Sue Nelson
Hello, I'm Sue Nelson and welcome to the Create the Future podcast, brought to you by the Queen Elizabeth Prize for Engineering.
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Engineering affects many aspects of our lives. And today's guest applies it to not just what we wear, but what our clothing is made from, and even how we think about making new building materials. Suzanne Lee is a designer, who after discovering you could grow fabric from microbes, began growing materials for herself, and helped change the way we think about clothing. Her 2005 book, 'Fashioning the Future' became a key text for designers, scientists, and engineers, considering the future of wearable technology. Suzanne is British, but now lives in the United States. She became Chief Creative Officer of a biomaterials start-up Modern Meadow in New York in 2014, for five years, and founded Biofabricate, which brings together brands, investors, and biomaterial innovators to produce more sustainable materials. As the company's vision states, "built with biology, not oil". But let's get back to those fabrics made from microbes. Because first, I wanted to know exactly what kind of microbes she's talking about?

Suzanne Lee
Well, it's a great question. The field of biofabrication is employing all kinds of living organisms. So, everything from bacteria, yeast, fungi, algae, through two mammalian cells, and you know, they're being used to grow ingredients or materials that otherwise we might be obtaining from an agricultural crop or an animal. It's a whole sort of new era of fabricating with biology that doesn't require us to grow a plant in the field or to slaughter an animal.

Sue Nelson
So how do you do it then? How do you convert microbes into fabric? You've said you grow them? So, do you just grow it in, in a lab? I mean, do you grow it on some sort of framework or in a vat?

Suzanne Lee
There's many different approaches now, when I, when I first started out, my kind of epiphany was talking to a biologist about how else we might grow fabrics. He was the first person, that was Dr David Hepworth at a company in Scotland called CelluComp. And he said to me, well, you know, rather than grow up a plant in a field, or use an animal to get its skin, we could create leather-like materials, for example, using microbes that literally turn sugar into cellulose, and not only produce a fibre, a natural fibre, but organise those fibres into a sheet material. And that, for me was an extraordinary moment of realisation that nature, you know, still has so much to teach us and offer us as, as I was thinking about, you know, rethinking materials for the fashion industry, if there is a living organism that can not only synthesise a material for you, but organise that into a finished structure, there are huge efficiencies to be gained there. So it was a very sort of radical idea. But if we think about different ways that you can grow fabrics, you can do it, design an engineer a microbe like a yeast cell to produce, like we were doing at Modern Meadow to produce a protein like collagen. So rather than getting the collagen from an animal, we don't need to do that we can design an engineer that microbe to manufacture the collagen. And then when the collagen is extracted, we can use material science to organise that into a sheet material. That's one way of using a microbe. The way I came to it was using bacterial cellulose. So that was using a bacterium to produce a cellulose material. Recently, we've heard some announcements by companies like Adidas and Hermes who are producing products using mycelium materials, which is the root system of mushrooms. So actually, there's no one method for growing fabrics or materials using microbes. There's actually many different approaches.

Sue Nelson

And that's great because you're like you said, you're effectively missing out a process. If, in some cases, you don't need to produce the fabric, and then you know, thinking of wool or cotton or anything like that, and then get them into thread, and then weave them and then make them into a fabric if you've then got them ready, you know, missing out that process and going straight to fabric, there's efficiencies. But what do these fabrics feel and, and look like because, you know, if I think of sort of plant fabrics, I think of the coolness of cotton or, or if it's from the natural world, the sort of smoothness of silk.

Suzanne Lee
It's a really interesting one, because naturally, we're wanting to draw analogies with the familiar, with the materials that we're used to touching and engaging with. But these are mostly a new generation of materials that we have never felt before. So, they're all very different. And, you know, as I mentioned, when I was talking about the different organisms that are growing these materials, the variation in organism is also seen in the outcome. So, if we think of a mycelium leather-like material, it might be used in products where you'd use leather, like a shoe or a handbag, and it might look like leather, but actually it does feel different, it feels drier, I would say it doesn't have the same sort of floppiness of a Napa leather, for example. But it's really sort of dense as a material, if we think of something like spider silk, which has been grown in a bacteria, and some of those fibres can feel softer than silk. So I've actually, you know, felt the fibres from a company in Japan called Spiber, and their fibres feel as soft as cashmere, if not softer. So, I think this is what's super exciting about the field is that these new materials and technologies are opening up new types of materials and material properties that we've actually never experienced before.

Sue Nelson
And do they all tend to come in a similar colour sort of neutral-If I think of fungi and mushrooms, I think of sort of cream or pale browns. I know you can get very colourful fungi as well. But is it neutral, like cotton in terms of the colours?

