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**DREW ENDY:** We've inherited this stuff, which is three plus billion years old, going on four billion years old. It's pretty sophisticated. You lift the lid on it and understand how it's working. It's unbelievable, right, the layers of sophistication and the architecture and how things appear to have been selected to perform. I mean, it's stunning.

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**KEVIN SCOTT:** Hi, everyone. Welcome to Behind the Tech. I'm your host, Kevin Scott, Chief Technology Officer for Microsoft.

In this podcast, we're going to get behind the tech. We'll talk with some of the people who have made our modern tech world possible and understand what motivated them to create what they did. So, join me to maybe learn a little bit about the history of computing and get a few behind-the-scenes insights into what's happening today. Stick around.

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**KEVIN SCOTT:** Hello. Welcome to Behind the Tech. I'm Kevin Scott.

**CHRISTINA WARREN:** And I'm Christina Warren, Senior Cloud Advocate at Microsoft.

**KEVIN SCOTT:** I'm really looking forward to our show today. We've got Stanford professor Drew Endy here to talk about synthetic biology, which is one of those topics that I am spending a lot of time trying to get ramped up on over these past six months or so.

So, I had this really great opportunity to meet Drew and chat with him about his work a few months ago, actually before the COVID-19 pandemic. And we had this wonderful conversation about all of the things that he's been doing in synthetic biology, you know, from things that have applications to healthcare all the way to, you know, how you can think about using biology to produce the materials that we need to build the things that we build in society.

And so, I thought it would just be a wonderful, wonderful thing to have him on the podcast and to let everyone else hear how brilliant he is and how cool the work he's doing is.

**CHRISTINA WARREN:** And it's super fascinating and I'm super excited that we have this opportunity. And it's actually kind of amazing that you were talking to him before all of this stuff happened with COVID, and now, it's even more timely and even more important to have this conversation.

But before we dive into the show, you know, I've actually seen a lot of articles lately about, you know, “what we should be learning from the COVID pandemic.” And those discussions can range from the pros and cons of, you know, off-site and remote working and online education to, you know, the need to create touchless technology. And so, Kevin, I'm curious, you know, now that some cities are starting to phase back in to incremental reopening, what are some of the learnings or discoveries that you've made in your day-to-day life during the past few months that you're going to continue incorporating?

**KEVIN SCOTT:** Yeah, I think some of the stuff that we've spent a lot of time talking about, at least in the tech ecosystem, about working from home and using collaboration tools and videoconferencing to collaborate in different ways, I think some of that stuff is going to stick. And one of the things that I'm really enjoying is, because I have so dramatically reduced the amount of commuting that I'm doing now -- like, it's basically virtually gone, I'm using a big chunk of that time to do two things.

So, one, I'm learning a bunch of stuff about biology, for instance. But also, like, I'm doing a bunch of coding again that I hadn't done in a really long while. And so, it's really nice to be able to more intensely learn new things than I was before.

And I'm spending the other chunk of this freed up time with my family. So, like, one of the traditions that we have now adopted that we didn't have before is I'm eating dinner every night with my wife and kids. And before, like, our kids were on a different schedule from us, and they would eat by themselves, and my wife and I would eat by ourselves later. And it's just been a real joy to be able to sit down with my family every night. And I think that is going to continue into the into the future. So, how about you?

**CHRISTINA WARREN:** Well, first of all, I love that. I love that you're getting more time to kind of nerd out on certain things and to spend time with your family.

Yeah, you know, I -- my team has been remote-first, even though there have been a number of us to work from the main headquarters. I think what I'm going to kind of take from this is kind of, A, a better understanding of different things that a lot of my colleagues are going through, regardless of where they work and where they're based. I think this situation has made me much more aware of that and much more empathetic. And I think the secondary thing is when we look at things like remote events, like, you know, I typically do a lot of speaking and go to a lot of different cities.

And when we think about virtual events and doing kind of presentations, and meet ups, and community things, what I'm hoping comes from this is not that we say we're never going to have in-person meetups or scenarios because I think that's great, but that, instead, we start to recognize the importance of having that same sort of connection and giving that same level of focus to things that are happening virtually.

**KEVIN SCOTT:** Yeah, I think that's a really good point. And I know, you know, for our Build conference….Build is Microsoft's developer conference that we usually run as an in-person event every May. We have 6,000 to 8,000 thousand people physically attending this big event. And this year, because of the COVID-19 pandemic, we had to turn this event into a virtual one, which, interestingly enough, meant that over 200,000 were able to participate virtually versus the 6,000 to 8,000 in person, which is a very interesting thing.

And anecdotally, I don't know whether you experienced this as well, but from the things that I was observing, like, I saw more of that person-to-person or, like small group interactions at this Build than I did when we were in person.

**CHRISTINA WARREN:** (Laughter.) Yeah, no, I would agree with that. It was sort of interesting. I felt like I saw, especially with people who could attend for the first time who wouldn't usually be able to attend a developer conference, you know, either because of money or because of how far away it was, or because of, you know, just work commitments or whatnot, seeing them be able to engage and seeing it work across time zones, having amazing keynotes like yours, I think it really did lend itself more to, as you said, like, I certainly noticed the fact that there was way more -- maybe not way more, but it was certainly evident how many side conversations and kind of one-to-one pairings of people meeting each other and having those sorts of interactions than what you might typically have when you've got, you know, 5,000 or 10,000 people crammed into a convention center.

**KEVIN SCOTT:** Yeah, awesome.

**CHRISTINA WARREN:** All right. Well, I'm curious right now to hear from Drew Endy and hear from his perspective, from a bioengineer perspective, all the different things that are going on right now.

**KEVIN SCOTT:** Great. Let's get started with Drew.

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**KEVIN SCOTT:** Our guest today is Drew Endy. Drew is a member of the Stanford University Bioengineering faculty. His research teams have pioneered amplifying genetic logic, rewritable DNA data storage, reliably reusable standard biological parts, and genome refactoring. Drew helped launch the new undergraduate majors in bioengineering at both MIT and Stanford. He also co-founded the iGEM Competition, a global genetic engineering olympics, now engaging over 6,000 students annually. In 2013, the White House recognized Drew for his work on opensource biotechnology.

Welcome, Drew. I'm so glad to have you on the show today.

**DREW ENDY:** Kevin, it's great to be here with you. Thank you.

**KEVIN SCOTT:** So, we usually get these conversations kicked off by talking a little bit about how you got into science and technology. So, were you interested in biology as a kid?

**DREW ENDY:** I grew up in Pennsylvania outside of Philadelphia near Valley Forge, and so, you know, I remember running around outside all the time, right? And so, that gives me, especially in the summertime, you know, those hot, humid eastern summers, a lot of engagement with biology, with the fireflies blinking, right?

And I was blessed to go to a public high school that had multiple offerings in biology. And so, we would do things like go camping on a stream and bring dissolved oxygen meters and just measure overnight at 3:00 a.m., 3:30 a.m., you know, how much dissolved oxygen is there in the stream, and collect the insects, the benthic macro invertebrates, like, oh my gosh. So, that was definitely a positive.

