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CLOUD REALITIES

CR042

The age of living machines
with Susan Hockfield,
President Emerita, MIT

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[00:00:00] And I would simply say, my daughter who studied Latin says it can't be emerita. It has to be emeritus. And I said, it can't be emeritus. It's emerita.

No, you got to love a good quality Latin joke though. They always go down a storm. We don't get them very often on this show.

Welcome to Cloud Realities, a conversation show exploring the practical and exciting alternate realities that can be unleashed through cloud driven transformation. I'm David Chapman. I'm Sjoukje Zaal, and I'm Rob Kernahan.

And in today's very special episode, we are going to look at the dawning of the age of the living machine.

For years, physics has been dominant in how we've been building machines and [00:01:00] thinking about things like computing and all of the platforms that we currently take for granted today. But the greatest minds in the world at the moment are looking at how biology and biological design can be tapped to inform the machines of the future.

Now before we get to that, Rob and I were in In the office the other day. Rob was drinking a gallon of water really quickly. And I was like, Rob, what are you doing? He's like, I am so thirsty. And I'm like, why? And he's like, well, I can't really tell you because I'm so, I'm so bound up in thinking about this thing.

And I'm like, well, what's confusing you this week, Rob? Thank you for that, Dave. Um, I don't know where I was going with that whole thirsty thing. I started the joke before I got to the end of it. But anyway, what are you confused about this week? I think you had a great idea at one point. Not sure how it got deployed.

But anyway, um, you know, we've all seen the film or Or read the book of Ready Player One, right? Yep. You've all seen it. [00:02:00] And we're interacting now on a virtual platform and there's this vision of the future, which is we're all immersed in this world where we can interact like we're together in 3D and interacting in 3D is always better and more successful.

However, When you join the average conference call, the disaster that is everybody sorting out their webcam and the audio. Oh, no, I've clicked on the wrong button and all this stuff. And you go, well, there's already quite a lot of faff involved in that. Right. Will we accept the fact that we then have to put on a bigger headset or something and get sucked into something else?

And have you installed the right drivers and everything else? So is that reality? Ever going to become a reality or that, that, sorry, I should say that that view of a reality ever come true. And that's what I'm confused about because I'm not sure the humans will put up with the faff. Well, it's a good, that, that is a good one.

And now, where do you think, um, Apple's augmented reality goggle things fit within that? You watch the advert, right? You think, they're cool. But then do you look like [00:03:00] a complete WALL E when you put them on in the office? That's the thing, isn't it, right? Yeah, so it's like... You'll have a, you'll have a, you know, like a digital version of your eyes on the front of them.

Yeah, it's like a face mask, you have to stick on with the headset behind it. I'm not entirely convinced the human wants to go through that process, and that's the bit I'm confused about. Will it actually catch on and be goes, I couldn't have lived without this before, type thing, or is it like, I don't want to look like a WALL E again.

So I'm, I'm deeply dubious of whether I would say, have work meetings where I'm talking to an avatar of somebody versus, you know, something else. But I say that as, you know, a 50 odd year old man slash Luddite. My kids who spend most of their time in fortnight or call of duty or something like that don't see the world in that way.

Do they know they don't and the integration I think of virtual reality into the gaming world to me feels like the natural course [00:04:00] that we will go through as a human race to really exist in digital worlds with each other. And then if that underpinned by real world value transferring into um, Digital world value, you know through things like you know, nft versions of I don't know pair of air jordan ones that you can buy in In fortnite that then have real world value because they're connected to something in a in a way that makes them unique I can sort of see how all of that comes together But I don't think it comes from us.

I think it comes from the next generation. The next generation. Maybe Ernest Cline's vision was true then, and we will live in that type of world, but I don't think it will be our generation that embraces it. To be honest, during the pandemic, we did lots of community events with those. Glasses on. Oh, they go.

And to be honest, you can connect better to each other. It is actually different than just on the screen with a camera, but those glasses are way too heavy for now, so. Right. They need some modification on That was the Oculus. Was the Oculus, yeah, that was the [00:05:00] Oculus. Yeah. Yeah, yeah, yeah. My kids absolutely love Oculus, then know the gun, meet with their mates, have a chat, watch a film.

Inoculus land. So I, so I could, yeah. Maybe it's happening then. Well, there you go. That's it. It is just a generational issue. There you go. Problem solved. Probably the first time, actually. We, we made progress on that one. So well done everyone. Nice, nice work. Now getting onto today's subject, I am absolutely delighted to say that we have Susan Hockfield, President Emeritus of MIT, joining us to talk about the age of the living machines.

