Thermophysiology with Dr. Shane Campbell-Staton
Ologies Podcast
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Oh heeyyy, it's your boyfriend's old roommate, who always put Pepsis in the freezer and then forgot about them until they exploded, Alie Ward, back with another episode of *Ologies*. So, check in with your bod right now. Are you cold? Are you hot? How do you feel? Are you sweating? Is this too many personal questions? Okay, let's change the subject… to me. Well actually, to you.

Thank you so much as always to the patrons who support *Ologies* at Patreon.com/Ologies, for everyone who gets themselves some *Ologies* merch to put on their warm (or their cold) bodies, and of course everyone who subscribes, rates, especially who reviews the podcast. You know I read your reviews each week, and as creepy proof, here's a fresh one. Bowerbird77 wrote:

> *I drive in to work 2 days a week. Some days the thought of getting out of the house with a bra and mascara seem too much, until I remember that a new episode awaits. I can't wait to hear what ol' Dad Ward has in store for my commute tomorrow. PS- Stay with me when you come to Philly. Open invitation. I'm mostly normal.*

How can I say no to that? Also, CaecincolaCookorum left a sweet review that asked:

> *Been listening for a while and I'm still not sure why Alie refers to herself as "Dad" Ward.*

It's a great question. It started in a podcast Facebook group because I like hot dogs and bad puns, and I'm just very likely to lecture you about tire pressure safety because I love you. I just want you to be safe.

Okay, Thermophysiology. Let's get into it! Let's get it into *us*, rather. *Thermós* in ancient Greek means 'hot'. 'Physio' derives from the word for nature. So, everything from hotness and nature to coldness in a lab, as we will soon discuss. This Ologist is amazing. I met him over Thanksgiving at a dinner held by our mutual bud, Cara Santa Maria of the *Talk Nerdy* podcast. New to LA, having just taken on the role of Professor at UCLA, he mentioned some of the courses he teaches and his podcast, *The Biology of Superheroes*. From there, I gently begged him to be on *Ologies*. Then I found out we had more mutual friends, such as the Erins Welsh and Allmann Updyke, of the Epidemiology episode and *This Podcast Will Kill You*. Essentially I was like, "Hello, Sir, I regret to inform you that you will be my friend, forever."

What a better time to talk about body heat issues than February, when it's cold, heaters are cranked, nary a daffodil bulb has sprung from the slush? So, we scheduled a time to record. I reached out to ask for a few more days though, because I was so behind working on the aging episode that I literally cried that day. So, this Ologist kindly let me reschedule for a few days. Then I headed over to his brand-new office at UCLA, where he was wearing normal person clothes and I was wearing four layers and a scarf because I'm a Chihuahua.

He showed me some fancy chambers in his lab and we settled in to have an absolutely wonderful and informative chat about how critters adapt to temperature changes, lizard storms, dinosaur blood, hibernating bears, why you sweat in your sleep, maybe *you* specifically, anti-freeze frogs, miracle hamsters, why different people run at different temperatures, how comic books influence the way he sees science, learning how his brain works, and some time management hacks that he uses as a professor and host of *The Biology of Superheroes Podcast*. So get ready to warm up to your new biology hero, Thermophysiologist, Dr. Shane Campbell-Staton.

Dr. Shane Campbell-Staton: … I get it every once in a while, or sometimes Staton-Campbell. It's a mess. Hyphenated names: it's a difficult life to live.

Alie Ward: Now, this is your first harsh southern California winter.

Shane: [*sarcastically*] Oh, *so* harsh. Yes, I've spent my life sort of bumping around a bunch of different places, and before I moved here I was in Montana. Before Montana I was in Illinois, and then before that I was in Boston. All of which have pretty harsh winters. Before that, I was in Rochester, New York, which may actually be the snowiest place in the entire country.

Alie: Ughhh!

Aside: Quick aside. I looked this up and Rochester is the 4th snowiest of the lower 48 States, clocking in at about 99 inches of snow per year, which is just an inch or two less than Anchorage, Alaska typically gets. Now, if you're listening in Syracuse, New York right now, you are screaming in your car or at your phone. You are saying, "Yes, bitch! Rochester is Florida compared to our 123 inches of snow!" So yes, Syracuse, New York, you win for most snow-related winter suffering. Also, on the sunny side, if you're doing all that shoveling, you probably have pretty good core strength, pretty good abs. I dunno, that's all I got.

Shane: And for the longest time, I remember moving up from South Carolina. I was like, "What is this 'lake effect' that people keep talking about?" Because it was the first time I'd ever heard of it. Then the first winter came and I was like, "Oh, it's like a hurricane but cold, basically." It was a harsh reality to live. So luckily, I bumped it over here to LA.

Alie: Good work on that. Now, what was it about your upbringing that you thought, "I want to study biology. I want to study science, and particularly temperatures and cold"?

Shane: Oh man. Those things did not come along intentionally by any means. When I was a kid, I got really obsessed with reptiles. I don't know what it was about the scalies that got me, but it was just a thing. My mother, bless her heart, she was super supportive, but she just doesn't do that sort of stuff. [*Pee-wee Herman, "Ugh, I hate snakes!"*] Yeah, but she was really supportive. I remember in high school I had all sorts of creatures for a senior project I did. I had a python, several different lizards, a giant green iguana, a breeding pair of corn snakes, all this sort of stuff. I was obsessed with it.

Aside: Shane wound up getting his PhD in Organismic and Evolutionary Biology at Harvard University. But before that, as a young herp nerd, he figured biology would be the best course if he wanted to study his beloved reptiles. And he got his Bachelor of Science in Ecology and Evolutionary Biology at the very snowy (but yes, not as snowy as Syracuse, Syracuse) University of Rochester.

Shane: So that's what I did, and that's when I got introduced to anoles.

Alie: Oh, I love those!

Shane: Yeah, they're amazing! They're so cool. Actually the one species of anole that is native to the United States, it's the very first animal I ever interacted with as a kid, because in South Carolina they're just all over the sides of houses and stuff.

Alie: And an anole is just a type of lizard, right?

Shane: Yeah, an anole is this typically small lizard that has this little throat fan, they do a bunch of push-ups, and they wave that little throat fan. There are about 400 species of anole that are distributed across the neotropics, central South America, the islands of the Greater Antilles, and then our one special North American anole that's native to the US. There's a bunch of other species now that are invasive, but that's the one that's native. That's also the species I ended up studying for my dissertation.

Alie: [*voice rising with excitement*] Oh, wait, so you started liking them when you were a kid and you studied them to get your PhD?!

Shane: Yeah, I know, right?

Alie: You're like, "Me again!" Oh, that's amazing! Did you ever think when you were a kid, studying lizards and having corn snakes and having pythons, that you would get to do this for a living?

Shane: I did not realize that this was a thing to do for a living, generally speaking. It is interesting that when you ask most biologists how they got into science, they typically have this, "Oh, when I was a kid, I was walking through the woods, splashing in a tidal pool and I just knew from that point on." That wasn't my life. My mom worked really long hours. I was a latchkey kid, I spent a lot of my time indoors, so my introduction to the outside world, to nature and wildlife, was through television; Jeff Corwin and Steve Irwin, and then the little green lizards that were around my house. So to go from there to being able to do things like this, communicating science to people who don't spend most of their lives doing this sort of stuff, that's a really special circle for me.

Aside: How great is that? For real.

Alie: So, when you got your PhD, what exactly were you studying about these anoles?

Shane: I was studying the evolution of cold tolerance in anoles. Trying to understand how geographic variation in temperature influences patterns of gene flow across space, and then how it influences physiology, which ended up being a big question of mine because the green anole came from Cuba originally. Sometime during the Miocene or Pliocene, it was transported from Cuba, most likely by storm. That's typically the way these small things jump from island to island.

Aside: So just FYI, yes, I did have to look up, "How long ago was somewhere between the Miocene and Pliocene?" The Miocene was anywhere from 5 to 23 million years ago. The Pliocene was 2 to 5 million years ago, so I think he's talking 5-ish million years ago, these adorable little green lizards came over from Cuba making things more enjoyable. Kinda like living daiquiris.

