Erin Welsh	"I contracted toxoplasmosis in my first trimester. I will never know how. The doctor did not educate me or test me for it. I was not given the opportunity to prevent the devastation this disease would have on my baby. It had a lot of time to go unchecked and do a lot of damage. My daughter Dana was born 6 weeks premature with severe damage to her brain and her eyes. She is now 22 years old. She has very little cortex to her brain, she has cerebral palsy, she is blind, she has severe developmental delays. Dana requires our full care. She cannot sit unassisted, walk, talk, feed herself, dress herself, or toilet herself. My husband and I still change her diapers day and night.
	The toll on her body has been tremendous. She has had 10 surgeries, 2 of which were so traumatic we almost lost her. She has a tube that drains excess fluid from her brain, she has a metal rod in her back to help straighten severe curvature of her spine so her organs and lungs can continue to function. She has a pump surgically inserted to give her constant doses of a medicine to help her relax her muscles from further contorting her body which by the way is only minimally successful. One hip was reconstructed, the other is currently dislocated.
	I hate what toxoplasmosis has done to my daughter. It has stolen the dreams I once had for her and for me, our whole family has experienced emotional and financial strain yet through this all we have loved this young lady. She is remarkably determined to endure. She laughs, she enjoys being a part of an active family life. Dana has a younger sister Rebecca who is in college right now, she is one of the smartest, wittiest, kindest people I know. Life has been difficult for her too. Watching Rebecca I can't help but think of what Dana's life would have been like if her infection were caught early on. What would her future have held?"
TPWKY	(This Podcast Will Kill You intro theme)
Erin Allmann Updyke	Oh my god.
Erin Welsh	Yeah. That was an account by Janet Morel who testified before the Illinois State Senate in support of Senate Bill 3667 which was the proposed Prenatal and Neonatal Congenital Toxoplasmosis Prevention and Treatment Act. This bill would provide that healthcare professionals shall provide counseling for toxoplasmosis and testing for Toxoplasma gondii when providing care to a pregnant woman during her pregnancy. So that was part of her testimony.
Erin Allmann Updyke	Wow. My god.
Erin Welsh	Yeah, it's really sad, it's very rough.
Erin Allmann Updyke	That is really rough.
Erin Welsh	Well, I'm Erin Welsh.
Erin Allmann Updyke	And I'm Erin Allmann Updyke.
Erin Welsh	And this is This Podcast Will Kill You. This week we are covering Toxoplasma gondii.
Erin Allmann Updyke	Yeah we are.
Erin Welsh	Which has been a pretty heavily requested episode, I think.
Erin Allmann Updyke	Has it? Yeah, I think it has.

Erin Welsh	Yeah, yeah. And it's going to be a heavy one, it's going to be an interesting one, it's gonna be all the things that you've come to expect from this podcast.
Erin Allmann Updyke	Yeah.
Erin Welsh	Speaking of things to expect-
Erin Allmann Updyke	It's quarantini time!
Erin Welsh	It is. Erin, what are we drinking this week?
Erin Allmann Updyke	This week we're drinking What The Cat Dragged In.
Erin Welsh	What is in What The Cat Dragged In?
Erin Allmann Updyke	Well of course it's not a dead mouse but that would be appropriate as well.
Erin Welsh	Yeah.
Erin Allmann Updyke	It's vodka, some sparkling wine, a little crème de violet, and lemon juice.
Erin Welsh	Yeah, it's tasty.
Erin Allmann Updyke	It's tasty.
Erin Welsh	But the crucial thing-
Erin Allmann Updyke	Crucial.
Erin Welsh	Is that you rim the glass with Pop Rocks.
Erin Allmann Updyke	Of course because they look just like kitty litter.
Erin Welsh	There you go.
Erin Allmann Updyke	We'll post the full recipe for this quarantini as well as our nonalcoholic placeborita on our website thispodcastwillkillyou.com and all of our social media channels, so follow us there for the full recipe.
Erin Welsh	And I think I wanna cover a couple pieces of business which I just don't think that we have done.
Erin Allmann Updyke	Let's do it.
Erin Welsh	It all pertains to live shows or live-ish shows.
Erin Allmann Updyke	Yeah. They weren't live-ish, like we were there.

Erin Welsh	Yeah, that's true. It wasn't like a full live show, we're not going on tour or anything like that.
Erin Allmann Updyke	Sorry.
Erin Welsh	But we were lucky enough to go to both the University of Florida thanks to Nick Keiser and also to the University of Michigan thanks to Laura Haynes.
Erin Allmann Updyke	Yeah.
Erin Welsh	We met so many amazing people during both trips, it was really, really fun.
Erin Allmann Updyke	We had the most fun at both of those trips, it was super excellent. So thank you for inviting us and thanks to everyone who came and watched, it was so fun.
Erin Welsh	Yeah it was great. And also I recently, Erin Welsh, I was recently a guest on a live show of a podcast called The Road To Now.
Erin Allmann Updyke	Yay yeah.
Erin Welsh	It was super fun. So this is a really great history podcast and it came to Chicago recently and I got to be a guest along with Obama's White House photographer Pete Souza.
Erin Allmann Updyke	It's so crazy! That's so cool.
Erin Welsh	Mindblowing. Surreal. But anyway you can hear that episode of the live show on The Road To Now so just look them up wherever you get your podcasts and we're also going to post a link, if we haven't already by the time this comes out, on our social media.
Erin Allmann Updyke	Yes. Any other business? We have new merch including water bottles.
Erin Welsh	Yes, they're gorgeous.
Erin Allmann Updyke	They're very, very cool and they're the nice insulated kind, metal water bottles. And fancy-smelling soap. New smells of soap.
Erin Welsh	Yeah. New smells.
Erin Allmann Updyke	So check that out, just go to our website thispodcastwillkillyou.com and click on MERCH to find that.
Erin Welsh	Yeah.
Erin Allmann Updyke	Any other business?
Erin Welsh	Nope, let's just dive right in.
Erin Allmann Updyke	Okay.
Erin Welsh	Erin, tell me about the biology of toxoplasmosis.

Erin Allmann Updyke	I just can't wait to do that.
Erin Welsh	We'll take a little break.
TPWKY	(transition theme)
Erin Allmann Updyke	All right, Toxoplasma gondii, toxoplasmosis. I've been looking forward to doing this episode ever since I was a guest on The Purrrcast.
Erin Welsh	Oh yeah.
Erin Allmann Updyke	Yep. We talked a little bit about toxo on that episode if you haven't heard it, it's really fun. But I didn't do any research on toxo before I went on The Purrrcast so I felt really silly because I didn't know the answers to a lot of questions. So I'm excited to finally have done some research on this. I like actually know what I'm talking about a little bit. Still not an expert, okay.
Erin Welsh	(laughs) Polished amateur.
Erin Allmann Updyke	Exactly. That's a good description for my life, I think. Okay so Toxoplasma gondii is a protozoan parasite, so like malaria or Giardia.
Erin Welsh	Oh you did a great job.
Erin Allmann Updyke	Thank you.
Erin Welsh	Is that condescending enough?
Erin Allmann Updyke	Just a little. So this is a single celled organism that's not a bacteria or a virus, okay?
Erin Welsh	Yeah.
Erin Allmann Updyke	Cool. And when I learned this fact blew my mind so hard that even though this is technically epi, I'm gonna say this up top. Toxo infects up to 1/3 of the entire world's population.
Erin Welsh	Uh huh.
Erin Allmann Updyke	1/3 of the globe or humans.
Erin Welsh	I know.
Erin Allmann Updyke	I know! That is just mindblowing.
Erin Welsh	It is wild.
Erin Allmann Updyke	It's so wild.
Erin Welsh	It is.

