**Tim**

Hey, Tim here. This next episode is a recording of a live event that we did, in which we interviewed two professors from MIT. This event was collaboration with taste of science, which is a nationwide science communication festival. And we teamed up with the local Boston team for a taste of science. And we gathered at night shift brewery who was kind enough to let us rent their space. We interview these two professors and we took questions from the audience. And all in all, it was a really fascinating discussion all about cell biology. So that all just queue up the recording. And just want to note that there was a little issue with the recording after we came back from a break so you'll hear my voice come in to kind of get you listeners up to speed with what was being talked about, and then it'll continue with the recording from the actual event. All right, here we go. Okay, so our two guests are still Garg. He's a professor at the Koch Institute for integrative Cancer Research at MIT. I know because we work on the same floor, so we're good buddies. And then next to him is Dr. Ian Cheeseman. He's a professor of the Whitehead Institute, which is right across the street. So we're all in the neighborhood. And so I'm going to turn it over first to Silvio. He's gonna share with you a little bit about his work.

**Salil**

Awesome. Thank you, everyone for coming tonight. And I would love any feedback you guys have and think of really hard questions. have as many beers as you need to be inspired with tough questions. Ian and I are up for the challenge, I think. Yes. All right. So all of us in this room started when egg met sperm. I know this is our parents. So we don't like to think about it, but that's how it started. And what's funny, right is that made one cell and we call that cell the fertilizer. zygote, but that one little cell had to figure out how to make the trillion cells that are in our body, which are all very different from one another, right? You know, it's funny, we actually I think don't really understand a lot about how that happens, particularly in mammals. So that one cell is going to divide and divide and divide, and it's going to make a little clump of cells. And at first, those cells are all identical. But at some point, they have to start to differ from wanting one another. They have to start behave behaving differently, but they have to do it in a very stereotypical way. Right? You want to end up with one head, two hands, two feet. And of course, there have to be some differences to you know, everybody's heads a little bit different size. Other things vary in size that can be important that we're supposed to be tongue in cheek, it's okay, you don't have to laugh.

What's interesting Alright, I'll lay off the jokes. Maybe I need more IPA. So, a long time ago, Alan Turing, right, the guy who invented computers basically came up with this idea. And he said, Actually, we have these things called more Fijians, and they tell cells what to become, you know, they're these chemicals and cells are in a gradient of chemicals nature, each cell what to do. And that seems to be true and a lot of lower organisms, worms, frogs, it's not nearly the case, it doesn't seem to be at least in mammals, though, you know, in mammals, those cells in the early blastocyst in when we have a clump of cells really seem identical. That's important because we can pluck one cell out and do preimplantation testing. For example, we can even make that early little clump of cells in a dish. That's what allows us to do in vitro fertilization. So where does that information come from? So what we work on in our lab is we actually think, random events. So chance events, things we might call noise, just random fluctuations and models. between cells actually get organized together, that we've evolved ways to take just random events, but them together and get something deterministic. That always makes sense. Like always ahead on one side, always a foot on the other side. And so we study how genes actually in mammals are wired together to give us this outcome. The funny thing is, as to mention, I'm also over at the Koch Institute. And you know, many of you probably know someone who's gotten cancer or actually fairly young audience, so hopefully not. And what happens is when we treat cancer, we treated with chemotherapy, and there's always like a few little cells that escape, right? Oftentimes, this is why people fail chemotherapy treatments. I have another life as a pathologist over at Mass General Hospital where we look for changes in those cells, changes called mutations like in the DNA, and a lot of times we don't find any there no mutations and we can't help patients understand why those few cells became a system to the therapy, why they randomly started behaving differently. So in our lab, we actually think that the same processes in genes that organize these random events together to give you these developmental steps, actually, later on get activated in this haywire way that actually also makes these rare populations in cancer that resist therapy. So that's pure conjecture. I have absolutely no evidence that that's the case. But I think cancer is kind of the price we pay for the ability to organize random events as mammals. So that's what we work on.