Big ol' stupid question, I'm just so glad that I asked:

Alie: Do they go in the air?

Shane: Yeah!

Alie: Really?

Shane: Yeah, they can fly through the air sometimes like flotsam, like driftwood or leaves sometimes get blown across the water.

Alie: Whoa, like a frog storm?

Shane: Yes.

Alie: Oh god!

Shane: Yeah, it gets real biblical real fast! [*laughter*] [*clip from The Ten Commandments: Moses, "You shall see hail fall from a clear sky and burn as fire upon the ground…"*]

Alie: So they can just rain down Cuban anoles in a different part of the world?

Shane: Yeah, more or less.

Alie: [*whispers*] Oh, that's awesome. That's so cool.

Shane: I have never heard of any first-hand reports of people experiencing lizard rain.

> **Aside:** PS, allow me to read to you an excerpt from the *Sunbury American* newspaper, dated November 21, 1857, headline: "Shower of Lizards":
>
> [*old timey voice*] *The LeRoy New York Gazette says that during the heavy rain of Sunday night last, live lizards, some of them measuring 4 inches in length, came from the clouds like manna, though neither as plenty nor half as welcome. They were found crawling on the sidewalks and in the streets, like fugitive infantile alligators, in places far removed from localities where they inhabit.*
>
> Nature: Just when you think it's not a hallucination, it rains anoles.

Shane: There's a scientist at the University of Tennessee at Knoxville whose work actually inspired the work that I did with the green anole. He showed me this photo when I went and visited him of this male green anole outside in the winter. There's this huge icicle on the side of the picture and that's just such a weird environment for this tiny little cold-blooded sub-tropical animal to live in. I just thought it was fascinating. I got obsessed with how these animals were dealing with these novel cold temperatures.

Alie: How were they?

Shane: It's actually kind of a complicated question. One of the things that we've found is that the farther north you go, essentially the more cold hardy the animals become. We do these tests when we're looking at the limits of thermal tolerance. For ectotherms, cold-blooded animals, their internal body temperature is really tightly correlated with the external body temperature, and that means that their performance is really tightly tied to the external body temperature.

> **Aside:** How much beach volleyball would you play in the snow? None? Because the answer's none.

Shane: So what we would do is go to a site, go into a population, catch animals, and bring them into the laboratory. Then we do these trials where we goose 'em, so we put a little thermometer in their cloaca.

Alie: [*laughing*] Oh!

Shane: Then we cool them down very slowly, like one degree Celsius per minute, and then we test for their ability to maintain a writhing response. We'll flip them onto their backs and then we try to get them to flip themselves back over because a lizard always wants to be on its feet. The temperature at which they can't do that anymore, we call that their lower thermal limit, what's called the critical thermal minimum. When we measured this across the geographic range, we found that populations where the winter temperatures were coldest had the animals that were the most cold hardy.

Aside: Hello, if you're new to *Ologies*, a cloaca is a butt, and reptiles and birds enjoy the convenience of a one-stop shop for poo, pee, sex, and scientific spa treatments involving thermometers.

Shane says there's a lot of local adaptation. The lizards that can survive that cold have offspring that can also survive it, but they also just become hardier because they're like, "Been there, done that." [*old timey snobbery voice*] "I walked two miles in the snow uphill." But unlike your friend's cranky grandpa, these lizards are doing all of this in the nude. Don't picture your friend's grandpa in the nude. Don't do it. Don't.

Anyway, in the wild, natural selection, right? But…

Shane: But we bring gravid females into the lab, and they lay eggs, and those babies are born. We raise those babies under common laboratory conditions so they've never seen a winter anywhere outside, and we do the same cold tolerance experiments. We find that the offspring have the same level of cold tolerance as their parents did, which suggests that there's some heritable, genetically based component to cold tolerance.

Alie: And then, you and I are endotherms, correct?

Shane: Yes, we are.

Alie: How difficult was it not to apply some of your knowledge that you gained through studying anoles to yourself as an endotherm walking around freezing in Montana?

Aside: PS, I got his timeline wrong. Shane was studying anoles at Harvard and did his post-doc on *very cold* ice in Montana. But anyway, in those cold places was he thinking about his own reactions to cold? I'm asking this as a person wearing a scarf in Los Angeles.

Shane: It was pretty easy for me because reptiles are just really different from mammals. The way that they experience temperature is very different from the way that mammals experience temperature.

Alie: How do mammals experience temperature?

Shane: Okay, so...

Alie: This is exciting!

Shane: Yeah, we're going to go in right now.

Alie: Okay. [*laughs*] [*clip from Parks and Rec: Leslie Knope, "I'm going in."*]

Shane: When we think about thermal physiology, how animals experience temperature and how that temperature influences their function, there are four major categories. You can sort of pick and choose the combination therein, and you can pretty much find an organism that fits that description.

Aside: Okay, here we go, into a matrix of different combinations of body heat you can have if you weren't already a hairy human. Maybe you shave. None of my business. Onward.

Shane: The first difference is being ectothermic or endothermic. Endothermic organisms can produce their own internal body heat. Ectothermic organisms cannot. Then we have homeothermic versus poikilothermic.

Alie: Whoa! That's a good word!

Shane: I know, it *is* a good word!

Alie: That is a Scrabble word!

Shane: [*laughs*] It's a good podcast word. Poy-key-low-therm-ick.

Alie: [*sarcastically*] I know what that means, I'm not going to be looking that up and defining it in the aside at all! [*laughs*] No, that's going to happen.

Aside: Yeah, I did not know this word, poikilothermic. And yeah, I gotcha covered with the definition. A poikilotherm is an animal whose internal temperature varies considerably. It's all over the place, as opposed to a homeotherm, which maintains homeostasis and keeps the temperature pretty constant, like you and me. Shane explains how this is not just ectothermic and endothermic. There's a difference, and thus, a matrix.

Shane: Homeotherms are able to maintain a constant body temperature. Poikilotherms have a fluctuating body temperature with respect to their external environment; so as their external environment fluctuates, their internal… So you have a tendency, generally speaking, to group endotherm and homeotherm together, and ectotherm and poikilotherm together.

Alie: That's what I would think.

Shane: Yeah, but it's not always the case. For instance, you can have an endothermic poikilotherm. These are mammals that hibernate. For animals that hibernate for really long periods of time, like weeks or months, their internal body temperature can actually drop to within about 1 degree Celsius of ambient temperature even though they have these internal mechanisms of producing heat. This is an energy-saving mechanism.

Aside: So these endo-poiks, if you will, generate their own heat, but it can vary. Kind of like a house with a furnace, but they set the dial depending on what they need. Now, in case you're on a first date or a job interview that's going badly and the only thing that can save it is naming some hibernating endothermic poikilotherms, here is a list: bears, gophers, bats, groundhogs. Just to name a few.

Now, let's say an ectotherm is like a house without a furnace. So the temperature *could* vary widely, but it doesn't mean it has to.

Shane: On the flip side, you can have an ectotherm that is actually homeothermic. This can happen a couple of different ways. The first way is just by being really large. This is what we call gigantothermy.

Alie: Oh, no! That's not a word!

Shane: Oh, it is a word!

Alie: [*yelling*] Oh my god! Gigantothermy!

Shane: [*laughs*] So for instance, the dinosaurs, but also things like saltwater crocodiles, which are massive animals. And the largest lizard on the planet, the Komodo dragon.

Alie: Oh, I was going to ask about them!

Shane: Yeah, this is essentially a byproduct of surface to volume. If you are really large, your volume with proportion to your surface area is very large. That means that you lose heat relatively slowly to the external environment. For instance, if you went to Australia or if you went to the Nile, you would see these really large crocodiles early in the morning, basking, just sitting in the sun with their mouths open, completely lifeless for hours.

Alie: Oh god.

Shane: Then, by the heat of the day, they're up and moving, they're swimming around in pretty cold water, and they can maintain that function because they're so big.

Aside: Okay, so that's an endothermic homeotherm, like us. Endothermic poikilotherms: bears, groundhogs, et al. Then we were talking about ectotherms that maintain constant body temperature just by being huge, but that's not the only way to be an ectothermic homeotherm. Did I say that right?

