Astrobiology with Dr. Kevin Peter Hand
Ologies Podcast
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Oh heeey! It's that guy in your video editing class, who chews so much gum you're actually worried about him. Alie Ward back with another episode of *Ologies*. So this episode, I'm just, I'm going to say this up top just to get it out of the way, it's out of this world. Okay? I said it. It's out of this world.

Now, we're going to start by talking about the passions that lead to a career in extraterrestrial alien searches, as well as lay down some foundations on missions in our solar system, and then we'll get to what could live where. But before to we get to alive things on distant space bodies, let's thank some earthlings. Thank you to all the people who make the podcast possible on Patreon.com/Ologies, all my buddies there; to all the folks sporting *Ologies* swag from OlogiesMerch.com; thank to all the folks who are rating (and making sure you're subscribed!) and leaving reviews for me to peruse, like a semi-creep, such as for example, one left by Anonymous Epidemiologist this week who said,

> *More years of grad school than I like to admit tends to hamper my ability to talk about my research without being boring, condescending, inaccurate, or worse – all three. I love this podcast because it helps me figure out how to talk about my own work in a way that is true but (hopefully) relatable.*

I think a lot of folks listening probably related to that. So Boom! There you go.

Okay, astrobiology. Let's get to it. Once called exobiology, but let's consult the Greek, shall we? So *astro* comes from the word for star and *biology* has its roots in the verb to live, so what is out there, living on those ding dang stars, what's on the planets? That's the big question. Is anything alive out there, what are the odds, is it big, is it small, is it cooler than us? To get some answers, we'll consult a professional. Over the course of 11 months and 27 gentle desperate emails from me, this ologist kindly obliged and the resulting interview is… I was literally about to say stellar. I'm not going… I swear that was an accident.

But it was a stellar interview. He's such a great dude. He has been a researcher at the SETI Institute (Search for Extraterrestrial Intelligence) that was founded by Carl Sagan and Frank Drake, he's a National Geographic Explorer who has trekked the arctic and down to the depths of the sea (you may have seen him in James Cameron's *Aliens of the Deep*) and is currently the deputy chief scientist for solar system exploration at NASA'S Jet Propulsion Laboratory in Pasadena, California. Sidenote: the opinions he expressed herein are his own, and not those of JPL or NASA. When you're in charge of looking for space aliens for NASA, you gotta toss out some disclaimers.

He stopped by last week after work and we settled in for an evening talk about icy moons, space drills, tiiiiiiny extraterrestrials, sci-fi movies, extremophile tardigrades, subsurface oceans, squirrels, ghosts, (Okay, I brought up the ghosts, sorry), various voyages made by NASA spacecraft and essentially what is lurking in the great darkness of the universe. And does it want to kill us? So make some space in your brain for the brilliant and wonderful astrobiologist, Dr. Kevin Peter Hand.

Dr. Kevin Peter Hand: H-A-N-D.

Alie Ward: Okay. That's what I thought. But just in case it was "Hond" I never said it aloud. I thought I'd ask. Now, you are an astrobiologist?

Kevin: Correct.

Alie: When you toss that out at parties, do people know what that means?

Kevin: No, because I don't toss it out at parties.

Alie: Okay. That's one way to avoid that. What exactly does it mean?

Kevin: It's a very good question. Many different ways to answer it, but simply put, astrobiology is the study of the living universe. That's it in a nutshell.

Alie: The study of the living universe.

Kevin: Correct.

Alie: So this is excluding rocks, air...

Kevin: Well, keep going and we'll come back to some of that.

Alie: Rocks, air, light, uh… cars… minerals?

Kevin: So what's important about it being the study of the living universe is that oftentimes when people think about astrobiology, they say, you know, okay, this is the search for life beyond Earth. And that's correct. That's certainly part of astrobiology. But what's also a very central task for biology is the study of the origin, evolution, and future of life on Earth. Where did we come from? Where are we going? How did life originate? And so, when you think about the living universe, of course right now, all we know of is life on Earth, we have yet to find even a little speck of life beyond Earth. But based on what we know from life on Earth and based on what we know about the other major sciences, physics, chemistry, geology, we can make the prediction that if the conditions are right, life should potentially arise beyond Earth.

Aside: To be an interplanetary alien hunter, it helps to have a background that's a bit interdisciplinary. Kevin, Dr. Hand, got his bachelor's from Dartmouth in physics, with a minor in astronomy, and studied some psychology in there as well; then went on to get a master's at Stanford in mechanical engineering with a focus on robots, and he continued on at Stanford for a PhD, and his dissertation was titled "On the physics and chemistry of the ice shell and subsurface ocean of Europa." It used Galileo spacecraft magnetometer data. More on that later. Now, the abstract for Kevin's dissertation uses

the term halophilic organisms, and yes I looked that shit up and halophilic means "I love me some salt" in science talk. So next time you single-handedly finish off the onion dip at a party, don't be ashamed. Just say, "I'm a halophile." Just own it, my salty bitches.

Alie: How did you start to get into this field, were you more of an astro nerd, or a biology nerd, or like an alien nerd? What was your history?

Kevin: I don't know. I'm a bit of an intellectual platypus in that I studied physics, and astronomy, and psychology in undergrad. Part of the rationale for the psychology was, well let's say we do get a signal from extraterrestrial intelligence; how do we, with our five senses, our senses that evolved under the conditions that planet Earth has presented us with... But from a captivation standpoint, my curiosity and my obsession with this question started at a young age and just looking up at the night sky,

Alie: Did you see *ET*, did you see *Alien*? There's no lack of aliens in pop culture. What's your flavor? What's your flavor of alien entertainment?

Kevin: Well, yeah, that's a broad question. So to your question of *ET*, as a young child, I grew up in a small town in Vermont and so the night sky captivated my imagination early on. It's hard to grow up under a clear night sky and not wonder what could be out there. So that coupled with Carl Sagan's *Cosmos*, both the TV series and books, and some great science teachers early on. Those were all big influences.

[*clip from Carl Sagan's Cosmos, episode 8: "The cosmos is rich beyond measure. The total number of stars in the universe is larger than all the grains of sand on all the beaches on the planet Earth."*]

And then, yeah, *ET*, *Close Encounters of the Third Kind*. Not only did I watch *ET*, but I also was ET for Halloween.

Alie: Nice! How many years in a row?

Kevin: Still going. Yeah. I haven't stopped, Alie, nope.

Alie: It's a tradition.

Kevin: As a kid, my mom sewed an ET outfit for me and oh, I just lived in that thing.

Alie: Yeah, that's the best. I can just imagine. They're like, "Kevin, it's February." "Shut up mom!"

Kevin: "Not taking it off!"

Aside: So when looking for alien life, real quick, let's get some stats out of the way. The Big Bang happened approximately 13.8 billion years ago (for more on that, see the two parter with cosmologist Dr. Katie Mack.) And Earth has been around for 4.5 billion years and there's evidence that life began on our planet at least 3.7 billion years ago,

maybe even over 4 billion years ago. Now, we are one itsy bitsy teeny weeny tiny tiny pale blue dot in the cosmos, but we know there are a lot of grains of sand out there. How many could have life?

This is where you just grab an envelope, and flip it over because it's time for the Drake Equation. Frank Drake, he's a round-faced man of 88 who looks like he could play a grandpa in an oatmeal commercial. He's one of the founders of SETI, and in their very first meeting in 1961 he busted out the Drake Equation, posing that the number of civilizations in our galaxy with which communication might be possible is based on – ready? A whole bunch of math!

