April

My name is April and this is my story on when I got bent. So I discovered scuba diving almost a dozen years ago. Like anyone else who first gets into the sport, I first started off by taking an initial open water class. Immediately I fell in love. I was completely hooked and diving has been a huge passion and part of my life ever since. After taking open water, I went on to train and gain additional further certifications such as advanced, dry suit, master, wreck, rescue, dive master, and on and on til I ultimately gained my certification to be an assistant instructor. I love wreck diving and northeast wreck diving has been an ultimate for me. After spending some time diving off of some of the local boats in the Long Island area I started working as crew on one of them and over the years I've wound up crewing on a few different boats, with my current and most recent being a boat in New Jersey for the last seven years.

Being able to spend my weekends out on a boat out in the middle of the Atlantic with a fabulous bunch of people, diving these amazing shipwrecks that are scattered all throughout the sand at the bottom of the ocean was absolutely what I wanted to do every chance I had. On my current boat annually there's a trip held where our boat moves from northern New Jersey down south to Cape May and we spend a week diving the different wrecks down in that area. Always, always a great time. After doing that trip, working as crew on that trip consistently for five years in a row, I decided the next time I wasn't going to work and I would go as a paying passenger in order to be able to completely enjoy my time and not have to worry about the work responsibilities.

Last year, July of 2021, I was on this trip and on this particular day we were visiting a sunken Navy submarine, a dive I've done every year for the last five years with no problem at all. It was always easy, always fun, so I thought at the time. When I first splashed off the stern of the boat I remember one of my ears bothering me as I was trying to descend, a bit of an ear squeeze. After working that out I eventually made it down to the sub. As we were tied into the stern of the sub I easily began making my way swimming the length toward the bow of the sub. And this is where things start to get super fuzzy as my recollection of these events are super unclear and super fragmented. At the bow I swam just a bit off of it to go look at something I saw in the sand. When I turned around to go back, the sub was gone.

Visibility underwater wasn't great but it wasn't horrible either, but either way I still lost sight of the sub. From my memory I began to ascend a few feet hoping to see it, hoping to catch the sight of the blinking strobe light that was tied onto the anchor line so I'd know which way to start swimming and which way to be able to head home. I saw nothing. I decided to ascend even further, just a few more feet in my mind. But again I still saw nothing. Though not thrilled with myself with the fact that I may have just got myself lost in the middle of the Atlantic Ocean, I felt like I was still in control, not panicked, I knew what I was doing, but that was not the case at all.

My next memory was of me being at the surface seeing the boat off in the distance. I was completely exhausted and I remember I kept telling myself just kick, just kick, legs keep kicking, just keep swimming and get back to that boat. My legs weren't kicking. My very last memory of being in the water I saw a couple of people notice me, they saw me out in the ocean just floating and they saw me come up where I wasn't supposed to come up which was on the anchor line. I saw myself a bit of an out of body experience. I saw myself actually swimming to the boat, making it to the ladder, climbing the ladder, and getting myself safe onto the deck. And I remember just thinking I'm okay, I made it. And then I went unconscious.

Next thing I know I start waking with a face mask smothering my face and oxygen being pumped into me and all of these different voices yelling at me, calling my name, telling me to wake up, open your eyes. I slightly started coming to and had no idea what was happening. All I knew was that I wanted all of these people just to stop yelling at me and get off me. I obviously knew something was wrong with me but at the time I didn't know how bad it was. Then I started feeling it. From the very bottom of my feet it started working so I up my leg, it felt like I was on fire. My feet felt like they were on fire and then up to my ankles and then up my calves and upward and upward. I remember starting to yell my legs are burning, my legs are burning, they're on fire! I knew I was in trouble. I finally stopped struggling and let whatever was going to happen happen. That's when they told me the Coast Guard was on its way.

So almost 50 miles off the coast of Cape May a helicopter was dispatched from Atlantic City to medivac me off of that boat. It was quite the scene. From the coast they're repelling down the line to the deck of the boat, trying to talk to me at this point though I was too out of it to be able to respond, to the basket being lowered to the deck, me being put in it, hauled back up to the helicopter, and the coastie on the deck being boarded. And then away we went. On the helicopter I began to feel it even more. The pain, the nausea. I began to uncontrollably vomit. I thought that what would happen was that the Coast Guard would eventually fly me back to their station, have me checked out, my captain and the boat would obviously be cutting their trip short in order to have to come get me. I just figured the captain would be mad, he'd slap me on the wrist, maybe give me a hard time for a bit but then all would be good. Again, not the case.

After flying for quite a bit I managed to ask the coastie attending to me where we were going. 'Ma'am, we're taking you to UPenn in Philadelphia. We need to get you to a chamber.' Things were getting fuzzier and fuzzier, I barely remember landing at the hospital. I slightly remember being on a gurney and pushed down and through the hallways to get me to where I needed to go. I was surrounded by half a dozen people, my coastie in front of the gurney leading the way with the doctor. We eventually stopped. I was being asked a lot of questions, none of which I really remember anymore. Next memory is of me inside the chamber with a nurse tending to me for six hours. This happened for the next three days. Still sick and vomiting the whole time, I was down 25 lbs by the end of it all.

There was a lot wrong with me, but the worst of it was that I ended up having spinal damage from the bubbles that entered my spinal column. I ended up being paralyzed from the waist down. I really everyday wondered if I'd ever be able to walk again. But happy to report after starting to get a bit of feeling in my lower extremities, a lot of treatments, a lot of work, I mean a lot of work, a lot of physical therapy, that I am walking again. Not perfect, not completely balanced yet but at least I'm walking. This accident happened late July of 2021 and I barely finished the last of my treatments this past June, just a couple of months ago. It's been a year of a lot to get me through this. Even though as hard as this was physically on my body, the truth for me is that it's actually the mental part of this whole experience that has been the absolute toughest. I'm still in therapy for it.

I could go to physical therapy, I could exercise at the gym, I could work out with a personal trainer, I could do any training plan you want, nutritional plans, eat right, I'll do whatever you give me, anything that I need to. But you can't stop the bad thoughts, you can't stop the being scared, you can't stop the nightmares, you can't get back that lack of confidence, you can't stop the anxiety and the panic attacks. I have been diagnosed with PTSD. So as of today we still don't know what went wrong that day of my dive. My memory of what happened that day conflicts with eyewitness reports. Others are saying they saw me at different places on the sub. Somebody said they saw me halfway back up the anchor line. Somebody else said they saw me at the surface of the water, at the bow of the boat and that I apparently descended back into the ocean. I don't remember any of this.

	I've also talked to a lot of doctors and specialists in the industry about what happened and I've got a lot of different opinions on it. Maybe it was carbon dioxide, a build up, maybe I got narced, it was nitrogen narcosis. Perhaps it was a bit of vertigo from the ear problem when I first splashed. Perhaps just a perfect storm of all of these. I'll probably never know. I would like to know for the sake of being able to share my experience and hope that nobody goes through it like I did but at this point I don't really care if I don't know, I'm just kinda happy to be alive and walking again.
TPWKY	(This Podcast Will Kill You intro theme)
Erin Welsh	Oh my. It is so terrifying.
Erin Allmann Updyke	It's so scary. Oh my goodness.
Erin Welsh	Wow. Jeez, yeah. Thank you so, so much April for being willing to share your story with all of us.
Erin Allmann Updyke	So much. Yeah, I can't imagine that reliving that was easy. So thank you.
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 talking about the bends.
Erin Welsh	The bends.
Erin Allmann Updyke	The bends.
Erin Welsh	It's not our usual fare.
Erin Allmann Updyke	It's not.
Erin Welsh	But I think it's one of my favorite topics that we've researched this season.
Erin Allmann Updyke	Ooh that's exciting.
Erin Welsh	Yeah, I hope you find my section interesting because yeah, we'll see.
Erin Allmann Updyke	I know that I will for a fact. I hope that I do a good enough job to explain the biology section especially.
Erin Welsh	I'm sure you will.
Erin Allmann Updyke	Or rather the physics section. But it's going to be a good episode I think.
Erin Welsh	I think so too. And to kick off every good episode is-

Erin Allmann Updyke	Quarantini time.
Erin Welsh	It's quarantini time. What are we drinking this week?
Erin Allmann Updyke	We're drinking Under Pressure. (hums Under Pressure by Queen) Is that a copyright issue?
Erin Welsh	I hope not. Very well done.
Erin Allmann Updyke	Thank you, thank you.
Erin Welsh	I think it's fair use.
Erin Allmann Updyke	Yeah, I've been practicing it all day.
Erin Welsh	It paid off.
Erin Allmann Updyke	Under Pressure.
Erin Welsh	Under Pressure might be one of our simplest quarantinis to date, although I feel like we've been doing that a lot lately.
Erin Allmann Updyke	We got to sometimes.
Erin Welsh	Hey, past 100 episodes it's difficult to come up with new recipes all the time. And so in Under Pressure it is simply like a whiskey and coke.
Erin Allmann Updyke	Yeah, just a fancy whiskey and coke.
Erin Welsh	Yeah. You make it fancy by adding some lime juice and a sprig of mint.
Erin Allmann Updyke	Make it fancy.
Erin Welsh	Make it fancy.
Erin Allmann Updyke	And we'll post the full complicated the recipe for that quarantini and our nonalcoholic placeborita on our website thispodcastwillkillyou.com.
Erin Welsh	We certainly will. And for anyone who is diving you probably want to stick with the nonalcoholic placeborita.
Erin Allmann Updyke	Definitely, definitely.
Erin Welsh	And on our website, I feel like I haven't done the website spiel in a while.
Erin Allmann Updyke	Yeah.

