Quantum Ontology with Dr. Adam Becker
Ologies Podcast
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Oh, hey. It's your old internet uncle, Dad Ward von Podcast, here with another episode of *Ologies*, Alie Ward. Hi. So, do you remember your first real existential crisis? Also, if you clicked on this and don't know jack or shit about quantum physics, you're in the right place! You're in good company.

Okay, before we spiral into deep, deep space and dark matter, let's shine a little light on some business. So, first off, thank you to everyone on Patreon.com/Ologies for supporting the show, sending in your questions. Thanks to everyone strutting about on planet Earth in *Ologies* merch from OlogiesMerch.com. Also, getting a gift? Getting something for yourself? We're having a sale this week from the Friday after Thanksgiving through Cyber Monday. 15% off anything and everything at OlogiesMerch.com. Use the code BLACKFRIDAY2019. Again, OlogiesMerch.com, code BLACKFRIDAY2019. Shannon and Boni put up some wintry new stuff for y'all. Go to town. Get a deal. It's there for you.

Also, thanks to everyone who rates, and subscribes, and especially reviews this show. You know that I peruse the reviews, and I pick a new one to read to you each week, such as, from irritated.eb:

> *One time, I was hiking while listening to the Ferroequinology episode, when I passed a lady riding a non-iron horse, and they were both listening* - I guess the lady and the horse - *to the same episode on a speaker. I yelled "Ologies!" and the lady fist-bumped me, and it was magic. The end.*

To irritated.eb and all of the horses listening to Ologies right now: Hot damn. Thank you so much.

Okay. Quantum ontology. So many syllables. What do they mean? 'Quantum', in terms of physics, deals with matter and energy at its most fundamental level, and 'quantum' comes from the Latin, meaning [*shouting a bit*] "How much? How far? How great an extent?" Already so many questions just to the definition of this.

Also, 'ontology' comes from the root 'ont-' meaning 'being', and it is the branch of metaphysics dealing with the nature of being. So quantum ontology: matter, what the hell is it? What are we made of? What is real?

Just tuck a bib under your brain, kiddos, 'cause this week's episode is just a hearty feast of information. It's dense. It's like a bucket of mashed potatoes. And it's filling, like drinking a pint of gravy. It's gonna make you question everything about life itself. [*distorted high-pitched alien voice*] What is reality? What exists? Why are we here?

But first, will we cover everything about this topic? Hell no. Will we have to leave out a bunch? Hell yes. Consider this, like, a warm welcome, an entrée into some of the basic concepts about the hiccups in observing and understanding existence.

So, this Ologist has a B.A. in philosophy and in physics from Cornell, and a PhD in astrophysics from the University of Michigan, is a celebrated science writer, and the author of the new book, *What is Real? The Unfinished Quest for the Meaning of Quantum Physics*, which, by the way, the *Wall Street Journal* calls "Fascinating," *The New York Times* calls a "thorough, illuminating exploration of the

most consequential controversy raging in modern science." "Splendid," says *The Washington Post*. *Science Magazine* calls it "riveting." So the book? It's good.

I met this Ologist about four years ago at SciCommCamp, and he handed me his business card, which read, 'Freelance Astrophysicist'. I was like, "I like this guy." And then the next year, he mentioned he was pitching a book, and then the following year, he said he had a book deal and was writing it, and now here we are! His book, it recounts a lot of the drama in the quantum physics worlds. Boy howdy, is there some. Not only are you gonna walk away with an exciting overview of what the hell the universe may be all about, but you'll also hear about some academic infighting and why it's exciting that there are so many mysteries in the universe. So, in between seminars and panels at SciCommCamp, we pulled up a couch, we got to talkin'.

Settle in for philosophical physics funtimes wherein we discuss what matter is made of, and how many universes there could be, and why what we think we know just does *not* add up. And how someone could say you're wrong, but maybe you're righter than everyone realizes. And also how an inbox can be a lot like a crackpot. And how to tackle your dreams when they seem too big to fathom, and Einstein, and string theory, and gravity, and tunneling, and wormholes, and cats, and more, with Astrophysicist, author, and Quantum Ontologist, Dr. Adam Becker.

Dr. Adam Becker: Okay. Hi. How's this?

Alie Ward: It's great. You have a good radio voice.

Adam: Thank you.

Alie: Let's go back in time, if you will.

Adam: Yeah, okay. Sure.

Alie: Would it be a wormhole that I could go back in time to ask you about your childhood?

Adam: [*laughs*] I guess you could, sure. Why not?

Alie: Would a wormhole do it or is it a different type of tunnel into time?

Adam: I mean, there's no known way that would definitely work to go back in time. But wormholes are one of the, you know, better theories about how you could maybe do it.

Alie: Okay. So let's go through a... wormhole. [*ba-dum-TSH!*] Now going back, did you always like physics, astrophysics? How do you, how does someone decide that they're into something so complex?

Adam: Oh, wow. Uh, that's a good question. So, yeah, see I didn't think that I was going to sit on the couch and talk about my childhood,

Alie: [*cackles*] I'm gonna invoice you.

Adam: But here we are. Yeah, you trapped me. So, when I was a really little kid, like a lot of other kids, I wanted to be a paleontologist because dinosaurs are awesome. [*clip from The Mik Maks song: "I love dinosaurs!"*] And then, I discovered space and decided, "No, no, space is more awesome." And so I got really into space, and astronomy, and astrophysics, and then sort of slowly slid from astrophysics just to physics. By the time I was in high school, I thought, "Okay, yeah, I think physics is the direction I want to go in. This seems really

interesting." And I had read a lot of pop physics books and they said some confusing things. In particular, they talked about two theories that said really wild and the strange things about the world.

One of them was Einstein's relativity and the other one was quantum physics; really, really weird things in both of those theories. But it turns out relativity doesn't require more than, like, early high school math. You don't need calculus; you don't even need pre-calculus. It's just geometry and algebra. So I learned relativity in high school and I thought, "Oh, all that weird stuff seems a lot less weird now. I bet when I get to college and I learn quantum physics, that's going to seem less weird too." That is *not* what happened.

Alie: Oh no.

Adam: Yeah, no. So instead I got to college and I started learning quantum physics and it didn't get better. It got worse.

Alie: Oh no.

Adam: And so I was in this class where the professor was talking about one of the weird things in quantum physics. I don't remember exactly what because it was a long time ago, but he was saying something about how when you're not looking at things, you can't talk about what's going on, but then when you look, things change. And I probably asked something like, "Okay, but what do you mean by looking? What does that mean?" And we kinda got into it. And I don't remember exactly how the fight went down, but I just remember that at the end he said in this really haughty, disdainful voice, he said, [*with an affected snooty tone*] "Well, if *that's* the kind of question that *you're* interested in, then why don't you go to the philosophy department?"

Alie: Burn.

Adam: Yeah. But, joke was on him. I'd already gone to the philosophy department. And so I did a double major in physics and philosophy in undergrad.

Alie: Oh, god!

Adam: A lot of that was trying to wrap my head around, like, what the heck is going on in quantum physics? Because this is a really weird area, but it's also supposed to be this really fundamental theory about, you know, the fundamental constituents of the world, right? Like, the tiniest things. The things that the things that make us up are made of, right? Like subatomic particles. And yet it wasn't at all clear what was going on. And so I started digging into that, and the more I dug into it, the weirder it got. And I just did that more and more and eventually thought, you know, I want to write a book about this because this is just so strange and I don't understand why this isn't more widely known.

Alie: Am I gonna feel like I'm on mushrooms?

Adam: I mean, look at the cover of my book. It says, "What is real?" And it's got like, wavy rainbow lines.

Alie: Woahhh.

Adam: So, yeah, the answer is probably yes.

Alie: Okay. [*"Don't you feel funny?" "Why should I feel funny?"*] Well, let's go back first and define what is quantum ontology.

