Sue Nelson
Hello, and welcome to the Create the Future podcast brought to you by the Queen Elizabeth Prize for Engineering.
[Music]
It's hard to believe that we've been living through a pandemic for over a year. But with vaccines and the increasing availability of tests, there is at least a hope that the world will eventually return to some form of normality. And today's guest is one of the many engineers who's made a huge difference during this challenging time. Chris Toumazou is the Regius Professor of Engineering at Imperial College London, and the founder and chief scientists of its Institute of Biomedical Engineering. Early on during the coronavirus outbreak, Professor Toumazou and his team engineered a highly accurate medical COVID-19 test called 'covidnudge'. Instead of taking several days to give a result, the test could tell if someone had the disease in just over an hour, regardless of whether they had symptoms or not. More importantly, it didn't require access to a lab, it's portable, and it's now being used by the NHS. The government has publicly paid tribute to this key COVID testing technology. And the Royal Academy of Engineering awarded Chris one of the President's Special Awards for Pandemic Service. He's also founded a number of technology-based companies making electronic devices for the early detection of chronic disease. And among his many engineering awards, he won the European Inventor award in 2014, and last year, the UK BioIndustry Associations Joint Entrepreneur of the Year. So, when the call went out from the government asking for support with tests for a new disease, how did Chris know he could help?

Chris Toumazou
It was before the call to action that we started to repurpose the technology for COVID. We had developed a technology that was tackling the then epidemic, which still is actually obesity and type two diabetes. So, we developed a sort of point of care consumer technology that was out of the lab could be run a department store could demystify genetics, but obviously wasn't a medical grade technology. And we weren't testing for any sort of virus. It was only when I got back to the UK and we started reading that this thing called Coronavirus, was polluting half of Asia and that was becoming pandemic.

Sue Nelson
So you sort of had the engineering infrastructure, but it sounds like it would work in a very different way. How did the diabetes one work?

Chris Toumazou
So the diabetes test was a non-invasive cheek swab. In terms of the architecture of the technology, it was almost a solution before the problem of Corona. So, the big, big difficulty for us was really repurposing it and really looking at ways in which we could go from a sort of early detection risk mitigator to a medical device that could effectively detect Coronavirus in your swab. So, we had a chip with lots of little wells, think of them as fishing wells. And in each of these wells, you can spot the bio marker of the DNA, in coronas case, the RNA that you're looking for. And so we already had a method of spotting in these wells, the biomarkers for predispositions to things like type two diabetes, obesity, hypertension, blood cholesterol, nutrition related conditions. And so, what we now had to do was instead of spotting these wells with these genetic mutation error biomarkers, if you like, we had to spot them with genes for COVID-19.

Sue Nelson
It's a PCR test effectively, your device. I mean, they're supposed to take at the level that yours works around 72 hours to get this really precise result. How did you manage to repurpose it so that it gave results in just over an hour?

Chris Toumazou
My whole mission. In fact, my mission over the last 20 or so years, has been to completely miniaturize and the laboratory onto something as small as a Hewlett Packard cartridge. That's because my background is semiconductors and microchips and mobile phones. So, I come from that domain of shrinking things with technology and because the engineering was such that it could be shrunk all the laboratory processes such as thermo cycling, and raising and reducing temperature, etc, could all be done in a miniaturized way. The big deal for us was, first of all, the ability to extract from the sample, be it saliva, or a nasal pharyngeal swab, to extract directly from that, without any pipettes and without white coats, and without labs, to go direct from the swab to the cartridge. And then the cartridge itself does all the things that you would do in a laboratory. And a couple of steps there, one is to deactivate the virus, otherwise, kill it, if you like, as soon as it gets into the cartridge. And the next step is to convert the RNA that's been extracted from the virus, again in the cartridge, and the extraction is really important phase that takes place automatically in the cartridge. This is a very long-winded laboratory step. So that step was not required. And thirdly, then cleaning and purifying the extracted DNA, so that you end up them with purified DNA on the surface of that chip. That process on its own is where a lot of manual steps take place in a laboratory. Importantly, you have to transfer the sample from the ward to the laboratory. So that whole step, the throughput of that could take several hours. With our test, everything's extracted automatically on the on the cartridge. And then I think of the DNA is the fish. And the fish needs to bite the bait in those wells. And the bait is a lot bigger than the fish. So we need to make the fish big. And the way we do that is through that process of PCR. And, you know, PCR is a process of, if you like, heating the double helix, which separates its two strands. So, you're heating the fish, if you like, the double helix fish into two strands, then add some synthetic DNA by cooling to bind. And then you heat again to separate then you cool to bind. So every time you heat and cool, you're making the fish bigger, and you make the fish big enough to bite the bait. And that's why it takes just over an hour. Once the swab is inserted into the cartridge, then the cartridge goes into the nudge box, not much bigger than a shoe box, basically. And then you close the lid of the box. And then all the magic takes place behind the scenes. And I've got one of these boxes at home. They're very small.

