

Erin Welsh	Hello listeners. Before we get to the episode, we want to take a moment to address the June 24, 2022 Supreme Court decision to overturn Roe vs Wade.
Erin Allmann Updyke	This decision stripped away the right to have a safe and legal abortion. Everyone should have the freedom to decide what's best for themselves and their families including when it comes to ending a pregnancy.
Erin Welsh	This decision has dire consequences for individual health and safety and could have harsh repercussions for other landmark decisions. Abortion is healthcare and restricting access to comprehensive reproductive care including abortion threatens the health and independence of all Americans.
Erin Allmann Updyke	You can learn more by visiting <a href="http://choice.crd.co">choice.crd.co</a> . That's <a href="http://choice.crd.co">choice.crd.co</a> .
Erin Welsh	And if you're able to support others please consider donating to abortion funds.
Erin Allmann Updyke	We encourage you to speak up, take care, and spread the word.
Erin Welsh	Hi everyone, Erin here. You are about to listen to a very exciting episode on immortality. And this episode is not just exciting because of the topic but also because it was going to be our 100th regular season episode. But when things with monkeypox started to ramp up we decided that we wanted to make sure that we got a monkeypox episode out to you as quickly as possible and that meant pushing back this immortality episode which we had actually recorded before monkeypox. So throughout this episode you may hear references to this being our 100th episode even though it's actually episode 101 and we just wanted to explain why in advance. Okay I think that about covers it, so let's get started introducing immortality.
Erin Allmann Updyke	The life that you seek you never will find: when the gods created mankind, death they dispensed to mankind, life they kept for themselves. But you, Gilgamesh, let your belly be full, enjoy yourself always by day and by night! Make merry each day, dance and play day and night! Let your clothes be clean, let your head be washed, may you bathe in water! Gaze on the child who holds your hand, let a wife enjoy your repeated embrace!
TPWKY	(This Podcast Will Kill You intro theme)
Erin Allmann Updyke	I still don't actually know the story of Gilgamesh.
Erin Welsh	I still only know a little part of the story of Gilgamesh. So yes, that was from the Epic of Gilgamesh which is one of the oldest, I think actually considered the oldest surviving document or text.
Erin Allmann Updyke	Wow. That's amazing.
Erin Welsh	Yeah, yeah. It's from a long time ago, like 2000 BCE. Something like that.
Erin Allmann Updyke	Wow.
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 today we're not just reading you the story of Gilgamesh.

Erin Welsh: No that's most of what you'll hear about Gilgamesh.

Erin Allmann Updyke: Today we're doing something very different in honor of our 100th episode.

Erin Welsh: 100th. I can't believe it.

Erin Allmann Updyke: I never would have thought we could make 100 episodes of a podcast, Erin.

Erin Welsh: Me neither. And okay here's the thing is that technically we surpassed 100 a long time ago.

Erin Allmann Updyke: That's true. I forgot about that.

Erin Welsh: With all the COVID episodes.

Erin Allmann Updyke: And all the bonus ones you've done.

Erin Welsh: And the bonus episodes, yeah.

Erin Allmann Updyke: Yeah well still.

Erin Welsh: This is our title episode 100.

Erin Allmann Updyke: Yeah.

Erin Welsh: And I think in honor of that as we slowly get around to talking about what we're going to be talking about today, we thought it would be fun to take the name of our podcast and change it up a bit, right.

Erin Allmann Updyke: Yeah.

Erin Welsh: This Podcast Will Kill You.

Erin Allmann Updyke: Today This Podcast Won't Kill You.

Erin Welsh: Yeah.

Erin Allmann Updyke: It might make you live forever.

Erin Welsh: Probably not.

Erin Allmann Updyke: Give you the secrets to eternal life.

Erin Welsh: Today we're going to be talking about immortality.

Erin Allmann Updyke

Immortality.

Erin Welsh

And aging and it's definitely not going to be a comprehensive journey through the history of aging and how immortality could be achieved but I think it's going to be a nice little taste.

Erin Allmann Updyke

Yeah. And our structure is going to be a little different than usual because it's such an amorphous topic.

Erin Welsh

Yeah. So I'm going to be starting out talking about the history of immortality and what that means in terms of evolution and then what that means in terms of human culture. And again it's just sort of a brief little jump through this topic.

Erin Allmann Updyke

Yeah. And then I'm going to talk about I don't really know what, Erin. Maybe where we stand in terms of aging today or anti-aging research or the quest for immortality, what we know about the biology of it. I don't know, it's going to be a little bit of a conversation.

Erin Welsh

I think it's going to be really exciting and fun.

Erin Allmann Updyke

Yeah.

Erin Welsh

I'm just looking forward to it.

Erin Allmann Updyke

Same, same.

Erin Welsh

Speaking of tastes of things, what time is it?

Erin Allmann Updyke

Quarantini time. Still is quarantini time.

Erin Welsh

Still is. Always quarantini time. What are we drinking this week?

Erin Allmann Updyke

Well of course we're drinking none other than the Elixir of Life.

Erin Welsh

We are. And in the Elixir of Life, it's a fun little drink because we've got gin, we've got lemon juice, we've got blackberries, we've got simple syrup, and then to kind of create the fun little magical, I don't know, aura around it, we've got butterfly pea flower extract which was sent to us by a very generous listener. So thank you so much. It is such a cool looking drink. It's amazing.

Erin Allmann Updyke

I'm really excited but I want to come visit you so that I can actually taste it.

Erin Welsh

Okay, let's make that happen.

Erin Allmann Updyke

Yeah.

Erin Welsh

We will post the full recipe for the Elixir of Life as well as the non alcoholic placebo on our website [thispodcastwillkillyou.com](http://thispodcastwillkillyou.com) as well as on all of our social media channels.

Erin Allmann Updyke

Our website [thispodcastwillkillyou.com](http://thispodcastwillkillyou.com) if you haven't been there yet, you should go and check it out. After 100 episodes, try it. We have merch, we have transcripts, we have links to our [bookshop.org](http://bookshop.org) affiliate account, we have links to our music, Bloodmobile. We have a Goodreads list, we have all of our sources for all of our episodes, we have our Patreon. We have more than I could say in that single breath.

Erin Welsh

Well I think you did a great job.

Erin Allmann Updyke

Thanks, love it.

Erin Welsh

All right. Any other business?

Erin Allmann Updyke

No, Erin. Please tell me, I don't know from Gilgamesh to now, how has humanity fared on our quest for immortality?

Erin Welsh

Great questions there. I will do my very best right after this break.

