



Futures in Biotech, 49: Brain-Machine Interfaces

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Marc Pelletier

This is Futures in Biotech, Episode 49: Brain-Machine Interfaces with Dr. Justin Sanchez.

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Leo Laporte

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[Music]

Marc Pelletier

I first would like to start off by introducing our guest host for today. We have Kirsten Sanford or Dr. Kiki and everyone knows her from her Dr. Kiki's Science Hour on this network, on TWiT. And her long running podcast, This Week in Science, and this is our first time actually meeting in person, Skypesaurus style.

Kirsten Sanford

Yes, Skypesaurus style, I like it. It's very nice to meet you, Marc.

Marc Pelletier

Likewise I've heard a lot of your podcasts and seen you on the Science Hour so it's really good to actually do a podcast together, this is really cool.

Kirsten Sanford

Yes. I am excited. Thank you for inviting me.

Marc Pelletier

Well, this is a sort of an interesting scenario. We had another guest on and he couldn't make it today. And so I called up Dr. Justin Sanchez and I thought inviting him would be really cool and to put him together with you because of his work in neuroscience would be like an interesting mix – scientific mix. So his name is Dr. Justin Sanchez and he is an Assistant Professor of Pediatrics, Neuroscience, and Biomedical Engineering at the University of Florida. Welcome.

Justin Sanchez

Hi, Marc, how are you? And nice to meet you. Dr. Kiki.

Kirsten Sanford

Nice to meet you, Dr. Justin Sanchez.

Justin Sanchez

So Marc, it's really great having me on Friday the 13th. I was telling you a little earlier, I had a particularly bloody Friday the 13th.

Marc Pelletier

Yes, well you tell us a little bit about that?

Kirsten Sanford

I am intrigued.

Marc Pelletier

Yes, give us perhaps a little recap of what you do and then how you got into hands full of blood. All the gory details.

Justin Sanchez

So, I am very interested, I've committed my life to really developing neuroprosthesis. And this is the idea of – to put it in simple kind of layman's term, it's the idea of kind of the cyborg, right; having artificial parts for the brain and peripheral nervous system. And one of the things that we are working on here at the University of Florida is developing this implantable chip that can be used to read out information from the brain and used to deliver therapy to disabled patients.

And today we actually – we had this implant that was in an animal for a little over a month and we wanted to finally extract that implant from the animal and see how well it performed and how good the electronics are after being in for that amount of time.

So we had a pretty tough surgery today. I got my hands really dirty, really bloody today.

Kirsten Sanford

So, where are you putting the electronics, what kind of electronics? I want to know the details, the gory details.

Justin Sanchez

Sure, sure. So one of the main patient populations that we are trying to target is paralyzed patients. Let's say somebody that's had a spinal cord injury and they either can't move their arms or their legs, and so if we want to try to restore that functionality to those patients, we need to implant a chip like this into their motor cortex. So this animal actually had this implant, these electrodes that just went into its motor cortex.

Marc Pelletier

By the way – I would like to interject that it's probably gory with the animals but not gory with humans, right?

Justin Sanchez

No, that's exactly right, so, but – so, let's clarify this here. So, putting those implants in is actually minimally invasive. You just have to drill a small little burr hole or what we call a craniotomy and this can be several millimeters in diameter and we can implant that electrode there.

Now for just the research purposes, right, you want to harvest tissue and you want to extract all of these implants and things like that to study the scientific principles behind it. So in that case, yes, you get a little bit more invasive.

Kirsten Sanford

What happens to the electronics? I mean when you think about an implant being put into the brain tissue, you have these small thin wires that are being put in that can pick up the electrical signals that are released by the neurons individually and you can tell what they are doing summing. But what does the brain tissue do to the electronics themselves? That's something I have never actually considered.

Justin Sanchez

[5:55] Yes, so one has to be really clever about how you design the implant. So the approach that we have taken is that we want to have as few pieces of electronics actually in the neural tissue.

Kirsten Sanford

Okay.

Justin Sanchez

So we only have these very, very fine micro-wires that actually go into the brain and can sense the activity of the neurons. And then we have developed this flexible cabling that channels those electrodes back outside of the skull. And what we can do is if we design those electronics in a really interesting way we can just put all the amplifiers and wireless electronics and things like that just right below the scalp and on top of the skull. So you can imagine the miniaturization that has to actually occur for something like this to happen. We want to record from hundreds of neurons, so we need to have some very sophisticated kind of electronics to sample that kind of activity.

So there is a great team at the University of Florida. We have people that are in electrical engineering, hardware design, microelectric or mechanical system fabrication. So all across the board it's really a great team here.

Marc Pelletier

Could you describe an electrode itself? How do you get that into the brain? And is it small? Is it the size of a hair? Is it like acupuncture? Do they feel it?