Suzanne Lee
Yeah, that's a good question. I'm not sure anyone's asked me that before. Yes, the mushroom materials are indeed, like the palest you know, kind of button mushroom colour in their natural state, I think there's probably variability between different species of mycelium. But essentially, they are very neutral. And the same goes for protein fibres like collagen or silk. So, they would require colouring just like natural fibres do. But where it gets interesting is where you maybe go beyond that. So, for example, there's actually a company in the UK called Colourifix. And they're using bacteria to produce not only the dye, so rather than getting the dye from a petrochemical source, it's being produced biologically. But they're also able to use that bacteria to lock the dye onto the fabric, which would normally be an additional process requiring another chemical. So biology is actually performing a double function there, it can both produce the dye and fix the dye onto the fabric. So, you know, we're early days in that but we are seeing various start-ups around the world really exploring colour, and living colour and how that might actually be translated into the fashion system.

Sue Nelson
And it feels like going back to nature as well in terms of the colour because I sort of associate I think, because like many people over the pandemic, I've really got into wildflowers and nature. And it's a reminder of all the beautiful colours that have come from plants. So, it feels like going full circle.

Suzanne Lee
Yeah, absolutely. And I think the other thing that is interesting is as we are designing an engineering an organism a microbe to produce a colour for us. We have, you know, incredible ability to tune those natural colours. There's an amazing library at Harvard, which has examples of colour throughout history. And I think

they have an example of the latest genetically programmed colour, which doesn't exist in nature, but is manufactured by a natural organism. So, you know, I think we're entering a sort of new world where, because we are able to design an engineer with DNA, we can open up, or extend the palette of colour or materials that we currently have access to.

Sue Nelson
It sounds like it's going to be a kaleidoscopic new world as well. What gave you the idea to grow fabrics this way? I'm assuming it came from a desire to reduce impact on the environment in terms of resources?

Suzanne Lee
Funnily enough, it didn't Sue. I mean, if we go back, my entry into this field is a long time ago. Back in 2003, the idea was very much just inspiration, or just "what if you could grow a dress in a vat of liquid?" and that was the original provocation. I think, as I started on that collaboration, you know, which was very much sort of design science coming together for the first time, through that process, I started to realise, "oh, this is all happening within one growth bath. Once we have the nutrients set up to feed this microbe and it's producing these fibres, it's turning the fibres into a sheet material". I found all sorts of things along the way, and I could introduce dye into that growth bath and, and it would be dyed, you know, it would come out the other end and it was dyed. So then I started to realise, okay, we are significantly reducing the amount of water that is required to produce this material, we're using minimal energy. I mean, I started out having what I nicknamed my fabric farm in London, all summer long, I had these growth baths outside, and they required nothing more than just the sun to provide the energy for the heating of the baths. So yes, the learning around just how sustainable these kinds of systems could be came along just by exploring it, but it actually wasn't the original provocation.

Sue Nelson
It's always good to be surprised. I think. So where did your career begin? Because obviously, you're now extremely knowledgeable about the biology side of microbes and how it relates to fabrics. But when you were younger, what were your main interests?

Suzanne Lee
Well, my training, I went to art school, I'm a fashion textile designer by education. And I worked in the fashion industry for 20 years. And it was actually a research post that I was offered at Central Saint Martins, which is the University of the Arts in London. That part time research post was the beginnings really of me diving in. I think I'd always had an interest in technology of one form or another, but from the creative perspective, so you know, I was interested in, you know, new machinery or equipment that would enable you to create clothing in you know, new ways. That was always an interest and even science fiction. So I think even though I came from a creative background, I had a bent towards reading about science and technology, and trying to sort of figure out how that might be applied to my own creative practice. And then just through serendipitous meetings with scientists or engineers along the way, you know, I'd get inspired by the work they were doing. And that led to collaborative projects. And I guess the last sort of 15 to 20 years has been me moving from the fashion world, towards the world that I now exist in. I mean, you know, I ended up joining a biotech company and building a design team within a biotech company. So it's been an interesting journey. And, you know, I think perhaps through that, I've been at the forefront of this emerging new world where design and science actually, you know, really comes together sort of innovation interface.

Sue Nelson
And you've been called part of this "biofabrication revolution", which is happening more and more people are getting interested in it. When you went to New York. I don't know where you living in New York before 2014, when you joined Modern Meadow as a Chief Creative Officer?

Suzanne Lee
No, I was consulting from London. So, I was working with companies in America. And Modern Meadow was originally a client of mine in London. And I just started going back and forth. And finally, the CEO persuaded me to come and join the team full time.