TPWKY

(transition theme)

Erin Welsh

Like we said, this is definitely not our typical format but then again this is not our typical episode topic. So the focus of our episode today is immortality. But what does that mean? Not just like what are we going to cover but the word or the concept itself.

Erin Allmann Updyke

Yeah.

Erin Welsh

Is immortality simply living forever? Not aging? Being invulnerable to any illness or injury? Does it mean that your name and life will be remembered hundreds of years from now? Or that your genes will be carried on in your offspring and their offspring and so on and so on down the line? There are many different ways that we can think of and have thought of immortality. And if your goal is to achieve immortality which definition you choose has tremendous bearing on how you go about that. And that can also be said for this episode. So how will we consider immortality today? Really we'll at least touch on the most common concepts in a general sense. But since we're a health and science podcast, most of what we'll talk about is immortality from a biological perspective.

Erin Allmann Updyke

Yeah.

Erin Welsh

First by talking about not what immortality is and how we can achieve it but what stops us from being immortal in the first place. Why do we die? Why do we decline as we get older? Are there any organisms that don't? What do we know or think about senescence, decline or deterioration we experience as we age from an evolutionary perspective? And then I'll turn from that to talking about the age long quest for immortality which has roots much, much older than these startups in Silicon Valley that have been looking for modern elixirs of life that I know you're going to be talking a bit more about Erin.

Erin Allmann Updyke

Yup.

Erin Welsh

What patterns do we see in the different ways that people have approached immortality through history? And how has this past century and our ever growing understanding of biology changed the targets for immortality research? And then that's sort of where I'll hand it off to you, Erin to tell us how close we are or probably aren't to achieving immortality and the nitty gritty of what people are working on.

Erin Allmann Updyke

Okay.

Erin Welsh

Okay, all right. So let's get into it. Living things age but they don't just experience the passage of time, they also change as time passes, first growing and developing and then at a certain point that growth ceases and a new kind of change occurs, one where maybe things don't heal quite as fast as they used to or those aches and pains get more frequent and eventually recovery is no longer a possibility, with death being the ultimate end. And this is generally how it happens for every living thing. And sure, the amount of time that you spend in each life stage may be different or how long you can expect to live will vary but death and aging are essential parts of life even for those supposedly immortal animals that you see clickbait headlines about like lobsters or certain jellyfish or bristlecone pines. But while senescence, the biological decline part of aging, may not be as marked as in other creatures, those organisms are not truly immortal. They will die eventually because nothing living is immune to death. Why does this have to happen? Why can't we go on living forever? Well let's think about it in the context of natural selection and evolutionary fitness.

Erin Allmann Updyke

Let's, Erin.

Erin Welsh

Evolutionary fitness for those who haven't heard the term before is essentially an individual's reproductive success, how many offspring they have. If an individual has no offspring, zero fitness. If they don't survive long enough to reproduce, fitness is also zero. But the individuals who do live long enough to reproduce and have a lot of offspring, those are the ones who are going to contribute the most to the next generation's gene pool. Traits that limit your ability to reproduce or survive through reproductive age, those traits lower your fitness and make it less likely for those genes to be passed on to the next generation. And over time those traits, those genes will become less and less common, maybe eventually disappearing.

But traits that make you more likely to reproduce or survive through the end of reproductive age, those are the traits that are going to be selected for, becoming more common. So we can think of tons of examples of this right, like the size of a bird's beak or the rate of development of a tadpole into a frog or fur pattern or susceptibility to disease. But what's so crucial about this for this discussion is not the traits themselves, not these examples but rather the time window when these traits matter most. And that is the critical period from basically prenatal development all the way through the end of when you are able to reproduce. That is when selection can act. With this in mind, what does it matter really in terms of natural selection if you live past reproductive age? It doesn't.

Erin Allmann Updyke

It doesn't at all.

Erin Welsh

It doesn't, yeah. If there are genes that affect at least in part your longevity, how will natural selection act on them if they don't have any bearing on your reproductive fitness?

Erin Allmann Updyke

It won't.

Erin Welsh

It won't. And there are genes in humans that are associated with longevity but it's likely that those play a role in maintenance or development and they don't just switch on later in life.

Erin Allmann Updyke

Exactly.

Erin Welsh

Yeah. So essentially in terms of natural selection, it doesn't really matter how long we live past the point when we're no longer reproductively viable. And this is of course a big oversimplification. And for humans and other animals, there are some very interesting hypotheses about why we humans live long past the age we reproduce, mostly centering around grandparents. And I'd love to get into that one day with an episode on menopause.

Erin Allmann Updyke

Oh we'll definitely do it on menopause because I love all of the evolutionary theories behind menopause and just aging and the grandparents. I love all of that.

Erin Welsh

Yes, the grandparent hypothesis.

Erin Allmann Updyke

Yeah.

Erin Welsh

It's so interesting. Yes.

Erin Allmann Updyke

I love it.

Erin Welsh

But anyway, we humans are not unique in that we live past the age we reproduce nor are we unique in the fact that our bodies and minds start to deteriorate as we get older. And even if life past reproduction is not part of natural selection, what makes us and other organisms age? Why do we age? And we have been asking ourselves this question probably since we were able to form thought but it wasn't until Charles Darwin introduced the theory of evolution by natural selection in the mid 19th century that people had a scientific framework that they could use to try to answer this question. Since that time many different hypotheses have been proposed, none of which seem to adequately explain senescence for every living thing. And I'm going to briefly go through a few of the classical hypotheses of senescence so that we can try to think about possible mechanisms that could explain why aging is universal.

The first of these hypotheses was proposed in the 1890s by the German evolutionary biologist August Weismann, the so-called germ soma theory. And so Weismann suggested that there were two types of cell lines in an organism, a germ line and a soma or body line. And the germ line is made up of the cells that are involved in reproduction and the soma line consists of the cells that make up the rest of the body. It's the sole duty of the soma cells to do whatever it takes to keep the germ line alive and reproducing. Beyond that, soma cells, basically disposable and the soma cell lineage will invariably die while the germ cell lineage can be viewed as potentially immortal. Aging happens as the soma line gets beat up by the environment while protecting the germ line. And that's the hypothesis.

Erin Allmann Updyke

Yeah.