**Iain**

This is the first time so Leo and I have met actually, despite the fact that our labs are across the street from each other. And so actually just heard about his work is pretty cool for me to what I liked there is actually I would have started in exactly the same place. And now I'm going to go very different place. So what's Leo says we started we all started As one cell, and our bodies are each about 30 trillion cells, that's a lot of cells, right. And so he focused on those differences and what makes our head different from our foot different from our liver from our brain, and and throw through that process, there has to be a lot of things that are changing. I think in a lot of ways. We're focused on that same process, but the things that are the same. And so if you imagine sort of the that first cell, that's a really important first cell, it has all of the information that's going to need to go into making your entire body. And so in the in the DNA, which is packages in these physical units called chromosomes, DNA basis that exists there are going to provide all of the instructions that we're going to need for anything that you'd ever want to do. They're going to need to be the instructions for just making a cell but also, if you want to be able to smell a certain smell, that information has to be part of the DNA in that first cell. And so what our lab cares a lot about is if we're going to go through that process of making body's 30 trillion cells. And then also think about like, just today, about 50 billion cells in your body died. And you have to have new cells to replace those your skin is going to be turning over other parts of your body keep turning over every single day, we get them to make 50 billion new cells. Every single one of those cells, with a couple minor exceptions, needs exactly that same information that that very first cell had. And so what our lab cares about is basically, how do you drive that process of making new cells over and over and over again, and never getting it wrong? Okay. And so we come back to that disease thing, too. So it's a little mention cancer, it's very important there, right? He mentioned that a lot of times there's not changes in the sequence of those those letters that make up our DNA. Cancer cells are cells that are prone to errors when they're going to transition that information. If you look at you know about 90% of cancers, Instead of having the 46 chromosomes that our first cell started with 23, from our mom, 23 from our dad, they might have 63 or 72, or 51. And so that process of transitioning that information when you make the new cells cells has gone haywire. And so ultimately, we care about how you do it right over and over again.

And I like this difference for here that we have now have well, but then what are the things that you're changing? How do you draw on that information and do different things on it? How do those cells, you know, seeing the entire map of the body as as they make things for us that process, you know, I just find infinitely beautiful and amazing and reproducible, that just can do this thing that all of us can actually be sitting here with our 30 trillion cells and exist, and just sort of every time you do that process, you have this huge premium on not screwing that up. And so we think about like, Well, how do you actually do that? It's one thing to say that, ultimately, that comes down to machines. How do you make protein machines Actually, you know, encoded in that DNA that sending that for cell that's going to allow you to do that. And so we really care like this a process that people have been watching for 150 years at this point, we still don't actually understand like, how do you build a nano machine that's, that's capable of doing that? How has the cell created those things that are capable of doing that? Well over and over and over again. So I think it's going to be a fun pairing to think about this core focus on one to 30 trillion, but where things come from from that, too.

**Max**

So I thought was really interesting. My first thought is, it sounds like the difference between your two ways of thinking is that there are things that just so fundamental about the cell that have to happen has to divide for the, you know, the organism to continue to exist, but then it also has to adapt and it has to, you know, build up new functionality. My thought is, what do you think the big experiments are to sort of prove this hypothesis that cancer is a result of this sort of enforcement of coherence.

**Salil**

So the question is why do I say cancer is related to this whole organizing noise anyway? Well, how can we prove it? That's a great question. And if you or anyone in the audience has ideas, I will credit you on the grant application we filed together. So it's challenging.

