Erin Allmann Updyke	"Professor Yokogawa casually spoke to me, jokingly saying, 'Yoshino, as Taenia solium is present in your home Okinawa, how about doing experimental infection for your PhD study?' Of course Yokogawa and I knew epilepsy and neurocysticercosis could be caused by accidental ingestion of eggs of this parasite. At first I was very nervous about accidental neurocysticercosis in my brain, etc. However it was an exceptionally big chance for me to do an experimental infection. Even if I had a serious health problem or sudden death, my data might contribute to this topic that nobody has done and therefore be highly informative for future advances in parasitology. Then I felt some power inside of my body which pushed me to do it right then and I swallowed three cysticerci. When I came back to my home in the evening I told this mission to my wife. She was very surprised but tried to understand my hard academic life and took more care of my health. As my purpose was observing gravid proglottids in feces, I stopped using toilets anywhere but kept a portable toilet and chopsticks for looking for gravid proglottids and collected them all every day for 371 days."
TPWKY	(This Podcast Will Kill You intro theme)
Erin Welsh	I love this firsthand account.
Erin Allmann Updyke	I love it so much, Erin.
Erin Welsh	Okay, let me tell you where it's from because I stumbled across this and it just proved to be so much deeper than I had expected. Okay so that is from Ito et al 2020, the paper is titled 'Kozen Yoshino's experimental infections with Taenia solium tapeworms: An experiment never to be repeated'. And this paper goes into this experiment that Yoshino did back in the 1930s I believe or late 1920s with this experimental infection of tapeworm and then the resulting papers that Yoshino published on the subject. And it's a really interesting paper. But yeah, I just loved that description of like, 'Well I'm going to do this and even if I die the data will be useful.'
Erin Allmann Updyke	Right? The description of feeling like a little power and then just doing it. I love that, yeah.
Erin Welsh	Yeah. Well 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 tapeworms.
Erin Welsh	Tapeworms, yeah.
Erin Allmann Updyke	Yeah. It's going to be fun to see how this one shakes out, Erin. I have no idea what you're going to talk about.
Erin Welsh	I know nothing about how tapeworm biology works and so it's going to be interesting but I'm excited for it.
Erin Allmann Updyke	It's going to be fun.
Erin Welsh	And I'm also excited because guess what time it is?
Erin Allmann Updyke	It's quarantini time!

Erin Welsh	It is. What are we drinking this week?
Erin Allmann Updyke	We're drinking Brave New Worm.
Erin Welsh	I feel like in one of our wormy parasite episodes we talked about how we're just going to do like worm world puns from this point on.
Erin Allmann Updyke	Worm puns. Yes, we did.
Erin Welsh	And I actually really like the name for this and I think it fits tapeworms because Taenia tapeworms, the ones that infect humans, part of their host-switching abilities and being able to find a new host, I feel like it's encapsulated in the name Brave New Worm.
Erin Allmann Updyke	I love it, I love it. How poetic, Erin.
Erin Welsh	Yeah. And in Brave New Worm is gin, lemon juice, earl gray tea, a little bit of honey, simple syrup, and then garnish with a piece of lemon that you cut in the shape of a worm.
Erin Allmann Updyke	Like a really long tapeworm preferentially.
Erin Welsh	Yeah.
Erin Allmann Updyke	We'll show pictures and we'll post the full recipe for that quarantini as well as our non alcoholic placeborita on our website thispodcastwillkillyou.com and all of our social media channels.
Erin Welsh	And on our website thispodcastwillkillyou.com, I've got my post-it note here which will tell me that you can find the sources for this episode and all of our episodes, transcripts, recipes, bookshop.org affiliate account, Goodreads list, music by Bloodmobile, merchandise, Patreon, and alcohol-free episodes.
Erin Allmann Updyke	I want everyone to know that Erin was genuinely looking at a little post-it note in her eyes kept flicking back and forth to read the post-it note and I really enjoyed it.
Erin Welsh	You know what? There's only so much I can fit into my brain on a given evening that we're recording and post-its really help me.
Erin Allmann Updyke	I know, I understand. Speaking of post-it's, shall we refer to our notes and-
Erin Welsh	Great segue.
Erin Allmann Updyke	Thanks, thanks. I tried. And dive into this episode?
Erin Welsh	Let's do it. I'm excited.
Erin Allmann Updyke	Right after this break.
TPWKY	(transition theme)

Erin Allmann Updyke	There are quite a few different species of tapeworm. As a general rule there's a lot but there are a few different species that can infect humans, those which we're going to be focusing on today. Some of these species infect humans because we are evolutionarily the definitive or final host for adult worms and some of which infect us incidentally, either as adult worms or as the intermediate stages which I'll get into in just a minute. So my plan for this biology section, and we'll see how this turns out, was to just talk very generally about tapeworms as a group because I think the broad strokes of their life cycles are not only so fascinating but we can also cover a lot of ground by keeping things pretty general. And then I'll focus on a couple of species of tapeworm in particular that for humans stand a little bit apart.
Erin Welsh	That makes sense. Let's do it.
Erin Allmann Updyke	So tapeworms are fascinating almost adorable little creatures.
Erin Welsh	Sure.
Erin Allmann Updyke	Some of the scanning electron micrographs are kind of cute. Tapeworms are flatworms in the phylum Platyhelminthes in the class Cestoda, so different than the other flatworm friends that we've talked about on this podcast, the flukes, which are the causative agent of schistosomiasis. And tapeworms are an entirely parasitic class of animals which is awesome in and of itself. And in general they have fairly complex life cycles, much like the flukes that cause schistosomiasis. So let's go over it. First we'll start with the eggs which are passed in feces. So in poop, the eggs enter the environment and then have to first be ingested by an intermediate host. Now this intermediate host can be anything from a copepod in the case of something like a fish tapeworm, to a pig or a cow in the case of various species of human tapeworms, or a sheep or a rat in the case of a dog tapeworm, etc etc. Right?
	And in these intermediate hosts in general, the eggs leave the guts of those animals and mature into a larval or immature stage which encysts. So they tend to form these little cysts in various organs in the body like the liver or the muscle or whatever. And then they hang out in these intermediate hosts, often not causing too much harm although sometimes they might hasten capture by a carnivore in some way, like maybe making a rat easier to catch by a dog for example. And then these cyst stages have to be ingested by their final or definitive host. And once they are, they excyst in the guts of that definitive host, they mature invertebrate guts into adult tapeworms.
Erin Welsh	So can we talk a little bit about the cyst?
Erin Allmann Updyke	Sure. What would you like to talk about?
Erin Welsh	What is it made of? Is the growth of the tape room just completely arrested?
Erin Allmann Updyke	Great question. It depends on the species but in general no. So the cysts are little baby tapeworms.
Erin Welsh	Oh okay.
Erin Allmann Updyke	They have a little head and a little scolex, that's what the head is called, I'll talk about it in a second. And then they have a part of a little body and then they have just a little structure around them which is what entraps itself in say the muscle or the liver of the intermediate host.
Erin Welsh	And it does that to evade the immune system?