Here we go – the rate of star formation, the fraction of those stars that even *have* planets, the number of planets per star in a habitable zone, and then the fraction that actually *do* develop life, then the fraction of those planets that have intelligent life or civilization, the fraction of those civilizations that make technology that can communicate their own existence into the universe, times the length of time they're beaming their "heeeyyy" into the cosmos.

So, this Drake Equation can come up with different outcomes that vary widely depending on your estimations for those factors but overwhelmingly, at the very most, our chances of being *alone* are 30%, based on some calculations last summer by some Oxford astrobiologists which included someone name Anders Sandburg, not to be confused with *Brooklyn 99*'s Andy Samberg. [*Andy Samberg sings: "Welcome to the Space Olympics, the year 3022…"*]

Anyway, that back of envelope deduction is called a Fermi problem. This was named after the Italian physicist Enrico Fermi, who's known for those equations like 'How many piano tuners are there in Chicago?' First you gotta figure out how many people are in Chicago, how many people have pianos, how many people need tuners, blah blah blah blah blah. Also, Fermi famously uttered what is now known as Fermi's Paradox, when discussing astrobiology over a summer luncheon in 1950. Discussing the seeming absence of aliens, he asked, informally, "Where is everybody?" [*"Where is everybody?" repeat with echo, then a kind of echoey collage of these bad boys:*

Star Trek's Captain Kirk
Buffy the Vampire Slayer's mom
Randall from This is
Marge Gunderson from Fargo
Lillian Kaushtupper from The Unbreakable Kimmy Schmidt]

Where is everybody, Fermi's Paradox, has become one of the smartest stupid questions ever asked. Now speaking of those questions, back to Kevin. When Kevin was an undergrad, he interned at the NASA Ames Research Center and he went to see his hero Frank Drake give a talk. I love this story….

Kevin: I was obsessed with this stuff since I was a little kid. I got to see Frank Drake give a talk and afterward, with a lot of trepidation I said, "Dr. Drake, um, I just had a little question

for ya. It's probably crazy, et cetera." and I said, "Yeah, so if we think about life on Earth, um, what do you think is going to be the next tool-using communicating organism?" He looked at me, and said, "That's not a crazy question. It's obviously going to be squirrels and raccoons." [*laughs*] MIND BLOWN! And he continued, he explained his rationale which is quite sound, which is that those creatures are coexisting with us right now and they are problem-solving.

Alie: Oh my god, this is going to delight my dad who has now constructed four squirrel houses on his property. It's like I am welcoming the next species.

Kevin: 100% and I like Frank's logic and… it's a fond memory that I have of my first interaction with a living, breathing scientist and, and to some extent having my, crazy obsession validated by his like, "No, great question! Raccoons and squirrels."

Alie: The BEST! Oh my god.

Aside: So, ask smart people stupid questions. Because they're great questions. Also hide your wallet from raccoons and don't tell any of your secrets to squirrels. (Dad.) Now, in his work, Kevin has traveled to all sorts of biomes but he says if you have the travel bug, you don't *have* to do astrobiology specifically to have fieldwork adventures: kinda any Earth science will get you out and about and also, there's a real need for folks who want to study geobiology, which is the study of microbes that eat rocks. Anyway, he loves to bop around for science.

Kevin: I grew up doing a lot of skiing, climbing, mountaineering, various things, and I've got to get out and see planet Earth. Exploring planet Earth is part of what grounds me, centers me, connects me back with the night sky, and helps reignite that curiosity and that passion for exploration and discovery. And so I feel very fortunate that I've been able to have some research programs where I've gone to Antarctica, made dives in submersibles to some hydrothermal vents in our ocean, gone up to the Arctic and explored icy environments up there. Yeah. So it's been amazing going to those places.

Alie: Now, what is a day in the life of an astrobiologist like? What does your work look like?

Kevin: There's many different layers to that. I'm a scientist at the Jet Propulsion Laboratory and part of the job of scientists at JPL is not only to do their own research and to publish papers, publish or perish, et cetera et cetera, write proposals and get in that hamster wheel of research. But we also are very engaged with the formulation and implementation of missions; missions to all sorts of different places. Small objects, big objects, nearby objects, far away objects. And for me, what that means is a focus on worlds in our solar system that could harbor life.

Alie: Ooh [*Alie doing her best theremin imitation*] Sorry, mouth theremin over here, couldn't help it. [*actual quiet, low pitched theremin*]

Kevin: I focus most of my time, both from a research standpoint and a mission standpoint on Jupiter's moon Europa. And to a slightly lesser extent, Saturn's moon Enceladus.

Alie: Why are we looking at moons so much rather than the planets?

Kevin: This has been one of the big game changers in astrobiology. I think people probably appreciate that an amazing revolution has happened in our understanding of planets existing beyond our own solar system. This goes back to the early 1990s when the first exoplanets were discovered. Fast forward to today and we've got both ground-based telescopic observations and spacecraft observations, Kepler being the most recent example, that have discovered thousands of exoplanets. So I think people are, for the most part, pretty familiar with the exoplanet revolution in the prospect for potentially habitable worlds.

Aside: Okay, in case you're like, "Remind me what Kepler was all about again?" This is a space telescope that NASA launched in 2009 and it flew around to determine the percentage of Earth-like planets out there. It weighed about 2,300 pounds and I did a bunch of comparisons size-wise and it was about as big as a HumVee. It scooted around taking dope-ass photos, observing 530,506 stars. It discovered 2,662 exoplanets, and after nine years – way beyond its expected lifetime – Kepler ran out of fuel.

Last fall, in 2018, it was deactivated with a "Good night" command sent from Mission Control. It's now just kicking it in space, millions of miles away, orbiting the sun, but its data helped astrobiologists conclude that there may be 11 billion Earth-like planets orbiting sun-like stars in the Milky Way galaxy. Eleven billion planets, in the Milky Way galaxy, a lot like Earth. Wha?!

Also, it was named after Johann Kepler, who in the 1600s was a contemporary of Tycho Brahe, the Danish astronomer who not only had a beer guzzling drunk pet moose that lived in his castle, but also had a metal nose after a sword fighting incident and who later died after his bladder exploded because he was too polite to go potty at a fancy dinner party. For more on that, see the Selenology moon episode. But anyway, Kepler changed the game in helping discover so many planets that could harbor life.

Kevin: The other big game changer in my opinion, has been what I like to call sort of a new Goldilocks.

Alie: Ooh. I think I see where this is going.

Kevin: In the early days of astronomy and planetary science and astrobiology, back in the 60s, 70s and 80s, when planetary scientists, astronomers, and exobiologists thought about what it takes for a world to be habitable, that framework was largely based on our Earth biases. Wherever we look and find liquid water on Earth, we generally find life. Therefore, you need liquid water for life. And in order for a planet to harbor liquid water, you've got to have liquid water on the surface in contact with a nice thick atmosphere.