Erin Welsh	You can find transcripts, you can find links to Bloodmobile, our music, to our bookshop.org affiliate account, to our Goodreads list, to our merch, to Patreon. We've also got for each episode all of our sources for every episode. There's probably more stuff on there but that's all I can think of.
Erin Allmann Updyke	I loved it, that was a great job Erin.
Erin Welsh	Thank you. All right, should we get started?
Erin Allmann Updyke	Should we dive in?
Erin Welsh	I can't believe I missed that. Thank you. Absolutely. Right after this short break. That was really good.
TPWKY	(transition theme)
Erin Allmann Updyke	So the bends. The bends, the name the bends is actually just one kind of manifestation of what is known as decompression sickness or DCS. Related to decompression sickness though technically different in its pathophysiology are various other forms of barotrauma, trauma associated with pressure changes, including one that you probably came across in your reading Erin that is arterial gas embolism. And when you combine these two things, decompression sickness and AGE or arterial gas embolism, those are often altogether referred to as decompression illness. I feel like it makes it a little more confusing but alas.
Erin Welsh	Yeah, it's kinda sus.
Erin Allmann Updyke	And so today in this biology section I'm going to talk about both decompression sickness and AGE and mostly in the context of scuba diving since that's maybe the most common place that listeners and other people may have had the chance of encountering these various decompression illnesses. But it's important to know, and I know you'll talk about Erin, that these are decompression-related illnesses, meaning they can happen from a lot of forms of pressure changes including other types of work in a compressed air environment as well as in aviation or aerospace industries. So it's not just scuba divers who are at risk. But do forgive me that I'm mostly going to use diving as my examples.
Erin Welsh	That's so funny because I barely talk about scuba.
Erin Allmann Updyke	Oh how fun.
Erin Welsh	Yeah.
Erin Allmann Updyke	It's just an easy example when we talk about the pressure changes.
Erin Welsh	Oh for sure. Yeah.
Erin Allmann Updyke	Yeah. And so I will talk about both DCS or the bends and AGE at least a little bit. But I think to understand both of those or either of those, we have to first remind ourselves of some basics of gasses and liquids and pressure and the different ways that gasses behave with pressure. Okay?
Erin Welsh	Yeah. This is reaching far back for me.

Erin Allmann Updyke	I know. It's truly mostly just physics so I'm going to do my best. So when we, the collective we, are standing at sea level on land which I am currently, you're not Erin.
Erin Welsh	No.
Erin Allmann Updyke	We are subject to a certain amount of atmospheric pressure. The air is exerting a certain amount of pressure on our bodies. At sea level, at 59°F or 15°C, it happens to be that we are under one atmosphere of pressure. That's the unit. It's 760 mm of mercury. Okay, who cares. As we ascend say a mountain as you live on top of Erin-
Erin Welsh	The mountain of Denver, yes.
Erin Allmann Updyke	I mean it's up there.
Erin Welsh	It is.
Erin Allmann Updyke	As altitude increases, the pressure of course drops. This is why your ears pop on a plane because the pressure inside your ears is suddenly higher than the pressure outside your ears, so you have to equalize this pressure. Now as we dive for example underwater, the amount of pressure increases and it turns out that it increases by a lot. For every 10 meters of depth, so about every 33-ish feet that you go down, the atmospheric pressure increases by one atmosphere, which is again the amount of pressure that you're under at sea level. So in that first 30 ft of say diving, you literally double the amount of pressure that your body is under. And the reason that all of that is important is that it comes back to a handful of laws of physics which are all named after old dudes but that deal with the particular ways that gasses behave with these changes in pressure as well as temperature. So let's get into it. You may or may not remember from chemistry or physics class-
Erin Welsh	Probably not.
Erin Allmann Updyke	This part you might remember, the volume of gas in any given space is directly related to the amount of pressure that it's under. So if you take a volume of gas, call it V, and you double the amount of pressure that it's under, the volume of that gas will be reduced by half. And the same is true in the opposite direction. If you take a volume of gas V and you decrease the pressure by half, then you double the volume of gas. And this is not only like an underpinning of all of physics but it's also an important thing to know in the context of diving or any other hyper or hyperbaric exposure. So as an example, where Erin do we have a fair amount of gas in our bodies?
Erin Welsh	Our lungs.
Erin Allmann Updyke	Our lungs, absolutely. So if you have a volume of gas in your lungs and you take a big breath and you dive down to 10 meters, again 33-ish feet, that volume of gas in our lungs is now half the volume it was at the surface because we doubled the pressure on our bodies. But if you're diving all the way to 10 meters, then you might be scuba diving. So once you get down there you can take a breath from your regulator and you can refill your lungs back to that volume V. Okay? You're doing fine. But then if you ascend, if you pop back up to the surface, that volume in your lungs is going to expand again as the pressure decreases back to atmospheric pressure and that increasing volume in your lungs has to be able to escape. If you breathe out as you go up, if you exhale, then that's fine, that volume of gas has somewhere to go. But if you don't, for example if you're holding your breath, then that gas has nowhere to go and instead can burst forth from the tiny alveoli trying to contain it and cause mechanical damage to our lungs.

Erin Welsh	Oof, yeah.
Erin Allmann Updyke	Yes. Now this is one form of barotrauma, this is not the bends but I do think it's important to understand because not only is it a form of barotrauma that can happen, but this is the mechanism by which air gas embolism can happen.
Erin Welsh	Okay.
Erin Allmann Updyke	Because as air bursts forth from those alveoli, it can enter the arterial circulation, right, because it's going from our lungs, now it can enter the left side of our heart, get into our arteries, and potentially go up to our brain and that's what causes an air gas embolism which can be catastrophic.
Erin Welsh	Terrifying.
Erin Allmann Updyke	Yep. These emboli, these little air bubbles that can make it into your arterial circulation, don't only go to the brain but it is kind of the most catastrophic place that they can go. And barotrauma can happen in other air-containing structures like our ears or our sinuses, so it's kind of just important to understand this relationship between pressure and volume of gasses. But this episode is about the bends. Air gas embolism is within the spectrum of these decompression illnesses and I think that pressure volume relationship is important but that's the end of that story. And now we get a little bit more into the weeds of the bends because it turns out that the pathophysiology is entirely different even though that pressure volume relationship is still really important within the bends. Okay, let me tell you. So when we breathe in air for example, air is about 78% nitrogen and about 21% oxygen. This air that we breathe at all levels of pressure makes its way into our alveoli, those little grapes in your lungs that can be exploded like we just talked about.
	Some proportion of that air that we breathe into our alveoli diffuses across our capillaries and into our bloodstream. And as it does this it becomes dissolved in solution. That is the normal physiologic process. So oxygen that we're breathing of course is very important to diffuse and become dissolved in solution because that's what we deliver to our tissues, that's what we use for metabolism. But the nitrogen and the carbon dioxide and everything else in the air, some proportion of these gasses as well that we breathe also become dissolved in our bloodstream and make their way into the various tissues in our body. That's normal. Now the proportion of the various gasses, nitrogen, oxygen, etc, that do this, that become dissolved in solution, are equivalent to the pressure of that gas in our alveoli in our lungs. And that pressure, how much pressure it exerts, will be dependent on both the overall pressure that our body is under, what's the atmospheric pressure around us, and the proportion of that gas in particular, that particular molecule in the gas mixture that we breathe.
Erin Welsh	Right.
Erin Allmann Updyke	So at sea level atmospheric pressure is the pressure that we're breathing under and the mixture of gas that we're breathing is air, 78% nitrogen, 21% oxygen. That all makes sense, right?
Erin Welsh	Right.

Erin Allmann Updyke	And then in our tissues, the sum total of all those partial pressures of all the various gasses has to equal the total ambient pressure that our body is under. And these pressure differentials are the forces that are driving each individual gas molecule, be it nitrogen or oxygen, into solution. And that's just what happens all the time whenever you're breathing, you just never thought about it. Your body is doing amazing chemistry.
Erin Welsh	I'm thinking about breathing now and I'm feeling myself breathing now. And yeah.
Erin Allmann Updyke	It's a weird feeling, isn't it?
Erin Welsh	Uh huh.
Erin Allmann Updyke	So as we say dive underwater, several things are going to start to happen. First of all, the ambient pressure around us is increasing like we talked about. So your body might be like, 'Hey, I need to think about equilibrating with some different pressures.' But a second thing is also happening when you are breathing air at this depth, like when you're scuba diving. And that is that the air that we're breathing is also becoming compressed because pressure volume. So as we dive deeper, you are essentially breathing in more molecules per breath. So more of this gas that we are breathing will be dissolved in our tissues because the pressure increases.
Erin Welsh	Gotcha.
Erin Allmann Updyke	Now oxygen our bodies will continue to use. So that's fine. We've got a higher partial pressure of oxygen, we'll keep using it. But nitrogen is an inert gas which means our bodies don't use it directly. So as it dissolves in our tissues at these deeper depths, we just become more saturated with nitrogen, we just have more nitrogen in our tissues. Now this process itself is not necessarily inherently dangerous, although as you heard about in our firsthand account and many divers will be well aware, there is something called nitrogen narcosis that can happen at depth that results in altered consciousness and potentially altered behavior as a result of breathing very high levels of compressed nitrogen at very deep depths. But that's kind of a story for another time and doesn't have much to do with tissue perfusion per se.
Erin Welsh	Is there like a one sentence why you could tell me?
Erin Allmann Updyke	As far as I could tell we really don't fully understand the mechanisms behind it.
Erin Welsh	Okay.
Erin Allmann Updyke	Except that it's the breathing of highly compressed nitrogen at these very high pressures.
Erin Welsh	Okay.
Erin Allmann Updyke	Yeah. But maybe a whole other episode, Erin.
Erin Welsh	Yeah. I'd be down.

