Spidroinology with Dr. Randy Lewis
Ologies Podcast
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Oh hey! It's that bottle of mustard you don't even remember buying, but you've moved with twice now, Alie Ward, back with another episode of *Ologies*. Okay, I just want to say, if you're listening, and you're not a huge fan of spiders, I wanna tell you that you're brave, I'm proud of you and, spoiler alert, this is not scary at all. We barely even talk about schpidahs themselves, but rather we just focus on things that come out of their rears. So, for anyone in your life who's a spiderphobe, just gently maybe send them this episode, tell them it's a great way to admire the critters and there are very few goosebumps in the road ahead. One day we're gonna work up to Arachnology, we're gonna talk about the animals themselves one day, but today is not that day, my friends. Today we're just walking into spiderwebs. But before that a quick detour into Thankyoushire.

Thank you to everyone supporting the show on Patreon, you submit questions for the Ologists each week. $1 month gets you in that club, just go to Patreon.com/Ologies. And it lets me pay my editors well and donate to four or five charities each month, while still getting to be choosy about who sponsors the show.

Thanks to everyone also wearing *Ologies* Merch from OlogiesMerch.com, thanks to everyone who has made sure you're subscribed. Especially with the recent iOS updates, so check and make sure you are subscribed, and it's auto-downloading the fresh ones. And thank you to everyone who rates the podcast to keep it up in the charts and of course those of you who leave reviews, for me to creep, with teary eyes, such as for example, EmStan96 who is applying to grad school and says:

> *Thanks Dad* - that's me - *for combating imposter syndrome by sharing the human side of science and for always supporting all of your pod-children's dreams!*

Well thank you EmStan96. I look forward to calling you *Dr*. EmStan96.

Okay, Spidroinology! What in the dark, shadowy night is that? Unless you are a schpidah doctor you probably did not know that there is a word for spiderwebs and it's spidroins. Well, spidroins are the main proteins in spider silk, and they're as strong as steel but they're more flexible, and they're similar to collagen or keratin, we're gonna get into it. So yes, kiddos, this is a whole episode unraveling the mysteries and looking into the future of spider silk: what it is, how it works, and how it may change all of our lives.

I met this ologist when I went to Utah State University to film a segment in his lab for *Innovation Nation* which is my wonderful dream job/day job as a correspondent for CBS for them, Saturday mornings - check your local listings - along with my other own show on the CW, *Did I Mention Invention?* Did I mention that I have a show called *Did I Mention Invention?* Okay so you can find those on weekends, CW & CBS. Anyway, it was a very beautiful April afternoon, and after we finished filming his segment, I coerced him into sitting down for a podcast chat. And he is a world-famous pioneer in spider silk, so *stick* around to get a lifetime's worth of appreciation and context about what a spiderweb is, what it's made of, how strong a single thread can be, how it's synthesized in labs, future medical uses, some superhero flimflam, transgenic goats, gene splicing, bow ties, the most beautiful thing I have ever seen, and what too much coffee does to spider brains, with Utah State Biology professor and your new favorite Spidroinologist, Dr. Randy Lewis.

Alie Ward: Cool beans. So, if you could tell me your first and last name and how you pronounce it.

Dr. Randy Lewis: Okay. Randy Lewis.

Alie: Mmhm. Dr. Randy Lewis.

Randy: Dr. Randy Lewis.

Alie: And if you were an ologist of any sort, what do you think you would be?

Randy: I'm probably a biomaterial-ologist.

Alie: Okay! Or, you deal with spidroins.

Randy: It could be spidroinologist, but most people wouldn't know what that was, so biomaterials might be a broader thing for people to know what I really am.

Alie: Well, they're about to know what a spidroinologist is!

Randy: True enough. True enough.

Alie: Of the people in the world who work with spider silk, is it a small group?

Randy: It's a relatively small group. I would say that the entire publication record probably involves no more than 30 labs. There might be a few more than that, and of those probably only 20 of them have ever published more than one paper.

Alie: How many papers have you published?

Randy: My total is like 150. And on spider silk, we're probably talking 70.

Alie: Oh my gosh. What about patents?

Randy: So, we have 11 patents right now, and we have three that are pending.

Alie: My lord! So how long have you been in the spider silk spidroin game?

Randy: Just call it - spider silk works. Because nobody uses the spidroin term that we came up with to describe the proteins.

Aside: I keep wanting to say spid-re-on, but it's spid-roin… like it rhymes with groin. Which is, I guess, where the silk comes from on your body if you're a spider.

Randy: I believe I should be considered the father of spider silk, at least at the molecular level. Although I've now passed enough generations that some are calling me the grandfather of it. [*"Hi, Grampa."*] But we cloned the first spider silk gene 30 years ago this coming summer.

Alie: 30 years ago, this coming summer?!

Randy: 30 years, yep.

Alie: Do you remember the day?

Randy: No, I don't.

Alie: You got to have a cake or something. Get a sheet cake from Costco.

Randy: That's probably true. We probably ought to celebrate somehow. Ice cream cake from the ice cream store is probably better for my group, anyway.

Alie: Get a Carvel, you deserve it!

Randy: We don't have them around here, so…

Alie: Now tell me a little bit about your backstory before we go into how you started cloning the proteins of spider silk. What was your backstory?

Randy: So, I was born and raised in northern Wyoming. I went to Caltech as an undergrad. I'm a two-time inductee into the Caltech Athletic Hall of Fame.

Alie: Really?!

Randy: Because I was the captain of the first wrestling team ever to win a conference championship and we actually won three in a row.

Alie: I didn't even know that they had a wrestling team.

Randy: Well, they don't anymore. But they did then. So, there are no academic marks for my history at Caltech, but there are wrestling marks. So, you know what, go to a brain school and be a non-brain, it's the way to go. I went to grad school in UC San Diego, did a postdoc at the Roche Institute.

Aside: So, Randy did his undergrad in chemistry and his master's and Ph.D. in Biochem, then did postdoc in molecular biology. So, notice, zero of those degrees were in entomology or arachnology. So how did he get all tangled up in these spiderwebs?

Randy: I got started on the spider silk sort of as a sidelight. And then it became the dominant thing that we did in the lab.

Alie: Your side hustle took over.

Randy: It's true. Absolutely true.

Alie: Did you have a thing for spiders before that?

Randy: I don't think that I had a thing for them. I think that I recognized spiders as being interesting organisms and knew some about them, but clearly, not nearly as much as I've learned since then, to appreciate just what an amazing organism they are.

Alie: And so, where did you start in the field? What was your first intro into spider silk?

Randy: I was working with a company out in California, a small biotech company, and they had developed techniques for vaccines. So, what they were wanting to do was to make silkworm silk. And it became clear that economically that never made any sense. So, they asked me to look at spider silk, and I did. And at the time there was a lot known about the biology, but absolutely nothing about the actual fibers themselves, except that they were made out of protein. And proteins were what my lab was good at.

So, they decided that it was too long term a project, which turned out to be true, obviously, because 30 years later, we still really don't have any products out there. So as a biotech company, you'd have gone belly up a long time ago. So, I was able to talk to the Office of Naval Research, which they had contacted about their vaccine stuff, and produced a fairly small little proposal to them to see if we couldn't clone the gene for protein that made up one of the spider silks.

And I ended up getting the grant but it's interesting because it got two reviews from the outside, one of which said, "This could be the best thing since sliced bread." The other one said, "This is the stupidest idea I ever heard of." And fortunately, the program officer chose to take the first one and give me money. Fortunately, in the first year we were able to clone and sequence the very first spider silk gene.