Susan, thank you so much for joining us today. Do you just want to say hello and just tell everybody about yourself a little bit? I'm thrilled to be on the show. I came to MIT about 18 years ago as president. I'm a neuroscientist by training. I studied the structure of the human brain and how it develops.

A fascinating topic, but was drawn out of my lab into university leadership, first at Yale and then was [00:06:00] called to MIT. I was president from 2004 to 2012. I'm now on the faculty. I do some teaching. I do a lot of consulting and, um, it's just, uh, incredibly exciting to be in the midst of a froth of experimentation and future gazing.

Mason So why don't we start the conversation today just by understanding the journey to writing The Age of Living Machines. So what journey have you been on and how did you get to something that's actually so technically challenging? Thank you. How I came up with the idea of the book is kind of the story of my coming to MIT.

So I had been at Yale for 20 years, great place, Yale University, and I think everyone knows that MIT is a different kind of university from the Ivies, which is where I had been. Maybe for those of us that don't really know that, maybe just set out that distinction for us. Yeah. Yale University is one of the oldest universities in the United States and is renowned for its strength in the humanities and social sciences and has [00:07:00] incredibly strong mathematical and hard sciences and has been working to build strength in engineering.

And so in a sense, Yale and MIT are reciprocally strong institutions. MIT, in contrast, is renowned for its strength in engineering and science. It has wonderful humanities and social sciences, but on a smaller scale. And as I said, these are just, you know, reciprocal strengths between Yale University and MIT.

When you come to any new university as its president, Task one is to learn as much as you can about the institution from the people who are there. So I spent a day, two, three days a week before I actually moved to MIT visiting and visiting with. a huge array of people to get their sense. Not just that, but stopping people as I walked around the campus, uh, just to talk to them about, uh, what they saw as MIT's opportunities and responsibilities over the next decade.[00:08:00]

Among the people I met with in my first set of meetings were the deans of all the schools. And the dean of the school of engineering was of course, most important to me because that was the most different from What I knew at Yale. Right, right. The dean then was a fabulous man, uh, named Tom Magnanti and in my conversation with him, he told me first of all that the school of engineering at MIT is our largest school credentials early on.

We like it. It at the creds out. Yeah, yeah, yeah. With close to I think 400. faculty members. And I, um, bit my tongue. Uh, and so I didn't say, yeah, yeah, I know that. No, I, but, um, I said, yes, a very large and very important school. But then he told me something that was astonishing. He told me that, you know, something on the order of a third of the faculty in the school of engineering were using biological parts in their work.

Wow. That's what I said. I said, wow. And what year was this? [00:09:00] This was, would have been the fall of 2004. Right. Wow. And, um, And I had not heard anything like that before. And so I asked him to tell me more about what he meant. And what he meant is actually the subject of the book. So that was my first, you know, kind of opening into the world that is evolving now.

And uh, the, the fundamental idea is that Biology is very smart. It has evolved all kinds of solutions to very important problems in the natural world. And if you can identify how biology has, may invented a solution, you might be able to import that solution into some technical product, some technical object that you're trying to invent.

And the book, uh, uses, you know, calls on four or five different examples. Well, fantastic. And just before [00:10:00] we delve into that deeply, I wonder if you recall the examples that your colleague talked about and back in 2004, were there any of the examples that the team were looking at already that were particularly resonant for you?

You know, so the examples were, you know, things that were, I can't remember exactly what examples he offered, but once I was aware of this new domain, I mean, for me an entirely new domain, I began to see examples almost everywhere I turned. And, you know, choosing examples for the book was really a, a winnowing down from, you know, dozens and dozens of fascinating ways that people, and it's not just people at MIT, engineers all over the country, all over the world.

have been turning to biology as a source of inspiration. This is kind of, it has been the story for probably centuries, turning to biology for inspiration about how to solve problems. Did we all just get [00:11:00] distracted by the physics side and the electron and forgot to pay attention to what had been happening for thousands of years behind us and went, Oh, look what we found.

It's like always been there anyway. But you know, it's interesting. So we didn't have a way of understanding how biology made its magic, how biology made things work at a very fundamental level until we got the tools of the molecular biology revolution. So in the book, I tell the story of what I call convergence 1.

0. So the technologies that we're using right now to communicate, these are products of understanding the fundamental components of the physical world paired with engineering. to give us computers and microphones and, you know, electricity, you know, all of the, uh, many, many technical wonders that we enjoy, but it required an understanding of what I call the parts list of the physical world in order to be able to use those parts to build the devices and technologies of the 20th [00:12:00] century.

