

TPWKY	This is Exactly Right.
Erin Welsh	Hi, I'm Erin Welsh.
Erin Allmann Updyke	And I'm Erin Allmann Updyke.
Erin Welsh	And this is This Podcast Will Kill You crossover edition with The Biology of Superheroes podcast.
Erin Allmann Updyke	Woo woo! This is actually part two of a crossover in which we're gonna talk about zombies.
Erin Welsh	Zombies!
Erin Allmann Updyke	In the first episode which was released on Halloween, we joined Shane Campbell-Staton and Arien Darby of The Biology of Superheroes podcast to talk all things zombies.
Erin Welsh	You guys should definitely go check out that episode, you can find it at The Biology of Superheroes podcast on whatever platform you listen to your podcasts.
Erin Allmann Updyke	And this week we're so excited to be joined by Shane to take a deeper dive into the physiology, history, and evolutionary biology of zombies.
TPWKY	(This Podcast Will Kill You intro theme)
Erin Welsh	Do you wanna introduce yourself, Shane?
Shane Campbell-Staton	Yeah it's good to be here. I'm Shane Campbell-Staton and I am an evolutionary biologist.
Erin Allmann Updyke	Heck yes.
Erin Welsh	Yeah!
Erin Allmann Updyke	Dr. Campbell-Staton.
Shane Campbell-Staton	Please, please remember it.
Erin Allmann Updyke	(laughs) Also the host of your own amazing podcast, tell us about it.
Shane Campbell-Staton	Yeah we do our thing. So host of The Biology of Superheroes podcast. Yeah, so we use a lot of science fiction basically as a way to talk about biology, evolution, physiology, so on and so forth. So merging the nerd multiverse over here.
Erin Allmann Updyke	(laughs) I love it.
Erin Welsh	Yes and definitely everyone check it out, it's an amazing podcast.
Erin Allmann Updyke	Yeah, it's fantastic. It's really fun.
Shane Campbell-Staton	Oh stop.

Erin Allmann Updyke (laughs) We've been waiting to do this crossover since before we even started our podcast.

Erin Welsh Oh yeah.

Erin Allmann Updyke It's been like on the books.

Erin Welsh It has been a long time coming, hasn't it?

Erin Allmann Updyke Yeah.

Erin Welsh Okay so before we jump into that we've got some important business to take care of.

Erin Allmann Updyke Yeah we do.

Erin Welsh Our quarantini. What are we drinking this week?

Erin Allmann Updyke This week we're drinking Rum For Your Life! (laughs)

Erin Welsh (laughs) And it's called that because guess what it has in it?

Erin Allmann Updyke Rum!

Erin Welsh And more rum.

Erin Allmann Updyke Rum! It has so much rum.

Erin Welsh And more rum. So we will post the entire recipe on all of our social media as well as our placeborita for this episode.

Erin Allmann Updyke Absolutely. You can find us @TPWKY on Twitter and @thispodcastwillkillyou on Instagram and Facebook. Let's get-

Erin Welsh We'll move on.

Erin Allmann Updyke Okay.

TPWKY (transition theme)

Erin Allmann Updyke All right.

Erin Welsh All right. So today we are talking about zombies and basically sort of the biological basis for whether zombification can happen via tetrodotoxin and then Shane is going to hit us with some expertise on the evolutionary history of tetrodotoxin. And I don't know anything about it yet so I'm really excited cause I think it's super cool.

Erin Allmann Updyke Same.

Erin Welsh I know it's gonna be super cool, I should say.

Shane Campbell-Staton

We'll see how cool it is when I'm done.

Erin Welsh

(laughs)

Erin Allmann Updyke

The coolest, everyone's gonna wanna become a marine biologist after this episode.

Erin Welsh

Yeah. I'm gonna take you through the cultural history of the zombie, tracing the origins of the modern zombie back to its religious and spiritual roots. And we're gonna have a blast because as we talked about, this is one of our favorite topics, all of us.

Erin Allmann Updyke

Heck yeah. Yeah.

Erin Welsh

And first I wanna ask you something. Have either of you secretly ever wanted to be in a zombie apocalypse? To maybe see how you'd react or whether you'd be the first to die?

Shane Campbell-Staton

I feel like this is a conversation that I used to have back in college, like one of those 2am conversations. 'Do you think you would be able to survive the zombie apocalypse?' 'Yeah man, I'd totally get a machete and this and that and I'd go up into the mountains,' and so on. You know meanwhile at that time I had barely slept outside but was like super confident that I'd be able to survive the zombie apocalypse.

Erin Welsh

(laughs)

Erin Allmann Updyke

Yeah. Yeah.

Erin Welsh

I feel like it's human nature to sort of think about these end of days scenarios.

Erin Allmann Updyke

Yeah.

Erin Welsh

Yeah. I think it's safe to say that we've all watched or read our fair share of zombie movies, shows, books, comics, etc because we're-

Erin Allmann Updyke

Nerds.

Erin Welsh

Nerds. But I don't think zombies are necessarily nerdy, are they?

Erin Allmann Updyke

Shane, you're the expert.

Shane Campbell-Staton

Yeah I'm gonna put them up as nerdy, they're pretty nerdy.

Erin Allmann Updyke

(laughs)

Erin Welsh

Cool, well I like being a nerd anyway.

Shane Campbell-Staton

Yeah, ain't nothing wrong with that. You gotta own the nerd.

Erin Allmann Updyke

Yeah exactly.

Erin Welsh: So now that we are self-proclaimed zombie experts, I wanna ask you guys what you see as the unifying characteristics of zombies or zombies as they are presented today.

Erin Allmann Updyke: Great question.

Erin Welsh: Let's do a little list.

Erin Allmann Updyke: I feel like they have to be after humans. So they've gotta be like aggressive in some way.

Erin Welsh: Oh after, okay. Not like post-humans.

Erin Allmann Updyke: Sorry. No, no, no. Coming after you for some reason.

Erin Welsh: Okay, so driven by human flesh.

Erin Allmann Updyke: Yes. Right?

Shane Campbell-Staton: Yeah I think there's a typical sort of mangled appearance one way or the other, right. Either if you're talking about the actual walking dead or you're talking about the infected, there's typically a very run down, dirty clothes, bloody thing happening.

Erin Allmann Updyke: True. They look unwell.

Shane Campbell-Staton: Once you turn into a zombie, yeah, you don't worry about taking a shower and washing your clothes anymore. You're preoccupied by brains and general biting=related activities.

Erin Allmann Updyke: And I do think the whole transmitted by bites thing, it's become pretty classic.

Erin Welsh: Right.

Erin Allmann Updyke: I'm not opposed to it, I'll say that much. I'm not opposed to that idea.

Erin Welsh: I mean I can't think of a modern zombie movie that doesn't have where a bite from a zombie turns you into a zombie in some way, shape or form.

Erin Allmann Updyke: Yeah I can't think of one either. Yeah, agreed.

Erin Welsh: Yeah. So okay. So we have that they're mangled, dead, undead, they eat human flesh, that's the sole thing that they're driven by, and they're infectious or being a zombie is infectious.

Erin Allmann Updyke: Yeah. For sure.

Erin Welsh: So the zombie that we just described is this modern zombie which was born in 1968 when Night of the Living Dead was released, which is kind of funny actually considering that the word 'zombie' is never used in the movie.