Justin Sanchez

So you don't really have pain receptors in your brain there. So if you – these electrodes, they are about 50 microns in diameter. So about the diameter of the human hair, and we are trying to make them even smaller as we improve technology and we typically arrange these into an array. So just think of – yes, there's an analogy that people usually use to describe this as the 'bed of nails' kind of concept. But again we have these very, very fine micro-wires and then we use tungsten micro-wires but platinum is also used in clinical settings. And once you have this array, then you can use stereotaxic neurosurgery techniques. So these are techniques that have been used in brain surgery.

Marc Pelletier

Stereotaxic neurosurgery, okay, this is the neurosurgery part of the podcast.

Justin Sanchez

That's right. So we don't have to go into all of the details of that.

Marc Pelletier

No, I do, I do. I want to hear. That's exactly what I'd like to hear.

Justin Sanchez

Okay. So, I would say...

Kirsten Sanford

Put their heads in a vice.

Justin Sanchez

Since the 1940s and 1950s clinicians and neurosurgeons have been trying to map out different areas of the brain and they have made these nice atlases and then you can couple those atlases with functional imaging like MRI and you can target, really, known structures in the brain that are known for controlling different types of behaviors. And once you have that coordinate system and

that map in the brain, you can place these electrodes very precisely in these circuits that you need to tap into to help the patient.

So, again it depends upon what kind of disability you're trying to treat. Let's say for somebody for paralysis it may be sufficient to just go into the motor cortex and this is only several millimeters from the surface of the brain.

Kirsten Sanford

Yes, now there – go ahead, sorry.

Justin Sanchez

I was just going to say if you are going to try to target some other kind of disability you may need to get a deep brain structure or something like that.

Kirsten Sanford

Yes. What do you think about the more recent research that's looking at picking up, say, electrical signals from the surface of the scalp? I saw a study recently that said they have actually – they are starting to get some pretty good idea of what the signals are coming out of the brain and they are able to get some good readings and maybe even control prosthesis through these little electrode caps that don't include any wires.

Justin Sanchez

So there's been lots of good work out there that people have recorded either EEG on the scalp or ECoG; these are electrodes that just sit on the surface of the brain or these micro-electrodes like we are talking about. And what it turns out is that there is just a trade-off between specificity, right.

As you go more to scalp kind of electrodes you are not able to resolve the activity of single neurons, right. So it becomes more of a signal processing issue of how do you appropriately extract out irrelevant information from these mass activity from the brain that you are extracting?

So there's no doubt in my mind that all three kind of levels of resolution provide something that's important for the user but the engineering part of extracting that – the precise information can be complicated if you got to EEG or something like that.

Kirsten Sanford

Yes. Do you see any particular areas where one – different levels of resolution, say in brain imaging have different uses? Do you see any particular uses for these different levels of resolution?

Justin Sanchez

Yes. So, it's my personal opinion that to have the most complete perspective into neural function you are going to have to tap into maybe all three. So if you want very precise intent kind of information maybe you want single neuron kinds of activity. But let's say you are looking at more cognitive type of activities; making decisions and things like that where you want to have more neural populations involved, then maybe the EEG is more appropriate in those types of scenarios.

I've heard there are couple of actual companies that are out there right now, it's quite interesting Bob Knight at UC Berkeley has a method of recording EEG from patients – or not from patients but from subjects while they are looking at commercials. And he is able to assess their kind of cognitive state and their cognitive assessment of those commercials just from their neural activity and it's really thought that you can have maybe more targeted types of advertising if you understand what that individual is perceiving about your commercials. So again, that's a great

example of how these kinds of high level more broad neural reporting techniques can be effective.

Marc Pelletier

That could be really good segue for Leo. He's – come on in like 30 seconds, our timing is just off, just a little bit off.

Justin Sanchez

Oh, God.

Marc Pelletier

So, this is wild; can the information go both ways? And do you want the information to go both ways or is it one directional?

Justin Sanchez

Yes. So there are a lot of therapeutic technologies that are out there that are using stimulation to cure things like Parkinson's disease, Tourette syndrome, obsessive-compulsive disorders, so that would be an example of when you are sending information back into the brain.

Now, the way that these technologies have been structured so far is that they are just kind of trying to disrupt abnormal activity. But I definitely foresee in the future that we will not only be able to read information, but deliver meaningful types of simulation back to the brain, not just to disrupt activity. So, yeah, this is a bright future for the bi-directional interface.

Marc Pelletier

What stage are you at right now with your animals? How far can you push it?

Justin Sanchez

Yeah, so for the animals that we've looked at, we are controlling a five degree of freedom robotic arm with neural activity from the motor cortex and from deep brain structures.

Marc Pelletier

Really?

Justin Sanchez

Yeah.

Marc Pelletier

So, they are mice – mice or rats, again, sorry?

