

Erin Allmann Updyke

"When I was a young boy I had two uncles, both were heavily infected with guinea worms and back then no one here knew how guinea worm was transmitted. People would become infected and we just kept wondering why. During those years we had some communal fighting, fighting between communities amid South Sudan's struggle for independence. One day fighting erupted in the evening so everyone in my village ran away. But my uncles could not run so they crawled to the garden to hide because no one could carry them. My mom could not carry them and I had lost my dad during the struggle. So we had to leave them. There weren't any options, we just cried. So warfare comes and fighters raid our cows and kill some people and then go back where they came from. After that when the people came back we found that my uncles were gone, they had been killed.

If it were not for guinea worm they would have just joined us and trekked away from the danger, so I say that it was guinea worm that killed them indirectly. When I was young I could not understand how the guinea worm killed my uncles but as time goes on I have come to know this is our story. Later we were living at a refugee camp and we were given pipe filters from the Carter Center. I didn't know why people were given pipe filters so I refused to use mine. My mom is educated and she told me these were for guinea worm and now she began to tell me this story and I finally could see the connection between the guinea worm and the loss of my uncles. I said okay, there are people that are working for this. And that was when I committed to working for guinea worm eradication because guinea worm had done something bad to me. And even if it had not been me, what of the rest of the community?

That's what inspired me to work for the eradication of guinea worm, so I went away to school and when I came back I looked for this work. When I found the man who would be my director I told him, 'I will never let you and my country down, I just need to relate to my community and see how this guinea worm is cruel to my community. I want my community to be free.' And that's why, you see, I am doing this work. It is very difficult. If you wanna work for guinea worm you need to leave the good things in your life behind and become part of the community, that way you come to understand the dynamic of how to help the community to eliminate the guinea worm. And that's been very effective. I've been there and I've worked and I've seen how the guinea worm can go to nothing and I have hope that one day we will be free and able to say that guinea worm is gone. It will be a very great achievement. I thank the Carter Center for helping us achieve it."

TPWKY

(This Podcast Will Kill You intro theme)

Erin Welsh

Wow. That was an amazing story.

Erin Allmann Updyke

Yeah, yeah. So that was from Daniel Deng and he wrote that story called 'Guinea worm killed my uncles' which we found on the Carter Center blog. So that's who that was from.

Erin Welsh

Yeah. 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 if you haven't guessed, today we're talking about guinea worm.

Erin Welsh

Guinea worm! Dracunculiasis! I am really excited for this episode which I know we say every episode.

Erin Allmann Updyke

Every episode. But we're always excited so it's always true.

Erin Welsh: We're always excited. I feel like it's been a while since we've done a parasitic disease so that's always interesting.

Erin Allmann Updyke: Yeah.

Erin Welsh: And the other reason that I'm super excited for this episode is that we have an incredible guest.

Erin Allmann Updyke: Yes!

Erin Welsh: We were fortunate enough to interview Sarah Yerian who is the Senior Associate Director of the Guinea Worm Eradication Program at the Carter Center.

Erin Allmann Updyke: How amazing! Oh my gosh.

Erin Welsh: I know. So we got to talk to her a bit about her experiences on the ground as well as some of the logistical finer points of how eradication is actually achieved.

Erin Allmann Updyke: Yeah.

Erin Welsh: So keep an ear out for that later in the episode.

Erin Allmann Updyke: Yeah, we're really excited about it. But first what time is it? I think it's...

Erin Welsh: I think it must be quarantini time if I'm not mistaken.

Erin Allmann Updyke: You're right! It's quarantini time, I checked my watch and everything.

Erin Welsh: (laughs) Well Erin, what are we drinking this week?

Erin Allmann Updyke: We're drinking The Littlest Dragon.

Erin Welsh: I love this name but it does require maybe a bit of explanation.

Erin Allmann Updyke: Just a touch.

Erin Welsh: So the species name for guinea worm is *Dracunculus medinensis* and 'dracunculus' means 'little dragon'.

Erin Allmann Updyke: Yeah.

Erin Welsh: And so it's like the littlest dragon.

Erin Allmann Updyke: Just the tiniest little dragon.

Erin Welsh: It's a cute name for a not so cute worm.

Erin Allmann Updyke: Right.

Erin Welsh: I have to admit it's not the cutest of worms.

Erin Allmann Updyke: Are there cute worms out there?

Erin Welsh: Absolutely.

Erin Allmann Updyke: Oh okay, yeah.

Erin Welsh: I know any by name but I'm sure that there are.

Erin Allmann Updyke: This isn't one of them. I think oceanic worms actually, there's some cute ones in the ocean.

Erin Welsh: Yeah, yeah.

Erin Allmann Updyke: Anyways so what's in The Littlest Dragon?

Erin Welsh: The Littlest Dragon is actually quite a delicious cocktail. So it had blue curacao, it has rum, pineapple juice, cream of coconut, and the most crucial part is that you garnish it with a toothpick with a sour gummy worm wrapped around the toothpick for reasons that will become clearer later in the episode.

Erin Allmann Updyke: Yes. And we'll post the full recipe for that quarantine as well as our nonalcoholic placeborita on our website [thispodcastwillkillyou.com](http://thispodcastwillkillyou.com) and all of our social media channels as well.

Erin Welsh: Yes. So I think we have a couple other pieces of business to take care of.

Erin Allmann Updyke: We do. So first of all I finally checked our PO Box after months of not going to the post office because of corona and I'm thrilled. We got a couple of really, really kind presents that we wanted to say thank you for. So first I wanna say thank you so much to Kira who sent us not only the most adorable, sweet, just the sweetest letter but also a handmade mat coaster for our quarantine that looks like the coronavirus.

Erin Welsh: Oh my gosh, it is incredible. Kira, thank you so much, that's so sweet of you. And yeah, that letter made us-

Erin Allmann Updyke: A little teary-eyed.

Erin Welsh: We were just like aw, we don't deserve this. This is too nice.

Erin Allmann Updyke: And also thank you so much to Melanie who made us handmade masks with little germs on them.

Erin Welsh: Oh my gosh, they're so cool, thank you so much Kira and Melanie, we appreciate it so very much.

Erin Allmann Updyke: So much, really.

Erin Welsh: Amazing. Well I think the only business is that we've got merch as per usual, go to [thispodcastwillkillyou.com](http://thispodcastwillkillyou.com) and click on the MERCH tab.

Erin Allmann Updyke Shout out to Abigail Ervin-Penner who designed all of our new merch, we love it so much.