Erin Allmann Updyke	Oh my gracious. Okay so because this is a parasite we have to talk about its life cycle because it's more complicated than some other organisms, okay. So the main host of Toxoplasma gondii is of course cats. Cats are the definitive host of Toxoplasma gondii and when they get infected with this parasite they poop out thousands and thousands of something called oocysts, that's the life stage that the cats poop out. Okay?
Erin Welsh	Yep.
Erin Allmann Updyke	And after 1-5 days in the environment, the environment being cat poop, so cat box or your sandbox where your kids are playing or your backyard or pretty much anywhere in the environment, these oocysts sporulate so then they kind of become infectious at that point. Once they sporulate they can persist alive and infectious in the environment for years.
Erin Welsh	Really, years?
Erin Allmann Updyke	Well at least a year.
Erin Welsh	Okay for a year.
Erin Allmann Updyke	Yeah. For months and year depending on the environment. So they can get into the soil, they can get into the water, they can get on your vegetables, etc.
Erin Welsh	What's the ideal environment?
Erin Allmann Updyke	The ideal environment would be kind of subtropical, so not too hot, not too cold, although they can survive freezing, you know, no big deal. Yeah. But we'll see in the epi section, burdens tend to be highest is warmer climates because they do persist better in warmer climates.
Erin Welsh	Okay.
Erin Allmann Updyke	So they get all up in the environment and then they're picked up by small animals, birds, mice, rats, generally things that cats might like to feed on. Once they get into these small animals they are now called tachyzoites, so that's the life stage that infects small animals, okay.
Erin Welsh	I wanna make some sort of joke about 'tachy' but I'm coming up blank.
Erin Allmann Updyke	I tried too, there's no good one. So inside of a mouse, generally the way that a small animal gets infected is by coming into contact with their mouth. So they eat some soil, they drink some water, they eat a piece of lettuce, whatever it is that has these tachyzoites on them and they get infected. Then these tachyzoites burst out of the intestine of these mice or these rats and they infect tons of different cells. So this is a parasite that has to be intracellular, so it invades cells inside of everything that it infects. And this life stage replicates asexually, so it just divides and it does so really, really rapidly and really profusely. So in the mouse you've now got this parasite dividing and replicating and swarming through the tissues. Then they'll find their way into two specific tissues that they like to invade: muscle and brain.
Erin Welsh	Why do they like those two types of tissues?
Erin Allmann Updyke	Well, let's talk about it.
Erin Welsh	I like how now you know me so well that you know what I'm going to ask.

Erin Allmann Updyke	Pretty much, most of the time. Doesn't mean I always know the answers though. But here we can talk about it. So they find their way not neural tissue and muscle tissue. I'm gonna first say what they do once they're there then we'll talk about why these are the tissues they invade. Once they're there they insist, so they actually transform into yet another life stage, the bradyzoite. The bradyzoite forms a cyst inside of the muscle tissue or the brain tissue. The cyst is surrounded by the animal's tissue, muscle or brain, but then full of hundreds of these bradyzoites. These continue to divide but they do so much more slowly, okay?
Erin Welsh	Okay.
Erin Allmann Updyke	But then to complete the life cycle these bradyzoites have to find their way into cat, right, so the cat is going to eat the mouse or the rat or the bird. What part of the mouse or the rat or the bird do cats definitely eat? Muscle tissue.
Erin Welsh	That makes sense.
Erin Allmann Updyke	Okay so that's why they insist in the muscle tissue. Why might they insist in the brain?
Erin Welsh	I think I know the answer to this.
Erin Allmann Updyke	Oh yeah. It turns out that Toxoplasma gondii is a parasite that can exhibit behavior modification. So that means that it can actually change the behavior of the animals that it infects.
Erin Welsh	It's really cool.
Erin Allmann Updyke	It is very cool.
Erin Welsh	It kind of like blows the lid off of the whole parasite-host dynamic in a way that is so scifi but also think it's just the tip of the iceberg. Okay I'm jumping the gun. Too excited.
Erin Allmann Updyke	(laughs) It is so scifi but it's something that's actually not that uncommon in parasites that are transmitted what we call trophically, so from one what we call trophic level to another. So if you think of the pyramid of life with carnivores on the top, carnivores are gonna eat herbivores and herbivores are gonna eat lettuce or whatever, right.
Erin Welsh	Secondary produces, primary produces.
Erin Allmann Updyke	Exactly, right. Lettuce. (laughs) And so in parasites that are transmitted through the food chain like that, it's actually not that uncommon for parasites to manipulate the behavior of that intermediate host, like the mouse, so that they're more likely to be eaten by the definitive host, i.e. the cat. In the case of mice and rats that get infected, what they do is not only do they seek out more rapidly novel environments and they're less fearful and more likely to be in open areas where normally mice and rats stay hidden because they don't want to be eaten for example. So infected mice and rats will seek out novel areas and explore more readily and they have done studies that show that they're not only less afraid of cat smells like cat urine, they're actually attracted to smells like cat urine.
Erin Welsh	Yeah.

Erin Allmann Updyke	Isn't that...
Erin Welsh	Yeah, it's almost unbelievable.
Erin Allmann Updyke	Like when you think about that the parasite has evolved to be transmitted this way and this is how... So here's the reason why this happens, or a reason why this happens is that only in cats can Toxoplasma gondii complete its life cycle because once a cat eats those bradyzoites that are in the brain or muscle tissue, inside the cat they actually undergo sexual replication and only in cats does Toxoplasma gondii actually sexually reproduce and then it produces those oocytes that the cat poops out and then the cycle can start all over again.
Erin Welsh	Right, the parasite has to find its way back to the cat.
Erin Allmann Updyke	Yes.
Erin Welsh	Yeah.
Erin Allmann Updyke	So there's a huge amount of incentive on the part of the parasite to make sure that they make it into the cat.
Erin Welsh	Yeah, it's gorgeous, it's beautiful.
Erin Allmann Updyke	It is. That being said, what about humans?
Erin Welsh	Yeah.
Erin Allmann Updyke	So that's the life cycle in the wild or in whatever, that's how Toxoplasma gondii evolved to exist. So what are humans? Are we the cat or are we the mouse?
Erin Welsh	Th mouse.
Erin Allmann Updyke	We're the mouse. So it turns out that we can get infected with almost any life stage of the parasite. So we can get infected directly from those sporulated oocysts that cats poop out, so that means if we get in contact with cat poop directly or with contaminated soil or contaminated water or maybe contaminated vegetables that haven't been washed or cooked, then we can get infected with that first stage, those tachyzoites. Okay. Those are the stage that's gonna invade tissues locally, that's gonna replicate really rapidly. But we can also get infected with those tissue cyst stages that would normally want to be eaten by a cat, the bradyzoites inside tissue cysts.
Erin Welsh	Gotcha.
Erin Allmann Updyke	So if you eat contaminated meat for example then you can get infected with that life stage. However since we're not cats the parasite can't complete its life cycle inside of humans.
Erin Welsh	We're a dead end host, just like in Lyme disease.
Erin Allmann Updyke	Just like in Lyme disease.
Erin Welsh	We're not contributing to the parasite life cycle and the prevalence.