As you're going back into the 19th century. Mason Well, in your, I think you call it Convergence 2. 0, which is then the coming together of technology and biology. Let's start with, when you say living machine, maybe just describe that for those of us that are coming across some of those concepts for the first time.

Blum Yeah, so what I mean by living machines are machines that are built with components from biology. Not components from physics, although, you know, one could argue if you go far enough back in how the biological components are made, they're actually made with physical components, of course. That's a whole other level.

That's a whole other level. That is how physicists annoy biologists, because they just say biology is just physics, as long as you pare it back far enough before you find the... Absolutely true. A fact. Uh, so I guess let, let me give you an example. Yeah. One of my favorite examples is water [00:13:00] cleaning, water filtration.

And let's just back up a second. So the reason I'm so enthusiastic about these new biology inspired technologies, which is way other people, uh, talk about it sometimes is that we have some incredibly pressing issues. We've got. You know, close to 8 billion people on the planet now. And it's estimated that by 2050, they're going to be 10 billion.

And we're not doing a great job at providing for the 8 billion today. If you think about clean water, you think about energy. If you think about health and health care, I mean, you just go down the list of things that we need. We are not meeting the needs of people around the planet. And how are we going to meet those needs in a way that is going to be sustainable?

We need to find better, better solutions. And biology is, uh, no surprise, very efficient. Biology has had... thousands and thousands of years to figure out how to, uh, [00:14:00] do what need, make what it needs, uh, more efficiently. So we are short of clean water. I mean, you look at what's going on in, um, the Middle East right now, providing clean water to the people of the Middle East has been an incredibly serious problem and it remains a serious problem.

But if we think about how nature does that, it's a fascinating process. So every cell. In every living thing, a cell is kind of like a little balloon that has an inside environment and an outside environment and each cell has to regulate what comes in very carefully so it doesn't get poisoned, so it gets the things it needs to live and can, you know, get rid of the things it doesn't need.

And that transit is provided by small pores in the surface of the cell. And, you know, obviously most of what cells are [00:15:00] is it's a bag of water with components in that water that are designed so the cell can do its particular function. So, I don't know, for, I would say forever, uh, people imagined that the cell water transiting in and out was important.

But no one could find a channel for waters. We know there are channels for important elements for a cell, for sodium, for chloride, for potassium. Particular channels that are designed to transport a particular component. And a water channel was, um. Discovered by accident by a hematologist named Peter Agrae.

He won the Nobel Prize for this discovery. That's a pretty good outcome from an accident, isn't it? Yeah, pretty good. Yeah, yeah. Above average, I would suggest. It's a bit like how I got my job, Dave. Are you going to talk about your level four architecture qualification, Rob? Peter Agrae was trying to identify the gene for a birth anomaly.[00:16:00]

that was in blood. And so he was, you know, preparing proteins from blood and looking for this particular thing. And he had, you know, purified it down. He got this single protein. He did some initial determinations of what that protein did, and it was the wrong protein for what he was looking for. And he was puzzled by what it was.

And a colleague of his suggested, huh, you think that might be the water channel? Right. We've been looking for that. We've been looking for that. It was, it was a water channel and it was, he named it aquaporin, which is beautiful, you know, water hole, water. And, and it's, it's an amazing little bit of biological machinery.

It sits in cell membranes of every organism and, uh, allows water to travel in and out of the cell. And. There are some variants that do more than water, but most of the aquaporin molecules in our bodies transit water and water only. Mason And how are we taking those insights [00:17:00] then and, you know, creating machines with them?

How does it actually port across? Is it the fact that we take the core... biological design and then recreate that in some sort of physical technology as actually using live biology as part of the machine. So that's a fabulous question. If we were to actually assemble an aquaporin molecule by ourselves by synthesis, I don't know that we would even know how to get that done.

Right. So instead, there is a company by the way, Uh, headquartered in Copenhagen called aquaporin and they build aquaporin based water filters. So how do they do that? You need a boatload of aquaporin molecules, aquaporin molecules, they're very small, right? You need a lot of them to do the job. And, um, happily the technology for getting a boatload or at least a tubful, or at least a cupful [00:18:00] of aquaporin has been established by a pharmaceutical industry.

So a lot of the drugs that we use today, the biological drugs, you hear about biologics, right, are made by finding the gene that you're interested in, putting that gene in some organism We used as our producer, like E. coli or, I mean, there are a number of, of small organisms and organisms that are very, very simple, single celled organisms.