Erin Welsh

Obviously it has many shortcomings, first of them being that it doesn't really explain why senescence evolved, like why the soma is disposable. And it doesn't explain senescence in single-celled organisms. But it did introduce the idea that reproduction is first and foremost the priority. And many later researchers built upon this idea, such as the famous mathematician and eugenicist Ronald Fisher who in the 1930s proposed a mathematical model in which he laid out his thoughts that senescence was the accumulation of harmful age-specific traits. A couple of decades later in the 1950s, Peter Medawar, whose name you might remember from our organ transplantation episode, he wrote a now famous essay describing how the force of selection weakens as we get older and past our reproductive age. He wasn't entirely right either. For instance, his belief that animals in the wild don't get old, they don't senesce because they just get picked off by predators or succumb to starvation. They actually do senesce, they actually do get older. But his essay did suggest a sort of mechanism for senescence. If there are certain genes that do exist that shorten our lifespan, they won't really be selected against if they only show their effects later in life. And so they will continue to appear and accumulate over generations, the quote "mutation accumulation theory".

Erin Allmann Updyke

Sorry, I just really do love these hypotheses.

Erin Welsh

I do too.

Erin Allmann Updyke

I find it really fun.

Erin Welsh

It was so interesting because even though I said humans have probably asked themselves this question forever and I've probably asked myself this question too but not in like an okay but why?

Erin Allmann Updyke

Yeah.

Erin Welsh

What is the actual evolutionary mechanism behind it?

Erin Allmann Updyke

I feel like I only ever thought about another hypothesis I think you're probably going to talk about next in the context of the evolution of human health class that I TA'd for. So that was a very specific subset of time that I was thinking about it.

Erin Welsh

Yeah. It's so fun to think about. Okay so there are there are a few more.

Erin Allmann Updyke

Yeah.

Erin Welsh

So a few years after Medawar's essay, George Williams added onto this by suggesting that in addition to these mutations appearing it's also possible that those genes that are helpful early in life, like in development and during reproduction, could also be bad or have negative effects later in life. For instance let's think about cell growth. If your cells grow super fast, that's potentially great when you're developing, right. You get larger faster and can be independent faster. But later on that could mean uncontrolled cell growth aka cancer. And this is something that's called antagonistic pleiotropy.

Erin Allmann Updyke

It's one of my favorite concepts and I love it.

Erin Welsh

They all make sense. And the thing that I like too about them is that none of them are really mutually exclusive.

Erin Allmann Updyke

Exactly. You can easily have mutations that accumulate as well as have genes that are beneficial early in life and maybe have a detriment later in life. So these mutation accumulation, antagonistic pleiotropy, these hypotheses really do work together to explain aging in a way that I think is just fascinating.

Erin Welsh

Yeah, exactly. And also what really helped things along in this field was when in 1966 William Hamilton combined some of these existing ideas on the evolution of aging into a mathematical model which maybe that doesn't sound very exciting but it really was.

Erin Allmann Updyke

It is.

Erin Welsh

And it still today is super impactful because it laid out a framework for why aging happens and it also showed that the strength of selection on traits that keep you alive, it becomes weaker over time in anything that ages and doesn't reproduce via fission.

Erin Allmann Updyke

Yeah.

Erin Welsh

Really also what it did was create a math model for people to be able to test ideas about aging. The last of the classical hypotheses of senescence I'm going to talk about is the quote "disposable soma theory" proposed by Thomas Kirkwood in 1977 which says that over time an organism's cells accumulate harmful genetic mutations. Mutations in your DNA happen randomly all the time because of environmental factors or mistakes in DNA replication and it gets increasingly costly to repair the damage from these mutations. And at a certain point the benefit of repairing the damage is outweighed by the cost. Repair and maintenance is always going to favor the germ line. Okay so these are just a few of the most impactful hypotheses to explain why senescence evolved but there are certainly others and no single hypothesis at this point seems to be able to explain aging for all organisms, there's no unifying hypothesis. Probably because there's tremendous diversity in life.

Erin Allmann Updyke

No, is there really Erin?

Erin Welsh

Yeah.

Erin Allmann Updyke

You're telling me that a bristlecone pine is not the same thing as a planarian?

Erin Welsh

It might not be. And even some of the fundamental assumptions about aging have been challenged. It's an extraordinarily complicated thing to study. You have to capture both how different environments and different genes impact aging, you have to consider ecological factors, determine whether aging in the lab is different or the same as aging in the wild, evaluate whether closely related species age more similarly than distantly related ones, and the biggest thing in my eyes is that we've really only begun looking at this within the past 130 years or so.

Erin Allmann Updyke

Yeah.

Erin Welsh

Which is shorter than the average lifespan of some organisms that could give us really valuable insight into longevity.

Erin Allmann Updyke

Good point.

Erin Welsh

How do you create a data set for giant tortoise?



Erin Allmann Updyke: Yeah. Right. Well even studying human aging, we live a really long time.

Erin Welsh: Right.

Erin Allmann Updyke: That's hard.

Erin Welsh: And there have been really cool census records and especially in certain countries or certain regions that keep really good track of people through time but we still don't have all the bits of information there.

Erin Allmann Updyke: Right, yeah.

Erin Welsh: So it's in a way we've been thinking about it for a long time but it seems like we're definitely in the infancy of having data to be able to test these hypotheses.

Erin Allmann Updyke: Erin, you just summed up my whole section. That's it.

Erin Welsh: It was really interesting to read through this also because I don't think I realized just how huge of a field of study this is.

Erin Allmann Updyke: Yeah.

Erin Welsh: And I guess I should have because there are entire journals and entire textbooks and entire companies and everything but it is really hard to do it justice.

Erin Allmann Updyke: Yeah, yeah, yeah.

Erin Welsh: So yeah. So I just kind of wanted to wander through some of these ideas and build a baseline for thinking about aging in an evolutionary context, especially when it comes to natural selection.

Erin Allmann Updyke: Yeah.

Erin Welsh: And wouldn't it be great if we lived forever? But we don't really need to in terms of our DNA getting passed on.

Erin Allmann Updyke: Evolutionarily.

Erin Welsh: Yeah.

Erin Allmann Updyke: Yeah, exactly.

Erin Welsh: Yeah. And I also thought it was important to think about these things like why we age before we start exploring some of the ways that we've tried and continue to try to stop or slow that process. So if there's anything that humans are good at, it's searching for the key to immortality. We're really good at searching for it but we are terrible at finding it.

Erin Allmann Updyke: Yeah.

Erin Welsh: Because we've not found it.

Erin Allmann Updyke

Yeah, spoilers. We don't have it.