Erin Allmann Updyke	Exactly. So these cysts tend to be very good at evading especially vertebrate hosts' immune responses. They just can hang out there for in some cases quite some time, like a number of months or even years, just waiting to be ingested.
Erin Welsh	And then another question about these cysts. I just am so fascinated by these cysts.
Erin Allmann Updyke	Okay, yeah.
Erin Welsh	So if the intermediate host dies with these cysts throughout their muscle, how long in the environment would they last? Would there be scavengers that could come in? How would that work?
Erin Allmann Updyke	That is a very good question. I don't fully know the answer and I expect that it varies quite a lot depending on the species. But in general this is something that usually needs to be ingested while it's alive.
Erin Welsh	Okay.
Erin Allmann Updyke	So a lot of times it's carnivores that are the kind of definitive host of these creatures or in the case of fish tapeworms, fish are ingesting copepods and things whole.
Erin Welsh	Right, okay.
Erin Allmann Updyke	Right, yeah. I want to talk for a little bit about the adult tapeworms because they're fascinating. So tapeworms, we'll post a lot of pictures of them on our Instagram so if you don't follow us, you should because again they're very cool. They have a head which has no eyes, no light sensing organs, no mouth. Their head is often called a scolex and it's just a set of hooks and/or suckers that they use to anchor onto the gut wall of their vertebrate host. And then attached to this little head or scolex they have a skinny little neck and from this neck they make their body. And their body is formed of a bunch of segments that are called pro glottids. So this worm, what it does is it attaches by the hooks on its head to our gut wall and absorbs its nutrients through its body by just diffusion across its body. It doesn't have a mouth.
Erin Welsh	What?
Erin Allmann Updyke	Exactly. It has no mouth. Just as our gut contents flow past, they absorb whatever they need through their tegument, that's their version of skin. And their neck is constantly producing more and more of these proglottid segments, you can think of it as from the top of the neck and then they displace the older proglottids down and down and down. Right? And so this tail of the body of this worm is just growing longer and longer and longer reaching toward our anus, right, as it grows along our gut tract, adding more and more segments. Now these proglottid segments, each one of these segments has an entire reproductive tract, both testes that make sperm and ovaries that are making eggs and they self-fertilize. It's amazing.
Erin Welsh	That is incredible.
Erin Allmann Updyke	I know. And as this worm matures and becomes longer and longer adding these segments, the mature final segments that are fully fertilized chock full of eggs break off and are passed through the feces of the host and enter the environment chock full of hundreds if not thousands of eggs.

Erin Welsh	Interesting. So it's not a lot of eggs in your stool, it's this whole proglottid.
Erin Allmann Updyke	Proglottid full of eggs, yeah.
Erin Welsh	Oh wow.
Erin Allmann Updyke	I know, it's great. Right?
Erin Welsh	My mind is just blown.
Erin Allmann Updyke	I know. And I know that that was a lot so I'm going to just do a very brief recap of the whole life cycle of tapeworms. Ready? Egg, intermediate host eats the egg, cysts in various tissues, definitive host eats those tissues, adult worm in the gut poops out eggs. That's all tapeworms in general.
Erin Welsh	Circle of life.
Erin Allmann Updyke	Circle of life.
Erin Welsh	Okay. So this probably varies a lot from species to species but how long do some of these eggs stay in the environment or can exist in the environment?
Erin Allmann Updyke	Great question. I don't have an exact number but they are quite environmentally tolerant in general, so they can dry out and still be potentially infectious, so they can live for a decent amount of time.
Erin Welsh	Wow.
Erin Allmann Updyke	Yeah. Now many tapeworm species, really I think some of the papers I read said that probably every vertebrate has at least one species of tapeworm that infects it, so there are tons and tons of tapeworm species and that was a very general overview. We're going to focus today on just a few of these tapeworm species that infect humans, Taenia solium, Taenia saginata, and Taenia asiatica which is very closely related to Taenia saginata. These three are the main species of tapeworm that have humans, us, as a major definitive host. Taenia saginata is commonly known as the beef tapeworm because its intermediate host is a cow and we get infected from undercooked cow meat. Taenia solium is commonly known as the pork tapeworm because its intermediate host is a pig and we get it from eating undercooked pork. Taenia asiatica also tends to infect pigs. Now there are a few other species that are very important for humans as well, like Diphyllobothrium latum et al, there are so many different species of Diphyllobothrium, these are the fish tapeworm. These also can use humans as a definitive host but they're not very species specific so they can grow to adulthood in various other mammals and birds as well.
Erin Welsh	Okay, question about that one actually.
Erin Allmann Updyke	Yeah?
Erin Welsh	So you said that in that genus that I'm not going to attempt to say-
Erin Allmann Updyke	Diphyllobothrium.

Erin Welsh	You're doing great.
Erin Allmann Updyke	Thanks.
Erin Welsh	But the fish tapeworms, fish are the definitive hosts and copepods are often the intermediate hosts?
Erin Allmann Updyke	Great question. They often have tWO Intermediate hosts.
Erin Welsh	Okay.
Erin Allmann Updyke	So they have an even more complex life cycle. First little copepods and then fish and then either a bigger fish or mammals or birds. A lot of times mammals or birds.
Erin Welsh	Okay cool. Cool, cool. Got it.
Erin Allmann Updyke	Yeah. Great question, Erin. So let's talk about the symptoms when you get infected with an adult tapeworm. The thing about, for humans at least, almost all these species of tapeworm, whichever of those four major groups we're talking about, is that these species that are well adapted to humans, when they infect us the way that they're supposed to as adult tapeworms in our guts, they really don't do all that much. To us, that is. They absorb some of our food, they can cause abdominal pain, maybe some cramping some diarrhea. If the worm burden got to be really high, then they could potentially cause a bit more of a symptomatic infection but it still isn't even on the scale of say something like hookworm that we've covered in the past because they're not burrowing into our gut wall, they're just hanging on, right. And they're not sucking our blood, they're just borrowing some of our food as it passes through our small intestine before we get a chance to absorb it.
Erin Welsh	Okay.
Erin Allmann Updyke	Fish tapeworms have been associated with some anemia due to poor vitamin B12 absorption because these worms attach in our small intestine and that's where we absorb vitamin B12.
Erin Welsh	Interesting.
Erin Allmann Updyke	Yeah. But even that is fairly rare.
Erin Welsh	Okay.
Erin Allmann Updyke	And I couldn't find very great data on this but I don't think in general worm burdens with tapeworm tend to be quite as high as they can get with hookworm anyways. But the point is that in a similar way that we actually saw with schistosomiasis, the severity of tapeworm infection comes not when tapeworms are acting the way that they're supposed to, but it's when they start acting away that they're not supposed to. That is when we as humans get infected with the wrong life stage of the tapeworm. So when instead of being the definitive host we become the intermediate host, That is when problems arise. And it turns out that this can happen with a few different species of tapeworm. The pork tapeworm which I've already mentioned, Taenia solium, and two species of dog or canine tapeworm, Echinococcus granulosus and Echinococcus multilocularis.
Erin Welsh	Interesting.