And for a planet to be able to sustain those kinds of conditions, you have to be at just the right distance from your parent star so that you're not too hot or not too cold. If you're too close to your parent star like Venus is, then you're too hot, and you probably boiled

off any ocean that you once had. If you're too far away like Mars, maybe some of the water froze out, you lost much of your water to space. But if you're at the Earth-Sun distance, then you're in that sort of Goldilocks sweet spot. [*male voice with plenty of vocal fry reads from Goldilocks: "And it was neither too hot nor too cold; it was just right."*]

And you can have liquid water on the surface of your planet. And potentially it's off to the races from a biology standpoint. That Goldilocks scenario has kind of been the paradigm. What we've learned in the past few decades, and this was largely informed by the Voyager spacecraft, and then the Galileo spacecraft, and then the Cassini spacecraft that went into the outer solar system…

Aside: Let's do a rapid rundown of these spacecrafts for your next pub trivia victory:

Voyager 1 & 2 are a set of twin spacecrafts launched in 1977. They explored all the giant planets of our outer solar system. We're talkin' Jupiter, Saturn, Uranus and Neptune; 48 of their moons; plus a bunch of planetary rings and some magnetic fields. As of November 5th, 2018, both are now exploring interstellar space, between 11 and 13 billion miles away. NASA/JPL's website has a constantly updated ticker of their location, which is kind of like Find My Friends but for 40-year-old very famous and respected spacecraft.

Now, Galileo was launched 1989, it got to Jupiter in 1995, and orbited the Jovian (aka Jupiterian) system. It did 11 flybys of Jupiter's moon Europa during this outer space stint. It went from 1989 to 2003.

Now, Cassini was launched in 1997. This was all about Saturn, and it entered Saturn's orbit in 2004 and did two flybys of Venus, saw a cool asteroid, checked out Jupiter, and it also deployed a lander on Titan, which is one of Saturn's moons, in 2005, and then we crashed and burned it on purpose in September 2017.

Okay, so moons. Europa is one of Jupiter's. Titan is one of Saturn's. If you already knew that, awesome. Here's something you may not know: In Scotland, it is illegal to walk a pig on a leash.

Kevin: ... is that these moons of the outer solar system are presenting us with a new Goldilocks scenario. It's a Goldilocks scenario where the energy to maintain and sustain liquid water comes not from the energy of your parent star, but rather from the energy of tides, the tug and pull that these moons experience as they go around their gas giants or their ice giants. The Jovian system, the moons of Jupiter, are great example of this. There are four large moons, Io, Europa, Ganymede, and Callisto. Io does not have an ocean. Io doesn't really have any water. Io orbits Jupiter and Io is tugged to such a great degree that it is the most volcanically active body in our solar system – more volcanically active than the earth. There are volcanoes erupting on Io right now.

Alie: Oh, that's cool.

Kevin: Yeah. It's just a beautiful, beautiful gem of a world and it really does kind of look like a gemstone when you look at these pictures.

Alie: My god! It's a lava party happening so far away.

Kevin: It is, break out the popcorn and just watch.

Alie: Spring break on Io!

Kevin: And so, in this new Goldilocks paradigm, Io is kind of like Venus. It's got too much tidal energy. It's too close. Venus is too close, too warm. Io has got too much tidal activity. Let's go to the further up, furthest out of the large moons: Callisto. We think it does have an ocean trapped beneath a very thick ice shell. But Callisto has very little tidal energy dissipation going on in it. So in that scenario, Callisto is kind of like Mars. It maybe doesn't have quite enough energy to really make it an ocean that we could explore and think could sustain life today. But in the middle, we've got Europa and Ganymede. Europa in particular we think occupies this new Goldilocks sweet spot where it's got just the right amount of tidal energy dissipation so as to sustain a global salty liquid water ocean that's 100 kilometers or 60 miles in depth.

Alie: Oh my god.

Kevin: Yeah, that's the right response.

Alie: How deep are our oceans?

Kevin: It's about ten times as deep as our oceans.

Alie: Holy smokes! The octopods they must have.

Kevin: So in the Mariana trench we're about seven miles deep, 11 kilometers down. Europa's ocean is 10 times as deep.

Aside: Our oceans are seven or so miles deep, but where did the water come from? Kevin says there are two sources: Water from the rocks from which Earth itself formed and then there's what they call water that's *exotic* in its delivery, so coming from comets or asteroids. This is like Postmates but a dirty ball of frozen space ocean. Ding dong! I'll get it!

Kevin: Water elsewhere in the solar system was delivered to the earth. And when it comes to finding water elsewhere, we now know that it exists not just on Earth but also on our moon and these various asteroids, comets, the moons of the outer solar system, in the permafrost of Mars. There's a lot of water out there. I should be clear, when I say water, I'm not differentiating for the most part, I'm referring to water in ice form, right? When we get to Europa and the ocean worlds, there we are talking about water in the liquid phase.

Alie: Slushy sloshy waters, what a lot of scientists call it, just in case you need to use that in a meeting.

Aside: So there's plenty of water on Jupiter's moon Europa, both in ice and liquid form. And it's deeeep. Could extraterrestrials be lurking in those deep dark waters?

Kevin: Europa's small, it's about the size of our moon. Europa has about one seventh of the earth's gravity. So when you do the math, the pressure within Europa's ocean, it's comparable to the pressure found within the deepest trenches of our ocean. And so when we think about, "Well, you know, could life survive within Europa's ocean?", we can actually do the experiment and look at places on planet Earth where the conditions are comparable and say, "Oh wow, life found a way in that environment that has parameters similar to Europa's ocean or Enceladus's ocean," and so on and so forth.

[*clip from Jurassic Park: founder John Hammond, "Life will find a way, as you once so eloquently put it"*]

And we can make that sort of biological plausibility connection.

Aside: Kevin says that they analyze magnetometer data to figure out what's creating the gravity fields on those worlds and with a lot of whiteboard number crunching came to the conclusion that Europa is encrusted in ice with liquid, salty water below it. But how thick is that magic shell of ice? Most of his colleagues would say, "Oh, like 20 kilometers thick," but he's in the minority and thinks it's quite a bit thinner, perhaps less than 10 kilometers thick.

So when do we get to bore into it like an icy coconut? Well, NASA is planning to launch the orbiting space probe – that's called the Europa Clipper – in about 2022, and that's gonna take a bunch of sassy photos and determine some chemical composition, setting the stage for a chilly, icy Europa landing by 2030. What do we call this lander? Well, Kevin kicked around the nickname Europa Landing Probe for Surface Astrobiology or ELSA.

[*clip from Frozen: Elsa sings, "The cold never bothered me anyway*]

How will they bust through this ice? This isn't a crème brûlée. At JPL they're prototyping these robotic arms and drills and saws and sampling systems, and some of the oceanic diving technology that they're tinkering with has a win-win bonus: because it's making waves in our own undersea exploration for this little planet we call Earth.

Alie: And now, Europa, is that where we're really looking in terms of searching for something alive? Is that really where… All eyes are kind of on Europa?

Kevin: Well, I love to highlight three prime ocean world candidates – Europa, Enceladus and Titan. Let me talk about Titan briefly first and we can come back to it. Titan is just an amazing world with this atmosphere in liquid methane, ethane, lakes carving out its icy

surface and there's a liquid water ocean beneath its ice crust. And from the standpoint of astrobiology, Titan is my favorite place to go and look for weird life.

Aside: [*theremin style "Haaaay"*]

Kevin: And what I mean by weird life is life unlike life as we know it. Life as we know it is based on liquid water as the solvent, the substance in which the chemical reactions of life take place, and those chemical reactions and the building blocks are of course based on carbon. We are a carbon and water-based life form. On Titan life would potentially also be carbon based, but the solvent might be liquid methane and ethane in those lakes that we see on Titan.