Erin Welsh

Spoilers, we don't have it, we may not have it ever. Immortality narratives are central to every culture and religion, like the Epic of Gilgamesh, the oldest known written document. So the reason that I included Gilgamesh in the beginning, I'm now calling back to it, is that a big part of the story is about the quest for immortality. So King Gilgamesh's best friend dies and in response Gilgamesh vows to find eternal life. Spoilers, he does not. And I'm sure between the two of us, we can think of dozens and dozens more books or movies or poems or songs about the search for eternal life. But it's not just like one of my favorite books growing up was 'Tuck Everlasting'. And for a long time, have you read 'Tuck Everlasting'?

Erin Allmann Updyke

No, I didn't even know it was a book. I thought it was a movie but I've never seen it or read it.

Erin Welsh

Okay. Basically it's about this family that is trying to find a home, they're homesteading and they stumble across this water. They all drink from it including the horse I think and it happens to be an immortality spring. And then there's a girl who stumbles across this family and then she's like do I drink it, do I not drink it? Blah, blah, blah. And as a kid, I was like drink it obviously, live forever.

Erin Allmann Updyke

Don't drink it. Don't drink it!

Erin Welsh

And yeah. Anyway but it's a really interesting contemplation about immortality and life.

Erin Allmann Updyke

Yeah.

Erin Welsh

I loved it. And that's just one of hundreds, dozens, thousands, an unbelievable number.

Erin Allmann Updyke

Yeah.

Erin Welsh

But it's not just in these fictional stories that people have been on the hunt for a way to live forever. The quest for immortality is a very real thing that takes many different forms and I want to talk a bit about these forms before focusing on a couple that are more in line with this episode. While researching for this episode I came across a book titled 'Immortality: The quest to live forever and how it drives civilization'. And in this book the author philosopher Stephen Cave groups the search for immortality into four different themes. The first two deal with the physical side of things. First there's living forever. You as an individual stopping aging or aging but not dying, living indefinitely. And then there's resurrection, being brought back to life after death, think Jesus. Third is the soul, the idea that a part of you but not the physical you lives on after you die. And finally there's legacy which can mean living on through memories or fame, as in you're only truly dead when your name is no longer said.

Erin Allmann Updyke

Coco.

Erin Welsh

Or also offspring, the idea that your genes achieve immortality by being passed on. And I wanted to explore some of the ways we've sought to achieve immortality throughout human history, focusing on those that fall into the first two of these themes, staying alive and resurrection. Because in terms of targets for biological research into immortality, all of those projects can be lumped into those themes.

Erin Allmann Updyke

Yeah.

Erin Welsh

And after going through some of these adventures in immortality, I want to end by reflecting on what these stories tell us about human nature. We humans may be unique in our ability to recognize our own mortality, that one day each and every one of us will die. And the knowledge of our own inevitable death yet the simultaneous inability to actually imagine what it will be like has driven us to find any way around it, either by delaying it, undoing it, or preventing it entirely. In ancient Egypt there was an entire industry devoted to preserving the body after death so it could be magically revived. And of course pyramids and other monuments were built as a testament to the person's life, immortality through legacy.

Ancient papyri describe not just preparation for the afterlife or resurrection but also ointments and elixirs that were meant to extend life and slow aging. The search for an elixir of life or a fountain of youth is similarly old. There are countless stories of emperors and kings searching in vain for a way to escape death, like the first Emperor of China who lived around the 200s BCE. He became obsessed with the idea of living forever and searched high and low for someone who could reveal the secret to him. He did find someone, probably one of the oldest known swindlers, who promised it all but delivered nothing and just ran away with his reward.

Erin Allmann Updyke

Of course.

Erin Welsh

Ultimately the emperor died young, only 49.

Erin Allmann Updyke

Wow.

Erin Welsh

Likely from either arsenic or lead or mercury poisoning, all of which were likely ingredients in his daily quote "life extending vitamins".

Erin Allmann Updyke

Gosh, that's just such a bummer.

Erin Welsh

I know. But he did achieve immortality in a way, I mean we're still talking about him.

Erin Allmann Updyke

We are.

Erin Welsh

Through legacy. The terracotta army, have you heard of the terracotta army?

Erin Allmann Updyke

Oh yeah.

Erin Welsh

Yeah, that's him.

Erin Allmann Updyke

That's him. All right.

Erin Welsh

The elixir of life wasn't always viewed as just a potion or something you ingest. At various points it was thought to be a plant or a series of exercises or a special object like the philosopher's stone which was one of the mythical substances famous in alchemy. Alchemy was a kind of pre science practiced by philosophers and early chemists, the goal of which was to transform one metal into another, typically gold, and to find the elixir of immortality or a cure all for any disease. It was practiced all over the world from ancient times all the way up through the 18th century when it declined after the rise of more rigorous scientific thinking. Although it might be more accurate to say that alchemy didn't decline but rather it was repackaged primarily into the field of chemistry. Nor did people grow tired of looking for the elixir of immortality. Instead the development of each new field or new scientific discovery was applied to that quest. For instance electricity. So if you think back to our electricity episode, you may remember me telling the story of Galvani and his metal wires and the frog's legs jumping.

Erin Allmann Updyke

Oh yeah.

Erin Welsh

So his nephew took a page out of his book and held public demonstrations where he reanimated corpses of freshly hanged murderers.

Erin Allmann Updyke

Oh my. Okay.

Erin Welsh

Yeah. And his demonstrations may have been the inspiration for Mary Shelley's 'Frankenstein'.

Erin Allmann Updyke

Frankenstein! Oh my goodness.

Erin Welsh

I know. Connections. And this pattern continues to be repeated. In the mid 20th century advancements in cellular technology allowed researchers to use previously frozen sperm for insemination, resulting in three pregnancies which was revolutionary. And that soon turned into whole body freezing plans. As we've learned more about genes linked to aging thanks to genomic sequencing technologies, those inevitably became our targets for modern day immortality projects. And the amazing thing in my eyes is that despite humanity's continuous and innumerable attempts to achieve immortality over thousands and thousands of years, we have not been remotely successful and we probably never will be. Maybe you'll change my mind.

Erin Allmann Updyke

Yeah we'll see, Erin.

Erin Welsh

Over the past couple hundred years or so the average age a person can expect to reach has been greatly extended, largely due to vaccines, antibiotics, and many other small things, especially a better understanding of disease overall. But this has not been an extension of our inherent lifespan. Humans have been able to live to 80 years old, 90 years old for thousands of years but were prevented from commonly achieving old age because of extrinsic factors like insert any vaccine preventable disease here.

Erin Allmann Updyke

Or also taking like mercury and arsenic as a vitamin.

