, we'll talk about it.
Erin Welsh	And while we don't have a cure for amatoxin poisoning, we do have a rapid diagnostic test, shout out to Candace Bever and team, which can really help healthcare professionals identify the cause of poisonings much more rapidly than before and start people on the supportive care that they need so much sooner.
Erin Allmann Updyke	Right.
Erin Welsh	Death cap mushrooms are responsible for the majority, 90%, of mushroom-related deaths around the world. Their toxicity is extreme. Like we said, half a mushroom can kill a person. It almost puts ricin to shame. Why are these guys so very, very deadly? What purpose, if any, do their toxins serve?
Erin Allmann Updyke	Tell me.
Erin Welsh	That is a fantastic question. The short answer is that it's likely for defense against things that eat fungi.
Erin Allmann Updyke	Right, it's logical.
Erin Welsh	Insects, nematodes, gastropods like slugs, and possibly other animals.
Erin Allmann Updyke	Okay.

Erin Welsh	This is a common reason that fungi, plants, and animals evolve the ability to produce similar toxins. The long answer to this question of why is that we don't fully know.
Erin Allmann Updyke	Of course.
Erin Welsh	We don't know. Of course not. We don't know precisely which organisms are the target of this toxin. Is it mammals? Maybe. But the toxin takes a long time to act.
Erin Allmann Updyke	Yeah.
Erin Welsh	Which could make it more difficult to associate the mushroom with symptoms. So it's like not a great learning tool, right.
Erin Allmann Updyke	Right, yeah. That's what's so confusing about it. And the other thing is like just how potent it is.
Erin Welsh	Right. And there doesn't seem to be any evolved resistance to the toxin in the mammal species that have been studied.
Erin Allmann Updyke	Yeah.
Erin Welsh	Which is not very many species.
Erin Allmann Updyke	But still.
Erin Welsh	But still.
Erin Allmann Updyke	Yeah.
Erin Welsh	So in a lot of these papers, especially the older ones, there will be repeated this common knowledge that squirrels are immune. But in this book that I read about this, the author was like I tried to track down the original study or source and I can't find anything.
Erin Allmann Updyke	Okay.
Erin Welsh	So yeah. So I mean it's possible that mammal sensitivity could vary across species but we don't have good data.
Erin Allmann Updyke	Yeah.
Erin Welsh	Mostly just anecdotes. And it might just be that mammals are collateral damage.
Erin Allmann Updyke	Interesting.

Erin Welsh	So is it insects? This seems more likely. Insects are more numerous across the landscape and thus may be a stronger driver for this toxin's production. And plus, studies of different Drosophila species, so Drosophila is a genus of flies, show that resistance to amatoxin varies across species. Some Drosophila species which feed on fungi are more resistant to the toxin than those that don't. And this resistance might offer an advantage to these flies beyond just surviving a meal. One study showed that these toxin-producing mushrooms might prevent these flies from getting parasitized by nematodes.
Erin Allmann Updyke	What?
Erin Welsh	Yeah.
Erin Allmann Updyke	Because the toxin is there in their body and so then it kills the nematodes or something?
Erin Welsh	Something like that I think, yeah. Yeah.
Erin Allmann Updyke	What?
Erin Welsh	The study of these toxins is fascinating.
Erin Allmann Updyke	Yeah.
Erin Welsh	Especially because they bear similarities to other toxins produced across the animal kingdom like venoms in cone snails, snakes, and spiders. And they could be affecting how this mushroom expands its geographic range and deals with environmental change. And so with that, Erin-
Erin Allmann Updyke	With that? What?
Erin Welsh	I'm leaving you with that. Leaving you with that to tell us where we are with this mushroom today.
Erin Allmann Updyke	I have so many different questions.
Erin Welsh	So do I.
Erin Allmann Updyke	Does that mean there's changes in like RNA polymerase in those flies? Like what is the mechanism of resistance? I have so many questions.
Erin Welsh	I'll link to the paper.
Erin Allmann Updyke	Okay, okay. I'll read more. But we'll wrap up soon right after this break.
TPWKY	(transition theme)