Alie: Oh my god.

Kevin: Could the business of life get done? Could life originate? Is there a weird life form that could arise in those lakes and seas? I don't know, but I'd sure love to get there and explore. And then Titan could of course, within its liquid water ocean beneath its icy shell, harbor water and carbon-based life similar to what we know and love here on Earth.

Alie: How flammable is it there? Like if you're made of methane and ethane...

Kevin: Can you start Titan on fire? The short answer is no because, in order to light something on fire, what do you need?

Alie: Oxygen.

Kevin: Yes. And Titan's atmosphere has basically no oxygen. And that actually is one of the limiting factors for me when I think about the feasibility life on Titan.

Aside: Okay so back to general habitability. Kevin says liquid water is one of the keystones. What else is on our intergalactic shopping list?

Kevin: The other keystones for life are that you need the building blocks, the stuff that life is made of, the bricks and mortar. For us, that's carbon, hydrogen, oxygen, nitrogen, a smattering of some 54 elements from the periodic table. And then the third, kind of, lesser appreciated keystone is: life needs energy. It needs a power source. It needs something that can sustain the growth, and reproduction, and the maintenance of life. Technically we call that the 'redox gradients' that life harnesses. You bring together a reductant, a compound that likes to give up electrons, with an oxidant that likes to accept electrons. And for us, we *Homo sapiens*, that redox reaction is eat some carbohydrates, eat some food, and breathe in oxygen. And then we do a slow burn in our stomachs. We're a glorified campfire, and so we're doing a slow burn with our redox chemistry, inside our bodies.

Aside: So next time you're eating fistfuls of cookie dough, just holler, "I'm redoxing!" Microbes, however, can vary quite a bit and have all kinds of metabolic

pathways. So by studying how they do it at the bottom of trenches, and in the arctic, and next to volcanoes we can try to determine how those little *bebehs* on other planets and moons might go about their business of eating, and farting, and pooping, and mating, as it were. Now, on some moons, that may be easier to envision than on others, Kevin explains.

Kevin: And I think that for Enceladus and Europa, there probably is some redox chemistry, a reductant-oxygen coupling that microbes could harness potentially quite easily. On Titan, the chemical story there for redox pairing is a little more complicated than… But we've got to go. We've got to explore. We've got to get out there and just see, because biology doesn't care what our hypotheses are, it's just going to… if it can take hold it will.

Alie: And do you think in terms of alien life… Well, number one, let me ask this: Is it correct to call alien life, alien life? Extraterrestrials? I mean, aren't *we* aliens as soon as we go to Europa? So why are they the aliens? What's the proper terminology?

Kevin: [*laughs*]Yes, frame of reference is important in all of these endeavors. If you're an intelligent octopus on Europa and our spacecraft lands there, then to them, we of course are the aliens, right?

Alie: Isn't it weird that we're aliens to someone else right now?

Kevin: I love it. Let's just hope we play that *Close Encounters* music, bom, bom. [*iconic five-note motif from Close Encounters*]

Alie: And so do you think that when we find life...

Kevin: Whoa, whoa, whoa, whoa. Let's dive into that a little bit more, but go ahead and say *when*.

Alie: Do you think we will find teeny tiny critters or do you think we'll find crazy, translucent mammoths? What do you think we might find?

Kevin: A lot to kind of unpack in there.

Alie: I know.

Kevin: But first let's change that *when* to *if*, and that's important, because both outcomes are incredibly profound. I certainly am excited about the prospect of discovering life elsewhere. And that's in part because, at a more philosophical and human level, and taking off my science brain, biology is beautiful. I love lifeforms and seeing how life works. I'm excited by the prospect of biology being out there and different ecosystems, different planets. So I do hope it is a when, but there again, the universe doesn't care what we want.

It could be that life and the origin of life is a singularity. It's only occurred here on Earth. And we are the first and only instance of it. And so if we do go out and explore and we don't find life elsewhere, that also is pretty profound because that means that life is rare. And it also puts an even bigger onus on us to take care of the only life we know. We of course have to do that even if we do discover life elsewhere. But…

Alie: But isn't it kind of like if you're looking for your cell phone and you're like, "Well, I checked my purse, it's not there. My cell phone doesn't exist." And meanwhile, you're like, "Your cell phone could be anywhere!" Like if we go check places… there's an infinite number of places we would have to check.

Kevin: 100%. You'll almost never prove a *no* result. Right. But let's come back to the other part of your question. Were we to find it, would it be small, would it be large, microbial, more complex? And this helps me sort of triangulate on one of the aspects of the exploration of ocean worlds like Europa, Enceladus, and Titan that I think is particularly important. And that is that I'm really motivated by the prospect of finding what we call *extant* life as opposed to *extinc*t life. In other words, life that is alive today, life that we could see and study and understand how it works.

And the reason for that is because I'm, in large part, interested in the question of: is the origin of life easy or hard? Is there a second origin of life in our own backyard here in the solar system? And the reason for that is because if we discover life in our own backyard, if we discover a second origin of life, one that was not seeded by life on Earth, that means that the origin of life is probably easy. Life arises wherever the conditions are right, and we potentially live in a biological universe. So, looking out at all those exoplanets and everything and saying, "Okay, there's a decent chance that since we found two independent instances of life in our own solar system, the origin of life probably proceeds in many different places."

Aside: So, we're looking for life in our backyard, i.e. our own solar system, because if it arose on its own it would prove that life might be easy, and the universe might be filled with critters. And if it's still alive, or extant, as opposed to fossilized, we could find out if the building blocks and genetic code involving DNA, and RNA, and the whole business of ATP is, as Kevin says: *not* the only game in town. Is there another system besides DNA and RNA? This is like asking, are there other restaurants in your neighborhood? Are they doing good business? Are they busy? Also, are they pizza places or it is something totally different, like acai bowls? Now, would Kevin care about, say, a shuttered and abandoned restaurant, like for example, extinct life on Mars?

Kevin: I love Mars. I do some work on Mars, um…

Alie: I'm sensing there's going to be a 'however' or a 'but' coming up, like you're breaking up with Mars right now. Mars, I love you, but...

Kevin: Mars is absolutely fantastic. There could be extant life on Mars in the subsurface of Mars and I hope we explore Mars in that context. But right now, our Mars exploration program is primarily focused on the past habitability of Mars. And that's for very good

reason. You look at the geologic and geochemical history of Mars, and we see that three and a half billion years ago, it had flowing water, rivers, lakes, perhaps even vast oceans, that would have been potentially very Earthlike and great places for life as we know it to have existed and thrived.

Aside: Buuuuuuut? [*repeated, distorted to low pitch*] Buuuuut?

Kevin: Now, today for example, the Mars Curiosity rover is making its way up Mount Sharp in Gale Crater, and tomorrow it could turn a corner and see stromatolites. Stromatolites are textures in rocks that can often be traced back to microbial mats, microbes that have worked in a consortia and perhaps lived three and a half billion years ago and left behind their, sort of, microbial fossil. That would be astonishing! That would be a game changer. Like, we'd be jumping up and down. I'd be super excited about that.

But there are some limitations. We can't drill into a stromatolite on Mars and search for DNA. We can't do that on planet Earth. DNA, the large biomolecules of life, do not last long in the rock record. So then we find ourselves at a crossroads. Are these stromatolites from a rock on Mars, are they evidence of an independent origin of life on Mars billions of years ago? Or are they evidence of life on Earth that was transported to Mars, hitchhiked on some ejecta from an asteroid impact, which then seeded life on Mars or vice versa? Or was life on Earth seeded by this ancient stromatolite life form on Mars and then came here? Earth and Mars have got a long-standing relationship of trading material.