Erin Allmann Updyke: Yeah but that's so typical and I feel like all zombie movies now do that because they did that and it really bothers me. Like in Walking Dead, why can't they just call them zombies?

Erin Welsh: What do they call them?

Erin Allmann Updyke: The walkers, the blah blah blahs.

Shane Campbell-Staton: Or 'biters' I think is a good one. Depends on the group, every sort of group that runs around has their own name for them.

Erin Allmann Updyke: Which is so unrealistic, bro! Everyone knows it's a freaking zombie.

Erin Welsh: Well so I think in later movies inbetween that time, they were called zombies in a lot of them.

Erin Allmann Updyke: It just annoys me.

Erin Welsh: Well it was actually... So George Romero only used the terms like ghouls or flesh-eaters when he made this movie and he didn't really encounter the term zombie until critics started using it when describing the film.

Erin Allmann Updyke: Oh.

Erin Welsh: So it was really only then when he was like, 'Oh these are zombies.' And he had taken clearly from zombie fictions but I think he put two and two together after the fact.

Erin Allmann Updyke: So he didn't know he was making THE zombie movie until after it was already made?

Erin Welsh: Well no, I don't think that's necessarily true. I just don't know if he would have called them zombies or a brand new creature.

Erin Allmann Updyke: Oh.

Shane Campbell-Staton: Oh okay.

Erin Welsh: Cause he did definitely take from zombie films.

Erin Allmann Updyke: Fascinating. Okay.

Erin Welsh: Okay. So if you haven't seen the movie, which Erin and I just watched it.

Erin Allmann Updyke: Yesterday for research.

Erin Welsh: (laughs) The plot revolves around a group of people hiding out in a house somewhere in Pennsylvania as reanimated corpses due to a radiation accident swarm around the house. This movie effectively began or created an entire new subgenre of horror movie. Romero and his co-writer John Russo drew from a bunch of sources as I mentioned for inspiration including a zombie called White Zombie, which I'll talk more about later, and I Am Legend, the book by Richard Matheson about a plague of vampires. But Night of the Living Dead was something brand new in many ways. This was the first movie to depict zombies as flesh-eating, as outnumbering people, as not controlled by an outside force, as being contagious, and a government struggling to maintain control. This was a far cry from the early depictions of zombies in Hollywood movies.

This movie and many zombie movies that followed used zombies as a metaphor for whatever was really threatening society or humanity, such as unchecked consumerism, the violence of the Vietnam War or the resistance against America, the threat of nuclear war, racial inequality, and so on. In modern zombie movies, zombies are used to expose the true nature of humanity. How are people going to react in a crisis? And it's not just using zombies as this apocalyptic backdrop. The zombies themselves are scary because they occupy this uncanny valley where the familiar appearance of your neighbors or friends or spouse or child suddenly becomes horrifying when they're trying to eat your brains all of a sudden.

Erin Allmann Updyke

Yeah. Then you have to shoot 'em in the head.

Erin Welsh

Yeah. I feel like it's a pretty common trope, right? There's that moment where there's a zombie horde and they're trying to get away and then you see the face in the horde that's your best friend or the person who you used to love. And you're like, 'Oh, but Susie. How could it be-' and then Susie chomps down on your jugular and then you're done.

Erin Allmann Updyke

Yeah.

Erin Welsh

Yeah. And all of these characteristics of modern zombie movies have the end result of making you scared of zombies, not of becoming a zombie. So you're more scared of the zombies attacking you rather than of actually becoming one, I feel.

Erin Allmann Updyke

Interesting.

Erin Welsh

So before Night of the Living Dead though, the perception of zombies in western culture was totally different. The modern zombie actually has its roots in Haiti and to understand how the Haitian zombie was warped and misappropriated into what we know as a zombie today, we have to go back a bit to the history of Haiti itself. Also I just wanna say that I'm totally out of my depth here and I'm probably gonna miss some stuff but I'm gonna do the best I can. So if there are any corrections, please send 'em our way. Yeah.

Erin Allmann Updyke

Send them our ways as always. Yeah.

Erin Welsh

Okay. At the beginning. Christopher Columbus-

Erin Allmann Updyke

(laughs)

Erin Welsh

Great guy.

Shane Campbell-Staton

Yay.

Erin Welsh

Landed on the island of Hispaniola, which Haiti is the western third of Hispaniola with the eastern 2/3 being the Dominican Republic, during his first transoceanic voyage in 1492. As you can imagine he instantly claimed it for Spain, set up camps there, and introduced diseases that led to nearly the entire indigenous population of Taíno and Arawak being wiped out.

Erin Allmann Updyke

Check our smallpox Episode 3 if you're interesting in more. (laughs)

Erin Welsh
Uh huh. And with many of the rest of the indigenous population being enslaved. Over the next couple of centuries, French, English, and Dutch pirates set up bases on the remote western and northern coast of Hispaniola which grew as a trading hub throughout the 1600s while Spanish control lessened. In the early 1700s, the French had taken control of the western part which would later become Haiti. They ramped up export and production and by the mid 1700s this small piece of land was responsible for producing 60% of the world's coffee.

Erin Allmann Updyke
Whoa!

Erin Welsh
Yeah. And more sugar than all the British Caribbean "possessions" quote unquote combined.

Erin Allmann Updyke
Whoa dude.

Shane Campbell-Staton
Wow.

Erin Welsh
Yeah.

Erin Allmann Updyke
I didn't know any of that.

Erin Welsh
Can you guess how it got to be so productive?

Erin Allmann Updyke
Slave labor?

Erin Welsh
Mm-hmm. Unbelievable amounts of slave labor.

Erin Allmann Updyke
Yeah.

Erin Welsh
Slaves on these plantations were treated so terribly and forced to live under such horrific conditions that at least 17,000 slaves died each year.

Erin Allmann Updyke
Whoa.

Shane Campbell-Staton
Jesus.

Erin Welsh
And the death rate outpassed the birth rate 8%-1%.

Erin Allmann Updyke
Oh my god.

Shane Campbell-Staton
Wow.

Erin Welsh
Yeah. Every year the number of people enslaved and taken from Africa to work in the French colony increased with around 40,000 slaves brought over every year in the years leading up to the Haitian Revolution. On the eve of the revolution, 32,000 white colonists ruled over nearly 500,000 slaves, the majority of which were born in Africa, like 3/4.

Erin Allmann Updyke
Whoa dude. So it killed off everyone who lived there and then they just kept shipping over more human beings that they just murdered.

Erin Welsh
Mm-hmm. Well, 1791 comes around and this marks the start of a 12 year revolution that would lead to the formation of an independent Haiti, which was huge.

Erin Allmann Updyke

Yeah.

Erin Welsh

This was the second oldest independent nation in the western hemisphere.

Erin Allmann Updyke

Whoa.

Erin Welsh

Yeah.

Erin Allmann Updyke

Tell me the year again.

Erin Welsh

1791 marks the beginning of that revolution.

Erin Allmann Updyke

Awesome, thank you.

Erin Welsh

So I talked a little bit actually about the Haitian Revolution in our episode on yellow fever.

Erin Allmann Updyke

Ooh.