Alie: [*in unison with Shane*] Eck-toe-therm-ick home-ee-oh-therm. [*whispers*] Yes!

Shane: -is through behavioral thermoregulation. Basically, this means paying really close attention to the microthermal environments that are available to you. If you are a small lizard, for instance, and it gets really hot outside, because you're so small you're gonna gain heat really quickly because of that same volume-to-surface-area issue. Except if you move into the shade. If you move into the shade at the right time and you stay there for long enough, you can actually maintain a steady body temperature even though you're not producing internal body heat.

Alie: Oh, okay!

Shane: And then insects do it a whole different way. Things like bees are technically ectothermic homeotherms because they can actually decouple their flight muscles and vibrate them without moving their wings to generate heat.

Alie: Why do some animals and humans have set body temperatures that they need to maintain in order to live? Like, why do humans have to be 98.6, and are dogs a different temperature? And do mice in Montana have to be a different temperature than the ones in New Mexico?

Shane: That's a great question. Generally speaking, it's all about strategy; evolutionary strategy and life history strategy. Mammals benefit from being warm all the time. I can get up and move regardless of what time of day it is. Because I have that high metabolism, I can go run and do really high-intensity activities for a pretty sustained period of time, much more so than if I was an ectotherm. On the flip side of that, it also means that I have to take in much more energy in order to fuel that internal furnace that defines endotherms.

Alie: So we have to be out grazing and hunting and finding food in order to have this 24-hour open supermarket of body heat?

Shane: Yes, basically. I do know that humans as a lineage, as we migrated out of Africa into the rest of the world, temperature played a huge part in that process. We can actually see it in the diversity of body shapes that we see around the planet. If we look within Africa, for instance, right around the equator, it's very warm and gets extremely hot during the day. In response, the body changes proportions to manipulate this volume-to-surface area. This is what we call Allen's rule. Allen's rule states that in these warmer environments, animals – mammals specifically – have a tendency to grow longer, narrower limbs.

By growing longer, narrower limbs, it's like having a little pipe instead of a big thick appendage. By decreasing the volume with respect to that surface area, you can then dump heat really quickly to the environment. That's one strategy, so if you look at a lot of sub-Saharan African populations that occur right around the equator—very tall, very thin phenotypes. But then, as you move north into really high-latitude environments, look at populations like the Inuit – very different build, very compact. It prevents them from dumping heat. It allows them to retain heat in the face of the cold much more efficiently.

Aside: Is there something from a physics standpoint, like a magic formula and the ratio of an animal's body to their metabolism or heart rate? Like, at some point in time, did someone just frantically crunch these numbers on a chalkboard and start weeping?

Shane: It's complicated because it is not just a function of size. Behavior plays a really large role in this as well. We can say things like Allen's rule or Bergmann's rule, which states that as you move farther north, you get generally larger animals because larger animals are able to maintain internal temperatures better.

Alie: Oh, I never would've thought about that. Like, woolly mammoths were in Siberia, not just kickin' it in Panama.

Shane: Exactly!

Alie: I never, ever thought about that.

Shane: Yeah, but the largest mammal on the planet, the elephant, is smack dab at the equator.

Alie: Well, what the hell's up with that? [*laughs*]

Shane: So, size is *one* parameter, but in order to get around the fact that they have so much volume-to-surface area, they've evolved very special features that allow them to cool. If you're out on the savanna or if you're in India, a lot of times in the heat of the day, you'll see the elephants are typically in the shade. But you'll also constantly see them fanning their ears, back and forth. If you look at their ears, they have these massive blood vessels that go out into their ears and it essentially acts as a personalized air conditioner. So, as they fan their ears, that blood cools, and then that cool blood circulates back into their body and it helps them to stay cooler.

Alie: What are some other crazy adaptations that you've seen to deal with extreme heat or cold?

Shane: Okay, I will go in on both. On the cold side of things, there are a lot of animals who have developed extreme adaptations. The subfield of thermobiology that specializes in those cold adaptations is called cryobiology. I'm not sure if you've seen the recent pictures, but people were freaking out because the lakes were freezing solid in North Carolina. And when you look at the lakes, every once in a while, you see like a little snout that's stuck and poking up in the ice.

Alie: Whose snoot was it?!

Shane: That snout was connected to an American alligator.

Alie: Oh, geez Louise.

Shane: The alligator is stuck in the ice, but they're able to deal with that really cold situation for a pretty long period of time. But if you took an animal like a saltwater crocodile, it's not an ancestral selection pressure. Even more extreme, if you take ectotherms like reptiles and amphibians that occur at really high latitudes, or even insects that occur at really high latitudes like close to the Arctic Circle, there are some species that can actually freeze solid for months at a time and then thaw out and go on about their business. Animals like the wood frog, for instance.

Aside: Okay, if you like badass frog stories that are bananas, and I know you do, here is a badass frog story. Wood frogs are like, "Oh, hibernation? Hold my beer. My very, very, very cold beer."

Shane: Wood frogs, when they begin to freeze, they undergo a lot of significant physiological changes. They begin to pump glycogen out of their livers into their bloodstream, so basically sugar. They also dump urea into their bloodstream, which we typically try to get rid of through peeing.

Alie: Uh, yeah. Usually that's something you wanna off-board there!

Shane: Exactly, *but* this combination of sugar and urea essentially acts as an antifreeze.

Alie: Oh my god.

Shane: So they can super-cool without the formation of ice crystals. Ice crystals are typically the thing that is most dangerous about cold temperatures, because when water crystallizes, essentially it turns into little daggers that start stabbing and ripping apart cells. When you get severe frostbite and your toes turn black and fall off, that's in large part because of crystal damage.

Aside: If you just spaced out wondering how snow crystals form, do check out the Snow Hydrology episode after this.

Alie: Oof, and also it expands, right?

Shane: Yeah, it's basically like having little ice fortresses forming inside of your body, which you generally want to avoid. For hot temperatures, obviously there are animals all around the planet that have evolved to live in extremely hot environments. In desert environments, there are some behaviors that evolved that are kind of funny. There's a lizard species, for instance, that lives in deserts and at the heat of the day, in order for them to survive, they essentially rotate picking up their feet. They pick up two at a time, and it's like if you were to walk out on asphalt barefoot and you do that thing where you hop back and forth? It's essentially how they get by.

Alie: Oh god, that's so fancy.

Shane: I know, they're very prance-y little lizards. I think they're adorable.

Alie: Like a dressage lizard, just [*singing*] boop-a-doop-a-doo.

Shane: [*laughs*] Yeah, exactly. But also, we can think of even more extreme temperatures, like hydrothermal vents in the deep sea, which can have temperature gradients that are hundreds of degrees Fahrenheit over a very short distance. The most heat-tolerant animals that we know of on this entire planet live around those hydrothermal vents. I'm sure you've seen these really large tubeworms that make these, sort of, tube forests around hydrothermal vents? They can take temperatures up to about 80° Celsius.

Alie: How many Fahrenheits?

Shane: Which is… [*drumroll*] like, 176° Fahrenheit.

Alie: Oh my god! That's so hot. [*Nicole Richie, "That's hot."*]

Shane: It's really hot. But they're not the most heat-tolerant organisms on the planet.

Alie: Which ones are?

Shane: There are these small microorganisms, they're called *Pyrolobus fumarii*.

Alie: Oh my god, wait, okay, so something with smoke and fire?

Shane: Yes, exactly. I think still to this day, they are the most heat-tolerant organisms that we have found, and they can take temperatures of 122°C.

Alie: Whaaaat?!

Shane: That's a little more than 250°F.

Alie: Where do they live?

Shane: They also live around hydrothermal vents.

Alie: Oh my god.

Aside: PS: Their name translates literally to, 'fire lobe of the chimney'. I pictured a tiny fireball or maybe a deep blue shiny creature with flames painted on the side of it, like a late 1980s Camaro, but these single-celled heat-lovin' microorganisms kinda look like a fuzzy brain.