Erin Allmann Updyke	Yeah. It gets so much more interesting. So first let's talk about how this actually happens. So humans get infected with adult tapeworms by eating undercooked meat of beef or pork or fish that is filled with cysts. Right? So if instead of eating undercooked meat that has cysts in it and getting infected with an adult tapeworm, if we instead come into contact with the eggs of these tapeworms, that is if we ingest anything contaminated with human poop or with dog poop, then we become the sheep or the pigs. And instead of an adult tapeworm in our gut, these eggs hatch in our stomach, become those adorable little embryos and invade through our gut walls, travel through our bloodstream to our tissues, and encyst themselves with the hope of eventually being eaten.
Erin Welsh	Does it ever happen where if you have an adult tapeworm infection and they're making those eggs and they're making that little egg sac thing, that breaks open and you get encystment that way?
Erin Allmann Updyke	Oh, do you mean auto infection? What a great question. Yes, it absolutely can happen.
Erin Welsh	Okay.
Erin Allmann Updyke	And that kind of is what in that firsthand account when the author ate cysticerci, that is the intermediate stage. So they ate the intermediate stage in order to grow the adult tapeworm. But what they were worried about is accidentally becoming exposed to the eggs that they were pooping out.
Erin Welsh	Right, right. And so when someone has these cysts in their tissues, is it more likely that they got it from ingesting eggs from another source or from this auto infection?
Erin Allmann Updyke	Great question. I think in general from any other source. One of the papers that I read said that about 25% of people with neurocysticercosis, which I'll talk about that in a second, but basically with these cysts either had in the past or currently had a tapeworm.
Erin Welsh	Okay.
Erin Allmann Updyke	So that's a fairly low percentage. But that was just one paper, I think we don't have a great handle on how much autoinfection happens.
Erin Welsh	Okay.
Erin Allmann Updyke	So let's talk about why these cysts become a problem and you probably already know why, it's because they can encyst almost anywhere. So in the case of Taenia solium, the disease that results from infection with this immature life stage is called cysticercosis. And the symptoms of cysticercosis can really vary because these embryos are traveling via our bloodstream and they're finding their way anywhere that our blood vessels go, which is really anywhere. And you can find them encysted in muscle tissue where most of the time they're asymptomatic. You can also find them in subcutaneous tissue underneath the skin which what's really interesting is that this tends to only happen from infections happening in Asia rather than in Latin America or Africa. And at least from what I can tell, this likely has to do with the genetic differences in the population of Taenia solium in these different areas rather than any human susceptibilities.
Erin Welsh	Okay. Quick question. How big are the cysts?
Erin Allmann Updyke	Great question. Usually for Taenia solium, 1-2 centimeters or so.

Erin Welsh	Oh, that's still bigger than I thought.
Erin Allmann Updyke	Yeah. Not huge. Just wait. And these cysts tend to be present for just a few months to years but eventually they do gradually disappear as the embryo dies and then our body recognizes it and kind of just takes care of that cyst.
Erin Welsh	I just tired of waiting around for you to be eaten by a predator.
Erin Allmann Updyke	Right. It just can't hack it anymore.
Erin Welsh	And how long do adult tapeworms live?
Erin Allmann Updyke	It really varies. Let me scroll back to where I had that. Some parasitology textbooks will tell you 20-25 years.
Erin Welsh	Oh my gosh.
Erin Allmann Updyke	But it's thought that that's probably an overestimation from anecdotal cases from a long time ago. So it's probably less than 5 years. But still, they're with you for a chunk of your life.
Erin Welsh	Right, yeah.
Erin Allmann Updyke	Yeah. These cysts from Taenia solium can also end up in the eye where in the eye you can imagine they can actually cause quite a bit of damage, like causing visual impairment because they're blocking vessels, etc. But the most common and most detrimental place where this particular parasite tends to encyst is in the brain.
Erin Welsh	Right.
Erin Allmann Updyke	And when it encysts in the brain it's called neurocysticercosis, brain cysticercosis. And what happens in the brain is very similar to what happens anywhere else. These embryos make their home, they form these 1-2 cm cysts, they usually don't get much bigger than that although they can, they hang out there for a number of months or years, and then eventually they degenerate. Our immune system, wakes up and kind of notices these cysts for the first time and in helping with that degeneration causes inflammation. So neurocysticercosis can end up causing, as you might imagine, any range of symptoms in your brain depending on how many cysts you have because if you're exposed to tapeworms, remember these proglottids are filled with hundreds if not thousands of eggs. So you could potentially be exposed to quite a large number.
	It also depends on if these cysts are growing because sometimes they do get a bit larger than 1-2 cm and if they happen to be in the wrong part of the brain that can cause blockage of the cerebral spinal fluid flowing in the brain, which can increase the pressure in your brain. But more commonly it's the end stages, this inflammation as our body is actually trying to get rid of this cyst that causes symptoms like headaches, like mental status changes, or like very commonly epilepsy.
Erin Welsh	Right.

Erin Allmann Updyke	And it turns out that neurocysticercosis is one of the most common if not the most common cause of infectious epilepsy in a lot of parts of the world, which I totally didn't realize until doing this episode.
Erin Welsh	Yeah. Can we talk worm burden or cyst burden? Do you have numbers for the median cyst burden in someone who has neurocysticercosis? Or is there a threshold at which point epilepsy is common or is it really just dependent on the placement of the cysts?
Erin Allmann Updyke	It's a really good question. I don't have good numbers on that. Really we don't have good numbers on that especially because as much as we have numbers on the percentage of cases of epilepsy for example that are caused by neurocysticercosis, what we don't have a good handle on is how many people with neurocysticercosis, with these cysts in their brain, actually have any symptoms at all, much less epilepsy.
Erin Welsh	Right. That makes sense.
Erin Allmann Updyke	So the only good thing to say is that in a lot of cases, even though this sounds like it would be very extreme having cysts in your brain, it's very often asymptomatic which is fascinating in and of itself.
Erin Welsh	Yeah. Is it just epilepsy that's the main side effect?
Erin Allmann Updyke	It's not just epilepsy, it can be in theory anything that your brain can do. So it can mimic a stroke or it could even cause a stroke, it can cause increased intracranial pressure if it's blocking the flow like I said of that cerebral spinal fluid, it can also cause massive headaches. Really it can do almost anything. But for some reason that I couldn't get a great handle on, epilepsy is one of the most common presentations.
Erin Welsh	And this neurocysticercosis, is it more highly associated with certain species of tapeworms more than others?
Erin Allmann Updyke	So neurocysticercosis is only from Taenia solium.
Erin Welsh	Okay.
Erin Allmann Updyke	Yeah.
Erin Welsh	We don't have to worry about fish tapeworms.
Erin Allmann Updyke	Fish tapeworms, nope.
Erin Welsh	Okay. No beef tapeworms.
Erin Allmann Updyke	And beef tapeworm, nope. It's just the pork tapeworm. Now that's not the only tapeworm that can infect us as an intermediate host, right. I already said Echinococcus species can also infect us as an intermediate host. Now here it results in an entirely different disease, two of them actually, hydatid disease or cystic echinococcus and alveolar echinococcus. So with this it's a similar idea except for some reason the cysts of Echinococcus first of all tend to infect our liver, not our brain.
Erin Welsh	Why?