Erin Welsh

And the possible but debated role that yellow fever played in destroying French troops when trying to quash the rebellion. So the takeaway from all this is that the free country of Haiti was largely composed of people who were born in Africa and had fought very hard for their freedom. In the decades leading up to the revolution, a religion had taken shape to unify everyone which drew heavily from some religions in West Africa, including the Fon people living in the area we called Benin, the Yoruba people in Nigeria, and the Congo peoples in Bas-Zaïre. And also this religion incorporated elements of catholicism and indigenous Taíno beliefs and practices.

Erin Allmann Updyke

Whoa.

Erin Welsh

Yeah. So it was really kind of this very interesting mix. And after the revolution the U.S. and Europe effectively cut contact with Haiti. They were like, 'No, you're on your own.' And they prevented trade from happening and they also didn't allow any Catholic priests to go to the country, which the French has set up as a Catholic colony. So as a result, Haitian culture is really strongly influenced by traditions and practices directly from different African cultures without the sustained colonial presence quashing these influences the way some other Caribbean nations were.

Erin Allmann Updyke

Wow.

Erin Welsh

Yeah. So this religion or more accurately spiritual experience continued to develop and is know as Vodou to those outside of it. So if you are someone who practices Vodou you don't call it Vodou, it's just your spiritual experience, it's serving the spirits. I'm not gonna go into any real details of Vodou cause there are many great resources for that, me not being one of them. But I will say that Vodou is the spiritual system focused on healing and spirituality. Zombies or zombification are not a part of Vodou as it is practiced, rather zombie-making is considered a folk religious practice that derives from Vodou but isn't a part of it.

Erin Allmann Updyke

Okay.

Erin Welsh

So just wanted to make that clear. So what is a zombie then in Haitian culture? Great question.

Erin Allmann Updyke

(laughs) Love it. Asked and answered.

Erin Welsh

Asked and complimented. I'm great at self-compliments. Well the word 'zombie' probably came from the West African Kikongo words 'nzambi' which is god or spirit of a dead person and 'zumbi' which means fetish. A zombie is created by a bòkò which is basically a priest who practices sorcery. There are two types of zombies. One is a zombie astral which is the soul of a deceased person that the bòkò can use to enhance his powers, and the other is the one that we are more familiar, the zombie of flesh. So this corporeal zombie is one who has either been raised from the dead or is made to appear dead and then awakened or reanimated by a bòkò.

Erin Allmann Updyke

Ah.

Erin Welsh

So this zombie of flesh has no will and is under complete control by the bòkò who uses the zombie to do his bidding which often involves laboring in some way. And so the threat of Haitian zombification is different than this modern zombification as in the movies. The loss of autonomy, being forced to work against your will, loss of contact with family and loved ones, these are the consequences of becoming a Haitian zombie which makes sense for a country with such a horrific history of slavery.

Erin Allmann Updyke

Yeah.

Erin Welsh

In contrast with the modern zombie, becoming a Haitian zombie is scarier than the zombie itself. So you're more scared of becoming a zombie than you are of the zombie.

Erin Allmann Updyke

Right. That does make sense. I now understand why you made that distinction earlier. Cause I was like I don't wanna become a zombie cause then you die. But now it makes more sense.

Erin Welsh

Okay, good. So how did the modern zombie evolve from this? Well in characteristic manifest destiny form, the U.S. invaded and occupied Haiti from 1915 to 1934.

Erin Allmann Updyke

Classic.

Erin Welsh

Uh huh. During the occupation, a bunch of ethnographers and writers including Zora Neale Hurston who wrote one of the first books on Vodou and Haitian culture, came to Haiti and exported stories of zombies. Many were very sensationalized which kind of gave rise to this fear and otherness of Vodou in U.S. culture and western culture in general. One of these stories was by a man named William Seabrook who wrote a sensationalist book called 'The Magic Island'. In one chapter, Seabrook describes seeing a zombie master controlling a group of zombies to labor for free. This was turned into a movie called White Zombie which has all kinds of racist and sexist... I guess not really undertones, like-

Erin Allmann Updyke

Overtones?

Erin Welsh

Overtones, yeah, sorry. So yeah, in White Zombie the zombies are catatonic and completely under control of the bòkò and this was the prevailing image of zombies in western culture until Romero changed the game with Night of the Living Dead.

Erin Allmann Updyke

Interesting.

Erin Welsh

We're still missing though a piece of the puzzle, which is the how of a zombie. So what is the medical basis for zombification?

Erin Allmann Updyke

Yeah bro!

Erin Welsh

And I think it's also just in passing worth thinking about why researchers - and I'm including us in this - feel the need to demystify some cultural or spiritual practices to reduce them to compounds or chemicals or 'Oh well this is how it can happen in reality.' You know? And that's something I wanted to just say to think about cause after reading Wade Davis' books I was like why? Why, why?

Erin Allmann Updyke

Why. Yeah no, it's a good question.

Erin Welsh

Okay so that aside, in general, back to zombies, there are two basic ideas as to how zombies are created.

Erin Allmann Updyke

Okay. Give 'em to me.

Erin Welsh

Okay. One basically says, this is Haitian zombies, one basically says that zombies are created through spiritual belief and that often so-called zombies are cases of mental illness and deprivation. The other focuses more on the medical basis of zombification. Belonging to the second category is Wade Davis. As a grad student, Wade Davis went down to Haiti in the 1980s seeking to uncover the truth about zombification, in particular whether it exists at all and whether there was a plant or animal-based compound that can actually cause a zombie-like state in people. In his journeys he came across the story of a man whose name I will definitely mess up the pronunciation of, Clairvius Narcisse.

Erin Allmann Updyke

You tried.

Erin Welsh

Who had emerged after years, 16 years actually, of allegedly being kept in a zombie-like state and forced to work. And he had been confirmed to have died and been buried. So this was like 1962 I think is when he was buried.

Erin Allmann Updyke

Okay.

Erin Welsh

And then only to emerge 16 years later.

Erin Allmann Updyke

Wait so he died and was buried and 16 years later he came up?

Erin Welsh

No, 16 years later he sort of re-emerged into society.

Erin Allmann Updyke

Got it, okay. He wasn't buried for 16 years.

Erin Welsh

No, no, no.

Erin Allmann Updyke

Okay. Cause I would call BS on that.

Erin Welsh

Well anyway. So Davis sought to find out how this could've happened and he was able to gain access to various quote "zombie powders" and to observe their preparation. The contents of these powders varied region by region but he found that a few ingredients were always present, among them human remains, cane toad, the Hyla tree frog, and various species of puffer fish.

Erin Allmann Updyke

Puffer fish, you say?

Erin Welsh

In examining each of these, he found one likely candidate for making someone appear dead, the puffer fish which contains a compound known as tetrodotoxin. Doo-doo-doo! Davis alleged that this toxin, when given to the intended zombie, could imitate death so that the person could be buried and then dug up and held under control by the use of other compounds including the Datura plant. Erin, please tell us how tetrodotoxin works and whether it is the true zombie powder.

Erin Allmann Updyke

I'd love to.

TPWKY

(transition theme)

Erin Welsh

I'm excited for this part cause I avoided it and I was like-

Erin Allmann Updyke

Oh great!

Erin Welsh

Yeah.

Erin Allmann Updyke

Then let me tell you about it. Tetrodotoxin. Okay the thing is as I started researching this I was like, we already did this, we've already done this episode. It's called-

Erin Welsh

Crossover with Matt Candeias, In Defense of Plants.