Alie: Let's say, turn a corner, they find a dancing Martian, and it's like, "Surprise! I was waiting for you to get here. Where have you been?" It's got maybe a CamelBak full of water. It's good. Do you think the government would tell us? How soon before, like, a lay person would know?

Kevin: Now you're trying to get the real secrets out of me, Alie!

Aside: Listen, I'm asking the questions I *know* that you have. I know you're wondering this!

Alie: But like how soon would that come out, because that would be something that would rock every society on Earth, to find out that there are aliens. Right? People would freak out.

Kevin: If it was a little marching Martian. Yes. That would freak everybody out. Absolutely. But let's be clear, there's historical precedent for exactly this. The ALH84001 meteorite? The Mars meteorite. The Allan Hills meteorite, that landed in Antarctica, and was studied, and could be determined to have come from Mars back in the late '90s. And this actually helped catalyze and then initiate much of the current field of astrobiology. Back in the late '90s, there was a big press release and publications about a set of evidence from studies of that asteroid, or that meteorite, that have pointed to past life on Mars.

Alie: Holy smokes!

Kevin: Yep. Bill Clinton got up and said, “Hey, look at this! How amazing is this?”

[*clip from YouTube video, President Bill Clinton: “This discovery is confirmed. It will surely be one of the most stunning insights into our universe that science has ever uncovered.”*]

Kevin: Great job, NASA! And it was incredibly exciting for NASA and the community. Now granted, that was a meteorite that landed on Earth. It wasn't a little Martian waving to Curiosity, but even that Martian meteorite created a tremendous amount of excitement. Fast forward to today... And just to make sure that I put a cap on the Mars meteorite story, most scientists who studied that meteorite think that probably what was seen in that meteorite was contamination from organics on Earth and potentially microbes on Earth.

Alie: Dangit. [*Price is Right loser horns*]

Kevin: Back to your question, if a spacecraft visiting another world such as the spacecraft on Mars, or a spacecraft going to Europa, or a spacecraft going to Enceladus or Titan, if it did find obvious evidence… if biology on those worlds was very generous and made itself readily apparent, that would just be phenomenal! I hope that everybody would be thrilled and excited. I often get asked, “Well, what then? What good is that? Why should we be spending money on this?”

It's like, yeah, that discovery, it's not going to change the way you make your coffee in the morning. It's not going to shorten your commute. But it really would mark the beginning of a new understanding, a new revolution in how we think about biology, the science of biology and the stuff that is us, the phenomenon of life, our very phenomenon.

And it's also very exciting in terms of the time in which we live. Galileo couldn't send a spacecraft to Mars to search for evidence of life on Mars, or to Europa, or Enceladus, or Titan, or any of these other places. For the first time in the history of humanity, we have the tools and technology to do this last great experiment to see whether or not biology and the phenomenon of life works beyond Earth. So let's get it done. You know, I'd love to get out there.

Aside: So when you think of aaaallliens, just slow your roll. Start small. Maybe think of some goofy little blorp bleep microbes instead of, you know, what we all think about when we talk extraterrestrials: [*sped up and mouse-pitched*] Why are they always naked?

Alie: Why do you think we have such iconic imagery of these grey aliens with big heads? Where do you think these kind of stories are coming from? Because when we expect to see aliens, why do you think we expect to see these particular visions?

Kevin: Yeah. I don't have a good succinct answer to that. I think really at the heart of it reveals some of our own anthropocentric bias. I'm a tremendous fan of what *Arrival* did in thinking about life forms that would evolve in much different environments. But I think

the whole phenomenon of aliens, UFOs, et cetera, that kind of stuff, it is interesting. Historically if you look at William James, the varieties of religious experience...

Aside: Dr. William James was a Victorian era psychologist who believed in ghosts and telepathy, but who thought that religious experiences can come in all shapes and sizes, from what I gather. Now, this dead psychologist Dr. William James is not to be confused with the alive ufolgist Dr. William J… Birnes, who is the editor of *UFO Magazine* and believes that, like an influencer wielding Facetune, NASA airbrushes extraterrestrials out of photos all the time. Anyway, theories have been simmering for centuries.

Kevin: … and the different kinds of experience people had centuries ago that they ascribed to divine intervention, et cetera, et cetera. I think some of those same psychological phenomenon also inform the experiences that people have when they think that they've experienced something with alien lifeforms, abductions, and all those things. I'm by no means a specialist in that. But there again, my interest in psychology has sent me down those roads many times.

Aside: How many people in the US believe in aliens? A 2017 poll showed that nearly half did, but a slim 16% had reported seeing a UFO. Now, among the believers: Kesha, Nick Jonas, that lady from The Nanny, Kacey Musgraves, Russell Crowe, Kendall Jenner, and Demi Lovato, who, if nothing else, has admirable conviction.

[*a very earnest Demi Lovato on Late Night with Seth Meyers: "I believe that there could possibly be mermaids, which is actually an alien species that lives in parts of the Indian Ocean which we have never explored before as human beings."*]

And also Tom Cruise, but, duh. So now Kevin, remember, was a researcher at SETI, listening for signals. Now, I found one very sketchy article claiming that a bunch of astronauts have reported that the skies above us are just a traffic jam of flying saucers and there's an alien space station on the moon, but even supposing all of that is true, how would we communicate? Charades?

Alie: When it comes to trying to, say, read signals from other planets, other civilizations, how do we know that we will have the right antenna to pick it up?

Kevin: We don't, and so it's a great question. And my friends and colleagues at the SETI Institute obsess over that kind of question. Even within the frequency space of our radio search, there's still so much to explore. Frank Drake, and Jill Tarter, and Seth Shostak, and Dan Wertheimer and others have focused in, throughout the years, on particular wavelengths, where the cosmos itself is quiet and it would make for a good broadcast and transmission in the radio part of the spectrum. But then another colleague of mine, Andrew Howard – who's now at Caltech – and his advisor at Harvard, Paul Horowitz, they were some big innovators on optical SETI.

If you think about an advanced civilization… Think about the center of the Milky Way Galaxy. I hope the center of the Milky Way galaxy is like… Well, okay, let's put this in

context. We are in the boondocks of the Milky Way. We're eight and a half kiloparsecs out. Suffice to say that's a long ways out from the galactic bulge.

Aside: That's right. The densely packed cluster of stars at the center of a spiral galaxy is called a galactic bulge. Someone *please* go as one for Halloween. It's March. It's not too late to get started on a luminous, starry codpiece and some twinkling, spirally arms.

Kevin: I hope that the center of the galaxy is teeming with life and we've got advanced civilizations in there. They're darting back and forth in there. There's a galactic internet, the modern version of what Carl Sagan used to like to call the Encyclopedia Galactica. I hope that is happening right now in the center of our galaxy.

Those civilizations would probably communicate with laser beams, with optical beams directed star to star, planet to planet, spacecraft to spacecraft, et cetera. It's just more efficient to send transmissions that way. And so one of the ways that SETI researchers are now looking for signals from advanced civilizations is looking for those nanosecond pulses in the, sort of, visible part of the light spectrum, which so far, nothing but there's still so much to search.