So you introduce the aquaporin gene into a tub full of E. coli, let them do their thing and then purify the aquaporin. out of that mix. And then you can use the aquaporin. You'll let someone else do the work. Let the cells do the work for goodness sake. And then you purify the aquaporin away from the other cellular, you know, bacterial components and, uh, embed that aquaporin in membranes.

And of course, because that's where they live, aquaporin [00:19:00] goes very nicely into membranes. And the water filter that is simply, frankly, frankly, just a sheet of aquaporin molecules. Wow. That's what I say. Oh, wow. We've taken something that is in nature everywhere and translated it to solve a massive issue, which is good.

And what's the performance like of those filters compared to, say, ones we might build with more traditional mechanisms? It sounds like they're probably really just really, really good at what they do. They're good at what they do. They're probably equivalent to, um, it's new. So part of the problem of the, uh, of technology development is, you know, You have to kind of, you know, find yourself along a path step by step.

But I haven't yet bought one for my home, but you can buy home aquaporin based water filters that fit under your sink and fried water. Mason But I wonder if we just step on a little bit and talk about some of the other Very serious challenges that the world is dealing with at the moment [00:20:00] and how this technology might help.

The one that's in my head at the moment, I guess, is energy transition, given it's one of the most profound challenges we probably have at the moment. What's your thinking on that, Susan, and how biological machines can assist there? Yeah, so energy transition is arguably among the greatest, uh, challenges, uh, for the globe.

You know, there's a lot of enthusiasm about bigger wind blades, you know, larger solar farms. As I look at it, I think the, um, the greatest technical barrier to the energy future we aspire to is actually energy storage. So there's energy cascading. out of many, many sources around us and we don't capture it.

Think about all the streams that are running, you know, uh, you know, streams, rivers that are running downhill and there's a tremendous amount of potential energy there, but we're not gathering it. And even if we could turn all the water flow that we can [00:21:00] access into electricity, we don't have a way to store it.

So energy storage now is, you know, I'm not going to say it's not good. It's very good. It's just, um, insufficient. And, uh, current batteries. Uh, to make batteries currently is inten energy intensive itself. Right. Right. And has a lot of toxic byproducts. Yeah. And so the question is how do we invent better energy storage is less toxic to the environment.

and more efficient. So one of my colleagues at MIT, a biological engineer named Angela Belcher, is working on batteries that are basically made by viruses. Not living viruses, so viruses that aren't going to infect you or me or anyone, but viruses have the most Many viruses have the most incredibly beautiful structure.

They're just like, they're, they're small tubes, very, very small [00:22:00] tubes. But we know how to manipulate viruses. We know how to change the genes in viruses to make them do some of what we want to do. So what Angie's done is figured out how to transform viruses. into vehicles that can bind the components of batteries.

So they can bind lithium, they can bind magnesium, they can, you know, she can do whatever she wants them to do. And because they have this beautiful, almost crystalline structure, once she has made viruses that bind the components of batteries, they will easily assemble into sheets. And she builds cathodes, she builds anodes, puts them together, and they are incredibly efficient batteries.

But most importantly, these batteries are built at room temperature without producing any toxic byproducts. What I'm sort of struggling to get my head around is what does [00:23:00] the physical product look like in this particular case? Does it look like a traditional battery? Is it profoundly different? Yeah, I'm sorry.

She gave me a sample and I wish I had it to show you right now. So these are the coin cell batteries that you use for your, you know, every electronic device. It seems that you're putting these, dropping these little coin cell batteries. So she has, you know, she uses the same. physical compartment that the standard batteries that you buy over the counter are.

But inside them are these components that are fabricated by viruses. So backwardly compatible. I like that though, because it's an easy transition for everything that we've created. So we don't have to smash it all apart. We just go, it just slots in, you slot the chain. Lithium mining is a very, it's very dirty, isn't it?

It’s not good for the planet at all. So if we can get rid of that, that’s a massive boon. And the battery performance then, is it equivalent or better than what we know from the lithium ion batteries that we use today. Equivalent performance. Cool. The question [00:24:00] for actually all of these technologies is how do you scale?

Yeah. A coin cell battery is one thing, a car battery is something else. Um, but you’ve got to start someplace. And, you know, to my mind, the hardest problem has been cracked, which is how do you put together the electric components? that allow some entity to store energy, store electricity. And she’s solved that part of it, out of the part, part of the problem.