There's another side of it, though, which was like, “Oh, hey, memorize the Latin species names of 200 insects.” And I was lucky to get a D minus that quarter in biology, you know. Like, it just wasn't my thing. And so, I had that experience growing up sort of love of nature, call it, love of the outdoors, but not love of memorization. And there's a lot of memorization built into biology as a student, if you will.

That set me up to not go into biology, but to go into engineering. And I wasn't quite sure what engineering was, and at the time, not really knowing one thing from another thing, felt that civil engineering would be the most broad and diverse form of engineering I could study.

And so, suddenly I found myself taking courses in surveying and learning how to do construction management.

I remember I spent one summer, maybe in the summer of 1990, working out of 30th Street Station in Philadelphia for Amtrak as a construction management intern. You know, you get on a train, you go towards Washington or New York City, negotiating change orders on excavation contracts in New York. Like, I wasn't prepared for that, right? But that really taught me how I like to build stuff.

And so, where this ends up basically is I stumbled back into biology through some really improbable connections with amazing educators. Vassie Ware was a teacher I had. She was a young faculty member at the time, had just earned a degree from Yale in RNA Biochemistry. And I think she was teaching a course in molecular genetics at 7:45 in the morning, and I was the only engineer in that course because the advanced course on structural dynamics and civil engineering had been canceled, and I had to fill the slot.

And she was just so generous in helping me understand what biology was at the level of molecules. And that was the first time I was like, “Oh, wait, wait, wait, wait. Like, these are building blocks?” At the level of molecules within living matter, we've got building blocks. And -- and she really lit me up to that and gave me an onramp into biology that, as a budding engineer, I could see as, well, this is the platform upon which I can do engineering things. But so, anyway, you know, it starts with, I would say, love of nature and fireflies, and stuff like that.

**KEVIN SCOTT:** Were your parents, engineers or scientists or mathematicians?

**DREW ENDY:** My dad graduated from high school and worked in the stockroom of a luggage shop in suburban Philadelphia, I would say. And that was his career for about 50 years, right? So, he went from being a stock boy to, over a 10-year period, taking over the business, buying out the original owner and running that as a career. So he took courses in penmanship at Villanova and business management, but that's about as far as it is. And if I remember correctly and you hear this, Dad, I remember you mentioning something about putting a clamp in your high school chemistry lab on a hose where you shouldn't have put the clamp, and that caused the steam explosion. (Laughter.)

You know, my mom on the other hand, big love of mathematics. She grew up in Beaver, Pennsylvania, on the river there and graduated from college. After raising three boys, went back to University of North Carolina, earned a PhD in Education and joined the School of Education as a professor. So I've got a mixed mode parental situation.

**KEVIN SCOTT:** That's really amazing. I mean, so it sounds like you had very curious, entrepreneurial, hard-working parents who were determined. And so, I mean, I'm guessing some or most of that rubbed off on you.

**DREW ENDY:** Yeah. The thing that blows me away specific to my mom, in particular was effectively, how she just let us do stuff. It was not prescriptive. It was, you know, make sure you don't come to permanent harm. But it was very open. I don't want to say permissive because it wasn't even a sense of permission. It was just open. It was as if there was this invitation to become who you're going to be, that she brought as a mother, which I still find amazing. Now that I have two young boys, it's like, wow, how as a parent do you project that without projecting it, just create that open invitation for individual growth? It's a total blessing. And still a mystery, still a mystery to me, how she pulls that off.

**KEVIN SCOTT:** Yeah, I mean, I have two young kids as well, and it's hard. (Laughter.) Like, I find more often than not, my anxiety about the safety of my children and wanting them to be protected gets in the way, even though I had a very similar sort of experience of yours.

Like, my parents, and I think you said it exactly right. They were just open. It wasn't -- like, I don't think they were deliberately trying to sort of curate anything, but like, they were -- you know, they knew that they had a curious child and they let me indulge the curiosity. And you know, where they could help, they helped, and where they couldn't help, they stood out of the way. It's very hard for me to replicate that with my own kids.

**DREW ENDY:** One of the things I've observed is when she interacts with her kids, which isn't happening now because of COVID, it's almost like she’s from the future. She sees them like when they're five or 10 of your -- so, suddenly, she's engaging with them as if they're adults or as if they are almost as if -- you know, they're three years old or they're one year old. But it's like, no, of course, right? You're an adult. And that is maybe a super move. I'm not sure, but that's as much I understand. (Laughter.)

**KEVIN SCOTT:** Yeah, that awesome. So let's, you know, get back to your first serious biology course you took in university. I love this story and, like, the role that serendipity played in it. So, like, you were taking it -- so, she was an RNA biochemist, and what was the course that you took?

**DREW ENDY:** Molecular genetics. Vassie Ware at Lehigh in Pennsylvania in Bethlehem, back where Bethlehem Steel used to have big factory. Vassie Ware, yeah.

**KEVIN SCOTT:** And so, what were you learning in this course?

**DREW ENDY:** The first thing I learned was that genetics is about logic. I didn't understand the jargon of biology very well, again, because I don't love memorization. But when you think about the science of genetics, which is in the business of trying to understand how traits in organisms are linked and encoded in genetic material, imagine trying to figure that out as a scientist. And all you know is I've got different individuals, and they look different. You know, like the flowers might be different colors or whatnot. And there's something about that difference in how they look that is traceable to their hereditary material, to their DNA, as we understand it.

And this is genetics, as a science, of course, begins before DNA sequencing exists. So, you don't have the code. You just have these relationships, like, oh, there's a link between this trait and something in the DNA.

And so, what you do in this context is you use the likelihood that any two traits are linked to each other. And this depends on how close or far apart on the DNA the changes in the DNA are, because if they're close together, they're more likely to be linked. But if they're far apart, the DNA might break and recombine when it gets copied during reproduction.

Anyway, so you're presented with all this data and you've just got to figure out what's going on. And it turns out you just use logic to figure it out. So, that's what I learned. I learned I could understand life using logic, which was amazing. Like, I would get 100 percent on a test. I have no idea what the biology was, right, but I could solve the logic problem. That was the first thing.

The second thing, you know, and Professor Ware, she would show up with orange juice, fresh squeezed orange juice and donuts at 7:45 and put on these – and put on these view graphs the structures of molecules. So, these are -- by structures of molecules, I mean you know, cartoon diagrams of the three-dimensional structure of a protein or something like that. And I'd just be sitting in this classroom, like, mainlining fresh squeezed orange juice and looking at these images of these cartoon images of proteins and stuff.

And I remember blurting something out. I blurted out -- like, she's given this beautiful lecture on, like, the shape and what it means, and how it’s all working. And I just blurted out one day, “Why do we care what it looks like? Can't you just tell me what it does? Just tell me what it does. I just want to use it. Just tell me what it -- I don't care what it looks like.” (Laughter.)

And I don't know what was going on in her mind, but if a student did that to me today, I go, “You idiot. It does what it does because of what it looks like, right? Structure, function, right? Its shape has to do with what it's -- what it does.” But she just looked at me and was like, all right, you know, okay. (Laughter.)

But so, so I was learning -- with hindsight, I was wishing for functional abstraction. As an engineer, I wanted an abstraction stack that I could redeploy to -- anyway, but that's what was going on. Yeah. (Laughter.)