Adam: Yeah. So, quantum physics is the physics of the ultra-tiny, except that we think that ultra-tiny things make up the world around us. So although it's a physics of the ultra-tiny, there is also reason to think it's just the physics of everything. Ontology is the study of what there is, of what stuff is in the world. So quantum ontology is the study of, 'Okay, what does quantum physics tell us is in the world?" Or you know, the title of my book, right? What is real? And it is not clear what quantum physics tells us about the world. It's just not clear at all, even though it's not a new theory. It's been around for almost a hundred years.

Alie: Okay. Well, let's start with a theory of relativity.

Adam: Sure.

Alie: Which someone with high school math could understand.

Adam: Sure.

Alie: Can you give that to me in, like, a nutshell?

Adam: ... Sure.

Aside: He sounds unsure, but that's okay.

Adam: Right. So here's one way of looking at what the theory of relativity tells us. So, we sort of think, from our everyday lives, that if I'm standing still or if I'm in a car going at, like, 20 miles an hour, there are some things that just don't change between those two situations. Like how fast my watch runs shouldn't change between those two situations. Or how far it is between my house and the movie theater down the street. That shouldn't change either. [*"You don't say?"*] It turns out though, that these things that we think of as not changing between those two situations. We call those things invariant because they don't vary. The invariance between those two situations aren't what we think they are.

Alie: Oh no.

Adam: It turns out that, actually, the rate that my watch runs at *does* change between those two situations, and the distance between my apartment and the movie theater down the street *does* change. There are things that don't change, but those things are not distances or time. They're a combination of space and time. Spacetime.

Alie: Okay. Is time the fourth dimension?

Adam: Sure, yeah. In relativity it is.

Alie: Okay. And now, quantum…

Adam: Yes.

Alie: Theory.

Adam: Yeah. Oh, you want me to do the same thing for quantum theory?

Alie: Just in a nutshell. [*Adam laughs*] Just let us know what we're working with.

Adam: Yeah. So, quantum theory says that there is something very, very unusual going on in the world of the very tiny.

Alie: [*high-pitched*] Really? Eek!

Adam: Yes. And we don't know what that is.

Alie: What's happening? [*Adam laughs*] Now, is this all about dark matter and it doesn't make sense that there's so much space between atoms…

Aside: Holy shit. I *just* realized writing this that Adam's name is Adam! Atom! What is life?

Also, real quick. The matter all around you, the stuff that makes up everything you see and touch and smell and lick, all that matter in the universe is 5% of what exists. And according to NASA, dark matter is something that we can calculate, but we can't see or detect. And it interacts with gravity but it doesn't emit or reflect light. Hence, it's dark. And it makes up about 27% of the universe. Something called dark energy makes up 68% of the universe. And we know it's strong, and it's getting stronger, but we don't get what it is. So, just know, the wisest minds alive don't know shit and it frustrates them enough to keep getting out of bed every morning just to figure it out.

Adam: Dark matter, sure. We don't really know what's going on there. We know it's around, but we don't know what it's made of. There is a lot of empty space inside of atoms, but that's not really what's going on here either. That's not why we don't understand this. What's going on instead is... [*sighs*] it is *hard* to understand the relationship between the mathematics of quantum physics and the world that we live in. The math works really well. We can use it to predict and explain all kinds of things. But it also doesn't really look like the world around us. And that's fine, you know, things can be weird. It's a big world. There's plenty of room for weirdness. [*"You're weird." "Thank you."*]

But there should be a story, even if it's a weird story, that quantum physics tells us about the world. And it needs to be a story that that makes internal sense, even if it's a really, really weird story. Right? There's a difference between being bizarre and being internally contradictory.

Aside: So what he's saying is that the universe, kind of like a huge restaurant tab at a friend's birthday dinner, where no one has accounted for tax or tip or their three beverages. Things just don't add up and everyone is testy about it.

Adam: The weird thing is that the standard way of answering questions like, "What does quantum physics tell us about the world around us?" is to say, "Shut up, that's a stupid question." There's actually a saying in physics to summarize this attitude: shut up and calculate.

Alie: Oh, boy.

Adam: That was originally coined by the physicist David Mermin as, like, a pejorative, like he was describing an attitude that other people have.

Alie: Right.

Adam: No one actually should say that in earnest. But some people do. And yeah, it's completely fucking ridiculous.

Alie: Yeah. Well, where are these logic gaps? Like, I know that it's so bizarre and at least if you could understand the bizarreness... But what is it that's so contradictory? Like what do we think? What don't we get?

Adam: Yeah. So there's this thing in quantum physics, this sort of fundamental role that the idea of measurement plays. Say that I'm holding a pen. Say I want to describe where this pen is, you know, or where I'm going to find this pen using the physics that we had before quantum physics, like Isaac Newton's physics.

Aside: Newtonian physics is also called classical mechanics, and it deals with objects that aren't at a tiny, tiny scale, and how they move, and rest, and such. So, apples falling on our heads. Tossing your socks in the hamper from across the room. The inertia that causes you to spill hot tea on your crotch in the car. All of those things exist in space and behave in predictable ways.

Adam: I can do that with three numbers. I can say, okay, this pen is this height above the ground, and it's this far off to the right, and it's this far in front of me. That's three numbers. It's all I need. If I want to take all the information I have about where I'm going to find an electron or some subatomic particle in quantum physics, it's not going to require three numbers. It's going to require an infinity of numbers scattered across all of space. And this set of numbers is called a wave function.

And as the name implies, it kind of waves. It undulates smoothly, right? And that wavy motion is described by this very nice, pretty equation called the Schrodinger equation. And the Schrodinger equation kind of smells like a law of physics. It looks like a good candidate for a fundamental law of physics. And it says that wave functions, you know, they wave. They move smoothly and they move in a completely determined fashion. There's nothing random or probabilistic about it.

Aside: Okay, so when we zoooooom all the way into an atom, or the elements that make up an atom, instead of having three dimensions – X, Y, Z – we have an infinity of numbers to describe its location. And those infinity of numbers make up a wave. Got it? Look! We understand! Everything makes sense. We're pretty much quantum physicists now, all of us. Just kidding. But we can still celebrate it.

Adam: But the standard way of using quantum physics says, "Okay, wave functions obey the Schrodinger equation." Except when you look. When you actually look for the electron, the Schrodinger equation is 'temporarily suspended', at which point this entire other law of physics that is completely different and contradictory comes in. It's called the Born rule. [*clip from The Bourne Ultimatum: Jason Bourne, "This is Jason Bourne."*]

Aside: Okay, it's actually named for German mathematician and physicist Max Born, who helped develop quantum mechanics and was nominated for a Nobel Prize by Einstein himself. But most importantly, Max Born is the grandpa of *Grease*'s Olivia Newton-John. When I read that, I had chills. Like, multiplying. But yeah. The Born rule measures probability of a particle's position, and it came on the quantum scene in 1926.

Adam: And that says, "Oh yeah, that wave function that moves smoothly, it stops moving smoothly. It goes to zero everywhere except in the spot where you found the electron."

Alie: What?

Adam: Yeah. And so this leads to a couple of questions. First of all: that's weird.

Alie: Yeah.

Adam: Why does that happen?

Alie: I don't know.

Adam: Yeah. Weirdness, though, is fine. The real problem, the contradiction, right? The gap in logic is, "Okay, we have these two rules. They're not the same rule. When do we apply one and when do we apply the other?" Because we need to know that, because they're not the same rule. The usual answer is, "Oh, we use the Schrodinger equation when we're not looking, when we're not making a measurement [*Alie laughs*] and we use the Born rule when we do." The problem is that the idea of measurement is really, really fucking vague. Like, is it when I make a measurement? Does quantum mechanics only apply to me, Adam Becker? That can't be right, right? Does it work when a dog looks at an electron? Or do you need to be, like, better qualified?

Alie: This is bananas!

Adam: It's completely nuts. And the other thing is, like I said, electrons aren't the only things that have wave functions. This pen has a wave function. You have a wave function. I have a wave function. The universe has a wave function.

Aside: [*pretending to be Oprah*] You get a wave function, you get a wave function, you get a wave function! Quantum ontology. It's like the Oprah of the physics world.