Hydrothermal vents: Hotter than… name a thing, it's probably hotter than that. Like, for example…

Alie: I was thinking the hottest place on earth would be a roller skate after you've used it. [*Shane laughs*] You know, sometimes you're like, "Ugh, it's hot and muggy in there." But no, it's a hydrothermal vent!

Shane: Yeah.

Alie: Oh my god! Okay, so they're just like, "I'm here, no one else can deal with it. But I can, so I can take as many resources as I need because I have adapted to just be able to deal with this."

Shane: Precisely! Extreme performance typically evolves under extreme conditions. I think one of the coolest ways animals use heat- every time I think about this, I kinda freak out a little bit. So, in order for me to tell you the story, I kinda have to give you the background.

Alie: Yeah! Bring it on!

Aside: Ohh, buckle up for a science saga you'll never forget, my friends!

Shane: In 1877, in Japan, people imported European honeybees for apiculture. There is a Japanese honeybee, but it does not produce nearly as much honey as a European honeybee. So they brought in European honeybees for apiculture, and they quickly found that European honeybee colonies would be destroyed by the Japanese giant hornet.

Alie: Oh, no!

Shane: It's a really large voracious hornet. A group of 30 hornets could wipe out thousands of European honeybees. I mean, they would just go in, and they're decapitating things and chewing 'em up because they're bringing those husks and bodies back to feed *their* larvae.

Alie: Oh my god!

Shane: They would just have these raiding parties where they go in and completely destroy these European honeybee colonies, which brought up the question: there's this Japanese honeybee that's been here for so long, how do they survive in the face of this predator?

Alie: Right!

Shane: What they found was fascinating.

Alie: Oh my god.

Shane: So the Japanese giant hornet has an upper thermal tolerance of about 115°F.

Alie: Okay. Ooh, that's still a lot.

Shane: It's a lot. The Japanese honeybee has an upper thermal tolerance of about 118°F. That difference in their thermal tolerance, the Japanese honeybees figured out how to use it as a weapon.

Alie: What?

Shane: Remember we were talking about before; bees have this ability to decouple their muscles from their wings in order to generate heat. So what they would do is they'd use their numbers, and when a Japanese giant hornet would come into the hive, they would sort of back off a ways and let it come into the hive, and then they would swarm it and form a ball around the hornet.

Alie: Nooooo!

Shane: And then they would start vibrating and generating heat, and they would essentially cook and kill the hornet.

Alie: Are you kidding me?! They would cook it?!

Shane: Yeah! It's this combination of the heat that's generated and the carbon dioxide that's produced. It would heat up the temperature, but the excess carbon dioxide would also lower the thermal tolerance of the hornet.

Alie: So it'd be like a one-two punch.

Shane: Exactly.

Alie: [*gasp*!] Oh my god. What about the European honeybees? Did they get wise to this?

Shane: No! Even now, if a Japanese hornet raiding party finds European honeybees, they can completely decimate a colony.

Alie: So that three degrees is enough to kill off something that's probably 10 times their size?

Shane: Yes.

Alie: Oh my god, that's sooo badass! Oh my god!

Shane: It's one of my favorite stories about thermophysiology. [*"Bring it onnnn!"*] These are the sorts of things that evolve in extreme environments. So yeah, it's crazy.

Alie: Why am I getting chills thinking about cooking hornets? That doesn't make any sense. That's so wrong!

Shane: Because it's dope!

Alie: [*laughter*] I know! But now, why am I cold?! Why does it give you chills? Okay, tell me a little bit about being a professor, because you are a professor.

Shane: I am.

Alie: You teach here at UCLA.

Shane: I do.

Alie: So what kinds of courses do you teach and what has the response been?

Shane: So, being a professor at UCLA is some kind of special. I really love being here. The thing is, when you're moving up through academia, there's always this veil, right? You kind of see other people moving back there, but you're not really sure what's going on back there.

As an undergraduate, you might see graduate students. You're like, "Oh, they look so stressed, I wonder what that's about." Then you become a graduate student and you're like, "Oh, that's what that was about." Then you see postdocs and they're like, [*sobbing*] "Oh my god, I'm never gonna get a job!" And you're like, "Why are they so stressed? They're postdocs!" Then you become a postdoc and you're like, "Oh yeah, this is really stressful." But then as a postdoc, [*laughs*] you see a professor and you're like, "How come their hair is always crazy and they can never remember anything?" Then you become a professor and you're like, "Oh yeah, because there are so many things that I had no idea people were going to ask me to do!"

Alie: Oh my god, what's it been like?

Shane: It's been fun and I've had to learn a lot really quickly. The biggest thing I've had to learn is how to multitask. I've actually very recently found out I have pretty severe ADD.

Alie: Really?

Shane: Yeah, really late in life, and I got through it because I could focus on one thing. I would wake up and my goal would be to accomplish this one thing, and regardless of how long it took, sometimes I go to bed at 10, sometimes I go to bed at 3am, but I could get that one thing done. I was a specialist, that's how I made my way through academia. Then I got here and I literally could not focus on one thing for more than, like, 45 minutes. Things really started to disintegrate for me really quickly. So I went and talked to a doctor and they ran some tests and they're like, "Yeah, this is really intense right now." [*laughs*]

Alie: Did that track for your past, too?

Shane: Oh yeah, looking back, I definitely see it now. It kind of makes me a little upset because I'm like, "How much easier could I have made life for myself if I had known about and could deal with this before?"

Alie: Yeah, I mean, you went to Harvard, you got a PhD, and you're a professor. So, speaking of adaptability, you must've found really great ways to adapt, to focus on what you need to focus, because you've accomplished *so* much.

Shane: I mean, I found a way to do it for sure, but here in this position, I've had to learn different ways of doing things and I've had to learn those ways pretty quickly.

Alie: Do you have any tips for the rest of us?

Shane: Oh, man. I think the thing that helps me the most is to make a concrete list the night before. That's the last thing I do before I close my eyes, and it's the first thing I see when I wake up. Not just, "Here are a list of things to do." Literally, from this time to this time I need to accomplish this goal because I have this meeting at this time, which means I only have this 45 minutes and it's best if I do this particular thing then. All the way through the day. Sometimes it doesn't work for me. Sometimes I sit down and things immediately fall apart. [*Alie laughs*] But the days where I can actually stick to that game plan are *by far* the most productive days for me.

Alie: That's so, so good to know. As someone who had to reschedule this because I was crying about missing a deadline, I'm like, "What else have ya got?!"

Shane: It happens to the best of us.

Aside: Shane is such a boss. I want all of his time management strategies forever. Please and thank you. Also, just listen to the name of this course he teaches at UCLA.

Shane: So, my first course here at UCLA is called, "The Biology of Superheroes: Exploring the Limits of Form and Function."

Aside: Let's hear that again, because it's that wonderful.

Shane: [*triumphant horn music in background*] So, my first course here at UCLA is called, "The Biology of Superheroes."

Alie: [*sings*] Aaaaah!

Shane: Yeah, it's been a really fun class and it's sort of been a slow build. I actually started thinking about this in graduate school as well. I got to a point when I was writing my dissertation where I was just burnt out. I was like, "I love science, but you can miss me with it right now because I can't stand this." [*Alie laughs*] I remember one night, I was in the Museum of Comparative Zoology at Harvard, that's where my office was. It was probably 8:30 or 9 at night, and I just had to get up and leave. I walked off of campus into Harvard Square. I was walking around the square and I passed this comic book store that was sort of in the basement of a building. As I was passing the window, I saw this large hardbound comic book, *Superman vs. Muhammad Ali*.

Alie: Oh! They made a comic book about that?

Shane: Oh yeah, they made a comic book about it. It was literally one of those double-take situations like, "I'm sorry, what??" Right on the cover was Superman and Muhammad Ali, both in their boxing gloves, in the middle of a ring, going at it. I was like, "I have to figure out who wins in this scenario." So I went in and that was the very first comic book I ever bought.

Alie: How old were you?

Shane: I was 26, I think.

Alie: So it skipped your childhood and you started getting into it in your 20s.

Shane: Yeah, I was late to the game.