Sue Nelson
And the cartridge itself is really small. And I saw a picture of it. And it's a circular device, it sort of fits in the palm of your hand. And it's amazing how I mean, as with the case with vaccines, for instance, procedures that would normally take so much longer have been speeded up through an incredible effort by scientists and engineers. But you still managed to get authorized for use very quickly by April 2020. And you had trials for 100 patients or hospitals. Where are they used now?

Chris Toumazou
So we worked very, very closely with the MRHA, with the government doing this intensive validation in St. Mary's, at Charing Cross, at the Hammersmith. And initially it was COVID positive wards because we knew the patients were positive, validating ours against their technologies, the lab technologies, then in A&E departments where you could segregate between the green and red lines very quickly. This was a really important use case, obviously not putting COVID positive patients in negative wards or vice versa. So that was really, really important. And maternity wards we've validated there. There was a case where the life of the baby was saved. So there was some really emotional cases where having the speed of a result made such a big difference. And that's great even today now with this deployment, you know, advice 1000 boxes and 5.8 million cartridges.

Sue Nelson
And has it gone beyond hospitals?

Chris Toumazou
We've got it in a number of mental health institutions, which is very important. I won't go through stories Sue, but it's quite sad. You know, you've got schizophrenic patients in hospital. And Corona obviously hasn't helped at all. You just can't have these patients in isolation for 72 hours on their own, these patients just would not psychologically cope with having to wait all that time. There's a true, real real value there. And then on the other side is the arts. We've been working very closely with the London Symphony Orchestra where we've been testing them regularly. They've been able to rehearse and this has been since November last year. So, Simon Rattle has been using the test. We've got Glyndebourne, the Opera House, they are using our test and they're going to start live performances very soon. We're looking at East Opera. We're working with the Old Vic. So, we're starting to bring the arts back with our test. And that's very much the consumer coming back into normality.

Sue Nelson
Oh, that's so wonderful to hear. You know, I felt quite emotional you saying that? Because it's just, it's a sort of thing we've all missed. And it's so important. Engineers are often called unsung heroes, anyway. But you know, you do wonder when somebody is sitting at Glyndebourne and watching an opera or you know, able to finally sit for a live concert, whether they will realise or be aware of that engineers have helped make this possible. Do you feel underappreciated? You've won so many prizes, I'd be surprised.

Chris Toumazou
The nicest tip for me was when Simon Rattle was interviewed, and there's a lovely piece on YouTube. Where he thanks us, just thanking DNAnudge for everything DNAnudge has done for them. Sometimes I wonder, Sue, I mean, I haven't seen my family for over a year. You know. My wife's Australian. So, they decided to spend a couple of years there, as of last year. So, the two years were up, they were meant to come back with me and to the UK. And then I just came on my own. And I left them there, because I anticipated, well, we were hearing about Corona or anyway. And so yeah, it's been quite difficult.

Sue Nelson
That's quite a sacrifice, but they must be so proud of you?

Chris Toumazou
Yeah, they're happy. And it's just, you know, with Zoom and everything we were managing,

Sue Nelson
It's not the same. It's good, but it's not the same.

Chris Toumazou
It's not the same and the dedication of some of the biochemists and scientists in my lab, these people, you know, half of them have had COVID, one or two of them have got chronic conditions and they've suffered, they've really, really put a lot of effort into this.

Sue Nelson
You've obviously had a tendency as an engineer towards health and the biomedical side of it. Where did that come from? Because you studied electrical engineering at university?