Erin Allmann Updyke	But in general this is just kind of a law of physics that you are going to increase the amount of nitrogen in your tissues. The problem arises as we begin to ascend. As the pressure decreases, now all of a sudden our tissues are supersaturated. So the amount of gas, especially nitrogen because we've used up the oxygen and we're breathing off the carbon dioxide, but all this nitrogen in our tissues is now at a higher total pressure than the ambient pressure around us. And so this gas can no longer stay in solution in our tissues. It has to come out of solution in the form of bubbles. For anyone for whom that's still confusing because physics and chemistry were so long ago, here's the best possible analogy.
	A two liter bottle of soda. Okay? This is why our drink is just a whiskey and soda by the way. A two liter bottle of soda is under pressure. And in that soda liquid is carbon dioxide gas in solution. When you open the top of that bottle you force the pressure to equilibrate with our outside atmospheric pressure and all of a sudden the pressure in the bottle drops and that carbon dioxide can't stay in solution. So what does it do? It comes out of solution in the form of bubbles or fizz. That is what is happening inside of our bodies when it comes to DCS, decompression sickness or the bends. That's what's causing the bends, when nitrogen comes out of solution in our tissues and in our bloodstream.
Erin Welsh	It's so scary to think about because it just seems like these tiny little missiles doing tons of damage everywhere.
Erin Allmann Updyke	That's a very, very good way to think about them. Now where exactly these bubbles form, when exactly these bubbles form, and what those subsequent symptoms are. It turns out to be a lot more complicated than just that simple physics but it is that simple physics that drives the whole pathophysiology of DCS.
Erin Welsh	I have a few questions.
Erin Allmann Updyke	Okay.
Erin Welsh	So the effect of this is not uniform across different tissues in the body. And I read that tissues that contain more fat for instance, it diffuses at different rates or whatever. Why is that? What does fat have to do with it?
Erin Allmann Updyke	Great question. Fat is more soluble to nitrogen. So nitrogen has different solubilities in different tissue types.
Erin Welsh	Okay.
Erin Allmann Updyke	And so essentially just the distribution of tissue types in your body and whether you have more fat tissue or less fat tissue as well as just the difference between say nerve tissue, muscle tissue, bone tissue, nitrogen is going to make it into all of these tissues but it's going to diffuse into and diffuse out of all of these various tissues at slightly different rates.
Erin Welsh	Right, okay.
Erin Allmann Updyke	Yeah.
Erin Welsh	And so that partially drives why we see such variation person to person and also within your body?

Erin Allmann Updyke	Yeah Erin. There is so much variation person to person. That's certainly one of the things that can drive it. There's also intraperson variability where people might do the same dive many, many times and only get the bends on one dive.
Erin Welsh	Why?
Erin Allmann Updyke	Yeah. All of that is really good questions. We really don't fully know. So these bubbles form because of these changes in pressures. And yes, there's differences in our tissue solubility. But what is the kind of nucleus for this bubble formation? It's still not entirely clear. And so some people might just have a tendency because of whatever their differences in anatomy or their individual physiology to make more bubbles to be high bubblers compared to other people who are maybe low bubblers, even if those two people are doing the same dives. It's really, really interesting.
Erin Welsh	Yeah. Okay tell me about the symptoms.
Erin Allmann Updyke	Okay. So the symptoms can be really varied because like I said they essentially depend on where these bubbles travel and how exactly they're causing damage. So these bubbles can cause damage in a lot of different ways. They can cause mechanical damage, they can cause anabolic damage, they can cause damage within blood vessels, they can cause damage without blood vessels. So are they blocking venous blood flow and is that how they're causing symptoms? Those symptoms are going to look very different than if they're just distorting tissues and causing pain because of that distortion. Or if the bubbles have gotten large enough to actually damage, like break or tear various tissues vs just compressing important structures, right.
	Then on top of that you can have symptoms that result from damage to the lining of blood vessels which might cause leaky blood vessels, which then is going to cause a response in your individual body, right, inflammation. So how much inflammation is being generated because of all this damage? So, let's talk about what it really looks like. Classically, historically DCS was categorized into type 1 and type 2 with type 2 predominantly being considered neurologic and therefore more severe. There are also a lot of colloquial names for DCS like the bends and the chokes. And these different things usually are colloquial based on what the symptoms look like in different people.
Erin Welsh	Right.
Erin Allmann Updyke	But the truth is that none of these classification systems are really all that great because then there also sometimes is like mild type 1 or type 1 and mild type 2 vs severe type 2. And we don't really have good metrics on which type you are at risk for necessarily. Which is a whole other interesting aspect. But okay let me actually tell you what the symptoms are, sorry. So the bends or type 1 DCS, the reason that it got the name 'the bends' is because it's commonly joint pains.
Erin Welsh	Right.
Erin Allmann Updyke	So joint and muscle pains which can range from mild, like achey, painful, may be difficult to use, all the way to debilitating, you can't move your limbs because of how much pain you're in. And this generally happens from bubbles in the joint space or the bones or any kind of articular surface. So it's a lot of joint related pain. The chokes is respiratory decompression sickness and this is from damage to the lungs.
Erin Welsh	Okay.

Erin Allmann Updyke	So this can be a cough, it can be difficulty breathing, you can end up with quite a lot of fluid in your lungs because of damage to the endothelial, the lining of the blood vessels in the lungs. So this can be very serious if not potentially deadly. And then there is what was classically called type 2 or neurologic decompression sickness. And neurologic DCS can cause really any variety of neurologic symptoms, anything from paresthesias or abnormal sensation to numbness or weakness of various limbs or muscles. You can see a lot of dizziness. If you end up with DCS affecting the brain itself you can see confusion, you can see loss of consciousness, seizures. And while usually DCS is described as not having purely stroke-like symptoms, so not maybe like one nerve distribution of say facial drooping and left sided weakness like you would think of with a stroke, and that kind of emphasizes that neurologic decompression sickness is generally not an arterial disease.
	However arterial gas embolism and DCS can co-occur. So you could get both going on at the same time or they can also just be really difficult to distinguish from each other, to know is this DCS causing these symptoms or is this gas bubbles in the arterial system causing air gas embolism? So it is possible to have those more classically stroke-type symptoms. And then there are also a lot of cutaneous or skin manifestations of the bends which can be also really varied in terms of what the rashes look like or even can just be itching, which I think is really interesting.
Erin Welsh	Yes, I read that.
Erin Allmann Updyke	And one kind of classic rash that you might see is called livedo reticularis, it's this very lacey purplish rash that happens not just from the bends but it's from spasms of blood vessels that happen near the skin surface.
Erin Welsh	Whoa.
Erin Allmann Updyke	And so that is something that you can see with the bends.
Erin Welsh	Okay.
Erin Allmann Updyke	Yeah.
Erin Welsh	So with these various symptoms, how much variation is there in the timing of their appearance?
Erin Allmann Updyke	Excellent question. In general any and all of these symptoms will start within potentially minutes but certainly within hours of coming up to the surface if you're talking about a dive.
Erin Welsh	Okay. And so this is something where really because the symptoms are so varied, it's like the history that's going to be the first sign that something is wrong and you treat accordingly.
Erin Allmann Updyke	Precisely. And it is possible for these symptoms to be delayed even longer than a few hours but that usually would only happen under circumstances like for example if you got on a plane to fly the day after you were diving.
Erin Welsh	Oh okay.
Erin Allmann Updyke	So now you've kind of re-decompressionified yourself.

Erin Welsh	Right, right.
Erin Allmann Updyke	If that makes sense.
Erin Welsh	Yeah. That's why they say don't go on a plane soon after diving.
Erin Allmann Updyke	Yep, yeah. And then how long they last depends not only on how severe they are but importantly on how quickly someone is able to access treatment.
Erin Welsh	Yeah, I was going to ask recovery times or recovery degrees but I think the answer is it depends.
Erin Allmann Updyke	It so, so, so depends.
Erin Welsh	Okay, I have a question about if you get the bends once depending on the severity, are you at increased risk of it again or are you just an increased risk of damage again if you get the bends again or is it just we don't really know?
Erin Allmann Updyke	Excellent question. I didn't see anything in specific about individuals being at higher risk if they've gotten the bends once before. Here's a caveat to that and that is PFOs, patent foramen ovale. This is a hole in your heart inbetween the two atria, it's actually pretty common, I think up to 20% or more of the general population probably has a small one. But what can happen in the case of decompression sickness is that these bubbles that are forming in the tissues and the venus circulation, if you have a hole between the right side and the left side of your heart, it can allow the bubbles to travel onto the left side of your heart which is what pumps into your arterial circulation. So now you can end up with an AGE, an air gas embolism from decompression sickness.
Erin Welsh	Okay.
Erin Allmann Updyke	Right?
Erin Welsh	Yeah.
Erin Allmann Updyke	So there has been data that suggests that people who have a PFO may be at higher risk of neurologic DCS. But the risk isn't great enough that everyone who wants to dive should be screened or anything like that.
Erin Welsh	Okay.
Erin Allmann Updyke	But that is something that maybe if someone had neurologic DCS, they might get screened after to see if they in fact have a PFO.
Erin Welsh	Okay.
Erin Allmann Updyke	Yeah. But other than that kind of specific individual example, I don't know that we have enough evidence to say that people are at higher risk on subsequent dives if they've had the bends one time. I don't think that we have enough data to say that aside from that one example.
Erin Welsh	Okay. So you mentioned that recovery time is highly dependent upon how quickly you get treatment. So what is the treatment?