**KEVIN SCOTT:** I mean, it sounds like this was an amazing course. I mean, any course that's lights some sort of spark or ignites a spark of curiosity, like, I think it's a wonderful thing. But like this one must have really done a number on you because you sort of pivoted hard from engineering. You know, like, now, you're one of the preeminent bioengineering researchers and faculty in the world.

So, like, what -- how, what was the next step from this course? Did you feel like you were behind, because like, now you wanted to do biology, but like, you had accumulated all of the civil engineering stuff? Did you feel like that was actually a blessing because you had this different context to bring to this new thing that you were interested in?

**DREW ENDY:** Yes and, right, all of those things. So, it was just jump in, and I had the benefit of staying on to do a master's degree. So, it gave me--you know, I shouldn't have gone to college for the first two years of college. I was lucky to be able to stay in school, frankly. You know, took a lot of courses at Delaware County Community College and paid for that by roofing, and stuff like that.

But by junior year, I had lit up and I was lucky to have another two years. I did a master's thesis in environmental engineering. So, I took advantage of how the administrative structure is setup. So, if you're in a civil engineering department, oftentimes the environmental engineering department will be in the same department. And so, that let me lateral from reinforced concrete and steel into wastewater treatment.

So, I did a master's thesis on sewage treatment, picking up samples from Allentown and figuring out how to get the nitrogen out of the sewage in a collaboration led by some great, great folks, Irv Kugelman, and others.

In any case, this gave me cover to just mainline biochemistry and all the basic knowledge I needed in the life sciences. It also taught me that the way engineering was approaching biology was not at the same level of resolution that the biologists were approaching biology, that there was a disconnect.

And so, that set me up to hunt down and find people I could learn from who were engineers, you know, pioneering that frontier of what would become 21st century bioengineering, who really were embracing biology at the level of atoms and molecules, the living matter of biology.

And I was super lucky to come across a chemical engineer, John Yin, who is now at Madison. But at the time, he was just returning from a postdoc in Germany and setting up shop at Dartmouth College. And Dartmouth, you would think of as an undergraduate liberal arts college. But they have an amazing engineering school that, one of the things that's cool about is there's no departments. Like, everybody's in one building and there's like 30 faculty.

And they took all their chemical engineering faculty said, “Because we only have three chemical engineers in the whole school, please, everybody do bio.” And so, there's this nice little cluster of bio. And John and others were really operating on this frontier. I couldn't get into the big programs because my GPA coming out undergrad was like a two. So, you know, but Dartmouth took a took a bet on me. And I think I graduated with a class of four engineering PhDs for the whole school, right, to give you a sense of scale.

But it was such a blessing to be able to play intellectually and to learn from John, and to take his advice. He set me up to-- what I could do as an engineer. It's like this give and get, like what's my value add to the biology world. And it was the tools of engineering. It was the ability to handle code and run some numbers, to use differential equations to model a process.

And so, I could bring that engineering perspective, which was then very new into the biology community, which is such a wonderful scientific community, very welcoming, very patient, you know, helping people immigrate into biology as a science. And so, John set me up.

At first, I tried to model HIV on a computer and the evolution of HIV, and I crashed and burned on that pretty hard at the beginning of my PhD, mostly because the literature was not consistent. I could read the papers, but I could read a hundred papers, but I couldn't relate them to each other, so I couldn't codify the knowledge and put it into a computer program.

So, John had this great advice. He pointed me towards bacteriophage, these viruses of bacteria, the phage. If you've read -- have you read Arrowsmith or heard --

**KEVIN SCOTT:** Yeah.

**DREW ENDY:** Yeah, and the cool thing about the phage literature, first off, it started in 19 -- late 19 -- well, 1917, but really started in the 1940s. It's the birth of molecular biology. And a lot of people working in that literature were trained in physics. And so, the description of the biology was just solid. And that gave me a great way of, of moving my engineering toolkit into the realm of biology and starting to create value, and also just to learn a lot.

That goes on for a while. What are the big lessons? One is no biologist will do an experiment for you, at least not any of the good ones. And that's because they're all bandwidth-limited. So I'm showing up as an engineer and I'm running fancy simulations of virus infections on my computer, and I'm coming up with all these hypotheses. And I can't get a single biologist to do an experiment.

And they all say the same thing. They say, “Well, you do the experiment, if you think it's a good idea, because I've got plenty of experiments.” And so, I had to learn how to do that. So, that was a good lesson. Like, teach me about the reality of doing physical experiments, and I had to go to Texas, in Ian Mullineaux's lab, learn how to mouth pipetting back when the safety officers didn't stop you from doing that, right? (Laughter.)

Have you ever, like -- do you know what cesium chloride tastes like, or do you know a culture of E. coli -- (laughter)? A culture, so like, I still remember a culture of E. coli tastes like blue cheese, which you know, is like -- which kind of ruined blue cheese for me for a while.

**KEVIN SCOTT:** Yeah, I bet.

**DREW ENDY:** I just, I don't recommend mouth pipetting. But those were the days. It taught me that I had to do my own experiments. And then, eventually what it taught me was biology makes stories. You know, like the knowledge we get gets turned into a story. And ultimately, I want to make things.

And so, my wish, basically this sets an arc that loops around and ships me out as not a scientist applying the tools of engineering to help understand the natural living world, but really an engineer who reemerges from this journey through the science of biology and says, “I want to partner with biology to make things.” And I'll just hang it there.

**KEVIN SCOTT:** Yeah well, so I think this journey that you were on, like, people are, in increasing numbers, waking up to the fact that biology can actually be harnessed to solve some of the more pressing problems that the world is facing right now. You know, and I know when we first met, it was just very coincidental, it was right at the beginning of the COVID-19 outbreak. And so, there's just this maybe even more intense interest in, like, how biology works and how we can use it, like, particularly for healthcare than there ever has been.

So, I'm just sort of interested in the big, interesting problems that you have encountered over the course of your career, like the things that you are -- that you think there's a lot of promise in that lie at this intersection of, like, will do a bunch of good and, you know, like there's a really daunting, interesting technical set of hurdles to overcome.

**DREW ENDY:** Yeah, that's a great question. Let me offer something in, something cultural first and then come back directly to it.

So, we're biology, right? Everybody listening to this is biology. We all have biology. So you know, like, biology is kind of important is a gross understatement. So how do we explain the fact that we tend to take biology for granted? And I think it's because, well, we just get biology. And so, there's a way of thinking about the living world, which is the living world exists before us, and we are a part of it and we inherit it. And we can't do anything about it. It's just-- it is what it is. And before the mid-19th century, not only is it is what it is, but it is what it is doesn't change. This is the pre-evolutionary view.

Now, post-Darwin and colleagues, we have another cultural perspective on biology. It exists before us and it is what it is, but it changes over time through this evolutionary process. And we all know well that that's controversial, still, culturally, for some, right? Do I have the pre-evolutionary view of biology or the post? But from my point, as an engineer, it doesn't really matter. Everybody in either of those tribes is just the living world. We just take it for granted. It is what it is. And it's not that we don't care about it, but we don't really think about it as this substrate, as this type of material.

And then a generation ago, starting 1970-ish, we get first generation genetic engineering and now we're getting second generation genetic engineering. And suddenly, we get to inscribe human intention into living matter very crudely at first, but we're getting better at it. And so, this is something of our time.

