Erin Welsh

Just a warning out there, this is a pretty gruesome firsthand account and so if you would choose not to listen to it, please fast forward a few minutes.

"The midsummer sun was already glaring on the morning of August 6, 1945. After the all-clear signal following the air-raid warning, everything went back to normal with people busy doing their own business. It was a Monday and the Japan Steel works where I had been working as a volunteer was closed. Going on an errand to a post office in Miyuki-bashi under the scorching sun, I could not bear the heat anymore, so I turned back home to fetch my parasol. I had just stepped out and was just about to open the parasol, when an intense flash burst upon me. It looked as if the gas tanks in Minami-machi on the other side of the river had exploded. The flash was a yellowish orange color, just like magnesium light but hundreds of times stronger. I instinctively rushed back into the house and laid myself down on my stomach as had been trained in evacuation drills.

Stepping outside, I found the clear, blue sky had turned dim as if it were at dusk. Dust in the air blocked the view across the river. The place was filled with an indescribable smell. Pulling myself together, I looked back at my house to see if my mother was all right. Her hair was a mess and standing on end; her lips were cracked and her head bleeding; she stood there like some unearthly creature. Then I saw my younger brother staggering about with his white cotton kimono soaked with blood. "Are you both all right ?" I asked. "That's my blood. He's not hurt," replied my mother. We carried her on a stretcher to the mutual aid hospital where the doctors sewed up the cuts in her lips, jaws, and shoulders but he did not do anything for her wounded wrist as it had already been given first aid. Because of this it took a long time before the wound got better and the thumb and the index finger of her right hand were left to be paralyzed. Mother passed away in January 1995.

I also remember seeing a woman lying dead at a house by the river bank, her next struck through with a piece of glass blown by the blast. The glass must have cut the artery, blood was scattered around her. She had been suckling her baby. The baby was still absorbed in sucking the breast. There was a middle school student who was severely burned above the neck except for the top of his head which had been protected by his combat cap. He was walking barefoot saying, 'Please give me water, I'm hot, hot.' His school uniform was burned to tatters. There came a drove of people whose faces and clothes were burned black, almost naked and burned beyond recognition, they came tottering along dangling their arms in front of them like ghosts. Some had their work pants burned away save the elastic strings, others had all their clothes burned except for the front part. They kept chanting, 'Water, give me water.' Exposed juicy, wet flesh, peeled skin hanging from their fingertips like seaweed.

An unfamiliar smell was floating in the air around the mutual aid hospital. Dead bodies were piled up on the roadside. Strangely enough, I never felt the dignity of life as seriously as I do now, faced with so many deaths. Had my mind stopped working after experiencing such a sudden attack by the bomb? I took my father back home from Ninoshima on August 8th. Flies swarmed around him because of the odor his festered burns and the white ointment gave out. It took some effort to chase the pests away. On the way to the mutual aid hospital there was a first-aid station where wounded people in a serious condition were laid on straw mats. They were delirious, begging for water. Those whose backs were burned lay on their stomachs and those whose front was burned lay on their back. They could not even move to change the position. Their wounds and burns were covered with countless flies laying eggs there, those eggs hatched into maggots and these crawled all over their bodies causing them infernal agony.

	My father asked for water. Knowing he would die if he drank too much, I only gave him a tiny cup of water. I did so because I wanted him to survive. I am not sure if I did the right thing and my heart aches whenever I think of it. On the day of Japan's surrender he mumbled, 'Japan lost the war'. He died undramatically the next day, complaining of the cold. The damage caused by the bomb was not confined to those who were actually exposed to it. People who sustained no injuries, e.g. those who went near the hypocenter to look for their children, suffered a high fever and got purple spots all over their bodies, went almost mad, and died one after another during the 6 months following the bombing. My elder brother was suddenly stricken with leukemia and died many years after that dreadful experience when we had almost forgotten about it. I myself suffered from diarrhea for some time at the end of August.
	It is not easy for me to talk about my experience as an A-bomb Survivor for me. It is like airing my dirty linen in public. But here I am to talk to you because I really want all of you to remember that the peace we have today has been achieved through the sacrifice of those people who were mercilessly killed without receiving a drop of water to quench their thirst. To keep a lasting, permanent peace I want to convey the heart of Hiroshima, hoping that what I do will be like all ripples growing into big waves and into a tidal wave."
TPWKY	(This Podcast Will Kill You intro theme)
Erin Allmann Updyke	Oh my god.
Erin Welsh	Yeah. I have no words.
Erin Allmann Updyke	No.
Erin Welsh	So that is the story of Miyoko Watanabe, one of the Hibakusha, which is the survivors of the A-bomb. And there are so many of these that have been collected in a big project and I really encourage people to go seek out more of them because it is just...yeah.
Erin Allmann Updyke	Yeah no, my goodness.
Erin Welsh	Yeah.
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 talking about radiation.
Erin Welsh	Yeah, it's a very, very big topic.
Erin Allmann Updyke	Massive topic, absolutely.
Erin Welsh	I don't know how this episode's gonna turn out, Erin.

Erin Allmann Updyke	Me neither.
Erin Welsh	(laughs) I don't know if we're gonna do it justice but we'll try.
Erin Allmann Updyke	We'll try, we'll do our best. That's all we can do.
Erin Welsh	Yeah. We are very excited this week because radiation is a very interesting topic, it's got a massive history, the biology is super fascinating, and we were fortunate enough to speak with Dr. Timothy Jorgensen who is Associate Professor of Radiation Medicine and Director of the Health, Physics, and Radiation Protection Graduate Program at Georgetown University in DC. And he wrote the incredible book called 'Strange Glow'.
Erin Allmann Updyke	It's really great.
Erin Welsh	It's really, really... It's like one of the best examples of science writing I have ever found, I love it.
Erin Allmann Updyke	Yeah. I agree. I never took the time to learn physics properly back in undergrad and so this was a very intimidating topic for me and I feel like in our interview he explains it so beautifully and his book is just so clear and it's engaging to read, it's really, really great. Highly recommend.
Erin Welsh	Yeah, totally. It's really great. And so we are going to bring him on to talk first about the physics of radiation and radioactivity.
Erin Allmann Updyke	Yeah.
Erin Welsh	How it works, what the different kinds are, and then we're gonna dive into the biology and then the history.
Erin Allmann Updyke	Right, yeah.
Erin Welsh	So pretty much standard but we're bringing some outside expertise who can talk about physics much better than you or I could do.
Erin Allmann Updyke	I would never be able to do it.
Erin Welsh	No. Although I will admit that after reading his book I was like oh my gosh, I wish I had taken more physics, I wish I had studied more about this because it is so beautiful, some of the examples of the logic that you need to understand oh, how is Bragg's peak measured? Whatever. Okay, getting too much into the weeds already. But still, anyway.
Erin Allmann Updyke	(laughs) Absolutely. Oh yeah. Well.
Erin Welsh	Well.
Erin Allmann Updyke	First of all, important business before we get started. It's quarantini time!
Erin Welsh	It is quarantini time. What are drinking this week?
Erin Allmann Updyke	We're drinking Glow And Behold.

Erin Welsh	Great name. (laughs) Great name. Shout out to Andy, thank you so much.
Erin Allmann Updyke	So what's in Glow And Behold, Erin?
Erin Welsh	Fantastic question, Erin. Glow And Behold has gin, lemon juice, Midori which gives it that lovely neon green color, and egg white.
Erin Allmann Updyke	Of course.
Erin Welsh	So it's like a gin fizz kind of a thing.
Erin Allmann Updyke	Fantastic. We'll post the full recipe for that quarantini as well as our nonalcoholic placeborita on all of our social media channels and our website. Do we have any other business?
Erin Welsh	I don't think so. I think we should just dive in.
Erin Allmann Updyke	All right. Let's start off by learning some physics of how radiation works right after this break.
TPWKY	(transition theme)
Timothy Jorgensen	My name is Tim Jorgensen and I'm a professor of radiation medicine and biochemistry at Georgetown University's School of Medicine. I've been working there for a number of years and I have a PhD in radiation health sciences from the Johns Hopkins School of Public Health. And my background is I'm really trained as a radiation biologist which has led me into various aspects of that. And I run a graduate program in health physics at Georgetown.
Erin Allmann Updyke	Excellent. So could you start us off really broadly just by explaining what is radiation and how does it work?
Timothy Jorgensen	Okay so the simplest way to think about it is it's energy on the move basically. It's energy moving through space and that can be empty space or that can be solid space because depending on type of radiation it has the ability to penetrate things like X-rays. There's two fundamental types. There's the electromagnetic type that has waves and we're familiar with that, microwaves, radio waves, X-rays, gamma rays and things like that. But then there's another less well known type called particulate radiation that is actually little pieces of atoms and we also have heard of those terms too, like alpha particles, beta particles, things like that. Those are the particulate types of radiation. So it comes in two flavors, electromagnetic and particulate. But the ones that we're most concerned about are those that are called the ionizing radiations, so they have enough energy that they can actually damage chemicals, they can break covalent bonds and that's what we think the mechanism for all the health effects are. So we focus a lot on the ionizing radiations because those are the ones that pack a punch in terms of health effects.
Erin Welsh	Gotcha.
Erin Allmann Updyke	So you mentioned at the beginning that there are these different types of radiation, electromagnetic, particle. Could you go into a little bit more detail on what those different types are and sort of the differences between them?

Timothy Jorgensen	Sure. So let's start out with the electromagnetic radiation. So these all essentially the same thing and they're waves of electromagnetism that are going through space. And they're all the same, the only thing that's different is their wavelength. So usually people talk about light first because that's right in the middle, wavelengths of light are around just a few hundred nanometers. And the thing that's interesting about this is this is the only part of the entire spectrum that humans can see. When things get longer than light, then we start getting wavelengths are longer, these are weaker types of radiation. Think radio waves, think microwaves and things like that. These are traditionally called the nonionizing radiations.
	So some of these are very long. Radio waves are about the length of a football field. And X-rays, on the opposite site, they're just like 1/100 of the width of a human hair, so that's the range that we're talking about. So as we go to the shorter wavelengths, the energy keeps going up and up and up. First we hit the X-rays and then beyond them are the gamma rays, gamma rays are much shorter so they have the highest energies. And everything that would be shorter wavelengths, shorter than visible light, these are called the ionizing radiations because they have enough energy to actually rip electrons off of atoms and produce ions, that's why we call them ionizing radiation. And the reason that that's not good is because they break chemical bonds, particularly in biological molecules. So they're capable for example of ripping electrons off of DNA and causing breaks in DNA and other chemical reactions to happen.
	So this is the mechanism of what we think all biological consequences are. So we worry about the ionizing radiation, we don't worry so much about the nonionizing radiation. And then there are the particulate radiations. So the particulate radiations are released from radioactive materials. So radioactive materials are all atoms are a combination of protons and neutrons in their nucleus. The stable ones, the ones that are nonradioactive tend to have an equal number of protons and neutrons in their nucleus. But that doesn't have to be the case and whenever there's excess protons or excess neutrons, the atom is unstable. And what it does is it does something we call decay and that means that either a proton becomes a neutron or a neutron becomes a proton. And when that happens energy is released. Now the energy can be released in the form of gamma rays which are the electromagnetic radiation and/or it can also release particles.
	And so those particles, the most common ones are something called a beta particle which is a negative particle equal in size and mass to an electron except that it comes out of the nucleus, that's the beta particle. Larger particles are alpha particles and an alpha particle is really like a helium nucleus without the electrons on it. Alpha particles and beta particles are the classic examples. There are other examples of things that are emitted, fission products and things like that, those are the main ones. And these particles also because they're charged and they have high energy, they move through materials and ionize things along the way. And so that's why we call them ionizing radiations as well. And we believe for the most part they act on biological materials in the same way. They rip electrons off, cause damage to chemicals, particularly biological chemicals, and that's the mechanism of their action.
Erin Welsh	Gotcha. Can you talk a bit about why there's no "safe level" quote unquote for radiation exposure because of the cellular damage?