Alie: In the first year?

Randy: First year. We got it done before a year was up.

Alie: Man, I've been meaning to reorganize my kitchen cabinets for at least two years, and you cloned a gene in a year.

Randy: Well, at a certain stage, it's the people you have. It's not you that accomplished something. And I'm at the stage where I know how to solve problems, but I don't know how to do most of the things in the lab anymore.

Aside: Okay, before we get too into how this golden fleece unicorn hair heaven tinsel unobtanium is obtained, let's get down to some brassy tacks.

Alie: Walk me through a little bit about what is spider silk, because I know enough about a spider butt to know that different things come out of their silk glands, but what's going on?

Randy: So, the spiders that we work with make six different kinds of silk and a glue. They are the ones that make the typical round web, it's called an orb web, that most people think about that spiders make.

Aside: Side note: if you're wondering what invisible force has captured your face, what gossamer, thready creation has veiled you at night, those are likely the work of orb weaver spiders. They are architects, and artisans, they are craft spiders. Their talent is innate, and their spiral spiderwebs are just iconic.

Now some, like the Nephila golden orb-weavers spin this brilliant yellow silk, it just glimmers. It's like threads of gold. So, what's up with cobwebs? Well, spiderweb tends to mean one that is still inhabited, and cobwebs refer to old abandoned ones. So, once they get dusty, they tend to lose their tack. But a cobweb is also a type of web, one that's less of a two-planed spiral net, and more of a three-dimensional maze. We'll get into that in a bit.

Randy: And they use the silks for very different purposes, and they have very different mechanical properties. So, evolutionarily you sort of have a lot of evolutionary tinkering that went on before we ever got to take a look at it. So basically, in most of the glands, there's a couple of them that don't produce silk all the time, but generally they produce silk, put it in a gland. They have it, in a form that's still not completely identified. But we think they're sort of very small little balls of protein that are present in there and micelles. But protein micelles, as opposed to membrane micelles, which is what most people think about.

Aside: When he says 'micelles', he's not talking about his own cells, but rather little gatherings of proteins hanging out in a huddle, that are called 'micelles'.

Randy: Then when they pull the silk out, they pull it out like floss, they don't squeeze it out like toothpaste. All of the silks have to be pulled out, and when they pull the silk at the very end of a tube going down from the gland that they make it to the outside, all the silk then behind it starts to get pulled out cause it's very viscous. [*"I want 'em real thick and juicy"*] On the trip down that tube, the shear forces cause the protein molecules to line up.

Like you can imagine if you were to take spaghetti and start getting it down through a funnel, all the spaghetti has to line up or it doesn't go down. So that's what's happening in this trip down there. When they do that the protein molecules lock together and become insoluble. And that's how the fiber forms. Amazingly enough, it can happen in as little as 10 milliseconds. So, if you see a spider fall, that silk is solidifying in milliseconds as it comes out of the spider.

Alie: And do they use a combination of their spinnerets, or their legs, or gravity? What gives it that force?

Randy: All of the above. They can't squeeze it out. So, they either have to pull it out with their leg… The other thing they can do is attach it to something and walk away from it. The silk that most people are interested in, called dragline silk, it's dragline because when they walk away, they drag it behind them.

So, if you see a spider crawling across the ceiling, for instance, if you watch it, it'll crawl further a little ways and it'll start wiggling its butt. ["*We can't stop twerking about it."*] When it does that, it's using another silk to attach the major silk to some kind of a protrusion on the wall. So just like a climber, if a climber climbs so far, then they put a piton or a hook or something in there. That's exactly what spiders have been doing for 400 million years. So, rock climbers are a little behind on that. And in addition, they can stick the silk to almost anything. Now they have trouble with something like Teflon, but they can stick it to glass wonderfully.

Alie: [*whispers*] Oh my gosh.

Randy: You put them in a glass aquarium for instance, or a plexiglass aquarium, and you can see the little attachments where they put all their silk down. That is how they produce the silk and have to pull it out.

Alie: And what are some other types of silk? Because you said six.

Randy: So, they have dragline silk, that's the framework of the web, and they use it for their protective line. There's a 'minor ampullate' silk that they use that's mostly for reinforcing of the web. There is a 'tubuliform' silk and that's almost crystalline, so that the silk is relatively strong, but if you try to bend it, it'll break easily. They use that for an outer coating when they lay their eggs.

There's an 'aciniform' silk that they use to both wrap their prey and wrap their eggs, so that's the inside case of an egg layer. They have aggregate silk, which is the silk and is the glue in there. 'Pyriform' the attachment, they use that to attach their silks down. And then there's 'flagelliform' silk, critically important, because that's most of the spiral in the web, and that's what they use to catch their prey with, so it's very stretchy. Basically, insect hits it, just stretches the silk out until all the energy's absorbed, and then it gets stuck in the glue.

Alie: Mm-hmm. So, it's a boi-oi-oi-oing silk.

Randy: Well, not so much.

Aside: Yeah, I was not right about that.

Randy: So, the key is you don't want a trampoline. What happens is, it absorbs that energy and then radiates it back as heat.

Alie: What?!

Randy: If you look at it, it hits the web... So, the web's doing this, the web comes back very slowly and loses, like, 75% of all that energy as heat on that retraction back up very slowly.

Alie: Wow. So, it doesn't just take the prey and then shoot the prey.

Randy: That would not be very efficient. You know, it would look cute, but it would not do the spider… you know, for the spider's lifetime it would not be very efficient. You'd lose a lot of your prey.

Aside: Okay, so real quick: they've got major ampullate, or dragline silk, one that is just super strong. It's as strong as steel, but it's tougher, and it acts as those web's spokes, and the non-sticky outer rim. And there's minor ampullate, which is temporary, kinda like a sketch while they're building the web. And they have flagelliform sticky silk for the inside spiral of the web, that little bullseye. Super sticky. And then tubuliform silk is stiff egg sac business. There's aciniform, which is the Saran Wrappy sheet that they mummy their prey with. It's two to three times as strong as that first dragline silk. And then there's also aggregate, which is hardcore glue silk.

They're produced by four-to-six hairy nubbins on their undercarriage, called spinnerets. And those each have a bunch of nozzles, kind of like froyo dispensers. And then they're stretched out, and it's extruded from the glands, from the spinnerets. Does it look like a glove, slowly waving at you, palpating some goo? Yes, it does. But let's get back to the silk itself.

Alie: And how different, from a molecular structure, are these six different types of silk?

Randy: All of them have what I call a 'Lego sequence'. So those are sequences that, naturally when they make a fiber, interdigitate. So, they literally have holes and pins just like Legos do.

Alie: Whaaaaat!?

Randy: So most of the silks have some form of Lego. Now it turns out some of them have longer pins, some of them had bigger holes, some of them have some variations. But all of them have something that allows them to stick together to make a fiber. Then the ones that have stretch have, in there, something that looks like a Slinky, at a nanoscale, so when it stretches and you let go, it retracts.

Now as we said, the difference is it doesn't retract as fast as you stretched it. So, in that retraction it loses heat and it keeps from basically serving as a trampoline. What's unique is that there are not variations in those proteins between different species of spiders.

Alie: Really?