Erin Allmann Updyke

Yes! So you already knew the answer. Yes, if you haven't yet listened to our crossover episode with Matt Candeias of In Defense of Plants where we discuss monkshood aka wolfsbane, then go listen to that.

Erin Welsh

You'll probably like it.

Erin Allmann Updyke

Because we're talking about something that has a very similar mechanism of action.

Erin Welsh

Interesting.

Erin Allmann Updyke

Yes. And by very similar I mean the same.

Shane Campbell-Staton

(laughs) I did listen to that episode and it was absolutely amazing.

Erin Allmann Updyke

Oh! Thank you!

Erin Welsh

Oh thanks!

Erin Allmann Updyke

Oh, I'm blushing.

Shane Campbell-Staton

(laughs)

Erin Welsh

Okay, I cannot wait for the evolutionary history and I'm excited for the medical part too.

Erin Allmann Updyke Okay I'm gonna speed through this cause I can't wait for the evolutionary history, that's what I wanna hear. Listen, okay, so. Let me give you the briefest of rundowns. Tetrodotoxin acts on something called your sodium channels.

Erin Welsh What?

Erin Allmann Updyke What? (laughs) That was cool of us, we didn't plan that.

Shane Campbell-Staton (laughs) It's less cool now that you've said it, though.

Erin Allmann Updyke (laughs) Again, if you want a primer on sodium channels, I really feel like I did a great job explaining them cause I got real stoked on them in the last episode.

Erin Welsh You explained it really well.

Erin Allmann Updyke Thank you. Basically for those of you who are like, 'Stop talking about it, I'm not gonna go listen to that episode,' or 'I listened to it and I don't remember a thing cause you did a crappy job of explaining it.' Sodium channels are these channels that are on your nerve cells and your muscle cells and you need to have them open and close at certain times to have nervous system impulses actually transmit to your muscle cells to cause things like muscle contraction. So if you wanna lift your arm or move your finger or talk with your mouth, you need these sodium channels to be working. That's the briefest of rundowns I can give. So tetrodotoxin is a compound which binds directly to these sodium channels and blocks them.

Erin Welsh That sounds pretty bad.

Erin Allmann Updyke It's not great, let me tell ya. (laughs) It's not great. It blocks them and what that means is that sodium can no longer get in. If sodium can't get in, your nerve impulses are not traveling, your muscles are not contracting, you're paralyzed. Yeah, that's exactly what it is. And the thing that makes this different than aconite which is the compound in wolfsbane that we talked about in the crossover with Matt, is that it's way, way more gnarly, way more potent.

Erin Welsh What does that mean?

Erin Allmann Updyke Let me tell you. I wrote some numbers down.

Erin Welsh Oh good.

Erin Allmann Updyke Cause I have fun with this. If you could think of a compound that's really, really poisonous, that could kill you really easily - don't guess, cause you might guess wrong. I'm gonna tell you, it's cyanide.

Shane Campbell-Staton (laughs)

Erin Welsh (laughs)

Erin Allmann Updyke Would you have guessed that?

Erin Welsh Absolutely!

Erin Allmann Updyke Cool, so cyanide-

Erin Welsh I know all the answers all the time.

Shane Campbell-Staton It's like you read my mind. Get out of my head.

Erin Allmann Updyke So cyanide is a compound that everyone knows, like if you hear the word cyanide, even if you have no idea how it works or what it does, you know like don't drink that, it's gonna kill you really quickly.

Erin Welsh Apple seeds.

Erin Allmann Updyke Exactly. So if I wanted to kill myself - no. If you wanted to kill me with cyanide, you would need at least 546 milligrams of cyanide.

Erin Welsh What does that look like?

Erin Allmann Updyke Well, great question. A teaspoon of salt is 5-ish grams. So that's like 5000 milligrams, so it's a tiny amount.

Erin Welsh Okay so it's like a little dash.

Erin Allmann Updyke Like a tenth, yes. It's a dash of cyanide, that's all you would need to kill me.

Erin Welsh Not even a sprinkle, less than a sprinkle.

Erin Allmann Updyke No, less than a sprinkle. Okay?

Erin Welsh Okay.

Erin Allmann Updyke If you wanted to kill me with tetrodotoxin? 22 milligrams.

Erin Welsh Oh my god. How would you even measure that out?

Erin Allmann Updyke I really tried hard to think of a way to quantify this for people.

Erin Welsh To kill you.

Erin Allmann Updyke To kill me with tetrodotoxin. 22 grams.

Erin Welsh Wait, wait, wait. Grams or milligrams?

Erin Allmann Updyke Sorry, milligrams. Whoa, bro. Great.

Erin Welsh Okay. I was like, that's a lot of teaspoons.

Erin Allmann Updyke

(laughs) No it's very few teaspoons. Yeah, right. So and the reason is because unlike aconite or other, there's actually a ridiculous amount of toxins. And Shane, I don't know if you're gonna touch on this at all, I have a feeling you are, how many different organisms produce compounds which bind to sodium channels. It's a lot.

Shane Campbell-Staton

Yeah, it is a lot. And it's a very diverse set of creatures.

Erin Allmann Updyke

Yeah.

Erin Welsh

Which is fascinating.

Erin Allmann Updyke

So interesting. Because the thing is we all have sodium channels. Like I said in the monkshood episode, insects have sodium channels, right?

Erin Welsh

Right.

Erin Allmann Updyke

So it's this very universal thing that if you can attack that sodium channel, you can attack absolutely anything. But tetrodotoxin is so good at binding to these sodium channels that we actually classify sodium channels, there's a lot of different types like sort of subsets of sodium channels that work better, like these ones are on your muscles and these ones are on your nerves. But there's kind of two broad categories. One, tetrodotoxin sensitive, one tetrodotoxin resistant. That's how we classify sodium channels.

Erin Welsh

Wow.

Shane Campbell-Staton

Wow.

Erin Allmann Updyke

Because that's how strongly tetrodotoxin binds. So we basically, like all of these different types of sodium channels we divide them into can tetrodotoxin bind or can it not? Right, isn't that cool?

Erin Welsh

That's amazing.

Erin Allmann Updyke

Yeah, it's super cool. So I know you really wanna know what happens to you if you take a bite of a puffer fish just like out of the ocean.

Erin Welsh

Just the liver, just the liver.

Erin Allmann Updyke

Gimme the liver. Here we go. If you ingest this, generally within a half an hour, often less, the first symptom that you'll have is paresthesia which is a fancy, silly medical word for your lips start tingling and they get a little numb and maybe they feel burny and like something's just not right in your lips. And then that might start to spread and then you might start salivating a lot and then you might start sweating.

Erin Welsh

Uh oh.

Erin Allmann Updyke

And then you'll get a headache cause you're like, what's going on with me? And then you'll feel really weak.

Erin Welsh

Oh my god it's like a subway experience.

Erin Allmann Updyke: Subway sandwiches?

Erin Welsh: Yes.

Erin Allmann Updyke: Not endorsed, guys. (laughs)

Shane Campbell-Staton: (laughs)

Erin Welsh: That's cause I've gotten food poisoning a number of times from Subway sandwiches and so far, that's what it sounds like.

Erin Allmann Updyke: Okay, well. And then you'll start to get a tremor and then paralysis.

Erin Welsh: That's no good.