Which to be fair is the hard part. Now you just need to get the manufacturing process online and scale it up. Yeah. Yeah. The scale is scale next. I think we’re going to come on to scaling and industrialization and some of this stuff in a second. But before we did that, I just wanted to touch on another use case, which I think is like, yeah, another one of the sort of profound questions that we have that we need to fix for, which is food production.

So it seems to me this type of technology that you’re describing, Susan, and food production and the challenges that come along with the food production at a level that we have to do it for our growing populations, [00:25:00] it feels like there’s a good match there. We had some quantum scientists on the show relatively recently, and they were talking about one of the first use cases they’re trying to do in the quantum computing world is to try and um, Address fertilizers.

Fertilizers have huge contributed to things like the ozone layer problems and things like that. And they think that being able to use quantum computers to better model what’s going on biologically in the production of things like fertilizers, they will end up being able to get past that problem. So I wonder if you saw any coming together of what’s going on in your world of living machines and food production and maybe some of those quantum concepts.

I can’t get as far as the quantum concepts, but, uh, We, we struggled as well, believe me, you’re not alone with that. It’s, it’s, that’s mad. You know, and it’s hard, I mean, one of the most astonishing, uh, statistics I learned and in my exploration of the applications of [00:26:00] this marvelous convergence of biology with engineering was that in the beginning of the 20th century, We were farming corn and producing something like, at the very best, 50 bushels an acre.

Today, we farm corn with a yield of over 150 bushels an acre. So it’s just a reflection of how much progress has been made and how much more can be made. There’s a wonderful... set of projects. I visited the, uh, Danforth Plant Science Center outside of St. Louis. And it’s one of these kind of, um, I don’t know, just a brain bank around plants.

It’s, and of course it’s the middle of, um, in the United States, what is our breadbasket. So out in Missouri, which is the middle of the country, which is, um, farmland. And, uh, you know, a couple of things caught my eye is ways of [00:27:00] monitoring crops. Cause you can’t, as you say, You can’t change what you can’t measure.

And so tremendously, uh, the, you know, adept geolocation kinds of technologies, monitoring presumably at some point by satellites, but, um, so the way of gathering information is changing so we can get information faster, we can monitor how crops are doing. There are ideas you can monitor it at the level of individual, um, fields and be able to dial up, dial back.

you know, water nutrients, uh, to optimize how the plants are growing. But to my mind, the, um, even more astonishing things are just what biological engineering has done for plants. And part of the change between 50 bushels an acre to 150 bushels an acre is actually hybridizing, you know, finding new kinds of corn or designing new kinds of corn that can, uh, be more productive.

I [00:28:00] think one of the, um, most compelling stories I heard, uh, was about a crop that we don't use in the United States. It's called cassava and cassava is the basic crop for poor people in many places of the world. And what happens to plants out there, it's like animals and humans, every once in a while, a virus comes along that threatens it.

And there, um, has been a cassava virus that threatened to wipe out all of cassava the world over. And, uh, they managed to engineer with a, in a cassava

variant. That had the same growth properties of the, uh, original cassava, but was resistant to the virus. And, uh, you know, these are things that don't get to the front page of the newspapers or the top line of our news feeds, because of course, who reads the newspaper now you [00:29:00] read it online. Um, so there wasn't a headline saying,

you know, cassava crops saved. Yeah. But that is exactly what this. a group got together to do and succeeded in doing is designing a cassava that was resistant to the cassava virus. Mason Well, you think about the impact that has is that, you know, it means a huge amount of the populace of the planet can continue to have food security off the back of what they've done.

So it's a marvel of science to protect humanity. And again, it's like the unsung heroes of the planet making sure these eight to 10 billion people who we're going to have to deal with. can continue to be and sort of live a life. And it's quite important. I don't think we talk enough about it because they're just these amazing things going on every day.

Yeah, exactly. It just, it takes my breath away. Uh, to understand what the downside was, if they hadn't succeeded, it would have been a catastrophe. Right. Absolutely. Absolutely. And let's move on then and return to the subject of industrialization. So we now have some [00:30:00] very, very significant things going on in this field.

As you said, much of which from general population is not reported or hidden. So what are the next steps, Susan? How does it go from here to something then that scales to a point where it can have the level of profound impact we've just talked about in the last example? Yeah. So let's talk about, obviously the cassava problem is, I would say this moment's cassava problem.