Erin Allmann Updyke	Unless a cat ate us.
Erin Welsh	Which does happen.
Erin Allmann Updyke	Could happen, yeah. Could happen.
Erin Welsh	And it definitely happened prehistorically.
Erin Allmann Updyke	Mm-hmm, for sure.
Erin Welsh	Apparently cats were like a major, major predator of humans or like of ancestors of humans which makes total sense.
Erin Allmann Updyke	Fascinating, yeah.
Erin Welsh	Yeah.
Erin Allmann Updyke	Okay so in humans then the main way that this parasite causes disease is in two main ways. First by invading cells and tissues so it can cause direct damage in those tissues that it invades and by forming tissue cysts in really important places in our body where you shouldn't have cysts full of parasites. Cool?
Erin Welsh	Cool. I mean not cool, but yeah.
Erin Allmann Updyke	Okay.
Erin Welsh	Got it. All right.
Erin Allmann Updyke	So let's talk about the symptoms that we see in Toxoplasma infection. The good news is that the vast majority of people who get infected, something like 80-90% of people will be entirely asymptomatic. That's it.
Erin Welsh	For some reason I expected it to be higher. Asymptomatic. You said 80-90 are asymptomatic?
Erin Allmann Updyke	Yeah, yeah.
Erin Welsh	Okay.
Erin Allmann Updyke	Yeah. But okay so even of those 10% of people who maybe do show symptoms, the vast majority of those people will have a very nonspecific self-limited illness. So they'll feel a little sick, kind of cruddy, and the most classic sign of an initial toxoplasmosis infection is lymphadenopathy, so your lymph nodes get swollen.
Erin Welsh	Okay.

Erin Allmann Updyke	And that's pretty much it. Those lymph nodes aren't usually very tender and they can stay enlarged for like a month o so. So that's even if you have symptoms, the vast majority of the time that'll be kind of your only symptoms. So not that big of a deal in that case. However in some cases a primary infection can invade specific organs and then cause illness in those organs. So if those tachyzoites swim through and find, say, your heart tissue. Your heart is a giant muscle so it wouldn't be surprising for them to try and find and insist in your heart muscle. Then you could get something called myocarditis which just means inflammation of your heart muscle. If those tachyzoites invade your lungs you might get a pneumonitis. If they invade your liver, a hepatitis.
Erin Welsh	Okay.
Erin Allmann Updyke	All of these are theoretically possible, they have happened, but they don't happen very commonly.
Erin Welsh	Is there anything... So I know like immunocompromise is one big aspect of where this might happen more than others but is there anything else that makes you more susceptible to organ invasion?
Erin Allmann Updyke	That's a really good question. So the only other thing besides immunocompromise which I'll talk in more detail about in just a second is potentially strain differences.
Erin Welsh	Right, okay.
Erin Allmann Updyke	So there are a number of different genotypes and strains of Toxoplasma gondii and there is some difference in virulence between those strains. How big of a role that plays is not entirely clear.
Erin Welsh	Okay.
Erin Allmann Updyke	But yeah for most people who are healthy, they will never have any signs of infection but in people who are immunocompromised, especially in people living with HIV, Toxoplasma can be an extremely serious infection. The most common form of Toxoplasma infection, of toxoplasmosis in people living with HIV or people who are otherwise immunocompromised is encephalitis, so that's inflammation of the brain. So here's the thing about Toxoplasma. If you get infected even if your asymptomatic it doesn't necessarily mean that you don't have cysts inside of you right now but most of the time your immune system is going to be able to keep those cysts kind of in check, they're never gonna do anything, they're never gonna cause harm. But if you become immunocompromised those cysts can reactivate essentially.
Erin Welsh	Oh.
Erin Allmann Updyke	And then you can get the encephalitis later on.
Erin Welsh	Okay, that's bad.
Erin Allmann Updyke	So if you have an immunocompromise you can get sick with toxoplasmosis from a primary infection like this is the first time you got infected or it could be that you've had cysts in your tissues and now they're reactivating because your immune system is low. It's really, really serious. It's considered an AIDS-defining illness, Toxoplasma encephalitis.
Erin Welsh	Got it.

Erin Allmann Updyke	In a person living with HIV. And then of course the other way that you can get infected besides eating contaminated meat which by the way is the most common way that people get infected.
Erin Welsh	But I do have to point out there was a study that looked at the rate or the prevalence of toxoplasmosis in people who were vegetarians and people who were not vegetarians and found equal rates.
Erin Allmann Updyke	Fascinating.
Erin Welsh	Yeah.
Erin Allmann Updyke	All right.
Erin Welsh	So it's very clear that there are many different routes for exposure.
Erin Allmann Updyke	Absolutely.
Erin Welsh	Much, much beyond cats as well, much beyond owning a cat I should say as well.
Erin Allmann Updyke	Yeah, owning a cat is generally not even, alone owning a single cat is not even considered a risk factor.
Erin Welsh	Right. And we'll talk more about the ecology of that and why that is.
Erin Allmann Updyke	Yeah. But the other way that you can become infected is congenital toxoplasmosis which is what we heard about in the firsthand account. It is horrible. So Toxoplasma can cross the placenta and then infect the fetus. It turns out that this is most common if a pregnant person gets infected for the first time while they're pregnant and what's interesting is that the risk of infection of the fetus actually increases with gestational age. So the later in a pregnancy that a person gets infected, the more likely it is that the fetus will be infected. But the severity of that infection is opposite, so it decreases.
Erin Welsh	Ah, okay.
Erin Allmann Updyke	So the earlier a fetus gets infected, the more severe the outcomes. Does that make sense?
Erin Welsh	The less likely they are to become infected.
Erin Allmann Updyke	Exactly, right. So overall without any treatment for a primary infection, so a pregnant person who gets infected while they're pregnant, the risk of congenital syphilis is between 20-50% depending on when during their pregnancy they get infected, what strain they're infected with likely, and how much they're exposed to probably as well. Severe infections can result in fetal loss, so it can result in stillbirth or miscarriage but other characteristic findings are things called chorioretinitis which is inflammation of the retina and the choroid which is basically like your blood vessels in your eye which can lead to blindness, hydrocephalus which is the buildup of fluid in the brain and intracranial calcification which is calcium deposits essentially inside of your brain and then seizures in a baby. So yeah, it's really bad, congenital toxoplasmosis.
Erin Welsh	Is it routine anywhere to screen?