Erin Allmann Updyke	We've said it a few times now but it bears repeating that this mushroom is now everywhere. It's on every continent except Antarctica. It is absolutely spreading especially in places like California, through parts of Canada, the Pacific Northwest, anywhere where suitable trees exist. and there's a wide variety of tree species, by the way, that this mushroom grows in association with. And like you mentioned, Erin, death cap mushrooms specifically, Amanita phalloides, in all of the papers, in all of the research, are by far and away the most common cause of mushroom-related death, responsible for in some papers over 95% of deaths related to mushroom ingestion. How many deaths a year does this mean? I still don't really know. A lot of papers cite somewhere between 50-100 deaths annually across Europe.
Erin Welsh	Okay.
Erin Allmann Updyke	But in some years, up to 100 deaths have been reported in China alone. So how many... And in places like the US and Canada, it really can vary year to year because some years there are kind of big... Whether it's because of rainfall where there's a lot more of this mushroom growing and then people find it unintentionally. So it really can vary year to year. And then the other big question that can also vary is like how likely is it that a poisoning will be deadly? And this depends on so many different factors. Not only how much mushroom did a person consume, were they able to get access to healthcare? Did that healthcare facility quickly figure out that it was death cap toxicity? Did they treat it correctly? What part of the mushroom did they eat? How high was that particular mushroom in amatoxin?
Erin Welsh	Right.
Erin Allmann Updyke	Like it really, really can vary. Looking at like all the case studies over the last several decades, it really can vary what the case fatality rates tend to be and it's anywhere from 5%-30% of cases that end in death in recent years. And it varies country to country how mycophobic or mycophilic countries are. And those are new words I learned, so I wanted to throw those in here.
Erin Welsh	I learned that too and I was like yeah, it cracked me up because I had never really thought that much about it.
Erin Allmann Updyke	Yeah. Me neither. But there are countries, like the US for example, are mycophobic countries, we don't tend to forage a lot for mushrooms. Whereas some places in Europe are considered mycophilic countries where foraging for mushrooms is like a big part of cultural traditions in those areas. So in those areas, you're going to see more accidental exposure to mushrooms.
Erin Welsh	Yeah.
Erin Allmann Updyke	But also in combination with more knowledge about mushrooms overall. So it kind of all just depends honestly year to year.
Erin Welsh	Yeah. Well and this is where I feel like awareness and raising awareness is so important.
Erin Allmann Updyke	It's so, so, so important because Erin, so there was a kind of outbreak that happened in 2016 in Northern California. There were 14 total cases that were reported. Nobody died but three people ended up needing liver transplants including one 18 month old baby who ended up with really severe neurologic impairment because of how sick she got from liver failure.
Erin Welsh	Oh my god.

Erin Allmann Updyke	So what was very notable to me in reading the case reports about this outbreak is that people were ingesting mushrooms that other people handed them without any idea in some cases who those people were, it was like strangers who were giving them mushrooms that they foraged, and without any knowledge necessarily that mushrooms could be this deadly or that this deadly of a mushroom existed in this region. So it really does come down to knowledge of what mushrooms you're eating, how to know which ones are poisonous and which ones are not because they can sometimes look really similar, especially depending on the stage of mushrooms. Like early, young Amanita phalloides can look really similar to a lot of other edible mushrooms whereas they look more distinctive as they're matured. So it just really can depend on where you find them and in what association. Yeah. So one other big need in addition to awareness among people who are foraging and consuming mushrooms is also awareness among healthcare providers and the ability to confirm that suspicion once you've thought of it. And especially a type of detection method that is cheap, that is easy to use, and that is fast because every moment counts.
Erin Welsh	Every moment counts.
Erin Allmann Updyke	And like you mentioned, Erin, people have been working on exactly this. Shout out to Candace Bever. Thank you for contacting us and providing so many sources by the way, super helpful. There now exists a test like this. It works a lot like a COVID test or a pregnancy test where you put urine or mushroom tissue that you extract onto a little test that looks like a COVID test and two lines means negative for amatoxin and one line means positive for amatoxin. And this has been used both now in theory and also in practice. So it's new but it exists and it's cheap. It's like $10 a test. And I don't forage for mushrooms but if I did I would definitely buy some of these tests. So yeah, so those kinds of diagnostic tools need to be able to be in the hands of people not only who forage but also veterinarians and healthcare providers, like people who are going to be seeing amatoxin poisoning on the front line.
	And then also newer treatment methods is the other thing. And it goes without saying that this is a huge area in need for research because we don't have anything that specifically treats or targets amatoxin poisoning. There was a paper that came out in Nature in 2022 that got a lot of press because it was very exciting and it was using a medicine, it's not really medicine, it was using a substance called indocyanine green which is actually a dye that is used in medical diagnostics. So we use it not uncommonly in diagnostics for looking at things like liver output or cardiac output. And in this study that they published it was effective at stopping amatoxin from entering liver cells in mice and in culture. So not in human peoples but it's still a really big deal.
Erin Welsh	Yeah.
Erin Allmann Updyke	Because this is something like milk thistle that is already available in the US because it's already used in diagnostics.
Erin Welsh	Right, yeah.
Erin Allmann Updyke	So while we don't have anything immediate, like brand new treatment, we do have people doing that research and things on the horizon which is really important. And that, Erin, is death cap mushrooms.
Erin Welsh	Before we do sources, I want to plug poison control hotline.
Erin Allmann Updyke	Poison control hotline!
Erin Welsh	And pet poison control or animal poison control hotlines.