Erin Allmann Updyke: No good. And the thing that gets really dangerous and why this ends up often causing death is if you have paralysis of the muscles that you use for breathing, so your diaphragm and your intercostal muscles of your ribs, if those muscles become paralyzed, you cannot breathe. See our polio episode for more on that.

Erin Welsh: Question. So it starts in your lips, that's just the first symptom or sign that you have?

Erin Allmann Updyke: Yeah, it's often the first symptom and that's if we're talking about someone who's eaten fugu or a puffer fish and that is often the first symptom and it's because that's sort of the first place where you're gonna encounter tetrodotoxin.

Erin Welsh: Improperly prepared fugu.

Erin Allmann Updyke: Yes, improperly prepared fugu, right.

Erin Welsh: Okay.

Erin Allmann Updyke: So like you caught a puffer fish and you took a bite out of it like an apple, then the first place that you'll start to notice symptoms is in your mouth but then quickly you'll also get gastrointestinal symptoms, nausea, vomiting, diarrhea. But again what ends up killing people is respiratory distress.

Erin Welsh: Right.

Erin Allmann Updyke: So you're not able to breathe because all of the muscles of your respiratory tract have failed and they're paralyzed and then you die.

Erin Welsh: Oh my god that sounds like a really horrible way to go.

Erin Allmann Updyke: It's not great, I wouldn't recommend it. And it happens insanely quickly and part of that's because it's this toxin right, it's there, it's preformed, you just eat it or whatever, but you don't have to just eat it, right. What's the preparation that's most commonly associated with zombies?

Erin Welsh: Powder!

Erin Allmann Updyke

Powder.

Erin Welsh

I was about to ask you that. Okay.

Erin Allmann Updyke

Beat you to it. So most people come into contact with tetrodotoxin by eating it, right, that's like the most common. But because we're not talking about a bacteria or a virus like we normally are, we're talking about a compound that's actually produced by bacteria, it's a toxin, because it's already something that's formed, you can take a puffer fish, take its liver, dry it out, grind it up into powder, blow it into someone's face, and absolutely expose them to the toxin in that way. So it's not necessary that it's ingested.

Shane Campbell-Staton

So is it just contact with like mucus membranes like your eyes and nose and mouth?

Erin Allmann Updyke

Exactly, yeah. Yes.

Shane Campbell-Staton

Okay.

Erin Allmann Updyke

And I'm so glad you brought that up, Shane. Because this is a toxin that is way more deadly for example if it's injected. So most of the studies on this are done in mice. So they'll inject mice with the tetrodotoxin, it's far more dangerous if you inject a mouse vs if you let a mouse just nibble on a puffer fish, okay. Same thing I would assume, I couldn't find evidence of this but I think that's cause they don't often just like blow tetrodotoxin into mouse faces, but one could assume that most of the ways people quote unquote "detoxify" things, which the way you do that is with your liver. So if you eat something then your gastrointestinal tract absorbs it and it has to go through your liver which takes care of a lot of the problem, okay. If you inject it straight into your bloodstream or you breathe it straight into your nose which basically goes straight into your blood through your mucus membranes, you don't have that liver detoxification happening so it's actually a lot more potent, so it's a lot more dangerous.

Erin Welsh

Interesting. To inhale is a lot more...

Erin Allmann Updyke

Yeah.

Erin Welsh

Okay.

Erin Allmann Updyke

Well okay, I couldn't find specific evidence of that because again I couldn't find studies where they blew tetrodotoxin on mice but based on what I know about how things work, for example if you take drugs sublingually or by an inhaler-

Erin Welsh

What's sublingually?

Erin Allmann Updyke

Sublingually is under the tongue rather than swallowing it down. It more rapidly gets into your bloodstream than if you eat something and it has to go through your GI tract. Yeah.

Shane Campbell-Staton

Can I just say like blowing tetrodotoxin into the face of a mouse is like the most depressing lab job I have ever heard of in my entire life.

Erin Welsh

Also can you imagine if you sneeze and inhale?

Shane Campbell-Staton

(laughs) Oh my goodness. If there's a hell, that's pretty much the quickest way to get there is accept a job blowing tetrodotoxin in the face of lab mice.

Erin Allmann Updyke

Yeah. Yeah. So really the question that we have to answer then is what does that have to do with zombies, right? Nothing that is aid was like, 'And then you go bite people,' or even like, 'You become controlled by these powers.' Right. You get paralyzed and then you die because you can't breathe. That's what happens.

Erin Welsh

Right.

Erin Allmann Updyke

So why, how could this have become a thing that people associate with zombie-ism? And I'm really glad that you mentioned how zombies in this non-George Romero idea, it's not like wanting your flesh and blood, it's being under someone else's power. It's also being dead and coming back to life. Now that tetrodotoxin can do, kind of. So I got thrilled when I learned about this. So one of the weird things about tetrodotoxin from what I've read is that when all of this is happening to you, you remain conscious. Doesn't that sound awful?

Erin Welsh

Oh god. Which explains a lot but keep going.

Erin Allmann Updyke

Yes. So you are aware of what's happening to you but it can have such a drastic effect because again, these sodium channels are everywhere, it can have such a drastic effect on your respiratory rate and your heart rate that you seem like you're dead. So you can appear for all intents and purposes essentially dead if you've been dosed with the right amount of tetrodotoxin where it's not completely paralyzing you, right, like your brainstem is still working, there's enough function in your diaphragm that your unconscious breathing is still breathing and your heart is beating just enough to keep you alive but maybe not enough to show a pulse, which can happen.

Erin Welsh

Wow.

Erin Allmann Updyke

Yeah. And so people can then pronounce you dead and your family can think your dead because you, you know, you started vomiting and diarrhea-ing and then you kind of went limp and paralytic and now you're not moving and it doesn't seem like you're breathing, you must be dead.

Erin Welsh

How long?

Erin Allmann Updyke

Great question. This can last... So symptoms tend to set in very quickly, like within 10-30 minutes, it can take hours also. So if you haven't ingested a lot and whatever, it can take a longer time. If you ingest it vs inject it, etc. But when people do recover over a period of many hours, maybe 24 hours or more, they recover completely. If you live. If you survive you recover completely, there's no neurological deficit. So once this tetrodotoxin sort of just makes its way out of your system, there's no residual effects of it.

Erin Welsh

So it's like the O-Town song, 'All or Nothing At All'.

Erin Allmann Updyke

(laughs)

Shane Campbell-Staton

(laughs)

Erin Allmann Updyke

Oh my god. Yeah sure, yeah. Just like that. (singing)

Shane Campbell-Staton

It's interesting that... Cause I would think that there would be at least some effects of hypoxia, having your tissues or brain being deprived of oxygen if you're not breathing very deeply or very often. And if your heart's not pumping very often, I imagine there'd be at least some effects from just like hypoxia, not getting enough oxygen.

Erin Allmann Updyke

Yeah but it seems like you either die or you recover completely.

Erin Welsh

That's bizarre!

Erin Allmann Updyke

It's super bizarre. I will say that if your respiratory muscles are affected, it's not a good sign. You're probably pretty much gonna die. Almost everyone who, if the paralysis spreads all the way to your diaphragm, you're probably going to die. So here's the thing, it's a gray area. I wouldn't say i buy it 100% that you could pronounce somebody dead because they dosed them with tetrodotoxin. But it's been used a ton in popular culture as, 'I'm gonna fake someone's death.' You know, like that happens all the time. They do it with tetrodotoxin often in movies.