Erin Welsh Oh my gosh, I'm obsessed. Seriously. And we also have a Bookshop affiliate account so you can find all of the books that we talk about on our podcast there and also a Goodreads list, so check those out. You can find all of those things on our website.

Erin Allmann Updyke Awesome. Is that all?

Erin Welsh I think that's all.

Erin Allmann Updyke Excellent. Shall we dive right into the biology of this little worm?

Erin Welsh Let's do it.

Erin Allmann Updyke Right after this break.

TPWKY (transition theme)

Erin Allmann Updyke Guinea worm or as you mentioned Erin, *Dracunculus medinensis*, right?

Erin Welsh I think that's how you say it.

Erin Allmann Updyke I even googled how to make sure I pronounced 'dracunculus' properly because I've never been able to pronounce it but everyone knows I have issues with pronunciation.

Erin Welsh (laughs) What do you mean? Cough cough, 'gerardia'.

Erin Allmann Updyke (laughs) Anyways, *Dracunculus medinensis* is a nematode or a round worm, so this is the same phylum as hookworm. This is our second nematode. Okay?

Erin Welsh Gotta love them.

Erin Allmann Updyke Gotta love them. That's their tagline. So because this is a complex parasite we obviously have to start with the life cycle, okay.

Erin Welsh Excellent.

Erin Allmann Updyke We are gonna start with the first stage larva so that when we end this cycle, we'll end with the human part of the life cycle, okay?

Erin Welsh Okay.

Erin Allmann Updyke So the first stage larva, if dracunculus are tiny dragons, these are the tiniest dragons, the babies. They're found in water sources, freshwater or brackish water sources. They swim and they thrash about in this water the way that worms like to do and then they find tiny little copepods. A copepod is a little crustacean, think Plankton from SpongeBob.

Erin Welsh They're really cute. Really cute.

Erin Allmann Updyke: Yeah, they're very adorable. These copepods swallow this first stage larva of the guinea worm and then within the body of the copepod the larva kind of burst out of their stomach and begin to develop and grow.

Erin Welsh: Question.

Erin Allmann Updyke: Yes, I know.

Erin Welsh: It's starting early. (laughs) Okay so the first stage larva is ingested by the copepod. Does it have any movement towards the copepod? You know what I mean, does it have any directional movement?

Erin Allmann Updyke: They have certainly movement, I don't know if they have directional movement towards copepods, I didn't see anything about that in the literature that I read. But that's a really interesting question.

Erin Welsh: Okay, gotcha.

Erin Allmann Updyke: Okay. So now they've molted, they've grown inside of this copepod, and then a human comes along and fills up their water container from the well or the pond or whatever that this copepod has been living in. And they've been walking for a while so they take a big old swig of that water and they swallow these tiny little Plankton copepods. And then inside our stomach, the human stomach, the copepods die because of all of the acid and they're obliterated and the larva come forth, burst free, survive somehow in our stomach, travel down into our small intestine, and then burrow their way out of the small intestine into the wall of our abdomen. What?

Erin Welsh: It's terrifying. It is truly like the movie Alien.

Erin Allmann Updyke: Yes.

Erin Welsh: But just on a much smaller scale.

Erin Allmann Updyke: The tiniest dragon of scale.

Erin Welsh: Which is actually really funny because there's a documentary I watched which is narrated by Sigourney Weaver about guinea worm.

Erin Allmann Updyke: About guinea worm?

Erin Welsh: Yeah.

Erin Allmann Updyke

Oh my gosh, that's phenomenal. Okay so now these tiny larval worms are basically the connective tissue layers of your abdominal wall, your belly wall. And there is where they will begin to mature into fully adult worms and these worms have male worms and female worms and they will mate and then the females will grow and grow and grow and become all full of millions of eggs. And this is a process that takes many, many months. And then over the course of these months, as her eggs mature into embryos she will then travel down through our connective tissues, down and down and down to the lower limbs like your leg, usually your ankle or your foot although she could travel anywhere cause she's basically just under your skin, just in the fatty tissue underneath your skin. And these little worms are migrating through down into your lower extremities and then 10-14 months after somebody drinks these copepods, this fully engorged female worm which is now 70-100 centimeters long, that's up to a meter long.

Erin Welsh

It's very long. It's very long.

Erin Allmann Updyke

It started microscopic and now it's a meter long, okay. Then they come all the way forth to the surface of your skin and in doing so it produces a blister and this blister is incredible, incredible itchy, like unbearably itchy and it's burning and it's really uncomfortable, so much so that the only thing you wanna do to try and stop the itch is submerge your foot in cool, cool water. So you find a pond and you do that and as soon as your foot enters the pond, that worm contracts and she pushes up and she bursts forth and literally pushed open part of her gravid uterus out of the blister, bursts open, and expels upwards of 500,000 larval worms into the water, thus completing her life cycle.

Erin Welsh

It's incredible.

Erin Allmann Updyke

It's incredible.

Erin Welsh

It seems so otherworldly.

Erin Allmann Updyke

Absolutely.

Erin Welsh

Everything about it is mindblowing.

Erin Allmann Updyke

It really is. Nematodes in general I think are absolutely mind blowing creatures.

Erin Welsh

I genuinely am fascinated by them.

Erin Allmann Updyke

Same. So I said that she bursts forth and releases all these larval worms, that's not the end of her story, that's just what happens the very first time that she comes into contact with water. But now she is partially freed from your skin, literally part of this female worm is sticking out of you and then every time that she's submerged in water, she'll release more larva. And the part that's outside of your body will kinda just shrivel up and die and then a little bit more of her will emerge everyday, everyday, everyday until finally she is completely gone and has released, I don't know, more than 3 million larval worms into the environment. Whoa.

Erin Welsh

It's a journey, yeah.

Erin Allmann Updyke

It's a real journey.

Erin Welsh

Okay so number one. What happens to the male?

Erin Allmann Updyke

Ooh, great question.

Erin Welsh

Cause he's just floating around in there somewhere?

Erin Allmann Updyke

He's pretty much just floating around, yeah. You can sometimes get a small inflammatory response from wherever he ends up but usually your body will just sort of calcify him and then you'll just have a little boop of calcium deposit somewhere in your body. Nothing much.

Erin Welsh

Does where he ends up dying, can that be problematic in terms of if he ends up in a joint or...?

Erin Allmann Updyke

Oh Erin, you are getting so far ahead, okay.

Erin Welsh

Okay. We'll just-

Erin Allmann Updyke

Put a pin in it!

Erin Welsh

Put a pin. All right. My next question then is how does the female know where to go?