Erin Allmann Updyke	I was waiting so long for you to ask me why, Erin. I was waiting for you to ask me why do Taenia solium go to the brain?
Erin Welsh	Oh yeah.
Erin Allmann Updyke	I don't know why, Erin.
Erin Welsh	You were waiting for me to ask a question for which you don't know the answer.
Erin Allmann Updyke	That's like most of our podcast I feel like. I tried so hard to find the answer to this question and I couldn't come up with a good one. The best one that I got was that in our brain Taenia solium is very protected by our blood-brain barrier. So it's a good place with minimal immune response for it to hang out. But Echinococcus, if we get infected with the intermediate stage, as it burrows its way through our gut wall it enters our portal circulation which brings it straight to our liver. Just like schistosomiasis, you might remember. Another place that it can commonly end up is in our lungs and in rare cases it can go other places as well. I know, your face is my face.
Erin Welsh	Well it's fascinating because it makes me think that if there is tissue tropism, if that's been selected for, then does it have to do with the particular predator-prey relationship that these species are a part of?
Erin Allmann Updyke	Yeah, that's a very good question. But really in pigs especially you can find cysticerci in the brains of pigs but really it's their muscles that are chock full.
Erin Welsh	Oh.
Erin Allmann Updyke	Right? And you can also find it in the liver and you can find in other places. Now with Echinococcus in the intermediate stage, normally when it's not humans, Echinococcus does make its home in the livers of sheep or in the livers of rodents for the other species of Echinococcus. So that does make sense, in humans it goes to the same place.
Erin Welsh	Interesting.
Erin Allmann Updyke	I know, it's very fascinating. I don't have a great answer. But I do want to tell you a little more about the cysts of Echinococcus and the disease that it causes because it's totally different than Taenia solium. Basically these cysts, you asked earlier how big do these cysts get?
Erin Welsh	Yeah.
Erin Allmann Updyke	Now with Echinococcus the answer is not 1-2, the answer is that these cysts can get to be so massive that they are larger than your entire liver.
Erin Welsh	Oh no.
Erin Allmann Updyke	Because what happens with Echinococcus, you also asked how active are these little cysts? Well Echinococcus is quite active because it in fact reproduces and makes more cysts within each cyst and that is how it continues to grow.
Erin Welsh	Ew, like a rat king of cysts inside your liver.

Erin Allmann Updyke	Yes. Exactly.
Erin Welsh	So I'm guessing that there aren't many asymptomatic infections.
Erin Allmann Updyke	People tend to be asymptomatic until these cysts grow so large that they start causing things like nausea, vomiting, abdominal pain. If these cysts are in the lung it's going to cause cough, shortness of breath, chest pain. And what's really dangerous about these is that because each cyst is full of hundreds if not thousands of tiny other cysts, if these have to be taken out surgically, it's actually very high risk because if you puncture that and you release those cysts, not only can that infest you in a lot of other areas of your body, those cysts can go on to re-encyst but it also can just cause a massive immune response in us.
Erin Welsh	And is that sort of the issue with treatment in general?
Erin Allmann Updyke	Yes. Great question. Treatment in general.
Erin Welsh	Okay.
Erin Allmann Updyke	For adult tapeworms treatment is very easy, it's like a single dose of an anti-parasitic. But when it comes to neurocysticercosis or hydatid disease or Echinococcosis it is much more difficult to treat, yeah, because you have to balance the inflammation that treatment is going to cause from your body kind of waking up and noticing these cysts with actually treating and getting rid of the parasite.
Erin Welsh	Right.
Erin Allmann Updyke	So it is a lot harder.
Erin Welsh	Yeah.
Erin Allmann Updyke	Yeah. That's the biology of a whole bunch of different tapeworms in very brief.
Erin Welsh	Fascinating.
Erin Allmann Updyke	Yeah. I hope it wasn't too messy.
Erin Welsh	No, it was great.
Erin Allmann Updyke	So Erin, I know nothing about where these tapeworms came from or why did we get infected with them. How did we figure this out? How many people have dug through poop to get us here?
Erin Welsh	Those are some great questions. I will see what I can do to answer them right after this break.
TPWKY	(transition theme)

Erin Welsh	Okay. The history of tapeworms. To cover the complete history of all tapeworms we would have to go back incredibly far and incredibly wide, like hundreds of millions of years all over the globe. But we're not going to do that today. For the purposes of today's regular season episode, we're going to skip ahead to just a few million years ago which is when the history of the tapeworms that I'm mainly going to talk about in this section, which are the three Taenia species that we already mentioned, it's when that history really begins. Before moving on to that history though I want to plug next week's bonus episode because that is when we will get to spend a bit of time in the distant, way distant, far distant past, like tens or hundreds of millions of years ago. And while we may touch on the early history of tapeworms in that episode, most of what we're going to be talking about is poop.
Erin Allmann Updyke	Poop. I can't wait. Oh it's gonna be so good, Erin.
Erin Welsh	When doing the research for this episode, the one that we're recording right now, I came across a paper describing tapeworm eggs found in the fossilized poo aka coprolite, I've been saying it wrong for years, of a 270 million year old shark. Which is so cool.
Erin Allmann Updyke	I love it. I love it so much.
Erin Welsh	I do too. And this got me thinking more about coprolites which if you've listened to the podcast before you know how much we love fossilized poop.
Erin Allmann Updyke	It's one of our favorite things.
Erin Welsh	It is. And I was thinking to myself well what else can poop tell us? What else can these coprolites tell us? So I reached out to one of the world's leading experts on - wait for it - dinosaur coprolites.
Erin Allmann Updyke	I'm so excited.
Erin Welsh	Next week Dr. Karen Chin, who is just up the road from me at the University of Colorado Boulder, will be joining me to dive deep into fossilized poo. What we can learn from it, how it becomes fossilized, and which kind of animals are most likely to have their poo become fossilized. So mark your calendars.
Erin Allmann Updyke	Which animals are most likely to have their poo become fossilized?
Erin Welsh	Right. Is it carnivores? Is it herbivores?
Erin Allmann Updyke	Which is it? I don't know.
Erin Welsh	I guess you'll have to wait and find out.
Erin Allmann Updyke	Oh my gosh.
Erin Welsh	Because I don't know the answer right now. (laughs) Okay. But like I said for today's episode we're going to start a while after the dinosaurs, a long while. Erin, one of the things you asked was where did these things come from?
Erin Allmann Updyke	Always.