Randy: If you look at all of the orb weavers, the individual six proteins and the glue protein all look very, very similar in each species compared to other species. Now they look very different from each other, but not from the same silk in a different species. They can be separated for as much as 150 million years, and still the silks, you would recognize it. I mean, somebody who's in the field would recognize instantly looking at a sequence, which silk it was from any of those.

Alie: I mean there's probably a handful of you on Earth that could probably look at that and say, "Oh, I know what that is!"

Randy: I would hope there's more than that now. At least, my students should all know.

Alie: That's a good point.

Randy: But yeah, I mean it's certainly a limited one, but they're really easily recognizable.

Alie: And how are the spiders determining, "Okay, I know I need a dragline here to make the framework of my net. I know I need something sticky." Any idea?

Randy: It's all genetically programmed. It's absolutely clear. I mean, they have no brain in the sense of being able to make that decision. And so, you know, they are hardwired, "This silk does this, this silk does this, this silk does this." So, in some cases we can collect the silks from the spider directly, but most of the time it's difficult. For instance, they know that they want to use the prey-wrapping silk when they have prey. So, it turns out if you can find just the right frequency, [*harp strum*] on the spider, then they'll believe that they have something to wrap and they'll start putting that silk out and you can catch that. But most of them, you know, major and minor, relatively easy. The rest of them are almost impossible to collect because you can't provide the right stimulus. You just don't have the right trigger to tell it to do it.

Aside: It's true! A web can act like a harp, and spiders hear with tiny slits in their feet - totally normal - and through little hairs all over their body. And I got ensnared, reading a paper titled, "Micro- and nano-structural details of a spider's filter for substrate vibrations: relevance for low-frequency signal transmission." Again, back to the web. You can buy a tiny spool of the golden silk on Etsy for [*cha-ching*] $200 a gram. And I googled it, and that was way more expensive than street drugs. So, with this smorgasbord of silks, some have to be stronger and cooler than others, right? Like some have to be better.

Alie: And now, which spider has the best silk?

Randy: You know, I think that's a tough question. There is a bark spider from South America that is argued to have the strongest silk. Now, it's strongest in the combination of stretch and strength because it stretches lots more than most spider silks do, not because it's necessarily strong. The variations in the silk, even with an individual spider are fairly large because they don't do a good job of controlling the diameter. And whenever you measure strength, you measure based on cross sectional area. So obviously if something's fatter, then it's going to be stronger than something that's thinner.

Aside: Just a side note: think of a braid versus a hair, or a rope versus a thread, or one string of the cheese versus the whole string cheese. I'm so hungry.

Randy: So when you say what spider has the best? I think its which silk is the best and that's clearly dragline. It's got the best combination of strength and elasticity to give you that unique combination that no manmade material can beat.

Alie: Is dragline silk the one where you're walking into the backyard at night and you get a web on your face and you feel like you're going to die?

Randy: No - well, I don't know about the last part of that statement, but certainly that it's actually the combination of all of them because the web has four different silks in it. So, it has major, minor, it has the glue, and it has the capture silk. So, when you hit that, I think it's probably more the fact that it adheres to your face because of the glue. It also stretches enough so you can sort of feel that your face is going into it. When it finally breaks, it's already now attached all over there and stretched tight.

Alie: Does that ever happen to you and you go, "Oh, good one, guys"?

Randy: Not very often, especially because, you know, in the Rocky Mountains, most of the webs are relatively well concealed, whereas in places like down South they stick them out anywhere because they have a much higher opportunity. Here in the Rockies, most of them are where there's some light shining or something like that, or in a dark place in a barn. So, it has happened occasionally in a barn where you just can't see until it's too late.

Alie: The ones that feel like a very fine fishing line, where you can almost feel it snap, like, "That was stronger than I expected it, and who did I just wake up?" Even though I love spiders, I'm like, "I definitely don't want to ruin your home." I don't wanna be, like, Hurricane Alie, just comin' through!

Aside: PS, one of the most beautiful things I have ever laid my actual eyes on is this eleven by four-foot tapestry woven from golden orb-weaver silk. It was on display at the American Museum of Natural History in New York in 2009, and it was the first stop I made in New York when I went then. And it looks kind of like a table runner, but made out of sunlight, or like a bedspread woven from an angel's laugh. It also looked expensive and took several years of milking wild Malagasy spiders to make. It was not casual.

Alie: And now, what are some applications of spider silk? The only thing that I'm familiar with, that I think of that comes to mind, is this tapestry that was woven out of golden orb-weaver silk that's been on display. And I mentioned it to you earlier and you said that it makes you kind of sad.

Randy: Yeah. Clearly it was done by hand, by women in Madagascar, and it's obvious they were not paid a lot of money for the amount of work they had to do. I think it's an amazing accomplishment. Clearly it is without a doubt the largest amount of spider silk that's ever been used for any purpose whatsoever. And you know, the women had to collect the silk from the spider, and then they had to weave it into the tapestry and that kind of stuff.

So, it's amazing. It's just, I feel like the people over there may have been… I mean, maybe they had no jobs and a dollar a day or whatever they got paid was still better than nothing. And maybe it was, but it's a huge amount of manpower for something that's wonderful to look at, an art object. But beyond that, I'm not sure you couldn't have made something, you know, a tenth that size and still been an impressive accomplishment, in terms of that.

Aside: I hadn't considered this, and it's a great point. The two men who made the tapestry were from Europe and America, and they were hiring locals, and with 3,000 giant spiders harvested, milked and returned to the wild, *daily*, over the course of four years, a budget of half a million dollars is pretty low for that amount of toil. And it rightfully dims the glow of the original work for me. But it also shines a light on why Randy's work, understanding and figuring out more affordable ways to harvest this material, is so important. He's not looking to fabricate a cape so that an alabaster supermodel can strut in it for a few minutes before it's returned to a lockbox.

Alie: And the work that you're doing with Spidey Tek, what types of materials do you think that you'll be getting to fabricate, and how will that change the way that we live potentially? Hopefully? Fingers crossed; all eight arms crossed.

Randy: I think that what most people are not very aware of is that we've been able to develop uses other than just fibers. And I think everybody, when you think about spider silk, you think about clothing, you think about bulletproof vests, you think about climbing ropes, think about lots of things along those lines. But on the fibrin, in addition, we think there's a real opportunity for composite materials, especially something like epoxy-based composite materials. That comes from two reasons. One is, you need a combination of stretch and strength, and there's no other materials out there that you could use for reinforcing to do that.

Aside: So, a composite epoxy material is usually made of, say, glass strands, or carbon fibers embedded in a glue or resin. Picture something made out of fiberglass, and then imagine an upgrade to spidroin.

Randy: The second is that we've found that spider silk can be made into an amazing adhesive. Well, we know ours adheres to plastic. It adheres to metal. It adheres to wood. I mean, there's almost nothing that we can't coat. Using it as thin films, using it for coatings, there's almost nothing we can't coat. Part of the coating idea is that we can put additives in there.

So for instance, coating catheters, we can put antimicrobials and antifouling factors so that you don't get infections when you implant a catheter and they don't plug up at the end, which happens to a pretty amazingly high percentage of catheters that get implanted in hospitals. I think everything from medical to… there's clearly interest in the defense department and lots of things in between.

Alie: It seems absolutely unreal that it can be as strong as steel, but a lot lighter.

Randy: Sure. It's because it's got a combination of strength and stretch and that's really what makes it unique, I think.