We've started by trying to figure out what those genes and those systems we've evolved as mammals are in development, define them very specifically, and then go chase them in patient tumor samples and to see if we can see the same processes being activated. In terms of what do we need. We need geniuses like Dr. Cheeseman here to tell us what the right machines are to ask, say, sell to sell. So we know actually the things that are the same sell to sell and the things that are varying. So right now we have really good essays or acids that are getting better for looking at all the genes in our cells one by one, one cell at a time, that are transcribed into what we call RNA. So everyone knows DNA. DNA is actually made into this intermediary called RNA, which eventually is made into protein. And protein is really kind of the business end of things. But we can look at all the RNA is in a cell. And we can say, these RNAs are different. And we can see which ones are different. And we can do that in cancer as well and try and get a sense of what that program of coherence is. We can't do that with proteins yet. You can look at some proteins that are different in a cell, but we can't say here is the whole landscape of proteins in one cell. And here's how that varies cell to cell. If we could do that it would be a huge step forward in biology. Perhaps the Cheeseman lab has insight or unpublished data, maybe doing it No, I don't know.

**Tim**

So let me just narrow in hopefully, I think on the some interesting overlap, it sounded like what you just described, which is true is that we can measure a whole lot of variation. If we look at this one set of the group that's inside of cells, which is RNA, right? We can get a whole lot of information, we can see a whole lot of variation sell, to sell to sell, but where does the variation give way to this perfectly conservative molecular machine?

**Iain**

I think maybe another way of saying that is the similarities are ultimately what we're studying, you want to understand how things work, right? But by the differences, then you really start to notice how things work in a deep way. Right. So, you know, I think we've all had that experience of, you know, we know how things work here. You go to a foreign country, and mostly everything is the same. You know, we're all people we're all humans, but there's going to be those few things that you notice that That are different, right? There's going to be, you know, some different food or a different tradition for how you say hello, right. And I think those things you notice when you cross cultures in a way that sort of stands out to you. And and I think the same is true for biology and that we're trying to define what are those core themes and ideas for how things can just work over and over again. I mean, biology really only makes sense in the context of evolution, where ultimately, life really happens. And very, very similar ways it's happening over and over again, and in a way that's reproducible and consistent and will always work. And when you look at that you you see these things where, you know, the yeast that made this beer, the way it's going to make a lot of itself is the same as ourselves. And yet, there's going to be clear differences. And I think it's those differences that you seize upon where something seems unusual, that actually tell you ultimately, the core who we are. And that you when you notice that someone says hello differently. It really makes you think about just your process of saying hello, and why are you doing that? And you know, what does it mean? And I think we do the same when we look at cells and cell biology and whether that's between organisms or within our own bodies, that those differences, the sort of subtleties of how things might work. tell you much more about that ultimate truth about what are the larger principles by which things exist?

**Tim**

Okay, um, that this has been, we got really conceptual really fast. So what happens when I have a beer, you know, in front of me. So let's drill down and get a little bit more fundamental. I thought I would ask my niece to contribute some questions. She's five. So I explained your research. It's both of you, as best as I could through my sister, her mom. So this is what Avalon has to say, when asked about your work filial, we were talking about how, you know, still I mentioned you can put embryonic stem cells in a dish and they'll actually, for a while kind of look exactly like they would look inside, you know, inside the body and start to do undergo development. She said her response was cells on a plate, she was amazed that there would be cells on a plate. And when asked if they would would know what to do when they're on this plate, or would they need to be inside of a body? She said they would have to be inside of the body. So I wanted to know if you maybe could respond to her, her assertion that cells would not really behave well on a plate.

**Salil**

So I will answer your question, but she's five. So that means she can join the lab in 14 years. So let her know she definitely has a spot. So interestingly enough, one of the ways we think about this, actually, is that they don't need to be inside the body, that actually the cells have these gene programs, that no matter where these kind of random fluctuations happen, they're funneled down the central pathways also. And so even if you have fluctuation at any one of let's say, 1000 genes, it ends up all being channeled through one or two central pathways. And so if you have two cells, and they're totally identical, if the fluctuations in one get channel down a pathway, then all of a sudden that cells starts to behave a little differently. And we don't know that this is true, but we think then that cell signals to the other cell, hey, I'm doing this, you do that. And so as a system, they always together make a decision about what they're going to look like as a group. But any one individual cell is essentially making a decision based on random inputs. I'm getting Really conceptual in the hopes that that stokes everyone to buy another beer from the night shift Brewing Company.