Erin Welsh	And I'm so excited to answer. Knowing what you know about the common human tapeworms, those three Taenia species and what their life cycle looks like and which animals that involves, when do you think humans and tapeworms most likely became acquainted with one another?
Erin Allmann Updyke	My guess would be sometime when we started domesticating livestock.
Erin Welsh	Great guess. That's such a good guess because 10,000-12,000 years ago, that is when humans started to domesticate livestock, that's when a lot of parasite and pathogen exchange happened. We've talked about this so many times in the podcast before.
Erin Allmann Updyke	And I can tell by your tone that I'm wrong.
Erin Welsh	You are. But that is what people thought for a really long time. They thought okay it had to have happened when people first started domesticating cows and pigs in particular and we picked up these tapeworms then. They were the ones that brought tapeworms to the table. However it seems that it was actually humans that first gave these worms to their livestock.
Erin Allmann Updyke	What?
Erin Welsh	What? I know, I know. Let's talk about why that revised version of events seems likely given some of the ecological, evolutionary, and life cycle characteristics of these tapeworms. Like we've talked about, the genus Taenia is chock full of species, just dozens of species. And we actually know quite a bit about the life cycles of many of the species in Taenia which is pretty awesome because it means that we are more easily able to explore evolutionary relationships and historical distribution patterns and host associations, all those sorts of things. So we can tell when a species diverged or experienced a host-switching event for example. Like you talked about Erin, Taenia tapeworms have a definitive host which is often a carnivorous or omnivorous mammal and an intermediate host, the prey species, also a mammal. And transmission primarily occurs in this predator-prey interaction. And Taenia are actually unique in that they have mammals as both definitive and intermediate host which I think is just a cool little tidbit.
Erin Allmann Updyke	Yeah, that is cool.
Erin Welsh	In the past when we've talked about parasites we sometimes talk about host specificity, how some parasite species are uniquely adapted to their host species and how they can't complete their life cycle in another. And maybe even the host and parasite have coevolved so tightly that you can mark host evolutionary events with parasite evolutionary events. But that does not seem to be the case for Taenia tapeworms in their carnivorous definitive hosts who don't necessarily have these super tightly linked relationships. Rather it seems that which worms are associated with which carnivores depends on where those hosts live and who the intermediate hosts are in the ecosystem. So you could have worms switching between unrelated hosts like hyenas and lions if they share the same ecosystem and prey species.
Erin Allmann Updyke	Okay.
Erin Welsh	And so the diversity of these tapeworm species is based more on ecological factors rather than on a phylogenetic or coevolutionary basis.
Erin Allmann Updyke	Okay, okay.

Erin Welsh	Which I think is really cool because you have to think about it in terms of ecosystems and who are the players in that ecosystem?
Erin Allmann Updyke	Right.
Erin Welsh	Yeah. And these host-switching patterns and tape rooms are relevant for today because things like climate change or land use change can lead to these ecological disruptions where a new tapeworm species could suddenly be introduced to a new ecosystem and then into a new host and we don't know what the possible consequences of that might be. All right but what is the relevance for the history of tapeworms in humans? I'm getting there. Phylogenetic analyses have shown that Taenia tapeworms and humans were well acquainted with each other long before humans were humans, which also means long before modern humans begin domesticating pigs or cows.
Erin Allmann Updyke	Right, right, right.
Erin Welsh	So how did tapeworms and humans get to know each other? About 2 million years ago or so early hominids in Africa began to incorporate meat into their diet, scavenging the kills of predators in the area such as lions or hyenas or later hunting animals themselves. And when they began taking the odd leg from an antelope or a rib from a warthog, maybe they also found themselves eating not just meat but also some of those tapeworm cysts.
Erin Allmann Updyke	Honestly once you go through that logic it makes so much more sense. Yeah.
Erin Welsh	It's so interesting because I was immediately assuming okay, here's going to be another classic example of agricultural revolution. Yeah. But no, I just find that so fascinating.
Erin Allmann Updyke	I love it. It's just like once we became omnivores boom, we get parasites.
Erin Welsh	Boom. And over time humans stopped becoming just this incidental part of the life cycle but the relationship grew much stronger and closer. And so when humans began domesticating livestock, it was the long infected humans that brought tapeworms to their pigs and cows.
Erin Allmann Updyke	Yeah. Wow. How fun.
Erin Welsh	And do you want to hear some evidence in support of this?
Erin Allmann Updyke	Always.
Erin Welsh	Okay. So for instance, the sister species of Taenia solium is Taenia hyaenae which infects hyenas and antelopes.
Erin Allmann Updyke	What?
Erin Welsh	And the sister species of Taenia saginata and Taenia asiatica, which like we mentioned are sister species with each other, is Taenia simbae which commonly infects lions and antelopes.
Erin Allmann Updyke	Oh what?

Erin Welsh	It's so interesting. Genetic analyses estimate that Taenia saginata and Taenia asiatica probably diverged around 0.78-1.71 million years ago which is pretty close to the period when humans began switching from herbivory to omnivory or a little bit after.
Erin Allmann Updyke	Wow.
Erin Welsh	And Taenia solium's estimated divergence is a lot more recent, about 359,000 years ago. And an interesting side note, some researchers have suggested that Taenia solium was maintained in some human populations via cannibalism in addition to this less sensational prey hyena association.
Erin Allmann Updyke	I mean, I feel like that goes along with the fact that we can also serve as intermediate hosts for this parasite, yeah.
Erin Welsh	Absolutely, yeah. So long story short, humans gave tapeworms to pigs and cows, not the other way around. And they seem to have done so on three separate occasions. So Taenia saginata in cattle, and Taenia asiatica and Taenia solium in swine. But those last two tapeworm species aren't closely related which is why it was thought to be two separate introductions in pigs.
Erin Allmann Updyke	Right. Which I know that's just interesting in and of itself.
Erin Welsh	Absolutely, yeah.
Erin Allmann Updyke	Right.
Erin Welsh	And once inside these livestock species they were there to stay and spread, especially over the long period of exploration and colonization that began in the 1500s. But that's getting a little bit ahead of things. So let's see what the ancients have to say about tapeworm, shall we?
Erin Allmann Updyke	We shall.
Erin Welsh	Unlike microscopic parasites or pathogens, wormy parasites are visible, you can see the actual worm segments in your poop. And for this reason it was probably easier for people to make that link between a disease-causing organism like the tapeworm and the symptoms of infection even long before the days of germ theory.
Erin Allmann Updyke	Right.
Erin Welsh	Imagine having stomach cramps and fatigue and then pooping out segments of something that looks like a worm. It'd be hard not to say, 'Oh, that's why I was feeling so cruddy these last few fortnights' or whatever. And so unlike infections from microscopic pathogens, for instance influenza virus or plague, the first descriptions we often have of these parasitic diseases is actually of the parasites themselves or sometimes the parasite plus symptoms rather than the disease. Which I find so interesting because I think it does change the way we think about the concept of disease vs pathogen.
Erin Allmann Updyke	Yeah.