Erin Allmann Updyke	Great question. Treatment for all forms of decompression illnesses is first of all oxygen and this is really interesting because what it's going to do is change the gradients in your lungs and therefore change the partial pressure of nitrogen you're being exposed to which can help to drive nitrogen back into solution and allow for quicker off gassing.
Erin Welsh	Okay.
Erin Allmann Updyke	Also if you have emboli that are blocking small areas and you increase the pressure of oxygen, you can actually help oxygenate tissues around those emboli.
Erin Welsh	Okay, that's really interesting.
Erin Allmann Updyke	Isn't that cool? Hydration is also important. Dehydration, alcohol use can cause dehydration, and just dehydration in general is a risk factor for DCS. But mostly it's re-pressurization in a hyperbaric chamber. So that means putting someone in a chamber and bringing them back down to a pressure probably close to whatever pressure they were at before the symptoms started. And re-compression, it's so fascinating, it's going to both stabilize and then potentially reduce that bubble size because you're essentially just undoing what has happened inside your body.
Erin Welsh	That makes sense.
Erin Allmann Updyke	And then you slowly, like there's protocols that were developed by the Navy and the Air Force to kind of slowly decompress in those hyperbaric chambers.
Erin Welsh	And so how long you spend at a certain depth is also related to how much nitrogen is getting dissolved. And then at a certain point does it just max out?
Erin Allmann Updyke	Great question. Kind of yeah.
Erin Welsh	Okay.
Erin Allmann Updyke	So there is a type of diving called saturation diving where people who are working on engineering things that are beyond my scope but that have to be down at depth to do a project for a long period of time, what they'll often do is go down to that depth and live inside a chamber at that depth and stay there for days to weeks. That way they only have to surface once so they're not going up and down and up and down which would increase their risk for the bends. But once you're down, you're not at any increased risk.
Erin Welsh	Okay.
Erin Allmann Updyke	Yeah. Which is really interesting. Again, nitrogen narcosis is a separate scenario.
Erin Welsh	Right. Okay, question about depths and the bends. How deep do you have to go before the bends might start to appear even if it's the mildest symptoms?
Erin Allmann Updyke	Great question. In general for humans you have to be at least about that 10 meters.
Erin Welsh	Okay.

Erin Allmann Updyke	And you'd have to be there for a very long time. So the deeper you go obviously the more pressure your air is under, so the more nitrogen you're sucking in exponentially. And so then the greater your risk at shorter time periods. Now this can also happen without diving. So this can happen just from rapid ascent to very low pressures which might happen in say flying in an unpressurized vehicle like a helicopter or like a military plane of some kind.
Erin Welsh	Or an air balloon.
Erin Allmann Updyke	Or an air balloon! I never thought about that. Do they go high enough?
Erin Welsh	Well I read, I didn't mention this in the history, I cut it but it was a part where the person who discovered nitrogen's role was really interested in all these different pressure changes and what happens to the human body. And so he sponsored an air balloon trip to try to max out the record, to get the record for how high you could go. So these three dudes went up in this air balloon up to 26,000 ft and two died.
Erin Allmann Updyke	Oh no. Oh dear.
Erin Welsh	That's high up there.
Erin Allmann Updyke	That's high up there. Okay, don't do that.
Erin Welsh	Anyway, air balloons.
Erin Allmann Updyke	Anyway air balloons. I do want to ride in one someday.
Erin Welsh	Yeah.
Erin Allmann Updyke	What else? There's probably more that I've missed but that's the basics of it.
Erin Welsh	Decompression sickness happens when you ascend too quickly. So can you talk more about the prevention side of things?
Erin Allmann Updyke	Absolutely. So anyone who dives will know that when you learn how to dive, you're given these tables and they're called decompression tables. And it's basically a list for like your first dive and your second dive and your 10th dive or whatever of how deep you go and how long you're allowed to stay down at that depth and then how slowly you have to ascend or how many what are called decompression stops you have to make. And so these tables were developed mostly by the Navy, I think the Air Force had their hand in them as well. But they basically are the maximum limits to then prevent decompression. So if you dive within your limits, which is what it's called, diving within the decompression tables, then your risk of the bends is extraordinarily low. But what can happen is a lot of different things, right.

	You can go a little bit deeper than you realized, you can be trying to come up slowly but the volume of gas in your buoyancy vest that you wear is increasing at the same time as you're going up because of those pressure volume things. So then you can end up going a little bit faster than you intended. There's just a lot that can happen to where you try to dive within these tables but maybe you end up not. The other things that people do to try and reduce the risk of bends, especially if they're wanting to or needing to for work reasons be down at very, very deep depths or stay down for a longer time, is change the mixture of gas that they're breathing. So if you're breathing compressed air, that's 78% nitrogen. But there are gas mixtures called nitrox and for very, very technical diving heliox that change the proportion of oxygen, nitrogen, or even add helium to decrease the risk of not only the bends but also nitrogen narcosis. But then you can get into the risk of oxygen toxicity.
Erin Welsh	It sounds so fascinating and also so complicated and intimidating.
Erin Allmann Updyke	It is.
Erin Welsh	It's impressive.
Erin Allmann Updyke	Yeah. And then there's temperature that can affect things as well and so that's totally outside of your control.
Erin Welsh	Yeah.
Erin Allmann Updyke	Yeah. I do want to stress how rare the bends really are and we'll talk more about it in the current events but it's very, very, very rare. So that's the good news.
Erin Welsh	It hasn't been rare historically.
Erin Allmann Updyke	Oh I can't wait to hear about it, Erin. Can you tell me?
Erin Welsh	Yes. We'll take a quick break and then we'll dive in.
Erin Allmann Updyke	Yay!
TPWKY	(transition theme)
Erin Welsh	So the bends. Who thinks of anything other than scuba diving, right? Probably not many people.
Erin Allmann Updyke	Probably just people who fly in airplanes or helicopters or the astronauts, they probably think about it.
Erin Welsh	Yeah. But okay, remember back to our scurvy episode and I started out by saying okay here comes the history of scurvy and you were like oh my gosh, I can't wait to hear about pirates.
Erin Allmann Updyke	Yeah!
Erin Welsh	And I was like I'm so sorry but I am not going to talk about pirates. I'm not going to talk about scuba at all except a very minor bit.

Erin Allmann Updyke	Oh my gosh. I can't. This is so fascinating. I love it when this happens.
Erin Welsh	It was totally unexpected for me to find out that the main players in first observing and then later understanding this new, bizarre, and often deadly condition were engineers, tunnel builders, caisson workers, miners. The story of the bends is I would say unlike anything we've covered on the podcast before but it does touch on some familiar themes like how the development of certain technologies often outpaces our understanding of how they work or their possible negative health consequences. And we saw that with radiation for instance.
Erin Allmann Updyke	Definitely arsenic.
Erin Welsh	And arsenic, yep. And how industry not only created this disease in effect but also allowed for its study due to the huge numbers of workers affected by it, fears of lost productivity driving medical innovation. Okay, so let's get started. The bends, decompression sickness, and I'm going to refer to those interchangeably basically even though the bends I know is just one symptom etc, etc.
Erin Allmann Updyke	Yeah.
Erin Welsh	But this has been called the modern age's first disease. It didn't exist until the Industrial Revolution and the invention of air compressing engines.
Erin Allmann Updyke	Oh my gosh, I never thought of that.
Erin Welsh	I know! Yeah, the same thing.
Erin Allmann Updyke	We did this to ourselves.
Erin Welsh	Yeah, we totally did. I'm going to read a quote: "100 years before Asbestos, 50 years before radium, and 30 years before industrial dyes, there was compressed air and the bends." And I think that really just kind of places it in a nice little context. When decompression sickness first emerged in the 1840s, no one knew what it was, what caused it, or how to treat it, even if they understood precisely how compressed air machines and steam engines worked. With a disease as recent as the bends, you're probably thinking that there's no way I can squeeze in a mention of something like the Hippocratic texts or the Ebers Papyrus, right?
Erin Allmann Updyke	Tell me your gonna do it. You're gonna do it!
Erin Welsh	I'm gonna do it. Because compression sickness when it comes down to it like you talked about, it's about air, it's about gasses. Air as a concept isn't something that many of us probably think of very often, air quality sure, but the actual idea of air and air composition is generally just part of the background. So I've never really thought about when people first conceptualized air. And the first written record describing the idea of air, the sea of air around us, comes from the Ebers Papyrus around 1550 BCE. Ancient texts described air as good, life giving and life sustaining or bad air, life taking. The lack of air was seen to be deadly and this was called asma which later gave rise to the word asthma, and I'm pronouncing them the same way but they're spelled differently, I assure you. And of course miasma is a word that listeners of this podcast are familiar with, which is the concept that bad air can cause disease.

	These concepts about air and the qualities of air had been around for hundreds of years before people started to take a more rigorous scientific look at what this thing that surrounds us is made of. And this closer examination of air around the 17th century happened at a time when nearly everything began to be studied in miniature. Antony Van Leeuwenhoek developed early microscopes to look at life in a water drop, people began wondering if we're all composed of the same basic things just in different arrangements from humans to trees, stones to water, and maybe air wasn't as uniform as had been previously thought. Perhaps it was also made of different particles in different proportions.
Erin Allmann Updyke	I do love thinking about when people first started thinking about that.
Erin Welsh	Yeah.
Erin Allmann Updyke	Wow.
Erin Welsh	It occurred to them to think of like oh wow, this thing that I just assumed and took for granted, maybe there's more to it.
Erin Allmann Updyke	Yeah.
Erin Welsh	Yeah. In the 17th century a Belgian scientist named Jan Baptist van Helmont put 60 lbs of coal in a 5 lb enclosed container and then he burned the coal which left him with 1 lb of ash. But when he weighed the vessel after the coal had turned into ash, he found that it still weighed 65 lbs. Which is very cool, right? It sounds like a math problem but it's very cool.
Erin Allmann Updyke	Yeah.
Erin Welsh	And so he figured that his burning of the coal had freed from solid matter some invisible, indefinable, and chaotic wild spirit which he named gas after the Greek word for chaos or empty space.
Erin Allmann Updyke	Wow.
Erin Welsh	Isn't that thrilling?
Erin Allmann Updyke	I love it. I have never thought about when the word gas came to be. What?
Erin Welsh	It seems recent to me, this is only the 17th century.
Erin Allmann Updyke	Yeah.
Erin Welsh	I just love that. And also around this time people began experimenting with vacuums and the relationship between living things and air and how air was essential and so on. In 1670 Sir Robert Boyle put a viper in an airtight chamber and then quickly removed the air with a vacuum. He watched as the viper grew rigid and as bubbles appeared in its eyes. And this has been chalked up as the first known case of decompression sickness in an animal.
Erin Allmann Updyke	Interesting.