Erin Allmann Updyke	It's not routine in most places to screen unless there is a risk for infection. So it's not universal.
Erin Welsh	And is it something where you could determine whether it's an active infection or something that you have been infected with and the cysts are just there?
Erin Allmann Updyke	Yes, you can.
Erin Welsh	Okay.
Erin Allmann Updyke	So in general and I will say that pregnancy is a form of immunocompromise so it is possible to have reactivation of cysts but it's much less likely that that will result in congenital toxoplasmosis.
Erin Welsh	Okay.
Erin Allmann Updyke	So it's really that primary infection, like if you get infected for the first time which you're pregnant, that's when it's the highest risk.
Erin Welsh	So it's like the tachyzoites.
Erin Allmann Updyke	Exactly, right. Yeah. But also even if you ate pork that was infected, so then you're getting infected with bradyzoites but it's just not from within your body reactivating, it's that primary infection.
Erin Welsh	Oh, gotcha.
Erin Allmann Updyke	Yeah. But yeah we usually use seroprevalence, so looking for antibodies but you can tell based on the type of antibody and the amounts of antibody whether or not it's a primary infection or you were infected say 10 years ago or something like that.
Erin Welsh	Okay.
Erin Allmann Updyke	And the good news is that there is treatment. The treatment is mostly aimed at that tachyzoite stage, that rapidly dividing stage so it doesn't affect the tissue cysts directly. So that's kind of the Catch-22 is that we can treat it but we can't really affect those tissue cysts.
Erin Welsh	But let's say for pregnant people if there's an active infection, that's really the thing that needs to be targeted anyway it appears?
Erin Allmann Updyke	Yeah and so for pregnant people there's two different ways that we can treat it depending on if we think the fetus is already infected or if we're trying to prevent the fetus from getting infected. So one you can treat just to prevent those tachyzoites from kind of crossing the placenta and infecting the fetus or if you think the fetus is already infected, you can give different drugs that actually help treat it within the fetus itself.
Erin Welsh	Okay.
Erin Allmann Updyke	And all of those are affecting the tachyzoite stage as well.
Erin Welsh	Okay.

Erin Allmann Updyke	So yeah, I mean that's basically the biology of toxoplasmosis.
Erin Welsh	Oh, okay.
Erin Allmann Updyke	Yeah.
Erin Welsh	It's a bad one. I mean I knew that it was bad but...
Erin Allmann Updyke	Yeah.
Erin Welsh	Yeah.
Erin Allmann Updyke	So Erin, how did we get here? Where did this thing come from and why does everyone get infected? 1/3 of all people.
Erin Welsh	I'll tell you after this quick break.
TPWKY	(transition theme)
Erin Welsh	So the actual written history of Toxoplasma gondii is just over 100 years old.
Erin Allmann Updyke	That's it?
Erin Welsh	Yeah, like the written history of 'there's this disease that does this, there's this parasite that does this.'
Erin Allmann Updyke	Wow.
Erin Welsh	Yeah. So this is gonna be a really short section. Just kidding, it's not.
Erin Allmann Updyke	(laughs) It's you.
Erin Welsh	Yeah it's me, it'll never be a very short section, it just means I'm gonna talk more about evolutionary history and other things that I'm just gonna sprinkle throughout.
Erin Allmann Updyke	Fabulous.
Erin Welsh	Okay but let's get to the written history part of it first. In 1908 the parasite was described for the first time. There were these two researchers working at The Pasteur Institute in Tunis, they were study leishmaniasis which is a disease caused by a different protozoan parasite. They were trying to figure out what the reservoir host was and learn more about the Leishmania transmission cycle, all of these things.
Erin Allmann Updyke	Okay.
Erin Welsh	And for their research they were using an animal called a common gundi.
Erin Allmann Updyke	Oh, what's that?

Erin Welsh	I had no idea. I looked it up and it's like kind of weirdly cute. It's definitely not like that cute, I mean...that's horrible.
Erin Allmann Updyke	We'll post a picture.
Erin Welsh	Yes, of course. And so this is about the size of a guinea pig maybe and it's a type of rodent that's native to Northern Africa.
Erin Allmann Updyke	Oh, okay.
Erin Welsh	It's super good at living in rocky deserts.
Erin Allmann Updyke	Okay.
Erin Welsh	And so they were looking at the tissues of a gundi for parasites, Leishmania, and they found a protozoan that they thought was Leishmania.
Erin Allmann Updyke	Okay.
Erin Welsh	But they looked a little bit closer and realized based on morphology this is a completely different parasite.
Erin Allmann Updyke	Awesome.
Erin Welsh	So they named it Toxoplasma gondii. 'Toxo' for the Latin word for arc, 'plasma' for former life, 'gondii' was the misspelling of the host, the common gundi.
Erin Allmann Updyke	Oh, gundi?
Erin Welsh	Yeah.
Erin Allmann Updyke	(laughs) No way!
Erin Welsh	G-U-N-D-I is how you spell the animal, G-O-N-D-I-I is how you spell the specific epithet of Toxoplasma gondii.
Erin Allmann Updyke	That is so funny.
Erin Welsh	Yeah.
Erin Allmann Updyke	I love it when things get named for silly reasons like that.
Erin Welsh	I mean it's one letter but it's just kind of like I never thought about gondii.
Erin Allmann Updyke	Me neither.
Erin Welsh	I just thought probably it was gonna be someone's name. But it's not.

Erin Allmann Updyke	Yeah, wow. That is so interesting.
Erin Welsh	Anyway, okay. So at the same time that these two researchers who by the way their names were Charles Nicolle and Louis Manceaux, at the same time that these researchers were finding and describing Toxoplasma gondii in the common gundi, on the opposite side of the world in Brazil another researcher, same year, another researcher named Alfonso Splendore was doing the same exact thing. Like he found Toxoplasma gondii but he found it in a rabbit instead.
Erin Allmann Updyke	What?
Erin Welsh	Same time.
Erin Allmann Updyke	Same time.
Erin Welsh	Yeah. Keep that fact in your head.
Erin Allmann Updyke	Ooh, is there gonna be drama?
Erin Welsh	I mean not really, I will say that by and large Nicolle and Manceaux are the two that get the credit for the discovery and in large part because their finding was written in English and Alfonso Splendore, his was written in Portuguese and not translated into English until 2009.
Erin Allmann Updyke	Wow.
Erin Welsh	And so this goes into the whole English as the only scientific language and blah, blah, blah, all the issues surrounding that.
Erin Allmann Updyke	Wow.
Erin Welsh	It's kind of interesting. He also didn't name the parasite, he just said, 'I found this parasite.'
Erin Allmann Updyke	Okay.
Erin Welsh	So that could have something to do with it too. But another 30 years would pass before people realized that this parasite could be harmful to humans. So it was in 1938, there was a 3 day old newborn that was born at Babies Hospital in New York City. She started having seizures and the doctors looked her all over and all they could see that was out of the ordinary were these lesions in her eyes. Sadly a month later she died. And so during the autopsy doctors saw the same lesions all over her brain and they wrote a case study up about this and this case study would end up being probably the first recognized case of congenital human toxoplasmosis.
Erin Allmann Updyke	Wow.
Erin Welsh	Cause they found the parasites in her brain and then they injected it into animal models and then they developed encephalitis and so yeah.
Erin Allmann Updyke	Wow.