There'll be another one. It's coming. There will be another one. And, um, you know, presumably what they learned in solving this cassava problem will be, uh, useful as they go to the next one. But let's talk about energy, for example. So Angie Belcher, like, you know, many of our... Engineers at MIT starts companies with her technology.

She hasn't yet done it with this, these virus batteries. They're not quite ready for scale up, but it's, you know, we have a fantastic system for taking things out of the [00:31:00] lab. into production. It's a high stakes bingo kind of thing. Um, but that's kind of how things move forward. It can be enormously accelerated by wise funding because a lot of these projects, when you actually look at.

the finances of them. You know, you've got to make back the money at some point, but at some point could be five years or 10 years down the pike. And one of the things that, uh, happens, I think, you know, certainly the United States and I imagine probably in all the companies represented on this call is that, that governments can direct funding toward next generation technologies.

And that's been hugely important. I mean, the fact that. Anyone at MIT or any of our research universities here anywhere can actually do their work is because governments fund in advance, they're paying it forward. So they have, uh, this was a, [00:32:00] a model that gosh, was developed over. in some part in the 19th century, but really started gaining steam in the 20th century.

And, you know, certainly not the happiest example, but the technology development for, let's just say World War II, the technology development for World War I was a consequence of government funding to actually produce it. One of the, uh, great technologies to come out of World War II was radar. And that collaboration between Britain, that had done the first couple of steps, had created kind of a first mini model that had to be scaled up and, uh, the materials were brought to MIT.

So MIT, uh, hosted, was called the Rad Lab, uh, the Radiation Lab, uh, because no one imagined that, uh, anyone would think radiation would have anything to do with the war effort. But it is where the place where radar was developed into an extraordinarily, [00:33:00] uh, not just a useful technology, but many people consider that to be the war winning technology with the, uh, bomb being the war ending technology.

but extraordinary advances in understanding and, uh, the development of technology. Mason Yeah, exactly. The war gives it a focal point, doesn't it? And it gives it a series of, for want of a less crass word, it gives a series of business cases that become, you know, quite clear when that kind of threat is looming.

There are a series of threats that we've alluded to during this conversation, not least things like climate change. Do you see them as a strong enough catalyst yet to do what's going to be required here? In the book, I make the cry for, um, the next technology revolution coming not from the threat of war.

But the promise of peace, because among the destabilizing elements among humans are the, you know, the things that we don't [00:34:00] have, we haven't solved. So one can imagine energy becoming a subtext for the next great war. We can think of food as being another subtext of the next great war. So, um, you know, there are many opportunities.

Uh, in my mind to improve the condition of humankind in ways that can be, um, beneficially and productively shared, you know, across countries, across societies. Mason If you gaze forward then maybe 10 years, something like that. How do you see this field developing and where might this technology be do you think in around a decade?

And it's astonishing to see a technology at its inception, which is like where we are with this convergence of biology with engineering. And uh, to see kind of, you know, lab experiments turned into, uh, you know, full wholesale technologies. Into water filters, actually in people's houses. Yeah. [00:35:00] Amazing. And you know, true enough, I'm old enough to have, uh, been around during the molecular biology revolution.

which gave us a parts list of the biological world, right? And without a parts list, it's hard to build anything. But among the things that we've built using the biology parts list are all of the, you know, modern medicines that are frankly, you know, biologically understood because we understand biology, but also as I described for making the viruses for batteries, the same technologies that are used to make, uh, the drugs that are saving lives today.

If we could have a minute to talk about one other case, which I think is one of our great problems is providing healthcare equitably and expansively across the world's population. There are, um, kind of, it's semi a joke, but it's not a joke, uh, that in the United States we talk about healthcare. Actually, in developed countries, we talk about [00:36:00] health care, but for the most part, it's sick care.

It's not preventative enough yet, is it? It's all about treating it as it arrives. We detected it. We best deal with it. So it's prevention and it's early detection. And so there are fabulous examples of, again, the convergence of biology with engineering, devising new ways to detect diseases early on. You know, so if you could detect a cancer, five years earlier than we're currently able to detect it, you have a very, very high probability of actually curing it.

Um, but our detection techniques are evolving, but are not yet where they need to be. But wonderful opportunities, some based on machine learning and AI, some based on just brilliant biology to actually see diseases at, you know, near the start so we could intervene early and, uh, protect people. Mason Are you seeing an example today of, of early technology in that space that may not be widely understood yet?[00:37:00]

Yeah. So, um, you know, I could give, you know, a dozen examples. It's, uh, of course, because it's so close to, uh, my home territory, um, I gather those examples perhaps more quickly than some of the other examples, but we are used to screening procedures. I mean, all of us have various screening things done to, uh, mammography for breast cancer, you know, for example.