Timothy Jorgensen	Okay so the key in terms of safety is that everything is related to dose. So what we mean by dose is the amount of energy that's deposited in the material. And so the more energy you deposit in something, the more likely you are to damage it. So you can have relatively high doses, at very high doses the damage is so severe that it will actually kill a cell and the way that it kills a cell is by damaging the DNA. So the DNA is the critical target and the reason we keep saying DNA, DNA, everything else in the cell can be replaced, all the proteins can be replaced, all the RNAs, carbohydrates, everything can be fixed or replaced. But there's only one set of DNA and each genome has two copies. If you cause a lot of damage to the DNA, the DNA can repair some of that damage but it can't repair a lot of damage and so the cell will die. So these are consequences when the doses are relatively high and that's what causes radiation syndromes, radiation sickness and things like that.
	But when you get to doses below which you cannot kill cells, then essentially you don't have any of those effects. And what you really have now is an increased risk of mutagenesis. Now most of the time this scrambling or mutation is of little consequence. So let's for example suppose you have a liver cell and the radiation damages the hemoglobin gene in the liver cell. Well liver cells don't produce hemoglobin, they don't really care that their hemoglobin is damaged, they just keep going on. But if you should get a mutation in the gene that regulates growth, then you can have a problem because growth regulation is what's keeping us from having a cancer. So if the cell loses its ability to control its growth, it starts proliferating and then you have cancer.
	So we say that there is risk involved with every dose, that's rather controversial and the reason it's controversial is there are some scientists that believe that's not true and the reason they don't think it's true is because we know that cells can repair low levels of damage but these levels are so low that we cannot measure the amount of damage and repair at those levels. So that may be true, it could very well be true but conservative assumptions are that some damage happens at every level because we cannot rule it out.
Erin Welsh	Gotcha. So kind of switching gears a little bit in talking about radiation not as much of something that will give you cancer but something that is used to treat cancer, we've come a long way in terms of the specificity and how accurately you can target certain tumors and so on. But can you talk a little bit about how that works maybe and some of the risks associated?
Timothy Jorgensen	Yeah. So the initial thought with radiation therapy is that it would be an ideal agent for treating cancer because it exploits that sensitivity of rapidly dividing cells. So when you have a tumor embedded within a normal tissue, the tumor is dividing more rapidly than the normal tissue is. So if you hit it with radiation, it's the tumor that will be preferentially killed by the radiation. And that is the underlying basis for radiation therapy. So it's also given in fractionated doses because if you've known anybody who's had radiation therapy usually they come back every day for a period of time and then they spread the dose over several weeks. And the reason for that is that the normal cells repair better than the tumor cells. So by giving a rest between doses, the normal cells can exploit that rest and repair themselves better than the tumor cells can so you have another differential. So you have two differentials, you have the dividing cells and the better ability of the normal tissue to repair itself compared to the tumor. And for that reason it's a very effective treatment for cancers.
Erin Welsh	I think a lot of people also don't necessarily realize that we're exposed to a certain level of background radiation all the time just by living. Can you talk a little bit about what that is and where it comes from?

Timothy Jorgensen	Yes. So we receive background radiation from a number of sources both internal and external to our bodies, okay. A lot of natural chemicals that we have in our body have atoms that are radioactive and some of the most famous ones that we hear are about potassium and potassium is a major part of the electrolytes in our body. And potassium-40 component of that potassium is radioactive. There a lot of potassium in bananas so if you eat a banana and you have excess potassium, you pee out the same amount of potassium that you just ate. So there's the radioactivity that's in your body. I believe that your internal normal radioactivity contributes just a couple of percentage points to your total annual background dose.
	But then there are external sources of exposure and a lot of that comes from the ground. For example there's uranium and radium in the ground, that varies tremendously by where you are in the country but you get some of that. So people who live in brick buildings or mortar buildings, they get more radiation exposure than people who live in wooden buildings. We get a lot from cosmic radiation, so cosmic radiation is coming from the sun and other areas of the solar system and pinging on Earth. And then we have exposure from radon, radon is a major source of exposure for those people who have radon in their homes largely. But it acts more like a spring, so you know how a spring will pop up here and not be there? So you could put one house on top of a radon spring and the neighbor have nothing. But anyway radon is a concern because you can breathe it and it can irradiate your lung and it can produce lung cancer, doesn't do anything else other than produce lung cancer.
	Those are the major sources but then apart from those things we also have to consider the average number of diagnostic and therapeutic radiation procedures that people have. And so now that's amounting to I think about 1/3 of the total background dose that people are getting annually but again that's spotty because one person may have a lot of procedures and then the other person may have none. So anyway but on average for people living at sea level they get about 3 millisieverts of background radiation a year. But again it varies. So for example people that live in Denver, they get about 12 millisieverts and the reason that they're getting this is because Denver is the mile high city, right, so the air is thinner up there, they end up getting more exposure to cosmic rays and so they have a higher background level. So within the United States the range is generally between 3-12 millisieverts per year but it's very heterogeneous among the population but that's the general range.
Erin Allmann Updyke	Awesome. So you kind of touched briefly earlier about this but I was wondering if you could explain a little bit more about the differences in elements and what makes some elements radioactive and others not?
Timothy Jorgensen	Okay so let's go back to the supernova that created our solar system. So you can think of this as a huge explosion like the Big Bang and all the elemental subatomic particles, the protons and the neutrons, they all just scrambled and coalesced and came back together. The ones that came back together with 5 protons and 14 neutrons, they were so unstable they disappeared instantly. And so the further away from being 1:1 ratio of protons to neutrons, every combination was possible but the ones that were too far out of the mainstream instantly disappeared.
	And so what we're left with after time are those things that are pretty close to 1:1 and they're still in the process of becoming 1:1, they're still in the process of decaying. So if you draw a line, they call it the diagonal stability, you put the number of protons, you put the number of neutrons on a chart and you wrote all the stable ones, they would fall along this line of stability. And then if you had things with other combinations, the further away from that line, the shorter their half-life would be. So everything we're left with now is clustered around the line because these are things that have half-lives anywhere from hundreds of years or so to thousands of years. So they're long enough to persist in our environment, okay, but they're still on their way to everything becoming stable.

Erin Welsh	That is so cool. It's fascinating. So then talking about some of the times where we see these unstable elements is when we talk about nuclear bombs or we talk about meltdown at nuclear power plants. Can you talk a little bit about first of all just a little brief overview about maybe what criticality is or what the self-sustaining reactions are and how that works in nuclear energy? And then also a bit about what happens in nuclear bombs sort of in a parallel way.
Timothy Jorgensen	So basically we're talking about now fission. So I didn't really talk about fission when I talked about radioactivity but there is another way that very, very large things become more stable quickly, okay, and that is they just split. So uranium is up there, the common uranium elements are like 235-238, these are huge atoms. Some of those atoms will just spontaneously break apart, that's what fission is. When that happens you have fission particles, you have two smaller pieces but also you'll have neutrons that will just break off and fly out. So the thing about these neutrons are that if they hit a neighboring uranium atom, they can induce them to split. And the specific isotope we're talking about is uranium-235 and when it splits it releases about 2 or 3 neutrons I believe for every fission, okay.
	So you can imagine that if this one were to split and release 2, let's just say 2, and it would hit two other atoms and they produce 2, and then 2 other atoms and they produce 2, you can see you have a chain reaction. And so you have all the uranium atoms disintegrating, that's what a nuclear chain reaction is. So why doesn't that happen? The reason that doesn't happen is because neutrons are very penetrating and so if you have a mass of uranium like this, most of them will escape that mass before they interact with another uranium. But if you keep increasing the size of the mass of uranium, you get to a point where most of them are not escaping anymore, they're staying within that mass and that is a critical mass. And what makes it critical is you have enough mass there now that you will have a chain reaction, you have a self-sustaining chain reaction because the neutrons cannot escape.
	So in terms of how that's used in nuclear power, if you can control that and you can control that by determining, they usually put the uranium in rods and they move them in and out of a contraption that determines how many neutrons are going to escape and how many are gonna stay in, they can control that reaction. Those reactions produce heat and after that it works just like any other power plant, it produces heat, heat turns turbines, turbines make steam and electricity and that's how it works. It's just a means to produce heat. And as long as you can control that you have a nuclear power plant. And a nuclear bond, it's the same principle but you produce criticality instantly, you push all the uranium together at the same moment and you produce this instantaneous criticality which results in a huge explosion and that's the basis of a nuclear weapon.
TPWKY	(transition theme)
Erin Welsh	That was awesome, thank you so very much Dr. Jorgensen, it was so great to talk with you and thanks again for writing such an incredible book.
Erin Allmann Updyke	Yeah, we really appreciate the time that you took to explain everything so clearly and how awesome that book is. Really great.
Erin Welsh	Yes.
Erin Allmann Updyke	Well then, now that we understand some of the physics of how radiation works, let's talk about the symptoms that we see, shall we?
Erin Welsh	Let's do it.

Erin Allmann Updyke	Okay. So like Dr. Jorgensen so beautifully explained, a lot of the damage that is due to radiation has to do with the free radicals that it creates that damage DNA directly. So we'll talk a little bit more in detail about that and then we'll talk about the acute and the chronic effects that we see from radiation exposure, sound good?
Erin Welsh	Sounds great.
Erin Allmann Updyke	All right.
Erin Welsh	I mean that's terrible but yeah.
Erin Allmann Updyke	Yeah, I know. That's true of all of our episodes though so nothing new.
Erin Welsh	Yeah.
Erin Allmann Updyke	All right so acutely, right, shortly after exposure to radiation like Dr. Jorgensen explained, you're making these free radicals that are damaging your DNA. So we can guess then and we are correct that the cells that are going to be the most affected by that type of damage are cells that divide rapidly or divide often. So we can exploit this when we think of tumor cells which are rapidly dividing cells and that's why we can use radiation as a treatment for cancers. But it's also going to affect things like our epithelial cells which are the linings of our gut and our lungs, our skin cells, the hair follicles are cells that replicate rapidly, our blood cells.
Erin Welsh	All right so it explains leukemia, it explains the GI symptoms.
Erin Allmann Updyke	Exactly.
Erin Welsh	And also I think I remember reading this but cells, if you think about the opposite end of the spectrum of tumor cells, you think of nerves.
Erin Allmann Updyke	Yeah.
Erin Welsh	That's why you don't see a lot of that.
Erin Allmann Updyke	We'll talk about that in detail.
Erin Welsh	Okay.
Erin Allmann Updyke	But yes, you are 100% correct. In general nerves and your brain cells are actually quite resistant to the effects of radiation and it's largely because they replicate so infrequently if at all.
Erin Welsh	So interesting. It's just like oh my gosh, it makes sense.
Erin Allmann Updyke	It makes sense.
Erin Welsh	I feel like there is such a big black box around how radiation works that makes people very scared of it.
Erin Allmann Updyke	Uh huh, totally.