Aside: Side note, if you've never had a catheter, but just googled one to get an idea of how they work, wow. Whew! Boy howdy, hot damn. I would like that to not get infected, please, so thanks spiders! And also, like we heard in the bones episode of Osteology, strength and flexibility is what make things work the best. So, let spiders inspire you. It's okay to stand up for yourself and be strong, but maybe have some wiggle room for compromise when called for.

Alie: So, we might have cars that have a chassis made out of spider silk and panels that are made out of spider silk?

Randy: Right.

Alie: [*squeals*]

Randy: And again, they'll be composite materials. But you can imagine, if you design it right so maybe you don't get a ding the next time somebody taps your bumper because you've got something that flexes and comes back again. They're just going to bend and pop right back out again.

Alie: Thanks, spiders!

Randy: Exactly.

Alie: What is your relationship to spiders? [*"I don't hate spiders. I love 'em!"*]

Randy: I guess I've always had some admiration, but certainly since we started this work, it's hard not to be incredibly admiring about their success. I mean, recognizing that you find them in the dead of the rainforest, you find them in the middle of the desert, every place but Antarctica, and they were there before it got too cold for anything to survive. The fact that they have such a wide variation in prey, they have such a wide variation in capture strategies, it's pretty impressive to realize just how successful they are as an organism.

Alie: Do you get a lot of spider gifts? I see that you have some knick-knacks.

Randy: I've got quite a few in my office and I've gathered most of them here. Some of them I've actually gotten, some of them been given to me. It's hard not to.

Aside: It's true. He had a fair amount of tasteful spider knick-knackery on the windowsill, and we took a picture, each holding a woven spider. They were not in a glass case, nor did they break anyone's bank. They were just made out of wire, probably cotton threads.

Alie: When it comes to the future of spider silk, how far off is it? I mean, are we talking like in maybe 20 years I'll get to wear a spider vest?

Randy: I think the answer is no. I think the fibrin is going to come faster than we initially thought because we can use the transgenic silkworms to make fibers now that our best fibers from the transgenic silkworms are as good as spider silk. And in some ways, you might even argue a little better, but certainly as good as native dragline silk. So that means we have a relatively easy manufacturing process to be able to make large amounts of that.

Alie: And walk me through how you have managed to take spider silk and have it made in the lab and made through other organisms instead of having to hand spool a Nephila spider in Madagascar. How are you doing it?

Randy: Sure. As part of the first work we identified the genes that the spiders used to make spider silk protein. Then what we do is, we take that gene and usually we make a synthetic copy because the use of certain codons in the DNA is species dependent. So, for instance, the spiders use certain ones and E. coli bacteria uses different ones. So, what we try to do is match up... We make the same protein sequence; we just make it with different sequence of DNA so that it matches better with what the organism uses. Then we just take that gene and pop it into the organism we're looking at.

Aside: Okay, sit the hell down, because this is bananas, and it may inspire this year's Halloween costume. So, almost a decade ago, Randy and a research team were able to splice spider silk-making genes into goats and the goats then produced liquid spider silk in their milk, and Randy was able to filter out the silk, and then stretch it to the right consistency using machinery.

So, while he got to hold a lot of baby goats, and pet baby goats on the head, and essentially be a wizardy science-shepherd of transgenic spider goats, there was a lot of milk being tossed. So then, they spliced the spider silk gene into the DNA of silkworm moths, and rather than standard silk, those caterpillars now spun this highly durable, and really prized, spider silk, with much less waste. And when I visited his lab, there were trays of chonky caterpillars, just monchin', monchin', monchin' on ground mulberry pellets. And there are also other trays, filled with soft egg-looking cocoons, that would be boiled, and spooled.

Randy: With the silkworms, one, because technology advanced significantly further, we were able to actually cut and splice in our gene in exactly the same spot as the gene was for the silkworm silk protein. So now everything there is exactly the same as it was except there's a different protein being made. Instead of the silkworm protein, it's making the spider silk protein, and it proceeds to just put it right into the cocoon as if it were its own silk.

Alie: And when you're saying you just pop the code in, I have a feeling it's a little bit more complicated than that. Well, how does one do transgenic… recoding?

Randy: Right, so in the random ones, there are lots of DNA out there that allows you to randomly insert something into a chromosome. And so, it just randomly goes in. The new CRISPR-Cas9 System allows you to very precisely make two cuts, and then you now have a gap in the DNA. And the cells use two methods, one of which is very precise but very low

frequency. There's another one that's very imprecise, but much higher frequency. And we went with both, and the only one that worked was imprecise in large males. So, it meant that we could put it in, we didn't have to be exact. If you do the other way, you've got to be exact because it's got to fit it right where it's supposed to be. This one you got some slop in exactly where it goes, but it still goes in the same site that we cut out, which was in this case, the silkworm silk protein gene.

Alie: And what did you start with? Did you start by putting these genes into E. coli, and then did you move up to goats, and then alfalfa, and then… what was the order?

Randy: So, we started with bacteria just because they're easy. We can come up with a new gene, we can pop it in E. coli and get a protein in three to four months. We then went to the goats, and we worked with a company in Canada who had already developed a technology to get it into the goat's milk so that we were able to take their technology, and our technology, put them together and end up with the spider goats.

Aside: Peanut butter and chocolate? Peter Parker and Gwen Staci? These pairings have nothing on spider goats. Now, what if you're too vegan, for all this business? Is outsourcing spidroin limited to goats and caterpillars? Nope, they're also working on cramming the gene into and harvesting silk from… alfalfa. [*low voice*] What?!

Randy: We started on alfalfa and then, you know, more recently in the last couple of years we've moved on to the silkworm, particularly precision. We did silkworms before, almost eight or nine years ago we did, but we did it very imprecisely. And so the problem was, is that when you bred those worms, a lot of times they'd lose that gene because it wasn't in the identical place that they expected it to be. So now we've got it in right where it should be and we've done four generations and it behaves just exactly like it's expected to be. I mean, it gets carried on to the next generation at a certain frequency, which is exactly what you'd expect to have happen.

Alie: And let's say you're working with E. coli, you are getting the protein in a liquid form and then extruding that? Or can you walk me through really briefly, like, with each of those different organisms, how you're harvesting it?

Randy: So, with alfalfa, with the goats, with the bacteria, process is the same. We have to isolate the spider silk protein, and although it's slightly different technology that you use, the bottom line is you have to end up with pure protein. [*"That's a protein file."*] Once you have the pure protein, then we've developed a technology that allows us to dissolve it in water, and that's a huge advance because previous to that, and still, a large number of people working in the field, dissolve it in some pretty nasty materials.

And the other thing is that they're all costly, so you can't imagine that as a real step forward in the manufacturing process. So being able to dissolve it in water is a big step forward. Then we can spin fibers out of that. We can use it for coatings, we can use it as an adhesive. All of those things fall out of having it in water. The silkworm makes fibers for us. And so literally we use the standard technology for unwrapping cocoons, washing the silk, and wrapping it onto a spool.

Aside: PS, how is silk spun? Well, I watched a video put out by *How It's Made*, and they had this to say:

[*"It's hard to believe this beautiful fabric comes from worms. The female silkworm lays up to four hundred eggs in one shot, then promptly dies."*]

Mmmm okay, *How It's Made*, it's not really a worm. Also, a lady silk moth has, like, a tragic, flightless life, and then her babies are boiled so that the cocoon doesn't break, and the threads, which can be nearly a kilometer long, stay in one continuous form. So, 50 or so cocoons are unraveled, they're spun into one thread, it's labor intensive. So if you see a guy who has ever tossed his tie over his shoulder because he's eating chili, you can be like, "I get it, a lot of non-worms lost their lives for that tie."