Shane Campbell-Staton

I do feel like that's a very common trope. And I could also see, you know, back in the late 1800s, early 1900s or even earlier than that, I could certainly imagine a doctor being like-

Erin Allmann Updyke

He seems dead!

Shane Campbell-Staton

Oh well he threw up and pooped himself and he's not moving and I don't wanna touch him cause he threw up and pooped himself.' Right? So just call him dead and leave it at that.

Erin Allmann Updyke

Right. We didn't have EKGs, we didn't have brain scanners. You can very easily survive if you're breathing, like there's a lot of different breath types that are really not good but will get your body enough oxygen and release enough carbon dioxide but might seem like you're not breathing cause you're breathing so infrequently. But if your heart is still pounding, however weak it might be, then the blood is still flowing, then things are still getting oxygen, then I agree. If you are in the 1700s and you touch them and you're like, 'Oh they're kind of cold, they must be dead.' You know?

Erin Welsh

And the stethoscope isn't invented.

Erin Allmann Updyke

Oh I don't know, don't ask me that.

Shane Campbell-Staton

But I guess also the tradeoff is that if you're completely still and comatose, you don't need as much oxygen as you would if you were up and moving around, so you have this lower metabolic rate as well, so you're using less oxygen so you don't need as much.

Erin Allmann Updyke

Exactly, exactly. Boom. So, zombies.

Shane Campbell-Staton

Biology.

Erin Welsh

Zombies, boom. But is it boom or is it...?

Erin Allmann Updyke

Yeah it is, that's the thing. Cause it's an almost maybe I could kind of buy it explanation for how someone could be appearing dead and then come back to life. Beyond that, nothing. There's no like, 'And then you will succumb to my will' or on the other end, 'Then you will eat flesh of humans.' You know, there's none of that.

Erin Welsh

But the other thing, is it buyable? Can you reliably make a zombie powder?

Erin Allmann Updyke

No, I don't even fully buy that you could make a powder period that you could be sure would just kind of paralyze someone to the point that you could convince someone else that they're dead but then make sure that they recover afterwards. Nah dude, I don't buy it in the slightest.

Erin Welsh

Yeah.

Erin Allmann Updyke

You could, if you worked really hard, probably convince people that you faked your death by using this maybe. I don't know.

Shane Campbell-Staton

So I was gonna ask, so when a person does recover, how does the tetrodotoxin unbind from the sodium channel?

Erin Allmann Updyke

That's a good question. I don't know. I mean I guess it just eventually something will come by and be able to degrade it. But I don't have a full answer to that cause from what I can understand, it's not like a reversible binding. Like it binds and then it's bound. So it's either just like your body has to make some new sodium channels maybe and maybe your body can make enough to compensate or eventually, like nothing in your body is gonna last forever right, so eventually that sodium channel will be recycled or some macrophage will come by and snag up that tetrodotoxin or whatever. I don't actually know the mechanism of it, I'm just making things up right now.

Shane Campbell-Staton

Generating hypotheses.

Erin Allmann Updyke

There we go, I like that. (laughs)

Shane Campbell-Staton

(laughs)

Erin Allmann Updyke

But it brings up a good point in that we don't have any treatment for it. So the only thing you can really do is if you know that someone ate a puffer fish and they shouldn't have, you can give them activated charcoal or do a gastric lavage, make them barf it all up and that can help somewhat.

Shane Campbell-Staton

That is a very fancy word for barf-inducing. Gastric lavage.

Erin Allmann Updyke

But there aren't any treatments so, wah-wah. People have tried different things, I don't wanna take too much time so I don't wanna get into the various specific things that people have tried, they don't work all that well. But here's my question. Clearly this mechanism of action of involving sodium channels, it's not something new, right. Puffer fish didn't invent this by any means, we've already talked about it with wolfsbane, we'll probably talk about it in the future with something else that binds to the same channels. But the thing about tetrodotoxin that makes it so forking terrifying is that it's so potent, it's so potent that we named the channels after it. And the tiniest amount, 22 micrograms can kill me, a full grown human, right. 22 milligrams, sorry. Get all those units mixed up. So my question and probably everyone's question at this point and Shane, why we brought you here, is why on earth would something as adorable as a puffer fish need to make such a potent toxin? Do they just wanna kill us? Do puffer fish hate us? Why? Tell me why, please.

Shane Campbell-Staton

That is a phenomenal question.

TPWKY

(transition theme)

Shane Campbell-Staton

So puffer fish, they did not, they weren't the first to invent tetrodotoxin but tetrodotoxin is actually named after them. Well, kind of. Tetrodotoxin is actually named after an order of bony fish called Tetraodontiformes which includes the puffer fish but also porcupine fish and the big floppy ocean sunfish, you know they're like huge and kinda flat and really goofy-looking, and also triggerfish. So altogether it's about almost 350 species in the order but not all of these species have tetrodotoxin. So it was named in 1910 actually as the principal toxin in puffer fish and obviously the principal component of fugu as you were saying before. Since then it's been subsequently described in a really wide array of organisms across the tree of life, both marine and terrestrial organisms.

So obviously several genera, which is the plural of genus, several genera of puffer fish have it, specifically in liver and gonads. The marine goby which is another bony fish has tetrodotoxin in its skin and muscles, and then there's several invertebrates, marine invertebrates that also have it. So there are several species of marine flatworms, there is trumpet shellfish which is a different invertebrate that has it in the digestive gland, horseshoe crabs apparently have them in their eggs, some starfish species. I should say one of the I think most interesting is actually the blue-ringed octopus that actually has it in its salivary glands and it uses it, it's co-opted as a venom in that species. So that's really interesting.

Erin Welsh

What?

Erin Allmann Updyke

The coolest. Love blue-ringed octopus. They're like, 'Take this!' They're so small and they're like, 'You wanna fight with me?' And then they bite you and then you die!

Erin Welsh

Oh my god, I love them!

Erin Allmann Updyke

(laughs)

Shane Campbell-Staton

(laughs) That's the first time I've ever heard, 'It bites you and it dies!' 'Oh my god, I love them.' You don't hear that very often except on this podcast.

Erin Welsh

I have a quick question, Shane.

Shane Campbell-Staton

Okay.

Erin Welsh

So you mentioned that the organ of where this tetrodotoxin is stored for a lot of these animals, why the liver, the gonads, the intestinal whatever system, why there?

Shane Campbell-Staton

So that is a great question and quite frankly, I don't think we know. So in doing research for this I realized that there's a ton that we don't know about tetrodotoxin in terms of how it contributes to biodiversity and how the vast array of organisms that use it, how they actually go about using it.

Erin Allmann Updyke

Yeah, yeah. That's so cool.

Shane Campbell-Staton

Yeah it's weird. It is very weird because essentially you're talking about chemical warfare, essentially. I mean you're taking this super, super toxic substance and integrating it into your body in some form or fashion and then using that as a defense.

Erin Allmann Updyke

Yeah.

Shane Campbell-Staton

So not only does it occur in marine organisms, but there are also terrestrial species, you know, species that live on land that use it. And this is the amphibians. So there are tree frog species in the genus *Atelopus* that use tetrodotoxin and then it's been most commonly studied in newts. So newts, what are called roughskin newts, they're in the genus *Taricha*, so they have really large volumes of tetrodotoxin in their skin. And actually also 5 different genera of salamander that have tetrodotoxin.