Erin Welsh	The rest of the 17th century saw further advancements in understanding the different types of gasses and how they act under certain conditions. Eventually, and I'm skipping over a lot here because I want to get to the meat of the bends, this growth of knowledge about the principles of gasses translated into technological advancements, arguably the most important of which was the steam engine of the 1700s. The steam engine was revolutionary in that it greatly increased not only the amount of power that you could generate but it also reduced the need to rely on natural sources of energy like wind or water in mills. And so then that also increased the places where you could use this power, you didn't have to be right next to a river for instance.
	In the 1800s the steam engine was adapted to power mechanical air compressors. Air compressors as a general concept have been around essentially forever, right. You can consider human lungs an early type of air compressor and we certainly used blowing air from our lungs to help light fires, to help get them going. And bellows of course, either the handheld ones or the big ones, those have been around for thousands of years, used to increase the heat of a blacksmith's forge for instance. But using the steam engine to power air compressors increased the possible applications of these machines far beyond just stoking fire. You could bring air, breathable air to places where it was scarce or ran out quickly, like down in mines or in tunnels.
Erin Allmann Updyke	I'm just loving this.
Erin Welsh	Good, good. With the Industrial Revolution kicked off by the steam engine, the demand for coal and raw materials with which to build machines and construct buildings grew higher and higher. But coal deposits aren't always readily available. Some were buried beneath tens of feet of waterlogged ground, out of reach for mining techniques of the day. Until a French geologist named Jacques Triger, I think is how you pronounce it, put his mind to the task in 1840, developing what he called a caisson which in French is a word for box. I'm going to attempt to explain how a caisson works but if I do a bad job or if you're more of a visual learner, I'm also going to link to a video by Practical Engineering that does a great job of explaining this. I loved it. Okay. Picture if you will a long rectangular tube with both ends open, right. And then imagine it placed upright in water, nestled at the bottom, sand is at the bottom but the top is sticking out so that you could go down in there.
Erin Allmann Updyke	Okay. Jump in, yeah.
Erin Welsh	You've got to get the water out of there, right, to get access to the very bottom. And so you pump it out. But how do you keep it out? Keeping water out gets increasingly difficult the deeper you go because you have to resist the higher and higher water pressure that's causing water to seep in from the bottom because water wants to get in there.
Erin Allmann Updyke	Okay.
Erin Welsh	But what if you got rid of that difference in pressure that caused the water to want to come into the tube?
Erin Allmann Updyke	Okay.
Erin Welsh	Then you could get rid of a lot of the seepage. And to do that, you create airtight chambers in your tube and you pump compressed air into them using a steam engine so that the air pressure inside the chamber of that tube matches the water pressure at the bottom.
Erin Allmann Updyke	Okay.

Erin Welsh	And so now you picture your tube with chambers filled with pressurized air.
Erin Allmann Updyke	Okay, so it's like now your tube is not just an empty tube because you have places in there that are closed off and at high pressure.
Erin Welsh	Exactly, yeah. So all the water is gone and you have that pressurized chamber at the bottom and so that's going to allow you to keep digging to allow you to sink that tube deeper and deeper as you build on the very top of it so that it still sticks out above the water.
Erin Allmann Updyke	Okay.
Erin Welsh	So the tube gets taller and taller but it gets also deeper and deeper as it eventually approaches bedrock once you get past the sand, bedrock or coal or whatever you're aiming for.
Erin Allmann Updyke	Okay.
Erin Welsh	Okay. And so of course as you're getting deeper the air pressure down there in that chamber, in that airtight chamber also gets higher and higher.
Erin Allmann Updyke	Right.
Erin Welsh	And then you have to create these like airtight locks in order to maintain that pressure.
Erin Allmann Updyke	Okay.
Erin Welsh	So then does that make sense? Do you have this picture of your caisson?
Erin Allmann Updyke	Yeah, I think so.
Erin Welsh	Okay, perfect. So that is effectively how Triger's caisson worked to allow him to dig through 15 ft of quicksand to get to the desired coal at the bottom. And when I say it aloud, Triger to dig, what I mean is it allowed many workers on this project to dig.
Erin Allmann Updyke	Of course, yeah.
Erin Welsh	Because those were humans that were down there actually in that highly pressurized chamber digging and digging and digging.
Erin Allmann Updyke	Right.
Erin Welsh	Dozens of workers would spend 7-10 hour long shifts digging down in the pressurized bottom chamber before passing through the airlocks to return to the surface. And it was in these workers that a brand new disease began to be observed. Even though it was only 15 ft of quicksand, maybe it was the length of time they were down there, maybe it was the fact that they literally had no decompression timing, it was just out of pressure.
Erin Allmann Updyke	At all. 7-10 hours at 15 ft. That's a very long time.
Erin Welsh	That'll do it, yeah.

Erin Allmann Updyke	Yeah.
Erin Welsh	Yeah. So it was actually Triger that not only wrote one of the first descriptions of this illness that he called mal des caissons but he also may have been one of the first people to experience it because he wouldn't let anyone else enter the work chamber before he personally checked it out for safety.
Erin Allmann Updyke	Oh wow.
Erin Welsh	Yeah. I was pretty impressed by that.
Erin Allmann Updyke	Yeah.
Erin Welsh	But it also meant that he spent a good deal of time under pressure. Triger didn't notice any symptoms while in the pressurized chamber or immediately after ascending but about 30 minutes later felt breathlessness and noted that some workers experienced joint pain. Generally mild all around.
Erin Allmann Updyke	Okay, good.
Erin Welsh	Yeah, good. Except for the fact that this was a really innovative and useful technology I guess.
Erin Allmann Updyke	Yeah.
Erin Welsh	And so despite the emergence of this brand new disease, mild though it appeared to be at the time, people were pretty thrilled to be able to use these caissons and so more and more popped up deeper and deeper. And Triger was involved with some of these mining and construction projects and he actually was like, 'You know what? I don't want a repeat of what happened. We don't need to have more people get sick.' So he requested a couple of physicians to come onto the project to monitor the workers' health. And this was all in 1845, the second mine. And the observations made by these physicians, Pol and Watelle, were the first medical writings on what would later be known as decompression sickness. They noticed that although spending time under compression led to a few symptoms like apparently a higher pitched voice or not being able to whistle - I don't know, I haven't confirmed that, that's according to 1845.
	But the strongest effects came not while under compression of course but after you had left it. Workers leaving the chamber felt a feeling of suffocation which is what they called the chokes. Some had tremendous muscle pains, arthritis, and a super painful itching. And the doctors themselves weren't immune to these symptoms because they were spending a lot of their time under pressure to observe the workers. And although by the end of the mining project, Pol and Watelle still didn't know what exactly was going on physiologically with mal des caissons, they made some pretty important observations. The symptoms seem to be caused by your body being removed from compressed air and the faster you underwent decompression, the worse your symptoms tended to be. Given these, they recommended adding an additional chamber exclusively for decompression and using recompression as a possible treatment for severe cases.
Erin Allmann Updyke	That is pretty cool.
Erin Welsh	Isn't it cool?

Erin Allmann Updyke	Yeah.
Erin Welsh	I feel like that's really impressive considering that they had no idea why decompression did this.
Erin Allmann Updyke	Right.
Erin Welsh	They thought that it was the blood congealed to a deadly level.
Erin Allmann Updyke	Right. They didn't know that pathophysiology but they did know... It's almost like the old hey, my elbow hurts when I move it like this, don't move it like this.
Erin Welsh	Don't move it like this.
Erin Allmann Updyke	These people are getting sick when they're in compression and then taken out of compression, let's put them back in compression, let's take them out slower. It's just so logical. It's beautiful.
Erin Welsh	It is so logical. And I think it's really interesting because it took so long, so many decades for people to understand why recompression was an effective treatment even though they saw that it was effective.
Erin Allmann Updyke	Yeah.
Erin Welsh	And so at the time the emergence of the field of homeopathy was sort of you treat like with like.
Erin Allmann Updyke	Interesting!
Erin Welsh	Yeah. And so it was like okay, I don't know if Pol and Watelle were but a later doctor that used recompression therapy, he was like well it makes sense that you give someone in a milder dose the same thing that has been known to cause their symptoms. And so that was why recompression was a thing.
Erin Allmann Updyke	How interesting. I love this.
Erin Welsh	Yeah. But despite all of these like kind of incredible advancements that they made, after their work on the mines these two physicians went back to their private practices and they left mal des caissons behind. And their writings gained some traction but not as much as the caisson did. And for the most part people didn't use recompression therapy, they didn't try it out at all.
Erin Allmann Updyke	Oh wow. What a bummer.
Erin Welsh	Yeah, I know. In the decades that followed, people continued to work under compressed air and of course continued to get sick. And as the caisson projects grew, so did the clinical picture of what mal des caissons could look like. I have a quote here that just has a lot of symptoms: "Bloody noses, ear pain and diminished hearing, excessive thirst and hunger, bloody coughs, bone pain, paralysis, intractable vomiting, bloody urine, excruciating headaches." It just goes on and on. And in an effort to combat these painful symptoms, people tried anything they could think of from tinctures to cold water ablutions, opiate linaments to belladonna and camphor oils, but nothing worked. Recompression would have worked but again, people were decades away from taking up Pol and Watelle's suggestion. It's a real shame.