Sue Nelson
How big a change was that because it's almost like switching sides in a way?

Suzanne Lee
It is, it's very much I mean, you know, that was a major step in my career to go from being surrounded, you know, working within a fashion studio surrounded by people whose skill sets I shared and understood, to being dropped into an environment where it was literally scientists in white coats in labs, and I was the one person on the team who had, you know, a very different background, and who was having to play catch up the whole time. So I was lucky, because I'd spent a previous decade really being surrounded by scientists going to science conferences, reading up learning about the fields, I wasn't just dropped in out of the blue, it was it was a gradual process for me, but then, you know, being at an American biotech start-up, you know, that's a very 24/7, enterprise. And, you know, it was a very steep learning curve from there to figure out as part of a founding team, how we bring these two very, very different worlds together.

Sue Nelson
And how did you find that because bio-engineering, which is effectively what your you know, your scientists are doing, but engineering it for fabrics, for fashion, did you find that you fitted in well? That you could get your points across to each person, that it was a good blend?

Suzanne Lee
It's such a good question. Yes and no I would say. I think there are some scientists who have a proclivity towards collaboration and are very open in their thinking. And then I think there are people who are very, very focused on, you know, their field, and are not used to being challenged by someone outside of that, especially someone who doesn't have a PhD or any kind of science background. So inevitably, I think with any group that brings together radically disparate educational backgrounds and levels of industrial experience, there are inevitably going to be tensions. But I think what my learning was, is that you need to be really patient. And it was certainly forced on me to adjust my expectations around just how long things take, because the fashion industry is very immediate, you know, there's no such thing really, as R&D, it's very process driven, and you work very, very fast, and you expect to get to a result very quickly. And then you're on to the next thing. And certainly the kind of very fundamental science discovery that we were doing in the early days of Modern Meadow was the opposite of that. So, I had to translate my creative process from one that normally would last perhaps a few weeks or months, into many years. You know, that requires some major adjustment in how you know, you operate within the team.

Sue Nelson
And what made you found Biofabricate was that spotting a sort of a networking gap effectively?

Suzanne Lee
Yeah, it was very much that. Even when I was still in London, I was always the one designer in the room at a lot of very geeky science events. And I had a hard time, you know, back then it was challenging to try and introduce yourself to some very eminent scientists, and even, you know, suggest opportunities for collaboration. And I felt like there was a big opportunity there if we could just bring people together in a more

balanced way. And so Biofabricate, when I moved to New York, I just decided to do a one off, or what was intended as a one off meeting that would bring together scientists and engineers with artists and designers and some brands and investors. And it was a very experimental event. You know, we curated a programme that brought together all of those people, and it was an immediate success. We had hugely positive feedback. On that one day back in 2014 people were saying “when's the next one?” and then we realised “ah okay, we're gonna have to make this at least an annual event”. So, I I've been running Biofabricate as a summit for the last seven years now. But after I left Modern Meadow back in 2019, that was really to kind of capitalise on the broader opportunity for the field of biofabrication. So now, because I'm not tied to one start-up, we're able to work with clients across this whole field, whether that's, you know, other biomaterial start-ups, or whether it's the brands who are trying to introduce these new materials to their products, as well as people like investors and certain elements of the supply chain.

Sue Nelson
I was going to ask you about that in terms of the applications. You've got your BioCouture as it's called, you've got the fashion applications. Give me an example of where these materials can be used elsewhere that's not something we wear.

Suzanne Lee
Yeah, I mean, one of the companies that we've worked with most closely in the last year is a company based in North Carolina called bioMASON. And we're super excited about their technology. So they are growing bio-cement. And if there's one industry that needs massive disruption, it's the construction industry. Its carbon footprint is so much bigger than the fashion industry. Cement alone is about 8% of global emissions. So bioMASON have a process which is using a naturally occurring soil microbe that binds together loose aggregate materials, just like the way coral is grown in the sea, except that the material that they're making is three times stronger than concrete. And it's grown in ambient conditions rather than being fired. And they can do it in just three days. So, for us, they were a fantastic company to work with. And the field of construction, I think, is one that is very ripe for disruption. So that's one example of how a biofabricated product is able to really radically offer alternatives to an industry that desperately needs those kinds of carbon solutions. Mycelium is also a material that has played a role in construction as an insulating material. Mycelium is one of those materials that has, you know, vast, I think applications that we're only just beginning to explore. There's a company in Italy called Mogu, who are making floor tiles and acoustic tiles, out of mycelium materials, packaging, that's a huge area. And actually, I think that's taking off really well in the UK, mycelium packaging is already being used in various consumer products now, and the great thing about that is that when you dispose of it, unlike the horrible polystyrene or styrofoams, that really don't disappear at all in the natural environment, mycelium packaging, which can have that same cushioning protection for a product, you can just break it up, throw it into your garden, and it will feed the soil. So, some of these materials have the potential to actually be very regenerative in their end of use.