Erin Welsh

Yeah, just like that too. But from what I've read, there's not a single anti aging serum, pill, potion, whatever that has been shown to actually slow aging or reverse or stop it. There is some evidence that diet and exercise may play a role. Longevity and aging are both such incredibly multifaceted processes that are nearly impossible to predict. And I'm not saying at all that I don't think this research should be done, some of these projects have uncovered knowledge that has had huge implications for improving quality of life and treating diseases that primarily manifest later in life. I guess I'm just expressing my skepticism that a meaningful extension of both lifespan and quality of life alongside that will be achieved in the near or even kind of near future. This section definitely came out differently than I had planned.

When I started it I thought I'd take us through the history of the search for the elixir of life or the beginnings of cryonics and those stories are fascinating and worth telling but I think that overwhelmingly while doing the research for this part and while going through it just now, I think that what sticks out to me most is how so many things have not changed. We will continue to keep looking for ways to live forever, to upload our brains or slow our aging, to reanimate frozen bodies or download our memories into a cloned body. And if any of those technologies are successful, you can also be sure that the select few, the richest and most powerful, will be the only ones to benefit from them. Which is also how it has been throughout history. But would it truly be a benefit to live forever? Would it be something you want? I've talked about a few stories about people who have searched for a way to live forever, now let's think of somewhere they achieved immortality. How did those stories end?

Erin Allmann Updyke

Never well.

Erin Welsh

Never well. Almost universally they end in profound loneliness, sadness, and regret. Not at first maybe but over time as their mortal friends and family grow older and die, as days pass and time becomes meaningless. Granted all of those stories have been imagined by mortal humans, so perhaps these endings are just consolation for not being able to live forever. But I don't know. Personally I don't think so. I think too often we decide we want to live forever without considering what that could truly look like. I want to end this section with a quote by Stephen Cave that I think puts it nicely. Quote: "The deep problem is this. The value of a thing is related to its scarcity. People conscious of their mortality value their time and aim to spend it wisely because they know their days are numbered. But if our days were not numbered, this incentive would disappear. Given infinity time would lose its worth and once time is worthless it becomes impossible to make rational decisions about how to spend it. The consequences of this for an individual would be bad enough, for a civilization of such ditherers it would be disastrous."

Erin Allmann Updyke

Yeah.

Erin Welsh

Yeah. And with that Erin, I'll turn it over to you to tell me how close we are to such consequences.

Erin Allmann Updyke

Oh gosh. Oh my goodness, Erin. This episode turned out so different than we expected. I'm going to need a break.

Erin Welsh

Okay, yeah.

Erin Allmann Updyke

And then I'll dive in to what's happening today.

TPWKY

(transition theme)

Erin Allmann Updyke

So when I first started trying to research for this episode I had a really hard time because I wasn't sure how to really approach this question and I actually wasn't sure what my question was. I normally do the biology section of whatever disease or thing we're talking about and then I talk about the current status, where do we stand today. So what was my question for immortality? Is it how close are we to immortality? Is it are we still pursuing this quest? Which spoilers you already told us and the answer is yes, we still are.

Erin Welsh

Oh yeah.

Erin Allmann Updyke

Was the question have we learned anything from these thousands of years of futility so far? I don't know what question I'm answering out of those but I did a lot of reading and I read a lot about the various Silicon Valley startups that exist, the number of companies, the number of billionaires and millionaires and the amount of dollars that are going into try to solve this quote "problem of aging" or the "problem of death".

Erin Welsh

It kills me, the problem of aging or death.

Erin Allmann Updyke

It's really, really interesting. And I think I got a little bit overwhelmed and also maybe a little cynical by the end of it.

Erin Welsh

For sure I got cynical by the end of it.

Erin Allmann Updyke

Yeah but it's not to say like what you said Erin, it's not that what any of these researchers are doing is unimpressive or unimportant.

Erin Welsh

Right.

Erin Allmann Updyke

It's just that we remain in the very early stages of this research. So let's kind of go through the way that I at least tried to frame thinking about this. If we're talking about immortality, like you said Erin at the top, then we're kind of talking about the idea of anti aging or we're talking about increasing our lifespan. And if we're talking about halting aging to the point of halting death, then for me the way to get there logically is to answer a series of four different questions. The first question you kind of answered Erin and that is why do we age? I think that you provided a lot of evolutionary perspective on the idea of why we as humans and we as living organisms on the planet earth age evolutionarily. But we still don't fully necessarily know but we at least have a lot of hypotheses. But a very closely related question to why do we age is how do we age? Fundamentally what governs the process of how our cells senesce? And how is this process related to those evolutionary reasons of why we age?

Because if we could answer those two questions really well then we could ask the next question, must we age? Are those processes like we said from an evolutionary perspective necessary for life and are they immutable? And if the answer to that question is no, they're not immutable, and if we can figure that out by virtue of figuring out the answers to the first two questions, then we can ask the final question. If we don't have to age, do we have to die? So at least to me those seem like the four fundamental questions that have to be answered if we have any hope of answering this riddle of immortality. And suffice to say those four questions are massive. And I think the biggest issue for me in talking specifically about immortality is the leap between those last two questions. Must we age and must we die?

Erin Welsh

Right.

Erin Allmann Updyke

Because while there are in nature and in the laboratory many, many examples, be they plant or worm or lobster that live a very long time, that seem to be immortal, nothing is invincible, right.

Erin Welsh

Right.

Erin Allmann Updyke

If you take one of these invincible planarians out of their worm juices, they're going to die, they're not invincible. And so that's I think one of the biggest issues I see with even just entertaining this idea of true immortality.

Erin Welsh

Oh yeah.

Erin Allmann Updyke

Right?

Erin Welsh

Immortality is not invincibility.

Erin Allmann Updyke

Exactly, yeah. Okay but so is that what people are working on? Are people working on immortality or are people really working on the first few questions but selling it, packaging it as the idea of immortality? Maybe that's more accurate. So what do we actually know about these first couple of questions, especially how we age and must we age? There has been like you said Erin without a doubt huge increases in the estimated life expectancy for humans globally and there is a lot of variation in estimated life expectancy between countries, between genders, etc. And most of that increase is like you mentioned credited to early life advancements, things like antibiotics, vaccines. Basically we know for sure that we've had huge reductions in early life mortality because of scientific and biomedical achievements over the last 50-100 years.

However there has also been a decline in late life mortality. So the fraction of each birth cohort that reaches old age has been increasing year after year. Or at least it had been until about the 1980s. And since then it's actually been very stagnant despite increasing overall life expectancy. But the maximum reported age at death has plateaued. You may have heard of Jeanne Calment who was a French woman who died in 1997 at the ripe age of 122 years and 5 months. She still holds the verified longevity record by a lot, by a couple of years. And while there are over 500,000 centenarians alive worldwide, at least that's what the UN estimated in 2020-

Erin Welsh

Wow.