Alie: When you think about ramping it up to a more, say, commercial level, what do you think is going to be the avenue that you're going to go down? Do you think it's going to be the pure fiber from silkworms or do you think the alfalfa has the best yield?

Randy: I certainly believe that ultimately alfalfa is going to be the way to go to make protein. The problem with silkworms is the only thing you're going to do is get fibers. Trying to dissolve that silk is an incredible losing proposition. It's not the way to get spider silk protein. So, spider silk protein's either going to be from one of the other three and hopefully we're going to advance the technology so alfalfa will be the choice because certainly by all stretches it looks like it's going to be the least expensive process to go to.

Alie: And then with byproduct, you were mentioning earlier, that when you put this into goats and goat milk, that's great, but then you have some excess goat milk that you can't do much with. You can't necessarily take that to the farmers market on a Sunday. Transgenic Spider Goat Milk.

Randy: Yeah, not going to happen. Not gonna happen. [*"Never ever."*] That's what one of the big advantages of alfalfa is that we'll take out 2% of the protein, the other 98%, we can use for animal feed, use it as a protein supplement. Turns out that things like fish farms are struggling to get enough protein to expand. So, we'd have protein that we'd be able to use there. You can also convert all of that waste into ethanol if you want to use that. So, I think there are a number of routes that you could use for your waste from alfalfa that actually would probably pay for the processing.

Aside: So, spiderwebs: not just terrifying midnight face veils. They could also feed fish, and keep lethal catheter funk away, and make your car lighter, and more efficient, and maybe be transplanted into your own body.

Alie: What is something that in your career, isolating this for the last 30 years and working with it, that you were really looking forward to as a goal or as kind of a goalpost?

Randy: I think it's still there, and for the last 10 to 15 years, I think all of the people that have been working in my lab want to see a product come out. And I think that's at least a major goal is to say that all the work that we've done is led to something that somebody can buy.

Alie: I feel like you are at the forefront of it. If there's an expert in this, it's you, in the world.

Randy: Well, we've certainly been at it longer than anybody else, and I would say without a doubt that we've done more basic science in terms of not only the proteins, but how the fibers are made, the three-dimensional structure in the fibers, and things like that. I think we've done more than anybody else. There are people who have niches, but I think we've covered the whole waterfront.

Alie: Have you ever thought about just getting a silk tie made, a bow tie for a special occasion?

Randy: You know, it's not my style. If it's going to be something, it'd be a golf shirt. So that's the direction I'd go, is a golf shirt.

Alie: A spider silk golf shirt?

Randy: Spider silk golf shirt, I've got no idea. There's no obvious reason why it would be an advantage, but at least you'd have a talking point when you're out playing.

Alie: You'd have to get a big embroidered spider on the back.

Randy: Exactly, front and back.

Alie: Can I ask questions from listeners?

Randy: Sure.

Alie: Oooh my gosh. Listeners have questions!

Aside: Okay, so before we get into your spidey silk queries, a few words about sponsors of the show who help make it possible to donate to a cause of the Ologist's choosing each week. And I realized this week I forgot to ask Randy, so I rang him up on the horn, just normcore as hell, and he answered at his desk; phones man, they're magic. And he said he'd like the donation to go toward the Women's Empowerment and Entrepreneurship project in Guatemala which supports women-run farming initiatives, to bring to market textiles, organic vegetables, and free-range chickens. And this was through Hefer.org. Now you may hear some words about some sponsors.

[*Ad Break*]

Now, this first question was also asked by Amanda.

Alie: Anna Thompson says: There's a series of photos that go around every now and then of spiderwebs when they are on different drugs. Are these real images, and have we learned anything from giving spiders drugs? Do they just have a good time? Are spiders given caffeine?

Randy: The answer is that because the web-spinning process is really genetically set, the drugs do mess it up. It turns out that the first paper was published in *Scientific American* in 1969. ["*That was the '60s, you know, a lot of drugs kickin' around."*] And the answer is yes, that various drugs have substantial effects on, sort of… deranged might be too strong a word, but probably not inaccurate about what the webs look like when they're on various drugs.

Alie: Really?!

Randy: Yeah.

Aside: This was indeed a study, and this was later replicated in the mid-1990s by NASA. So, if you look at pictures, you'll see these scattered and kind of haphazard webs on uppers and caffeine. There are half completed ones on hallucinogens, and let's just say some geometric minimalism done on sleeping pills. According to researchers, each of the spiders interviewed during the process during the process thought the web looked great, and was hella tight, and then upon waking the next morning, a lot of spiders reported being embarrassed by their work. They thought it was a lot better when they were under the influence. [*pause*] That's not true.

Randy: To the best of my knowledge, there's no real correlation between what the drug was and what it did to disturb it, but it's probably because we don't know enough about the nervous system of a spider to actually be able to make an accurate judgment about what they're doing on various kinds of drugs.

Alie: I just looked at my phone, by the way, and I accidentally asked that question at 4:20, which, I'm not a big smoker, but it was… I gotta say that was good timing. Kimberly Fajardo wants to know: Just how strong is spider silk?

Randy: So, the idea is that, in terms of energy to break, which is the combination of stretch and strength, it's about four times stronger than Kevlar, 10-12 times stronger than steel, and it's important to remember that it's that combination of stretch and strength that makes the spider silk unique. So, there are no manmade materials, there are no other biological materials that have that kind of a combination.

Alie: Yeah. Ooh! Evelyn Jensen wants to know: Does spider silk come in different colors?

Randy: Interestingly enough, the answer is yes, to a certain extent. One of the spiders that we work with is called a golden orb-weaver, and its silk is actually a gold color. You mentioned the tapestry. If you see a picture of the tapestry, it's very gold colored. Very distinctive of the golden orb-weavers. By the way, nobody knows why it's gold. We actually spent a little time and got a little sidetracked trying to identify the dye or whatever it was. We never were successful in getting there. To the best of my knowledge, neither has anybody else.

There's another spider that makes sort of a greenish hued silk. And then there's a whole family that make everything from sort of a brownish silk to a pinkish silk, but they use it almost exclusively for their egg cases. So, it's clearly to camouflage the egg case. So, if you go out, you can find these… because you don't see it in the dragline silk, you only see it when they make their egg case. So, there is a pretty wide variety of colors that are out there, particularly for the egg cases.

Aside: So, spiders are just out there using their stiffest silk to make little Easter eggs! Oh, and if you are an expectant parent, and you're not sure what kind of nursery theme you want, consider… camo. I mean, you won't be able to *find* the baby, under all its grease paint, and tiny mossy ghillie suit onesie, but also, no bears will probably eat it! Spiders know what's up. Moving on.

Deli Dames, Ashley Kelly, Caleb Patton, Canon Purdy, and first-time question-asker Laurence, all echoed Christina's question.

Alie: Christina Neel wants to know: How do you feel about Spiderman? Is there even an ounce of truth to the idea that spider silk supporting the weight of a human being could be used, or that it can be used in weaponry?

Randy: So, it turns out that that's a very interesting question and we have answered it. We got asked that question the first time from a children's program, at the Canadian Broadcasting Company radio program. And they asked us, particularly I guess in *Spiderman II* where he stops the train, and asked the question, could he really do it? So, we put the students to work on it and the answer is yes, there was no question.