Alie: That's so cool.

Shane: I had always been into science fiction and I remember watching the *X-Men* TV show as a kid and the *Spiderman* TV show on FOX Kids. But yeah, my first comic book I bought what, 5 years into my PhD?

Alie: Oh my god! So did you go back for more after you read that?

Shane: Oh my goodness, yeah! I unlocked the beast. [*Alie laughs*] I went back and I bought several over the next few weeks, and it ended up being sort of a guilty pleasure. It was funny because I would spend hours during the day reading the scientific literature, trying to figure out how to formulate my own dissertation, and then I would go home and read *Green Lantern* or the *X-Men* as a way to escape from the rigors of academia. Then when I would go to sleep, I'd have these really weird, messed-up dreams that would fuse the two together, and all these questions of how the physiology and biology dealt with the science fiction.

It got so intense that I actually decided to teach a short course as a graduate student for two weeks to this small group of undergraduates. We just explored all these different questions like where the science meets the fiction, [*"Science fiction, right?"*] and that turned into this course. I also started my own podcast that deals with the biology of superheroes. I found that it's actually a really fun thought experiment.

In science, there's these thought experiments, like Schrödinger's cat, that really it's an abstract way to help you understand concrete ideas. I found that science fiction actually is a really interesting thought experiment to understand the limits of performance and where those limits stop and why they stop where they stop. Then theoretically what would need to be accomplished in order for those limits to be pushed beyond. So yeah, that's what we do in the class. That's what we try to do in the podcast.

Alie: How quickly did that course fill up?

Shane: Almost immediately. [*laughter*]

Alie: That's also perfect for Los Angeles, too, this hub of academia and art on the same campus. So, which superheroes could withstand the most extreme temperatures?

Shane: Obviously, you have characters like The Human Torch, for instance.

Alie: Well, there you go.

Shane: I mean that's pretty spot on. [*clip from Brooklyn Nine-Nine: "I'm a human torch!"*] Also, Ghost Rider with his flaming skull. [*clip from Ghost Rider: "You are the rider. The Ghost Rider!"*]

But you also have other characters that just generally have high endurance, like Wolverine, for instance. [*clip from X-Men Origins: Wolverine: William Stryker, "I can give you the tools to defeat him!"*] This adamantium skeleton of his, plus his general ability to regenerate. I imagine he'd be able to take some pretty hot temperatures. If I'm not mistaken, I think the Incredible Hulk has been thrown into the sun at least once [*Alie laughs*] and survived. [*clip from Thor: Ragnarok: The Incredible Hulk, "Raging fire."*]

Alie: [*laughs*] What kind of adaptation would you need skin and organ-wise to even deal with that?

Shane: I don't think there is an adaptation that would allow for any organism to do it. So, even if we think about early Earth, for instance. Earth itself is 4.5 billion years old, more or less, and it took half a billion years for life to even show up in the first place. A big part of that was because that epoch before - the Hadean, which is literally Hell on Earth - it was really, really hot. You're talking about surface temperatures that are approaching 600°.

Alie: Oh my god.

Shane: So, life had to kind of wait for things to cool down before it even had a chance to proliferate.

Alie: The Hadean. I didn't realize that's what that was called. It's just hell , literal hell on Earth. Just too damn hot. [*Shane laughs*] "Call me when you've cooled off. I'm not coming out of the primordial soup."

Shane: Exactly.

Alie: Oh my god. Now, what about climate [*singing*] chaaaange? How are we doooing?

Shane: Yeah, climate change, man. This is actually one of the major aspects of my research now, is trying to understand how thermophysiology evolves in response to these rapid changes.

Typically, when we think about evolution, we think about it as this kind of slow, gradual process, especially when it comes to complex traits.

Aside: Shane says that, for example, coat color is controlled by a couple of genes. Relatively simple, but a lot of the aspects of form and functions that he studies are, in his words, "the byproduct of the interaction of hundreds of genes that interact in these complex, regulatory networks," which means there's a lot of complicated shit happening to make an organism efficient and well adapted to its environment. So, you tinker with one part and, well...

Shane: There's a saying that there's a lot of ways to break a clock, right? So, if we think about an organism as a clock, tinkering with something, you're most likely going to break it. So, trying to understand how these complex systems can actually adaptively evolve in the face of rapid change is one of the major research goals that I'm pursuing right now in my lab.

Alie: How do you think humans will do with it? I mean, I wanna say, "Who cares about us? Because it's our fault," but for the other humans out there...

Shane: The thing about humans that makes us special is that we have this remarkable ability to buffer ourselves against extremes. So, if it gets too hot outside, we turn on the air conditioner. If it gets too cold, we turn on the heater or put on a coat and we're perfectly fine. [*clip from Groundhog Day: Phil Connors, "Bundle up warm, of course, but I think you can leave your galoshes at home."*]

When thinking about climate change in that framework, as our technology develops as environments get more extreme, technically, we'll have the ability to buffer ourselves against it. But, in reality, we have to think about how those resources are partitioned, and so on and so forth. If we think about the recent polar vortex that passed through the Midwest, homeless populations in Chicago are not buffering themselves against that sort of extreme.

Here in Los Angeles, if you think about things like urban heat island effect, especially in the middle of the city, in the middle of the summer, where you can have temperatures approach 100°, maybe even more. I mean, those are populations that can't buffer themselves against those sorts of extremes. Even the political situation now, all the debate going on about building the border wall, one of the things that we forget are the biological consequences of these political actions. "Prevention by deterrence," is typically what it's called. This is Clinton-era border protection philosophy.

But essentially what that means is that you're intentionally funneling human beings out into the most extreme thermal climates on the planet, into deserts. So, the Arizona Desert, the Sonoran, the Chihuahuan deserts, these are really extreme environments, both in terms of temperature and in terms of water availability. One of the ways that we as mammals cool ourselves is through what we call evapotranspiration – sweating. Sweat gets wicked away and it cools us, but that costs us water. And if you're trying to make your way through a place that's really hot and you don't have any water, it makes for this sort of double jeopardy.

One of the most recent projects that I picked up with some collaborators of mine at University of Idaho and another lab who will soon be here at UCLA is actually doing physiological modeling of energy expenditure of undocumented migrants trying to cross the desert, trying to understand exactly how stressful this is and how much energy is needed to perform these sort of extreme migration events.

Aside: Shane says that this research he's doing is one of the more unique applications of thermophysiology that he's attempted to undertake in his career, and that a border between, say, Mexico and the US, is a corridor for many species to move and that migration is extremely important.

Shane: It's one thing to think about this in evolutionary terms, but one thing that we know about evolution - evolution by natural selection - is that it comes at a cost, and that cost is death. If you think about surviving these sort of extreme migration events in terms of humans, I'd like to think that we've gotten to a point as a contemporary society where human life is paramount. If human life is paramount, then this idea of evolution by natural selection doesn't really apply because the cost of that evolution *should be* too high.

Alie: Exactly. Is there anything anyone can do to assist that? I've seen pictures of people pouring water out in the desert. Is there anything a layperson could do?

Shane: Hmm. Vote?

Alie: Yeah. [*sighs*]

Shane: I mean honestly, I think that's the most important tool any of us has when we're talking about making this level of change.

Aside: So yes, *vooote*. Vote, vote, vote, vote! Shoot, I forgot to ask him about those little moss piglet water bears that are more tough than all the Harley riding, leather clad, tattooed dudes combined. Sorry dudes. Tardigrades kick your ass.

Shane: How do tardigrades survive? I actually do not know. They are extremophiles and I do know *what* they can survive, which is crazy.

Alie: What can they survive?

Shane: They can survive temperatures near absolute zero.

Alie: [*high pitched voice*] Hoooooow?

Shane: Through extreme desiccation. They can stay desiccated for a very long time. They can survive the vacuum of space. They're found naturally all the way from in hot springs to the top of the Himalayas. They can survive extreme UV radiation exposure. They're nature's badass.

Alie: Are they Martians?

Shane: They might be! [*laughs*]

Alie: That'd be great.