Alie: There could be aliens sending lasergrams right now? Like, "Party! Party at my moon tonight!"

Kevin: Exactly.

Alie: Okay. I'm going to pose a theory. You can use this in a paper if you want to. It's fine. Just credit me. But what if dark matter, dark energy is just full of ghosts and aliens.

Kevin: Yup. That's, that's beyond my pay grade. [*laughs*]

Alie: We don't know exactly what it is… What if it's lousy with ghosts and aliens?

Kevin: Right. Yes. And to that I say: we are the 4%. Right. Everything that we see, we know and love is 4% of the known universe. And actually I think it's closer to 1% when you actually consider the particles with which we interact.

Alie: If you're going to use it in a TED talk, it's fine. Just put a slide that says thank you.

Okay. Are you ready for some Patreon questions?

Kevin: Sure!

Aside: But before we get to listener questions from Patreon, a quick word from our sponsors, who have allowed me to raise the pay of the folks who help me make *Ologies* and also let me donate to a cause of the Ologist's choosing. This week. Dr. Kevin Peter Hand chose to support the work of Traveling Telescope. This is a cause started by Susan Marubona and her husband Chu and colleagues, to share astronomy with schoolkids

and the general public in Kenya. They say they, “regularly visit both government and private schools, and expose students to a variety of astronomy tools and concepts. Giving the students practical, hands-on experience with astronomy is important if we are to inspire young people to be the scientists of tomorrow.” So that is Traveling Telescope and there will be a link in the show notes if you want to know more about them.

Now, an additional donation this week was made to Vermont’s Manchester Rescue Squad in memory of Peter Hand, Kevin’s father, who passed away last summer. The Manchester Rescue Squad provides 24 hour/365 paramedic-level emergency care via paid staff and volunteers. They also do CPR and First Aid classes. So on behalf of all the Ologites, our heart goes out to the Hands.

[*Ad Break*]

All right, your questions.

Alie: Patreon questions. We got a gazillion.

Kevin: I’ll do what I can.

Alie: It's kind of a lightning round. Shoot from the hip. I categorized them as best I could. Okay. Jasmine Wells, Vincent, Madi Worker and Mike Marlow all want to know: As a firm believer of other forms of life, what's the most probable planet for alien life to exist on? Like, what are the most likely places? Europa, Titan?

Kevin: Mars is fantastic. Mars is still a wonderful place to look for evidence of past life and potentially life that's alive today. We'll just have to dig a lot deeper. So I put Mars, Europa, Enceladus, and Titan. And when it comes to the search for extant life, I really prioritize Europa and Enceladus for extant life similar to life as we know it. And then if we go one layer deeper, I prioritize Europa over Enceladus for a couple of different reasons.

Europa, we have good reason to predict, has had an ocean for the history of the solar system. So, it's an ocean that's been around for a while. Enceladus, there's still some question marks. The reason Saturn has rings is because some sort of collision, some sort of impact event happened in the neighborhood of the moons of Saturn in the past tens to hundreds of millions of years ago.

Aside: Remember Enceladus, one of Saturn’s moons? Kevin says that Saturn has had some draaaama in the last tens of billions of years.

Kevin: So did Enceladus form from that? Is its ocean relatively young? We don't know.

Alie: Will those rings glom together to form moons eventually?

Kevin: Well, a bunch of it will go into Saturn, and a bunch of it will sort of drift in the other direction further out, and stuff will continue to glom onto the existing moons. And so yeah, it's going to continue to be a bit of a pinball game out there in the Saturnian system.

Alie: So many people had the same question and I'm going to say all of their names right now. Elizabeth Gabel, Xuan Wei, Renee Coley, Mads Clement, Moses Bibi, Devon Robertson, Dionne Dabelow, Anthony Stull ...

Aside: Also Lani Bouwer, Nathan Ahlgrim, Theodore Vician, Zineera Seth, Sarah Clark, Jack Gavin, Jordan Werme, Lauren Paul, Erica Kane and...

Alie: Tone Rossow all asked: Is there already non-carbon-based life on Earth? What is the possibility of extraterrestrial non-carbon-based life? Could it be silicon-based? Is that possible? What would that look like?

Kevin: It's a great question, one that I definitely ponder, one that I don't necessarily have a good answer to. What we know of life so far is that life needs a good balance between larger information molecules that can, you know, store the software. For us that's DNA obviously. You need those molecules to be made of elements that can bond together and are stable, but you don't want those molecules to be too stable because you got to tear them apart and translate them and figure out what they're saying. And then the RNA and the worker bees of life as we know it, has to go off and build the proteins and make the business of life.

So from a feasibility of life using other things like silicon, et cetera, every time I go down this road, it's like, gosh darn it. Carbon is just such a good element for, not just bonding with itself and bonding with other elements and forming long molecules, it's also really good, albeit, at temperatures and pressures that are found here on Earth and, frankly, many of the other planets. It's also really good at forming molecules that occupy that nice sweet spot of 'you can be large and stable but not so stable that you can't be broken apart and replicated or metabolized and stuff'.

And all you gotta do is look at the rocks on Earth. The rocks on Earth are made of strings of silicon. The silicates, the silicon link to four oxygen atoms and then various metals bounded in there. You know, if silicon-based life could have evolved on Earth, it had plenty of opportunity. So water and carbon-based life, it's a pretty darn good solution. Using the word solution appropriately.

Alie: [*laughs*] A rock-solid pun there. [*ba-dum-TSH!*]

Kevin: But I would love nothing more than to go to a world like Titan or see some big mothership in the sky that comes down with silicon-based life. And keep in mind of course that silicon-based life could be the future of life as we know it. When we think about our mushy bags of water and carbon, a silicon-based life that we then create and advance could obviously have a much greater staying power galactically than the carbon-and water-based life.

Aside: So that's like a [*slowed down, distorted*] maaaybe?

Kevin: It's a great question and I love to think about it. But every time I go down the rabbit hole of chemical feasibility, carbon pops its head up, "Oh yeah, you think you can beat me?" [*laughs*]

Alie: Carbon's like, "Yeah, I got this in the bag."

Kevin: Exactly. I think that's exciting to see that your audience is interested in that question.

Alie: Other people had questions about the oceans. Trying to settle the debate, Oceana Rhyse asks: Are deep sea creatures aliens? I think they are. And also are we looking at the deep sea to provide any clues of what could exist on other planets?

Kevin: Great questions. The first one is, as alien as they are - and I've gotten to see some of them up close - and as astonishing and beautiful and bizarre as they are, they are very well connected into our tree of life. They are based on DNA and RNA in the ATP paradigm, with proteins, et cetera. So yeah, they are not different from life as we know it.

Are we looking at our own oceans to see whether or not our search for life elsewhere can be informed by life that works in these deep ocean environments? The answer is, absolutely. And it's something that I'm very passionate about and I've been fortunate to be able to take part in some of that exploration and science.

The depths of our trenches, the Mariana Trench, the New Britain Trench, the Japan Trench, all these places that are in what we call the Hadal Depths, deeper than six kilometers down in our own ocean. Those environments are incredibly poorly explored. There's so much great work yet to be done. And from an astrobiology standpoint, they offer a great bridge for learning about the environmental conditions that could affect the habitability of these distant worlds. It's entirely plausible that we could go to a world like Europa or Enceladus and discover that it has the right liquid water, chemical conditions, et cetera. It is "habitable" but not inhabited. And that could be because the origin of life is a bottleneck. The origin of life could be quite hard. So, going to these deep ocean environments, going to places on Earth that serve as analogs for the conditions that we might find elsewhere is part of NASA's astrobiology program.