Erin Welsh	But also rightfully so.
Erin Allmann Updyke	Yeah.
Erin Welsh	And I think that part of assessing where our fear level should really be is just breaking down that black box.
Erin Allmann Updyke	Absolutely, understanding how it actually works. I agree entirely.
Erin Welsh	Yeah.
Erin Allmann Updyke	But another thing I do wanna say that another mechanism of damage beyond just this DNA damage is that these free radicals that are produced by radiation... So radiation isn't the only thing in the world that causes free radicals to be produced and actually bacterial infections often result in the formation of free radicals. So our body knows how to respond to the production of free radicals and can actually go ahead and minimize the damage. The way that it does that is through the inflammatory pathway. So exposure to radiation also results in our pro-inflammatory pathways being activated. So that means that kind of long term and chronic exposure to radiation can result in a lot of long term inflammatory symptoms. Okay, does that make sense?
Erin Welsh	Yes. And long term inflammatory symptoms, isn't that also increasing your risk for cancer in absolute time?
Erin Allmann Updyke	Absolutely, absolutely, absolutely. Yeah.
Erin Welsh	Okay, okay.
Erin Allmann Updyke	Okay. So now that we have that even more context, let's talk about some of the different symptoms that we see depending on the amount of radiation that you're exposed to. Okay?
Erin Welsh	All right.
Erin Allmann Updyke	So first we'll get the worst of it out of the way. And you heard about this in our firsthand account and that is acute radiation sickness or acute radiation syndrome. So this is what we saw from people who worked at Chernobyl, this is what we saw after the atomic bombs in Hiroshima and Nagasaki, and it's also been described in some cases after total body irradiation for treatment of cancers but that's not normal and pretty rare. Okay.
Erin Welsh	Well yeah.
Erin Allmann Updyke	Oh I guess you'll probably tell me whether it's actually rare. I modern day.
Erin Welsh	(laughs) Yeah.

Erin Allmann Updyke	All right so there are a couple of different, three different clinical syndromes that can happen after acute radiation exposure and the type that you will get will depend on the amount of radiation you are exposed to. So those three are neurovascular which means central nervous system and vascular, so blood supply effects; hematopoietic which means your stem cells that produce blood cells, white blood cells and red blood cells and platelets; and gastrointestinal. Those are the three syndromes. So let's go through them. The neurovascular syndrome requires the highest doses of radiation to see that syndrome. In general it's over 20,000 millisieverts of exposure which is a huge, huge amount of radiation, okay. If you're exposed to that much radiation that's how much it takes for your brain and blood vessels to actually become affected. So the symptoms that you see are things like headache which is very severe headache, apathy, lethargy, seizures. Because it affects the blood vessels your heart will start to go into an arrhythmia and basically you're dead within 24-48 hours.
Erin Welsh	Your body just shuts down.
Erin Allmann Updyke	Absolutely. Your brain and all of your blood vessels just are wiped out, the cells are just destroyed and so you die. Not great. Okay. Next syndrome, the gastrointestinal syndrome. This generally happens after exposure to also very, very high amounts of radiation between 10,000-20,000 millisieverts. And your GI tract we already talked about is very susceptible to the effects of radiation so these symptoms are gonna be like nausea, vomiting, diarrhea, anorexia, so not wanting to eat anything, huge amounts of abdominal pain, you can get distention. It can affect the cells of your gastrointestinal tract so much that they are unable to undergo peristalsis so they stop moving, so you're not basically able to move any food or liquid through, so your not absorbing things properly, you can become massively dehydrated and you'll likely die. But it's a slower more prolonged death than with the neurovascular syndrome.
Erin Welsh	Wow.
Erin Allmann Updyke	The hematopoietic syndrome is what happens when your bone marrow, your blood cell regeneration stem cells are affected. So the first cells that tend to be affected are your lymphocytes which are one group of your blood cells and then your granulocytes which are like your neutrophils, another white blood cell, then your platelets, then your red blood cells. So basically whichever cells turnover the quickest are the first ones to start to die off and not be able to be replaced. Those purple spots that you described in the firsthand account, those are because of hemorrhages because your platelet count is low. So that's not good.
	And so basically because your blood cells, especially your white blood cells as those start to decrease, your body is defenseless against other pathogens. So if you don't die from that and then from bleeding because you don't have any platelets to clot your blood, then you die from super infections, so bacterial infections or viral infections or reactivation of any latent infection. So it's really common if you have like an underlying, a lot of us have viruses just sort of hanging out in our bodies that never cause problems until you have no white blood cells to fight them off.
Erin Welsh	Right.
Erin Allmann Updyke	So you generally see the hematopoietic stem cell effects anywhere from about 1000 millisieverts all the way up to 10,000 millisieverts of exposure to radiation. But you usually won't die from it unless it's at least more than 5000 millisieverts of exposure.
Erin Welsh	So one of the things that I thought was interesting is that in one of the books that I was reading it talked about how in some of these tests, when they test the hydrogen bomb or something, there would be soldiers at different distances from that.

Erin Allmann Updyke	Yeah.
Erin Welsh	And within that same distance which first of all you could then see the stages of the very dose dependent-
Erin Allmann Updyke	Right.
Erin Welsh	But even within a certain quote unquote "dose" you had differences in reaction. Why is that?
Erin Allmann Updyke	Absolutely. That's a good question, I don't fully know the answer. Whether it it has to do with how much your body just happens to be able to be resistant to it, like if you're really young and healthy and you don't have any latent infections then maybe you can survive that hematopoietic effect whereas someone else who has CMV, that gets reactivated so they end up deteriorating faster. Or whether it just has to do with maybe even though you were standing at the same distance, you were at a different angle so you got exposed differently, you were wearing different clothes so your exposure was different. It's a really good question.
Erin Welsh	Right. Yeah.
Erin Allmann Updyke	But so that's kind of the acute radiation syndrome. And again this, if you are exposed to less than about 500 millisieverts of total body radiation, you basically won't see any of these syndromes.
Erin Welsh	Of the acute.
Erin Allmann Updyke	Of the acute, exactly. And there are also phases of this illness especially as you're exposed to the lower, lower but still higher than 500 dosages where first onset you'll have like a prodromal phase where you'll still get nausea and vomiting even minutes or hours after exposure or it might be kind of days or weeks after exposure. And then there'll be a period of time where your GI symptoms have cleared up and then you'll go on to have more of the stem cell of your blood cell effects where you'll see your blood cell counts will drop etc. So you go through all of these phases and how long each of those phases last and how long it takes between them depends on the total body exposure to that radiation. What symptoms you're going to see depend on what cell type and how long the turnover is, how quickly those cells replicate. So the GI symptoms are some of the first that you see because the turnover of our epithelial cells of the GI tract are like 7 or 8 days, it's really fast. Whereas our red blood cells have a lifetime of about 120 days, so it takes a long time before you'll see any anemia from radiation exposure.
Erin Welsh	Yep, yep, yep. Okay.
Erin Allmann Updyke	But then white blood cells have a shorter half-life, platelets are somewhere inbetween. So yeah. So it's really gnarly but again that's all acute radiation syndrome which is from exposure to very, very high levels of radiation which is very, very rare in the modern day and age. It's not impossible but it's very rare.
Erin Welsh	Right.
Erin Allmann Updyke	So what about chronic effects, what about the normal kind of radiation that we're all exposed to? What is that, how does that affect us? Okay. Basically the biggest risk overall of late radiation exposure, so kind of cumulative radiation exposure over your lifetime whether small amounts over time or a large amount all at once but not enough to cause ARS. The biggest risk is the development of cancer.

Erin Welsh	Question.
Erin Allmann Updyke	Yeah.
Erin Welsh	Is there any treatment?
Erin Allmann Updyke	Oh good question. So for acute radiation syndrome, no, absolutely not. If you have for example the hematopoietic, so if you don't die from the CNS effects, the central nervous system effects or the GI syndrome. If you have high amounts of exposure and you have this hematopoietic response, the best treatment is essentially supportive care, making sure they're super sterile so they don't get a secondary infection so that their stem cells have time to regenerate and heal essentially. They have used blood transfusions and bone marrow transplants to try and give someone back those stem cells.
Erin Welsh	Okay.
Erin Allmann Updyke	But again because it's generally so rare and there's been so few cases of it throughout the world comparatively, there's not like an antidote to radiation exposure. And then even chronically like from overall exposure, when we use radiation for cancer treatment there's no treatment for those effects. There's symptomatic relief, so for radiation-induced nausea for example which is really common, we have drugs that help to treat the nausea associated with it, they don't do anything to change the effects that radiation is having on the GI tract but they help your brain deal with the nausea so that you don't feel nauseous.
Erin Welsh	Okay. But in any case you cannot reverse the effects of radiation on your cells.
Erin Allmann Updyke	Nope. Womp-womp. Too depressing?
Erin Welsh	I mean we're not even in the history yet, Erin.
Erin Allmann Updyke	No I know, yeah. So tell me about the Erin, I wanna know how depressing it can get and where this all came from. How did we first figure out radiation?
Erin Welsh	I can't wait to tell you.
Erin Allmann Updyke	Great.
Erin Welsh	We'll take a quick break first.
TPWKY	(transition theme)
Erin Welsh	Okay. This is a massive history as you might expect with tons and tons of different aspects to cover and I'm gonna do the best that I can to tell this story but it's not gonna be super in-depth because then we'd have literally like a 10 hour episode, we could do a miniseries on this.
Erin Allmann Updyke	Of course.
Erin Welsh	But each part of the story of radiation has its own history and I'll recommend a ton of books and some documentaries to watch to get more in-depth info on each of these topics.