Erin Allmann Updyke	Absolutely.
Erin Welsh	Both of these things are crucial.
Erin Allmann Updyke	Yeah.
Erin Welsh	And people are amazing in how they can help you.
Erin Allmann Updyke	Yeah because they're the ones who are going to think of mushroom poisoning.
Erin Welsh	Yes.
Erin Allmann Updyke	If I forgot to ask that question, they're not going to forget to ask that question.
Erin Welsh	Right. And also like mushroom ID is another really important thing that experts can do.
Erin Allmann Updyke	Yes. Yeah.
Erin Welsh	So it's just... Yeah, don't forget poison control.
Erin Allmann Updyke	Poison control. 1-800-222-1222. If you don't have it saved on your phone, you can save it, that's the phone number.
Erin Welsh	You can save it. And there's-
Erin Allmann Updyke	And there's an online-
Erin Welsh	I have the animal one. It is 888-426-4435.
Erin Allmann Updyke	Does that work across the whole US?
Erin Welsh	I'm not sure.
Erin Allmann Updyke	Okay.
Erin Welsh	But it has worked for me in Colorado.
Erin Allmann Updyke	Okay.
Erin Welsh	I had to call it for my little puppy. He was fine.
Erin Allmann Updyke	Good. Not for mushrooms.
Erin Welsh	Not for mushrooms.
Erin Allmann Updyke	No.

Erin Welsh	I forget what it was for. Oh cherry pits.
Erin Allmann Updyke	Oh I remember that.
Erin Welsh	Yeah, that was a really lovely evening cleaning up vomit.
Erin Allmann Updyke	Right before a trip.
Erin Welsh	He was fine, he was fine. Everything's fine.
Erin Allmann Updyke	Well if you want to read more, we have so much more. I also have a great paper, it's not my turn yet but about more generally all the other toxins that are present in mushrooms and all the other syndromes that you can get from other mushroom toxicity. So we really need to do more episodes on mushroom toxins.
Erin Welsh	Love it, let's. I mean I would love to do that.
Erin Allmann Updyke	Yeah.
Erin Welsh	Do you want to go first?
Erin Allmann Updyke	I mean I guess. That was a cool paper. Other sources. There were two papers that I read by Vetter, one from 2023 and an older one from 1998. So the 2023 one was published in Molecules and it was called 'Amanitins: The Most Poisonous Molecules of the Fungal World'. And a few other really interesting papers on Amanita, on Amanita phalloides, on the amatoxins in general. Some really depressing ones like when people got it wrong in how they treated an Amanita poisoning before someone got to the hospital and the consequences of that. And then also the MMWR report about that outbreak in 2016 in Northern California. Erin, you should go because then I usually do the wrap ups. I don't know how to end my sources section.
Erin Welsh	Hilarious. I don't know how to end this. So I have a number of articles and maybe a book or two in there. The book where I got a lot of sort of the history part of the Amanita phalloides is from 'Mushrooms: Poisons and Panaceas: A Handbook for Naturalists, Mycologists, and Physicians' by Denis Benjamin. And if you want to read more about the evolutionary significance of these toxins, there is a chapter in a book and the chapter is titled 'Ecology and Evolution of the Amanita Cyclic Peptide Toxins' and that is by Walton from 2018.
Erin Allmann Updyke	I also think I might have misspoke and said that the paper that was using indocyanine green came out in 2022. It was actually 2023 in Nature Communications. But we'll post all of the sources from this episode and all of our episodes on our website thispodcastwillkillyou.com under the EPISODES tab.
Erin Welsh	We will. A big thank you again to the provider of our firsthand account. We really cannot thank you enough for being willing to share your story and for all the awareness work that you do.
Erin Allmann Updyke	Yeah, thank you. Thank you also to Bloodmobile who provides the music for this episode and all of our episodes.
Erin Welsh	Thank you to Tom Breyfogle and Lianna Squillaci for the amazing audio mixing.
Erin Allmann Updyke	Thank you to everyone at Exactly Right network.

Erin Welsh	And thank you to you, listeners. We hope that you learned something about mushrooms. How do you feel about mushrooms?
Erin Allmann Updyke	Do you eat mushrooms? Do you not eat mushrooms?
Erin Welsh	Do you forage mushrooms?
Erin Allmann Updyke	Do you forage mushrooms? I really wanna know.
Erin Welsh	Are you mycophobic or mycophilic?
Erin Allmann Updyke	I'm mycophobic.
Erin Welsh	Or somewhere inbetween? Myconeutral.
Erin Allmann Updyke	Myconeutral, I like that. And as always, a special thank you to our patrons. Thank you so much for your support. It really means the world to us.
Erin Welsh	It does, it does. Well until next time, wash your hands.
Erin Allmann Updyke	You filthy animals.