Erin Allmann Updyke

No idea. Great question. It is the weirdest thing and all of the things that I read was just like yeah, most of the time it's from the lower limbs but it could be anywhere. I think that there's some thought that they travel in part along lymphatic routes. So if they just get on the right lymphatic tract in your abdomen, a lot of your lymphatics are gonna be draining down to your legs or your lymphatics from your legs are gonna be draining up towards your abdomen. So it kind of makes sense if they're in your lower abdomen already that they just sort of end up going down to your legs.

Erin Welsh

Gotcha, gotcha.

Erin Allmann Updyke

Yeah.

Erin Welsh

Okay. My other question pertains to the longevity of these worms.

Erin Allmann Updyke

Oh good.

Erin Welsh

So 10-12 months and that's typically just in correspondence with a rainy/dry season in the places where these are most abundant/prevalent?

Erin Allmann Updyke

Good question, very good question. Yeah so there is definitely seasonal dynamics in terms of transmission but whether people are more likely to get infected in the wet or the dry season depends on where they live and what region. So in some parts of the world transmission is highest during the rainy season if it's areas where people are primarily using ponds as their water sources that are otherwise dry during the dry season, right.

Erin Welsh

Okay.

Erin Allmann Updyke

But in other places that are maybe more wet in general where you have stepwells or other types of cisterns, then transmission tends to be highest in the dry season or right before the rainy season starts at the very end of the dry season because at that time the water quality supports higher numbers of copepods. The water is less turbid and there's not as many streams washing things away so the copepods aren't as dilute as they would be during the rainy season when water levels are high.

Erin Welsh: That makes sense.

Erin Allmann Updyke: Isn't it?

Erin Welsh: Ecology, there you go.

Erin Allmann Updyke: It's so cool!

Erin Welsh: It's very interesting.

Erin Allmann Updyke: Okay but that didn't answer your question. So the worms live a long time, yeah.

Erin Welsh: Yeah I guess I'm thinking other species of nematodes, they mature a lot more quickly than that.

Erin Allmann Updyke: Right, yeah.

Erin Welsh: And so I wonder whether it does seem to be more in correspondence with the timing of the dry and the rainy season.

Erin Allmann Updyke: Yeah, that makes sense cause pretty much across the board even though in some places it's the wet season and in some places it's the dry season, either way we definitely see seasonal trends. So that does make sense, yeah.

Erin Welsh: Cool.

Erin Allmann Updyke: Yeah.

Erin Welsh: All right.

Erin Allmann Updyke: Okay.

Erin Welsh: So.

Erin Allmann Updyke: So that was just the worm, right.

Erin Welsh: Right.

Erin Allmann Updyke: That was just the life cycle of the worm, we're missing the human part of it right, these are humans that are being infected. So what the heck is going on in you? Let's find out.

Erin Welsh: Tell me.

Erin Allmann Updyke: Okay so for some people the first sign of infection might be noticing the worm itself just kind of beneath the skin a few days before it emerges, kind of as it's traveling down. For others and very commonly it's kind of a more generalized allergic-type symptoms, so maybe hives, maybe a bit of a fever, some swelling under your eyes, you might think I have an allergy to something.

Erin Welsh: But all of this would be still around the time of its emergence.

Erin Allmann Updyke

Of its emergence, right. Not of when you get infected. Pretty much there's basically no symptoms when you first get infected so this is a year after you drink the larva, okay. But for most people, the very first indication of infection is the blister. And like we said already, 80-90% of the time it's on the legs or the feet and it usually starts pretty small but it grows fairly rapidly, it can grow over a number of hours or over a couple of days and the blister before it opens is sterile, so it's not filled with pus and bacteria like a pimple kind of blister.

Erin Welsh

Right, it's just clear.

Erin Allmann Updyke

It's clear liquid, it's inflammatory fluid, and it's filled with larval worms. So the female starts to release larval worms underneath your skin as part of the formation of the blister.

Erin Welsh

So it's not quite sterile, is it?

Erin Allmann Updyke

Well yeah, it doesn't grow bacteria is what we mean by 'sterile'. And what's so interesting is that it's not entirely clear pathologically what causes the formation of the blister, like whether it's the adult worm releasing enzymes that cause tissue death or whether it's the embryos, the larva themselves that are causing the tissue damage which I think is really interesting that we still just don't quite understand.

Erin Welsh

Well I also think, jumping ahead a little bit, that there's probably a lot that we don't know about the biology or the ecology of this simply because it's not directly relevant to the control of the parasite.

Erin Allmann Updyke

Right, exactly. I think there is so much of this that we just don't know because it hasn't been studied because we didn't technically "need" to, quote unquote, to get it under control.

Erin Welsh

Right.

Erin Allmann Updyke

Yeah. Okay so now you have this blister and then it'll start to open. So very often it opens at first in contact with water because that does produce in the female worm this intense contraction where she pushes herself forth. But it is possible to have the blister break open even if you don't put your feet in water. So now you have this female worm half sticking out of a wound in your foot and basically the only way to get her out is to slowly pull her out in a process that can take usually at least a month where you slowly twist the worm around a small stick.

Erin Welsh

Yep.

Erin Allmann Updyke

And that's why we have a gummy worm in our quarantine.

Erin Welsh

It is indeed. If anyone still even wants to make it after this.

Erin Allmann Updyke

After that description.

Erin Welsh

Yeah.

Erin Allmann Updyke

Of a worm coming out of your foot that you're wrapping around a stick slowly over the course of a month. Okay. And that is the best case scenario.

Erin Welsh

Right.

Erin Allmann Updyke

That's not what always happens. More than 50% of the time the wound itself is complicated by a secondary bacterial infection and there's a whole bunch of different ways that this can happen, okay. So when the worm is happily living under the surface of your skin in your subcutaneous tissue, it's in this little worm house, okay. So it forms this little fibrous worm sheath around itself and that's how it can move without getting stuck to your tissues because of our inflammatory response.

Erin Welsh

Whoa.

Erin Allmann Updyke

Yeah, it's really cool. Which I think is probably part of why it takes so long to travel down, right, it's not just swimming through, it's slowly moving within its little sheath.

Erin Welsh

Oh my god.

Erin Allmann Updyke

I know. Okay.

Erin Welsh

Wow.