Erin Welsh	I don't know, something I was just thinking about. Given their size and conspicuousness, tapeworms of course make an appearance in the Ebers Papyrus from around 1500 BCE and we also have tapeworm infections in the stomach and intestines of some Egyptian mummies. Aristotle in the 300s BCE described how some pig muscles appeared to have bladders or cysts that look like hailstones. And he also noted that adult pigs who were free roaming tended to have this so-called measled appearance while nursing pigs did not. Pliny the Elder in the 1st century CE may have been the first to use the term Taenia in reference to these worms from the Latin word for flat band or ribbon.
	And references to the worms, I mean really they can be found all over the world in ancient texts from China, India, Middle East, just to name a few. But the ancients didn't quite have it all figured out when it came to these parasitic infections, especially in terms of tapeworms. They may not have understood for example how exactly you get these parasites although the consumption of pork is banned in several cultures or religions which could have something to do with tapeworms. The oldest mention of banning pork comes from Leviticus and the Hebrew Bible from around 600-500 BCE. Have I read this on the podcast before? I can't remember.
Erin Allmann Updyke	Maybe.
Erin Welsh	Okay. Well I'm gonna do it again. And quote: "And the pig because it parts the hoof and is cloven footed but does not chew the cud is unclean to you. You shall not eat any of their flesh and you shall not touch their carcasses. They are unclean to you."
Erin Allmann Updyke	How interesting.
Erin Welsh	Yeah, it is.
Erin Allmann Updyke	Yeah.
Erin Welsh	And of and of course the consumption of pork is also forbidden in Islam. It's entirely possible that tapeworms specifically in pigs were responsible for this ban but there are also several other parasites that could have contributed to the unclean and I will say unfair reputation of pigs.
Erin Allmann Updyke	Yeah. Plus you can get tapeworms from lots of other things.
Erin Welsh	Absolutely.
Erin Allmann Updyke	Like cows and fish.
Erin Welsh	And also not all possible symptoms of tapeworm infection were recognized as being related to the parasite, such as this epilepsy that can emerge later in life as a result of neurocysticercosis which was described in Hippocratic texts, the epilepsy, but not in relation of course to tapeworm.
Erin Allmann Updyke	Right, right, tight.

Erin Welsh	We haven't gotten to do a possible retrospective diagnosis of a historical figure in a while, so I'm excited to announce that a few researchers have suggested that the epilepsy that Roman dictator Gaius Julius Caesar from 100-44 BCE, that he began to experience when he was around 54 years old, that might be related to neurocysticercosis. Who knows? But what is clear is that people didn't really fully know how this life cycle was completed and the role of pigs vs cows vs whatever. And so there was no reason to try to control these diseases. And so the parasites just spread and spread and spread, especially like I mentioned as widespread travel and colonization occurred.
	With more tapeworms in circulation and the rise of human anatomists in the 1500s and 1600s, it was really only a matter of time before people started recognizing the other primary way that tapeworms could infect you besides intestinally. They had seen the measled appearance of pig tissue had already been observed but not so much in humans. And the first recorded cases of neurocysticercosis were described by Rumler in 1558 and by Panarolus in 1652, both of whom described the liquid-filled vesicles that they found in the brains of their deceased patients. And not terribly long after these vesicles were shown to be parasitic, shown to have those tiny little worms which I think is absolutely amazing.
Erin Allmann Updyke	I think in looking through so many pictures it makes so much sense that they were able to make these connections sooner because these cysts are not just a fluid-filled sac with nothing in it, it's a fluid-filled sac with a tiny little tapeworm in it. And if you already know what tapeworms are and that they're in your guts, then it makes sense that they were able to make these connections. That's really interesting.
Erin Welsh	Yeah, exactly. And so yeah, they pulled one out and you can see oh that looks like a head, oh that looks like suckers.
Erin Allmann Updyke	Right.
Erin Welsh	So it must be a living thing.
Erin Allmann Updyke	Yeah.
Erin Welsh	Although the debate was kind of on for a bit as to whether these arose spontaneously in your gut or in your brain or something like that.
Erin Allmann Updyke	Interesting.
Erin Welsh	But in general, yeah. By the 1700s people were trying to classify these different species which is just so much earlier than we usually end up talking about on the podcast.
Erin Allmann Updyke	Yeah.
Erin Welsh	Which I think is a really fun thing. By 1782 the three species of Taenia that I've mostly been talking about, Taenia solium, Taenia saginata, and Taenia asiatica, these three species were differentiated. And 10 years later in 1792, a Peruvian physician named Hipólito Unanue was the first that we know of to record a case of someone, a soldier, with both an intestinal tapeworm infection as well as neurocysticercosis.
Erin Allmann Updyke	Wow.