Shane: Phylogenetically speaking, we know they nest within life on Earth, but I like to think that they could be Martians if we put them there.

Alie: [*laughs*] That's true, I'm sure they'd be like, "I LOVE IT!" They'd be fine! I feel like they're the kind of person you could take to any party and they'll make friends. You know what I mean?

Shane: Oh yeah, definitely.

Alie: "Here's my cousin, Tardigrade, he's fine. Oh! You already made a friend? Okay, cool."

Shane: "Hang out by the hydrothermal vent? Yeah, do your thing. Imma go over here to the Himalayas real quick to hang out. I'll be right back."

Alie: I love it. So adaptable!

Lightning round, are you ready?

Shane: Ooh, lightning round. Let's do it.

Alie: Okay, here's the deal. Number one: laser printers, so much more effective than an inkjet. I got a laser printer, which is helpful because this was 22 pages of questions for you.

Shane: You have a bible worth of questions right now. It's like, full New and Old Testament.

Aside: Okay, so on to Patreon questions. But before those, I do share a few words from our sponsors. Also, a portion of the ad revenue goes to a cause of the Ologist's choosing.

This week, Shane picked the Environmental Defense Fund, which is a non-profit that tackles urgent threats with practical solutions. So thanks, Shane, for choosing that. That's the Environmental Defense Fund. Now, usually I call a few listeners, but I just found out I'm supposed to do fresh recordings per episode. I spent a few hours doing each one, so instead, I'm just gonna tell you about some stuff I've been using by companies that I like that support *Ologies*. But, BFF tier Patrons, don't worry. I've still randomly been calling you just to chat and leave you weird voicemails. They're just not ads. Just saying hi. Alright, your questions!

Okay, some ads, in which I've hidden some weird factoids.

[*Ad Break*]

All right, your questions.

Alie: So many people asked the same questions and I'm just gonna read through their names because I kind of categorized them. Okay, Megan Younce, Sarah Clark, Anna Thompson, and Ashley Kelly all kind of want to know: Can people have different set body temperatures or is it total BS when someone says that they run hot and someone else runs cold?

Shane: No, there is variation in average body temperatures.

Alie: Oh! So, when we say a human being should be 98.6°, that means that just like any bell curve, that's the top of the bell curve.

Shane: Yeah, I think most humans typically fluctuate between 97° and 98.5° or 99°.

Alie: Okay! Alright! I always think thermometers are broken because mine show that I'm just a corpse. Am I dead? Did I die?

Shane: No, no, there's variations. Also, there are all sorts of different things that can influence what we call thermogenesis, how much heat you're producing. When we get sick, we get fevers, and that obviously elevates our body temperature. But conditions like anemia or other situations can actually lead to depressed thermogenesis because you can have a depressed metabolic rate.

Alie: Oh! That leads me to a question by a few different listeners. Areologist, who studies Mars, who was on this show, Jennifer Buz, and Suki Hawley both want to know: What's the point of fevers?

Shane: Oh, what's the point of fevers?

Alie: Why do we get 'em?

Shane: The point of fevers is more or less the same point of the Japanese bee heat balls. We have things that are attacking our body, and by generating a fever we're hedge betting that we are more heat tolerant than the things that are invading our body.

Alie: So, if you have a fever you should keep it up?

Shane: No, not necessarily. First of all, you should see a doctor is what you *should* do. Not a PhD. You should see a medical doctor, not a thermophysiologist.

Alie: Do not just tweet at Shane.

Shane: No, don't tweet at me, go see a doctor. I don't have anything for you over here. Don't @ me. [*laughter*]

Alie: But that's why you're getting it. It's just cooking the bugs.

Shane: Yeah, but at the same time, if you maintain a fever for a really long time, it can actually have extremely detrimental effects.

Alie: You cook your own brain.

Shane: Yes, precisely. And cells, generally speaking.

Alie: Ooooh. Don't poach yourself. Okay.

Shane: Don't do that.

Alie: But at least you know why it happens. A few people had a question about their partners having different heat tolerances than them. Bethany G. says: Why are women so much colder in office buildings than men? Generally speaking. [*laughs*] Cassy Flint asked the same question: Disclaimer – sorry for the sweeping gender generalization, but why do men seem to be walking heaters? Kelli Meeker also asked this. So did Anna Thompson.

Shane: If I had to make a guess at this, I would say it has to do with body size. On average, men have a tendency to be larger than women – sexual size dimorphism. What that means is that they have more volume-to-surface area, which then means that they can retain heat more efficiently than smaller-bodied individuals. Of course, this is regardless of gender. It's just a property of size, but because there are different distributions of size for men and women, on average it can create that shift.

Alie: So, tinier people are not just bigger whiners. They're actually colder.

Shane: Yes.

Alie: So, listen to us! Sometimes if you're short and cold…

Shane: They physiologically have to work harder to keep their heat.

Alie: Yes, because as a person who's shorter and has been freezing and worn fingerless gloves in an office building *in August*, [*Shane laughs*] I understand that very much. Erica Smith, Margaret Ebacher-Rini, Bob White, and Christine Thompson all kind of wanna know: Does genealogy play any part in our preferences for hold or cold weather?

Shane: Hmmm. That's actually a complicated question because genealogy has both a genetic and a cultural component. I think the answer in either case can be yes. Thermogenesis or thermal preferences, just like any trait, can have a distribution. Very few traits are fixed where every individual has the exact same value. There's typically a distribution, a bell curve. These sorts of things can be heritable. I spent most of my life studying lizards. We know that thermal tolerance and also thermal preference changes between species and even between populations. That is a function of genealogy. There's no reason to think that we would behave any differently.

Alie: It's interesting though, if you live in a climate you hate and you hate where you live, go to a climate you like. If you have kids, chances are they'll dig the climate too. You know what I mean? You love Florida? Go have some babies in Florida! They're gonna be like, "I love this, Mom!" You're like, "I know, right?" Or maybe they'll hate it.

Shane: "It's the best. Thanks, Mom!"

Alie: "Thanks, Mom!" My whole family is still in California and I feel like if you took anyone in my family and put us in Boston, we would just be like, "Noooooo!" Just no. Could not deal.

Okay. Many people have this question, including the wonderful Skype a Scientist, Todd McLaren, Joyclyn Vincent, Ivey Crutchfield, Chris Hubbard, Alina Pritchett, Jamie Cattanach, Jessie Cole, Charity, Abbey Harrison, and Kitti Halverson all had the same question: Why do I turn into a human furnace when I sleep? Why can't we regulate our body temperature when we sleep? Why do we wake up or stick a foot out? When animals sleep, what happens with their body temperature?

Shane: I actually don't know if I know the answer to this question.

Alie: Neither do I!

Shane: Yeah, because I also get super sweaty in the middle of the night. It's kind of absurd.

Alie: [*laughs*] Sleeping on a huge kitchen sponge.

Shane: [*laughs*] Yeah, basically.

Alie: Man-sized kitchen sponge!

Shane: That's a special kind of nasty right there.

Alie: [*laughs*] But I talked to the sleep expert, the somnologist, and he said that we sleep better in colder temperatures and it might be because we just evolved to be out of doors more. So, we know that when the temperature dips we sleep better, but a lot of times we have fitful sleep if you're sleeping in too hot of a room which, guilty as charged. I'll look into it.

Shane: I think insulation might play a role because people still like to sleep with blankets, just as sort of a comfort thing. But that adds a lot of insulation.

Alie: That's a good point. Even in the summer, if I don't even have a light sheet on me I'm like, "I need a cover of some sort. I need a wisp of gauze over me!"

Shane: Even that thin layer creates a pocket of your people air. It's like you're basking in your own juices, so to speak.

Alie: Your 'Hooman cloud,' if you will.

Aside: So, side note, if your temperature feels all wonky, you can thank your glands. The hypothalamus acts as a thermostat. It helps your body adjust to whatever your heat needs are. Typically when you're asleep your temperature drops to its lowest point a few hours before you wake up, which kind of keeps you comfortably snoozing. Now if you're sweating a bunch, it could be hormonal changes that are messing with your hypothalamus, or a sudden plummet in blood sugar if you kinda went a little hard on the desserts. Also, if you're always freezing and you feel tired and sluggish, you may wanna have your own one-on-one *Ologies* episode with an endocrinologist to chat about thyroid levels. Another symptom of that: having freezing hands and feet. Which I know for a fact, some of you do.