Erin Allmann Updyke

Yeah. But once it starts to emerge and it breaks through our skin, then our inflammatory response can really start to kick in and it can form adhesions to the worm itself rather than the sheath which can complicate the removal and make it harder because it's stuck to our tissues. So if the worm gets broken during the extraction process because it's quite a fragile little worm, then what's left of the worm in your body kinda withdraws back into its little sleeping bag and it brings with it all of the bacteria from the outside of your skin, so Staph. aureus, E. coli, anything living there. So then you can get deep tissue infections because of that. But you also could get an infection even if you don't break off the worm, right, just because you have this open wound and it's on a place like your foot or your ankle that's in contact with the environment, right.

Erin Welsh

Right.

Erin Allmann Updyke

Tetanus is also a very real and very common complication. So secondary infection with the Clostridium species that produces tetanus toxin and then you end up with tetanus because of this. So that's kind of the most common complication of guinea worm infection but it's also possible, like you mentioned Erin when you were jumping ahead, for the worm to get a little bit lost on its way to try and emerge. So whether that means it makes it to your skin but for some reason can't quite penetrate through your skin which can happen, then what will happen there is the worm just kinda becomes calcified with our own immune response which wouldn't be a problem if it's just say in the subcutaneous tissue of your abdomen or your arm.

But if it's in an important organ like your pancreas or your heart or like you mentioned Erin, in your joint space, then you could end up with arthritis. It can also lead to deep abscesses. So even though I said that this blister is "sterile" quote unquote, if the worm begins to release the embryos or the larva in your deep tissue it will cause a really dramatic inflammatory response and that will lead to a serious abscess where you would find a lot of pus and white blood cells and things like that. You still wouldn't find bacterial infection but it would be full of larva.

Erin Welsh

Right.

Erin Allmann Updyke

And so overall the reported period of incapacitation due to this infection on average is 8.5 weeks but that range is from 2-16 weeks or even longer and it really depends on how many worms you're infected with or whether you get a secondary infection and things like that. Because P.S. getting infected with one worm doesn't prevent you from getting infected with multiple worms.

Erin Welsh

Right, there's no immunity.

Erin Allmann Updyke

Yeah, exactly. So usually most of the time people get infected with 1-3 worms that emerge at a time but some reports have found up to 40 worms emerging from one person at a time which just sounds unimaginably awful.

Erin Welsh

Yeah, yeah, yeah.

Erin Allmann Updyke

Because even like I said in the best case scenario where you have a worm that emerges without any complications or infection, this is a very painful process. You're slowly winding a living worm out of your tissue in your leg. There's nerve pain, there's itching, there's burning, it's extremely painful.

Erin Welsh

Yeah. Just even getting around, even not just the process of pulling the worm out but walking is really painful and challenging.

Erin Allmann Updyke

Yeah. It's very painful.

Erin Welsh

Yep.

Erin Allmann Updyke

That's it Erin, that's the biology.

Erin Welsh

Okay.

Erin Allmann Updyke

Do you have any other questions for me?

Erin Welsh

I don't think so.

Erin Allmann Updyke

Well good. So Erin, where did this worm come from? I didn't mention this but it only infects humans for the most part, why? How did it find us? Where did it come from? What are we doing about it? Tell me everything.

Erin Welsh

I can't wait to, right after this break.

TPWKY

(transition theme)

Erin Welsh

All right. It's kind of funny that you asked me where does it come from and why does it only infect humans and etc because to be honest I couldn't find a ton on the evolutionary history of it except for just like here's the phylogeny of these worms. And so to answer those questions, I don't really know. I know that it's been with humans for a very, very long time and it actually does seem to infect other animals, maybe not as readily as it does humans but the infection in dogs seems to be a problem that's contributing to some of the difficulties in the complete eradication.

Erin Allmann Updyke

Right. Yes, yeah.

Erin Welsh: Yeah, I don't know. Anyway. I'm sorry, I wish I had more. If anyone has any great *Dracunculus medinensis* evolution papers, please send them our way, I'd like to know.

Erin Allmann Updyke: Yeah.

Erin Welsh: Okay but the history of guinea worm has got all of the other usual suspects: mummies, fun etymology, imperialism, and more. And it's maybe the most "classic" disease quote unquote that we've had in a while.

Erin Allmann Updyke: Yeah.

Erin Welsh: So if you're playing TPWKY bingo, get your cards ready.

Erin Allmann Updyke: (laughs) I love it.

Erin Welsh: All right, let's begin.

Erin Allmann Updyke: Ancient Rome.

Erin Welsh: To Ancient Rome. No actually let's go back even earlier Erin because this worm seems to have been known to humans for basically all of written history and it makes an appearance in - you might guess - the Ebers Papyrus.

Erin Allmann Updyke: Ebers Papyrus! Bingo!

Erin Welsh: There we go, bingo number one. That's from around 1550 BCE by the way, so it's very old.

Erin Allmann Updyke: Very old.

Erin Welsh: And so researchers think that the rare and obscure verb 'dqr' which is just like all on word together refers to the pulling and spinning of the worm for its removal.

Erin Allmann Updyke: Interesting. Like they had a specific verb that meant that.

Erin Welsh: Right. And so researchers were like well it kind of looks like it's referred to with a spindle against one's leg but it's also something beneath the surface and so they think it refers to the removal of the guinea worm using that method.

Erin Allmann Updyke: Okay.

Erin Welsh: And there's also evidence to support this or to support at least the fact that guinea worm was present in Ancient Egypt because a calcified worm was found in a mummy of a 13 year old female from 1000 BCE roughly who had died shortly after her lower legs had been amputated.

Erin Allmann Updyke: Oh!

Erin Welsh: Right, which some researchers have speculated was done to try to save her from the secondary infections that you mentioned caused by the worms.

Erin Allmann Updyke

Oh my goodness, wow.

Erin Welsh

Yeah. And then of course there's the biblical mentions. So in the Old Testament in Numbers 21: 6 which is thought to have been written around the 8th century BCE, there's this line: "Then the Lord sent fiery serpents among the people and they bit the people so that many people of Israel died." And so this is where the worm gets its fiery serpent nickname that you've probably come across.

Erin Allmann Updyke

So that they think is Dracunculus, guinea worm. Fascinating.

Erin Welsh

Yeah and the Ebers Papyrus and the bible aren't the only ancient texts to mention guinea worm, there's also talk of the worm in Ancient Greece and Ancient Rome. For instance there's this from around 46-120 CE, quote: "The people who live near the Red Sea are tormented by an extraordinary and hitherto unheard of disease, small worms issue from their bodies in the form of serpents which gnaw their arms and legs. When these creatures are touched, they withdraw themselves and insinuating themselves between the muscles give rise to horrible sufferings."

Erin Allmann Updyke

100% guinea worm.