Erin Welsh	Yeah. Even still it wasn't fully recognized that the worm in someone's gut could be linked to those cysts in their brain until the 1800s. At that point some German doctors floated the idea that the adult might also be the same species that causes those cysts. But how do you prove something like that? Yeah.
Erin Allmann Updyke	Oh no.
Erin Welsh	Well if you're thinking like one of these German doctors, specifically the one by the name of Kuchenmeister, you would find yourself a quote "volunteer".
Erin Allmann Updyke	Oh no.
Erin Welsh	In his case a few condemned prisoners. And you would feed them sausages and a noodle broth containing Taenia solium cysts from a pig. And then you'd just wait a few weeks for the execution date and then perform your autopsy. Boom, results. That's exactly what Kuchenmeister did. And in the autopsies he did find quote "a small Taenia that was tightly attached with his proboscis to a piece of duodenal mucosa" and nine other worms. There you go.
Erin Allmann Updyke	Wow.
Erin Welsh	Question answered, all you had to do was just find yourself some volunteers. And over the next few decades the life cycle of this and other Taenia species was more fully fleshed out. And this classic TPWKY episode wouldn't be complete without an instance of self-experimentation or more accurately self-experimentation plus a few volunteers. And this is what you heard in our firsthand account. Basically in the 1930s this researcher mentioned named Kozen Yoshino infected himself so that he could better study the life cycle of Taenia solium. I think it was actually for his dissertation.
Erin Allmann Updyke	Wow.
Erin Welsh	And he published six papers from it which is pretty impressive, true commitment.
Erin Allmann Updyke	That's a heck of a lot more than I published.
Erin Welsh	And other good news, as far as we can tell Yoshino never developed any signs of cysticercosis and his experiment did show us quite a bit actually about the different stages of infection, symptoms, life cycle, and the infection rate of this parasite. Into the 20th century cysticercosis grew in prevalence in some areas and declined in others, especially in those places where food inspection or livestock feeding laws were enacted to try to reduce transmission of these parasites. And prevention really was key because like we talked about treatment can be difficult, especially for the cysticercosis and treatment is still not that great. The drug that seems most commonly used today wasn't developed until the 1970s and it has nearly as many terrible side effects as earlier drugs which were questionable in their efficacy.
Erin Allmann Updyke	Right.
Erin Welsh	Still the side effects from this drug, however horrible, aren't nearly as bad as an infection with tapeworms can be. Maybe it goes without saying after what you heard in the biology or maybe it bears repeating. Because let's talk about the tapeworm diet real quick. This last bit of history is maybe a little bit out of order but I promise I'll bring us up to the present day at the end of it. Have you heard of the tapeworm diet?

Erin Allmann Updyke	Oh yeah, oh yeah, definitely.
Erin Welsh	I feel like I've heard it mentioned jokingly here and there but I always assumed that that's exactly what it was, a joke. Where would you even get tapeworm eggs? A tapeworm infection has to be bad for you. How do you get the worm out? It just seemed kind of ridiculous and a terrible idea through and through. But when it came time to do this episode, I wanted to dig a bit deeper just to see what was out there. Was this tapeworm diet based in anything real? Who first got the idea and how did they implement it? To answer these questions we have to go back to the Victorian era around 1830-1900. The predominant beauty aesthetic during this time in Europe and North America was tiny waists, transparent skin, delicate features, rosy cheeks, red lips and so on. And this aesthetic kind of coincided with the rising prevalence of tuberculosis which can cause someone who is infected to have many of those features because you're dying of this horrible disease. And I think we talked about the romanticization of TB in our episode.
Erin Allmann Updyke	We did. Yeah, yeah, I remember that.
Erin Welsh	It also coincided with the rise of the temperance movement which urged self restraint and a controlled diet with flavorless foods, this is kind of where graham crackers got their start.
Erin Allmann Updyke	Oh yeah. We've talked about that on this podcast before too.
Erin Welsh	We have. And the history of the thin ideal, the so-called thin ideal and the factors behind its rise is too much to cover in this one episode. But I just wanted to briefly describe how over this period, especially during the Victorian era, body shape and size became tied to morality and the pressure to conform to these new "beauty standards" quote unquote and societal expectations lead people to seek ways that they could do that. Any way they could do that. Or you could also look at this as people using these manufactured expectations to make money through wacky and dangerous exercise machines, a pamphlet on the chew and spit diet, or tapeworm pills. In the later decades of the 1800s, various companies advertised a mail service where they would send you a few tapeworm eggs for a nominal fee, which is funny now that I know more about the biology that they would send eggs.
Erin Allmann Updyke	So I have so many issues with this.
Erin Welsh	Yeah. Go ahead.
Erin Allmann Updyke	Yeah. The idea you're saying is that someone would get an adult tapeworm to suck up some of their food so that they then lose weight, right? That's the idea behind the tapeworm diet.
Erin Welsh	Yes.
Erin Allmann Updyke	Yeah. So eggs is obviously not going to do that.
Erin Welsh	Nope, they're just going to encyst.
Erin Allmann Updyke	Also these are environmentally stable eggs but you're not going to ship them across the world in what year is this? You're saying 1700s?
Erin Welsh	No, late 1800s, early 1900s.

Erin Allmann Updyke	In the 1800s and 1900s, you're not going to ship these eggs and have them survive the journey and even be infectious.
Erin Welsh	No. Not to mention the fact that even if somehow you could give someone tapeworms, adult tapeworms, they're not going to eat enough.
Erin Allmann Updyke	Enough of your food.
Erin Welsh	Right.
Erin Allmann Updyke	It could cause some vitamin and mineral deficiencies. Ooh great.
Erin Welsh	You could have diarrhea and stomach cramps.
Erin Allmann Updyke	You sure could.
Erin Welsh	You could have fatigue. Yeah. And so that's that's the thing is that if we're talking about this in the late 1800s/early 1900s, clinical trials, it wasn't even like a glimmer in the eye of someone, it wasn't even remotely a thing first of all.
Erin Allmann Updyke	Yeah, right.
Erin Welsh	Second of all these quote unquote "tapeworm eggs" may have just been placebo, they may have just been empty little pill canister thingies.
Erin Allmann Updyke	Yeah or little granules of rice.
Erin Welsh	Sure, anything. And third I also want to point out that somehow, despite the fact that you and I both had heard of the tapeworm diet before doing this episode, it wasn't even very popular or a big fad, so people weren't really doing it all that much. So yeah, so it made me wonder why is this still around? And the the answer is I don't know the answer. Probably because it does conjure up a very visceral image of a giant parasitic worm that's eating your food even though that's not what happens.
Erin Allmann Updyke	Yeah. I mean it is what happens and that they can get to be quite large and they do eat your food.
Erin Welsh	Right.
Erin Allmann Updyke	But it's not like that.
Erin Welsh	No. So yeah, I think that it's kind of a very interesting snippet of history that somehow has left an impact on popular culture.
Erin Allmann Updyke	Yeah.
Erin Welsh	It has been referenced recently on reality shows, there have been news reports of people trying this out at home which absolutely don't do, and actual super sketchy websites that claim to sell either eggs or other life stages to help you grow an adult tapeworm.