Adam: Was the wave function of the universe just waiting for billions and billions of years for someone to come along and suddenly collapse it and, you know, have the Schrodinger equation not apply? It's just not clear when one equation applies and when another applies. There are people who would say that I am wrong about that. These are the same people who tell you to shut up and calculate. If you ask them, if you pin them down and try to ask them, "Okay, fine, Hot Shot. When do you use one and when do you use the other?" They're going to give you something that's either internally contradictory or that contradicts the idea that quantum physics is more fundamental than Newton's physics.

Alie: Okay. And now… Oy vey. There's a lot going on there.

Adam: There is a lot going on there, yeah.

Alie: And so, the notion of… do you remember Snuffleupagus from *Sesame Street*?

Adam: Of course I remember Snuffleupagus!

Alie: Is there a Snuffleupagus rule?

Adam: [*laughs heartily*] He's only there when people who aren't Big Bird aren't looking?

Alie: Yes.

Adam: Oh man! Big Bird is definitely not the prime observer of quantum mechanics. I can tell you that right now. Caroll Spinney does not have, like, special quantum power. [*clip from Sesame Street: Gordon, "Big Bird, Big Bird, Big Bird, it's all right, it's all right." Big Bird: "No, it's not."*]

Aside: Just a side note, Caroll Spinney is the actor and puppeteer who played Big Bird until his retirement last year. And also, did everyone else know his name and that he also voiced Oscar the Grouch, or do astrophysicists just have large brain-buckets full of trivia?

Where were we? Yes, okay. So the wave function that describes the place of a tiny particle collapses, to a point, when it's observed. This is wave function collapse. Does observing something make it exist differently?

Alie: Okay. So then what does that mean for us? Like, if I am a wave function until someone looks at me and then I'm not, what does that mean for ontology, for the science and the study of being? What is anyone?

Adam: Yeah. It means that there's something we don't understand here. It means that the story's clearly not complete. It means that shutting up and calculating is good practical advice if you want to, you know, calculate stuff. But it means it can't be the real story about the world. Like, it is good to ask these questions because there must be something else going on. So the problem then is: what *is* that story of the world? And the answer is we have multiple candidates for a possible story of the world, an interpretation of quantum physics. There are multiple interpretations running around. There isn't a consensus about which one is the right one.

Aside: Okay, so when it comes to quantum ontology, are we real? What are we? What is reality? How does it work? Why don't things add up between points versus waves, and why can't we detect or describe dark matter or dark energy? Nobody knows! But there have been scratch paper pads and whiteboards just chockablock filled with theories. Let's hear a few.

Alie: Give me some of the top ones. Like, is multiverses one?

Adam: Yeah, that's one of them. That's probably the most popular one other than, you know, the non-answer of 'shut up, that's a stupid question'. So the many worlds interpretation, which was developed by this joker named Hugh Everett III, in the mid-1950s, while he was a grad student in physics. He basically got drunk on sherry one night with a couple of other physicists and then, basically, developed this interpretation, in part to stick it to the guy he was drunkenly arguing with, who was an assistant of this guy, Niels Bohr, who's a big famous physicist.

Aside: Okay, so Hugh Everett, who as a child wrote a letter to Einstein and got a nice response, and then later in his life sat in on some of Einstein's lectures, ran with his posse. So this Hugh Everett, oh, he loved booze, and smoking, and quantum theory. And he got his PhD in it, in the quantum theory at least. And Niels Bohr, who, by the by, was a big deal, Nobel Prize-winning quantum physicist, and one of the folks who proposed the structure of an atom with the electron spinning around it, and parts of what became known as the Copenhagen interpretation that a particle exists in every position of the wave function until it's observed.

Okay, so Everett. He was gently schmammered and arguing with someone from Niels Bohr's lab about Schrodinger's equation, which tries to find the probability of a particle at a certain point surfing that wave function when we look at it. Okay, so they're arguing:

Adam: So yeah, Everett basically said, "Look, what if it's just all Schrodinger all the time?" What if that's the only thing that plays on the quantum physics radio station, just 100% Schrodinger? What if that other thing, the Born rule never comes in, wave functions never collapse?

Aside: What does it mean to be wall-to-wall Schrodinger? Is that, like, boxed in by Schrodinger? Is a dead cat involved?

Adam: Well to explain that I need to bring in like the most famous thought experiment in all of quantum physics: Schrodinger's cat.

Alie: Yes.

Adam: So Schrodinger came up with this way before Hugh Everett. He came up with his cat in the 1930s to explain why he thought there was a big problem here. Because Schrodinger, and Einstein, and a couple of the other founders of quantum physics were really bothered by this problem. It got a special name later on, the measurement problem. They were really, really concerned about this. They thought there was something missing from the theory.

Schrodinger illustrated this by saying, "Look, you know, maybe quantum particles are weird. Maybe they can perform strange tricks." That wave function describing where you're going to find an electron, it's sort of smeared out over all of space. That kind of suggests that maybe the electron is in multiple places at once until you look.

Aside: But who's looking? And what counts? Nobody actually knows. Anyway.

Adam: So he said imagine that you have a box, a sealed box, and in that box you have a very slightly radioactive, you know, lump of metal, and you have a radiation detector pointed at it. And you have this contraption set up so that when the detector detects radiation, it drops a little hammer that smashes a glass vial of cyanide. And there's a cat in there with this whole thing. So basically, if the lump of metal emits any radiation, the cat will die.

So, you put this all together, you seal the box, and you wait like 30 minutes. [*cute little meow*] And at this point the Schrodinger equation says, the chunk of radiation that could be emitted by this metal, it either has or has not been emitted. And so the wave function sort of says, well, it's been emitted and not emitted, which means that the detector has and hasn't been tripped, which means that the glass vial has and has not broken. So the cat in there is, according to the Schrodinger equation, is sort of part dead and part alive or both dead and alive. It's in this state called a superposition, which is generally the state that most things are in most of the time according to the Schrodinger equation.

But according to the usual way of thinking about quantum physics - this sort of very unsatisfying and incomplete idea that you just shut up and don't think about what it means to measure - when you open the box, then the cat is either dead or alive and somehow opening the box made that happen. And that's ridiculous, Schrodinger said. You know, maybe particles can be in more than one place at a time, but cats are either dead or alive. And if you open the box and find a dead cat, then the minute before you open the box the cat was either dead or dying. And if you open it and find a living cat, it's not like it was not entirely living before you opened the box.

Aside: Okay, so remember our sherry shit-hammered fun-loving physicist, Hugh Everett, arguing with the biggest fish in the physics pond that their Copenhagen interpretation was bull-caca-horsepucky?

Adam: Everett solved this problem a different way. Everett said, no, no, it's all Schrodinger all the time. So when you open the box, [*"What's in the boooxxxx?"*] you know, the cat's both dead and alive before you open the box. And then when you open the box you get entangled with the stuff in the box.

Aside: Okay, heads up on this next part. Entanglement sounds like a boundary issue in an unhealthy relationship, but it's actually quantum physics, and it's cool as hell.

Adam: And so Everett said, sure. So what that means is, you know, the box split according to the Schrodinger equation. And then when you open the box to look, *you* split into two copies. [*"Hello, John." "Hello, John!"*] And the reason that you don't see both a living and a dead cat is because *you* split. And so each copy of you only sees one cat, one of you sees a living cat [*"Thank god."*] and one of you sees a dead cat. [*"Nooooo!"*] But both copies only see one cat.

Alie: So then every time there is a decision, it splits and splits and splits and splits and splits.

Adam: Yeah, this entanglement's sort of contagious and ends up going through the whole world. And so the whole world eventually splits into the dead cat and the living cat branches. And this happens over and over again all the time. And so you end up with this massive collection of universes, a multiverse.

Alie: What if there's three options? 'Cause not everything's on a binary!

Adam: That's right. Yeah. So then you get three copies.

Alie: Okay.