Erin Allmann Updyke	Excellent.
Erin Welsh	And I have to say just across the board every single book that I read for this was absolutely incredible, like really fascinating and interesting and well written and horrifying and all the things.
Erin Allmann Updyke	Everything you want in a book!
Erin Welsh	Basically. All right so here's what I'm gonna do. I'm gonna start with the early discovery of radiation from a physics perspective.
Erin Allmann Updyke	Awesome.
Erin Welsh	And then I'm gonna talk about how the harmful effects of radiation were first discovered, particularly from an occupational exposure standpoint.
Erin Allmann Updyke	Yes!
Erin Welsh	And then a little bit about human experimentation.
Erin Allmann Updyke	Because of course.
Erin Welsh	Unethical studies, of course. And then I'm gonna talk about how radiation has been used as medical therapy.
Erin Allmann Updyke	Cool.
Erin Welsh	I'm not gonna go into too much of the story of meltdowns like Three Mile Island or Chernobyl or Fukushima simply because each one of those is an entire story and I wouldn't be able to do it justice.
Erin Allmann Updyke	Yeah.
Erin Welsh	But I'll recommend some reading.
Erin Allmann Updyke	Perfect.
Erin Welsh	There you go. Okay, let's dive in. "I have discovered something interesting but I do not know whether or not my observations are correct."
Erin Allmann Updyke	(laughs) If that is not written in every student's lab notebook...
Erin Welsh	(laughs) But then most of the time, 99% of the time it's like, 'Nope, just miscounted.'
Erin Allmann Updyke	Yeah.
Erin Welsh	Nope, my model had a weird variable in it. Those are the words that Wilhelm Conrad Röntgen said to a colleague of his in December 1895, just a few days after discovering invisible rays that could pass through solid objects. And I mean it's maybe not that surprising that he was so skeptical of his own observations because invisible rays that don't follow the rules of physics-

Erin Allmann Updyke	Right, it seems like magic.
Erin Welsh	Yeah, sci-fi novel type stuff.
Erin Allmann Updyke	Yeah.
Erin Welsh	Röntgen who was an experimental research, empirical evidence kind of guy, he wasn't like a super big thinking theoretician, he had been conducting some experiments in his lab on running an electric current through a Crookes tube looking at cathode rays. And he had observed a faint glow that appeared on fluorescent screens that weren't near the tube where he was doing his experiments.
Erin Allmann Updyke	Okay.
Erin Welsh	This glow even appeared if he blocked the tube with books or cardboard, anything he could find in his lab. So he was like okay, this has to be a new kind of ray. It was one that couldn't be bent by a prism, it couldn't be deflected by a magnet, but it could pass through solid objects. So he gave these rays a temporary name: X-ray. Because X, he wasn't really sure what X stood for yet.
Erin Allmann Updyke	Yeah it's like disease X when we don't know.
Erin Welsh	But then it stuck, yeah. And he continued to toy around with these rays and discovered that while they could pass through wood, they couldn't pass through metal. So then he got to wondering what about human flesh?
Erin Allmann Updyke	Of course, isn't that the next thing you would wonder? Wood, metal, human flesh.
Erin Welsh	(laughs) I mean honestly, kind of. And so when he held his hand in front of the screen he could see his bones but not his flesh. Can you imagine?
Erin Allmann Updyke	I would love to imagine. Is there a show about this yet cause I wanna watch that episode.
Erin Welsh	Good question, I don't know.
Erin Allmann Updyke	Okay. We'll find out.
Erin Welsh	There should be.
Erin Allmann Updyke	Someone tell us. I mean to see your bones when no one has ever seen their bones unless they take off the skin and muscle to take a look at it, like to see your bones without cutting your skin. What?!
Erin Welsh	Yep, oh yeah.
Erin Allmann Updyke	It's magic!

Erin Welsh	Well and it gets even better because he was never described as a big theoretical thinker but he connected these dots pretty quickly between this new technology and its possible application in medicine. He was like oh this could be used for medicine, we could look for things inside the body.
Erin Allmann Updyke	Yeah.
Erin Welsh	Okay. I mean it make sense but holy cow. And he also realized that if he replaced the fluorescent screen in his lab with photographic film, he could capture the images.
Erin Allmann Updyke	Side note, I still think that photographic film is also like magic.
Erin Welsh	Oh totally. I mean so are records and CDs.
Erin Allmann Updyke	Yeah! And computers. All of it.
Erin Welsh	(laughs) And computers.
Erin Allmann Updyke	Actual magic.
Erin Welsh	Records especially, I remember laying next to my record player being like I don't understand.
Erin Allmann Updyke	Still don't.
Erin Welsh	I have since watched YouTube videos about how it works, still don't get it. Okay but you've probably seen one of the very first X-rays ever taken. It's of his wife's hand with her wedding ring on it. It's very cool. And apparently after he showed her the image she was like, 'I've seen my own death.' That's what she said. (laughs) Well I mean it is sort of like this is eventually what you return to. It's very interesting. Anyway.
Erin Allmann Updyke	Yeah.
Erin Welsh	So I feel like in so many of the histories that I've researched it's like someone discovers something amazing and then people ignore it for decades or they don't believe them or whatever.
Erin Allmann Updyke	Yeah.
Erin Welsh	This is not the case with radiation and X-rays at all. At all.
Erin Allmann Updyke	Awesome.
Erin Welsh	So in almost record time, Röntgen got his finding published in a scientific journal and less than 2 weeks later there were newspapers all over the world announcing this discovery, this new kind of ray that allowed you to peek at your skeleton.
Erin Allmann Updyke	Oh my gosh.

Erin Welsh	Researchers were able to easily replicate Röntgen's experiments because the equipment was pretty simple and some kicked it up a notch, like immediately replying it to medical intervention. So the first time that it was used in a medical intervention way was to help surgeons locate a bullet in a guy's leg which they were able to successfully remove.
Erin Allmann Updyke	And we still do that. How cool.
Erin Welsh	We still do that. Okay so December 28, 1895, X-rays are first published in a scientific journal.
Erin Allmann Updyke	Okay.
Erin Welsh	February 4, 1896, so less than 2 months later-
Erin Allmann Updyke	2 months later.
Erin Welsh	They're used to help save a person. Has anything ever moved from discovery to application so quickly?
Erin Allmann Updyke	Certainly nothing we've ever talked about.
Erin Welsh	No. And you know it's sort of a mixed blessing because we had this amazing power, ethics and knowledge moves at a much slower pace than technology.
Erin Allmann Updyke	Oh yeah.
Erin Welsh	Anyway, for his work Röntgen was awarded the Nobel Prize in physics in 1901. And side note, in the first half of the 20th century there were over 21 Nobel Prizes in physics for research related to radiation and one in physiology or medicine.
Erin Allmann Updyke	Wow.
Erin Welsh	That's a lot of Nobel Prizes.
Erin Allmann Updyke	Yeah, it is.
Erin Welsh	As you can imagine the history of radiation is filled with many, many sad stories. And some of those are about people not knowing the dangers of radiation and dying horrible early deaths. Röntgen actually always protected himself, I don't know whether it was out of an extreme caution but he died in old age apparently not ever having been negatively impacted by the rays that he discovered. But not so luck were Edison who through his work on a fluoroscope nearly lost his eyesight-
Erin Allmann Updyke	Whoa.
Erin Welsh	And Edison's assistant Clarence Dally fared even worse. He first got severe burns that covered his hands leading to amputated fingers and then a hand and then cancer creeping up his arms into his chest which is what ultimately killed him. Okay so as we have talked about, radiation is a broad word for this whole episode because there's ionizing and nonionizing radiation, there's particulate and there are differences in which of these types of radiations can hurt you and how they can hurt you and the doses and blah, blah, blah.

Erin Allmann Updyke	Right. Yeah.
Erin Welsh	So I've talked about one type of radiation and how it was discovered, X-rays.
Erin Allmann Updyke	Right.
Erin Welsh	But I wanna talk about how particulate radiation was discovered.
Erin Allmann Updyke	Yes!
Erin Welsh	And it actually wasn't long after Röntgen's discovery of X-rays when a guy named Antoine Becquerel started wondering about the link between X-rays and fluorescence. In particular, where was that visible glow from the fluorescence coming from?
Erin Allmann Updyke	Yeah. Becquerel, isn't that a unit or something?
Erin Welsh	Yeah.
Erin Allmann Updyke	Okay.
Erin Welsh	Basically if you were one of the first people who worked on radiation, you had a unit named after you. Curie is next. Röntgen, Becquerel, Curie.
Erin Allmann Updyke	Gray.
Erin Welsh	So in 1896, Becquerel tested a bunch of chemicals and long story short, found that the presence of uranium sulfate alone would expose film without the help of other light source or X-rays. So he concluded that uranium atoms emitted some kind of invisible radiation along the same lines as X-rays.
Erin Allmann Updyke	Yeah.
Erin Welsh	In short, he discovered radioactivity.
Erin Allmann Updyke	Yes!
Erin Welsh	So Becquerel along with Marie Curie and Pierre Curie, aka the French trifecta is what they were called, they were awarded the Nobel Prize in physics in 1903. So again, just rapid pace stuff going on.
Erin Allmann Updyke	Yeah, 1903. That's only a few years later.
Erin Welsh	Oh yeah. Yeah. And uranium of course would go on to play a major role in the history of the world as I'll talk about later with the development and deployment of atomic bombs as well as with human experimentation.
Erin Allmann Updyke	Naturally.

Erin Welsh	Mm-hmm. So Becquerel got out of the radioactivity game pretty early but the Curies would go on to contribute to the field for years and years. They were the ones who actually coined the term 'radioactive' which is pretty cool. For their share of the Nobel Prize, the Curies realized that uranium ore actually emitted more radioactivity than could be accounted for by just uranium alone. They found that there were at least 3 radioactive elements in the ore: uranium and tow new ones, one which they named polonium after Poland which was where Marie was from, and radium which is from the Latin word for ray.
Erin Allmann Updyke	Okay.
Erin Welsh	Side note, Marie also died of radiation poisoning and her body is in a lead casket that's protected by a lead whatever because there was so much radiation in it.
Erin Allmann Updyke	Oh wow. Oh my gosh.
Erin Welsh	Research on X-rays and radioactive elements continued at full speed throughout the 1920s and the 1930s and the start of WWII brought this increased urgency to it as well as a narrowing focus on the possibility of nuclear weapons.
Erin Allmann Updyke	Which is just so typical of humans!
Erin Welsh	I know, man. I know.
Erin Allmann Updyke	Hey, here's this so powerful thing, how can we weaponize it?
Erin Welsh	Yeah, rinse and repeat.
Erin Allmann Updyke	Let's experiment on our most vulnerable populations without their permission and find out!
Erin Welsh	Oh yes. Let's not jump the gun now, Erin. There's plenty of that in here. (laughs) Okay so for a while it had been thought to be too impractical, like there's no way we could actually make these weapons but then when the concept of these self-sustaining chain reactions, so criticality as Dr. Jorgensen talked about, once that was discovered then it was like, 'Oh! We can do this.' So if you can get that criticality to happen, you've harnessed an absolute unbelievable amount of energy. But if you lose control of it, you're looking at a meltdown, as we've seen happen. Or a bomb. Okay. In a project headed by Enrico Fermi under the University of Chicago, criticality was achieved on December 2, 1942.
Erin Allmann Updyke	Wow!
Erin Welsh	About the midway point of WWII.
Erin Allmann Updyke	Okay.
Erin Welsh	Yeah. And this work would pave the way for the Manhattan Project and the development of nuclear weapons.
Erin Allmann Updyke	Wow.