Erin Welsh

100%. And it was Galen who gave the infestation its first name, dracontiasis. And one more thing.

Erin Allmann Updyke

Are you getting to my favorite part yet?

Erin Welsh

I think it might be right now.

Erin Allmann Updyke

Okay good.

Erin Welsh

This might be it. I'm sure you've heard it said before that the Staff of Asclepius-

Erin Allmann Updyke

Asclepius, yes!

Erin Welsh

Which is that symbol that you often see associated with medicine and medical things, it's basically a singular snake winding around a rod.

Erin Allmann Updyke

Yes.

Erin Welsh

It's been said that the snake actually represents guinea worm, some people hypothesize.

Erin Allmann Updyke

Yeah. That's my favorite, it's my absolute favorite, it's so much better than it being just a random snake. It has to be guinea worm. Of course it's guinea worm.

Erin Welsh

Well there are other hypotheses.

Erin Allmann Updyke

Yeah, I know.

Erin Welsh

So before I get to those, the WHO logo actually has the Staff of Asclepius on it and side note, a lot of the times you'll see - and I was always confused that the Caduceus which is two snakes and the wings, that's actually something else.

Erin Allmann Updyke

That's Hermes, not Asclepius.

Erin Welsh

That's Hermes, right. And so that refers to more like messaging or trade or commerce, information flow, etc. But the other thing that I think is really interesting about the Staff of Asclepius or the Rod of Asclepius is that Asclepius was his Greek god that was associated with medicine and healing and so some people hypothesize that the snake, part of the healing process was shedding the skin and that renewal. And so that's why they think the snake might represent besides guinea worm.

Erin Allmann Updyke

I don't like it as much.

Erin Welsh

You don't have to like it. (laughs)

Erin Allmann Updyke

You're just the messenger.

Erin Welsh

I'm just the Hermes of this. Okay so whether or not the Rod of Asclepius truly represents guinea worm-

Erin Allmann Updyke

It does.

Erin Welsh

From all of these ancient references to the parasite we can at least tell that it was pretty prevalent across the tropical and parts of the subtropical regions of the Old World. And while most of these ancient folks seemed to recognize it as a parasite, so as an animal, a creature that has somehow invaded your body and is now causing you harm, others including the famous Avicenna weren't as convinced, instead claiming it was actually a vein gone awry.

Erin Allmann Updyke

Interesting.

Erin Welsh

Yeah. He did give it a name that would stick with the worm until present day though, the Medina sickness or the Medina vein because apparently it was quite prevalent in Medina which is a city in western Saudi Arabia.

Erin Allmann Updyke

Oh, like that Funky Cold Medina?

Erin Welsh

(laughs) That funky worm from Medina.

Erin Allmann Updyke

There you go. (laughs)

Erin Welsh

Okay. Anyway so the scientific name of guinea worm which was given by Linnaeus in the mid 1700s is *Dracunculus medinensis*.

Erin Allmann Updyke

Right.

Erin Welsh

So as we mentioned from the Latin 'draco' meaning dragon or serpent and 'medinensis' meaning from Funky Cold Medina.

Erin Allmann Updyke

Wait, 'draco' means serpent? Like Draco Malfoy meant literally serpent?

Erin Welsh

Or dragon, yeah.

Erin Allmann Updyke

I never knew that. Okay, sorry.

Erin Welsh

Yeah. No, I didn't know that either. So basically its scientific name means little dragon from Medina.

Erin Allmann Updyke

Okay.

Erin Welsh

It's kinda cute.

Erin Allmann Updyke

Yeah.

Erin Welsh

As travel and trade expanded throughout the 16th and 17th centuries, reports of the worm became more numerous as did hypotheses about its nature. Was it an animal or was it just part of your body? It's life cycle and how a person became infected in the first place. And it was also during this time that it was first called guinea worm as it was seen in super high numbers along the west coast of Africa. The transatlantic slave trade also led to the introduction of the worm in parts of North, Central, and South America but it doesn't seem that local transmission was sustained for very long after the mid 1800s, possibly because of environmental conditions, possibly because the right copepod species weren't there, I don't really know for sure.

Erin Allmann Updyke

Okay, okay.

Erin Welsh

But throughout the 1800s and early 1900s, the rapid expansion of travel and in particular colonization led to a heightened interest in the parasite. In India and parts of Africa for instance, British officers reported seeing cases of infestation among the military serving there. And so as you might expect this led to calls for doing something about this guinea worm problem. Although the association between the parasite and water had long been recognized especially in places where it had been prevalent for basically all of human history, there still wasn't a very clear understanding of how exactly they were connected and whether there were any other players in the game.

Erin Allmann Updyke

Okay.

Erin Welsh

In the 1870s a Russian parasitologist named Alexei Fedchenko, getting his start just as the field of parasitology was taking off, what an exciting time, we would never have been allowed to pursue this career.

Erin Allmann Updyke

Never.

Erin Welsh

So Fedchenko was encouraged by leading helminthologist Rudolf Leuckart to look at the possibility that infected copepods might be harboring the larvae of the worm.

Erin Allmann Updyke

In 18-what now, Erin?

Erin Welsh

1870s.

Erin Allmann Updyke

They were, 'Hm, pretty sure it's a copepod.' What?

Erin Welsh

Well so this guy Rudolf Leuckart, he had either discovered this or learned about this in another species of worm that was using copepods as an intermediate host.

Erin Allmann Updyke

That's amazing.

Erin Welsh

Yeah.

Erin Allmann Updyke

I know that we've talked about early discoveries like this before but it still blows my mind that people could figure out a life cycle as complex as this.

Erin Welsh

Oh just you wait.

Erin Allmann Updyke

Oh gosh, okay.

Erin Welsh

Just you wait. Okay so yeah, so Fedchenko looked and sure enough, within some species of cyclops copepods that he had found in contaminated drinking water, he found larval worms that he thought might be the intermediate stage of guinea worm. There you go.

Erin Allmann Updyke

Incredible.

Erin Welsh

And then he was like all right, you know what? Humans probably become infected when they drink water containing these infested copepods.

Erin Allmann Updyke

Because that's logical.

Erin Welsh

Yeah and he was like, 'I'm gonna try to show this experimentally, so I'm gonna give some infected copepods to cats and dogs.' But they never developed the infection.

Erin Allmann Updyke

They didn't.

Erin Welsh

And so his hypothesis just kind of sat there quietly in the parasitology journals for a couple of decades while others argued that it infected humans by boring into their skin directly, kind of à la hookworm.

Erin Allmann Updyke

À la hookworm.