Erin Allmann Updyke

What?

Erin Welsh

Why?

Erin Allmann Updyke

Yeah, just tell us why Shane, we need to know. What's the deal here, bro?

Shane Campbell-Staton

(laughs) Okay. So if I can before I get to the why, the question is how?

Erin Allmann Updyke

Yeah. Okay, good question. Good first step.

Shane Campbell-Staton

Is that okay? Can we get to the how before we get to the why?

Erin Allmann Updyke

For sure, we accept.

Shane Campbell-Staton

Okay. So just to give you sort of the scale of this, we're talking about hundreds of millions of years of diversity of life, right. So if we're talking about across the tree of life between worms and other invertebrates and terrestrial organisms, terrestrial vertebrates and fish, we're talking about hundreds of millions of years of diversity and you get these species popping up across the tree of life that all are using this chemical warfare, like co-opting tetrodotoxin to use typically as defense. So there are actually two major hypotheses about where tetrodotoxin comes from. So one is an endogenous origin, right, so something that is genetically coded in an animal to produce tetrodotoxin.

And there is some support for this and that typically comes from the tree frogs I mentioned in that genus *Atelopus* where if you take those tree frog species and you bring them into a controlled environment where you control what you feed them, what they're in contact with, even years after that they can maintain really high levels of toxicity. And even frogs that are hatched in labs still have measurable amounts of tetrodotoxin in their skin which suggests that they're actually producing it somehow.

Erin Welsh

Whoa.

Erin Allmann Updyke

Oh. What?

Shane Campbell-Staton

Yeah, exactly. And again I don't really think we know how this works yet which is really surprising actually. But then the second hypothesis is actually in exogenous origin, so that animals are uptaking tetrodotoxin either through the food chain or through symbioses. And a lot of evidence for this actually comes from the puffer fish, so people captively breed puffer fish for food and also for the pet trade and puffer fish that are born in captivity are actually not toxic, they don't have any measurable amounts of tetrodotoxin.

Erin Allmann Updyke

What?

Shane Campbell-Staton

But if you feed them tetrodotoxin, they very quickly become toxic.

Erin Allmann Updyke

Ooh.

Erin Welsh

Wait, so is it possible that there are distinct groups of animals that some can produce, some it's endogenous and for some it's exogenous?

Shane Campbell-Staton

Yes, exactly.

Erin Welsh

What?

Erin Allmann Updyke

Erin's face is so excited right now, she's just like, her eyes can't contain it.

Erin Welsh

I just can't. Oh my god, that's amazing. That's amazing.

Shane Campbell-Staton

Yeah and it's this really sort of wild example of this classic question in evolutionary biology of, so the repeatability. Like if you get the same results i.e. 'I have tetrodotoxin, don't eat me or I'll mess you up.' Do you get there by the same path? And it seems like at least in this case, the answer is there are several paths to potentially get there, either through producing it or through uptaking it in the environment or, which I think is an even cooler potential explanation is through symbioses. You know, a major hypothesis is that a lot of these species that have tetrodotoxin have them because they formed a symbiotic relationship with bacteria that produced the tetrodotoxin. So like Vibrio bacteria is most often suggested as the symbiote in this case but also Pseudomonas and Actinomycetes.

Erin Allmann Updyke

Mm-hmm.

Shane Campbell-Staton

Yeah but in either case there remains this really important question about the repeatability of evolution, right. So either you have independent origins of tetrodotoxin production via these endogenous means or even if you're uptaking it from the environment, you still have to biologically incorporate it into your own body without being affected by it. So you still have to have some level of resistance.

Erin Welsh

What is... This is insane. Yes.

Erin Allmann Updyke

It's not like puffer fish don't have their own sodium channels, they do!

Erin Welsh

Right. Right!

Erin Allmann Updyke

Like what? How? What?

Shane Campbell-Staton

Exactly.

Erin Allmann Updyke

You can feed them tetrodotoxin and they're like, 'Don't worry bro, my liv will take care of this.'

Erin Welsh

My 'liv'. (laughs)

Shane Campbell-Staton

Exactly. (laughs)

Erin Allmann Updyke

I just skipped the other half of the word, that wasn't intentional.

Erin Welsh

It's pretty usual.

Shane Campbell-Staton

My liv totes got this, bro.'

Erin Welsh

(laughs)

Erin Allmann Updyke

Exactly.

Shane Campbell-Staton

And this obviously brings us to your initial question which is why?

Erin Allmann Updyke

Yeah.

Shane Campbell-Staton

And as I described, most of these species are incorporating it in their organs and it seems that this is mostly associated with defense against predation, right. So there are a lot of species that incorporate it in different organs but a lot also have it in their skin and in their muscle, right. So if you bit them or tried to hold onto them, obviously if you're biting them, you're biting them with your mouth which leads to a lot of the issues that we were just talking about when it comes to human infection with tetrodotoxin. So it seems to be associated by and large with defense against predation which also sort of brings us to this weird dynamic that comes out of these prey species having tetrodotoxin which are what we call evolutionary arms races. So if you're a puffer fish or if you're a roughskin newt swimming around or walking around, doing your thing, you don't want to be eaten, that's generally an unpleasant experience that we all try to avoid.

Erin Allmann Updyke

Yeah.

Shane Campbell-Staton

But if you're a predator, typically you like to eat things. This sort of very simple dynamic, two competing factors, lead to evolutionary arms races where things that don't wanna get eaten figure out ways to not get eaten, either by running really fast or growing large or growing hard parts that can't be chewed on. But then predators, they find ways to get around that. And there's a really interesting case when it comes to tetrodotoxins particularly in these roughskin newts that I mentioned before. So this species ranges across the west coast of the United States all the way from southern Canada down through southern California. And across the range they vary in their toxicity, so some populations are very highly toxic and some are only mildly toxic. And across their range there are also garter snakes, very common, I'm sure we've all seen garter snakes outside sort of racing from place to place.

Erin Allmann Updyke

Yeah.

Shane Campbell-Staton

And garter snakes, they occur across the same region and they're the only predator of the newt that is known to be resistant to tetrodotoxin.

Erin Welsh

What?

Erin Allmann Updyke

What?

Shane Campbell-Staton

I know, right? So these snakes, they eat newts regularly and this has led to amassed resistance to tetrodotoxin. So where the newts are more toxic, the snakes are more resistant to tetrodotoxin.

Erin Welsh

Oh my god!

Erin Allmann Updyke

I love biology.

Erin Welsh

It's so beautiful!

Shane Campbell-Staton

I know! So just to give you an idea, this range is by three orders of magnitude.

Erin Welsh

Oh, what?

Erin Allmann Updyke

What?

Shane Campbell-Staton

So we're talking about some snakes are 1000x more resistant to tetrodotoxin than others.

Erin Allmann Updyke

What? That is so cool.

Shane Campbell-Staton

I know! Which brings us back to this idea of the repeatability because this resistance, it seems to have evolved independently at least twice within garter snakes. So separate lineages have come up with this solution to being able to eat these roughskin newts. It's wild.

Erin Welsh

Are you serious?

Erin Allmann Updyke

It's like different garter snakes. It's like garter snakes you think those are the same snake but there's different populations that have evolved this different times?

Erin Welsh

And clearly these newts are a really important food source.