Adam: Or what if you left the cat in there for 15 minutes? Right? So instead of leaving it in there long enough that you had a 50/50 shot of finding a dead cat, you've probably got a living cat. Right? [*"Sweet"*] So then there's two copies, but somehow you're more likely to be the copy that sees the living cat. And this is another part of the problem, right? Because quantum physics famously only gives you answers in terms of probabilities, almost all of the time. [*"Aw, shit."*] But the Schrodinger equation isn't a random equation. It's completely determined. So where did the probabilities come from? Well, they come in when you use this other rule, the Born rule.

Aside: Born rule, to refresh, calculates the probability of measuring or observing a particle at a particular spot on the wave.

Adam: One way of thinking about this is to say, "Well, sure, you know that when you open the box, you're gonna split. But you don't know which universe you're going to be in when you open the box." You don't know which branch of the wave function that you're going to be in. And so, you know this rule is about figuring out the probability that you're going to be in the branch with a living cat or a dead cat. It gets really trippy.

Alie: Oof!

Adam: Yeah.

Alie: Well, so this is the many worlds theory, which is one of the ways that you could try to explain the inconsistency. What about your own life? Do you think about that when you are about to make a decision?

Adam: [*laughs*] You know, I don't go through my life assuming that there are multiple copies of me. Part of the reason is that I don't subscribe to the many worlds interpretation. I think it's a reasonable option, but I don't know that it's the right answer. I don't know what the right answer is. And I don't think anybody can say for sure that they know what the right answer is here, because we don't have a good scientific consensus on this debate. But I mean, in my everyday life? I don't know. I think I'm a pretty regular guy. I just do things the way I do them.

Alie: You wouldn't be like, "Well, I might as well make this risky choice 'cause somewhere there's someone making the less risky choice."

Aside: [*as if through an old phone*] I'll have the pufferfish.

Adam: Yeah. That's definitely not how I approach my life. I do not recommend that anybody do that. Do not try that at home.

Alie: Okay. You're a young guy. [*Adam laughs*] Does it ever trip you out that like, in our lifetime you may not figure out what's up?

Adam: Yeah. Yeah. I mean… [*sighs*] That is frustrating, right? Because you asked me… again, we're on a couch talking about my childhood. But you asked me about what got me interested in this stuff in the first place. I wanted to know what was going on, right? I wanted to know what was up. This is why I keep saying, you know, it's fine if our theories are weird. We live in a weird place. There are so many weird things about the world. Have you seen a platypus?? [*Alie laughs*]

Like, have you seen… This is one of my favorite examples of, like, just a weird thing in physics that has nothing to do with quantum anything. Have you done that demo at, like, a science museum where you sit in a spinny chair, and you're holding a bicycle wheel, and then you flip it upside down? All of a sudden *you* start spinning? That's weird! The wheel feels like it's fighting you! What the fuck is going on? But there's a good answer there, right? So, this is just a strange place and I want to know what's going on in it.

So on the one hand, yeah, it's frustrating that we might not know. But on the other hand it's kind of amazing that we don't know, right? We have been doing science, we have been thinking about this stuff for a long time, and every time we discover something new we find more interesting questions. And this is a complete cliché, and I'm not the first person to say this, but the idea that that there are such fundamental things in the world that we do not understand, that we don't know why these things happen, we don't know what the nature of the world is... And we are in it. We are of it.

One of the great illusions that being human - and especially being human here and now in this culture - fosters is this idea that somehow we are separate from the world. We are of the world. We are pieces of the world. This is one of the things that's so frustrating about this idea that, "The rules are different when you measure." I'm not special! I'm of the world! There are not different rules for me than there are for anyone else. I am a piece of the

world. I'm part of the world. So are you, so is everyone! We are all of a part with this strange and wonderful place that we live in. And it is not clear how any of this works.

Alie: Well, what are some other theories? Okay, so we've got multiverses, many worlds. What are some other leading theories of what the hell is going on?

Adam: Okay, so another one, and this is really gonna piss some people off if I describe this as the leading theory, but it totally is and they're wrong. There's so much controversy here. There's so much drama. This is a lot of what drew me to this. Once I realized there's so much weird stuff in this area and this unresolved debate, I started wondering: why is it unresolved? And it turns out a lot of it has to do with just, like, debate and interpersonal drama between really interesting people. And then I tried to find a book about it and I couldn't find one, so I wrote one.

Aside: Again, the title is *What is Real? The Unfinished Quest for the Meaning of Quantum Physics* by Dr. Adam Becker. Available wherever you get books. Makes a great holiday gift. He did not ask me to say that, but it is legit a very good book.

Adam: Another leading theory is this thing, it goes by several different names, but I like to call it pilot wave theory. It's this idea that when you're talking about, you know, where is that electron? It is in a place before you look and when you look, you find it. [*"Here it is."*] But there's a wave that's associated with each particle, and these waves sort of guide the motion of those particles. And that wave is associated with that wave function that we were talking about before. One of the things that really clued physicists in, in the early 20th century, to something really profoundly strange going on was that they found that things that they thought were waves sometimes acted like particles, and things that they thought were particles sometimes acted like waves.

Alie: Ooh.

Adam: Yeah. So like, something that you thought was in one place suddenly, like, started rippling outward like a wave. Something that you thought propagated like a wave and could ripple out and do all those weird wave things suddenly was acting like a baseball. Like, just really weird. So this is sort of a puzzle. How can particles act like waves and vice versa? What's going on? Why does everything seem to have both a particle and a wave nature? And the answer in this theory, the pilot wave theory is: that's because there are particles and waves and every particle has a wave associated with it that determines how it moves. And so that sounds really simple and really cool. There are problems, right? There's problems with everything. Otherwise there'd be no controversy.

The first issue, though I hesitate to call it a problem is, remember entanglement? When things interact, they start sharing a wave? So when you have two entangled particles, one particle… say that they're entangled and they go flying off in different directions. One of them is way over here and one of them is way over there, right? Like one of them is in Mississippi and one of them is in Calgary. Right? Okay. Then the one in Mississippi, if it moves a little bit, that's going to affect the pilot wave that guides the particle in Calgary. Instantaneously, immediately. It happens faster than the speed of light. So that's weird, especially because we can prove in the math of the theory that that's what happens. But you can also prove that you can't use it for signaling.

You can't send messages faster than the speed of light this way. Somehow there's this subtle connection that we don't see direct evidence of. When I said we don't see direct evidence, we do see evidence, but it's indirect evidence. It's evidence that they are connected. You can't use that connection. No one would dispute that they were connected if you could use one to instantly make the other one, you know, send a message. But that's not how this works.

Aside: So, in the pilot wave theory, there's not a wave or a particle, there's a wave that the particle is kind of surfing, and it can affect the particles in numerous superpositions. But it would be faster than light, which really irks some people, because ol' Alby Einstein's relativity says nothing is faster than light. So he didn't like that. Also, Adam says:

Adam: The basic idea was developed by one of the founders of quantum mechanics, a guy named Louis de Broglie in the late 1920s. But then he was convinced by some other physicists that it couldn't be right. He dropped it. It was independently rediscovered by another physicist, David Bohm, in the early 1950s and he sort of fixed up the problems that were with it, that de Broglie had left, and sort of made it a fully-fledged theory and published it. And then his life descended into a living nightmare for mostly unrelated reasons.

Alie: Oh no!

Adam: Yeah, he got caught up in the Red Scare in the 1950s. He got blacklisted. He ended up being effectively exiled to Brazil. Then the U.S. government confiscated his passport so he was trapped in Brazil. Like, there's a whole… It's like a movie. It's like a frigging spy thriller. Like, dude got the fucking short end of the stick.

Aside: Okay. Whew! Now, this guy's life. My word. He had his own work at Berkley confiscated and then classified so he didn't have access to it, so that it could be used on the Manhattan Project?! And he eventually, in his 70s, had to have electroconvulsive therapy for depression. And just the saga and the drama of his life and political affiliations affected the reception of his work, sadly.

But one hiccup is that the particle surfing a pilot wave doesn't work with other theories like the relativistic quantum field theory that explains what happens when you smash particles together in a nearly 17-mile particle accelerator tube underground, which, as discussed in the Cosmology episode with Dr. Katie Mack, is not called the Hard-On Collider.