Sue Nelson
And does this mean you're sort of you're not limited with your supply of microbes either?

Suzanne Lee
Yeah, there's no limit to the supply of microbes, the microbes will multiply so long as they are given sufficient nutrients to multiply Yeah. And that's what's kind of incredible about it. I mean, bioMASON with just a tiny jar of bacteria are able to manufacture millions and millions of bio-cement tiles.

Sue Nelson

Now your 2005 book ‘Fashioning the Future: Tomorrow's Wardrobe’. It's been described for scientists and engineers to glimpse that future of wearable technology. 15 years on from the publication of that book, I wondered where you thought we are now because it can so often take so much longer to get to places in reality and the practical aspect of it compared to what's available and what you can do at the time.

Suzanne Lee
It's a great question, and it's one I like to remind people about when they talk about material innovation or technology and fashion, because the book for me was written at least 10 years after a whole bunch of research I’d done into wearable technology specifically. And you know, if I go back to sort of 1996, then we were talking about electronic textile, conductive fibres that were going to enable a whole new generation of clothing, that would have us speaking into our cuffs or the collars of our jackets. And while some of that technology was feasible, what people weren't considering I think very much from the engineering side, was just that, just because you can do something with technology doesn't actually mean that that is going to be desirable. And the big piece there was that there was very little understanding about why we wear the clothes that we do, and how we wear them, why we buy them. And very often, that is much more wrapped up in status and sex appeal than it is functionality. So, you should always be very cautious when people try and predict the future. And with the book, you know, I certainly did the best I could by talking not just to scientists and engineers and technologists, but also to people from the fashion industry, from the textile industry, who had a more perhaps sophisticated understanding of what customers would likely adopt.

Sue Nelson
It's such an interesting topic, because it has so many potential applications. When I'd seen that you were a Launch Material Innovator, with names like NASA and Nike, and, you know, the US State Department attached, it reminded me of a living architect called Rachel Armstrong, who has always been advocated that we rethink how we make spacecraft, for instance, and she's saying we should maybe make them instead of, you know, the sort of science fiction, metal and steel or whatever goes into a spacecraft is that you think of living walls.

Suzanne Lee
Yeah.

Sue Nelson
And living materials. And this could be a part of the future, which sounded so amazing and different and far-fetched. But actually, it doesn't now. And particularly, combining what you're thinking of and the companies that you're working with, and what they're thinking of, because if the construction industry could be made to change, then a spacecraft with living walls sounds normal.

Suzanne Lee
Yeah, it's funny you mentioned Rachel, because I know her very well. It's a pretty small world.

Sue Nelson
Ah. She’s so interesting.

Suzanne Lee
Yeah. And so, you're 100%. Right, the future I think of space, and certainly, as we start thinking about colonising Mars, is that synthetic biology is going to for sure play a major role in how we are able to, you know, create habitats in those environments. We're certainly not going to be transferring materials from Earth to other planets, we're going to have to build them or create them there. And that's where this whole idea of taking the tiniest amount of a microbe to a place that can then feed on, or be designed and engineered to feed on the

resources that we find in that place, are really what is going to enable us to build in those environments. So, one example of that is we're currently seeing the beginnings at least of the transition from engineering microbes, you know, bacteria or yeast cells that rely on a feedstock like sugar. To synthesising a feedstock like CO_2. And if you can do that, then these might be some of the inputs that we can take from other environments. So for sure, synthetic biology and biofabrication are going to be key processes and technologies that we employ as we think about colonising Mars and, you know, travelling more in space.

Sue Nelson
And finally, do you have a BioCouture outfit that you wear?

Suzanne Lee
I did about 10 years ago, I moved on, really from the BioCouture work and that's probably a whole other hour session Sue as to why that came about. But the ultimate point around BioCouture was, you know, was to have materials that completely disappear at the end of their life. And so that's what they did. I didn't to conserve them, you know, they were exhibited around the world but at their end of life, they naturally biodegraded they literally kind of crumbled and disappeared, as I think ideally all things should.

Sue Nelson
That's great. Suzanne Lee, thank you very much for joining me on the Create the Future podcast.

Suzanne Lee
Thank you so much Sue for the invitation.