This third reality that that we can express and inscribe human intention in living matter is really a third cultural perspective. And it forces us to confront, ultimately, what do we want to say and what do we wish of our partnership with the living world, to the extent we can partner with it, to the extent that we can take responsibility for our writing, so to speak?

Now, what are people good at? People are very good at caring about people. And so, of course, health and medicine are a big deal. But it doesn't stop there. And when I take a look at what's going on, like, just to get some numbers out in the conversation, how's biology powered? Well, right now, it's mostly powered by photosynthesis. Well, how much? And the answer is 90 terawatts, plus or minus, 70 terawatts of photosynthesis on land and 20 terawatts in the oceans.

What's 90 terawatts? Well, civilizations running on, what, 20 terawatts these days, plus or minus? So, okay, that's interesting. The energy powering the natural living world is four and a half times the energy consumed by the human civilization. Huh.

Now, you asked me, like, what's the big deal? How about civilization-scale flourishing, because what's biology doing with those joules, that energy coming in? It's organizing atoms, right? So, biology is operating at this intersection of joules, the energy, the atoms, the material and bits, by the way, right, the DNA code, which is -- which is abstractable information.

And so, we've got this stuff, this living matter. It's atomically precise manufacturing on a planetary scale, operating at almost 5x civilization. What should we be looking at? Lots of individual things, of course, vaccines here and there, a big deal. But the big prize I would submit for consideration is civilization-scale flourishing where we can provision for 10 billion people rounding up without trashing the place. And that's never been true before because we've never understood biology and the way we're approaching it, both as a science and engineering discipline.

And if I go away, right, and if all of bioengineering goes away at Stanford or MIT, both -- not that I'm advocating for that, obviously – like we're still running on this trend of we're understanding we're about life and we're getting better at tinkering with it. Those trends will continue for the rest of our lives.

So, the big prize got, while this is -- this is where it comes back to what's our dream? You know, like what do we -- do we share a dream in common, you and me, and maybe everybody listening? Is there a dream we could share in common regarding our relationship with the living world? And I just start with how about civilization scale, planetary scale, flourishing? I should put in a postcard to give an example of something very exciting to me specifically. It's looking like the chemical engineers and chemists are learning how to take electricity, and split water and fixed carbon from the atmosphere.

So, formate is my favorite example, a little small, organic molecule, carbon molecule. Genetic engineers are figuring out how to modify the metabolism of E. coli, yeast and other things to grow not on sugar, glucose, but to grow on formate. So, what this means, if you put those two facts together, you can take a kilowatt hour of electricity and make grams of new biomass.

And so the significance of that, if you're following along, is that ceiling of 90 terawatts of energy that powers biosynthesis is not an absolute limit. To the extent we can generate electricity by any mechanism -- solar panels are a fine example -- we can make biomass from that. So, making electro biosynthesis come true is very, very exciting to me.

**KEVIN SCOTT:** Yeah, it's -- I want to go back to what you said just a few minutes ago about how we take a lot of biology for granted. And, you know, I had one of these moments of wonder a few weeks ago where my son, who's nine years old, was doing this project for a school where about photosynthesis and plants.

And the experiment was he took five dried cranberry beans from the pantry, which in my mind are not seeds but food, and he wrapped them in a paper towel and stuck them in a plastic bag, and taped them to a window to let them germinate. And then he planted them, and I'm, like, thinking to myself, my god, like, this is, you know, maybe a more complicated machine than almost any that we deal with where this little dried thing that was, you know, like, I didn't even realize was alive can be coaxed not just to life, but into something that can replicate itself. And, like, all I needed was water and sunshine and soil, and you know, I'd taken those sorts of things for granted my entire life. So, like, that's maybe one reason why I take them for granted.

And like, maybe another reason is I'm a computer scientist by training. I deal with things that are complex, but they're complex in a way where, you know, a lot of it is just sort of human fabricated, right? We've sort of built computer science. Like, some of it's phenomenological and like, you know, there are theoretical, weird things about our mathematics and computer science that are, like, very surprising, and they get to be intractable in ways that there's nothing we can do about.

But for the most part, like, it's pretty orderly, and biology just seems… I don't want to call it disorderly. Maybe it's just I think it's disorderly because I just don't have a big enough brain to comprehend it or because its complexity is, you know, just on another scale.

But I just sort of wonder, like, you know, what your thoughts are on this. Like, how much of this is because biology is so complicated, you know, that we've had a hard time wrestling it to the ground, and like, and on the other hand, like, we've just sort of coevolved with the natural world and like, it just sort of does actually seem like all of this beauty and complexity seemed ordinary, in a way.

**DREW ENDY:** Yeah. It's a great example and you're hitting some profound points, right? So, you know, like what would Johnny von Neumann think? Well, what did he think of this stuff, right? We've got reproducing machines. Like, actually, actually. Holy cow. And how many people right now are gardening, right? Like, the gardening stores are sold out, right, due to COVID.

And what's a seed, right? It's unbelievable, right? I get the seed packet. I have this thing that makes its own solar panels, the leaves, leaves. We call them leaves, and we rake them when they fall off and compost them. But I've got a system that can grow solar panels and recycle the solar panels. Holy moly.

And you're right, we take it for granted. And what's the quote? It's like sufficiently advanced technology indistinguishable from magic.

**KEVIN SCOTT:** Yep.

**DREW ENDY:** Is that Arthur Clarke?

**KEVIN SCOTT:** That is Arthur C. Clarke.

**DREW ENDY:** Yeah, we've inherited this stuff, which is three plus billion years old, going on four billion years old. It's pretty sophisticated. You lift the lid on it and understand how it's working. It's unbelievable, right, the layers of sophistication and the architecture and how things appear to have been selected to perform. I mean, it's stunning.

I'm not sure I have an example of finding the end of the layering of sophistication. And so, in a way that's very different from computer code that is maybe a few centuries old, if I'm being generous, right, in its history -- it depends what you think about human-to-human languages. But living matter is billions of years old. And so, it's like it's magic, and we're lifting the lid on that magic box and coming to understand it.

We don't understand it, which is an important point to land. If the fundamental unit of life is a cell, right, this system that's capable of taking in stuff and reproducing, there's not a single cell on Earth that we understand operationally to 100 percent, right? So, we're still encountering mystery or magic, if you will, which by the way, when we go to apply biology as a technology, we're still encountering tinker and test, Edisonian tinkering and testing, not as sort of engineers' operational mastery. We haven't gotten to that.

**KEVIN SCOTT:** Yeah, I think that was one of the quotes or things that I took away from our first meeting, the fact that we don't completely understand a single cell of the human body, which, you know --

**DREW ENDY:** Or any cell, or any cell at all, like, even the simplest microbe. There's not a single microorganism on Earth we understand completely.

**KEVIN SCOTT:** Yeah, and we're sort of tangibly wrestling with this right now. You've got this SARS coronavirus 2, this little, you know, 50, 100 nanometer particle that is, like, really doing a number on civilization right now. And, you know, like, I'm sort of glad that it's happening now versus 30 years ago, because we have, as a matter of fact, come a very long way in our understanding of these biological systems over the past several decades.