Erin Allmann Updyke

500,000 people over 100. That number is 20 times higher than 50 years prior. But the average age at death for these centenarians has not increased since 1968. So there is a lot of research and mathematical modeling like you mentioned Erin as far back as the 1800s that really suggests that there may be a true upper limit to the human lifespan. And while this idea is still a little bit controversial, there are people who don't like to agree with the idea that there is a limit to human life expectancy, a lot of studies that have used various methods and are to varying degrees controversial have converged around this idea that perhaps Between 120-150 years might be the maximum human lifespan that one could expect. So could we even live forever? It seems highly unlikely.

Erin Welsh

Yeah.

Erin Allmann Updyke

But there is another piece to this puzzle besides actual lifespan is like you mentioned Erin, quality of life. This is often called healthspan. So if lifespan is the length of your life, healthspan is often defined as the period of your life that is free from disease. I personally will take slight issue with this definition because health is of course a lot more than merely the absence of disease. But this is generally how health span is defined so we'll go with it for the purposes of this episode.

Erin Welsh

Okay.

Erin Allmann Updyke

And if we look worldwide, despite how much lifespan has increased, chronic diseases are the leading cause of morbidity and mortality worldwide. And many of these, cardiovascular disease, cancer, dementia, these are often considered diseases of aging. And an estimated 58% of chronic disease-related mortality happens in people over age 70. So if we look at the discrepancy between healthspan and lifespan, there's an estimated gap right now in the world of 9 years. So there's a 9 year gap where you are still alive but you are no longer quote "free from disease". And a lot of the field of what is called gerontology research isn't truly focused on the idea of immortality, at least not overtly or in a lot of cases they're not even focused on the idea of increasing our lifespan but rather they're focused on increasing healthspan. So they talk instead about the idea of compressing our morbidity to the end of life such that we live healthier lives for longer and can either avoid or prolong the onset of these various age-related diseases. And this I think sits as both a more palatable goal for sure.

Erin Welsh

I would agree with that.

Erin Allmann Updyke

But I also think that it's closer to what seems maybe feasible.

Erin Welsh

Yes.

Erin Allmann Updyke

Although I do stress that we're not there yet.

Erin Welsh

It's so interesting because I think that given the past 150 years of scientific research, we tend to view things as science will always progress at an increasing rate, right.

Erin Allmann Updyke

Yeah.

Erin Welsh

We make bigger leaps and bounds in our understanding and in our technology and so on. And that's not necessarily the case I think with every field.

Erin Allmann Updyke

Yeah. It is really, really interesting to read a lot of this research and then also read the media reports about this research or about the companies that are funding this research.

Erin Welsh

I bet.

Erin Allmann Updyke

Because it's very different, right.

Erin Welsh

Yeah. This is where reading between the lines of popular news articles is tricky.

Erin Allmann Updyke

It's tricky.

Erin Welsh

Have a heavy dose of skepticism and go to the original text.

Erin Allmann Updyke

Yeah, definitely. But there are I will say a lot of researchers out there that are trying to really get into the nitty gritty of answering those first couple of questions that I posed. How and why do we age and can we alter this process? So while we don't have a single answer I will link to a couple of different papers that go into a lot more detail on these mechanisms. But we can define based on what we know so far about nine different flavors or nine different targets that are related to aging and potentially modifiable at least in cell culture and/or in animal models or maybe just theoretically modifiable. So I'll mention all of these but spoiler alert, reading some of the papers that go into detail on this, I had a very difficult time following through. But let's at least look at what we know about aging because it turns out we know a lot more than you might think.



So when we look at the mechanisms of aging, one of them Erin you mentioned already and that is damage to our DNA, be that nuclear DNA or mitochondrial DNA. Basically over time insults to our bodies result in the inability of our bodies to properly repair damage to our DNA the way that it is supposed to. And there are a lot of different potential genes involved in this and specific mechanisms that researchers have altered in flies or in worms or just in cells. But essentially this genomic instability does play a really big part in the process of aging. So if there was a way to make our DNA more easily able to repair itself, that could then delay that process of aging. And we know delay a lot of the age-related diseases that are related to this like cancers, like maybe heart disease. There's also telomere damage. Telomeres I think we talked about in our HPV episode. Was that right?

Erin Welsh

You talked about it in some episode but can you do a refresher?

Erin Allmann Updyke

Of course, I'd love to. So telomeres got a lot of press in aging a while back but basically they're the end caps of our DNA. They're these strings of repeat DNA that sit at the ends of our chromosomes and in a lot of cases they don't get completely copied over when our cells divide. So over time telomeres can become shortened and this process of telomere shortening or telomere exhaustion then leads to a decline in the regenerative capacity of tissues and therefore accelerated aging. So in mice models and in other animal studies, telomere length has been shown to be associated with lifespan. In humans it's not quite that simple but this is at least another potential target.

Erin Welsh

What do you mean it's not quite that simple?

Erin Allmann Updyke

It's not like the length of your telomeres determines how long you're going to live, it's not a 1 to 1 association. So just adding on to our telomeres doesn't necessarily mean that we're going to increase our lifespan or our healthspan because this is one of nine processes related to the aging process.

Erin Welsh

Nine that we know of so far.

Erin Allmann Updyke

Okay, there's more. Lots and lots of research right now especially by some of these big biotech companies into epigenetic modifications. Epigenetics we've only ever briefly mentioned but I actually think I talked a bit about it in our folate episode, it was kind of fun. Callbacks.

Erin Welsh

I was thinking that, yeah.

Erin Allmann Updyke

Basically epigenetics are changes to DNA patterns that are not within the DNA itself, so not within a gene. But it's changes to things like methyl groups that are attached to our DNA. It's changes to things like histones which are the proteins that our DNA wraps itself around. It can be changes to how our DNA is stored. Any of these changes are considered part of epigenetics and changes in a number of different things from methylation to histone proteins have been shown to be associated with aging. There is a family of enzymes called Sirtuins, I think that's how you pronounce it, that are involved in DNA methylation and got a lot of press because in yeast and in worms, when these enzymes are manipulated then you can increase lifespan by significant amounts in a worm. Again in humans we don't have any data to show that as of yet. But that's at least the idea that epigenetics likely plays a big role in the process of aging. So if this is something that we could target, we could may be affect it.