We took, like, the last speedometer reading was like 120 miles an hour, and we counted up how many cars there were, and how big the engine; we got rough weights for those. So, we were able to calculate how much energy was in that train and then go back and look at how many times did he stick the web onto the wall, and the answer is, he actually was about three times over having the ability to stop the train. That was kind of where we left it.

Then we got another question, and somebody came up with, well, "How much would he have to consume to make the silk, because it's all protein, right?" We calculated that was about… he had to eat about 85 pounds of steak a day. So, we felt like, yes, it was possible,

but clearly, practically, it's unlikely that he could have managed to eat enough to make as much spider silk protein as he was able to shoot out.

Alie: He's gotta go to Sizzler! ["*Sizzler is the one!"*]

Aside: PS, in real life, it wouldn't shoot from his wrists, though, because a more anatomically accurate Spiderman would extrude silk from the slowly wriggling fingers right next to his anus. Keeping that in mind, are you hungry? Who else asked about eating?

Alie: Brandon Butler wants to know: Is it true that spiders can eat their silk and recycle it?

Randy: The answer is yes. Several species do that. Some of them do it actually on a daily basis. So, it turns out to be very useful, because initially when people were trying to understand something about the proteins, they would put radioactive amino acids on the web and then allow the spider to eat it. What we've done is not used radioactive but used amino acids that we can use for nuclear magnetic resonance studies for structure, and we put it in their water. And so, when they drink the water, they recycle those amino acids and it goes right into the silk. So, the answer is yes, they do. And it's a very useful thing to do when you're studying the silk itself.

Alie: Yeah. And I imagine then they can just kind of destroy and munch on their own web and rebuild it if it gets damaged, right?

Randy: Yes. Frequently they don't do that. Usually when it's going to be repaired, they don't seem to clean up the old web. They just put a new one… you know, fill in that area with new silk.

Alie: Oh!

Aside: Just imagine an HGTV show where you make a house, but your building materials come from your butt. And then, when it kinda starts lookin' shabby, you just eat the whole house. Make another butt house. It's rustic! It's resourceful. It's D-I-WHY?? Speaking of why, some other folks shared this next question, and they are Evan Jude, Amanda Palvano, [phonetic] Casey, [ph.] and…

Alie: Anna Thompson wants to know, related: Why do some spiders string webs across wide expanses like paths and trails and doorways instead of smaller areas? I imagine she has gotten a spider piece on her.

Randy: Yeah, so there's two possibilities. One is that, again, they don't plan very well. They're not really intelligent about it. So, they may start with some guidelines that are way out and a web that's more in the middle. But also, as it gets larger, they need to make a bigger web just to catch more prey. So, as they increase in size, their need for food increases. so they usually make a bigger web.

Alie: Ah, they gotta catch more little buggos!

Randy: That's right.

Alie: Ashley Kelly wants to know: After listening to a podcast called *The Biology of Superheroes* Spiderman episode, I have so many questions, like can it really be used in healing wounds and tendons? And how thick would it need to be to support me in order to swing from building to building?

Randy: So, we can go to the last one. I have no idea what your weight is, so I won't presume to say anything like that. We have had a student suspended in a chair from the ceiling and the line was narrower than a pencil, [*Alie shocked gasp*]so it was not that big. Certainly, in the

Spiderman movies, you look at the diameter of the silky shooting, there is no question that he could do what he does.

Alie: Oooh, this is changing how I feel about Spiderman movies! I like them even more now! And then what about biomedical purposes? Tendons?

Aside: Patrons who wanted to know about medical uses are: Lacie J Scheuer, Amanda, and Laura Merriman, who shouted out ologites' beloved Thermophysiologist, Dr. Shane Campbell-Staton and his *Biology of Superheroes* podcast episode on Spiderman as another excellent resource on medical uses of the silk.

Randy: So, we certainly think there's a good opportunity for artificial ligaments and artificial tendons because one of the unique features about spider silk is that, for whatever reason, it's almost impossible to get an immune response to it.

Alie: Really?

Randy: Even when you try. So, for instance, I know of nobody who's ever made antibodies to the main portion of the spider silk protein. You can make it to the end parts. You can't make it to the main part of the protein. And we've tried. We've tried different organisms; we've tried doing it different ways. It just does not generate an immune reaction. We've done some work here, not in massive detail, but we've demonstrated that you can implant our synthetic spider silk fibers and some of our synthetic fiber silk films into animals and not get any reaction at all.

Alie: Which is a huge benefit.

Randy: Absolutely.

Alie: And now Spidey Tek is a company, obviously, that you're involved with. What do you think the principal goal of Spidey Tek is? And also, how did you come up with the name?

Randy: I didn't, Roberto came up with the name. I think that adhesives and coatings are going to be the first place we go, because I think it's got the lowest barrier to market in terms of that. I think it has unique capabilities that aren't out there right now, which again, I think is important if you're coming out with a new product.

Alie: Yeah. He mentioned to me that 'Spidey' was a good way to get people not scared of spiders and to think of it like, "Oooh, spidey!" Kind of a more friendly way.

Randy: And I think, you know, part of that comes from Spiderman movies, because Spidey certainly, is used multiple times there. [*"You like that, Spidey?"*] So, you're right. I think it does present a much more acceptable kind of use as opposed to Arachna-Cream or something like that.

Alie: Spidey does seem so friendly! "I'm a spider. I make cool stuff! Here to help." It's a very, super heroic name.

Aside: Eva also asked this question.

Alie: Nadinne wants to know: Is it true that most spiders we see out in the world are female?

Randy: For the orb-weavers - and that's what most people see - the answer is yes. In general, the females do put out the webs. Many… I would say probably most of the males hang out and actually steal their food because they're much smaller, they're only about a tenth the size of the females. They steal their food and hope not to get eaten because… I mean, the males are

there for one thing, that's to deliver up a sperm sac, and to procreate. That's the only thing they do. [*"I have a delivery for you!"*]

Alie: They're just busters. They're just baby daddies.

Randy: Pretty much leeches.

Aside: Speaking of little disappointments…

Alie: Emily asks: What are cobwebs versus spiderwebs, and why don't I notice the cobwebs until long after the spider is gone?

Randy: So, the proteins that cobweb weavers use are in many cases very similar to the proteins the orb-weavers use. So, the cobweb's basically a three-dimensional net. It does not have any adhesive on it. So, what happens is that the organism physically gets in and can't find its way out. As opposed to being stuck on the web, like with an orb web. And so that's one of the major differences. That's why most of those have a more potent poison because they've got to catch them and keep them from getting away.

Alie: Got it. So, like a black widow has a cobweb?

Randy: Exactly.

Aside: So, if they're spun as a cobweb, they're a different structure. But also, a cobweb can refer to that dusty web that's lost its stick and been abandoned. Think of how many more cobwebs you would have to clean up if spiders didn't do it for you by eating them. [*"Thank you, spider!"*]

Randy: I think part of the reason you don't see them normally is you usually see them after they're abandoned, and dust starts gathering on them. So, when they're there, you want them so that they're not very visible, because you want something to fly into it and then get lost in there. So, if it's very visible, they're going to avoid it. I think the reason you see it is that they're cobwebs, and people usually think about them after they get dust on them.

Alie: This is just my question, but how dope are your Halloween decorations every year?

Randy: Umm… Not all that much, actually. We don't do anything unique there, and for some reason, to me, spiders are more an all-year thing than a once-a-year thing.