But still, you know, I think we're, in many ways, completely flummoxed by the mechanism of this virus and, you know, why it does one thing to one person and another thing another. And like, even when you get down to the, you know, we sort of got lucky, you know, as you mentioned in that first meeting that we had a solved structure for the spike glycoprotein pretty quickly in the outbreak.

And I know a bunch of work that people have done to simulate in computers the interaction of that spike protein with these Ace2 receptors in the human body, which is, like, one of the -- is the mechanism that the virus used to invade a cell. But, like, even those computer simulations are relatively low resolution compared to what the actual in vivo interactions are of that virus spike protein in the cell. So, like, we do have a long way to go, still.

**DREW ENDY:** Yeah. And honestly, we're playing. We're not serious about biology yet. We're not treating biology like a strategic domain. When an enveloped RNA virus can take out a carrier task force, something that no number of Chinese submarines can do, apparently, and all we can do is do F15 flyovers to celebrate the healthcare workers, that means we are not taking biology seriously. We are misspending our treasure.

Thirty years ago, by the way, 30-40 years ago, by the way, it was HIV, and we had that experience. So here's a question I'm wrestling with. Why in infectious disease and epidemiology is it okay for us to adopt a strategic posture of, “Let's wait till we're surprised”? I don't know of any important strategic domain where, you know, community gets together or the leaders get together and say, “Well, we're really worried about this issue. And so, our strategy is going to be we'll wait for something to happen and then we'll react. And let's get better at reacting.” Like, that's bizarre, and I think it's linked back to biology happens to us.

**KEVIN SCOTT:** Yeah.

**DREW ENDY:** We're not -- it's this first way of thinking about biology. I am uneasy, would be the honest thing to say. I am very uneasy with the failure of collective leadership in the United States over the last 20 years, in terms of engaging with biology strategically and looking ahead to the status quo path we're on, and what 2030 looks like or 2040 looks like if we don't figure out how to collectively consider biology as a strategic topic. And I know this sounds self-interested, right, because I'm in the space and I'm like, unbelievably committed to it. But on the other hand, like, you just index off of COVID-19 and we're reacting. So, yeah.

**KEVIN SCOTT:** Yeah. I mean, it's one of the -- COVID-19 experience has obviously been extraordinarily painful. And we've had just a tragic number of deaths that could have been theoretically or potentially avoided if we had invested in. And maybe even the investments didn't need to be in super sophisticated biology. Like if we had had, you know, better early warning mechanisms and, you know, better scenario planning on what you do when an upper respiratory virus comes to your doorstep. Like, we could have made things a lot better than they were.

But what I'm hoping here, you know, and I had a boss many years ago who used to tell me that if you're going to have a crisis, like, you might as well get as much learning out of it as humanly possible. And I hope that the learning that we're getting here is that we do actually need to invest way more than we are right now in biology.

And to your point, like, it's not just about healthcare and making people's physical quality of life better. It's about climate change. It's about feeding a population, you know, when your food supply is going to be stressed by climate change increasingly over the next many decades.

And like some of the stuff that, you know, you were talking about when we first met, like the fact that we have this opportunity with some of these new technologies to do things, for instance, like reprogram yeast to, like, have it fabricated a whole variety of organic compounds for us that might be good substitutes for petrochemicals or, like, might be the cheapest, most sustainable, innovative ways to go build a future society. So, it's just -- like, if you think like an investor, like, the leverage that you get from investing a little bit in biology is just absolutely enormous, I think.

**DREW ENDY:** Yeah, I'm totally with you. And the way I think about it is as we secure operational mastery of living matter, by which I mean we can express our intentions into cells and they behave as we intend for them, we transition from designed in one location, made in another location, to designed in any location and grown in any location. So, it's not designed in California, made in China. It's designed anywhere, grown anywhere.

I want to loop back, right, and as horrible as COVID is, I'll say something that might provoke, but I mean it constructively. We're really lucky. We're really lucky the lethality rate is a single-digit percentage. Thank goodness for that. You know, glad it's not Nipah. You know, glad it's not something with a 30-to-70 percent lethality rate.

And I do want to acknowledge sometimes the solutions are low-tech, right? With Nipah, you know, another virus associate with bats, as I remember, the solution to prevent transmission to humans is to put lids over the buckets collecting the sap from the palm trees so that the bats don't defecate into it, so that the people who get the raw milk, if you will, for their breakfast drinks don't have, you know, viral titers coming in.

I also want to land, you know, I bet everybody, most people listening, even if you're in computer science or electronics, you've probably heard about the Plague. You've probably heard about the Black Death. And why is that? Well, the answer is obvious, because it killed a significant fraction of the European population and elsewhere. But it's like, what is it, six centuries ago? And yet there's ten times more people in Europe today.

So, what I'm using with this example is I'm trying to highlight biology is going to biology. It doesn't care about our culture or our politics very much. And so, a perturbation like the plague can create a resonance that lasts for probably going up to a thousand years, easy. But the biology doesn't care. Homo sapiens, you know, Homo sapiens going to Homo sapiens.

So, I want to then return to -- the way I think about it, is “making things awesome.” (Laughter.) I've got a problem with climate change, which is the structure of the narrative. It's a way of organizing people in response to a crisis. And the problem with that strategy is the bad thing has to happen or at least start to happen before people will take action.

It's like when we wanted to get the firehoses all on the same screw thread standard in the United States. We didn't do that until Baltimore burned down, and the fire trucks from Washington and Philadelphia couldn't connect up to the hydrants. So when you structure a dream in reaction to a negative narrative, the negative thing has to start happening.

And I'm suspicious that climate change has this hidden negativity in it. Whereas if you said, “Oh, let's do climate awesome,” well, people go, “Oh, well, what sort of climate would I like, and how do I contribute to that positively?”

So, the key puzzle -- here's the type of ambiguity. Where's biology and synthetic biology are going to land culturally, post-COVID? You know, imagine the ambiguity we're wrestling with. Like, well, did it emerge from nature? Did it emerge from a lab? Did somebody make it? Is it a bio weapon? You could keep ratcheting that up.

And collectively, we're going to have a view of biology as a partner or not, as a threat platform or not. It's going to be all these things. But if we can't connect it to the positive dream, then we really don't have any chance of organizing people in advance of the work to make it true.

And so, I want to highlight this operational ongoing struggle to figure out how to tell the stories, the many diverse stories of what we wish for in regards to biology, whether that's keeping nature natural and keeping things from going extinct or, yeah, vaccines for sure, unless you don't like vaccines. But I'd like to have a COVID vaccine right now.

But what's the positive narrative here? And I wonder for you in all the things you see across the spectrum of technologies, you know, how good a job -- what are the best examples of “making things awesome”? And are there lessons we can adapt, or port into the world of life, of living matter, or can biology connect into some of those bigger dreams?

**KEVIN SCOTT:** Yeah look, I think you are absolutely right, just in the sense that we have to believe that our science and technology, like, all of the stuff that we built, this understanding of the world, all of these tools that we've given ourselves can be deployed to make the world better. It's not that all of this stuff is just a bunch of things that happen to us and we constantly have to react.