And, you know, that's better than it was, but there is a fabulous. a project between one of MIT's world leaders in machine learning AI, a woman named Regina Barzilai, working with the mammography group at Mass General Hospital, which is just, you know, half a mile away. Proximity helps. My colleague, Phil Sharp, a Nobel Prize winner, says technology travels on two feet.

It helps. You can read about it, but you can talk to people about it more easily. What Regina's story is that, [00:38:00] and she tells it so I'm not revealing anything out of school, she had her annual mammogram and a concerning lesion was identified and she was diagnosed with breast cancer. And she went back and looked at her mammograms from the previous five years and she said, there was a smudge there.

There was a smudge. And so when that smudge becomes a biopsy You know, then it gets, um, uh, diagnosed, but you have to know which, which, which smudges are which. And she has devised with her colleagues a AI enabled machine learning paradigm algorithm for reviewing mammograms that actually can identify a potentially cancer, uh, carcinogenic lesion five years earlier than currently possible.

they've developed another algorithm very much like it for lung cancer, lung cancer screening. I don't know what it's like in other countries, but in the United States, all of a sudden, you know, lung [00:39:00] cancer screening has also, particularly for smokers, has, you know, emerged on the scene as something you need to do fairly regularly.

And similarly for lung cancer, as for breast cancer, the algorithm they've developed can identify potentially carcinogenic lesion much earlier than straight radiology. And would that be less invasively as well? Well, the Identification is as invasive as the imaging, which is. Non invasive. Yeah. Yeah. But the help, the, you know, the advances, if you have a, you know, a lesion that's, uh, a millimeter, that's one thing.

If you have a lesion that's five, you know, five millimeters, that's a very different state of cancer, likely. So the question is getting it early, getting it biopsied, and, you know, whether these algorithms will have the resolution at some point simply by imaging to be able to say whether. it is cancer or not.

Where we are [00:40:00] now is these algorithms can tell you whether it has the potential of being a cancer or not. The improvement in cost to manage at that stage, the lack of trauma the individual has to go through, the, you know, there's so many benefits to that being true. You avoid so much heartache and pain down the road.

It's just picking up those early whispers. are like the key to making the whole planet a lot healthier and a lot happier and not having to deal with all the, we've detected it now we have to do harsh management of it. So how long does it typically take to. Uh, now you have that in the lab, those results, to make it available to the public or to the people.

Yeah, that's a really great question. And one of the things that, uh, we've, um, heard is that diagnosis of cancer is dependent on all of these other variables. And so Professor Barzilay has collaborated beyond MGH, which is not an entirely Caucasian population, but [00:41:00] obviously biased to the population in Boston.

They've, uh, deployed... this method at the Henry Ford Hospital in Detroit, which is largely black population with equivalent results. They've worked with the Karolinska Hospital and demonstrated that in Scandinavian population, equally effective. Also collaborating with a hospital in Mexico for Hispanic population.

And the results are as powerful, as accurate as with the original population and getting it deployed. You know, the thing I love about it is that mammography machines are expensive. Machine learning, uh, algorithm is you need a computer, right? But everyone has a computer, but you've got to put your program on a computer.

And, uh, you know, the deployment is not as expensive as moving to an entirely new kind of diagnostic machinery. It's a diagnostic analysis, which is far more transportable [00:42:00] than, uh. Getting these incredible machines, incredible expensive machines. So this also makes it available to other areas on the globe.

Yeah. Yeah. That sounds really good. Yeah. Massive hope for the future though, isn't it? If you just think about playing all this technology forward. Mason And what I think is wonderful about the conversation today, and maybe just to bring it to a bit of a close, is the notion that it's sort of already here.

And there are the beginnings of this sort of technology seeping into our communities today. Like we talked about looking out a decade, a little bit earlier. When you look forward, Susan, how long do you think it's going to be before this type of technology is just the mainstream way of thinking about solving problems?

I don't know how long to be mainstream, but how long to be... So I wrote the book to help people understand that there is a revolution in progress, a good revolution, a beneficial revolution. And I think that once you [00:43:00] understand this idea of the, uh, technologies of today, having emerged from some peculiar conversation between physicists and engineers in the past.

But I think, at least to my mind, putting biology to work for us is incredibly exciting. And, um, I would, I would suggest that, you know, once you've heard it, you can't get it. This is what happened to me. I couldn't get out of my head. And so when I see a perfect cantaloupe, At the grocery store, I stop and think, Wait a minute.