Erin Welsh	And I'm not gonna go too much into the history of the Manhattan Project itself but by the time that the project was underway, the dangers of working with radiation had been well recognized. And research done by Hermann Muller, so he was a Nobel Prize winner and also a huge proponent of eugenics.
Erin Allmann Updyke	Oh!
Erin Welsh	He loved eugenics.
Erin Allmann Updyke	Great. What a stand-up guy. Not at all.
Erin Welsh	Nope. So he showed that radiation induced genetic mutations in fruit flies and that finding attracted a lot of medical science attention.
Erin Allmann Updyke	Gross.
Erin Welsh	Because if it caused mutations in fruit flies, in their DNA, what would it do to humans?
Erin Allmann Updyke	Yeah.
Erin Welsh	How much could hurt you? What was the safe level? Was there a safe level? And as more and more people worked with radiation, its dangers both short and long term became more clear. So whereas the dangers of electricity were very much feared in its early days, maybe helped along by the alternating current smear campaign by Edison - I would love to do an episode on Edison and Tesla just because the history is so interesting.
Erin Allmann Updyke	I was waiting for you to smear Edison, like you mentioned him earlier and then didn't smear him and I was a little shocked.
Erin Welsh	Oh no, it's happening now. Not even really relevant to the discussion of radiation but I just had to throw in a 'but did you know?' (laughs) Anyway. But electricity you could directly see the damage that it could cause, right, you could electrocute a person, an animal, a tree, whatever.
Erin Allmann Updyke	Right.
Erin Welsh	But the effects of radiation were mostly invisible.
Erin Allmann Updyke	Right, okay.
Erin Welsh	And so precautions weren't always taken and when they were taken it was often too late.
Erin Allmann Updyke	Well and also like we talked about, sometimes the effects are so long after exposure it's even hard to correlate back.
Erin Welsh	Mm-hmm.
Erin Allmann Updyke	Right.

Erin Welsh	But still a lot of the people who had been working with radiation were working with these incredibly high doses and so the negative health effects of radiation had been known basically ever since its discovery.
Erin Allmann Updyke	Man oh man.
Erin Welsh	Yeah. Like I said, many of the people who used X-rays and had studied radioactive elements had suffered or died from their exposure to radiation.
Erin Allmann Updyke	Right.
Erin Welsh	But I think it's really interesting that these people, the researchers who worked on this weren't actually the first to experience this. That prize goes to some miners in Schneeburg, Germany who for as long as people could remember had gotten sick with a mysterious lung ailment. Later research showed the mine to be full of radon gas which is produced when radium decays and so is a source of radiation.
Erin Allmann Updyke	Wow.
Erin Welsh	Uh-huh. So they all had lung cancer at a time when lung cancer wasn't as common as it is now.
Erin Allmann Updyke	Wow.
Erin Welsh	And so that was sort of a pre-X-ray thing, but those mines full of radon gas weren't the only radioactive workplaces. Fluorescent paint containing radium glowed in the dark which made it perfect to paint the numbers on a watch face so that people could tell the time in the dark. So in the early 1900s, wristwatches were largely worn by women while men used pocket watches. But WWI changed that because you needed to see the time in a trench, you needed to have one, it was much faster to just look at your wrist rather than pull something out of your pocket which could easily be lost. And so these glow in the dark wristwatches with the numbers painted made coordinating night maneuvers possible.
Erin Allmann Updyke	Whoa.
Erin Welsh	And WWI, once it was over, also made these watches the thing to have, like they were super popular, everyone had to have one. I mean demand absolutely skyrocketed. And so these watch factories were a great place for a young woman to work at the time.
Erin Allmann Updyke	Wow.
Erin Welsh	You were paid by the dial, so if you were a fast painter you could make up to $24 a week which is $317 in 2015 dollars.
Erin Allmann Updyke	Okay.
Erin Welsh	And that was at a time when the average weekly wage for a woman was $15.
Erin Allmann Updyke	Okay, so it was good money.

Erin Welsh	It's good money. Factories popped up all over in New Jersey, Illinois, Connecticut and it was in Connecticut where a 17 year old named Frances Splettstocher had started working in 1921. Four years later, Frances went to the dentist complaining of facial pain and toothaches.
Erin Allmann Updyke	Uh oh.
Erin Welsh	The dentist pulled a tooth and a piece of her jaw came out with it. Yep. The tissues in her mouth basically at that point started to deteriorate, a hole appeared in her cheek, and a month later she was dead. And unfortunately her story is not unique, not at all. All over these factories, dial painters were getting sick and dying, earning them the name 'Radium Girls' which is an excellent piece of nonfiction, you should definitely read it. Apparently it's also a movie but I haven't watched it, I don't know.
Erin Allmann Updyke	I've heard of it, yeah. I haven't seen it either.
Erin Welsh	Oh my gosh, the book is so good. Okay. One of the keys to being a good dial painter was that - have you ever tried to paint fine, the bristles get so smudged so easily.
Erin Allmann Updyke	Oh no. Smudged.
Erin Welsh	And you have to keep them together.
Erin Allmann Updyke	Yeah.
Erin Welsh	And so in order to keep that brush paint super sharp to paint accurate numbers, you would put the tip of that paintbrush in your mouth and twist it.
Erin Allmann Updyke	In your mouth, oh no.
Erin Welsh	If you did this, which by the way was a technique taught at the factories, like this is what you should do-
Erin Allmann Updyke	Oh no. Yeah.
Erin Welsh	You would end up consuming about a coffee cup worth of radium-containing paint over the course of a year. You would literally sometimes come home and your clothes and your body, you would glow in the dark because of the radium dust.
Erin Allmann Updyke	Oh my god.
Erin Welsh	Mm-hmm, the fluorescent dust. And while a lot of this radium would end up being passed through the gut, about 20% of it would be absorbed in the bones, essentially leading to a radioactive skeleton. And the jaw was one of the places of course first because you're putting it in your mouth.
Erin Allmann Updyke	You're putting it right there.
Erin Welsh	Yeah.
Erin Allmann Updyke	And the blood supply too is just gonna go straight into those bones right there. Oh no.

Erin Welsh	Mm-hmm. And so this led to an unbelievable amount of these radium girls becoming sick and dying or permanently disabled or injured by this radiation exposure.
Erin Allmann Updyke	Oh my god.
Erin Welsh	And the companies fought and fought and fought to acknowledge that they did any wrong, to enact safety measures, and to give any sort of compensation to the girls or the families of the girls.
Erin Allmann Updyke	Shock of all shocks. It surprises me not at all, Erin.
Erin Welsh	Oh I know, I know.
Erin Allmann Updyke	But ugh.
Erin Welsh	Eventually a handful of the women got some compensation.
Erin Allmann Updyke	Jesus.
Erin Welsh	But at any amount of time about 2000 women were working at these factories with a substantial portion of those getting sick.
Erin Allmann Updyke	Oh my god.
Erin Welsh	So the radium girls story is this horribly sad reminder of how a company can value greed and the bottom line over the health and safety of their employees because they view them as dispensable. But I think it's also inspiring in a way because despite being ignored and told they were faking it and being told no, you have no right to argue this, despite literally nearly dying of radiation sickness while giving their testimonies in the courtroom, these women fought and fought and fought and eventually won the battle that they should never have had to be a part of. It's a really great book. So while the biggest obstacle in the way of the radium girls was the - I think 'evil' is a fair word - company, evil company that refused to acknowledge their wrongdoing, another challenge was fighting against the popular opinion that radiation was this miracle cure. Cause that was just sort of how it had been advertised.
Erin Allmann Updyke	Yeah.
Erin Welsh	Like name any household product and you could probably get a radioactive version of it in the 1910s, the 1920s, and into the 1930s.
Erin Allmann Updyke	Weird!
Erin Welsh	Low levels were thought to be beneficial for overall health.
Erin Allmann Updyke	Okay, cool.
Erin Welsh	Yeah. And any negative outcomes from larger exposures were thought to be relatively short-lived.

Erin Allmann Updyke	Okay.
Erin Welsh	Yeah.
Erin Allmann Updyke	The opposite is true.
Erin Welsh	Yep. One medication, "medication" is in quotes, called Radithor was simply radium dissolved in water.
Erin Allmann Updyke	Oh no, oh no!
Erin Welsh	That's it. It was prescribed to people to help them heal after a broken bone.
Erin Allmann Updyke	(laughs) Okay.
Erin Welsh	Yep. So one of the people who had been prescribed Radithor was a golfer named Eben Byers who drank over 1400 bottles of Radithor and he eventually developed holes in his skull and he lost his jaw and his body is now in a lead-lined coffin to protect people who visit the cemetery from getting radiation from him.
Erin Allmann Updyke	Oh my.
Erin Welsh	Mm-hmm. And fortunately I think the other thing to point out is that radium-containing medications didn't cause an epidemic of radiation poisoning necessarily mostly because the vast majority of these treatments contained no radium at all.
Erin Allmann Updyke	They were snake oil medicine?
Erin Welsh	Yeah! Because the ones that actually did were too expensive for most people to use regularly.
Erin Allmann Updyke	Oh gosh.
Erin Welsh	But radiation was also used to irradiate hair like, 'Oh you want hair removal? Let's irradiate your upper lip.'
Erin Allmann Updyke	Your little mustache?
Erin Welsh	And then your upper lip falls off.
Erin Allmann Updyke	Uh-huh. The hair will be gone too but...
Erin Welsh	Yeah. It wasn't false advertising necessarily.
Erin Allmann Updyke	Right. (laughs) It's effective but...
Erin Welsh	So early in the 20th century those that worked with radiation were well aware of these hazards but what was more difficult to determine was what levels of radiation were necessary to cause harm.

Erin Allmann Updyke	Right.
Erin Welsh	And a big challenge or a big hurdle was not having a standardized way to measure radiation exposure but that sort of is a whole separate story.
Erin Allmann Updyke	Yeah.
Erin Welsh	But eventually standards were put into place for the safe level of exposure to radium and X-rays and gamma rays.
Erin Allmann Updyke	Yeah.
Erin Welsh	But debates over whether these standards were accurate continued. And when the Manhattan Project to develop the atomic bomb began, it was clear that more fine scale information on the dangers of radiation exposure was necessary for the researchers to understand their level of risk. After all, two researchers died in two separate instances in the Manhattan Project after experiencing a massive dose of radiation when an experiment went wrong. But where would they get this information on radiation exposure? Well for one, the atomic bombs themselves. Okay. The catastrophic impact of the atomic bombs dropped by the US on Hiroshima and Nagasaki without any warning in WWII was not just the enormous loss of life from the direct impact of the bomb but also in the lingering effects of radiation sickness that would only be felt weeks, months, and years after the bombs. I mean the trauma is immeasurable.
Erin Allmann Updyke	Yep.
Erin Welsh	And a lot of what we know today about the harmful effects of radiation on the body, both acute and chronic, come not from early occupational exposure to X-rays or radium but from these bombings. In the Red Cross Hospital in Hiroshima only 6 out of the 30 doctors and 10 out of the 200 nurses were able to function after the bomb was dropped. An estimated 90% of Hiroshima's doctors and nurses had been killed or injured by the bomb. The 600 bed hospital was completely unprepared for the 10,000 bomb victims that would head there that day alone. Many of these people would die vomiting and with burns all over their bodies and many others would be left with this insidious internal radiation injuries whose effects would only manifest later on in their life. And the world had never seen radiation illness on this scale before. And the doctors at the hospitals in Nagasaki and Hiroshima were unprepared to deal not only with the sheer number of people needing help but they also didn't even know how to help them.
Erin Allmann Updyke	Right.
Erin Welsh	Because no one had told them anything about radiation, no one had ever experienced anything like this before.
Erin Allmann Updyke	Right.
Erin Welsh	And like you said, there were no treatments.
Erin Allmann Updyke	There's no treatments, yeah. There's nothing you can do.
Erin Welsh	Yep. The number of people killed in Hiroshima is not quite certain, like how many were actually just vaporized by the bomb and didn't survive the initial blast but estimates range from 90,000-165,000 deaths, about 75% of those died from fire and trauma and the other 25% died from the direct effects of radiation. And that's like the immediate death toll.