**Tim**

We're gonna we're going to take our break pretty soon. But maybe one more question.

**Audience Member 1**

So one question. If would you expect it to be differences between organisms that were sort of brought up in a dish versus brought up in through the normal means within a host? would you expect that to be an obvious results?

**Salil**

Yes, that's a great question. Are there differences if you grow up in a dish, or if you grow up in a body? So you can see that that's the case for certain organisms. I don't want to judge but the only word that's coming to mind is lower. So like, for example, like a worm or something like that. But what's interesting is we've been doing IVF now on people for many decades, everyone's fine. You know, there's nothing you can detect and people have looked. So somehow, everything internally just knows where to go. And I think You know, as as Ian has pointed out, you know, we have machines that do the same things in every cell. And yet they know somehow to just do it just a little differently in one cell from the other to make this 30 trillion cell types. I think it's fascinating. One other thought I want to mention while I'm rambling, you know, the concept of evolution came up, it is totally wild to think about why we evolved complex things such as 30 trillion cells working together in the first place, like what's the drive for that? Right? That's a highly ordered system. It's a system that you would think would take a lot to make and shouldn't just kind of like spontaneously happen. So there's got to be some real deep principles there. And I think we're just starting to scratch that surface.

**Tim**

I agree. I think actually, my niece had an evolution question. How did the eyes get to be like the thing to see? So she was right there with you the whole time. I'm. So with that we'll take a 10 minute break, get some beer, and then we'll reconvene. And I'll just scream at you until you're quiet. And we'll get going and hopefully get some questions from you all.

Okay, as we return from the break, Ian Cheeseman is describing what it is his lab studies and how it's kind of different, but in some weird ways a little bit similar to what silly old guards lab studies. So he's setting us up with this. All of the cells in your body came from one single cell. And they add every single division had to partition perfectly, the DNA content from the one cell into the two daughter cells. And that is iterated over millions and millions of times to build an organism. Right. And so he takes us first to the simplest way that we know that this happens, and that's in bacteria. Bacteria are really simple. They're much smaller than ourselves than mammalian cells. And they can be That's pretty well, right? So they take genetic information and physically separate them inside a dividing cell. So we rejoin Ian, as he's describing that, and telling us how it gets a little bit more complicated.

**Iain**

As cells evolved and developed and particularly made, you know, we have much larger information amounts of information. So therefore much larger physical units, and we have all these different pieces, you want to be able to do that same thing. And so you have to build a machine. And so every single one of our chromosomes has to build this machine that our lab cares about, has to be able to grab DNA has to be able to hold on to that and has to be able to distribute that when you divide, okay? And so instead of the, say three proteins and bacteria, the building blocks that a human cell needs, there's about 110 different factors, proteins that do this, each one of those, each one of our chromosome needs about 500 copies of every single one of them, okay? And it really for me, is this just sort of beautiful engineering process of how to You build this molecular machinery that does this stuff. Okay?

So it's kind of like building a car, you know, you need to know what all those parts are, you know, you need to know, okay, I need a wheel, I need a steering wheel, I need the brakes, I need the motor. I need to know what all those different things are. I need to know how you put them together. It doesn't help if you're putting the wheels on the top, you know, how are we actually assembling all these things together. And then ultimately, the car is more than just, you know, a bunch of little parts together, it really has to work together as this well oiled machine. And so we we approach this, these molecular machines that ourselves build in a very similar way, how, who are the factors that are there? How do they fit together? And then how do they really work to do this thing that happens again, you know, this over and over and over again, you have to build a car that's not going to break down, you know, not going to run out of gas, that it's going to work where I well over and over and over again. And so I think that in this process of these machines that we care about, we know the building blocks, we know the parts we know mostly how they're put together. I still have no idea how it works.