Alie: A lot of people had questions about extremities and parts of the body like Joyclyn Vincent, Marisa Brewer, Mariko Shinn, Meag, Megan Younce, Heather Hutchison, Radha Vakharia, Heather Wills, Asriel King, and Moritz Latuske all kind of asked: Why are feet freezing while the rest of our body is warm? Why are our hands cold? What is happening with different parts of bodies?

Shane: This phenomenon is called regional heterothermy.

Alie: Ooh! These are great terms!

Shane: Thermophysiology has some awesome terms. I do like that part about being a thermophysiologist. Essentially what happens is, your body has priorities and your core is the top priority. If you're in a cold environment and you need to preserve heat, one of the first things that your body does is it shunts blood away from your extremities in order to preserve it at your core, because the same thing would happen as I talked about with the elephants. As they pump blood out it cools and then it returns but if you're in a cold environment and you're pumping blood to your extremities and it cools and comes back, then your internal body temperature begins to plummet much quicker. So, your feet get cold and your hands get cold so that your heart, and lungs, and liver, and all that good stuff can stay warm.

Alie: Because we gotta keep all those organs pumping, but we can lose a hand, we'll be fine, right?

Shane: Yeah, but at the same time, you notice that if you're out in the cold, your head is always steaming even though it's technically an extremity. That's because that's where the money maker is – the brain. [*cash register ding*]

Alie: Do we lose a lot of heat from our heads?

Shane: Yes.

Alie: Oh my god, okay. Let me find who asked this again. Claudius and others asked: I've heard it's an urban myth that we lose most of our body heat in your head. Time to have an expert be the judge, they say.

Shane: It's not an urban legend for multiple reasons. One, because technically when we wear clothes, our head is least likely to be covered. So just as a product, we would lose most of the heat by way of our head because the rest of us is insulated.

Aside: This is another great time to *not* imagine your friend's grandpa walking around in a ski hat and no pants.

Shane: The other thing is that this regional heterothermy doesn't really apply to your head because your body will do pretty much anything to keep your brain functioning. You'll continue to pump blood to your head, which means you're continually supplying warmth to your entire head, your face, except for like your lips and all the cartilaginous places. In the cold, your lips and nose and ears get really...

Alie: Purple?

Shane: Yeah, exactly. Well, they get purple on *you*. Not so much on *me* because of the melanin. [*laughs*]

Aside: I drink one iced tea and I'm Rose floating on wreckage. I'm Jack Nicholson in a dead-end hedge maze. [*clip from Titanic: Rose Dawson, "Jack. There's a boat. Jack!"*]

Alie: So many people, Cara Fiacco, Todd McLaren, Michael Peskura, Joshua Kuhn, Aleina Tanabe, and Katie Boyd all wanna know about acclimation: Over time does the body adapt to climate?

As a person who lives in Southern California that gets very cold everywhere else, and as you've just moved here, just wait 'til it happens to you. [*Shane laughs*] You'll start getting weaker and weaker. Do we adapt that quickly?

Shane: Individuals can acclimate to temperatures. Again, I study this mostly in reptiles, but in reptiles and ectotherms, we call it, 'heat hardening'. Essentially, when you're exposed to a hot temperature for an extended period of time, you become more adept at functioning at high temperatures and vice versa. This is called acclimation or phenotypic plasticity. We have one genome that can produce multiple phenotypes depending on its interaction with the environment.

Alie: Oh, really? So, you can kinda switch off what you need?

Shane: Yeah, so for instance if you or I were to go up to high altitude, our bodies would physiologically change. We'd begin to produce more red blood cells, what we call erythropoiesis. It's the same genome. Genetically we haven't changed, but the way that our body is sensing the environment induces a change. The same is true in response to temperature.

Alie: Oh my god. That's crazy! I didn't realize that! So, I *am* getting weaker by living in Southern California.

Shane: Probably. [*laughs*]

Alie: It's 100% for sure. I go anywhere else and I'm like, "Eeewwww*."* Mac, Armando Trujillo, and Mae Merrill all kinda asked about adipose tissue. Mac asked: How significant is the activation of brown/beige adipocyte thermogenesis as far as raising total body temperature is concerned? Then, Armando and Mae both said that they recently lost a lot of weight and they're constantly cold. Does weighing less affect body heat?

Shane: Weighing less does affect body heat, again, because of this volume-to-surface area. But also, fat, generally speaking, does also act as an insulator. A lot of mammals that occur in polar climates – things like polar bears, walruses, seals that can live in really cold waters - they all have blubber, which is fat.

Alie: They're so cute! They're little chunks!

Shane: Yeah, more cushion for the pushin'! [*clip from Spinal Tap, Big Bottom: "The bigger the cushion, the sweeter the pushin'."*]

Alie: [*laughter*] Arctic chonks! The cutest! They are scientifically cuter.

Shane: Scientifically speaking.

Alie: Yeah, I'm just sayin' an arctic chubbalubber is gonna be cuter than a seal with a six-pack.

Shane: Chubby things do have a tendency to be cute.

Alie: They're so cute! But if you've lost a lot of weight, you might be a little cold. Get a sweater. One of them asked: Is there any way to alleviate that without gaining the weight back, lol? I think, Armando, just get a sweater. Get a hoodie. You deserve it.

Shane: This ability to buffer ourselves is one of the reasons why we're still here. It's called the Bogert Effect.

Alie: The Bogert Effect?

Shane: Yeah, this ability to thermally buffer yourself.

Alie: That means get a sweater. [*laughs*] There should be a Bogert sweater company. A Bogert sweater mercantile. Sam F wants to know: Okay, frogs (or are they toads?) that basically suspend all their bodily functions and to the external observer appear dead to deal with cold and then when you thaw them out, they're just alive all of a sudden. What the hell is up with that? How do we get that?

Shane: Yeah, those are the wood frogs.

Alie: Those are the wood frogs!

Shane: Those are the wood frogs.

Alie: There you go, Sam!

Aside: So, yes, those are the froggers with the antifreeze blood. I was actually able to track down audio of their mating call, which is really cool. Sounds like this: [*clip from Frozen: Elsa, "The cold never bothered me anyway."*] JK, it's actually this: [*three rapid, clicky chirp sounds*]

Also, I'm sorry but I had to share an important life experience with Shane because he's a professional in the matter.

Alie: I'll tell you a quick story. My dad is from Montana. Love Montana. I had a hamster and for some reason the hamster was outside and it got very cold and I woke up and the hamster was frozen solid.

Shane: Ohhhh….

Alie: Like a chicken cutlet. And my Dad was like, "Don't worry, rodents like this, they do this and they hibernate. I'm from Montana. Come on." I was like, "Really?" He's like, "Yeah, they just warm up." I was like, "Okay." I got back from school and my hamster, Bacon, was fine and I was like, "Oh my god, that is crazy that rodents can do that!" Anyway, cut to 20 years later at Thanksgiving when I mentioned it and my dad is like, "Ohhh..." He had gone out on his lunch break and just gotten a new hamster! [*laughs*]

Shane: I was hoping that I didn't have to break that to you here, on this microphone. [*laughs*]

Alie: Two decades! I was like, "Bacon bounced back!" My dad just went out on his lunch break!

Shane: And he lived for 47 years! Best hamster ever!

Alie: His spots kept changing. They do that!

Shane: It's an acclimation effect!

Alie: I know! His face though, when I looked over and I was like, "Oh no!"

Okay, cryogenics. Sonya Karlepovic [phonetic] and Asriel King want to know: Is cryogenic freezing in any way realistic or possible?

Shane: It depends on what you mean. In terms of Walt Disney-style cryogenics…

Aside: Side note, a few of Walt Disney's biographers say he was keenly interested in the future, see Tomorrowland, and that he knew about cryogenics. But Disney's daughter denies that he is in suspended animation awaiting a thaw. Also, his cremation report is on file. But hear me out – that could've been for his body without his money maker. Know what I'm saying? But Walt, either way, I trust you did whatever it was that you wanted to do. Also, I will never think of the show *Disney on Ice* quite the same.