Erin Allmann Updyke	Immediately, right, yeah.
Erin Welsh	And then once those three waves of death had ended it was just a waiting game to see how radiation poisoning would continue to manifest in those who had been exposed. In both Hiroshima and Nagasaki, one of the health outcomes of these bombs wouldn't be seen for several years after the bomb had been dropped: leukemia. And it turned out that the rates of leukemia among atomic bomb survivors were skyrocketing. And soon it became apparent that other types of cancers were also on the rise and the effects on the bomb would continue to be felt for decades and decades. To some of the people in power in the US, a lot of the people one might say, these bombings were viewed as an absolute win. Not only did they result in the absolute surrender of Japan and the end of WWII but they also provided this fantastic opportunity to see how different doses and types of radiation impacted people. It's horrible.
	So the US immediately sent physicians to Japan to study the effects of the bomb and write down what they witnessed. And what they witnessed obviously horrified them. They had expected to see acute radiation poisoning, they had seen that before. But the increase in cancers later on and the huge geographic radius of fallout, like so much larger than they anticipated was new. And so the word 'fallout' just to define it is radioactivity that settles to Earth's surface from the sky. So if you drop the atomic bomb, all of that dust and dirt and debris that goes up into air and then settles down is radioactive and that can cover a much larger radius than the direct impact of the bomb itself, if that makes sense.
Erin Allmann Updyke	Yeah, absolutely.
Erin Welsh	But these doctors who went to Japan, they couldn't make these verbal observations known because maintaining trust in the government and a positive in radiation and nuclear weapons was cited as a reason to not be forthcoming in the risks involved in nuclear weapons testing and the horrors involved in nuclear weapons deployment. And other people viewed widespread fallout from nuclear weapons testing a small price to pay for advancement of technology and global superiority of the United States.
Erin Allmann Updyke	Erin. This is not...
Erin Welsh	It's awful. It gets worse.
Erin Allmann Updyke	Yeah of course it does, it's This Podcast Will Kill You.
Erin Welsh	Yeah. After the atomic bomb was developed, the US continued working on making a bigger and better bomb. The US decided to use Bikini Atoll which they took control over from Japan after the end of the war to use as a nuclear weapons testing grounds. One day as the entire community of Bikini Islanders were leaving church, so around 160-170 people, the US military governor said, 'Hey, the US needs your island for important research so you're gonna need to move to another island.' And so they moved them. Even though archeological evidence showed that this island had been inhabited since 2000 BCE.
Erin Allmann Updyke	Colonialism doesn't care.
Erin Welsh	Colonialism does not care. There's a documentary called Atomic Café which shows some footage, it's such a fascinating documentary, holy cow. It's from the early 80s and they show footage of propaganda footage of the US military, this very paternalistic white savior colonialism like, 'You know, we're doing what's best for you and don't you want the world to be protected from nuclear weapons?' It's so gross, dude.

Erin Allmann Updyke	You know what voice they're using, too? (old-timey voice) 'We're doing what's best for you!'
Erin Welsh	That's exactly right.
Erin Allmann Updyke	(old-timey voice) 'We know exactly what's right for you so give us your island and we'll make the world a better place!'
Erin Welsh	I mean honestly I think you just watched the documentary, you just quoted directly from it. (laughs) So anyway with now the island empty for their own use, the US was able to test the hydrogen bomb on March 1, 1954. This bomb produced a fireball 4.5 miles in diameter - that's just the fireball alone.
Erin Allmann Updyke	That's the size of the town that I live in.
Erin Welsh	It was visible over 250 miles away and it produced a crater over a mile wide and 250 feet deep. The mushroom cloud was 25 miles high and 62 miles in diameter. It's huge, it's huge. Yeah.
Erin Allmann Updyke	Oh my.
Erin Welsh	Nearly 7000 square miles of the Pacific Ocean were contaminated which was far beyond, far beyond what the US calculated it might be.
Erin Allmann Updyke	Shock of all shocks.
Erin Welsh	It was probably like, 'Oh well it'll be fine, everything's fine.' Everywhere the ground was contaminated, marine life was contaminated, reefs, fish, people died and unfortunately the US missed in their scans a Japanese fishing vessel who happened to be in the direct proximity of this. The fishermen were close enough to see this blinding light and hear the blast and they started showing signs of radiation poisoning shortly after returning to shore. All the fish that they had caught with them and sold at the markets was full of radiation, people started experiencing radiation symptoms who had purchased the fish and ingested it, etc.
Erin Allmann Updyke	Oh my god.
Erin Welsh	And the US soldiers who were present also experienced both short and long term health consequences from this and other weapons testing. And they weren't told about the risks, they just said, 'Stand in place.'
Erin Allmann Updyke	They're soldiers, they're just supposed to stand there and do what they're told.
Erin Welsh	Mm-hmm. But ultimately the US, the people in charge viewed these as unfortunate consequences and a small price to pay for the advancement of technology.
Erin Allmann Updyke	Small price to pay, human lives. NBD.
Erin Welsh	Human lives. And the sad story doesn't end there. The Bikini Islanders ended up suffering malnutrition on the smaller island that they had been relocated to and later tests showed dangerously high levels of radioactive elements in their bodies and in the food that they consumed. And so in 1980 the Atoll was entirely evacuated.

Erin Allmann Updyke	There are so many levels of horrific-ness to that, you know what I mean? Forcibly removing people from an island they've inhabited for thousands of years, absolutely decimating their culture. Now you can't eat the food that you've been eating because it's all radioactive. Now you can't even live anywhere on any of these islands. Oh and by the way, you're all gonna die from radioactivity poisoning and develop cancers down the line.
Erin Welsh	Mm-hmm. I hope that you have it in you to hear a little bit more of the dark side of this. I mean the thing is I think it's really important to tell these stories because one of the things that I wrote down in my notes was like any one of us who is doing any sort of job, particularly in research, where does our information come from? Where did we get this knowledge when it comes to medicine, when it comes to ecology, when it comes to chemistry, when it comes to physics.
Erin Allmann Updyke	Yep.
Erin Welsh	What lives were sacrificed unknowingly, unwillingly?
Erin Allmann Updyke	Right.
Erin Welsh	At what cost?
Erin Allmann Updyke	At what cost?
Erin Welsh	To make sure that we don't do it again.
Erin Allmann Updyke	Yeah, I agree entirely. I think it's so important to know where we got this information because you can talk about what we know about the symptoms of radiation poisoning but if you don't understand how we got that information then you're missing such an important part of the story.
Erin Welsh	The humanity part of it which is the only thing that keeps... You know, we need to keep that sense of humanity so that this doesn't happen again. Yeah. So the atomic bomb victims in Japan, the Marshall Islanders, the American soldier ordered to stand at varying distances from test bomb sites, the people in fallout regions, these were all unwilling and unknowing participants in the search for information on how radiation affected the human body. But they weren't the only ones. Earlier when I asked how researchers would get information on radiation exposure, if you had guessed human experimentation in addition to nuclear weapons, you would be correct. Yes by US scientists, yes often without the people's knowledge or consent. I highly recommend the book 'The Plutonium Files' for more information on these horrific examples of medicalized torture. So someone pointed out on Insta that that's what people are using in place of the words 'experiment' or 'study' for these types of things since those words, 'experiment' or 'study' can give them this air of legitimacy. Totally makes sense.
Erin Allmann Updyke	Oh that's so important.
Erin Welsh	It's a good point.
Erin Allmann Updyke	Yeah.

Erin Welsh	So during the last couple of years of WWII and throughout the Cold War, the US was involved in a multitude of different medicalized tortures or I don't know how the plural of that is but to examine the effects of radiation. For instance, plutonium was injected into people without their knowledge or consent. Yep. These people were followed for years and years surreptitiously by the researchers and when they died samples from their bodies were taken, often without consent from the family.
Erin Allmann Updyke	This was in what year?
Erin Welsh	I don't know when the first injections were, it might have been the late 1940s but throughout the 50s and 60s into the early 90s, the last person died in the early 90s.
Erin Allmann Updyke	When we knew the effects of radioactivity for decades.
Erin Welsh	Yes. Right. But what about plutonium compared to uranium?
Erin Allmann Updyke	Yeah. Let me guess what these people looked like.
Erin Welsh	Oh yeah.
Erin Allmann Updyke	Yeah.
Erin Welsh	It was always disproportionately minorities, people who were below the poverty line, children who were disabled, orphans, oh yeah.
Erin Allmann Updyke	Oh my god.
Erin Welsh	Like I mentioned, some of the children who lived at orphanages or children who were disabled were fed radioactive milk to see how that affected their growth since according to at least one scientist samples from children were far too few and far between. So Willard Libby who was the head of the Atomic Energy Commission during the time, this was in the 50s I think he said this, quote: "I don't know how to get them but I do say that it is a matter of prime importance to get them," referring to samples, "and particularly in the young age group. So human samples are often of prime importance and if anybody knows how to do a good job of body-snatching they will really be serving their country." That's a quote from who was the head of the Atomic Energy Commission at the time. Prisoners had their testicles irradiated, often without their consent or without at least informed consent, rendering them sterile and often resulting in cancer. And then you know what did consent really mean if you're imprisoned?
Erin Allmann Updyke	If you're in prison, mm-hmm.
Erin Welsh	Pregnant people were given injections of caesium to see whether radioactive elements could pass through the placenta to the fetus. And as we talked about, the people who were sought out to perform this medicalized torture on were those who didn't have the power, the voice, the ability to stop what was happening. They weren't deemed to be worthy of being protected by the scientists and project heads, the perpetrators of these crimes. And of course there were disproportionately high numbers of black people and poor people unknowingly and unwillingly enrolled in this medicalized torture. Throughout the Cold War, body parts from an estimated 15,000 humans were used in this quote unquote "research" according to a 1995 General Accounting Office study. So bodies or organs or tissue samples were taken from people without any consent from their families and much less they didn't inform them of course.