Yet another target would be proteostasis. So basically ourselves are both DNA and proteins, right. So as we age our cells become less able to maintain proteins in the correct stable configurations and correct functionality. If you think of something like Alzheimer's disease, this is largely a disease of protein misfolding. So there are a lot of studies in cells in yeast and I think at least some in worms and flies that if you mess with some of the genes related to protein stability then you can precipitate aging, make them age faster. So that suggests that these systems are directly involved in the process of aging and thus if they could be manipulated in the opposite way could perhaps promote longevity or reverse aging.

Erin Welsh

Reverse aging. Interesting.

Erin Allmann Updyke

Yeah. There's more, I'm only on number four of nine.

Erin Welsh

Oh my goodness.

Erin Allmann Updyke

I don't have as much detail on all of them, let me tell you. There's also the idea and I think this one has gotten probably the most press very recently or at least maybe just the most press that I read. But it's this idea of as we age we have a deregulated ability to do nutrient sensing. Basically our bodies are not able to tell as we age if we have an abundance of food or if we have not enough food. And this goes along with a lot of data in mice and in some primates of caloric restriction, so having less food for a portion of your life increases lifespan in a lot of animal models. So there are a lot of different host factors that are implicated as a possibility in this. Some of them are things you've definitely heard of like insulin, right. Or IGF1, insulin growth factor one. There are a lot of others like mTOR, AMPK, Sirtuins are an AMPK.

These are all various fancy names for factors that our body uses to help signal to our brain when there is food that needs to be digested vs when our nutrient stash is very low so we need to engage in catabolism, break down our own stores instead of building a bunch of muscle and fat. So there's evidence to suggest that states of anabolic signaling, that is our body saying hey, we've got a lot of food, we need to build up stores. That process accelerates aging at least in mice and so manipulating this signaling so that a mouse's metabolism thinks it's living under limited nutrients by manipulating some of these factors can extend longevity.

Erin Welsh

Interesting. So that's what is meant by caloric restriction is manipulating the factors not straight up caloric restriction?

Erin Allmann Updyke

No, straight up caloric restriction means straight up caloric restriction.

Erin Welsh

Okay.

Erin Allmann Updyke

This is trying to get out a way of can we trick our bodies into thinking that we're living calorically restricted but we don't want to live calorically restricted.

Erin Welsh

What is the mechanism for caloric restriction increasing longevity and what does caloric restriction mean?

Erin Allmann Updyke

Great questions. So caloric restriction in animal models means reducing an animal's nutrient intake to about 30%-40% of what is typically considered necessary for the amount of calories that a mouse needs. So it's very, very restricted. I want to be extremely clear on here that I am not by any means recommending this for human beings. This could be very dangerous, okay. But in mice, restricting them to that very small amount of calories, 30%-40% of what would normally be needed does increase lifespan. And it also increases the age at which animals are able to reproduce if that makes sense.

Erin Welsh

It increases how long you are reproductively viable?

Erin Allmann Updyke

Well no because um these animals tend to not be able to reproduce while they're living under caloric restriction but then they get to an age where normally a normal mouse at say this many months of life would no longer be able to reproduce, this mouse who's been calorically restricted now can reproduce if you start feeding them. It's kind of amazing.

Erin Welsh

Okay but if the mouse is only consuming 30%-40% of what is considered necessary for it to live, how is it living?

Erin Allmann Updyke

Well so that is the idea behind all of these factors. Basically the thought is that in so doing, in restricting these calories you're altering the way that the body is metabolizing everything in a way that is promoting catabolism, so that breaking down of our own body stores rather than anabolism, the building up of our muscles, the building up of fat stores. Right? So that's the idea behind why caloric restriction works. We know from animal model studies from a long, long time ago that restricting animals' diets makes them live a longer time. These genes and these factors and these hormones that have been identified seem to be the possible mechanistic way that caloric restriction manifests. So if we could directly affect those mTOR or insulin or what have you, then we could trick our bodies into breaking down stores rather than building fat and that might make us live longer. That's the theoretical idea behind it.

Erin Welsh

Interesting.

Erin Allmann Updyke

Yeah.

Erin Welsh

It kind of reminds me of going back to the evolutionary hypotheses, that germ soma theory.

Erin Allmann Updyke

100%.

Erin Welsh

Where it's like the germ line is always favored but maybe here's the exception where if the soma line can't support the germ line, then the soma line has to be favored first.

Erin Allmann Updyke

Exactly. I think that is a good way to kind of piece those together,

Erin Welsh

Interesting, okay.

Erin Allmann Updyke

There's a few more but I will say I'm not going to go into quite as much detail because from what I read the topics that I've already covered are maybe the ones where we're a little bit farther along in that we have data from animal models and from cell models to show that manipulating these various things, be they nutrient sensing or protein stability, can affect aging. The other ones are a bit more theoretical still at least from what I read. And apologies if someone has some great data that I didn't see on these last few topics.

Erin Welsh

Send it our way if you do.

Erin Allmann Updyke

Yeah, I would love to read it. So another possibility is the idea of mitochondrial dysfunction. So our mitochondria are often called the powerhouse of our cells. They do a lot for our bodies and the idea is that over time just like our DNA in our nucleus, these mitochondria can just sort of not function as well anymore. This is thought to be very related to things like oxidative stress over time. That's all I got for you on mitochondrial dysfunction related likely to the process of aging.

Erin Welsh

Okay.

Erin Allmann Updyke

There's also just the idea of cellular senescence in general, cells going quiescent over time. A lot of our cells in our body are not dead but they no longer divide, they're no longer active. So there's a large thought that just this entire process of cells kind of turning off a lot of their activity then relates to aging and it's likely protective to reduce the amount of DNA damage that might occur through the process of replicating cells that don't need to be replicated, etc. So this might be something that's more related to protection against aging rather than involved in the process of aging, like protective against it.

Erin Welsh

Yeah, yeah. Okay.

Erin Allmann Updyke

Then there's the idea of stem cell exhaustion which I again didn't get that much into detail of but the idea that our stem cells are the ones that aren't able to keep up the way that they need to to be able to produce more cells correctly, like the basal layer of our skin cells are stem cells that can become any various type of cell. But as insults occur to these stem cells then hence the process of aging. And finally there is also this thought of defective or diminished cell to cell communication. And there's a lot that probably goes into this. One that I think is interesting and I didn't full disclosure actually read any papers by him but I watched a TED Talk of this researcher named Michael Levin who is a researcher at Tufts University and does really interesting research on cell-cell communication from a bio electric field perspective. Right? It's very, very interesting.