And I think the way that you get -- I think you're totally right. Like, you have to have some sort of vision for how it is that you're going to make things better. And then you have to engage with a whole bunch of people who are optimistic about that vision and help make sure that you are, you know, educating those people, giving them the skills that they need, like funding research that is, you know, sort of pushing on these areas.

You basically have to structure the game where we can win it, you know, which is about incentives and access to tools, and sort of the instrumentality of a winning game. I've been -- this is not biology, but, like, I have been having the same conversation with folks about AI for a while now. In the sense that I think that if you apply AI to a bunch of these big societal challenges, you're going to get pretty good results, and that for relatively small investments of our societal wealth on these things, you know, just sort of imagine the Apollo programs is my favorite thing in the world.

Like, we invented the aerospace industry out of this Apollo program. We picked the moonshot, you know, which now has become a metaphor for like a whole set of activity in our society, like completely arbitrarily. Like, we didn't need to go to the moon. Like, we --you know, the moon was a sort of an audacious goal that we set for ourselves to, like, push our science and technology to go accomplish a thing that everybody was going to be excited about, where we knew the side effects of accomplishing the thing were going to give us better national competitiveness and produce this industrial capacity around aerospace that has been, you know, arguably largely beneficial for society.

I think we need to think about this moment with biology and COVID, and like, climate change and all of these big challenges that we're facing in the same way, and like, figure out, what are the moonshots that would alloy everyone around, like, something that they could believe it that would get everyone excited.

I mean, like, almost everyone on the planet with a television was tuned in when Neil Armstrong set foot on the surface of the moon. Like, that was not a -- that wasn't a national thing. That was a human thing. And so, like, we've got to find, like, that aspirational human thing to go after, and, like, and design it in a way where, like, the side effects of achieving that goal are going to produce a whole set of structural good. So like, I totally agree with your premise.

**DREW ENDY:** Yeah, in the abstract, but we've got to run it real. So, one of the things I experience is hashtag bio ignorance. It's okay to be a leader of an organization, whether it's government or industry or academia or charity, and to not know anything about biology. That's not -- well, it just is what it is, you know, in a way that's not true for information, science or physics.

And so, what that leads to is it's very hard to have conversations about biology. Instead, for example, when had the summit at the White House last October on synthetic biology, it was not that. It was the bioeconomy summit because jobs and money was serving as a proxy. Oh, if it's jobs and money, then that must be important. Whatever it is, you know, it's the FU economy. Whatever FU is, it's a valid topic because it's economy, because it's jobs and money. And so, that's our starting point.

Now, what's fun, though, and awesome about being in the USA is you -- when you go way back, we can say, you know, “Hey, what would make the bioeconomy a uniquely American bioeconomy as opposed to a Czech bioeconomy, you know, or a Brazilian?” And it's going to be about life, for sure. It's going to be about health, and medicine, and food, and fuel, and shelter. It's going to be about life, but it's also maybe going to be about liberty and the pursuit of happiness, that a uniquely American bioeconomy could be about life, which is what everybody focuses on, but it also could be about liberty and pursuit of happiness, and what might that be?

And by liberty, we mean, you know, I'm going to be a citizen of this future bioeconomy. I'm going to have standing. I'm going to have the option of doing what I wish to be doing, right? And so, that suddenly implies a whole bunch of opportunity and constraint on tooling and infrastructure, and ways of being.

And then, pursuit of happiness is kind of interesting because it instantly invokes creative expression, and individuality, and diversity. And suddenly, we think about governance frameworks that are more like speech, you know, that a DNA synthesizer that makes DNA from scratch is like a printing press for living matter. And so, how do we govern the press and how do we govern expression of intention? And maybe we turn to the Supreme Court cases on obscenity and lawlessness, Jacobellis and Brandenburg.

And suddenly, if you bring all of that together, you get a sandbox to play in that says biology is about many things. I wonder about the moonshot. You know, of course that -- I would wish for that. And I can give you one, like, almost perfect analogy, but I'm not sure people want it. So -- so, the --

**KEVIN SCOTT:** Yeah.

**DREW ENDY:** So -- so, the -- but here -- here it is. So, go ahead.

**KEVIN SCOTT:** It's so my argument there is, like, I don't know that people knew that they wanted to go to the moon until you basically --

**DREW ENDY:** (Crosstalk)…he was dancing around on the moon. (Laughter.)

**KEVIN SCOTT:** Yeah. You basically had persuasive leadership who, like, understood that we needed to accomplish a set of things, and they -- and, like, I just cannot -- I cannot overstate the extent to which the Apollo program shaped everything. It wasn't just building technology. Like, it built, like, all of the science fiction that we had for 30 years after that. Like, we just sort of inspired an entire generation about a more hopeful future. So anyway, I want to hear your moonshot.

**DREW ENDY:** No, no, but I'm with you. But note Apollo -- when did Apollo start, '60, right, roughly?

**KEVIN SCOTT:** Yeah, late 50s is, like, when the seeds were planted.

**DREW ENDY:** So, but the rocketeers from Germany arrived in the United States a decade earlier. And so, what I've been learning about that I find interesting is it wasn't instant go, that that decade post-WWII really required the generative dreaming of like, oh, let's yearn for space. And then, of course, it piles on once it starts going. But I was surprised to learn how hard it was to get that narrative structure.

**KEVIN SCOTT:** Yeah.

**DREW ENDY:** Well so hey, rockets get us up out of a gravity well, right? A gravity well's defined by mass at a position in space time. I'll submit for consideration we live in another well that we don't see. It's the life well, and what I mean by a life well is that we're -- the life at a point in space time is constrained in three ways, first, by the life that came before.

You know, we're not that interesting in terms of the differences from our parents. We're different, but not that different. So, that's a big constraint on what we are. And then, of course, we have to be able to reproduce. And then, of course, over long timescales, we have to be able to evolve. So, there are three structural constraints on life at any moment in space time, and that's what I mean by a life well.

Now, what does it mean to claw and crawl and climb up out of a life well? It means increasingly being able to instantiate life without being beholden to these constraints, without the constraint of lineage, without the constraint of needing to reproduce or evolve. If I could just make a living organism from scratch, I'm suddenly outside of the Earth's life well.

Now, do you want that? We don't know yet. I want it for sure, because I'm, like, so smitten with the technical challenges. What I think, though, is unlike coming out of a gravity well where you get into the vacuum of space, coming up over the lip of the Earth life well doesn't get us into the void. It gets us into a way of relating to the living world where we can make improbably beautiful, diverse patterns, living patterns that promulgate in space time.

Some of them could be harmful, but others could do things like provisioning for, you know, the six billion people who don't have access to medicine from the Western supply chains because they don't have enough money, or how about we not have things go extinct, or maybe we could even increase biodiversity?

So , I'm kind of down for the life well haul, and oh, by the way, bringing it back to COVID for a second, if we don't understand life well enough to build it, good luck securing it. Because I'm securing the black box where I got a third of the objects, the parts inside that I have no idea what they do. I'm always going to be on my heels and wait and see.