Okay. And so I think for, for me, if you talk to people who learned about biology and the 1960s, they learned about mitosis, you know, they learned about chromosome segregation. It's something we've known about for a long time. And so you know, that's something that we've known about for that long, you kind of just assume that, wow, we should probably know everything about how it works. And I'm pretty excited that my lab is gonna have a lot of work to do for decades in the future, because I still, I still don't understand how that works, okay. And so really, on this fundamental molecular level of building a machine that does this core thing, that every single organism on the planet every single cell in our body needs to do. And the fact that we don't have that fully nailed, it's kind of fun. And and I think that what we learn about how you build that machine relates a lot as well to all of the different machines that function for making energy making proteins, you know, chewing things up, you know, inside of ourselves. There's so many of these images genes that are built. And this just happens to be the one that I find the most fascinating.

**Tim**

Fascinating. So I think we'll open up with questions and I will walk to you with the mic. Okay, one of us will. I see a lady in the red back here. Did you raise your hand? Yeah. Okay.

**Audience Member 2**

Thank you. Um, so yeah, guys, you mentioned how we are able to do like a pretty accurate photography of the DNA, the RNA, and we're just not there yet with proteins. What would it take today to get that like if you had to design your dream essay that would give you that photography, what it would, what would it look like and what information would you be looking for, that's additional to what we already Do you have with DNA and RNA?

**Iain**

Your question partly comes in maybe we can both enter in different ways is like, how do you measure stuff? Right? And so measuring DNA is about sequencing that right. And so, you know, DNA sequencing, probably we're talking about, you know, 70s, basically, in terms of being able to do that, for a large amount of DNA. I think that the thing that's been really fun recently, and what's the what is lab also uses this idea of being able to do that from an individual cell, right? So all of these measurement techniques, measurement DNA, measuring RNA, measuring protein, we can do those, what we can't necessarily do is achieve that from just one cell. Okay? And so I'd say that the DNA measurement now you can do from a sound does that all the time, and that's pretty fascinating. The RNA I think, you can take an individual cell and also measure and say, you know, how much of this RNA or that already exists. So our lab does a lot of mass spectrometry which is, you know, basically ways to measure protein. And the way that that relies on is that you're sending these ions on to the machine. And you need a lot of copies of each. And so your, your sensitivity and detection threshold is just not that good for on the protein side. And so if if we have the ability, instead of doing that from 10,000 cells to do that from one cell, I think that'd be pretty good. So I would say we we have the ability to measure, but the sensitivity of that just doesn't allow you to do that to see the store Cassidy showcase disease.

**Salil**

Oh, I definitely agree. I don't have much to add, because if I knew how to detect protein from one cell, we would drop this variation question and work just on that. No, honestly, it is exactly as the inset it's a measurement challenge. there's just not a lot of material in one cell. So how do you detect that and catalog all the proteins?

If you think about actually the thing about just assets that we do in biology. Most things that we do are an average. Right? We're getting information that is the the information from many, many, many things. And so the a lot of the beauty and I think what Sylvia likes is the noise right here is what we're measuring. But actually the way that a sinking individual celebrate, like, you know, all over the map, and I think that it's this sort of idea of similarity in differences you've got, you've got to have a way to say, what's the broad theme? What does the average, but if you can draw that from a single cell, just with that sensitivity over the noise, that's going to be a much better way to go?

**Tim**

Do we have another question?

**Audience Member 3**

I so I want to ask a question that like I'm hoping you'll have different answers to. So what I want to ask is like how a cell state is actually defined, like, you know, we can look under a microscope and identify a neuron or a muscle cell, but like, what is it in the cell? Exactly, that's that difference on a molecular level? Is that Is it protein? Is it the state of the the methylation or simulation of the DNA or histones or something? Where? So I guess my question is basically, where are those differences? Sort of a rising between self states?