Erin Welsh

Meanwhile in Britain's colonies in Africa, guinea worm continued to pose a threat to productivity and political stability.

Erin Allmann Updyke

Oh gosh.

Erin Welsh

And so the committee of the London School of Tropical Medicine asked fresh out of medical school with basically no research training, 24 year old parasitologist Robert Leiper whom you would may remember from our schistosomiasis episode.

Erin Allmann Updyke

I don't.

Erin Welsh

That's okay. (laughs) I just remember the name and that's it and now I'm wondering did I pronounce it differently in that episode? So anyway they asked Leiper to head to Accra in Ghana to learn more about the parasite so that it could be controlled. And he entered this field of conflicting hypotheses and big egos and made frankly incredible progress towards understanding the key components of the parasite that would allow for its dramatic decline in prevalence over the next 100 years.

Erin Allmann Updyke

Wow.

Erin Welsh

Most of that decline was concentrated in the last couple decades but anyway. First of all he demonstrated that no, the larval worms do not burrow into your flesh. He fed a monkey bananas that contained infested copepods and then he waited 6 months and carried out a postmortem that showed that yes indeed there were some *Dracunculus medinensis* in the monkey. Are you laughing at the banana?

Erin Allmann Updyke

Yeah, the banana. I don't know why that's so funny.

Erin Welsh

I don't know either. (laughs)

Erin Allmann Updyke

Like he can't just put it in his water, you gotta add it to the banana.

Erin Welsh

That's what made me include that detail. Cause I was like it's not just feeding them infested copepods, it's the banana.

Erin Allmann Updyke

Right, the banana.

Erin Welsh

Well and then next Leiper ruled out that it was any other intermediate host besides copepods. He then decided to do a series of experiments showing under what environmental conditions the larvae can live-

Erin Allmann Updyke

Awesome.

Erin Welsh

-the timeline of their maturation, and he mimicked conditions of the human stomach, he made an acidic solution to show how the copepods are killed, allowing the larvae to burst forth and then continue their passage through the human body.

Erin Allmann Updyke

He did this in what year now?

Erin Welsh

1905!

Erin Allmann Updyke

What on earth?

Erin Welsh

And so from all of this he concluded that quote, "The young larvae must be discharged directly into freshwater soon after the parent worm has succeeded in creating a break in the overlying skin and before the wound has become markedly septic. The embryos must find a cyclops within a few days. They must moreover succeed at entering its body cavity. 5 weeks later they will have developed to mature larvae. They must therefore be taken into a human stomach and having been set free from their host by the gastric juice, reach the connective tissues by penetrating the gut wall."

Erin Allmann Updyke

Wow. That's everything I described.

Erin Welsh

Everything, yeah. (laughs) And so basically within two years of his arrival, the 24 year old had essentially laid out in impressive detail the life cycle of this parasite. Also he didn't stop there.

Erin Allmann Updyke

They never do.

Erin Welsh	Never. Leiper took this information and made recommendations for its control. Basically clean the water to eliminate the worm. He also stressed the importance of knowing the seasonality of infection, the timing of dry seasons and wet seasons and where people get water as crucial in knowing where and when water supplies are most likely to be infested.
Erin Allmann Updyke	Wow. Oh my goodness.
Erin Welsh	He also recommended filling in surface water and shallow wells, getting rid of stepwells where people have to descend to get water, and instead using draw wells, artesian wells, or pipes from rapidly flowing streams.
Erin Allmann Updyke	Wow.
Erin Welsh	And finally, just the cherry on top, he suggested that certain fish species might be a great way to naturally control the copepods and hence the disease.
Erin Allmann Updyke	Oh my goodness. Oh my gracious. Wow.
Erin Welsh	And so all of this he did in a couple years and then he wrote a couple of papers and then didn't do anything with guinea worm ever again.
Erin Allmann Updyke	He's like, 'I did it all, I'm done guys. I solved it, just do it.'
Erin Welsh	Kind of. (laughs)
Erin Allmann Updyke	I mean he wasn't wrong.
Erin Welsh	Yeah and so after that he just went to hookworms and schisto and that was it.
Erin Allmann Updyke	Wow.
Erin Welsh	So I think that's one thing that I find so fascinating about guinea worm is that so much of the information that we use today to control guinea worm is literally ancient or at the very least old knowledge.
Erin Allmann Updyke	Right, over 100 years old.
Erin Welsh	Over 100 years old, sometimes over 3000 years old.
Erin Allmann Updyke	Wow, yeah.
Erin Welsh	In the early 1900s the development of certain arsenical treatments for other wormy parasites led to some researchers trying them out on guinea worm but none worked very well or they caused greater problems because then the worm would die in a joint or something and then as you mentioned all the horrible effects that can come from that.
Erin Allmann Updyke	Right, on its way down.

Erin Welsh

And then even if those side effects weren't an issue there was the aspect of getting access to any potential treatments and the financial aspect of that as well. The method described in the Ebers Papyrus from 1550 BCE of winding the worm around a stick to remove it, that's what we use today.

Erin Allmann Updyke

2020!

Erin Welsh

2020. I mean that's incredible to me.

Erin Allmann Updyke

Yeah, yeah.

Erin Welsh

The connection between water and the parasite was long known in the areas where the parasite has been historically most abundant, even while western researchers were fighting amongst themselves over whether it was from water or from the grass or from this or that. And the larger scale control efforts that we use still follow the same principles that Robert Leiper laid out in 1907 which brings me to the last part of the history.

Erin Allmann Updyke

Yes!

Erin Welsh

The eradication campaign. Although by the early 1900s the information needed to make serious progress towards controlling guinea worm was there, the disease remained neglected for almost 7 decades, receiving little to no priority in national or international health campaigns for many reasons. Certainly part of it was that the populations that were most affected were often poverty stricken in rural, hard to reach areas. But another aspect is that there were or are often many other diseases that had higher mortality rates or prevalence or both.

Erin Allmann Updyke

Right.

Erin Welsh

And so this was just lower on the priority chain.

Erin Allmann Updyke

Yeah.

Erin Welsh

There were some regional eradication efforts made during those 70 years and other places made larger infrastructural changes to the water supply that essentially eliminated guinea worm even if that was not one of the primary intended goals. But it was only in 1981 when the United Nations added guinea worm to the United Nations International Drinking Water Supply and Sanitation Decade. It was only in that year that the parasite was featured in an international elimination plan. And so the Carter Center was founded a year after this was added to this elimination plan in 1982 and one of its goals was the eradication of guinea worm, a cause that former president Jimmy Carter became very interested in after a trip to West Africa in the early 1980s in which he witnessed some of the devastating effects of the infection. With the Carter Center's involvement, in 1986 the WHO added support to the campaign to eradicate the infection.