Alie: I felt that way about Halloween when I was goth. I was like, "Don't dress up as me on *one* day!"

Randy: "I'm like this all the time!"

Alie: "Yeah! I'm constantly wearing fishnet shirts. Don't do it just on Halloween!" So I get it. Do you ever watch a movie about, like, a haunted house and think, "Spiders wouldn't make those kinds of webs."?

Randy: Yeah… but you know, the fact is that that the spiderwebs come in such a variety of different shapes and sizes that, yeah, you'd say that's probably outlandish, but you'd never say, "I guarantee you'd never find one like that."

Alie: Oh, I forgot to ask you, before we get back to Patreon questions, is there any flimflam that you'd like to debunk? Like any myths about spiders or spider silk that you're just sick of hearing? Like, "Okay, let's clear this up."?

Randy: Hmmm… I think part of it is certainly that a lot of people believe that all the spiders are poisonous, and certainly as far as poisonous for humans, the answer is that's just simply

not true. There's three, depending on how you argue about it, there might be a fourth one, in the US.

Aside: And Randy means venomous; poison is ingested, venom is injected. But you know what he means. Do not waste your finger muscles emailing or tweeting me about it. Spend that energy giving a hardworking and busy spider a little wave! Give them a little thumbs up.

Randy: So, the thing is a study done in Australia demonstrated - and this was people who came to the hospital claiming they'd been bitten by a spider - and they actually checked it. And less than 10% of them were actually bitten by a spider.

Alie: Really? It's mosquitoes?

Randy: Yeah. All kinds of other things. Some of them weren't even bites.

Alie: [*exasperated*] Oooh!

Randy: So, you hear all these people say, "Oh yeah, I got a spider bite last night." And you're going, "You know, you've got a 90% chance of being full of it."

Alie: Right! "Trish, that's a hickey! Can you not?"

Randy: Yeah, that's right! [*laughs*]

Alie: **"**Dave, you've got a zit on your neck! Get out of here!" Jen Athanas asked: All this talk about eating bugs. Can we eat spiderwebs? Sometimes that's the only thing I have in the house. Shrug emoji, she says. There's a lot of protein. Could we one day be eating spiderwebs?

Randy: So first of all, there isn't a lot of protein. Most of the web weigh very little.

Alie: Mmm, okay.

Randy: So, for instance, the entire gland that makes dragline silk is only good for about a hundred milligrams, max. Now that's good for several hundred yards of single fiber silk, but that's not a lot to eat. Number two, the spider silk, I'm sure, is digestible to a certain extent, but what we found is that there are very few organisms who could break it down. So, we know fungi can, but fungi can break down almost anything, or at least some species of fungi can. So, I think that would probably not be a very nutritious way to go about augmenting your diet.

Alie: Right. Not to mention that it's expensive, right?

Randy: It would be expensive.

Alie: Like how much a kilogram?

Randy: $2,500.

Alie: That's like… I have no idea how much chicken costs a kilogram, but I'm thinking less.

Randy: Yeah. Quite a bit less.

Aside: Okay, I had to crunch some numbers, because I live in America, and the only reference points I have for kilos are when there are headlines about people smuggling heroin in their suitcases or under toupees. But a kilo of chicken is 2.2 pounds, which is about half a whole-roaster chicken, or about $5 worth of chicken breasts, which is 300 times as expensive as spider silk. Probably even more, actually, if you're starving for spidroin, and lazy, and you just have it delivered on Postmates.

Alie: Billy Marino wants to know: How do spiders use their silk to fly? I think he's talking about ballooning?

Randy: Yeah, ballooning. So basically, especially when they're small, there's a nest of a 100–150 little itty-bitty spiders, and they've got to spread out if they're going to eat anything. So, what happens is they usually go up into something, they lay a big line off the end, and when the wind gets up, they jump, and their fate is now completely dependent on where they end up.

But here in the spring, what happens is, you can go out and see some of the fields and they look like they're coated in spider silk, because all of these spiders have jumped, and their lines are laying out across the sagebrush, or the grass, or something like that. And I've seen pictures along the coast of California where you see that, because the marine layer comes in and you get drops of dew forming on that. So, it looks like the whole entire thing is covered with spider silk because all of these little guidelines are laying out there.

Alie: Can't they get pretty high? Like 10,000 ft, or something?

Randy: I think they've found them clear into the 30 to 40… I mean, up as high as jets fly.

Alie: How do they not run out of silk?

Randy: They don't, they just put one thing in and let the wind get it. So, it's like they're putting out a sail. They use it like a sail.

Alie: Oh my gosh! So, it really is wherever the wind blows.

Randy: Yeah, you got that right!

Alie: Zwelf Juniper wants to know: Hi-ya, how many animals did you consider before landing on these goatseses?

Randy: Not very many because the company we work with specifically focused on goats, for a multitude of reasons. One being that these goats were called breed-early lactate-early, so at five months they're sexually mature. You breed them and five months later you have a goat producing milk.

Alie: Dang.

Randy: So, in less than a year you've got a complete cycle. That's a huge advantage. And especially being here in Utah where dairy's a big business, we always get asked why goats and not cows. So, the answer to that question is, number one, milk production per pound of feed is basically the same in goats as it is in cows. They don't produce as much. They're much easier to deal with. So, if a 1,500-pound cow doesn't want to go anywhere, you've kind of been backed into the corner. They also are much more adaptable to human orientation.

So, our kids, shortly after they're born, after a couple, three days, are then fed by hand, milked by hand. And I'll guarantee you they have no idea they're goats. They think they're humans. So, they really are easy to work with in terms of that. The waste is much less than it is with cows and makes it easier for cleanup and that kind of stuff. And last but not least, my people tell you that baby goats are much cuter than baby cows.

Alie: That's very factual. There's nothing cuter than a baby goat.

Randy: It's a fact. Absolutely.

Alie: Did you, like, low-key love getting to work with the goats? Were you like, "I never really realized that working with spider butts would lead me to getting to cuddle baby goats."?

Randy: No, not so much. Because I raised sheep when I was a kid. And then when my kids started growing up, we moved out. I had a place out of town, and they raised sheep, so I got to see baby lambs, you know, multiple times every year. So, baby goats probably are cuter than baby lambs, but not by a lot.

Alie: I'm going to do a poll, because I think that that would be a very heated debate to be honest.

Randy: Yeah. It's a tough one because I certainly do like to like lambs, there's no doubt about it.

Alie: Just do a transgenic one where we got a little bit of both.

Aside: Okay, I took a Twitter poll, and at press time, it was baby goats, in the lead, 62%. I regret not including baby spiders in the poll, so that's now a mystery that's just lost to time.

Alie: Okay. Gregory O Conway wants to know: Dear AlWard, can we use spider silk to make a kick-ass parachute?

Randy: The answer is yes, but what we're probably more interested in is the parachute lines. One of the problems you have is, especially if you're dropping, let's say, a tank out of a cargo, more frequently than I think any of the DoD would like to believe, the parachute collapses. Because obviously it goes out, it tries to open, and then at the end it goes *wham* when it opens up, and it collapses. So, what we see is that if we made the guidelines out of spider silk, when it hit that end, they would just stretch it, so the parachute would no longer collapse. It would allow the guidelines to absorb all of that energy.

And then as we talked, it gets released as heat, so it's not going to go bouncing up and down like a trampoline. It's going to go down and then slowly come back up and keep the parachute from collapsing. Now, we may also want to do it for all the parachutes, but particularly those where you're dumping something heavy out, we could see this would be a huge advantage to what they have right now.