	In the meantime the 1850s and 1860s saw enough cases of mal des caissons that it became a notorious and feared industrial disease but one that was also viewed as inevitable as the rate of new bridge and tunnel projects grew and grew. And it was two of these bridge projects in the US that would prove to be kind of a major turning point for mal des caissons. Eads' St. Louis Bridge and Roebling's Brooklyn Bridge. By the 1860s, St. Louis had become an important distribution and processing center and westward expansion thanks to the railroad turned it into the gateway to the west. But ferry transport across the Mississippi couldn't keep up with the growth by a long shot. Ferries had become inefficient, expensive, time consuming, and they were vulnerable to winter conditions. What they needed was a bridge and a person to build it. Enter James B. Eads, quote "a dignified sea captain who had lived his entire life in St. Louis, a true pioneer who would bridge St. Louis' past with its industrial future."
Erin Allmann Updyke	Wow.
Erin Welsh	So does sea captain just means someone who's worked on water? Because if he's lived in St. Louis his entire life...
Erin Allmann Updyke	That was my literal first thought.
Erin Welsh	I just loved it. That's why I wanted to keep it in there.
Erin Allmann Updyke	Yeah. He wrote his own biography.
Erin Welsh	He totally did. So despite being this quote unquote "sea captain" and extensively exploring the Mississippi River, Eads had never actually built a bridge when he was hired to do this.
Erin Allmann Updyke	Okay.
Erin Welsh	But he did his homework, researching the latest technology and consulting with European engineers, which I think the equivalent today is watching a bunch of how to Youtube videos. Yeah.
Erin Allmann Updyke	I could do it.
Erin Welsh	He decided that what he needed to span the 1500-1800 ft or 450-550 m section of river would be the biggest and deepest caissons ever built, at least 90-110 ft below the surface of the water.
Erin Allmann Updyke	Wow.
Erin Welsh	That's deep. So caissons used for bridge building are the same ones as you use for mining. You dig out debris and you sink the caisson and you rinse and repeat until you hit a good foundation on which the caisson would rest like bedrock. And then you fill the caisson with concrete to create a support structure for the bridge.
Erin Allmann Updyke	Okay, okay.
Erin Welsh	It sounds fairly simple kind of. But what Eads was proposing was uncharted territory. The amount of pressure you'd have to have in a 100 ft deep caisson to prevent water from coming in hadn't been attempted before.

Erin Allmann Updyke	Okay.
Erin Welsh	It's a lot of pressure.
Erin Allmann Updyke	Yeah.
Erin Welsh	And no one knew what that would do to the human body, although the previous decades had given them some idea. Work on the bridge started in the summer of 1868 and things started out just fine, at least until the caisson got to about 60 ft deep. After their 4-6 hour shifts working at that depth, workers would leave the compression chamber and then go into the quote unquote "decompression chamber" which was really more about maintaining pressure inside the caisson rather than ensuring that workers decompressed safely.
Erin Allmann Updyke	Okay.
Erin Welsh	Then they would have to climb a winding staircase up to the surface.
Erin Allmann Updyke	Oh no!
Erin Welsh	The staircase would eventually reach to be 100 ft tall.
Erin Allmann Updyke	Oh no.
Erin Welsh	Yeah. That climb could be excruciating for some workers who found that when they got out of the decompression chamber, they could barely move their legs. Again all of the usual symptoms appeared, excruciating joint pain, itching, headaches, stomach cramps. At this depth workers were experiencing all of these symptoms and one in particular would give it the name that we commonly use today, the bends. All right, let me go into the story of the bends a little bit more.
Erin Allmann Updyke	I can't wait.
Erin Welsh	At the time, one popular fashion trend involved women wearing dresses where a bunch of the fabric was gathered up in the back and then supported by a bustle. So just imagine this immense weight of fabric all on your back. So picture yourself wearing that plus tight and incredibly uncomfortable corsets and then high heeled shoes.
Erin Allmann Updyke	Of course.
Erin Welsh	And all of this, all of these things caused many women to lean forward nearly in half to try to balance the weight and discomfort.
Erin Allmann Updyke	Wow.
Erin Welsh	This trend was called the Grecian bend after Greek statues of women where they seem to hunch forward out of modesty or so I read.
Erin Allmann Updyke	Okay.

Erin Welsh	What does this have to do with the bends? After coming out of the caisson, some workers experienced joint pain or partial paralysis that caused them to walk with a stoop and someone joked that you've got the Grecian bend. And that's what it became known by, the bends.
Erin Allmann Updyke	The bends.
Erin Welsh	Yep, out of an absurd amount of fabric on your lower back. As the caissons sunk lower and lower in the Mississippi, cases of the bends climbed higher and higher. And when the first caisson hit bedrock on February 28th, 1869 after about nine months of work and 93.5 feet of depth, the first death followed shortly after. Leaving his shift, a young man climbed the nearly 100 ft staircase to the surface, staggered around a bit, gasped, and then collapsed dead. Six more deaths followed within 10 days.
Erin Allmann Updyke	Whoa.
Erin Welsh	Yeah. Eads, the head of the project, was horrified and asked his personal physician to establish a floating clinic to observe and care for the sick workers which mostly meant observation and unlimited hot beef tea, which I assume is just broth, since no one still knew what precisely caused the bends which left these physicians somewhat powerless to prevent or treat it.
Erin Allmann Updyke	Yeah.
Erin Welsh	Like Pol and Watelle, this physician, Alphonse Jaminet, was no stranger to decompression sickness himself. In one instance he stayed at three atmospheres for 2.5 hours and then underwent decompression for about 3.5 minutes.
Erin Allmann Updyke	Oh woops.
Erin Welsh	Yeah, that's about 2.5 hours less than what would be recommended today or something around there. And it was terrible for him. He could barely walk, he had horrible stomach pains, became super cold, and it took him days and days to recover. But one possible outcome of having both the project physician and head engineers experience the bends firsthand is that these individuals in power took the disease very seriously and did what they could to limit the damage that it caused. And that meant in the case of Jaminet and the St. Louis Bridge, regular physical examinations, an elevator to replace the staircase, and decompression timetables which had been used before but we're far from ac accurate. And Jaminet's weren't either. For instance his timetable suggested that you should undergo decompression for 20 minutes after working for two hours at over three atmospheres which is nearly 12 times shorter than what's recommended today. By the bridges completion in 1874, about 25% of the 352 workers on the project experienced some post decompression ailment.
Erin Allmann Updyke	It's a lot and it's also somehow way less than I would expect if you think about it, right.
Erin Welsh	Me too.
Erin Allmann Updyke	If you think about the fact that all of these people are working and it just really goes to show how much interpersonal variability there is.
Erin Welsh	Totally. Yeah, to be working 4-6 hours at 93 ft at a time?
Erin Allmann Updyke	Right.

Erin Welsh	And then basically not undergoing any sort of stage decompression.
Erin Allmann Updyke	Right, how interesting. And I think it also highlights how conservative our timetables today are if you think about it in that context.
Erin Welsh	Yeah.
Erin Allmann Updyke	I mean 25% is a lot.
Erin Welsh	Well and our timetables today weren't always, it was only in the 1970s really that they were effectively preventing decompression sickness in people who were not recreational or professional divers. I'll talk about it later but the divide between industry and maritime or recreational diving has always been a pretty big division in terms of safety and technology.
Erin Allmann Updyke	Oh I bet. Interesting. Yeah okay.
Erin Welsh	But yeah, 25% is both a lot and also less than I expected.
Erin Allmann Updyke	Yeah.
Erin Welsh	And I have a few more stats here. So 30 people were hospitalized, 13 died, and two had lifelong paralysis. The Eads Bridge in St. Louis broke new ground as a feat of engineering and also by revealing just how varied the bends could be in terms of symptoms, severity, and how different people were affected. And while some of the measures that Jaminet put into place helped to reduce the chance of getting the bends, we were still no closer to understanding how exactly the disease did the things it did, which would prove to be a big problem as the next big American engineering project got underway.
	If the mid 1800s turned St. Louis into a booming commerce city, that was nothing compared to the change that New York underwent during that same time. It grew into an enormous commercial shipping giant, nearly becoming the world's busiest port. But transport between New York and Brooklyn was still being done by ferry. People didn't want to have to use a ferry, the idea of a bridge had been floated many times before but there was always a reason, a good reason, why the proposed plan wouldn't work. The East River currents were too strong or the river bottom was too muddy. But German engineer John Augustus Roebling sought to defeat the naysayers and he submitted his ambitious bridge plans to the New York Brooklyn Bridge Company in the early 1860s.
	By the time he submitted his plans, Roebling had already built a reputation as the suspension bridge guy. He had built a suspension bridge over the Allegheny River in Pittsburgh, across the Niagara and across the Ohio River in Cincinnati. The bridge that he planned to build connecting Manhattan and Brooklyn was like these other bridges except much, much bigger, a scale never previously attempted. A size that was honestly downright terrifying to some of the people in the bridge company. Rather than put in mid river piers to support the structure like the Eads Bridge which I think has three, Roebling proposed that the 1600 ft roadway, so that's just the middle chunk, would just be suspended from two towers across the East River. So the section just between those two towers is 1600 ft, the bridge is a lot longer itself.
Erin Allmann Updyke	Yeah, a lot longer.
Erin Welsh	And that was the longest suspended section of roadway in the world at the time when it was completed. Because I don't think this is a spoiler, the project was successful.