Erin Allmann Updyke	Of course not.
Erin Welsh	In the US, all over the world they would do this. They would ship internationally specimens, especially from the poorest regions of the world. Read up on Project Sunshine which was the largest of these projects.
Erin Allmann Updyke	That's a disgusting name because sunshine is something beautiful.
Erin Welsh	Isn't that horrible? So one of the theories as to why it was named Project Sunshine is because like sunshine, fallout from radiation impacts the entire world.
Erin Allmann Updyke	Well also sunshine, it sounds like beautiful and happy but it also has UV radiation which can cause cancer and kill you.
Erin Welsh	It causes cancer, there you go.
Erin Allmann Updyke	So it's insidious. Wow.
Erin Welsh	And I think it is important to consider the historical context of this time and this is in the opposite of excusing it. So at the height of these studies, the world was barely 10 years out from WWII and Nazi Germany and the horrible human experimentation and medicalized torture that went on and the Nuremberg trials during which many of these Nazi doctors were put on the stand and made to account for their crimes. And yet when conducting this medicalized torture on people, these American researchers and doctors involved in Project Sunshine and other radiation projects didn't for once think that they were in the wrong. To a great many of them, the Nuremberg Code was written for barbarians, not for them.
Erin Allmann Updyke	Wow.
Erin Welsh	They were doing this research for a higher purpose, for the technological superiority and might of the United States. And upon reflection of this time, one doctor involved in the project said, quote: "The connection between these horrendous acts and our everyday investigation was not made for reasons of self interest to be perfectly frank. As I see it now, I am saddened that we didn't see the connection but that was what was done. We wrapped ourselves in the flag."
Erin Allmann Updyke	Saddened.
Erin Welsh	Saddened.
Erin Allmann Updyke	That's it, I'm just saddened.
Erin Welsh	How regretful. (laughs)
Erin Allmann Updyke	Yeah, woops.
Erin Welsh	My bad.
Erin Allmann Updyke	My bad. Wow. Geez Louise.

Erin Welsh	So yeah. I mean there's a lot more where that comes from, please go read 'The Plutonium Files', it is an incredible book. Anyway, okay.
Erin Allmann Updyke	Oh gosh, Erin.
Erin Welsh	So yeah, a lot of what we know about the effects of radiation on the human body come from atomic weapons or come from this medicalized torture. And while a great deal of this medicalized torture was not at all therapeutic, as in the doctors weren't trying to improve the health or treat the disease of someone, it was just to see what happened. But some were actually intended to help people. And so I'm gonna end on what I hope is a little bit of a happier note by talking about the development of radiation therapy.
Erin Allmann Updyke	Okay. We'll see if we can get there.
Erin Welsh	I know. So in the early years of radiation therapies, most were actually snake oil as we've pointed out, just designed to make money. Snake oils still exist today, ahem, GOOP. Some physicians began to recognize that while radiation can cause cancer, it may also be able to treat it as well. And this is super early on too, this is a great story.
Erin Allmann Updyke	Okay, cool.
Erin Welsh	So a man named Emil Grubbe was simultaneously the owner of a light bulb company and a med student.
Erin Allmann Updyke	Like you do.
Erin Welsh	Like you do. (laughs) So he showed up to med school one day with his hands all bandaged up and one of his professors was like, 'Are you okay? What happened to you?' And Grubbe explained, 'Oh yeah, I've been working on X-rays at this factory, just testing things out.' And the professor who was named John Gilman was like, 'So X-rays are damaging to normal tissue. I wonder if they would damage or destroy diseased tissues as well.' And then thus the field of radiation oncology began.
Erin Allmann Updyke	Wow!
Erin Welsh	In 1896!
Erin Allmann Updyke	That's like months after they were discovered.
Erin Welsh	A month. A month after.
Erin Allmann Updyke	Wow!
Erin Welsh	Two days after his professor made this remark, Grubbe decided to test it out on people with cancer. And again probably there wasn't informed consent or consent at all, a lot of the people that he initially started with, there was big resistance to allowing him to do this to people who had cancer but maybe not terminal cancer.
Erin Allmann Updyke	Okay.
Erin Welsh	And so the earliest people that he tested it on were people who had terminal cancer.

Erin Allmann Updyke	Okay, that makes a lot of sense.
Erin Welsh	It makes sense. And their pain did seem to be reduced but a lot of them died anyway simply because they were in such late stages of cancer. But Grubbe wasn't discouraged. Doctors would send him people with late stage cancer, Grubbe would continue to blast them with X-rays, most died but some actually did seem to be improving which is amazing, this was 1896.
Erin Allmann Updyke	That's incredible.
Erin Welsh	This is before basically any effective medical interventions had been developed, before antibiotics even.
Erin Allmann Updyke	Wow.
Erin Welsh	Yeah. At the time that radiation therapy began to be developed, the biology of cancer hadn't even been fully clarified.
Erin Allmann Updyke	Wow!
Erin Welsh	It's amazing. And obviously there was a trial and error process to find the right dose to kill cancer cells without killing the patient, doing a better job of targeting the affected area and overall standardization on equipment. At first radiation therapy was used primarily on tumors close to the skin's surface which is where it seemed to have the best effect because that way you're not trying to penetrate too deeply into the body. And tumors deeper in the body didn't seem to decrease as much as well.
Erin Allmann Updyke	Okay.
Erin Welsh	So we know now why that might be but Alexander Graham Bell said he thought it might be because the radiation had to travel through layers of healthy tissue, cancerous tissue is more susceptible to radiation, before it got to the tumor. And he then suggested that quote, "There is no reason why a tiny fragment of radium sealed upon a fine glass ampule should not be inserted into the very heart of the cancer, thus acting directly on the disease material."
Erin Allmann Updyke	We do that!
Erin Welsh	We do that, brachytherapy.
Erin Allmann Updyke	Yeah.
Erin Welsh	That's widely used today.
Erin Allmann Updyke	Yeah wow, how cool.
Erin Welsh	Isn't that amazing?
Erin Allmann Updyke	Yeah.

Erin Welsh	Anyway. So in the early history of radiation therapy, X-rays took a backseat to radium and radon. The X-rays produced from the X-ray tube couldn't penetrate tissue very well and their application seemed limited.
Erin Allmann Updyke	Okay.
Erin Welsh	But then the physicists developed something called the linear accelerator or LINAC, I think that's how you say it-
Erin Allmann Updyke	Sounds right.
Erin Welsh	Which could produce higher energy X-rays than those that came from these X-ray tubes. And one of the first clinical trials to use the LINAC was for Hodgkin's disease, a type of cancer that is very localized in lymph nodes, often deep within the chest. And the people in the trial had well-defined early stage Hodgkin's disease which was crucial to the success rate of the treatment as later stages could mean that the cancer had spread out of the target area. The trial was a huge success. 50% of the people with Hodgkin's had been cured and that rate continued to increase.
Erin Allmann Updyke	Wow.
Erin Welsh	Yeah.
Erin Allmann Updyke	That's really cool.
Erin Welsh	It's super cool. The development and successful application of the LINAC was also an important lesson in choosing the right therapy for a person since cancer is not a catch-all disease, it's not a one type of disease.
Erin Allmann Updyke	Right. Yeah.
Erin Welsh	It's super variable even when you're talking about the same type of cancer, you're gonna have different manifestations, different areas, and not all treatments are created equal.
Erin Allmann Updyke	That's why it's so hard to treat still today.
Erin Welsh	Still today, yeah. And it's also why now today we have some cancers that are treated with radiation and others with chemotherapy or maybe a combination or in different times. Or surgery.
Erin Allmann Updyke	Yeah, or all three.
Erin Welsh	Or all three, yeah. And another big step forward in radiation therapy was when a researcher named William Bragg discovered that there was a big burst of energy released just before an alpha particle reaches the end of its track. This is now called the Bragg peak. Okay, what does that mean? It's important because you can use this Bragg peak to more precisely target a tumor and avoid the surrounding healthy tissue. And because of this super high specificity and efficiency in tumor killing, proton accelerators are apparently now being installed in clinics all over.
Erin Allmann Updyke	Yeah.

Erin Welsh	How cool is that?
Erin Allmann Updyke	That's very cool.
Erin Welsh	I love it, I love it. Okay. So that was the quick and dirty history, I didn't talk much about the whole body radiation that was performed on people without their consent all in the name of, 'Oh this'll help you.' No.
Erin Allmann Updyke	Sure, sure.
Erin Welsh	Yeah. Basically this is just a read more books to learn more. Anyway.
Erin Allmann Updyke	It's an intro.
Erin Welsh	It's an intro, yeah. This is not even a primer, it's very surface level. It is true that we have come a very long way from the early days of Röntgen playing around with Crooks tubes and from injecting plutonium into people without their knowledge and consent. Radiation therapy is incredibly powerful and so much safer than it once was. But other things like Three Mile Island and Chernobyl and Fukushima aren't so far away. And I had been planning initially on talking about these meltdowns a little bit but I realized I just couldn't do them justice. Don't worry, I'll recommend books. And I'm definitely not equipped either to go into the pros and cons of nuclear power plants. But I do wanna say that one of the things that I've taken away from all this reading about radiation is that it seems to have unlimited potential. Potential to do good and potential to do harm. And like some of the poisons that we've talked about in these episodes, radiation is this Janus-like thing, this duality of nature, it's good and bad, dose-dependent, etc etc, you know?
Erin Allmann Updyke	Yeah.
Erin Welsh	And I don't really know how the scaled are currently tipped in terms of the good or bad, probably bad. But I think we do need to fight very hard and to be very vigilant to make sure that the harm doesn't outweigh the good or won't outweigh the good in the future.
Erin Allmann Updyke	Yeah.
Erin Welsh	And I think the story of radiation also serves like I said before as this very important reminder to think about where our knowledge comes from and at what cost so we don't make these same mistakes again because they're probably still being made right now. We're just not gonna learn about it for 30 years.
Erin Allmann Updyke	Right.
Erin Welsh	Anyway.
Erin Allmann Updyke	It'll be like, 'That was 2020?!' And then we'll be more horrified than ever.
Erin Welsh	Mm-hmm. Anyway so Erin, tell me some good stuff about the use of radiation today.
Erin Allmann Updyke	We might end on a note right after this break.
TPWKY	(transition theme)