So, if you actually care about biosecurity, I think we got to get to this operational -- we've got to get out of the life well. And then, of course, we have to do the other things which are cultural and political. But anyway…

**KEVIN SCOTT:** Yeah, I think that's a very exciting, optimistic, hopeful way to think about the future. The other thing, too, like, I will go back to your -- the point that you were making about liberty before. Like, I -- one of the reasons why I'm -- I've spent as much time as I have on machine learning over the past whole bunch of years, and why I'm spending an increasing amount of time on biology is I think we really can't have democracy or liberty, or like, all of these sort of freedoms and inclusiveness that we want in society, unless we can more expansively solve these problems of -- at the bottom of Maslow's hierarchy of needs, so basically, subsistence.

It's just too damned hard to subsist as a human being in huge swaths of the world right now. And like, part of that is, like, too expensive to feed yourself, even though, like, we have an abundance of nutrition and, like, on the planet. Like, we have enough calories to sustain everyone, but like, we can't equitably distribute them or like, sensibly distribute them. You know, we -- it's too hard to stay healthy, like you know, universal healthcare and, like, all of these notions that everybody should have equal access to the -- some high-quality level of healthcare.

And I think, you know, you just sort of go down the list of all of these things, and a bunch of them right now, the reason that we don't have what we would like is that we are looking at them as zero sum games, so finite resources, huge amounts of constraints, and that we're sort of trapped into that zero sum thinking.

But if you think about AI and you think about biology as tools that you can use, like, they can actually convert zero sum problems into non-zero sum ones to like, create abundance where there was scarcity before to relax these constraints. And like, I think that is, you know, one of the ways that we should potentially be thinking about making the world better, is like, how do you -- like, let's just tackle subsistence.

And like, if you have ubiquitous, like, free subsistence, like where you don't have to struggle against that, that lets all of us sort of get up into those higher parts of the pyramid to like have real freedom to be who we are, and to, you know, sort of explore to the world and contribute to society in sensible ways rather than just having this anxiety around like, how do we function.

**DREW ENDY:** I'm totally with you, and I think we have to call something out carefully. The systems that we inherit, be they institutional, organizational, cultural, political, they developed in a time of scarcity. So, from the nerds’ perspective, people and civilization needs joules, bits and atoms-- energy, knowledge and stuff. And the networks by which joules, bits and atoms were provisioning things for almost all of human history until right now are defined by scarcity, all right? And now, the napkin math's looking pretty good that we can, for the first time ever, pull off making and distribution of joules, bits and atoms for 10 billion people.

Just let's note that what we're inheriting in terms of ways of relating to each other were adapted for a prior reality characterized by scarcity. And so, somehow, we're going to have to transition, and I sort of view this as, like, going over a “whoop-de-doo” on a roller coaster where you feel a little bit funny in your tummy. And we've got to go from one type of dynamic steady state to another in a way that's hopefully constructive and healthy. But the systems are going to have to recognize that we're moving beyond this physical constraint of scarcity.

And we have plenty of examples of how we don't do this. My favorite is the 1930 essay by Keynes in the Depression. Roughly, the title is “On the Economic Possibilities for our Grandkids,” which is us. And he says, look, the Depression is a blip. The structural trends in the economy are great. We're going to get compound growth for a century. By our time, there'll be so much economic growth, there'll be plenty money for everybody. And he's right, except, not -- plenty of money, but not for everybody.

So , somehow, we've got to confront this puzzle. And this is where, in my mind, it really does go back to life, liberty and pursuit of happiness. I think, you know, the USA is onto something, if we return to that, and take that way of thinking and use it to guide us in structuring how we develop institutions and ways of relating. I think we can pull off this transition into a flourishing, you know, dynamic, steady state.

**KEVIN SCOTT:** Yeah. But like, I think this is sort of the heart of it. Like we, as a society, as a culture, we get wrapped around the axle when we frame problems in terms of in order for you to have more, I have to have less.

**DREW ENDY:** Yeah, totally.

**KEVIN SCOTT:** And I think technology, AI, biology, like some of the things that we're doing across the board with our science right now, means that everybody can have more. And, like, we still have this question we have to debate about, like even, you know, what a more equitable distribution is of what we already have. But like, I really do think, like, how can we structure things in a way where our science and technology gets more for everybody.

**DREW ENDY:** I'm with you, and I want to plant a metaphorical seed. I think a clue is when we think about being in this future, what is our standing in this future? Are we consumers in this future or are we citizens of this future, or subjects or objects, right? Those are the options, right? And I would prefer, you know, my kids and everybody's kids grow up and we're citizens of this future.

**KEVIN SCOTT:** Yep.

**DREW ENDY:** And that's a clue, just to land it, right, is like well, universal basic income. What does that do? It reinforces somebody's standing as a consumer. You need money, but it's not sufficient. You might want to think about universal basic capacities, which is optionality around doing things. Anyway, yeah.

**KEVIN SCOTT:** It's my -- this is my kung fu move for my son and trying to get him to learn how to program. So, he loves his tablet and he loves Roblox. And so, and I keep telling him I'm like, look, buddy, you're consuming what other people are making in this game, and it's very entertaining and you enjoy it. But like, why don't you spend some time learning how to create experiences like this for other people, that that's a -- that's a really, you know, a more interesting way of sort of understanding your own interest and of sharing yourself others? And like, I think I'm actually making some progress. (Laughter.)

**DREW ENDY:** Cool.

**KEVIN SCOTT:** But the whole point is, like, I just don't want him to be 100 percent a consumer. Like, I want him to, in some way or the other, to create, to like, make something that benefits others.

**DREW ENDY:** Yeah, it's reading and writing going together and how to get that transition. And in a way, this returns us to biology in that we've been historically reading biology and describing what we're reading. And now, we're getting into the writing side of it. And, of course, we'll learn a lot by learning how to write, but we're going to have to say something, too.

**KEVIN SCOTT:** Yeah. So, I think we're just about out of time and that was -- that was a fine way to almost end things. The last question I wanted to ask you is outside of your work, like, what are your hobbies? What do you read? Like, what do you do for fun when you're not absorbed by your professional passion?

**DREW ENDY:** Hmm. Well, you know, the reality is many things in prior times. But now, I'm a dad and a husband. I've got a three-year-old and seven-year-old boy, and you know, first grade ended last week. And I have great photos of him literally climbing the walls. He's learned how to hang back off the molding in the doorways and ascend to the ceiling.

We -- my wife, a colleague at her company, brought in a puppy from Oakland that was left on a porch and starving, a husky/shepherd mix, we think. And he's 11 months old and going on 70 pounds. And we were up at five o'clock this morning out in the yard playing and working on being awesome together. And his name is Indiana Bones, the Pupper of Doom.

**KEVIN SCOTT:** Nice. (Laughter.)

**DREW ENDY:** (Laughter.) Yeah. So, what Indie has taught me is I have no clue how to be a parent. But so, I would say, you know, that's that. We're running a garden and surprised with that, and we're clearing out the ivy and poison oak, and spending a lot of time on the weekends outside with a rake. So, that's the gist of it. I did get a book of sheet music, Thelonious Monk's stuff, and --

**KEVIN SCOTT:** You play piano?

**DREW ENDY:** I used to play piano a lot, and Max is taking piano lessons through Facetime, so I hold the tablet while his teacher's helping. And that's gotten me playing again, so that's about it. But I will say, right, we're pegged, right, in terms of work right now.