Adam: No one has found a way to unequivocally take that theory and reframe it in terms of this pilot wave stuff. That doesn't mean it's wrong. It just means that if it's right, the job isn't finished. But there are a lot of physicists who don't like this stuff for that reason, and because it's got this weird tangled history. So yeah, that's another option, is this pilot wave theory. There are lots of other options.

Alie: How often do you think people get stoned and come up with their own theories and email physicists?

Adam: Oh, well I can tell you that happens a lot because I get a lot of those emails. Some of those people, by the way, I think are not stoned. I think that there could be an interesting psychology paper done here – oh man, I'm going to get some hate mail for this – that, like, being an old retired white male engineer must have some effect on the brain that is similar

to, like, cannabis or alcohol or something, because those people, I'm pretty sure they're sober and they send me all sorts of wacky stuff all the time and it's not correct.

Alie: Do you have a favorite? Any simulation theories?

Adam: Yeah, I definitely get those. I also get, you know, "Einstein was wrong and a complete fraud and here's why and I'm the only one who found it."

Alie: [*knowingly*] Mmm.

Adam: And "I'm like Galileo, I've been persecuted," right? There's this thing called the crackpot index online, which, basically you assign more and more points to a crackpot email depending on what kinds of claims they make.

Aside: Okay, sidenote, this crackpot index is indeed a real thing, and it was published in 1998 by mathematical physicist John Baez. And one's score is determined by points, with infractions being five points for each word in all caps; 10 points for mailing your theory to someone you don't know personally and asking them not to tell anyone else about it for fear that your ideas will be stolen. 10 points for each statement along the lines of "I'm not good at math, but my theory is conceptually right, so all I need is for someone to just express it in terms of equations." 10 points for each comparison of yourself to Einstein. 20 points for emailing to complain about the crackpot index. 20 points for suggesting that you deserve a Nobel Prize. 30 points for claiming that your theories were developed by an extraterrestrial civilization. And...

Adam: And I think the worst thing on that index that you can do is compare yourself to Galileo.

Alie: Oh no.

Aside: In that vein: [*clip from Code Conference 2016 recording: Elon Musk, "Either we're gonna create simulations that are indistinguishable from reality or civilization will cease to exist. Those are the two options."*]

Alie: Now what about a simulation?

Adam: Okay.

Alie: What if the reason why we cannot reconcile the wave versus the particle, and the Born versus the Schrodinger, what if that is because it's all fake?

Adam: Right. So, couple of things there. First of all, you'd still need to have rules. Like if it's a simulation in a computer, like any computer we know, there's still rules that the simulation runs on, right? And that means that there still has to be some internal logical coherence, right? It can't contradict itself, even if it's weird. So there's that.

But more importantly, and I don't know if you're going to like this answer. I think that the simulation thing is kind of... No, okay, no, I'm not going to mince words. Simulation thing is fucking bullshit.

Alie: Okay! [*laughs delightedly*]

Adam: It's fucking bullshit and here's why. And this is going to take, like, a sharp left turn. It assumes that that's something that... It assumes that that's a thing that you can do, which we still don't know that you can do that. And it also assumes that… And I guess what I'm really talking about here is this argument that we almost definitely live in a simulation,

right? Like there are those people who say, "No, no, no, we definitely live in one. Like almost certainly, there's almost no chance that this is like the base reality," whatever that means.

I really think that's wrong because it assumes a lot about the future progression of technology, but it also assumes that technology always progresses through the same inevitable stages. It assumes a lot about history, and culture, and the nature of life and intelligent life, and intelligence itself. And I think that basically all of those assumptions that go into that argument, that fuel that argument, are hopelessly myopic. They're just like completely blinkered and narrow-minded about the wide variety of ways that things in the world can be and that, you know, technology and civilization and culture can be, even in this world here and now.

Like it's a very Western-centric, male-centric, white-centric, rich-centric argument, that, basically, "yeah, the inevitable progression of any intelligent being in any logically possible universe is basically gonna be, like, a rich white dude born between 1970 and 1990." And that's some fucking bullshit.

Alie: Yeah, that is bullshit. And also I've been using, "maybe everything's a simulation" as an excuse for why things are bad, [*Adam bursts out with a laugh*] but I shouldn't do that. Right?

Adam: Yeah. I think, like, two things. First of all, you shouldn't do that.

Alie: Okay.

Aside: So yes. Clearly we can't look at global warming, and agonizing political situations, and forests burning, and that time you farted in ninth grade history class, and people having cancer, and being driven from their homelands because of greed just as a video game gone wrong, and that we should give up and fold our hands in our laps and just wait for the apocalypse. Or the game over screen.

Adam: Second, even if this is a simulation, the suffering is real. I am suffering. You are suffering. We've got to fix that shit.

Alie: Yeah. A lot of people out there, real suffering. We can't just shrug it off as, "it's all a video game."

Adam: Yeah, exactly. Yeah.

Alie: Do you think that we're real?

Adam: I mean, yeah. I mean, I guess it depends on what you mean by real, but for any good meaning of that word, sure. We're real. Yeah. I mean, say that it is a simulation. Say that everything I said was wrong. Say that there is some other universe with other laws of physics and other beings and for whatever reason they decided to build this simulation, like, build a computer and inside that computer, there's a simulation going on and we're in there. We're real, we're in that simulation! We're really in that simulation in that scenario. There are real entities in that simulation that are you, and me, and all the things around us, even if that's not how the programmers think about it.

I am having experiences here in this simulation, and I have a hand over here, and I'm waving it around, and I'm banging it on the edge of the sofa. That's all happening. Does the actual structure of the world at its most fundamental level look anything like the way we

think it looks? Probably not. Whether or not we're in a simulation, I think that's wrong. But does that mean that we're not real? Absolutely not.

So here's the thing. I think everyone, I hope everyone can agree that temperature is a real thing. Like things have temperatures. You know, I can take my cool nerdy infrared thermometer and point it at the wall and it will tell me that the wall is 74.6 degrees Fahrenheit, because we live in a country that doesn't know how to measure temperature. But the thing is, temperature, according to our best understanding of temperature in physics, (it comes out of thermodynamics, which is itself something that comes out of statistical physics, a really, really interesting field of physics) temperature is an emergent property. It's not a property that individual subatomic particles can have. It's something that only aggregate collections of stuff have.

Aside: So one molecule can't have a temperature, but a group of them can because they're all moving around. So Adam likens temperature to existence and asking the question "are we real?"

Adam: These things in this world around us can emerge out of that lower level in the same way that temperature is a property that emerges out of the lower level, little jostlings of tiny things because that's where temperature comes from. It's a tiny object, a tiny piece of that wall, is moving around a little bit and all that jiggling together comes out and looks to us like temperature. That's a real thing. That wall is actually a temperature. And we are here and we are having this conversation. Even if the perception that there is such a thing as space and time is something that emerges out of some lower level of reality, there's still a space and a time that we're in. Even if it's not fundamental.

Alie: All right. You've not let me get off the hook about existing, and I still have to, like, do all my bullshit and get through my to do list, and like, I can't… arrrghmmmm! Okay, can I ask you Patreon questions?

Adam: Yeah, yeah. Let's do it.

Alie: Are you ready?

Adam: I mean, I'm never gonna be completely ready, right? For the weirdness that is Patreon. Hi, Patreon.

Alie: That's the right answer.

Aside: But before we get to your genius, and weird, and dry, and perfect questions submitted on Patreon, each episode we donate to a charity of the Ologist's choosing. This week, Dr. Becker chose Techbridge Girls, which excites, educates, and equips girls from low-income communities by delivering high quality STEM programming that empowers a girl to achieve economic mobility and better life chances. And Techbridge Girls was one of the earliest organizations to focus on introducing girls and marginalized communities to the STEM fields. And it's based in Oakland, California, where Adam lives. So that's TechbridgeGirls.org. That donation was made possible by sponsors of the show, and so you may hear some words about them right now.

[Ad Break]

Okay. Back to your questions.

Alie: Travis DeMello wants to know: How does quantum... stuff relate to nature? What is its role beyond technology?