Erin Allmann Updyke	The Brooklyn Bridge does in fact exist.
Erin Welsh	It does in fact. This version does in fact exist. And another little factoid that I think is really also fascinating is that this road would be suspended using cables of bound wire rope for a total of, and I've seen estimates from 14,000 to 21,000 miles of wire.
Erin Allmann Updyke	How do you even possibly make a wire that long?
Erin Welsh	Industrial Revolution, baby. I don't know, I don't know. So that's my answer.
Erin Allmann Updyke	I love it.
Erin Welsh	The weight of that suspended roadway and everything on it had to be fully supported by those two towers and whatever they rested on.
Erin Allmann Updyke	Wow, yeah.
Erin Welsh	Ideally stable and reliable bedrock. And the caissons needed to make these towers had to be absolutely massive, three times the size of Eads' and covering more than 1.4 acres which I meant to look up in hectares but I didn't, sorry.
Erin Allmann Updyke	Wow.
Erin Welsh	Sadly John Augustus Roebling never got to see the Brooklyn Bridge completed or even started. In 1869 his foot was crushed in an accident, he developed gangrene and then tetanus, pre-vaccine days, pre-antibiotic days, and died of tetanus. A horrifying death.
Erin Allmann Updyke	That's awful.
Erin Welsh	Yeah. His son Washington Roebling who had worked with him on previous projects took over the Brooklyn Bridge project as chief engineer and in May of 1870 sent to sinking the caissons. But the going was tough. For the caisson on the Brooklyn side there were giant boulders and rocks that had to be blasted away and initial progress was only like six inches of depth per week.
Erin Allmann Updyke	Whoa!
Erin Welsh	Yeah. But finally after about 10 months of digging, the caisson on the Brooklyn side hit bedrock at about 45 ft, not too deep.
Erin Allmann Updyke	Yeah.
Erin Welsh	And there were some cases of mild decompression sickness but nothing as severe as what had been seen in St. Louis so far.
Erin Allmann Updyke	Uh oh.

Erin Welsh	But the other caisson for the Brooklyn bridge, the one on the Manhattan side, had to go much deeper to at least 100 ft depth. With the Manhattan caisson things were off to a much better start, going 20 times faster than the Brooklyn caisson did. But by 45 ft, the depth at which the Brooklyn Caisson hit bedrock, workers began showing signs of the bends. And with not a close end in sight to how much deeper they had to go, Roebling asked a physician named Andrew H. Smith to supervise. Smith, like physicians before him, documented the wide array of symptoms, introduced guidelines for longer decompression, and tried out a number of therapies, none of which seemed to work except one, recompression. But recompression therapy was introduced too late for Washington Roebling who like Eads and Triger was very much involved in the day to day work at the excavation site. And after returning to the surface one day he experienced the worst case of bends of his life. His arms and legs and chest were on fire with pain and he was unable to move for days.
Erin Allmann Updyke	Oh no.
Erin Welsh	He never fully recovered and spent the rest of his life in a wheelchair, directing the project from his apartment while his wife Emily warren Roebling, self taught in bridge construction, effectively ran the project in everything but name.
Erin Allmann Updyke	Wow.
Erin Welsh	Which is awesome.
Erin Allmann Updyke	Yeah.
Erin Welsh	I loved that tidbit. And there was still a lot left to do. Progress on the Manhattan Caisson slowed to a crawl at around 70 ft depth. And that's when the dying started.
Erin Allmann Updyke	Oh no.
Erin Welsh	Which was worrying not just because people were dying but also because there was still so far to go, perhaps 30 more feet.
Erin Allmann Updyke	Wow.
Erin Welsh	And at this point they were going one foot per week and so that was months and months more work at these deadly conditions.
Erin Allmann Updyke	Yeah.
Erin Welsh	So Roebling made a decision. He looked at the sand in the river at the base of the Caisson and concluded that it hadn't shifted for about a million years. So he figured it probably wouldn't start changing now and ordered the digging to stop at 78 ft. And thus the Manhattan tower of the Brooklyn Bridge rests on sand and not bedrock.
Erin Allmann Updyke	Whoa.
Erin Welsh	So far so good.
Erin Allmann Updyke	Whoa.

Erin Welsh	It's amazing. And I have to think too that with his horrible case of the bends, he was probably motivated like we can't do this, we can't subject people to this.
Erin Allmann Updyke	Yeah.
Erin Welsh	Yeah.
Erin Allmann Updyke	It's just like a really big risk to take when you're building a bridge like this. I feel so anxious and I know it turns out fine. I've been on that bridge.
Erin Welsh	I know, I know. It definitely does feel like a dun-dun-dun moment.
Erin Allmann Updyke	I know.
Erin Welsh	But like I said, so far so good.
Erin Allmann Updyke	Okay.
Erin Welsh	When construction on the Brooklyn Bridge ended in 1883, the structure represented one of the biggest accomplishments of modern engineering to date and really still today is an incredibly impressive and beautiful bridge. But the human body had been pushed to its limit and no more ambitious bridge or tunnel projects could begin before researchers figured out the root cause of the bends and how to reliably prevent it. Fortunately on that end progress was already well underway, it just hadn't reached the US. French scientist Paul Bert, which I have to keep resist saying Paulburt, identified nitrogen as the causative gas in decompression sickness in the early 1870s but the word didn't get out to the American engineering community for about 20 years or so.
Erin Allmann Updyke	Oh my goodness.
Erin Welsh	Yeah. Bert was interested in what happened when deep sea fish were brought to the surface or how people responded when going up in an air balloon like I mentioned.
Erin Allmann Updyke	Okay.
Erin Welsh	But especially after that air balloon disaster, he felt most comfortable in a lab and began a series of what seems like general exploratory experiments. What happens if I decompressed this animal after it being at pressure for this amount of time at this rate type of thing?
Erin Allmann Updyke	Okay.
Erin Welsh	I'm going to read the notes from one experiment but I'll warn you it's a bit grisly, pretty grisly.
Erin Allmann Updyke	Oh dear.
Erin Welsh	So skip ahead about a minute if you don't want to hear. Quote: "Experiment number 608."
Erin Allmann Updyke	Oh dear.

Erin Welsh	"Poodle placed in the apparatus in the morning. At 10:30 it is well, the pressure is 9.5 atmospheres. Immediately a violent explosion is heard, the porthole glass is burst and its fragments cut the lead water pipe a meter away. The apparatus was lifted off from its supports and overthrown. I take out the animal with great difficulty, for it has become cylindrical and is hard to pull through the door. Subcutaneous intra and submuscular emphysema, gas escapes whistling when the belly is opened. The right heart, as all the veins, is full of gas but none in the left oracle or aorta. The nerve fibers of the spinal cord are dissociated by bubbles of gas. I extract 50 CCs of gas from the right heart which contains 1.9% oxygen, 15.1% carbon dioxide, and 83% nitrogen." End quote.
Erin Allmann Updyke	That is horrific.
Erin Welsh	It is horrific. Fortunately we have to IACUC these days.
Erin Allmann Updyke	Oh my.
Erin Welsh	Yeah. Bad news. And the conclusions that he drew from these experiments, if you can call them experiments, they were different from those of Robert Boyle who was the one who saw the bubble in the eye of the snake. Because science had progressed to the point where people could distinguish among different gasses and calculate their proportions thanks to Bunsen of Bunsen burner fame. And so Bert was able to conclude that quote, "the gas which would threaten life on being liberated would be exclusively the one the proportion of which was considerably increased in the blood, that is nitrogen."
Erin Allmann Updyke	Right, yeah. Okay.
Erin Welsh	His results didn't convince everyone mostly because of how varied individual responses to decompression could be. And understanding a big source of that variation fell to somebody else, John Scott Haldane, father of famous scientist JBS Haldane. Haldane the father was famous for self experimentation and also experimentation on his son and played around with different mixtures of gasses and decompression times from 1903-1904 to see the effects both on himself and lab animals. And one thing he noted was that different tissues decompress at different rates, with fat content playing the largest role in determining that. And this was a huge leap forward in understanding the pathophysiology of decompression sickness because it allowed him to create the first actually safe more or less timetables for decompression and to also do something that he called staged decompression.
	A lot of Haldane's research was done in conjunction with the US Navy who had begun using compressed air for diving. So much of the focus was on ascending from underwater safely, maybe using a decompression bell, like a diving bell, but where you could decompress underwater more warmly. But decompressing after a dive is different than decompressing after working in a caisson. For one, a typical shift for Caisson worker was 4-6 hours which is way beyond what a dive would be and they'd be going back down day after day after day, up and down up and down.
Erin Allmann Updyke	Right, yeah.
Erin Welsh	And so the timetables weren't quite as accurate for caisson workers. And this represents the beginning of a divide between the two realms of decompression that I mentioned.
Erin Allmann Updyke	Interesting.

Erin Welsh	And it still seems to, I mean this book that I read I think was written in the 90s or early 2000s but it still seems to at least at the time of publication exist then. Navies and private commercial diving firms used top of the line decompression technology while many workers in tunnels and caissons may still be using outdated decompression tables or at least ones that maybe could be reexamined. But the work of Bert and Haldane finally allowed for a more thorough understanding of the pathophysiology of this disease that had plagued mining and bridge and tunnel projects for decades. And not only that, it was instrumental in both the prevention and treatment of the bends. Modified decompression chambers were developed during the Hudson River Tunnel project in the late 1890s, reducing the mortality from the bends more than twelvefold.
Erin Allmann Updyke	Wow.
Erin Welsh	Which is pretty amazing.
Erin Allmann Updyke	Yeah.
Erin Welsh	And laws regulating working conditions with compressed air were put into effect beginning in 1915. And these further reduced cases and death from decompression sickness. These measures were too late to stop the long term effects of the disease though which had just started to emerge by the time that these laws were enacted. In one tunnel project in Milwaukee, 35% of the 170 workers developed bone necrosis. That's a lot.
Erin Allmann Updyke	That's a lot.
Erin Welsh	But having safer decompression and effective treatment for when something did go wrong was crucial because the invention of modern scuba by Jacques Cousteau and Emile Gagnan in 1943 that led to an enormous rise in cases of the bends as recreational diving became more and more popular. Like it from oh the bends is being pretty well controlled and then it was like boom, the bends is back and everyone's getting the bends.
Erin Allmann Updyke	Wow.
Erin Welsh	And that in itself, the invention of scuba and all of that is a fascinating story but I'm not going to go into it today because I've talked long enough. And instead I'll just close the history of decompression sickness by saying that it seems like we've just gotten better and better and better at understanding and dealing with this condition. And so I'm very curious to hear what you're going to talk about in the current events section, Erin.
Erin Allmann Updyke	Oh I can't wait to do it right after this break.
TPWKY	(transition theme)
Erin Allmann Updyke	It's probably not a huge surprise that I don't have great numbers in terms of data for you.
Erin Welsh	No, that's classic TPWKY.