Chris Toumazou
Yeah, I studied electrical engineering and I studied so called 'analog' and 'not digital'. Analog is the real world you know, it's the interface, it's speech, sound, you know, all those things that go from the real world to the

digital world. Then I got fixated about biology, because Imperial College, then it merged with its medical school. I always thought that biology was analog as well. So, I started to move away from developing technologies for mobile phones. And in fact, I created a group called 'Bio-Inspired Technology'. And I started modelling things like cochlear implants and retinal implants. And I modelled them in silicon chips. We were able then to replace the biology with the silicon chips. But I guess my big turning point was when my oldest son now but then he was six, seven years old, lost his kidneys through genetic mutation, my wife and I had the combination of two mutations in our DNA gave him the gene for juvenile kidney failure, effectively, his kidneys just being rejected. And we didn't know about this at all. He just collapsed when he was six, seven years old. And I've always thought that if we'd known about it early enough, we could have managed his lifestyle very differently. It was almost like watching a Mini engine growing in a Rolls Royce car, you know, if we'd known about it, we would have made a sort of Mini car for that engine, then that got me on to trying to sort of therefore demystify genetics, because there's always this stigma attached to genetics, you know, it's clinical, it's medical, do I really want to know if I've got this or I've got that, and I wanted to move away from it being a diagnostic, because a genetic error doesn't mean that you've got the medical condition, it means you've got a predisposition to that medical condition. It's not predetermination, it's predisposition, what pre-determines is your lifestyle.

Sue Nelson
It's sort of society's gain really, unfortunately, based on personal circumstances, and you know, what's happened to your, to your son, that you were able to put your background, you know, your engineering background, an interest in biology, and then have this sort of personal involvement, that it's all come together to help so many other people than your son.

Chris Toumazou
I was very lucky to be in an environment at Imperial that gave us the freedom to innovate. When we pulled together the Institute of Biomedical Engineering, the whole idea was to break the silos of engineering, and any sort of discipline, if you like, and try and get almost the, the ingredients mixed in one environment. So you've got chemists, with electrical engineers, with doctors, with physicists, all working together in one environment. And honestly, so it's these eureka moments, particularly with this one where there was a 'what if', you know, what if we put, for example, DNA on a microchip? Or what if we look at the way the physics of the semiconductor works and relate it to neural systems in biology? And it's really fascinating that naivety for me is the source of innovation. The more naive, the more I feel, we can innovate.

Sue Nelson
It's that creative freedom as well, yeah. When you're when you're naive, you don't limit yourself.

Chris Toumazou
Exactly, exactly, and it's those boundaries, between those different disciplines. Were all the sort of broken languages between you and the clinician, and you're having this wonderful discussion. And you really don't know what they're making of what you're talking about, you don't know what you're making of what they're talking about you. So you always end up with almost a solution before you know what the problem is.

Sue Nelson
Very useful, quite frankly.

Chris Toumazou
Then you find the problem, and then you end up with a you've invented something. And with the genetics, that was always the case, when we came up with the idea of trying to integrate everything into a cartridge. This was not long after the Human Genome Project had been published. And that was all about discovering new genes. If

it wasn't for the Genome Project, we wouldn't have known that there were mutations for kidney failure, etc. But, you know, it really affected me so much. And not only Marcus's kidneys collapsing, and you know, obviously, his well-being, but how primitive chronic disease management was, and still is, in a sort of consumer setting. My wife and I had to run the analysis on him on a daily basis, you know, from morning to night for several years, and, you know, we're not trained, and the paranoia of the carer is more, affects him more, then anything because we don't know, is this blood pressure correct or not?

Sue Nelson
Which is why it's so important to make these devices simple.

Chris Toumazou
Exactly these wireless devices, these monitors.

Sue Nelson
What about before your son was ill when you were growing up. Was there anyone in the family who was an engineer were your parents in this profession that sort of sparked off your initial interest?

Chris Toumazou
My parents are typical Greek Cypriot parents, running various sort of trade businesses. My father ran a number of different restaurants, and in the catering and hotel management business, which was something that I probably would have ended up doing. And I think one of my big inspirations was my uncle. And I guess he was an engineer. He was a sheet metal worker. And for me, gosh, this is something very different, very exciting, it wasn't catering or washing up dishes in restaurants. This was this was really sort of interesting and I got into you know how they were soldiering things I got into some of the electronics and I ended up doing a radio and electronics technicians course, of course we didn't have O Levels at the school I went to. We only did CSC's.

Sue Nelson
That's quite a leap. Here you are at the position you are now, you know, multi award winning, you know, invented this device as well as many others. You were also Imperials, youngest professor in 1994. So, for you to go from there to here is extraordinary and brilliant.