But one of the biggest challenges in this plan was the lack of accurate surveillance data. A survey in 1986 revealed that the disease was endemic in 20 countries, most of which were in Africa, and there were an estimated 3.5 million cases. The economic strain caused by the infection as well as the relatively inexpensive methods of control led to both continued support of the initiative as well as rapid progress in the control of the parasite. Still setbacks occurred in the shape of logistical difficulties, political instability, financial or technological shortcomings. But despite these, within 4 years the number of estimated cases fell from 3.5 million in 1986 to 892,000 in 1990 and then in 2015, 22.

Erin Allmann Updyke: Wow. Oh, okay.

Erin Welsh: I know, there's more to that story which you're gonna pick up on.

Erin Allmann Updyke: Yeah.

Erin Welsh: 2015 it sounds pretty great, only 22 cases.

Erin Allmann Updyke: Yeah.

Erin Welsh: And each year seems to bring an article with the headline 'Guinea worm eradication: could it be this year?' But complete elimination has remained just out of grasp. And so Erin.

Erin Allmann Updyke: Yeah?

Erin Welsh: That's where I'll leave off and leave it to you.

Erin Allmann Updyke: Okay.

Erin Welsh: To tell us what's going on with guinea worm today.

Erin Allmann Updyke: Right after this break.

TPWKY: (transition theme)

Erin Allmann Updyke: So Erin, you asked for me to tell you what's going on with guinea worm today but I'm not gonna do that because as we mentioned in our intro we were fortunate enough to talk with Sarah Yerian, the Senior Associate Director for the Guinea Worm Eradication Program at the Carter Center who obviously knows a lot more than I do about what's going on today. So I am thrilled to introduce her and we'll let her tell us all what's been going on.

Erin Welsh: Awesome.

Sarah Yerian: My name is Sarah Yerian and I am the Senior Senior Associate Director for the Guinea Worm Eradication Program at the Carter Center. And I started this job about a year ago following 6 years working with the Carter Center and the Guinea Worm Eradication Program in South Sudan, a few years as a technical advisor in the field and then my last 3 years in South Sudan as the country representative for the program in South Sudan. And so now here at headquarters I work with the team here to provide support to the country programs in the remaining endemic countries which is Chad, South Sudan, Ethiopia, Mali, and now Angola.

Erin Welsh: Awesome. Thank you so very much for taking the time to chat with us, we really appreciate it. So could you start us off by telling us a little bit about the history of the Guinea Worm Eradication Program and sort of what kind of work was being done in the early days there in terms of systems that were put into place for surveillance or direct care and fieldwork, those sorts of things?

Sarah Yerian

Guinea worm, though it's not a deadly disease, it does cause debilitating pain when it's emerging from the body and then also during the healing process and particularly if there has been a secondary infection associated with the emergence of that worm. And so this disease is something that was devastating communities and there were even parts of West Africa where it was called 'the disease of the empty granary'. And so simultaneously we're having the success of the smallpox eradication campaign in the late 1970s, the global community was looking for what might be next.

And so now you have guinea worm disease which is devastating communities and it's also a disease that potentially meets the criteria for eradication. And also there was an assessment done by the World Bank where they determined that actually the cost of the eradication campaign would be less than the costs that are associated with the socioeconomic impact of not eradicating guinea worm. And I think that's a critically important part of the consideration. And there was also sufficient funding and sustained political will. And so with all of those factors and the devastating impact of guinea worm on communities, that's how it was taken on as the next disease to try to eradicate.

When we talk about setting up a surveillance system to address guinea worm, we're talking about two phases of guinea worm eradication. The first is breaking transmission and then the second is certifying a country as guinea worm-free. And so currently we have gone from over 21 endemic countries in Africa and Asia in the 1980s to 5 now. We have South Sudan, Mali, Ethiopia, Chad, and Angola that remain endemic for guinea worm. And they are still working to break transmission. And so endemic countries have to establish active, community-based surveillance and the foundation of this community-based surveillance structure is the village volunteer. So at every endemic village the volunteer actually walks house to house on a daily basis searching for possible cases of guinea worm and providing health education to the community residents and treating any potential cases of guinea worm that are detected. And these volunteers are also supported by a hierarchy of other health workers who support their work and implementation of a package of interventions to stop transmission.

But at this point we know now that we have a suite of interventions that when applied together can be successful in stopping transmission and that includes searching for cases and treating them. Another intervention is health education to the communities on transmission and prevention of guinea worm, we also distribute nylon filters so that the communities can filter their drinking water and we also over the years have developed a pipe or a straw filter. And finally treating water sources with a chemical that's safe for drinking water but that reduces the presence of cyclops in the water and therefore the population of infective guinea worm larva in the water.

Guinea worm is about behavior change and that requires a constant presence from program staff in affected villages and it requires building trust and that's something that takes time and it's not gonna be bought with any amount of money. And so I think the success of this campaign is really credited to the endemic communities themselves and the actions they've taken to stop guinea worm in their communities. And so after transmission is broken, the second phase of the eradication campaign takes place in a country and so after they've reported zero, they go 3 years without reporting another case of guinea worm, and then they can apply for certification as guinea worm-free from the ICCDE which is the International Commission for the Certification of Dracunculiasis Eradication.

Erin Welsh

Gotcha. Awesome. So one thing I wanted to ask was about how there are these certain large scale infrastructural changes that would make not only guinea worm eradication more possible but would also greatly reduce the prevalence of other diseases, particularly water-borne infectious diseases. So how do you strike that balance between investing in the underlying infrastructure such as a consistently clean water supply vs a more targeted approach like the use of those filters that you mentioned that prevent guinea worm transmission but not of other water-borne pathogens?

Sarah Yerian

So two things here. One, as you've said, the guinea worm program has to remain targeted on guinea worm disease in order to be able to demonstrate success. But at the same time the program is training and developing a group of volunteers and health workers who will be prepared to provide other health services once guinea worm is eliminated in that country. And in some countries we've seen that these health workers and volunteers have gone on to be involved in programs such as river blindness or trachoma control and in some places they've even been absorbed into the National Ministry of Health's health system once guinea worm is gone. So I think that's one good example of the effects of the campaign that are beyond just the targeted disease eradication.

And the other thing is guinea worm because it is a water-borne disease, the presence of guinea worm in endemic communities has been an opportunity to leverage access to safe water and so the guinea worm program in many countries has been able to work with ministries of water and UNICEF and others to prioritize certain villages or locations for provision of safe water because guinea worm is an indicator that safe water is not present in that location.