Shane: I'm always reluctant to say anything is impossible, but it's highly improbable. If you're talking about cryogenic freezing, this is actually a really active area of research when it comes to things like organ transplants and extending the longevity of transplants and how long they can survive outside of the body. Actually, a lot of this work is being done on animals like the wood frog. If you have an animal that is able to do this for an extended period of time and have properly functioning organs, that's a good place to go to find solutions to being able to freeze an organ solid and then revive it and still have it be able to function.

I do think that is a possibility. Essentially, we just need to really know more about the physiology of this process and how it plays out in nature. But, in terms of freezing heads and reviving people – improbable, I will say. Highly improbable.

Alie: But I mean – most questions I've ever had. 191 questions.

Shane: Wow! That's amazing. I feel special.

Alie: You *should* feel special! People were excited! Okay, what sucks the most about your job, or about your pursuit, or the cold, or the heat? What sucks the most about being a thermophysiologist?

Shane: Hmm... That is a good question. What sucks the most?

Alie: When people come to your office and ask you stupid questions for a podcast!

Shane: No, that's one of the best parts! Especially because a lot of the times I'm that person that's bothering the scientist about their work. [*laughs*] You get a lot less slack when you are also a scientist, I must say.

Aside: Again, he, a scientist, interviews other scientists for his incredible podcast, *The Biology of Superheroes*. Okay. So, what sucks?

Shane: Two things: one is the sort of mundane everyday stuff. I have yet to meet the biologist where you ask them, "Why did you get into biology?" And they're like, "Man, I just love answering emails, and typing up memos, and responding to administrative stuff. Mm! That's just the best!" No one says that. But that has become such a huge part of my life. Not the best.

As a thermophysiologist, you have to put yourself under some extreme thermal conditions as well. I spend summers driving around the South. In Florida and the southern tip of Texas, Louisiana, it gets really hot and really muggy in the heat of the day. But if the lizards are out doing their thing, you gotta be out there doing *your* thing, and sometimes it's just a miserable existence. Every once in a while I will take my research team to just go see a movie in an air-conditioned movie theatre right at the heat of the day when it's even too hot for the lizards.

Alie: Are you teaching them about Bogert's effect?

Shane: The Bogert effect. [*laughs*] Yeah, exactly. We call it a lesson.

Alie: "We're going to experience a 62° movie theatre right now." Is it worse when it's muggy because your sweat can't evaporate as much?

Shane: Yeah, evapotranspiration is not efficient in really highly humid environments. That's why people who live in Tucson or other places in Arizona are like, "Oh yeah, it's 150 but it's a dry heat." I'm like, "What does a dry heat have to do with anything? It's still heat!" But in actuality, because it's so dry, evapotranspiration does help to more efficiently cool the body. I still think it's horrible though.

Alie: What is the best thing about being a thermophysiologist?

Shane: Oh my god. How much time do you have?

Alie: Lizaaaaaards.

Shane: Yeah. It's definitely the animals. Certainly, being a thermophysiologist - and I think this applies to pretty much any scientist - but the idea of waking up in the morning and you know that your day is going to be spent trying to answer questions that have never been answered before and may have never been asked before, there's just something so deeply satisfying about that. Obviously, being in the field, those WTF moments when you're going out and maybe it's super hot outside and you're kinda tired, and then you see something that you've never seen or thought about before and it just sparks something like, "WTF! What in the good hell was that?"

Just being there, putting yourself in that environment, it's a whole different frame of mind. We spend our entire lives making all kinds of decisions that don't have any real consequences in terms of life and death. So, to be able to go and put yourself in an environment and observe organisms where the decisions that they're making aren't, "Oh, what pair of Converses should I put on," but, "Do I move here or there? Do I do this or that?" That decision can literally be the difference between finding food and being food, and how that plays out in populations over time.

Being able to see this grand story of evolution played out on this thermo-hydric stage and how it's played out over millennia. Seeing all the different ways and all the different solutions that life has come up with to solve those problems. Darwin called this, "Endless forms most beautiful." Being able to partake in that process in such a tangible way as a scientist, it's the thing that really just drives me. Plus, the toys.

Alie: [*laughs*] What kind of toys do you have!?

Shane: Oh my god. Running lizards on racetracks. I'll take you up there. I just had these two beautiful, amazing environmental chambers built that allows us to manipulate temperature like, every half hour, and manipulate humidity. I call them the twins: Chuck D and Alfie.

Aside: Okay, so, side note: these environmental chambers he just got, Chuck D and Alfie, are named after Charles Darwin and Alfred Wallace, who are two naturalists who conceived the theory of evolution. If you haven't heard Evolutionary Biology yet, now would be a good time.

Alie: Are there lizards in them?

Shane: There are not lizards in them yet, but there will be lizards in them very soon.

Alie: Are you gonna have grad students manning the lizard chambers?

Shane: Yes. It's gonna be the best. I'm so excited!

Aside: Of course, being a professor isn't all he's working on.

Alie: And your podcast, which is amazing. It's just so good!

Shane: Oh, thank you. It is nerdgasmic. [*Alie laughs*] It's one of those guilty pleasures to be able to merge the nerd multiverse, bringing in the comic books and the science. It's awesome. It's been a lot of fun.

Alie: What episodes do you have coming up?

Shane: We *just* put out a *Star Trek* episode looking at evolution and genetics in *Star Trek*. We interviewed Dr. Mohamed Noor who is an evolutionary geneticist at Duke. The next episode will be about the Immortal Iron Fist, talking about the biology of a living weapon. I interview someone who studies biomechanics. She studies this amazing, amazing creature, the mantis shrimp. Its punch is one of the fastest motions recorded in the animal world. There's a lot of science, a lot of really cool stuff that we talk about there.

Alie: Oh my god, it's so good! I'm so excited! Thank you so much for letting me barge into your office with 22 pages of questions.

Shane: Oh my goodness! I love you and your bible full of questions.

Alie: Thank you so much for doing this!

Shane: Of course! This is a lot of fun.

So, ask the smartest people your stupidest questions because all of that smartness only makes the world better. To find Dr. Shane Campbell-Staton, go listen to *The Biology of Superheroes* right now. Go do that. On Twitter that's @SuperBioPodcast and he's @SCampbellStaton on Twitter as well. I'll link those in the show notes.

More links are always up at AlieWard.com/Ologies. *Ologies* is @Ologies on Twitter and Instagram. I'm @AlieWard on both. Thank you to everyone on Patreon.com/Ologies for supporting this show. I couldn't make it without you. For everyone getting merch at OlogiesMerch.com. Thank you, Shannon Feltus and Boni Dutch, for managing that. Thank you, Erin Talbert and Hannah Lipow, Esq., for managing the Facebook Ologies Podcast group. Thank you to interns Haeri Kim and Caleb Patton for the extra research help this week.

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Now, at the end of each episode I tell you a secret and this week's secret is: I was supposed to fly somewhere *today* but all of the flights got canceled because it was snowing. Now I'm sad I missed the trip. I was also like, "Yesss. That sounded very cold anyway." Also, I fell asleep working and I still technically am in yesterday's clothes because I gotta get this episode up but I'm fine. I'm gonna be fine. There's no one here to smell me so what's the problem? Okay, stay warm!

Berbye.

Transcribed by:

Mara Spensieri, Toronto, Ontario

Florence Yuan, your old-soul medical student friend who is happy to proofread your writing as her own weird form of procrastination!

Edits by Mike Melchior

Some links which may be of use:

Dr. Campbell-Staton: coolest professor ever?

This week's donation was made to the Environmental Defense Fund

OKAY SYRACUSE, YES YOU ARE THE SNOWIEST

LIZARD STORMS

Poy-kee-loh-therm

The cutest matrix on the Earths

Pyrolobis fumeri: get a gander

Disney …on ice?

You're Never Too Old, intern Caleb Patton's podcast

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