Adam: Oh, that's a great question. Quantum physics explains a huge variety of natural phenomena. Like, without quantum physics, we wouldn't understand why the sun shines. We wouldn't understand how our eyes can see that the sun shines. We wouldn't understand - and I mean this in the most general way possible - the phenomenon of solidness. Like, we wouldn't understand not only why I'm not passing through this couch right now, but why my bones are solid at all in the first place. [*Homer Simpson scream!*]

Aside: For more on that topic, you can see the Osteology episode about bones. Just sayin'.

Adam: Quantum physics is necessary for understanding where the periodic table of the elements comes from and the idea of molecular structure. So all of chemistry, and thus all of biochemistry, and thus all of life. So quantum physics explains, or has a really important role in explaining, almost every single possible natural phenomenon.

Alie: So it's important.

Adam: Yeah. Just a little.

Alie: Little bit. So, a bunch of folks asked about existence and what it really means, and why, such as Wendy Lockhart, Sarah Piette, Matthew Thomas Hill, and Sam Gordon, who wants to know: How do you deal, knowing what you know about existence? And Kristi Stuart wants to know: Why does it matter if we exist or not?

Adam: Humans are curious. It we're going to try to engage in the dangerous game of coming up with fundamental human behaviors that are true across cultures, I do think that curiosity is a really good candidate for one. And also more generally - and this is me stealing from my book - the ideas that we get from science, the picture of the world that comes with our best scientific theories, it filters out into the wider culture. Science is not a separate human activity from the rest of the human world.

It is of a piece with the rest of human activity with art, and politics, and music, and the social sciences, and the physical sciences, and the biological sciences. These all form a unified whole. And so the pictures of the world that come from science not only go out into the other sciences, but out into the wider world. Like a really, really simple and facile and total white dude example: if Copernicus and company had not uncentered the Earth and shown us that no, the Earth is not at the center of the universe, it seems hard to imagine that Charles Darwin - or Chucky D to his friends - and company would have had the audacity to suggest that humans are not at the center of biological creation. Right? And instead that we're just another ape, just another organism in a giant tree of organisms.

And without both of those changes in the way that we think about the world… I mean, first of all, you can probably come up with your own examples, but without both of those changes, Stanley Kubrick wouldn't have been able to film *2001*. [*clip from Richard Strauss song "Also Sprach Zarathustra," the opening and closing theme of 2001: A Space Odyssey, plays under Adam's words*] All those apes at the beginning? Come on! That wouldn't have happened. There's lots of other art, and culture and just important things that have happened because of our scientific theories. And vice versa. Yeah.

Alie: Samuel Vaal wants to know: Has the impossible issue of tunneling been solved yet? Or are there any good theories out there? What is tunneling?

Adam: What is tunneling. So the short answer is, in classical physics, if I put my hand on this table and leave it here, then it will just sort of stay on top of this table. But in quantum physics, there's a small chance that my hand will suddenly pass through the table. But it's phenomenally unlikely because my hand is quite large and the probability of that kind of tunneling has to do with, among other things, the size of the object involved. For tiny objects, tunneling happens all the time. In fact, if tunneling didn't happen, the sun would not shine. So we know that tunneling happens. Tunneling is not more strange or unexplained than the rest of quantum physics. So if you can get a good picture of the world that comes with quantum physics, you get tunneling for free.

Alie: Ooooh. I didn't know what tunneling was until right now. I thought it was maybe something that college kids did at parties.

Adam: It does kind of sound like that.

Aside: This next question about something we keep in our pants... pocket was asked by patrons juliebear, Will Matlack, Jess, CJ Stuart-Hodges, Mike Rotch, Courtney Markham, Euan Munro, Michael Preston, who wanted to know why we should give a rat's left ear about the topic, Philip Wehry, and...

Alie: Spencer wants to know: No matter how much I research I don't understand quantum computing. Is there an easy way to understand it? Also, will quantum computers replace all computers eventually (like our phones)? Or just super computers?

Adam: Yeah. So I'm going to take the second part first.

Alie: Okay.

Adam: I don't think that anyone who works seriously in that field thinks that quantum computers will ultimately replace all computers.

Alie: Okay.

Adam: I don't even think that they're going to replace all supercomputers. There are things that classical, normal computers can do better than quantum computers and vice versa. And I don't think that that's going to change.

Alie: Also let's explain what a quantum computer is.

Adam: Also let's explain what a quantum computer is. Quantum computer is a computer that harnesses some of the strange and... No, that's not a good way of saying it… The usual way that people say it is, "Quantum computer is a computer that runs on quantum physics." Everything runs on quantum physics! So all computers run on quantum physics! Then people say, "Quantum computer is a computer that uses special properties of quantum physics to do certain computational tricks." That's not specific enough either, because semiconductors, which are what the computer in your lap, and in my pocket, and like all computers are built on basically, semi-conducting itself is a quantum property. Like you can't explain that without quantum physics.

A better definition of a quantum computer is: a computer that uses specific quantum properties like superposition and entanglement to perform certain computations that normal conventional computers cannot perform as quickly in that way.

Alie: So it's using the superposition of, say, positive/negative, here/there as kind of a replacement for the binary 10010.

Adam: Yeah.

Alie: And so it can go much faster because it's at an elemental level?

Adam: Sort of. I mean, it can do some things more quickly. Basically, instead of having a bit that's either one or zero, you can have it in a superposition. And then you can take advantage of some of the wave properties of matter to give you a speed up for certain kinds of computational algorithms. The more specific you get about this, the more wonky and less cool it sounds. It is, I assure you, very cool.

Alie: Okay! [*laughs*]

Aside: Also, if you've been seeing the words 'quantum supremacy' lately, thank Google. So, in late 2019, just a few weeks ago, Google announced that their quantum computer, which looks to be about the size of a small chandelier that dangles in a cryochamber colder than outer space, is named Sycamore. Well, the processor, a small chip, is Sycamore, but it needs all those kinda sparkly golden wires to function. Anyway, a team out of University of California Santa Barbara's labs just published a paper revealing that Sycamore had solved a math problem in 200 seconds. So, way to go, Sycamore! Who cares?

Well, a lotta people. Because that same math problem when beep-booped by an existing supercomputer would take *years* to solve. How many years, you wonder? 10,000 years! So what would take a supercomputer 10,000 years to calculate, Sycamore did it in 200 seconds. Like, three and a half minutes. So quantum computing: it might save us, it might kill us. Either way, get hype.

Alie: But so, you don't think that it's going to replace all supercomputers?

Adam: I don't think anyone serious in the field thinks that. I mean, there are people who know a lot more about quantum computers than I do. My book is, I mention quantum computing, I talk about it briefly, it's not primarily about that. I do touch on it because it's important. But I have talked with a lot of people who work in that field. I don't think anyone thinks that. So unless everyone's wrong, I don't think that it's going to happen.

Alie: Okay. Jennifer Coil wants to know: A therapist once suggested to me that one day a physicist will prove the existence of God. Thoughts?

Adam: Get a new therapist. Fire your frigging therapist. Is she on mushrooms? Yes/no. This is a safe space. You can tell us if you think your therapist is on mushrooms. Yeah, I… no.

Alie: Okay. That's gonna be a no from you, dawg.

Adam: Yeah.

Alie: Got it.

Aside: Okay, old Uncle Dad Ward here poppin' in to say, everyone is entitled to their own spiritual beliefs so long as it's not oppressing or screwing up other people's lives. But if

you're wondering if scientists tend to be atheists at a higher rate than the general public, that's a yes. Rice University sociologist Dr. Elaine Howard Ecklund had this same question, and in her 2010 paper "Science vs. Religion: What Scientists Really Think," she crunched the numbers. So, only 2% of the general U.S. population says, "I don't believe in God." But over a third of what she describes as 'elite scientists' are atheists. But, Ecklund continues, 22% of the scientists who identified themselves as spiritual also describe themselves as atheists. So wait, huh? What is a spiritual atheist? Dr. Ecklund interviewed one biologist who described spirituality this way, said:

That feeling you get by the seashore, looking over the endless expanse of water, or the feeling you get considering the age of all things in existence and how long it could go on. Sort of an awe at the totality of things. If that's what spirituality is, then, I get it.