Erin Allmann Updyke	Yeah.
Erin Welsh	But I think the fact that it's still known today really says more about just how much cultural pressure there is to conform to these certain manufactured quote unquote "beauty standards" that intentionally ingesting a worm could ever seem like a good idea.
Erin Allmann Updyke	Yeah.
Erin Welsh	Not to mention it draws attention to all these predatory people and companies out there that take advantage of that. So anyway, the tapeworm diet, though a blip in the history of snake oil salesmen, still has relevance for today. And speaking of today Erin, see I promised I would get us here, where do we stand with tapeworms?
Erin Allmann Updyke	I will hopefully answer that a little bit right after this break.
Erin Welsh	(transition theme)
Erin Allmann Updyke	So I don't have great numbers on overall tapeworm burdens, I'm just gonna say that one right out front.
Erin Welsh	Okay.
Erin Allmann Updyke	Largely because like we talked about and like I said in the biology section, when humans get infected with adult forms, especially of Taenia saginata, Taenia solium, Taenia asiatica, the symptoms are generally quite mild. So we just don't have solid numbers. World Health Organization on their website is like, 'We don't track it. We just don't.' But suffice to say these are incredibly, incredibly common parasites causing millions, tens of millions, hundreds of millions of infections worldwide. I do have some numbers from the fish tapeworm shockingly enough, a paper that I found estimated that up to 20 million people are infected worldwide with Diphyllobothrium species and that's just fish tapeworm, right. Beef tapeworm, pork tapeworm, these are going to be incredibly common as well. We do have some numbers when it comes to neurocysticercosis as well as hydatid disease or echinococcosis.
Erin Welsh	Okay.
Erin Allmann Updyke	Because unsurprisingly these cause more severe infections. So the World Health Organization reports that worldwide the number of people estimated to be living with neurocysticercosis, that is the cysts in the brain, is somewhere between 2.5-8 million people worldwide.
Erin Welsh	Oh my gosh.
Erin Allmann Updyke	Right? Huge number and huge range.
Erin Welsh	Right.
Erin Allmann Updyke	The range is because this is an estimate that includes both people who are asymptomatic and might be symptomatic.
Erin Welsh	Okay.

Erin Allmann Updyke	And in endemic countries, and the list of endemic countries is very long, this is a globally distributed parasite, it's estimated that up to 30% of people living with epilepsy have neurocysticercosis as a potential cause of their epilepsy.
Erin Welsh	Wow.
Erin Allmann Updyke	Yeah. And in some under resourced impoverished rural communities in these endemic countries, it's more like 70% of the burden of epilepsy is due to neurocysticercosis.
Erin Welsh	I had no idea.
Erin Allmann Updyke	I know. And the World Health Organization also estimates that 75% of people living with neurocysticercosis are getting little to no treatment. I know, not great. When it comes to Echinococcus, the other multiple species of parasites which we can be the intermediate host and cause severe disease, worldwide it's estimated that there are at least a million people, one paper I read said between 1-3 million people worldwide living with the various forms of echinococcosis.
Erin Welsh	Okay.
Erin Allmann Updyke	So all of these parasites are globally distributed and incredibly common.
Erin Welsh	I have a question about cooking. If you follow the standard temperatures for pork and beef and so on, does that kill the cysts?
Erin Allmann Updyke	Great question. Yes.
Erin Welsh	Okay, okay.
Erin Allmann Updyke	I also want to kind of emphasize that pork gets a really bad rap but neurocysticercosis is not caused by eating pork, it's caused by exposure to human feces that have the eggs of the parasite. So while pigs are an essential part of that life cycle because pigs are the normal intermediate host, it is not eating uncooked pork that gets someone infected with neurocysticercosis.
Erin Welsh	That's I think a really interesting and important point.
Erin Allmann Updyke	Yes.
Erin Welsh	And I didn't know that before doing this episode.
Erin Allmann Updyke	Yeah. And I think it's an important part because certainly you could have pig meat that becomes contaminated with human feces, especially if conditions are such that human feces is being used as fertilizer and then becomes contaminated in the pig meat, etc. That's definitely possible. But it's not the same as getting an adult tapeworm from the cysts that are in the pig meat. It's a pretty complicated life cycle.
Erin Welsh	Yeah.
Erin Allmann Updyke	And so unsurprisingly prevention of this disease is the best thing that we could try and do, right.

Erin Welsh	Yeah.
Erin Allmann Updyke	And as all of the complex life cycle parasites that we talk about on this podcast, prevention of a disease like any of these tapeworm infections requires a one health approach.
Erin Welsh	One health!
Erin Allmann Updyke	It does. It requires that animals can be vaccinated and treated for these parasites, it requires that adequate sanitation for both humans and livestock and domestic animals is available, it requires treatment for humans. So these are very complex diseases, all of these, to try and kind of get a handle on. And that's I think a large part of the reason why they're still so widespread.
Erin Welsh	That makes sense. But it also seems pretty crucial. 2.5-8 million people?
Erin Allmann Updyke	I know. And I had no idea what a large share of the overall global burden of epilepsy was due to neurocysticercosis specifically.
Erin Welsh	Yeah, me neither.
Erin Allmann Updyke	So we need to do a whole episode on epilepsy because I also tried to look into how epilepsy and then I was like whew.
Erin Welsh	Oh no, it's on our list, it might even be on our list for this season though I'm not entirely sure.
Erin Allmann Updyke	Yeah. But that is a bunch of species of tapeworm.
Erin Welsh	How about it?
Erin Allmann Updyke	How about it?
Erin Welsh	Are we ready for sources?
Erin Allmann Updyke	I think so.
Erin Welsh	Okay. I have several, I'm going to shout out a few. So Hoberg either as an individual author or Hoberg et al, there are a few papers that I really liked to understand more about the evolution of tapeworms. And then one that was really helpful for the human history was a paper by Del Brutto and García from 2015.
Erin Allmann Updyke	I had a number of papers specific to Taenia infections, papers specific to the fish tapeworm infections, as well as a couple on Echinococcus. But I also want to give a special shout out to a series of YouTube videos that I watched that were put together by the Robert Wood Johnson Foundation and Stanford Medicine. They're available on YouTube and they're really great short clips and there's one for each parasite species that we talked about and I really like them. So we'll link to that as well.
Erin Welsh	I used that for the pronunciation.
Erin Allmann Updyke	Yeah, me too. That's how I found them. And then I was like wow, these are really useful.

Erin Welsh	Yeah. Listen, follow, and leave us a review on Amazon Music, Apple Podcasts, or wherever you get your podcasts. And don't forget you can listen to new episodes one week early on Amazon Music or early and ad free by subscribing to Wondery Plus in the Wondery app.
Erin Allmann Updyke	Yeah. Thank you to Bloodmobile for providing the music for this episode and every one of our episodes.
Erin Welsh	And thank you to the Exactly Right network.
Erin Allmann Updyke	And thank you of course to you, listeners. We love that you listen, we love making this podcast. Hope you learned some fun things about tapeworms.
Erin Welsh	Yeah, absolutely. And a special thank you as always to our wonderful, generous patrons. We love you and appreciate you.
Erin Allmann Updyke	So much.
Erin Welsh	Okay well until next time, wash your hands.
Erin Allmann Updyke	You filthy animals!