Alie: All right. I'm going to keep blazing through these. Ready? Sophia Garbos, great question: Do you think 'they' have been here and left? What are the chances? Have aliens been here and bounced?

Kevin: I don't know. If they came and went, they haven't left so much as a paperclip. And as a scientist I need hard evidence. So as much as I have read anecdotes and [*DJ airhorns to the tune of X-Files theme*] want to believe, to use the X-Files… At the end of the day, gimme an alien paperclip or as they say, "Bring back a fork from the mothership."

[*clip from The Little Mermaid. Ariel hands Scuttle the seagull a fork: "What is it?" she asks in wonder. "It's a dinglehopper!" he replies*]

Alie: That brings me to someone... Two people had the same question. Sophie Cousineau and Heather Shaver wanted to know: Are you more of a Mulder or a Scully? Are you in the Mulder fan cult?

Kevin: I just, yeah. I'm the hybridized love child of the two of them.

Alie: Both of their DNAs combined into a carbon-based waterbag known as you. Justin Griggs and Kacie Wight, first time question askers, wanted to know: What's the coolest gadget we currently have? And if you were given unlimited funds, what kind of imaging or radio equipment would you use?

Kevin: Well that's a really interesting question. Layered into that question is that when we think about the search for life elsewhere and actually doing those experiments… and this is what I spend much of my day's doing. I'm the pre-project scientist for the Europa Lander mission concept. This is a mission that is far from green lit. Our team of scientists and engineers has been working on this for many years. NASA currently has a mission going to Jupiter to study Europa. That's the Europa Clipper mission. It's a mission that will fly by Europa and do remote sensing, look as it makes those flybys, to take images, do spectroscopy, do ice-penetrating radar studies, it's an absolutely amazing mission and the data is going to be incredible.

I'm a co-investigator on that mission. And hopefully someday following on that mission, we can put a landed vehicle on the surface to dig up some material and look directly for signs of life, use a microscope to look for morphologic indicators, little cells if they exist. Use things like mass spectrometry or infrared or Raman spectroscopy, to look for organics and other things.

And so to your listener's question, in the biotech world here on Earth, we've made tons of progress in sequencing DNA, and 23andMe, and all this stuff. But when I think about a payload for exploring a world like Europa, we can't use DNA-based analytical systems because then we might miss life even if it's carbon- and water-based. It may well not be DNA-based. It would be really interesting if it was because that would set the stage for some evolutionary debates and convergence versus contingency and DNA arising independently more than once.

Aside: I think what this means is, would DNA appearing in extraterrestrial organisms be total chance, or developed because circumstances kind of steered evolution toward that efficient coding formation again? Who the hell knows, people? Literally no one. At least on this planet… Well, maybe Kesha knows. [*Kesha, her voice sped up to chipmunk velocity, sings: "Let's make the most of the night like we're gonna die young"*]

Kevin: But we certainly don't want our instrumentation and our measurements to require that life form to be based on DNA.

Alie: Right. It's like taking a VCR somewhere. Yeah. They got laser discs.

Kevin: Great. Great analogy to do that. Exactly. Yeah. And that's important to appreciate with a lot of the biotech, they're feeding into that instrumentation, our primers that latch onto DNA in different ways. And so, yeah, it's like a VCR.

Alie: You got a thumb drive in an eight track. What the hell you gonna do???

Kevin: Exactly.

Alie: A lot of people, including Lauren Murray, Sarah Clark, Timothy Dykes, Joe O'Bannon, Jane Joy, Jenni Hoover, Jeffrey Katz, all kind of wanted to know, in Jeffrey Katz's words: Do you think intelligent aliens would look somewhat like us? As we evolved, some things seemed efficient, like bilateral symmetry for extremities, to use to manipulate tools. Are they going to look like us?

Kevin: Instead of answering the question, will alien life look like us, I like to do the experiment of what if we re-ran life on Earth again, would we end up with *Homo sapiens*? You can look at different convergent and contingent events in evolutionary history. Obviously one that's great to examine is the impact event that extinguished the dinosaurs. What if that didn't happen? Would the dinosaurs have evolved into intelligent communicating creatures with useful thumbs and all that? And *Star Trek* certainly has examined those kinds of scenarios.

I think there's a case to be made that early on in the evolution of intelligence, if you do not figure out how to use tools, and how to build shelters, and how to propagate information beyond the single generational timescale. In other words, the printing press, the Internet and all of these things. If you don't develop that relatively quickly, you will become extinct just by the nature of the fact that the cosmos is full of hazards. And eventually a large impact event will wipe you out. [*a female voice very politely says "Kaboom" and "No thank you"*]

Kevin: Fast forward to us and now clearly *we* are at an inflection point.

Alie: Yes!

Kevin: We're messing up the home planet. Climate change is going gangbusters and planet Earth is saying, "Hey, we're going to shut down this subsystem." Our life support system is being challenged by our own existence. Coupled with that, we could still have an impact from outer space that wipes us out. And so in my opinion, the clock is ticking on us to get some real intelligence and learn how to be a longer-lived species.

If we re-ran the clock, would you end up with bilateral symmetry? I think yes. Would you end up with eyes? I think yes. You can look at the evolution of eyes and it's occurred some 50 or more times in different organisms on Earth. Obviously, photo sensing makes a lot of sense. The senses that we have, smell and taste, are variations on chemical sensors, and that's very useful. I get intrigued by some of the sensory modalities that are

not as ubiquitous; sensing the polarization of light as bees do; sensing magnetic fields; echo location as obviously bats, and dolphins, and other creatures do. Is there a world in which those sensory modalities become more prevalent in the primary biological paradigm of a planet, perhaps?

Alie: Ooh, yeah. Who knows what an ultrasound antenna would look like?

Kevin: Well, and that in part goes to *Arrival*, and the way in which those creatures communicated through sound and the circular, timeless inkblots.

Aside: From ink blots to… the Great Filter. Several listeners, including Dionne Dabelow, Tyler Q, Donald McLeod, Christopher Barley, and Katie Boyd, asked about the Great Filter, which is the notion that the reason we've got radio silence from extraterrestrials is that our kind of advanced civilizations are either a one off, just us, or they die out before they're capable of communicating with one another. Kevin says that if we make it through our own population growth and carelessness with the planet and aren't just randomly boned by a space rock, there *is* the prospect of finding another civilization if a signal is out there. But, he says, on the flip side:

Kevin: I'm sure many of your listeners have probably read *The Three Body Problem* and that trilogy, which is a fantastic trilogy and the second book called *The Dark Forest*, which really gets into the question of, do you actually want to reach out and make contact? Is that a safe thing to do? And I think that's a very important question to ponder. From a transmission standpoint, do you really want to transmit? I don't think I have a clear answer right now. I've got thoughts on both. Yes and no for transmitting, but short of that we can certainly do a heck of a lot more listening. That is something that I advocate for and hope we do more of.

Aside: So it's like texting your ex versus just lurking on their Twitter late at night. [*drunk sounding female voice slurs "I read it!"*]

Alie: A few people asked, Christopher Barley, Lale Stefkova, and first-time question-asker Rebecca Leigh Richardson: Does the Fermi Paradox make you sad?