… said the biologist. So, while the narrative of what's controlling our existence - is it a sentient, shadowy figure in a cloud watching over us, getting pissed when we lie, or is it chaos, mixed with chance, mixed with logic, and a heavy proportion of mystery? Those sources may change. They might be different for each individual. But in the end, perhaps what matters most is the awe that keeps you inspired and the respect that you show to the fellow lumps of molecules with whom you share the universe. Or maybe it's all a video game! Are we real? Probably. But nobody knows. And that is why quantum ontology is cool.

Adam: Favorite uncertainty principle joke?

Alie: Yes.

Aside: Hi. Me again. So the uncertainty principle was drafted by German physicist Werner Heisenberg. And yes, *Breaking Bad*'s Walter White took his alter ego name after this very renowned physicist who, Adam explains in his book, had a deep loyalty to Germany. And was the head of its World War II nuclear program. Gross.

Anyway, the uncertainty principle theorizes that when it comes to a particle, its momentum and location cannot be known at the same time. And Adam remains on the spot for a good uncertainty principle joke. Per listener juliebear.

Alie: Juliebear wants to know: Favorite uncertainty principle joke?

Adam: [*Jeopardy theme "Think!" plays under Adam's words*] Yeah... I mean... [*sighs*] God, they're all just flying out of my head right now except for the most boring one. [*Jeopardy song ends*] The most boring one is... [*sighs*] I apologize to physicists who are listening. You've all heard this before. And probably the person who asked this. A cop pulls Heisenberg over for speeding and says, "Sir, do you know how fast you were going?" And he says, "No, but I know exactly where I am."

Alie: Amazing.

Adam: Yeah. [*clip from Bon Jovi song Bed of Roses: "I laughed so hard I think I died."*]

Alie: Isabelle B Holper wants to know: Which movie or TV show gets it best?

Adam: Ooh. Like, just quantum in general? Which movie or TV show gets it best?

Alie: How does *Quantum Leap* do?

Adam: Oh man! *Quantum Leap*!

Alie: Yes? No?

Adam: *Quantum Leap* has almost nothing to do with quantum physics, but I watched that show so much growing up.

Alie: It was a good one.

Adam: Yeah, it was good. [*clip from Quantum Leap: Narrator, "Theorizing that one could time travel within his own lifetime, Doctor Sam Beckett stepped into the Quantum Leap accelerator – and vanished." whooshing air and lasers.*]

Alie: What about *What the Bleep Do We Know!?*, Julie Noble wants to know. [*clip from What the Bleep Do We Know!? trailer: "Are people affecting the world and reality that they see? You betcha they are!" "What is reality?" "What is reality?" "Have you ever thought about what thoughts are made of?" "It is so mysterious you can't explain it."*]

Adam: Oh, really? *What the Bleep Do We Know!?* is… Okay, so take it out of what computer you've got it in. Put it on, like, a thumb drive that you don't care about, set it on fire, [*Alie laughs*] bury it. *What the Bleep Do We Know!?* is wrong about everything *and* the people who made it are malicious.

Alie: Oh no!

Adam: They tricked a friend of mine, who is in that movie, they tricked him into participating and then they misleadingly edited his contributions to make it sound like he supported their crazy stuff. Also, they are literally a cult.

Alie: Oh no. Okay, so you heard it here first.

Aside: Okay, this next one is about string theory. And as patron Nate Rynders inquires: String theory. Come on, what the fuck? That's an excellent question, Nate. I will attempt to summarize it in the smallest, jankiest nutshell I can. String theory is that particles are actually teeny, tiny tiny strings, which means that there could be more dimensions. And also, string theory may unify Einstein's theory of relativity about gravity with the other quantum physics that just do not comply. In his book, Adam writes, "String theory doesn't describe a single universe, but instead describes a string landscape, a phenomenally huge number of possible universes. 10 to the 500th power or more."

So what is happening in all those universes? Is my dog there? Am I still wearing this yellow sweater? And does string theory finally reconcile the other theories that don't mesh together? Is string theory the dongle that all of science is waiting for? Kitti Halverson also asked about it, as did...

Alie: Graham Tattersall wants to know: String theory, flimflam or science?

Adam: Sure seems like science.

Alie: Okay. Amanda J wants to know: Does quantum physics have anything to do with our consciousness?

Adam: [*drawn out*] Yeah...

Alie: Because it has something to do with everything.

Adam: Yeah. So… Yeah, on the one hand, sure, right? Putting my cards on the table: I see no reason to think that consciousness is not something that arises purely out of the behavior of neurons in our brain.

Alie: Okay.

Adam: I think there's a lot of good evidence for that. Our neurons are made of subatomic particles. Those subatomic particles are governed by quantum physics. So in one sense, yes. But there's often another sense that people have in mind when they ask this question.

Aside: Okay, real quick. Remember Schrodinger's cat? So if you observe or measure it, it flips to one position. Mew, mew or ohhh nooooo!

Adam: But what's measurement, right? What counts as measurement? Some people will say things like, well, maybe consciousness counts as measurement. Maybe it's when a conscious being interacts with a thing. Maybe that's what measurement is in quantum physics. A couple of things; first of all, that still leaves you with this problem of, does that mean that, like, the wave function of the universe was waiting for a conscious being to come along? Also, what is conscious? What do you mean by consciousness? What counts as conscious? You still have that problem. It really seems like a very human-centric view and I'm always really wary of human-centric views. There is a mystery in human consciousness, right? Or there seems to be one, like, what is human consciousness? Where does it come from?

Sure, you can have different views on how consciousness works, and what it is, and whether or not there's even a mystery there. But I do not see a compelling reason to invoke consciousness in quantum physics given that there are alternatives. And I do not see why we would say that it is more related to quantum physics than to any other issues in physics. I don't think that consciousness plays a more special role in quantum physics than it does in any other area of physics. The question of consciousness? Sure. Whatever. That's a good question. We can have interesting conversations about it, but I don't see it as related to these questions about quantum physics.

Aside: Katherine W asked Adam: What does an average day of your life look like? So, as an author, he took me through his process of writing the book, which is so, so, so helpful no matter what you're working on, and earlier off-mic he had mentioned that he has ADHD. You can see the Molecular Neurobiology episode with Dr. Crystal Dilworth, where we touch on that. And so these are his secret tips on how he accomplished his huge goals. This is, honestly, lifechanging. I loved this.

Alie: What was the process of writing the book like?

Adam: So, first it was abject terror after I got the contract, because after I finished partying, I realized I was on the hook for 90,000 words, and I'd never published anything longer than about 3,000. So that was completely fucking terrifying. I had a history earlier on in my career of having difficulty getting work done and getting it done on time or getting it finished. And I had by that point moved past that. I finished my degree and whatnot. But I still had this mental image of myself as someone who had difficulty getting work done on time, and so I was really extra scared.

But I decided, okay, the only way that I'm going to get through this is if I plan it and then just only pay attention to whatever's in front of me, because I can't write 90,000 words, but

I can write 600 words a day. And if I do that for a while, eventually I'll have 90,000 words. So I outlined it, and I went over the outline with my publisher, and they like the outline. Of course it changed, right? No plan survives contact with the editor.

So, for each chapter I'd outline the chapter and then I just sort of worked through that outline and write a really shitty first draft and try to do 600 words a day. And what I'd do is I would do 50 minutes on and 10 minutes off, and in the 10 minutes off I wouldn't look at anything with a screen and I wouldn't read any nonfiction. I read exclusively novels, and that really helped my brain work because I found that if I didn't read it all, I couldn't write because if there's nothing going in, nothing's going to come out.

Alie: Right!

Adam: So I would write 600 words a day, and then get the shitty first draft done, and then walk away from it, and then come back and clean it up, and fill in all of the blank spots where I knew I had a quote but I had to find the quote and stuff like that. And things would change and then eventually I'd have a chapter draft that I wasn't embarrassed about and then I'd send it to my editor and move on to the next one.