**Salil**

All right. And so the question, if I, I might rephrase it, just to make sure I understand is I'm saying we're saying all the cells start to vary in behavior, how to actually define what the differences. A lot of the brilliance of this is, you can define it any way you want, depending on what funding body you're writing to. I'm joking, we, we actually need good definitions of that. So I would submit, it's kind of obvious that the 30 trillion cells in your body behave differently. But how actually to define what that differences. What makes a hard sell different from a neuron from a skin cell. It's actually not trivial. So in our lab, we've done that a lot based on what RNAs or what genes are expressed and how those differ between cells. You can also do it based on things that regulate gene expression. So regions of the DNA that sort of don't necessarily code for proteins themselves, but control what genes and proteins come on and often cells, that also turns out to be a really good way to define and say, Okay, these two cells, I think, are significantly different. But I think it does run into this question of a lot of the machines between the cells are the same. So what actually is a meaningful difference? And I think that is, on its surface, a statistical question, and at a deeper level, a question that we don't have a great answer for.

**Iain**

I will defer. That's excellent. Next question.

**Audience Member 4**

You manage, you mentioned at the beginning that you think these random fluctuations cause these differentiation? Could you give us an explanation of what types of random fluctuations you're talking about?

**Salil**

Alright, so the question is like, what kind of fluctuations are we really talking about? The real true scientific answer is we don't know, because we haven't defined them precisely yet. So I'm going to speculate and speculating great because I don't need data for it. One of it is just the fact that like, let's say a cell divides and it forms two cells, and you have five copies of a molecule. That molecule can only split two versus three. It can't split evenly into both cells, because there's five molecules, right, so it's an odd number.

So there is an entire school of thought that says in homogeneity or differences between cells actually arise just based on that chance distributions of molecules between cells. There are more sophisticated models or well maybe not sophisticated is not the right word, but more even speculative models, that actually by chance and certain cells within them, they can form these little micro aggregated regions and focus have called these condensed seeds. Literally liquid in liquid emotions the same way if you mix oil and vinegar. You know the if you do this, like when you get your bread at the Italian restaurant and you like put the oil and vinegar on, you'll see right like the balsamic vinegar makes a little droplet that's colored in the middle that sells maybe do that. And they do it differently cell to cell, and maybe that can start to introduce random fluctuations between them. I would say this is very speculative, and nobody really has data on it. Or if they do, please tell us because we're working on it. It's a great question. What, what's the actual source of randomness and what is it really that's fluctuating? That's important. Right now, you could write a perfectly reasonable perspective piece, basically guessing, amongst all the kinds of machines, you know, that Ian's lab works on and all the other things we've described in cells, it's we're still at the level of guesswork and it's only Because now that we're getting the ability to measure things in individual cells, that we can start to even say what it is that varies cell to cell. So remains to be seen.

**Iain**

I think probably maybe we need to start drawing out our disagreements as well at some point. So I love this idea of diversity and difference and change and stochastics. And I think that that's a feature of just biology. I mean, things are noisy, right. And, and we should, we should own that. I think that I guess my perspective is that, on some level, it shouldn't matter. And that what we ought to do is to build a system like if you want to build a machine, you want to build a cell, that cell out to be robust. And so if you just imagine, you know, all of us can exist out in the snow. You know, we can exist in in the Bahamas, or Florida or something like that, like we can exist in different environments, and that the way that our bodies work are created to be able to deal with those variations and those changes. And so I think maybe it's the opposite way of thinking about maybe you can own the noise and you do need these differences. But let's build a system that doesn't care. And let's build something that you know, no matter how you try to push on it, that it's able to come back to what that state is. And so even if you have those fluctuations, you should you should be able to get around that. I think both are probably true.

**Audience Member 5**

Thank you. We have seen such great advances and are continuing to see great advances in the field of genetic medicine, and the ability to do things like silence RNA and edit jeans. Is there any thing any examples that you can point to that have informed your opinion on the inner workings of the cell or anything that you're kind of looking to, as that you think might inform your future thoughts?