Erin Welsh	And so at this point Toxoplasma gondii is a recognized pathogen but there are still many mysteries surrounding the parasite including the extent to which people were infected, like the prevalence, how they became infected, and many characteristics of the parasite itself like its life cycle and its hosts. So researchers had detected the parasite in many different mammal species but they were unsure of which animal was the definitive host. And at first they suspected it had something to do with eating undercooked meat which as you said it definitely does. And so in the 1960s these group of scientists designed an experiment in which they fed essentially raw lamb, like just barely cooked lamb chops to people with tuberculosis living at a sanitorium to see if they could transmit Toxoplasma gondii.
Erin Allmann Updyke	I'm sorry.
Erin Welsh	Yeah.
Erin Allmann Updyke	Is every episode this season gonna have some horrible experiment that we've done on humans?
Erin Welsh	Yeah. Well the experiment was successful.
Erin Allmann Updyke	Of course, they killed a bunch of people.
Erin Welsh	They didn't kill people.
Erin Allmann Updyke	Okay.
Erin Welsh	But these people did become infected. But that didn't quite answer the question of what the definitive host was, it was just like can you get it from uncooked meat. So a few years after this experiment a parasitologist decided kind of on a whim to check out whether his cats had the parasite. Bingo! They did! And it didn't take long for other labs to confirm these findings and then this is like in the early 1970s and there was like a strong backlash against cats. Apparently according to one of the articles I read, there was a lot of people and I don't know where exactly or how many killed cats out of fear thinking these cats are killing my children, these cats are killing through this parasite.
Erin Allmann Updyke	Oh my gosh.
Erin Welsh	But I think for the most part that was not the common response, I think it did happen but I don't think it was the common response because cat ownership has only continued to increase since that study was released. So after finding that felines are the definitive host for toxo, a lot more of the pieces began to fall into place. So the complex life cycle of the parasite was figured out and people started to get an idea of how it causes these behavioral changes in rodents that influence the parasite's transmission.
Erin Allmann Updyke	So cool.
Erin Welsh	It's so cool. And it's these early studies on the behavioral influence of rodents that really opened up this huge field of research about behavioral manipulation of parasites and what that might mean for humans and our microbes. So I'll get to that in a bit. But that's basically the written history of toxo.
Erin Allmann Updyke	Wow, so short.

Erin Welsh	It didn't cause any massive pandemics or overtly change the course of history in some dramatic fashion and it isn't even old enough to have any bizarre cures associated with it. It just basically consists of a series of scientific developments and findings. But there is more to toxo than that.
Erin Allmann Updyke	Yeah, like where did it come from?
Erin Welsh	Exactly. So remember how the parasite was discovered simultaneously at two different points on opposite sides of the world.
Erin Allmann Updyke	Yeah.
Erin Welsh	There's a certain amount of coincidence that goes into that but really what it tells us is just how incredibly widespread this parasite already was.
Erin Allmann Updyke	Yeah, like that wasn't new at that time.
Erin Welsh	That wasn't new. So the question is how did it get to be like that? And the answer is domestic cats. That truly is the answer. So I mean yeah, let's go back in time. Let's go back to around 11,000 years ago. So it's around then when we see the very first evidence of agricultural societies, so people actually settling, keeping livestock, growing grains and plants at home, and we see this happen in different places all around the world over the next several thousand years. So in the Fertile Crescent is where it began, then in China, then Mexico, then Western Africa and so on. So around like 11,000 years ago to 4000 years ago is when the biggest movement or shift started to happen. And I've talked on this podcast before about how the formation of agricultural societies and farming, how that would have impacted disease transmission and what types of diseases were transmitted and what they would look like.
Erin Allmann Updyke	Right.
Erin Welsh	So just a refresher, larger human settlements means more transmission between humans, so you get these crowd diseases like tuberculosis and influenza, and then you also get zoonotic diseases transmitted between humans and their livestock or humans and domestic animals.
Erin Allmann Updyke	Yeah.
Erin Welsh	And the human-animal contact increases not just because of people choosing to own cattle or whatever other livestock but also because of keeping large stores of grain and other food.
Erin Allmann Updyke	Yeah.
Erin Welsh	And then you get other little animals finding you.
Erin Allmann Updyke	Like mice and rats, etc.
Erin Welsh	Exactly. For example the house mouse. So there's archeological evidence if the increase of the house mouse as human agricultural settlement increased. So 12,000 years ago the proportion of house mice bones found among small mammals near hunter-gatherer communities was about 5%.
Erin Allmann Updyke	Okay.

Erin Welsh	But within 1000 years which is like a long time but also very short time, that number jumped up to 80%.
Erin Allmann Updyke	So like of all the animals that they found near, like 80% of them were house mouses. Way to go, Erin. Wow!
Erin Welsh	Isn't that wild?
Erin Allmann Updyke	Yeah. That's a huge change in 1000 years, that's massive.
Erin Welsh	A huge change.
Erin Allmann Updyke	Yeah.
Erin Welsh	So it's probably a good thing or at least no surprise that cats were domesticated in the Fertile Crescent around the same time that agricultural societies began to form there 11,000-ish years ago.
Erin Allmann Updyke	Cause there's so many mice for them to eat.
Erin Welsh	Yeah it's probably not coincidental.
Erin Allmann Updyke	Yeah, no.
Erin Welsh	But anyway, so there was a little cat named the Near Eastern wildcat who even like the wild populations today seem to be very bold and not very aggressive towards humans or fearful which is kind of interesting and makes sense. So these types of cats came up to human dwellings and they made themselves at home and probably in a way that's familiar to a lot of cat owners today. Just like, 'Hi, I'm here now. This is my home.'
Erin Allmann Updyke	I'm here now, I will live here. (laughs)
Erin Welsh	And so this caused a major shift in the dominant transmission pattern of Toxoplasma gondii. The sylvatic cycle which is the natural cycle in the forest basically or in the wild-
Erin Allmann Updyke	Right, like wildcats.
Erin Welsh	Exactly. This is the one that still seems to be quite active in many places today. So this involves the wild felids and wild rodents while the domestic cycle is the one that we are more familiar with and it's the one that has led to the huge prevalence of toxo around the world today. This is the one that involves our house cats and house mice. And scientists have looked at the genetic diversity of toxo around the world and found that in urban areas where the domestic cycle dominates there's less diversity because there's more mixing of the parasite populations. And that's in contrast with the higher diversity seen in places where the sylvatic cycle is more common such as the forests of Central and South America. But overall the domestic cycle is the more common one and the simple answer for that is housecats. So felines are the only animals that can serve as a definitive host, as you said, and wild felines have never really been at high enough population densities around the world to be able to result in the widespread and extremely high prevalence of toxo.
Erin Allmann Updyke	In humans.

Erin Welsh	In humans, yes.
Erin Allmann Updyke	Yeah, in humans. Yeah.
Erin Welsh	But also in places where wildcats do not occur, we still see a ton of toxo.
Erin Allmann Updyke	Yeah, in other animals.
Erin Welsh	In wildlife.
Erin Allmann Updyke	Right, yeah. I'm not surprised about that.
Erin Welsh	And that is largely due to house cats as well. Why were cats domesticated in the first place?
Erin Allmann Updyke	To eat the mice?
Erin Welsh	So that's probably part of it. So I read this book that's called 'The Lion in your Living Room' and it talks all about the history of the cat, it's very fun. And she is a huge lover of cats and she's like you know, it just doesn't really make a lot of sense. Dogs have tons of different roles, they have tons of jobs they can do, they're protective.
Erin Allmann Updyke	Yeah, they're useful.
Erin Welsh	They can work, they're useful. Cats, you know, they can kill rodents.
Erin Allmann Updyke	So can dogs.
Erin Welsh	So can dogs. Yeah and dogs are actually more effective at actually lowering populations of rodents.
Erin Allmann Updyke	Oh, I didn't know that.
Erin Welsh	Because they can be task-oriented whereas cats aren't as task-oriented.
Erin Allmann Updyke	Yeah.
Erin Welsh	And so they've shown studies that cats don't often actually effectively reduce rodent populations unless other food is extremely scarce.
Erin Allmann Updyke	Interesting.
Erin Welsh	Because they'll go for the low hanging fruit, that just makes more sense.
Erin Allmann Updyke	They're lazy. Those lazy kitties.
Erin Welsh	This is famously captured in a video of cats scavenging for trash right next to rats. Because they're like why would I waste my energy killing and eating a rat when I could just eat trash?