It was terrifying. There was a lot of research involved. There was a lot of running around and interviewing people. Like, a lot of people. If you look in the references there, the very beginning of the references of the book has the list of interviews I conducted. I think it's like 42 interviews or something like that, most of which were in person.

Alie: Isn't 42, though, the answer to the universe?

Adam: It is. I don't know if it's actually 42. I know that it's like, it's somewhere around 40, but yeah.

Alie: Okay. I'm gonna count.

Aside: Okay, at this point in the interview, another Ologist had stopped in to record, and I'm gonna make you wait to find out who it was. But we counted his list of interviews in the back of his book, and:

Adam: 'Cause like, I love *The Hitchhiker's Guide to the Galaxy*.

Alie: Yeah! It's 42!

Adam: It i*s* 42, yeah.

Aside: So yes, it was indeed 42 interviews.

[*clip from The Hitchhiker's Guide to the Galaxy, Deep Thought, with a crowd cheering during pauses: "The answer to the ultimate question... of life, the universe, and everything... is... 42."*] For more on why, you can see *The Hitchhiker's Guide to the Galaxy*, by Douglas Adams. Oh my god, Adams. Again. Adams! Is anything fucking real? But yes, Adam Becker says don't be afraid to start something. Start writing. Just jump in. Shitty drafts are your BFF.

Adam: Shitty drafts are really important. I also had, like, a spare parts bin, where if I had one of my darlings that I couldn't kill, like a sentence that I didn't want to get rid of but it didn't fit, I'd put it in there and tell myself… I'd lie to myself and tell myself that I'd come back and never came back. But more generally, I spent a lot of time thinking about narrative structure. Like, my overall approach was, "This is a book about really abstract ideas. People care about

ideas, but they generally care more about people than they care about ideas." And I wanted to make it compelling. I wanted to see if I could write a book about some of the most abstract and strange ideas in physics, or in all of science, that was difficult to put down.

And so I thought, "Okay, the way to do that is to wrap these ideas up in people and stories about people." Then it was a question of okay, how do I build a narrative arc that will give me good excuses along the way to explain the ideas and introduce the new characters that are going to come into the story? And that was a real learning process for me. And I spent a lot of time like watching YouTube videos about film editing to learn what narrative structure looked like in other forms of stories.

Aside: Also, Adam stuck to another edict to make a book about quantum ontology accessible.

Adam: Oh, and no math. That was the rule.

Alie: Oh, no math in the book?

Adam: No math at all. No math.

Alie: It's a math-free zone.

Adam: There was one equation in the book, and I didn't want to have any math in the book, so I wrote it out in words. The equation was two times three equals three times two. That's it.

Alie: Nice. And what's the shittiest thing about quantum ontology? Is it answering those, maybe, religious questions, or too philosophical, or too loaded questions? What's the shittiest thing?

Adam: The shittiest thing is definitely dealing with physicists who think that this was all resolved 90 years ago and we should just shut up and calculate. There are so many of them. They are wrong. There are so many good arguments about why they're wrong and why these questions are interesting. And they're still out there, and it's just kind of astonishing. But it is getting better, and I really think that as a new generation comes into physics, we will see more and more acceptance of these questions as legitimate areas of scientific inquiry.

Alie: Now, what's the best thing about quantum ontology? What do you love the most about it?

Adam: You get to ask the biggest questions!

Alie: I know!

Adam: Right? Like, these are the biggest questions.

Alie: Oh, I thought you meant me, right now. [*laughs*]

Adam: Oh. No, no. Well, you totally do. That's the best part about *your* job. The best part about thinking about quantum ontology is you get to ask questions like, what is real? Like, what's goin' on [*clip from Marvin Gaye song What's Going On*] and other Marvin Gaye songs. You get to ask these really deep questions about the world. You get to think about these wonderful things.

Chemists have really good demos, right? They get to blow things up and you know, put one liquid into another liquid and suddenly it's foaming everywhere and stuff like that. [*clip of Bill Nye the Science Guy: "And because for some reason, John, you're a 42-year-old man who*

needs his attention sustained with tricks, here's some fucking Mentos and a bottle of Diet Coke." Audience applause and laughter.] And like, biology, you get like creepy crawly things, and cute baby chickens, and things like that. And there's all sorts of fun stuff.

Physics doesn't have cute baby chicks. I mean, you can have cool explosions, but like chemistry really is really, really sweet for that kind of thing. But physics does have the truly pervasive on its side, right? Like if you want me to talk about some of these questions in the foundations of quantum physics, I can point to literally any object and say, "Look, let's talk about the constituents of that object. Let's talk about why that chair is solid. Let's talk about why this ring on my finger is yellowish instead of silvery." Right? All of these things come back to quantum physics and thus ultimately to foundations of quantum physics. And it's just amazing. It goes after a lot of the reasons why I wanted to go into science in the first place.

Alie: So it's everything and it's everywhere and we don't understand it.

Adam: Yeah.

Alie: [*laughs*] Is what it comes down to.

Adam: Yeah, absolutely.

Alie: I love it. Well, thank you. I'm more confused about my existence.

Adam: Good. That means I did my job. There's a question mark at the end of the title of my book, right?

Alie: I love it. Thank you so much for doing this.

Adam: Absolutely. This is so much fun. Thank you for doing this with me.

Alie: You're my favorite quantum ontologist.

Adam: Aw, thank you.

So remember, ask smart people the big questions, even if it's about the littlest stuff, because how else in the world would you discover that there's another you eating pufferfish and cutting bangs and texting your crush? Oh, also, if you're jealous of that person, then go do those things yourself! Except maybe the poisonous *poisson*. That means fish. Whatever.

More links are up in the show notes and up at AlieWard.com/Ologies/QuantumOntology. And you can get merch through that site or at OlogiesMerch.com. Thank you to Shannon Feltus and Boni Dutch for managing that. Once again, BLACKFRIDAY2019 is the shopping code if you're shopping this weekend. I'll link in the show notes, along with the nonprofit and the sponsors.

Thank you Hannah Lipow and Erin Talbert for adminning the wonderful Facebook group, and to Jarrett Sleeper of Mindjam Media for assistant editing. And of course to the wizard of awe, Steven Ray Morris, who edits all these pieces together and also hosts the kitty pod *The Purrrcast* and the dino-centric *See Jurassic Right*. And the theme song was written by Nick Thorburn of the band Islands. Thank you also to Emily White and everyone in the transcribers group making transcriptions available at AlieWard.com/Ologies-Extras. I'll link it in the show notes.

Now, if you stick around 'til the end of the episode, I tell you a secret. This week, my friend Simone Giertz was in town, and I was telling her that I wish there was a word for when you try to improve something but you make it way shittier. And I forget what we were talking about – maybe the Tesla cyber-truck window demonstration? - but essentially, a word for one of those things where you want to make something good, and somehow it would have been so much better if you had just not. In the Etymology episode, I was talking to Helen Zaltzman, and I pitched maybe a 'bonne-mal'? Like French for good-bad? Or Greek, like 'voy-vlap'. Anyway, I told Simone I wish there was a word, and she said there is. In Swedish it's called a bear favor, and it's from a fable about a bear trying to help someone by shooing away a fly with a boulder, on their face, and kills them. So, a bear favor. Y'all, there's a word for it. I'm thrilled. It's very exciting.

Okay. Berbye.

[*clip from Family Guy: Peter Griffin, "Yeah, Lois, that'll be about as much fun as a lecture on ontological empiricism."*]

Transcribed by Hannah Dent, that friend who pulls out Google to figure out who's right during an argument and then spends the next five minutes reading you weird facts about whatever you were arguing about.

Links which you may enjoy:

Purchase Dr. Adam Becker's book What is Real? The Unfinished Quest for the Meaning of Quantum Physics

Review of Dr. Becker's book

Elon's thoughts on the simulation hypothesis

Crackpot index

The Schrodinger Equation

Quantum Field Theory

Wave function collapse

Born's work on the Born Rule

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