When I was a kid, cantaloupes were undependable. Right? Bananas. You know, bananas were almost wiped out by a virus similar to the cassava virus. So every time I go to, you know, buy bananas and they're all beautiful, I think, Whoa! What genes are working here to create bananas that where, you know, every single one of them is going to be delicious when you open them.

And so I, you know, I think the [00:44:00] appreciation of How much innovation goes into the things that we buy without thinking about them. I, I just find that to be, oh, exciting and optimistic.

Sjoukje, what have you been looking at this week? So each week I do some research on related ideas and transformation and tech. And this week I thought we should take a look at the next frontier for large language models is biology. So large language models have taken the world by storm with their ability to master natural language.

But the most significant long term opportunity for them is the language of biology. Biology is a programmable and digital system, and LLMs can apply their capabilities to biology and learn the language of life to unlock huge possibilities. By ingesting biological data, LLMs can reason [00:45:00] over patterns and deep structures and use this understanding to generate advanced outputs.

So a question for all of you. Do you also see huge possibilities for large language models in biology? And where do you think they will add the most value? So I'm going to use the phrase, Dave, and I know you're going to love it. I'm going to say this is a good example of confluent technology coming together, isn't it?

Look at that. Top of mind for me, that. Well, I mean, it's um, you think about a few years back, well, maybe it's a bit longer because I'm a bit older than I might think I am. We used to struggle to be able to parse and understand the English language in computers. And now it's just happenstance that goes through and now we can ask it and it can reason and do all sorts of stuff.

So it's. Fundamentally dealing with complexity. So to think that then biological systems and physics system are again, just inherently complex, anything that helps us model them and understand them and be able to reason to take the toil out of trying to get them to place when [00:46:00] we need to, so we can. Do something that has got to be good and you can imagine that if you, you know, you've mastered one complexity over here, there must be so many other domains it can be turned to.

So it sounds like this is the next exciting one where technology can help out and do some heavy lifting for the human. Susan, do you have a perspective in terms of what you're looking at and the developmental AI?

Yeah, so I gave you one example in terms of being able to, uh, better interpret the kinds of, uh, tests we currently do. But I love this idea of LLMs in biology. I went to a mind blowing seminar, uh, earlier this week. Our understanding advances step by step and we think that where we are today is kind of the end of the story, but then the story of course gets deeper and more interesting.

And so this may be too technical, but you know, when I learned about DNA, I learned that there are regions [00:47:00] that. Code for proteins called the coding regions and regions that don't non coding regions, which um, have historically been called junk and yeah, I made, she just kept him around. There's a second class, but you can stay and watch.

Yeah. But I, I heard this amazing, amazing seminar. of information in those non coding regions that, of course, doesn't code for protein, but codes for the regulation of proteins and the specificity of the expression of proteins. There's all kinds of information in those non coding regions. And to your point, Juca, um, how are we going to understand what it is?

And it's not going to be by going in and doing Manually, or using our brains, um, I'm just going to be so fascinated to know what happens when we put in the sequences of all these non coding regions and what the information is. And I [00:48:00] think that's an LLM problem that, uh, has not yet been, uh, cracked.

Amazing. What a phenomenal conversation today has been. So Susan, thank you so much for your time and really great insight today. It was fun talking with all of you. Thanks so much. And thanks for bearing with me through my technical difficulties. We all have them. Don't worry. Now we end every episode of this podcast by asking our guests what they're excited about doing next.

And that could be anything from I've got a great restaurant booked at the weekend, all the way through to something in your professional life. So Susan, what are you looking forward to doing next? Susan Denver Oh, I am such a nerd. The external advisors for the MIT Energy Initiative are meeting next week.

And, um, I am just so eager to Hear what MIT is going to present and then to hear what our energy external energy experts have to say about it The ideas they bring to the table. These are wonderful, you know Kind of brain melds that I find incredibly exciting Incredible and how does that take [00:49:00] place? Is that conference over a couple of days or is it?

just an afternoon. What, how does it get set up? It's a couple of days, you know, the advisors come to town and we have, um, session, summer formal. And there's a lot of just, uh, you know, eating together, right? Foster's conversation. Doesn't it just, so a huge thanks to our guests this week, Susan, thank you so much for being on the show.

Thanks to our funny producer Marcel, our sound and editing wizards, Ben and Louis, and of course, to all of our listeners.

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See you in another reality next week

[00:50:00]

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