Erin Allmann Updyke	I mean who could blame 'em?
Erin Welsh	It makes sense. And certainly now they do little to affect urban rodent populations.
Erin Allmann Updyke	Right.
Erin Welsh	So the author of this book though started a file apparently called 'Uses for Cats' when she was researching this book and I just wanna list a few of these cause they crack me up.
Erin Allmann Updyke	Please.
Erin Welsh	So first of all there's to encourage rain people in Indonesia would parade cats around their fields.
Erin Allmann Updyke	(laughs) Parade cats, I love it.
Erin Welsh	I wonder if parading cats is easier than herding cats, I don't know.
Erin Allmann Updyke	It's probably equivalent.
Erin Welsh	People used cat skin for musical instruments a lot. Apparently people in China used to use the cats dilating pupils to estimate the time of day. And they were also a critical part of many types of European tortures.
Erin Allmann Updyke	Ooh, what?
Erin Welsh	I'm quoting directly from her book, "Medieval murderers were sometimes burned in a sack with 12 cats to maximize suffering and during a punishment called cat-hauling, a cat was dragged by its tail down the length of an offender's body."
Erin Allmann Updyke	Oh my god!
Erin Welsh	Yeah.
Erin Allmann Updyke	I feel so bad for the cats.
Erin Welsh	I know! Okay so then there's some more modern things. So cat hair has been used in DNA evidence for murder trials which is pretty cool.
Erin Allmann Updyke	Okay, okay. Yeah.
Erin Welsh	So anyway those were a few of the things on the 'Uses for Cats' list. But regardless of their questionable skills as rodent controllers or any of these other powers, humans kept them around and that's maybe putting it mildly. There's archeological evidence of the love that humans have for cats. There's a 9500 year old grave for a kitten on the island of Cyprus.
Erin Allmann Updyke	Aw, baby.
Erin Welsh	There's of course Ancient Egyptian artwork showing housecats, worship of cats.

Erin Allmann Updyke	Weren't cats to ward off evil spirits and stuff? They were like protectors of the living or something.
Erin Welsh	They were. And then on the flip side of that things weren't always so good between cats and humans. So I talked a little bit about during the plague but also cats in general during some times in a lot of places were thought to be demons or agents of Satan.
Erin Allmann Updyke	Yeah.
Erin Welsh	And some historians think that this might be due to the fact that allergies to cats are fairly high.
Erin Allmann Updyke	(laughs) Aw.
Erin Welsh	So if a cat jumps on you and goes around your face and stuff and then all of a sudden your throat itches and you can't breathe, I mean I would probably think yes, this cat is an agent of Satan. Anyway wherever humans went they brought cats with them. Maybe as mouse or rat killers or maybe just as a good luck charm. And cats of course were especially valued on ships and sometimes sailors would refuse to get on a ship if it was missing its resident cat. But when humans and cats traveled the globe together there was this other hitchhiker that tagged along, Toxoplasma gondii. And the proof of how far cats have traveled is in the global distribution of toxo. Toxoplasma gondii is now found all over the globe, even above the Arctic Circle.
Erin Allmann Updyke	Whoa.
Erin Welsh	Yeah. And there it's found its way into beluga whales and other arctic dwellers and it's like quite a problem.
Erin Allmann Updyke	Okay, yeah.
Erin Welsh	And it's not just that where you find cats, you can find toxo. Thanks to water, toxo can travel incredibly far and over the past 100 years or even 50 years cats have grown incredibly in popularity. People have moved into apartments, in cities, cat litter was invented, and globally now there are around 600 million domestic cats.
Erin Allmann Updyke	That's not as many as I expected.
Erin Welsh	Well there are around anywhere from 600 million to 1 billion cats worldwide.
Erin Allmann Updyke	Okay, okay.
Erin Welsh	And these aren't just pets, these are also feral cats.
Erin Allmann Updyke	Right. Right, right, right.
Erin Welsh	And everyday in the U.S. more cats are born than there are lions in the wild.
Erin Allmann Updyke	Whoa!
Erin Welsh	Yeah.

Erin Allmann Updyke	That is a shocking statistic.
Erin Welsh	Yeah. And these cats aren't always pets.
Erin Allmann Updyke	No.
Erin Welsh	In Australia for every one pet cat that has a home, there are 6 feral ones.
Erin Allmann Updyke	That's bad.
Erin Welsh	It's really, really, really, really, bad.
Erin Allmann Updyke	Yeah.
Erin Welsh	And in the U.S. only about 60% of the American pet cat population are kept indoors.
Erin Allmann Updyke	Ooh, that's bad.
Erin Welsh	Yes, that's really bad.
Erin Allmann Updyke	We touched on this in the Chytrid episode, but I assume we're gonna talk a bit about how important it is to keep cats indoors.
Erin Welsh	Yeah. So it's not just that cats have single handedly wiped out entire species, many different species, but even researchers have shown that even just their presence alone causes many problems such as increased stress, making it difficult for some prey species to breed or parent properly and they also spread disease, feline leukemia, toxoplasmosis. And for the most part these problems can be greatly diminished or completely fixed by keeping cats indoors.
Erin Allmann Updyke	Right.
Erin Welsh	Cats have a huge cascading effect on the ecosystem and then when you throw in toxo it's a pretty big conservation and public health problem, outdoor cats.
Erin Allmann Updyke	Yeah.
Erin Welsh	And this is not easy to talk about.
Erin Allmann Updyke	No.
Erin Welsh	At all. Because people love their cats and they love cats in general and they can feel defensive about this. And by and large if you have a cat and keep it indoors, you're not part of the problem, your cat's not part of the problem.
Erin Allmann Updyke	Yeah.
Erin Welsh	Strays and feral cats are much more problematic and finding a solution that works has not been easy.

Erin Allmann Updyke	Yeah.
Erin Welsh	And in this book 'The Lion in the Living Room' she goes into this in a lot more detail. But a lot of cities practice TNR which is trap, neuter, release programs and people who are opposed to that point out that these cats are still outside and they're still releasing toxo and they're still killing birds and endangered reptiles and mammals.
Erin Allmann Updyke	It's interesting cause I knew how big of a problem cats were for wildlife and things and trap, neuter, release for cats that you know are not going to get a home if you try and adopt them out because they're feral cats, like they're not going to tolerate or no one would want to adopt them, it's like oh yeah, trap, neuter, release, at least they're not going to be making more cats. But then when you think about when I started reading about toxo and just how much of an impact a single cat can have, oh man. It's rough.
Erin Welsh	It's really rough. And trap, neuter, release is meant to reduce the population of feral cats. It does not work cause you would have to... If your goal was simply to reduce population of feral and stray cats, trap, neuter, release doesn't work. It's too effortful for the number of cats that you actually can capture.
Erin Allmann Updyke	There's too many cats out there that aren't being captured?
Erin Welsh	Yes. But you know euthanasia doesn't work either. Estimates suggest that if only if 97% of all feral cats in an area are euthanized will population numbers actually go down permanently.
Erin Allmann Updyke	Whoa.
Erin Welsh	Cats are very effective at breeding like rabbits, I guess.
Erin Allmann Updyke	Wow.
Erin Welsh	Mm-hmm. And so this debate continues to go on over which practice is better or which practice is more humane but the conversation is starting to shift a little bit because people are realizing maybe it's not this vs this, we just have to accept that cats are part of environment. So what do we do about it? That's maybe the more pressing issue. And that's not something that I'm gonna attempt to answer, I just wanted to bring this up because I think it's a really important bit of information about the problem of outdoor cats and I think it's an interesting example of how conservation, public health, and animal rights can all be at odds with one another.
Erin Allmann Updyke	Yeah.
Erin Welsh	There's no easy answer, there's no easy solution here.
Erin Allmann Updyke	Well at least you can keep your own cat indoors, that's an easy solution.
Erin Welsh	Yes, yeah. Okay so you talked about some of the negative effects of toxo in humans but toxo also can really devastate other animals, sometime leading to or often leading to fatal infections. So this is the case for example with kangaroos.
Erin Allmann Updyke	Kangaroos?!