Chris Toumazou
Thank you, I think that one of the good things, though, what was the, okay. I mean, I had to sort of break the tradition to do this, which was sort of part of the culture. So yeah, that was difficult. But there were opportunities, actually, I mean, obviously, I went to a college of further education. And these vocational courses were really good, you know, things like city guilds, technician certificates.

Sue Nelson
And lots of apprenticeships as well.

Chris Toumazou
Yeah, that was really good. And then there were opportunities for you to aspire because you then thought, "oh, gosh", you know, you've been exposed. I would not be where I am now if I wasn't given the opportunity to go through that route, just because I wasn't given everything at school didn't mean to say that I couldn't succeed. Nowadays, I think it's quite sad. I wish we had more of those sort of vocational causes for kids that want to leave school earlier, but they feel that there are still ways that they can move forward. So, I think the City Guilds and all that stuff should come back big time.

Sue Nelson
Now I'm gonna move on to how you relax, I don't know what you do to relax, and I wonder whether you have any time to relax. But I am going to hazard a guess. purely because with your description of the cartridge and the device and the wells and so many fishing analogies. Do you go fishing?

Chris Toumazou
No I don't. As a kid, I'd, I wouldn't fish but deep sea fishing because of the Greek Cypriot community I was in, we'd sort of drive to Devon or Cornwall and go deep sea fishing. But that's my only experience of fishing.

Sue Nelson
So what do you do to relax then?

Chris Toumazou
Dare I say it, I don't do much to relax. I do like listening to music. But I walk I walk a lot. I like to keep healthy. I like to sort of go to the gym when I can, now you can't, so I go running.

Sue Nelson
That it's definitely a time to clear your head. In terms of the future, what next in mind for you, obviously, apart from being reunited with your family?

Chris Toumazou
I feel that there's a lot of scope for the technology. I think we've we broken the mould. In terms of decentralization, we've demonstrated that we can get these devices and boxes into environments where untrained personnel can run them. Two things that have come out this whole Corona. One is the severity of COVID is very, very dependent upon chronic conditions such as obesity, type two diabetes, and hypertension, etc. So it's almost the pre COVID work, which was epidemic, it's now becoming almost as pandemic as COVID. Because people have to come out of isolation, come back into the real world, obesity levels have gone up. And I think people will be very anxious about their health. So I see this great synergy, how actually a pandemic is helping an epidemic.

Sue Nelson
There's that spin on that old saying that, you know, COVID-19, the 19 actually refers to the number of pounds that everyone's put on during this last year.

Chris Toumazou
There's a huge potential there. Then there's the two branches. I feel like in the hospital environment. We're starting now to develop different platforms. Obviously, there's the COVID platforms and there's FluA, FluB, RSV, all the stuff that's COVID related. But then there's other applications, I think of this as almost the sort of Nespresso cartridge equivalent where you've got a different cartridge for different applications. So you've got in the medical arena, you've got things like STIs and STDs that we can start to look at on these cartridges. I mean, gonorrhoea, chlamydia, all these rapid tests, can take place in clinical environments outside of labs, BRCA1 genes looking at early detection of breast cancer for example, other woman's health is really important with some of these cartridges. And then in the consumer health, we've got a whole array of cartridges that we've started to develop. One of them is obviously for the nutrition, so you can go and shop with your DNA. If Sue, you've got the genes for say, hypertension, and it's salt, which is your issue. If it's type two, then it's saturated fat and sugar. We've got obviously a cloud that's got all the food market supermarket products and we've related all the ingredients in those food products to these genes. And then you can go and shop with your DNA by just scanning any food product in any supermarket, it will be green or red. We've developed an

equivalent for supplements and vitamins. and dare I say it you know, we've got vanity for health care, which is skin DNA that's looking at collagen degradation, hydration, people been wearing masks a lot so skin hydration, things like antioxidant protection, free radicals, vitamin D. And so we we've got a cartridge which enabled you to go and shop for skincare products based upon your skin DNA COVID testing, if anything is given us a sort of mark of good scientific credibility because we've obviously used the technology for a very rapid high performance diagnostic.

Sue Nelson
And we're very grateful to it, absolutely. It's exhausting just listening to what you've got planned ahead, but delighted that this has all come out of something that's been so important and helpful during a very challenging period for everybody. Professor Chris Toumazou thank you so much for joining me on the Create the Future podcast.