Erin Allmann Updyke	It really is. Gotta keep something original. I also realized as you were talking about the discrepancies between decompression tables for diving and maybe what happens in more commercial engineering, not diving-specific decompression, I really didn't see any data on decompression sickness in those industrial settings. Certainly a lot of the papers that look at it talk about maybe the difference in incidence of decompression sickness in different types of diving, be it recreational or technical, saturation, etc. But not so much just industrial engineering vs scuba diving which feels like a big oversight.
Erin Welsh	It's interesting. And I think the other thing too that the book I read pointed out was that air quality is very different. So if you're breathing compressed air at the bottom of a caisson where there's potentially a lot of other gasses from whatever mining processes you're doing, that is far and away a very, very different air composition and quality than your breathing from a beautiful little scuba tank.
Erin Allmann Updyke	A scuba tank, exactly. Oh yeah, definitely. Yeah there's probably a lot of other mining associated diseases that we're going to cover at some point as well.
Erin Welsh	Oh for sure.
Erin Allmann Updyke	So there's that. We'll have some data at that point. But from what we do know when it comes to diving, decompression sickness, decompression illness really combining AGE and the bends is very rare. Incidence across the board looking at all different types of diving tends to be less than 0.5% per dive. And based on data from the Divers Alert Network which collects a lot of data primarily though just on US and Canadian divers, worldwide but just people of US and Canadian citizenship, their estimate is an incidence of DCS of just over 3 cases per 10,000 dives.
Erin Welsh	Wow.
Erin Allmann Updyke	And that's of all forms, both mild and severe.
Erin Welsh	Okay.
Erin Allmann Updyke	And predominantly these do tend to be mild cases. Although there is some interesting data, a lot of data that we have just about the risks and things does come from the Navy when it comes to diving risks. And there is discrepancy in what the kind of acceptable risk level for more mild vs more severe cases is vs what you actually see in mild vs severe cases, if that makes sense. So what the Navy has called acceptable risk for mild is a lot higher than what they would call acceptable risk for severe. And the amount of DCS that we see is well below those acceptable risks but the proportion is more severe than that ratio, if that makes sense.
Erin Welsh	Okay.
Erin Allmann Updyke	But that's kind of all that I have for you in terms of numbers.
Erin Welsh	Okay.
Erin Allmann Updyke	I wanted to just mention because I came across it in my reading and I went what? And it kind of gets back to something that you mentioned towards the end which is this idea of chronic illness associated with decompression in people who perhaps work or are subjected to a lot of repeated decompression. That is what about other animals?

Erin Welsh	Oh yeah. I was going to ask about seals and stuff that dive super duper deep. That was the question where I was like I know I have one but I forgot it.
Erin Allmann Updyke	Well I'm so glad we remembered. I came across several papers looking at the bends in animals that dive deep like sperm whales and sea turtles. Do they get the bends? They're subjecting themselves to the same pressures. They're not breathing underwater but they're staying down at depths for in the case of sperm whales up to 90 minutes they can hold their breath, which oh my goodness.
Erin Welsh	Amazing in and of itself.
Erin Allmann Updyke	Right.
Erin Welsh	Let's do an episode on lungs.
Erin Allmann Updyke	Oh okay, love it. So historically ,traditionally it's been thought that no, these animals don't get the bends. One paper that I read from a while back, I think it was from the 70s, it was about why sea snakes don't get the bends.
Erin Welsh	Oh sea snakes, your fave.
Erin Allmann Updyke	I know, my fave.
Erin Welsh	Your mortal enemy.
Erin Allmann Updyke	Terrifying. So they suggested that it was for two reasons. One because snakes and many reptiles have a right to left shunt in their hearts, so they mix their oxygenated and deoxygenated blood which might decrease the overall super saturation of nitrogen in their tissues.
Erin Welsh	Whoa.
Erin Allmann Updyke	Right? But also snakes have skin that is partially permeable to nitrogen. So they also suggested that perhaps they're able to diffuse nitrogen more efficiently. Because sea snakes, while they don't dive as deep as a sperm whale, they come up apparently really quickly.
Erin Welsh	And sperm whales don't.
Erin Allmann Updyke	So sperm whales tend to not. Sperm whales, dolphins, sea turtles have a lot of likely behavioral adaptations to decompression, they're basically decompressing themselves.
Erin Welsh	That is too cool. They have decompression timetables.
Erin Allmann Updyke	Timetables! But it doesn't always work. And at least a couple of papers that I found were very interesting in that there is evidence in sperm whales as well as a couple of Risso's dolphins which are very cute, google pictures, of effects of the bends. So let me tell you about it. In sperm whales there was in necropsies of over 100 whales, they found evidence of osteonecrosis in their bones that suggested chronic decompression damage.
Erin Welsh	That's amazing.

Erin Allmann Updyke	Right? And in sea turtles as well as dolphins, there have been a lot of cases of what looked like decompression sickness and deaths due to decompression sickness linked to things like military sonar operations or other acoustic interference or in by-caught turtles that are pulled up from depth in nets, fishing nets. Right? And that makes sense because then they're not undergoing their normal behavioral adaptations. But at least two Risso's dolphins, I found a paper, I'll link it, were found beached with evidence of DCS on necropsy and there was no known association with any of these anthropogenic sources. So why? What else was going on? Did they go into a fight with a squid that they were trying to eat and they surface too quickly? I don't know.
Erin Welsh	That is fascinating. Okay. And I have a question which is not well formed but I'm going to do my best.
Erin Allmann Updyke	Okay.
Erin Welsh	And that is about the impact or the relative impact that the bends would have on a human, a terrestrial being vs a whale for instance. So joint pains and stuff like that. Is there anything about being on land vs being on water and would that be as impactful in their survival?
Erin Allmann Updyke	Oh what a fun question. I have no idea. I think it would be so difficult to answer because we can't ask a whale if their joint hurts.
Erin Welsh	Right. Are you in pain? I mean at least not yet. Maybe forever from now.
Erin Allmann Updyke	Once Free Willy. But it does seem based on this evidence of osteonecrosis happening in sperm whales that aren't dying from this osteonecrosis, it's just found in sperm whales who have died.
Erin Welsh	Right.
Erin Allmann Updyke	So yeah, maybe it's happening to them at low levels but they're not being affected by it unless very randomly in only two Risso's dolphins we've seen evidence of these animals being beached and then dying. Was it even because of the DCS or was the DCs not related? I don't know. It's really interesting. But it kind of just highlights that they might not be as immune as we thought, right.
Erin Welsh	Well here's another thought because I'm going to plug in climate change in here too. If the cues are related in any way to temperature, because temperature changes substantially as you go up and down the water column, then that could also mess up the timing of decompression or the timing of ascent for these marine mammals.
Erin Allmann Updyke	Oh my gosh. I want to do a whole episode on sperm whales or something. I don't know. I don't know how to make it work.
Erin Welsh	Perfect, let's do it. We'll make it happen somehow.
Erin Allmann Updyke	Yeah. But anyways that's all I really have on the current status of the bends, Erin.
Erin Welsh	That's fascinating.
Erin Allmann Updyke	Isn't it? Sea snakes, sea turtles. Wow!

Erin Welsh	I know, I feel like we talked, this is a long episode and yet there is so much more that we could have talked about.
Erin Allmann Updyke	Yes. I know, 100%. 100%.
Erin Welsh	Wow.
Erin Allmann Updyke	I know.
Erin Welsh	Should we do sources?
Erin Allmann Updyke	Sources! Let's do it.
Erin Welsh	I have basically just one which is the book called 'The Bends' by John Phillips. It was a fascinating and informative read.
Erin Allmann Updyke	Great.
Erin Welsh	So two thumbs up.
Erin Allmann Updyke	I had a lot, a lot more than one. My favorite, I think kind of just the most basic and comprehensive was a paper in The Lancet from 2011 just called 'Decompression illness.' There were a number of other ones and I will definitely linked to the sperm whale, Risso's dolphin, sea snakes and sea turtles ones. Those are great. And we'll post the sources from this episode and all of our episodes on our website thispodcastwillkillyou.com.
Erin Welsh	We certainly will. Thank you again so much April for taking the time to chat and being willing to share your story.
Erin Allmann Updyke	Thank you. Also a special thank you to Rafael who I chatted with about this episode and how to explain all of this physics. So thank you so much for your time.
Erin Welsh	Thank you, Rafael, you're the best. Thanks also for putting us in touch with April, we appreciate it.
Erin Allmann Updyke	We love it.
Erin Welsh	And thank you to Bloodmobile for providing the music for this episode and all of our episodes.
Erin Allmann Updyke	Thank you to Exactly Right network and thank you to you, listeners.
Erin Welsh	Thank you. We hope you liked this episode.
Erin Allmann Updyke	We had fun with it.
Erin Welsh	Yeah, we certainly did. And a special thank you also to our wonderful, absolutely fantastic patrons. We love you, we appreciate you.
Erin Allmann Updyke	We love you so much.

Erin Welsh	Well okay, until next time, wash your hands.
Erin Allmann Updyke	You filthy animals!