Erin Welsh

Gotcha. Okay yeah, that makes a lot of sense. So throughout the history of the program there has been an absolutely incredible amount of progress made towards eradication, so for millions of cases in the 1980s to just dozens in the last few years. So can you bring us up to speed a bit with the latest numbers and especially the biggest hurdles that remain?

Sarah Yerian

So as you've said since the 1980s we've seen a 99% reduction in cases which is phenomenal. So we've had 21 cases so far in 2020 which is a 56% reduction compared to the same period in 2019. And at this point in the campaign really our biggest challenge is transmission in animals and mostly in domestic dogs in Chad. Just to give you a sense of the numbers, in 2019 we had almost 2000 infected dogs that were detected globally and only 11 that were detected outside of Chad. We've talked about guinea worm being transmitted through drinking infected water but we also have some evidence that dogs in particular could be getting infected by eating aquatic animals or aquatic animal waste that contains infective larva. And so as we're tackling the problem with dogs we've had to think outside the box a little bit and try to tailor some of our interventions to better target dog infections.

And so the program is also working with the communities to kind of figure out what works best in each location but to provide supplemental food to the households to feed the dog with and then also access to veterinary care and good access for the dogs to exercise. And so far this is something that has been a very recent intervention but we are encouraged by the 26% reduction in dog infections in Chad that we've seen so far in 2020. And so while we may not have all of the answers or a perfect intervention or a silver bullet just yet, we are excited about some evidence that these new interventions to target dogs might be working.

Erin Welsh

Yeah, it's fascinating. I think there's a lot to uncover there which is really cool. And so the last question that I wanna ask is about you. So how did you get involved with the Guinea Worm Eradication Program? And I was wondering whether you could share with us any memorable experiences that you've had while working with the Carter Center?

Sarah Yerian

When I was doing my masters in Public Health at the Rollins School of Public Health at Emory University there was a professor, Stan Foster, who had been a big part of the smallpox eradication campaign. And one day I was in his office, we were talking about something else and he said, 'You could do it.' I said, 'Do what?' And he said, 'I think could be a technical advisor for guinea worm.' And so a few months later I found myself signing up for a 6 month contract with the Guinea Worm Eradication Program working in South Sudan that turned into 6 years working with the program there and then now in this role here, a total of 7 years later.

And I think for me initially going into this what interested me was this really seemed like an opportunity to apply field epidemiology, you're collecting data and making decisions in real time and it's really an honor and it's really a privilege to be part of a program and to work in places where the community has invited the program to work there with them. The governments themselves indeed have invited the support of the Carter Center and other partners in their national eradication campaigns. And so I think that level of discipline and diligence that's required for everyone in the program is really incredible and to just imagine how many tens of thousands of volunteers and health workers around the world that have all displayed that level of commitment to support their communities to get rid of guinea worm is I think truly remarkable and for me, as I said, has been a real privilege to be part of that.

TPWKY

(transition theme)

Erin Welsh

That was so great, thank you so much Sarah for taking the time to chat with me about guinea worm. It was great, I loved it.

Erin Allmann Updyke

Oh I was so great. How amazing that we get to interview people who have actual experience working on these things. That's incredible.

Erin Welsh

It blows my mind.

Erin Allmann Updyke

Thank you so much for taking the time.

Erin Welsh

Yeah. It's kinda nice that we get to end this episode on a happy note.

Erin Allmann Updyke

Yeah!

Erin Welsh

I feel like it's not often that we get to do that when we discuss diseases, particularly neglected tropical diseases.

Erin Allmann Updyke

Yeah. And do you know we could actually make this episode even a little happier if we wanted to. We of course did an episode on polio way back in...was it 2017?

Erin Welsh

I think it was.

Erin Allmann Updyke

Yeah, our first season. And there's been some new news on the polio eradication front that is absolutely thrilling. So we now are even closer to polio eradication because as of 2020 the World Health Organization African Region has been declared free of wild polio. They haven't had a single case of wild polio on the continent in the last 4 years.

Erin Welsh

That is remarkable.

Erin Allmann Updyke

I know!

Erin Welsh: I mean to hear that it is on the verge of eradication is absolutely incredible.

Erin Allmann Updyke: It's phenomenal. There's only two countries left in the entire world that are still left to be eradicated, Pakistan and Afghanistan, so incredible.

Erin Welsh: Wow.

Erin Allmann Updyke: We're so close.

Erin Welsh: We're so close. Ugh, that's very cool.

Erin Allmann Updyke: Yeah.

Erin Welsh: Awesome. So is that it? Should we dive right into sources?

Erin Allmann Updyke: I think we ought to, yes.

Erin Welsh: Okay, cool. So I read a few things. One was a couple chapters in a book called 'A History of Human Helminthology' by David Grove. And then a few papers that I found super helpful were 'Dqr, spinning and treatment of guinea worm' by Miller in 1989 and by Tayeh et al 2017, 'Guinea worm: from Robert Leiper to eradication'. And then I also wanted to shout out a couple of really interesting papers by Amy Moran-Thomas, one titled 'A salvage ethnography of the guinea worm' and another called 'The creation of emergency and afterlife of intervention'. And these I thought were very interesting discussions on sort of the merit of targeted approaches to disease eradication or elimination vs a more integrative, bigger scale infrastructure approaches. Very, very interesting papers.

Erin Allmann Updyke: I feel like those are really important discussions to have in the context of these kind of eradication campaigns. So definitely shout out those papers.

Erin Welsh: Absolutely.

Erin Allmann Updyke: Awesome. I have a number of papers for the biology as well. We'll post the full list of all of our sources for this episode and every episode on our website [thispodcastwillkillyou.com](http://thispodcastwillkillyou.com), just click on the EPISODES tab and you can find all of our sources there.

Erin Welsh: Thanks again to Sarah for taking the time to chat with us about guinea worm and also thank you to Emily for helping set that up.

Erin Allmann Updyke: Yeah, it was really incredible. And thank you to Bloodmobile for providing the music for this episode and all of our episodes.

Erin Welsh: And thank you to you listeners for still tuning in and listening to us talk about disease. We really appreciate it.

Erin Allmann Updyke: We hope this can be like a small little ray of sunshine in your September 2020.

Erin Welsh: Yeah, yeah.

Erin Allmann Updyke

Yeah.

Erin Welsh

Well okay, until next time, wash your hands.

Erin Allmann Updyke

You filthy animals!