Erin Allmann Updyke	I don't know if this is gonna be a happy or a sad note to end on but it's a note. And so this is how I've decided to end this episode is basically to just kind of talk about how we use radiation in medicine today, like where do we see it, how do we use it? Cause I think like you said, of course I'm understanding where this knowledge came from, it's so important and moving forward understanding the risks and benefits I think is super important in terms of how we use radiation. Cause it does sound scary, right, the word 'radiation' sounds scary.
Erin Welsh	Yeah.
Erin Allmann Updyke	So how scary is it? So where do we use radiation in medicine today? A few different things. We use radiation for diagnostics, so is your arms broken or not, we use an X-ray to see that. Do you have diverticulitis? We can use a CT scan to see that. So that's diagnosing, if you come in with a disease or an illness or a problem, we can use radiation to try and diagnose that problem. We use radiation for screening which is a very interesting and potentially controversial area to use radiation.
Erin Welsh	Yeah! Okay, are you gonna talk about that?
Erin Allmann Updyke	We can talk about it, yeah, absolutely.
Erin Welsh	Okay.
Erin Allmann Updyke	So we use radiation in screening, that's like for example a mammogram, okay. So a mammogram is a CT scan of your breasts. So we can use that to look at the tissue to see, to screen, which means screening is essentially using these tools in healthy people with no evidence of disease, that's what a screening tool is.
Erin Welsh	Right.
Erin Allmann Updyke	To see if you have evidence for concerning for breast cancer, okay. That's an example of radiation for screening. And then we also use radiation for therapy, right. We use radiation for therapy for cancers. I think those are kinda the three big areas that we use radiation in medicine today. So let's kind of talk about what are the risks of radiation overall and then we can talk in a little more detail about those three areas. Cool?
Erin Welsh	Mm-hmm.
Erin Allmann Updyke	Cause the risks and benefits are of course different in all those three scenarios whether you're talking about diagnosing something where you come in with something wrong vs screening healthy people vs treating a potentially fatal disease. Okay. So overall the biggest long term risk of radiation exposure, long term, is cancer which we've talked about. So what is that actual risk per unit exposure? Luckily Dr. Jorgensen in his book told me this, okay. If you calculate it per unit of ionizing radiation, the risk of cancer is 0.005% per millisievert of whole body radiation. That's what your risk of cancer is per 1 millisievert exposure. Okay?
Erin Welsh	And this is like a cumulative exposure?
Erin Allmann Updyke	Yeah, it's cumulative, absolutely.
Erin Welsh	Okay.

Erin Allmann Updyke	Right. So let's put some more concrete numbers on that cause that's too tiny to talk about, okay. A whole body spiral CT scan, CT stands for computed tomography I think, but it's basically X-rays that they go in a circle around your whole body and take tiny pictures of tiny layers of your whole body. So it's a relatively large dose of X-rays compared to an X-ray of your arm. A whole body spiral CT would expose you to 20 millisieverts of ionizing radiation, okay. So that would be a 0.1% increased lifetime risk of cancer, aka 1 in 1000. So of 1000 people that get a spiral CT scan, one of them is expected to develop cancer as a result of that spiral CT.
Erin Welsh	Gotcha.
Erin Allmann Updyke	Okay.
Erin Welsh	So two questions.
Erin Allmann Updyke	Okay.
Erin Welsh	One, how does age play a role in this in terms of making decisions?
Erin Allmann Updyke	Okay.
Erin Welsh	And number two, what about background radiation, like what we experience on a daily basis?
Erin Allmann Updyke	Okay listen Erin, your questions are great but they're totally getting ahead of the point, okay?
Erin Welsh	Sorry! I'm too excited. (laughs)
Erin Allmann Updyke	No, those are the exact questions that you should be asking when you think about radiation, right, because we can't look at exposure to a CT scan in a vacuum because medicine is not the only place that you're exposed to radiation, right, we're exposed to it every day. And you also have a baseline risk of cancer, whether from environmental radiation or from genetic predisposition or from other exposures, everyone has an overall risk of cancer, right. Exposure to CT scans is not the only thing that causes a risk of cancer, okay. So we can't look at it in a vacuum. So let's talk about kind of what the overall lifetime risks of cancer are to get an understanding on how this CT scan increases that risk. Okay?
Erin Welsh	Okay.
Erin Allmann Updyke	It turns out that in the US, this is from cancer.gov, the lifetime risk of developing a cancer is overall about 40% which is pretty high. About 1/2 of all males and 1/3 of females will develop some type of cancer in their lifetimes.
Erin Welsh	Wow.
Erin Allmann Updyke	And that's not including by the way basal and squamous cell carcinoma which is like the skin cancers that aren't invasive or aren't malignant.
Erin Welsh	Wow.
Erin Allmann Updyke	Yeah.

Erin Welsh	Holy cow!
Erin Allmann Updyke	And the risk of dying from cancer overall in the US is about 20%. Okay? It's really high.
Erin Welsh	Wow. Sorry I just keep saying wow like Owen Wilson. Wow! Sorry but like holy cow.
Erin Allmann Updyke	(laughs) Yeah, it's really, really high, right? So if your overall average risk is 40% and you increase that by getting a spiral CT to 40.1%, is that significant?
Erin Welsh	Right. What is the threshold at which we declare something too high or a risk?
Erin Allmann Updyke	Exactly. And the thing is that 0.1% is significant to that one person who develops cancer from that spiral CT scan.
Erin Welsh	Uh-huh.
Erin Allmann Updyke	But then there's 999 others who 40% of them are going to still get cancer from some other source and maybe that person who might have developed cancer from a spiral CT got cancer from something else instead. Okay. So yeah. And this is something that makes it really difficult or maybe at least really complicated to quantify the risks and benefits especially when you think about the 3 different areas that we use radiation: screening vs diagnosis vs treatment, okay.
Erin Welsh	And so the threshold is different. If it's for treatment, you're gonna wanna push the start button on radiation earlier than you would necessarily do for screening.
Erin Allmann Updyke	Exactly. Because the benefit is a lot greater for treatment of a potentially fatal cancer.
Erin Welsh	Yeah.
Erin Allmann Updyke	So yes, there might be a risk of you going on to develop a secondary cancer but the benefit is you're going to kill that breast cancer that you already have that's going to kill you in the next 5 years, right?
Erin Welsh	Right. It reminds me of how antibiotics are easier to test than vaccines.
Erin Allmann Updyke	Yes, exactly! Exactly.
Erin Welsh	Therapeutic vs preventative, yeah.
Erin Allmann Updyke	Therapeutic vs preventative. And the other thing is even that number, 40% okay, 40% lifetime risk of developing a cancer in the US, that's an average. For some people that risk is going to be a lot higher and for others it's going to be a lot lower and this will depend not only on like you mentioned Erin your age, but also your genetics, the area that you live, maybe your occupational exposures. For example if you have a BRCA mutation, that's the breast cancer mutation, your lifetime risk of breast cancer or ovarian cancer might be over 80% which is really high. If you have a mutation in a gene called APC, that leads to a disorder called familial adenomatous polyposis, your risk of colon cancer is 100%, like everyone with that genetic mutation is going to get colon cancer and has to have their whole colon removed prophylactically so they don't die.

Erin Welsh	Oh my god.
Erin Allmann Updyke	so vs someone else who may for one reason or another might have a very low lifetime risk of a certain type of cancer, okay. And it gets even better. This is fun. The other thing is that overall in medicine our use of radiation has been increasing while the dosages that you're exposed to in a single X-ray or a single CT scan are vastly lower now than they were when we first discovered X-rays for example, like per unit they're really, really small doses. Overall we're using them more and more often. But we're not using them equally. Does that make sense?
Erin Welsh	Oh yeah.
Erin Allmann Updyke	Oh gosh. So it makes that again even more difficult to overall balance the risks and benefits. So when you're thinking about do I need this test that involves radiation, you have to think about how much radiation have you been exposed to in the past or if you are the one ordering the test, how much radiation has this person been exposed to in the past? How often have they got these types of scans? What types of scans are they getting and how much radiation is it exposing them to? Because an X-ray of your broken wrist is a lot less radiation than a CT scan of your head and neck or your abdomen and pelvis, right. And what are we using it for? Are we trying to diagnose a broken wrist that we really need to treat or are we trying to screen for breast cancer that this person maybe has a very low lifetime risk of overall? Or are we trying to screen for breast cancer in someone who has a genetic mutation that makes them very susceptible to breast cancer?
Erin Welsh	Right, it's a very individual question. You have to consider the context.
Erin Allmann Updyke	It's very individual. So breast cancer's a really interesting example because there is no consensus guidelines on how often, depending on who's website you look at, whether it's like the Cancer Society vs the Breast Surgeon Society vs the United States Preventative Health Task Force, they have different guidelines on who needs to be getting mammograms and how often and how old to start them, right. Because it's difficult, it's a very individualized decision. So yeah, I don't know. That's all I have to talk about in terms of how we use radiation today but I think it's a really interesting and I do think the most important thing to keep in mind is thinking about the risks and benefits depending on the scenario in which you're using radiation.
Erin Welsh	Totally. Yeah, it's super context-dependent. It's really interesting.
Erin Allmann Updyke	Yeah.
Erin Welsh	Interesting. All right well, should we cite our sources for this episode?
Erin Allmann Updyke	I'm gonna guess there's gonna be a long list of them.
Erin Welsh	Mine's all books this time, I didn't even have time for the articles.
Erin Allmann Updyke	Great.
Erin Welsh	And documentaries. Okay so first, 'Strange Glow: The Story of Radiation' by Dr. Jorgensen who was awesome.
Erin Allmann Updyke	It's great.

Erin Welsh	Such a good book, so interesting. And then like I said I didn't talk about Chernobyl at all or Fukushima but I did read a couple of books about Chernobyl so the first is called 'Midnight in Chernobyl: The Untold Story of the World's Greatest Nuclear Disaster' by Adam Higginbotham. Such a good book, really fascinating. And this also is what the show Chernobyl which is excellent took a great deal from. And then the other thing that I really want to mention about Chernobyl is a book called 'Voices from Chernobyl' which is an oral history of the disaster by Svetlana Aleksievich.
	And then 'The Radium Girls' of course by Kate Moore, great book about that struggle and the occupational exposure to radium-containing fluorescent paint. And then Robert Jungk, 'Brighter Than 1000 Suns: A Personal History of the Atomic Scientists', I read that a long time ago in college but it was really interesting about the Manhattan Project. 'The Plutonium Files' which is what I talked about America's secret medical experiments in the Cold War, so good, that is by Eileen Welsome. And then also Harriet Washington's 'Medical Apartheid' has a lot of discussion about this as well. And then finally I'll recommend a documentary called 'Radio Bikini' and a documentary called 'Atomic Cafe'. Watch those, they're both on YouTube. Read those books. There's definitely more than what I was able to tell.
Erin Allmann Updyke	Strange Glow' also has a ton of information both on the current uses of radiation in a medical context and the biology of radiation. But there's a couple of other good articles that we will link to on our website where you can find all of our sources from this episode and every single one of our episodes. So definitely check those out.
Erin Welsh	Yeah. Definitely.
Erin Allmann Updyke	And we also have a bookshop.org affiliate link program if you'd like to purchase any of the books that we recommend, we get a small commission from that. And you can check out our Goodreads list which just has recommendations.
Erin Welsh	Yeah. Thank you again so much to Dr. Jorgensen, we really appreciate you taking the time to chat with us and explain radiation.
Erin Allmann Updyke	Yep. And thank you also to Bloodmobile who provides the music for this episode and all of our episodes.
Erin Welsh	And thank you to our listeners. We love you, we appreciate you, we hope that you enjoyed this episode.
Erin Allmann Updyke	Yeah.
Erin Welsh	All right well until next time, wash your hands.
Erin Allmann Updyke	You filthy animals!