Kevin: The Fermi Paradox make me sad? Like where are they and why haven't we found them yet? Yeah. In some ways it does. To the extent that it makes your listener sad, I sympathize. But, people like Jill Tarter and the folks up at the SETI Institute serve as great inspiration. And when we talk to them about this stuff, I was like, "Well, we just… we really have not listened to enough. We haven't looked." We know where to look. We just have not yet had time or the computing power to really search the haystack for the needle. So we've got to keep searching.

Alie: Keep working. You're employed forever. Okay, one last question from listeners. Great question, asked by Joe Porfido as well as Chris Baumann, Danny Kang, Jenny Kovacic: In your opinion, did the tardigrade come from outer space? What's the deal with tardigrades? Should we send them to Mars? Let's talk tardies.

Kevin: Tardigrades are those little water bears. They are curious little creatures. And they are, again, DNA-based, RNA-based. We can fit them into the tree of life on Earth very well. So they make sense. That said, they sure are curious little creatures, aren't they?

Aside: A tardigrade, by the way, is a teeny tiny micro animal that looks like if a futon cushion had 8 stumpy little legs and then a vacuum for a face. They're 530 million years old at least and they've been everywhere, from the Antarctic to the deep sea to volcanoes and they can survive, like, a decade without any water, and crazy temperatures, and space radiation. If you soak a piece of moss in water and you look under a low power microscope, you might be able to spot one! But yeah, Kevin says, [*snarky voice*] "Sorry, y'all, they're Earthlings."

Alie: Last two questions I always ask: what is something that is the shittiest part of your job, the thing that you dislike the most about what you do or about alien life or maybe some flimflam that you'd like to debunk, some myths that irk you? What gets your goat when it comes to astrobiology? So annoying.

Kevin: Honestly the thing that that comes to mind of course as a scientist, the ubiquitous answer is, we hate writing proposals, begging for money, getting rejected. That's just part of the life cycle of a scientist across the board. That's not specific to astrobiology. I guess the sad part is for all of the exciting stuff that we discussed here today, boy, I wish we could just get going with it. It is through the generosity, and dedication, and excitement of the taxpayer who makes NASA and all of this stuff possible. So if you want to see us move faster, just keep on being interested in this stuff and express it to your various folks who help make the high-level decisions that are well beyond my pay grade.

Alie: Tweet about NASA. That's what we gotta do.

Kevin: And the search for life and astrobiology.

Alie: What about your favorite thing about astrobiology or your job, the best?

Kevin: I've got a lot of great colleagues and we love brainstorming, forcing each other to think out of the box. I have a position at Woods Hole Oceanographic Institution, an amazing institution that is a pioneer in the field of ocean exploration. And I go there and I visit colleagues like Chris German, Julie Hoover and others. And we just have a blast forcing each other to think out of the box about how to explore planet Earth, and understand life on Earth, and how to apply that to worlds and wonders beyond Earth.

So that kind of intellectual popping the popcorn is a lot of fun. And at JPL, I get to do that with engineers. I'm just a silly scientist with crazy ideas. I can't do anything without the engineers who figure out how to actually implement the ideas of myself and my fellow colleagues. They're the ones who are actually getting these missions done and making sure that when they fly by or orbit or land on a distant world, we get those bits back that can revolutionize our understanding of how the universe works.

Alie: If someone wanted to be an astrobiologist, what would you tell them? Where do they start?

Kevin: It's a great question. In the field of astrobiology today, there's biologists, chemists, geologists, geochemists, oceanographers… my own background, physics and astronomy and geological environmental sciences. I also did a masters in robotics. It takes all kinds to get this sort of - well, let me use a few buzz words; interdisciplinary, multidisciplinary, transdisciplinary - kind of research done. And so what I tell students and folks interested is, within the framework of sciences that feed into astrobiology, follow your passion - biology, geology, physics, astronomy, et cetera et cetera - chemistry, and enjoy that fundamental research and then extend and bridge it into astrobiology.

Alie: Smart. That's just the sound of so many people changing their majors right now. Thank you for studying aliens.

Kevin: Thanks for having me here to talk about aliens.

Whether it's about aliens or squirrels, the theme here: ask smart people stupid questions, because what a shame not to know your surroundings. Now, you can become a Dr. Kevin Peter Hand fan by following him @alienoceans on Twitter, on Instagram he's kevin_peter_hand. Once again, the charities we talked about were Traveling Telescope and The Manchester Rescue Squad. Both are linked in the show notes in case you're curious about them, alongside all the sponsors of the show and any codes that you might need. You can find those links up at AlieWard.com/Ologies.

To find Ologies, you can follow along @ologies on Twitter and Instagram. I'm Alie Ward on both. And yeah, that's *alien*, no *n*. If you're in the LA area, I'm moderating talks at the Natural History Museum for their First Friday Series, so that's the first Friday of April, of May, of June. You just come in, I'm doing some talks with ologists there, I'm just kind of doing a live Q & A with them—so come say hi! More on that is at NHM.org. I also have my own science show on the CW called *Did I Mention Invention*, and I'm a correspondent on *Innovation Nation* on CBS every Saturday; and if you're a Netflix haver, you can check out *Brainchild*, wherein I am in a beehive explaining science every episode.

Also happy birthday to my wonderful sister, Janelle. I'm very, very proud to share earthling DNA with you. For Ologies t-shirts with the Ologies logo and mugs and totes and pins and hats, go to OlogiesMerch.com. You can tag your instagram photos #ologiesmerch so I can post them on Mondays! Thank you, Shannon Feltus, and Boni Dutch for managing that, thank you Erin Talbert and Hannah Lipow for adminning the Facebook group. Thank you to interns Haeri Kim and Caleb Patton, to assistant editor Jarrett Sleeper of MindJam Media, and the new combat podcast *FightStuff* in case you're into boxing and MMA. And of course the Mully to my Sculder, Steven Ray Morris, of *The Purrrcast* and *See Jurassic Right*, and to Nick Thorburn who wrote and performed the theme music.

Now, if you stick around to the end you know I tell you a secret and this week:

When I was younger my sister and I used to love eating SpaghettiOs with meatballs and we had this tactic where we would eat the SpaghettiOs and then save all the meatballs on a smaller, separate plate, and then at the very end you would just get an entire mouthful of meatballs. Thinking about now it sounds so gross, but it was just heaven as a child, so um, that's it. That's all I got. Have a good week everyone.

Berbye!

Transcribed by Amy L. Greenan, who has been inspired to consider a mid-life career change to astrobiology because of this, the first Ologies *episode she ever heard. It was an honor to transcribe it. (She is also participating in a NASA online summer academy right now because she went down a rabbit hole of astrobiology internet searching! Hello Dr. Hand, and thank you! Maybe I'll see you on a mission one day.)*

Some links you may find of use:

Dr. Hand's CV
Sagan gets beachy
Planetary porridge: the Goldilocks theory
Salty bizness: Abstract of Dr. Hand's dissertation
Communicating with the Mothership a.k.a. ur new ringtone
X-Files theme, of course
Like Earth, but hella faraway
Thank you, Galileo
Hello, Kepler
Goodnight, Kepler
Voyager WHERE U AT
William James was like "Sure! Ghosts maybe!"
A weird webpage that asserts astronauts have seen a whole bunch o' aliens
Percentage of folks who believe in aliens
UFOhhh yes they did, Ke$ha
"Stars, they're just like us." - aliens
You are … here
What is the Great Filter?

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