Erin Welsh	Oh yeah, it's a big problem in kangaroos. It's also the case for sea otters which I know is your favorite animal.
Erin Allmann Updyke	I know. Toxo in sea otters is so sad.
Erin Welsh	It's so sad. And the fatal outcome in sea otters isn't necessarily just the direct effects of the parasite but also the behavior alteration. So we know that toxo can affect the behavior of rodents infected with the parasite and we've hinted at the subtle behavioral effects on humans but it turns out that sea otters that are infected with toxo are three times more likely than their uninfected counterparts to be killed by a great white shark.
Erin Allmann Updyke	Whoa! That is really fascinating.
Erin Welsh	Yeah.
Erin Allmann Updyke	Cause I was also reading that it's probably an underestimate how many otters die from toxo too just because we only see the ones that wash up on shore and not all of them obviously wash up on shore and things.
Erin Welsh	Right. And the prevalence is something like 36 to 40 something percent in some populations.
Erin Allmann Updyke	It's really high, yeah.
Erin Welsh	Yeah. Which brings me to the possible effects of toxo on humans.
Erin Allmann Updyke	Yeah let's talk about it, Erin.
Erin Welsh	Toxo in humans is very interesting and it's both a budding field and controversial. There have been many different studies that have tried to associate toxoplasmosis infection with increased risk of car accidents, suicidal tendencies, just overall attitude or personality changes and there are some compelling results but a lot of them seem a bit difficult to disentangle, like not everything has been controlled. And it's just hinting that there might be something going on there.
Erin Allmann Updyke	Yeah.
Erin Welsh	Not enough to I think say this is conclusively showing an effect.
Erin Allmann Updyke	Yeah we definitely don't have any solid...
Erin Welsh	Right. But the big one that has made the rounds is the association with schizophrenia. So basically what proponents of this hypothesis believe or suggest that infection with toxoplasmosis leads to an increased risk of being diagnosed with schizophrenia. So let's go through some of the evidence in support of this. One thing that a lot of people say or that a lot of people point to is that there don't seem to be descriptions of schizophrenia prior to the 1800s and that's sort of when cat ownership really came into fashion. There's also the seasonality of schizophrenia, so people diagnosed with schizophrenia tend to be born in winter and early spring which means that during the time their mom was pregnant, an outdoor cat might be spending more time indoors. But I also don't know if they looked at people from both hemispheres and if they controlled for that and then whether it's latitude alone.

Erin Allmann Updyke	Yeah.
Erin Welsh	Okay. Another piece of compelling evidence is that people with toxo - and this is sort of like the bottom line evidence.
Erin Allmann Updyke	Okay.
Erin Welsh	People with toxo are three times more likely than uninfected people to be diagnosed with schizophrenia.
Erin Allmann Updyke	Okay.
Erin Welsh	But at the same time the vast, vast majority of people with toxoplasmosis have not been diagnosed with schizophrenia.
Erin Allmann Updyke	Right.
Erin Welsh	And there are people who have been diagnosed with schizophrenia and do not have toxo. So then they suggest maybe it's more of a predisposition or a susceptibility thing.
Erin Allmann Updyke	Yeah.
Erin Welsh	And also compellingly some antipsychotic medicines that are used for people who have been diagnosed with schizophrenia do seem to be effective in stopping the progress of at least one stage of the parasite.
Erin Allmann Updyke	I think that that is very, very interesting.
Erin Welsh	Yes.
Erin Allmann Updyke	But does not mean that toxo causes...
Erin Welsh	No.
Erin Allmann Updyke	Yeah.
Erin Welsh	Let's look at the other side of the evidence.
Erin Allmann Updyke	Okay.
Erin Welsh	Because this has gotten a lot of popular science press and I think that just weighing the evidence is important.
Erin Allmann Updyke	Yes.
Erin Welsh	Okay so there are huge geographic differences in toxoplasmosis prevalence and some countries have prevalence rates of 90% and others are much lower, like 10%, 20% which is still really high but anyway. But the corresponding rates of schizophrenia diagnoses don't match with these.

Erin Allmann Updyke	Okay.
Erin Welsh	So the places where you find the most toxo, you don't necessarily find higher rates of schizophrenia diagnoses.
Erin Allmann Updyke	Okay.
Erin Welsh	And even looking within a country you don't see a drop in schizophrenia diagnoses following a drop in toxo due to increased food hygiene standards or something. And the other thing is that these are all correlation studies.
Erin Allmann Updyke	Yeah.
Erin Welsh	So we don't know what came first. Was it toxo or schizophrenia? Could it be that someone who has been diagnosed with schizophrenia is more likely to get toxo than someone who is not?
Erin Allmann Updyke	Yeah, yeah.
Erin Welsh	These are correlation studies. And so some researchers have criticized these tentative links between toxo and schizophrenia as building false hope. One the public though got wind of the possibility that infection with this parasite could alter human behavior, the headlines have gotten just a bit more bizarre and some of them pretty cringe or eye-rolling.
Erin Allmann Updyke	Yeah.
Erin Welsh	There's an opinion piece suggesting that the Brazilian soccer team was so good because high rates of infection led to increased risk-taking and aggression.
Erin Allmann Updyke	Oh my gracious.
Erin Welsh	Yeah. (laughs) Or maybe toxo did shape civilization itself, who knows? I wanted to talk a little bit about these studies bu mostly to say grain of salt this.
Erin Allmann Updyke	Yeah.
Erin Welsh	So I think I'm ready to get back onto some solid ground with real numbers.
Erin Allmann Updyke	Can we please?
Erin Welsh	Erin, tell me where we stand with toxo today.
Erin Allmann Updyke	Oh you want me to do that. (laughs)
Erin Welsh	I do.
Erin Allmann Updyke	Okay. We'll take one more quick break.
TPWKY	(transition theme)