Shane Campbell-Staton

Yeah and it must be extremely important right because this fundamental question ideal is like how do you get this resistance? Well you've said how tetrodotoxin affects your sodium channels but these snakes actually have mutations in their sodium channels that make tetrodotoxin less efficient at binding to them.

Erin Allmann Updyke

So cool.

Erin Welsh

What?

Shane Campbell-Staton

It said there was different kinds of sodium channels man, they're just like, 'We're gonna skip to all the resisting kind and just forget about these ones over here.' That is so cool.

Erin Welsh

Wow. Why don't we all have resistant sodium channels?

Erin Allmann Updyke

(laughs) Cause we're not all eating puffer fish.

Shane Campbell-Staton

Cause our species haven't been... Yeah, exactly. Yeah. But it does come at a tradeoff. Obviously these sodium channels, they provide a very basic biological function, they help us to contract our muscles and move around. And snakes that have very high tetrodotoxin resistance cannot move as quickly as those that don't.

Erin Welsh

Interesting.

Erin Allmann Updyke

Weird.

Erin Welsh: Huh. So there's like a substantial tradeoff.

Shane Campbell-Staton: Yes. Absolutely. But it would be really cool if that was the whole story, right? But recently, actually just earlier this year in 2018 there was a study again in two species of roughskin newts that suggest that... They showed that individuals that were more toxic also had fewer parasites than less toxic individuals.

Erin Welsh: (gasps)

Erin Allmann Updyke: (gasps) We just both got so excited.

Shane Campbell-Staton: I thought you would like that one.

Erin Welsh: One more time just for emphasis, please.

Erin Allmann Updyke: Yes, say it again please.

Shane Campbell-Staton: (laughs) So roughskin newts that are more toxic have fewer parasites than their less toxic counterparts.

Erin Allmann Updyke: Oh my god.

Shane Campbell-Staton: Yeah, so it seems like they're actually... There's the possibility that not only does it help them in defense against predators but it may also help them defend against infections and parasites.

Erin Allmann Updyke: That's amazing!

Erin Welsh: What kind of...? So parasites meaning like ectoparasites or are we also talking like bacteria viruses, etc?

Shane Campbell-Staton: So if I remember correctly, they looked mostly at sort of larger parasites, so things like parasitic worms and even they looked at fungi as well, parasitic fungi that affect newts. Things like chytrid fungus, for instance.

Erin Welsh: Oh! Oh.

Erin Allmann Updyke: That's gonna probably have to be its whole own episode.

Erin Welsh: Oh yeah, for sure.

Shane Campbell-Staton: Yeah, won't dive too deep into that one.

Erin Welsh: That's amazing!

Shane Campbell-Staton

Yeah and so this brings me back to this original question, Erin Welsh, that you posed of like why do we care? Why do we wanna get into the mechanisms of all this stuff? I mean obviously hearing these stories it's actually really cool just on its own but there is I think some utility in really trying to understand the mechanisms either when it comes to zombie powder or when it comes to these crazy creatures across the tree of life that are using tetrodotoxin, there is some inherent utility there when it comes to our understanding of basic biology and medicine. So back in, I think it was 1929, there was this guy August Crow, he has what became a pretty famous quote and he said that for some large number of human-related problems, there will be some animal of choice for which that problem can be most conveniently studied. And this became his principle.

Right and that's based on this sort of fundamental observation that evolution by natural selection has produced a vast array of diversity and form and function and because of this, some species are really well suited for understanding human-related problems because they've evolved extreme characteristics that mimic human disease states or they allow us to conduct experiments that would be otherwise impossible. And this gives us fundamental insights into the diseases that plague us and help us to design effective treatments for those diseases. So in the case of tetrodotoxin resistance in these species, understanding how their ion channels allow them to live with tetrodotoxin may provide really valuable insights into many diseases that are thought to result from ion channel dysfunction. And this includes things from color blindness and night blindness to cystic fibrosis to Alzheimer's to Parkinson's to schizophrenia. So they potentially provide some really fundamental insights into understanding how these really basic aspects of biology can be modified and improved upon.

Erin Allmann Updyke

That was so gorgeous.

Erin Welsh

That was so perfectly put and fascinating and we were both at the same time formed hearts with our hands-

Erin Allmann Updyke

And we were putting them towards our computers.

Erin Welsh

We're like, 'Oh my god, this is the best.'

Shane Campbell-Staton

Will you guys stop that.

Erin Welsh

No but that was just really well said and really well put. And I think that you made a really good point that it's not just driven by this curiosity but there is a function and a reason, an application for doing this type of research and for being even just interested in it and learning about it from a comparative angle or from a historical angle or from a medical angle, like there's a reason.

Erin Allmann Updyke

From all the angles.

Erin Welsh

Yeah.

Erin Allmann Updyke

Ugh, cool!

Shane Campbell-Staton

I know, science!

Erin Welsh

(laughs)

Erin Allmann Updyke

Dude, that was great.

Erin Welsh: That was a great episode. So should we do sources?

Erin Allmann Updyke: Probably.

Erin Welsh: Okay so I read a few books or sections of books. I would recommend 'Invisible Powers' which is edited by Claudine, Michel, and Patrick Bellegarde-Smith. And also 'Passage of Darkness' by Wade Davis. 'American Zombie Gothic' by Kyle William Bishop which kind of details the transformation of the evolution of the zombie genre in movies.

Erin Allmann Updyke: Okay.

Erin Welsh: KOSANBA or the Congress of Santa Barbara too which is like a place to learn about and to have scholarship on Vodou.

Erin Allmann Updyke: Sweet. I don't have...

Erin Welsh: We'll post all of these too.

Erin Allmann Updyke: Yeah, that's the thing is mine are always way too long. I have a bunch of articles that were cool but you can find them on our website thispodcastwillkillyou.com. We have every single one of our episodes, we have our sources listed there, so.

Erin Welsh: Mm-hmm.

Erin Allmann Updyke: Shane, do you have any things you'd like to shout out besides your brain?

Shane Campbell-Staton: Oh I guess what I will shout out is the last paper I mentioned about poison and parasites in newts was published earlier this year in the Journal of Animal Ecology, the lead author's last name is Johnson. Johnson et al, 2013.

Erin Allmann Updyke: Sweet.

Erin Welsh: That's very cool.

Erin Allmann Updyke: Also Shane tell us where everyone can find you and stalk you and listen to your podcast.

Shane Campbell-Staton: Yeah so you can find me at @SCampbellstaton on Twitter. You can also hit up @superbiopodcast to check out new episodes.

Erin Welsh: Shane, thank you so much for joining us, this was awesome.

Erin Allmann Updyke: Yes! It was super fun.

Shane Campbell-Staton: I had a great time, thank you guys so much.

Erin Allmann Updyke: And thank you everybody for listening, we love you, you're the number one greatest.

Erin Welsh: Thanks to Bloodmobile for providing all of our music.

Erin Allmann Updyke

We love you so much. And yeah.

Erin Welsh

Join us next time.

Erin Allmann Updyke

For something else creepy.

Erin Welsh

Mm-hmm. Now, guess what? Wash your zombified hands.

Erin Allmann Updyke

Yep. You're filthy animals.

Shane Campbell-Staton

Don't be nasty.

Erin Allmann Updyke

(laughs)

Erin Welsh

(laughs)