**KEVIN SCOTT:** Yeah.

**DREW ENDY:** And a lot of people are playing catch up with bio.

**KEVIN SCOTT:** Yeah, and I think a lot of people are pegged right now. But it sounds like what your -- like, family and puppies and garden sounds really fantastic to me. (Laughter.)

**DREW ENDY:** Yeah, yeah. I just -- yeah, I always -- the way I think of it is microscopically blessed, macroscopically stressed, you know, is what's going on. Grateful for that.

**KEVIN SCOTT:** Well, thank you so much for taking an hour of your precious time to chat with us. This has been a fantastic conversation, as always. I enjoy chatting with you.

**DREW ENDY:** Kevin, thank you so much for your curiosity and engagement. It's really great to reconnect.

**KEVIN SCOTT:** Great.

[MUSIC]

**CHRISTINA WARREN:** So, that was Kevin's chat with bioengineer Drew Endy.

**KEVIN SCOTT:** Yeah, it's a really fascinating conversation. I think Drew is easily one of my favorite researchers to chat with. He has such an interesting perspective and, you know, just shocking technical mastery over his material. But also, you know, he has this very humane vision for where he thinks the research in his area ought to be taking us all, which is always a great thing to see.

**CHRISTINA WARREN:** Yeah, no, I thought the conversation was so interesting. And his perspective being both the engineer and the biologist, I think is something that we need more of. And I would love your perspective on this, but I feel like that's kind of where -- that's real innovation, right, is kind of when we can take people who have these different points of view and can see two what might seem like unrelated fields, but have expertise in both and can find those commonalities. I think -- that's, like, the best part of tech.

**KEVIN SCOTT:** Yeah, I totally agree with you. And I think when you look at some of the more, or maybe most of the interesting breakthroughs that we've had in science and technology over the past many hundreds of years, what you will find is they often come about when you have the blending of multiple points of view. You have a particular area of study that's got its own momentum, and then the disrupting thing is you just sort of connect it with something else that maybe is a little bit surprising.

And I know that when Drew was taking this molecular biology course, his first one when he was an undergraduate, like, bioengineering was in -- in a very nascent state. And, like, the idea that you could have someone who had been studying civil engineering pivoting into biology career, like, must have seemed very unusual to this professor that he had. But like, thank goodness for it, right, because that connection between that engineering mindset and a bunch of the stuff that's been going on in biology has been one of the things that's driving so many of the advances that we've seen over the past few decades in the biological sciences, and it's really, really exciting.

**CHRISTINA WARREN:** Yeah, no, I absolutely agree. As you said, so many of the innovations that have happened have been because of kind of those two merging. And I think this is probably one of the hopes that, you know, from a physics community perspective, of one of the things that's going to continue happening with quantum, right, is that you're going to have kind of those two worlds continuing to come together to lead to the next big advancement in computing, and from that perspective.

**KEVIN SCOTT:** Yeah. I think we've got a bunch of really exciting things in science and technology right now, like the development that we have in quantum continues to be super interesting. But, like, the thing that I am getting really fired up about that I'm inspired and spending a ton of my time looking at is this intersection between high-performance computing AI and biology. And I think there's some truly remarkable things that we're going to accomplish for society over the next 10-to-20 years when we make those connections across those three domains. I'm certainly learning a ton, and I'm – like Drew is totally inspirational in that, like, he's one of the pioneers in exploring this new frontier for all of us.

**CHRISTINA WARREN:** Yeah. Let me ask -- and I realize this might be kind of a loaded question, and I don't mean to put you on the spot, but how do you think that we encourage more people to kind of follow Drew's footsteps?

**KEVIN SCOTT:** I think there are a bunch of things that we can do. Like, part of it is I really do think that we need to reimagine some of the curriculum that we're teaching K-12 and at university, where the boundaries between these disciplines and the, you know, the skills that we're trying to teach people are so siloed.

You know, the thing that occurred to me when we were chatting with Drew is that it feels to me, and I don't know whether this is right or not because I haven't been in the academy for a while, that it's easier now to have these cross-department research collaborations and to teach courses that don't neatly fit into the orthodoxy of a particular profession. And like, that's nothing but a good thing.

But to really get kids to participate in this, to study these things is you have to have really fantastic K-12 teachers and to give them the opportunity to explore in whatever way feels natural to them. You know, it sounded like Drew and I are wired a little bit alike in that, like, I have always had a hard time learning for the sake of just putting new things into my head. I want to understand the context and, like, why am I learning this? And I hate memorizing things because, you know, you should have things memorized according to someone. Like, it's just never been a good enough reason for me to go learn anything.

And I'm even finding it a little bit, right now, and I'm doing a whole bunch of stuff with trying to do factor analysis on the COVID-19 outbreak in the United States to understand what it is from a data perspective that may be causing outbreaks in different geographies to be quantitatively different from one another.

And the tools that I'm using are a whole bunch of things that I could have learned earlier, but I didn't because I didn't really understand how useful they could be. So I'm, like, doing a ton of stuff with Bayesian analysis and some of it's new in the past five years, like the really good tools for doing probabilistic programming with Monte Carlo, Markov Chain Monte Carlo simulation techniques. Like, the tools are new and, like, what you can do with them is different.

But like, the baseline approach was -- been around, like, I could have chosen to take all of these courses when I was in graduate school and I just didn't, and it's because I didn't understand what they might be useful for then. Like, I understand acutely how they might be useful now. And so, I'm like on this intense learning curve on that.

And so, like, I think, you know, the same holds true for a bunch of kids. Like, I see it with my nine-year-old and my eleven-year-old. If you can tell them why learning something is important and it helps them do something that they're interested in, like, they will go and make the time and learn it. If you are telling them, you know, you need to learn this because I told you so, good luck. (Laughter.)

**CHRISTINA WARREN:** No, I mean, I think you're right, and I think that's the case for a lot of people. And we need to find a way to make something interesting or at least spark that sense of curiosity into why it might be useful.

Also, like your kids, I love Roblox. (Laughter.) So, I hope they continue to experiment and play with those and that might unlock their enjoyment of programming because that's a great entry point too.

**KEVIN SCOTT:** Yeah, I think at this point, it's going to be very difficult to get my son disengaged in any way from Roblox. And, you know, funny enough, like, I will say I was a little bit worried about how much time he spent on Roblox, but Roblox and the sort of companion chat that he can do with his friends -- so, like, he has, I think because of this virtual experience, been able to navigate the shelter-in-place better than he otherwise would. Like, if anything, he's got more connection with his friends now than he did before because they're all hanging out in this virtual environment together, doing stuff.

**CHRISTINA WARREN:** Which is really important, right? And you can build relationships that way that are just as crucial as anything else. And so, I'm glad your son has had that opportunity, A, to be able to still stay connected with people through all of this, and B, to you know, maybe had his mind opened up to some new things by using play.

**KEVIN SCOTT:** Yeah, for sure.

**CHRISTINA WARREN:** All right. Well, thanks again to Drew Endy and to all of you for listening. As always, you can reach out anytime at BehindtheTech@Microsoft.com. And be sure to tell your friends and your colleagues about the show. Stay safe and be well.

**KEVIN SCOTT:** See you next time.

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