Erin Allmann Updyke	All right so toxoplasmosis today. Like we said already but it bears repeating, the estimated prevalence in humans of Toxoplasma gondii infection is between 25% and 30% of all humans.
Erin Welsh	25% and 30%.
Erin Allmann Updyke	Of all of humanity. But like you mentioned this isn't equitably divided. In some places where for example consumption of raw meat is more common or in tropical areas that are very favorable for that oocyst persistence in the environment, in those areas seroprevalence can be as high as 50%, 75%, or even 90% in some areas. And in other areas it's a lot lower. In the U.S. it's estimated around 22%.
Erin Welsh	Okay.
Erin Allmann Updyke	And seroprevalence tends to increase with age which makes sense because it's kind of just like you're living your life and at some point you'll be exposed so the older people are, the more time they've had to be exposed. But these infections really do have pretty serious consequences. In the U.S. it's estimated that the annual cost, I know you don't like looking at the numbers, I mean the dollar numbers-
Erin Welsh	Oh, no I mean I thinks it important, I think it's just important to keep in mind also that the U.S. cost is going to be very different than other places that have better health services for their population.
Erin Allmann Updyke	For sure. But in the U.S. it's estimated that the cost of illness is 3 billion dollars and 11,000 quality adjusted life years lost.
Erin Welsh	Wow.
Erin Allmann Updyke	Also did you know that over 2000 people develop eye disease from Toxoplasma in the U.S. every year?
Erin Welsh	No.
Erin Allmann Updyke	But - and here is something I absolutely did not realize - Toxoplasma gondii is one of the three, Salmonella, Listeria, and T. gondii, these three pathogens account for over 75% of all deaths due to foodborne illness in the United States.
Erin Welsh	Whoa.
Erin Allmann Updyke	Yeah.
Erin Welsh	Whoa.
Erin Allmann Updyke	Right? It's estimated that Toxoplasma in 2011 I believe caused 8% of hospitalizations and 24% of deaths from foodborne illness. Why don't we hear about this more?
Erin Welsh	Why don't we hear about this?
Erin Allmann Updyke	We hear about this bananas tenuous at best links with schizophrenia and we don't hear about people dying from Toxoplasma infected meat or food.

Erin Welsh	Hold on. Are these associated with particular, is this like an outbreak or are these individual cases?
Erin Allmann Updyke	No, individual cases. So we don't really see-
Erin Welsh	Which probably explains why they're not as headline worthy.
Erin Allmann Updyke	For sure, for sure, for sure. Yeah. Now that's in humans. It's not only in humans, it's not only in mice and rats, and it's not only in cats. Over 300 species of animal can be infected that we know of with T. gondii. Hugely important is the fact that because these oocysts persist in the environment they can get into the soils and the water and end up like you mentioned in our oceans. Did you know that in Morro Bay alone, Morro Bay is in northern California by the way-
Erin Welsh	Yeah.
Erin Allmann Updyke	Okay. In Morro Bay alone domestic cats deposited 77 tons of poop. That's not including free roaming cats which deposited another 30 tons of poop. That means 45000 little parasites, oocysts per square meter.
Erin Welsh	It's really hard to even fathom.
Erin Allmann Updyke	Yep. Because these cats... So infection in cats is generally asymptomatic. Cats are the definitive host for the parasite, the parasite doesn't cause illness in cats very often at all. But cats shed this parasite for up to three weeks at a time when they get infected and they're shedding thousands and thousands of these parasites every time they poop. So it really does have a huge impact on wildlife and other animal populations across the globe.
Erin Welsh	It's a pretty big conservation and public health problem.
Erin Allmann Updyke	Yeah so one of the things that really interesting is that there's a big push to look at toxoplasmosis from a one health perspective. Which we've talked very briefly about one health on this podcast before but essentially one health is just this idea that animal health, wildlife, domestic animal, and environmental health all play into each other. So looking at disease from all of these different aspects and trying to get a handle on understanding the risks of disease from an interdisciplinary perspective is really important for control, not just for humans but for the entirety of wildlife, domestic animals, and the environment. So for toxoplasmosis that means trying to get a better handle on the risks from the environmental perspective, so soil studies, land use effects, also a better understanding of the potential effects on human behavior, tenuous though they may be, understanding the extent of congenital transmission. It's estimated that there are anywhere from 400-4,000 cases of congenital toxoplasmosis in the U.S. alone every year.
Erin Welsh	Wow. And we have a relatively low prevalence rate compared to other countries.
Erin Allmann Updyke	Yeah we do. Yeah we really do.
Erin Welsh	And this is not a reportable illness. Is congenital toxo reportable?
Erin Allmann Updyke	It is not a nationally reportable disease.
Erin Welsh	Wow.

Erin Allmann Updyke	Which means we don't really have a good handle, that's why the estimates are anywhere from 400-4,000 cases.
Erin Welsh	It's makes sense I guess.
Erin Allmann Updyke	Yeah. But then also understanding the wildlife and domestic animal cycles, food safety is really important in talking about toxoplasmosis, and then like you mentioned outdoor cat monitoring and control efforts. And of course vaccine development. There is actually vaccine for sheep that's licensed in some countries.
Erin Welsh	Yeah.
Erin Allmann Updyke	But there isn't even a vaccine for cats which is kind of bonkers to me. There was one that was made at some point but it was very expensive to produce, it was difficult to keep, it had a very short shelf life, and cat owners didn't care about it probably because it doesn't generally affect cats negatively, so it was discontinued by the manufacturers. Yeah.
Erin Welsh	Interesting.
Erin Allmann Updyke	So that sucks. Yeah. It does seem that sort of the biggest ways that you're likely to be infected are from contaminated meat sources, so cooking your meat properly is important but also the oocysts can persist in the environment, so contaminated water is a huge issue. The oocysts actually are viable, they're not killed by chemical and physical treatments that we use for water treatment including chlorination and ozone treatment.
Erin Welsh	Yeah.
Erin Allmann Updyke	And they can survive freezing and pretty high water temperatures.
Erin Welsh	Yep. Wah-wah-wah.
Erin Allmann Updyke	Cool.
Erin Welsh	Cool.
Erin Allmann Updyke	Yeah. So toxo is pretty much everywhere. Again, the vast majority of humans who get infected will never ever know that they were infected. But for people who are immunocompromised or for pregnant people who get infected the first time, the effects can be very devastating.
Erin Welsh	Yeah it kind of remains this vague threat that-
Erin Allmann Updyke	Yeah, it does. And then for wildlife species it can be really damaging as well. So it's a really happy ending, toxoplasmosis.
Erin Welsh	As per usual.
Erin Allmann Updyke	Yeah. Erin, tell us about your sources.

Erin Welsh	I read a couple of books. One I already mentioned called 'The Lion in the Living Room' by Abigail Tucker, this is a very fun read, I recommend it. And then another book by Kathleen McAuliffe called 'This is Your Brain on Parasites' and that's another fun read as well. And then I read a bunch of different articles, mostly by J.P. Dubey.
Erin Allmann Updyke	Oh! I read some of him, too.
Erin Welsh	Yeah. Tons and tons of history research.
Erin Allmann Updyke	He wrote a whole book.
Erin Welsh	Yeah and one of the books, yeah.
Erin Allmann Updyke	Yeah.
Erin Welsh	And where I got all the information or a lot of the information about sort of the human evolution and agricultural settlements was from a paper by Shwab et al from 2018, it was great.
Erin Allmann Updyke	Cool. Awesome. We'll post all of our sources for this episode and all of our episodes on our website thispodcastwillkillyou.com under the EPISODES tab.
Erin Welsh	Thank you to Bloodmobile for providing the music for this episode and all of our episodes.
Erin Allmann Updyke	Thank you all for listening and for keeping your cats indoors safely with you.
Erin Welsh	And with that, wash your hands.
Erin Allmann Updyke	You filthy animals!