**Iain**

I think I actually really liked that question a lot of ways right. And I think that Some level what you're saying. So we both exist at this corner in Cambridge on Vassar Street and Main Street. Okay, so what white hand sitting right there, the Koch Institute sitting right there, like that center right there just like has more science than you could possibly imagine. If you think about the science that was done just at that intersection, there's a lot of these things that have really pushed us forward. Okay. I think the thing that makes me really happy about this is that, I don't know what that next thing is. Okay. And so partly, maybe the way to say it is okay, so your question was genetic medicine, you know, we have this ability to make changes, right? There's, there's a company in Ireland, they're there. They're building this idea to not use RNA to knock things down. And can we use that to treat people right? And this came from this idea of, you know, basic accidental discoveries, right, the whole idea of this enzyme machine called CRISPR, this ability to come in and edit our DNA. And that was it. Total accident like that that thing came from yogurt company trying to stop the killing of their bacteria. Right. And and I think that for me, is there something today that I think is going to change the way that we're understanding and treating disease? I think it's probably, you know, hundreds of those.

So we exist at slightly different ends of that spectrum. I want to understand how things work. And so I think that most of those discoveries that you can point to, that have truly pushed us forward have been things where someone was trying to understand and curiosity discovered different way, fundamentally just how things happened. And we didn't know where that was going to lead at that time. But it led to something that was much more than we would ever would have anticipated. And and in a normal context, for sure today that that ability is as CRISPR if we have the ability to make clear, tangible changes to the genetic information we can do. Quit, you know, amazing things. What changes you want to make is going to rely on really understanding the process so that you can do that in a you know, thoughtful way. And here I'm talking about modifying small subsets of persons cells once they're made not not doing this genetic in babies thing, which is a horrible idea. Anyway, so my broader answer from me is that I think that's what keeps me in biology. What I care about is is so basic, and like, I didn't mention the word, you know, cancer that many times. I love this idea that the way by understanding life and understand biology and the way things work, it's going to lead forward to those leaps that I can't I can't anticipate, and I think we have some of those on the horizon, but then it's the next ones I'm most excited about.

**Salil**

So awesome. That's fantastic question. So I would say for me, I find myself obsessed about thinking About the diseases and the conditions were actually we haven't made that much progress in genomic medicine. So we can we absolutely can silence things, we're going to CRISPR cure many of these diseases we've known for a long time where there's a single gene, we know that gene is missing. And we're going to put it back with CRISPR. But what I find fascinating, for example is, you know that we talk a lot about this or we hear a lot about this personalized medicine revolution. Now, what's interesting is that has really only hit certain spaces. So I'm, I'll just talk about cancers and sets of space. I know a little Well, if you get a lung cancer now, we can tailor your therapy based on the mutations, the changes in DNA super well, but so many cancers, prostate cancers, pediatric cancers that don't have mutations, we have no idea what's going on. And we can sequence the DNA and sequence and more and do ever bigger and bigger omics, and I think it's still Not going to answer the question. There is a conceptual piece, I think I feel we're still missing to address that next set of diseases. But so I find myself fascinated by what we're missing actually in the current genomic medicine revolution.

**Tim**

Sorry. Thank you. We are over time. Thank you, everyone. This was great. Our guests will be here for hopefully a little bit because we have prizes to give to them. So hopefully, they'll stay around for that. And during that time, you can also ask them more questions if you want. Thank you, everyone. I'd like to thank the whole glimpse team, Max Robinson and Alex Albanese glimpse as funding from the postdoc Association at MIT. So we would like to thank them for their generosity. And you can find out more about this episode or listen to previous episodes at glimpse.mit.edu for this live event, we have to give a very Special thank you to the entire taste of science Boston team that but especially Eliana Manousiouthakis and Jared Hicks. And for Nightshift brewing, we have to give them a very, very special thank you for letting us rent space in their tap room in Everett. And I highly recommend anyone go by to their tap room because it's really fun and their beers are really delicious. And we especially want to thank Brittany Hirst who coordinated with us. You can check out taste of science at tasteofscience.org and you can check out the local team here in Boston at tasteofscience.org/boston. All right, thank you very much.

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