But there's also a lot of other ways that our cells communicate with each other besides potentially a bio electric field. But I will link to that TED Talk because it's fascinating. And it's likely that this process over time also becomes defective and is involved in the process of aging. That was a very fast speed through and I know that I left a lot of detail out. I will cite a couple of papers, one from 2013 that's a few years old now but another that is a summary of a 2021 symposium of gerontologists that has a lot more detail on these nine different processes and where we kind of stand in terms of in vitro cell data, animal model data, and human data. But the thing is I think it's very clear just by going over all those various processes that these are all very interconnected.

Erin Welsh

Right.

Erin Allmann Updyke

Especially when we talk about humans, it's not one single piece. All of these processes are likely at play and we are not at a point where we can say that we have an answer or a drug or an intervention at all that can prolong our life in any meaningful way. We don't even have one that could likely prolong our health, at least not yet. So really for me what it comes down to is that forever is a very, very long time. So do I think it's possible that humans will ever unlock the many locks between us and immortality? No, I will say no.

Erin Welsh

Yeah, it doesn't seem likely.

Erin Allmann Updyke

It doesn't. Do I think that it could be theoretically possible this concept of immortality? I kind of don't, Erin. Do you?

Erin Welsh

No but I will say that also what occurred to me while listening to you and while thinking about the part that I went through is that maybe this is one of those things where in the future, in the distant future if anyone ever stumbles across this podcast and they'll just laugh at how naive we were and how unbelieving we were.

Erin Allmann Updyke

I know. Yeah. Maybe.

Erin Welsh

Maybe. I similarly doubt it. And I think that's another thing too is that immortality is not what people are working on.

Erin Allmann Updyke

Exactly.

Erin Welsh

It's how it's being sold.

Erin Allmann Updyke

Yes. And one of the things that I think is really interesting in reading from the gerontology perspective is that I do think that a lot of the research into these questions of how does aging happen and can we manipulate those processes, this research can be used to improve the lives of humans. And I do think that it could potentially increase our healthspan and delay the onset of all these various aging-related diseases. But what's interesting is that we tend to study all of these various age-related diseases, cardiovascular disease, cancer, Alzheimer's disease, we study these diseases in isolation.

Erin Welsh

That's such a good point.

Erin Allmann Updyke

And aging itself is not considered a disease. So you cannot study it from an applying for NIH grants perspective or from a drug development perspective, you cannot study it in the same way that you can study diseases.

Erin Welsh

That is very interesting.

Erin Allmann Updyke

It really is because it also means that the funding is not actually being directed towards aging, the funding from the government is being directed towards addressing these diseases that we think maybe could be preventable, right. But if we think that these are interrelated diseases that are all part of the process of aging, then wouldn't it make more sense to address them from a wider perspective by addressing these underlying mechanisms rather than addressing cardiovascular disease or diabetes itself and cancer itself? Let's think about these things that underpin both of those or all of those. And so I think that that's kind of the argument of a lot of the people who do this type of research and I think it's really valid. And maybe that's the gap that some of these biotech companies are filling by directing their funding to address that. I don't know, maybe that's an optimistic view but maybe.

Erin Welsh

That's a really good point. And I know that a lot of epidemiological studies will look at all of these things together but there are so many different avenues of research and it does seem like aging is super multifactorial.

Erin Allmann Updyke

Right.

Erin Welsh

A lot of these diseases are super multifactorial but they are siloed diseases.

Erin Allmann Updyke

Right, exactly.

Erin Welsh

Yeah.

Erin Allmann Updyke

I also think it's important to point out, like you mentioned Erin, there are a lot of other in my mind ethical and moral concerns related to this idea of pursuing an increased lifespan or healthspan in thinking about the state of our planet and climate change and how we've impacted our planet with the lifespans that we currently have. And also in like you said, where is this development and technology going to go? Who is going to benefit from it? Because the increase in lifespan that we've seen in the last 50-100 years hasn't been even across the board.

Erin Welsh

No.

Erin Allmann Updyke

And people who are wealthy live much longer than people who are not wealthy. And so that is likely going to continue to be true, especially if all of the research being done on this is from a capitalistic perspective of companies trying to make money off of it. I don't know.

Erin Welsh

Yeah. I mean anti aging is one of the world's biggest industries.

Erin Allmann Updyke

Yeah, definitely. It really is.

Erin Welsh

And I'll repeat again, not a single anti aging product has been shown to actually slow stop or reverse aging in any capacity.

Erin Allmann Updyke

Right, yeah. Diet and exercise, Erin.

Erin Welsh

Diet and exercise. Yeah.

Erin Allmann Updyke

Listeners, do you think you'd want to live forever? I'm curious.

Erin Welsh

I'm curious. And if so why?

Erin Allmann Updyke

Why? Or why not?

Erin Welsh

Or why not?

Erin Allmann Updyke

Yeah.

Erin Welsh

Should we do sources?

Erin Allmann Updyke

Yeah.

Erin Welsh

I have a bunch but I'm going to shout out two books in particular that I found really helpful. So in terms of the evolution of senescence and the evolution of aging, there is a book by Shefferson et al or a bunch of editors titled 'The evolution of senescence in the tree of life' and that's from 2017. And then the book that I already mentioned by Stephen Cave, 'Immortality: The quest to live forever and how it drives civilization'. And those are both really, I just really enjoyed the Stephen Cave book as an interesting way to look at immortality.

Erin Allmann Updyke

I had a couple that I enjoyed, those two that focused on the various hows of aging were a paper from Cell in 2013 titled 'The Hallmarks of Aging' as well as a symposium report from the Annals of the New York Academy of Sciences from 2022 titled 'Extending human lifespan and longevity: A symposium report'. I also thought an important one to mention is a paper from 2021 called 'Longevity leap: Mind the healthspan gap' and then there's a bunch more so I'll link to them on our website [thispodcastwillkillyou.com](http://thispodcastwillkillyou.com) under the EPISODES tab.

Erin Welsh

Thank you to Bloodmobile for providing the music for this episode and all of our episodes.

Erin Allmann Updyke

Thank you to the Exactly Right network of whom we are proud to be a part.

Erin Welsh

And thank you to you listeners. I really hoped that you liked this one.

Erin Allmann Updyke

Yeah, I hope so too. And a special thank you to our patrons as always, thank you so much for supporting us.

Erin Welsh

Yeah. Well Erin, happy 100.

Erin Allmann Updyke

Happy 100.

Erin Welsh

And until next time, wash your hands.

Erin Allmann Updyke

You filthy animals.