Alie: And speaking of DoD stuff, what about armors, things like that? Not so much?

Randy: We don't see spider silk as… from our perspective anyway, as the way to go for protective armor, particularly things like bulletproof vests. And the reason is it stretches too much and that's what's unique about it. That's what makes it key. So, my joke is when somebody asks is, "I know I can make you bulletproof vests, it just stops a bullet on the wrong side of your chest. So that's not particularly useful."

Alie: Also, any movies that you've seen with spiders or spider webs that you very much enjoy?

Randy: Oh, oh, *Eight Legged Freaks* is a movie you *have* to see.

Alie: What it is?

Randy: It's like the parody of every B horror movie you've ever seen. [*"Our town is being attacked by giant spiders!"*] Radioactivity, guy has spiders there. They all become giant spiders. This little 12-year-old kid sees it. He tries to go to the sheriff and tell the sheriff, the sheriff doesn't listen to the little kid. So, these are loose, destroying, picking up trailer houses, chasing people down, having eggs and magically getting giant, whatever else. And then toward the end, that little kid comes and says, you know, "I know what's going on." And somebody says, "Sheriff, why don't you listen to the little kid?" And so, they finally managed to clear out.

But when it first came out, I took everybody in the lab for the movie. We went and I said, "Everybody has to come up with at least 10 things that are absolutely totally false that they

find in this movie." And trust me, we had lots more than 10. It's hilarious. It's absolutely hilarious.

Alie: But those things are also delightful because they're so false.

Randy: Absolutely. Except some people don't see it that way, which is the unfortunate part!

Alie: Here's spiders, just going about their business, and the things that they're making naturally could literally save our lives.

Randy: I hope so.

Alie: So, thanks, spiders. [*"Thank you, spider!"*] Just get one of those little spider catchers, take them outside, let them go do their business. Let them keep evolving. It's been 500 million years. Let them do their thing.

Randy: That's right.

Alie: The thing that you hate the most about your job or about spider silk, what's so annoying, or irksome, or just troubling? Is there anything that you're just like, "Ugh, this sucks"?

Randy: For us I think it has been heading toward the commercialization direction. Just because it's been difficult to convince people that it can have advantages over what they're currently using, particularly in the medical world. It's astounding to me that advances ever get made in medicine, based on our experiences, because these people, if you say you're going to have to go back to the FDA for approval, immediately it's off the table. They would rather have inferior products.

So, for instance, we've made a hernia mesh that is far superior what they use right now. Absolutely no question, but hernia meshes are off the table. There is not a company that we know of, that wants to touch it because of lawsuits around vaginal meshes failing, hernia meshes failing. Well, the reason they failed is because they're made out of lousy material. But you talk to them and it's like, "We're not touching it with a 10-foot pole. We don't want to have to take it on, we don't want to have to do the FDA testing. We don't want to deal with possible lawsuits. We don't want anything to do with it. So, we'll keep using our lousy stuff."

Alie: Yeah. So, it's that technology has advanced faster than, maybe, mindsets.

Randy: Certainly, acceptance.

Alie: Yeah. But I think it's so great to know how it's made, and that it's a protein structure that is so versatile, and that it can be manufactured. I think it's just so unreal to people because it's so science fiction. You're like, "Oh no, this is 2019." Like, "We can actually do this now," which is so exciting. And what about the best thing about spider silk, or your job?

Randy: I think the best thing about my job, and I always say it, it's coming to work and having a realistic expectation that you're going to find something new multiple times a year. I have to say that, other than a day I have meetings all day, I've not dreaded a day coming to work since I started.

Alie: Oh, for 30 years?!

Randy: For 30 years.

Alie: You gotta get this cake, man! You deserve it! You've got a great job. And where can people find out more about you, or about your work, or about Spikey Tek?

Randy: Certainly, Spidey Tek has a website. We have a website on USU, if you just do spider silk USU, you'll get to our website. And we have a Facebook page. We're not quite as good on the social media side of things.

Alie: Yeah, you got to get a social media intern.

Randy: Yeah, that's right. I'm afraid it's passed me by.

Alie: You're not out at Coachella, wearing a spider hat, and just being an influencer?

Randy: No, I am not, and I'm not tweeting to keep up with the president or anything else here.

Alie: Hashtag spidey life! Thank you so much for doing this, it was such a joy.

Randy: Certainly, I really enjoyed it!

Okay, so ask smart people some silky questions, because you'll never know what they know unless you ask. And I hope this has given you greater appreciation for our leggy friends, and this Halloween season, when you see a spiderweb decoration, just feel free to stop everyone around you, inform them of the molecular engineering that goes into it. Maybe if you get a spiderweb in your face, eat it like cotton candy! That shit's expensive.

So, for more on the topics discussed, you can head over to my website for links, it's AlieWard.com/Ologies/Spidroinology, and there are links to sponsors and codes in the show notes as well. And for merch, there's a link at AlieWard.com. Thank you for Shannon Feltus and Boni Dutch of the podcast *You Are That*, which is a hilarious podcast, for managing that. Thank you to Erin Talbert, and Hanna Lipow for adminning the Facebook Ologies podcast group.

A few things live-appearance wise, I'm keynoting SciComm Camp in Southern California on November 8th, and there may still be a few spots left in case you can convince your work, or your lab, or yourself that this conference is an important thing to attend to communicate science. You can go to SciCommCamp.com, they have more details, and it's November 8th through 10th. The lineup is awesome, it includes *Flash Forward*'s Rose Eveleth, and 'Physics Girl' Dianna Cowern.

Also on October 17th it's the International Myeloma Foundation's annual comedy benefit in L.A. And it's hosted by Ray Romano, and there are performances by Patton Oswalt, and Amanda Seales, and Demetri Martin, and Kevin Nealon, and I'm hosting the red carpet live on the IMF Facebook page and there will be links to all this in the show notes. Or up at Alieward.com/Ologies/Spidroinology.

Thank you to Jarrett Sleeper of the mental health podcast *My Good Bad Brain* for assisting editing, and to the center of our webs, Steven Ray Morris of *The Purrrcast* and *See Jurassic Right* for adhering the pieces together each week.

And if you listen to the end of the podcast, you know I tell you a secret, and this week's secret is, Shannon and Boni stayed down here in L.A., and when they did, they left a loaf of sourdough bread, and I've just been slowly eating it piece by piece by putting it in the microwave until it's all gooey, and then putting butter on it, and then putting salt on top of that, and just walking around eating this soggy piece of buttery bread. And I'll have you know, Shannon, Boni, I finished it today. I tore through it like a locust.

Also, while I recorded all these asides, Gremmie, my dog, is sitting next to me, and she is wearing a spider-themed sweater that I got her, so do keep an eye out, I will be posting a picture of her in the spider sweater on Instagram.

Okay, berbye.

Transcribed by Aska Djikia, with the assistance of her furrball cat Lenjamin Djikia.

Edits by Kaydee Coast, who reminds you don't lick toads, check your crevices, milk your thumbs, and never apologize for asking questions. Kthxbi.

Some links which may be of use:

One $200 dollar of spider silk

Spider vibrations

Golden Orb Weaver Silk Tapestry

More on the tapestry

How spiders sense

"How It's Made: Silk"

8 Legged Freaks

Spidey Tek

For comments and enquiries on this or other transcripts, please contact OlogiteEmily@gmail.com