Justin Sanchez

These are rats. We've done work in rats, monkeys, and then we've even done some work in humans where we've done computer cursor control just from their neural activity alone. And, we and other groups have shown evidence of this type. So it's definitely not unique just to our laboratory, this has been repeated many, many times internationally in fact.

Marc Pelletier

Walk us through that – through those levels like does a rat – can a rat be smart enough to manipulate a robotic arm to go fetch a piece of cheese. Rats are extremely bright when it comes to food, right. They'll learn.

Justin Sanchez

That's exactly right.

Kirsten Sanford

They'll do anything for food.

Justin Sanchez

With the minimal amount of effort, so you know this is the – the important aspect of this is rats are very clever, they use very limited resources to do very effective things and we essentially did that; the rat had to navigate a robotic arm in order to get some water, water rewards that. So yeah, they are able to do that, and again the remarkable thing about this is if you have neural activity that modulates for things that you can map to the external environment, you can make a neural interface for almost anything; I'm completely convinced of that, you know, it's been shown in so many animal models and in even in humans that it's – I think it's a principle of designing these neural prostheses.

Marc Pelletier

How about monkeys?

Kirsten Sanford

Now – yes.

Justin Sanchez

Yes, monkeys, monkeys have done this too.

Marc Pelletier

Wouldn't monkeys last than – go ahead.

Justin Sanchez

There are great videos on the internet right now from Andy Schwartz's lab where he has monkeys that are feeding themselves with a prosthetic arm and he is even showing that the animal is incorporating that arm into its own cognitive space, so it sees it as a part of its body. And he has this great example of this monkey is – it puts this piece of food right on its mouth and it doesn't quite make it in and then he uses the robotic arm to kind of nudge it back into his mouth. So, while that is not really a strict scientific quantification of that, it shows evidence that the animal is using that prosthetic arm in a meaningful and kind of a part of its own cognitive space, right, it's using it as a tool.

Kirsten Sanford

[15:26] Yeah and that gets to the point of how these devices, these brain computer interfaces, it's actually mapping whatever it is as an extension of their body. I mean is that a way to look at it in terms of the way we use a pencil or a car; that our brain actually takes that object into our own perception of our body space.

Justin Sanchez

Yeah, I am so happy that you mentioned this point here because it's something I am very passionate and very excited about.

Kirsten Sanford

Yeah.

Justin Sanchez

So if one goes back and looks at tool use in humans, even since the dawn of time there are lots of studies that, at least in monkeys, that show that as animals use tools that their neural representation of the world expands, okay, and there are some nice images of that – of this that's out there. Now what's remarkable about neural interfaces is that that extension of your body out into the environment is not just through your extremities any more, right. This is through a direct interfacing with your nervous system. So we feel that your connection to the environment can be much more seamless, right? And maybe you can have more of a kind of symbiotic relationship

with your environment and do things that are much more powerful than you could do with your natural extremities that are out there. So this is what I think is the real transformative part about neural interfaces and really helping us to evolve as a species that we can use our technology to impact the world in a much more deeper and meaningful way.

Marc Pelletier

Well, this will be...

Kirsten Sanford

Yeah, I am waiting for the full Gundam suit.

Marc Pelletier

We're at the interface, right? Did our human brain evolve with the mental capacity to then extend to the point where I guess you could use electrodes to then control far more than just the human body, right. Because if you are a monkey you might have a limited sense of self. With humans you have a sense of self and a sense of virtual self and you could extend it to so many different levels. I guess you could...

Justin Sanchez

I think we definitely, we have the neural substrates to support that, right. So the thing that we always talk about is something called the perception-action reward cycle, right. You have some perception or some antecedence of the world in your brain, you take actions and interact with the environment and you perceive the consequences of that and you are in this continuous loop with interacting with the environment and we think that through that loop, through interacting with that perception-action cycle is how we incorporate all of these sophisticated interfaces, right and we think that even by exploiting that in the case of neural prostheses, we can enhance the user's ability to use the perception-action cycle.

Marc Pelletier

Let me take this to the – take that statement and say well your intent is translated quickly. In a physiological sense the connection to my fingers actually takes some time. If the electrode is placed directly on the part of the brain that controls a virtual arm or a robotic arm it can be quicker. Could you foresee a human brain controlling robotics for a limb that's better?

Justin Sanchez

Yeah. We believe you can scale speed, right. So this delay you can overcome that delay. You can even overcome the limitations of your own muscles, right, through using artificial kinds of prostheses that are much, much quicker. Now there is an interesting anecdote or not an anecdote, but a story that surrounds this very idea that we are talking about. I don't know if you saw on Gizmodo this week but they are running a series of stories called the Cyborg Life. So it's actually quite appropriate we are talking about these topics, but they, we are – I guess they have a guest editor Aimee Mullins. Do you know who she is? Have you ever heard of Aimee Mullins? She was a track star.

Kirsten Sanford

I want to say yes but I don't know.

Marc Pelletier

Well of course, yeah.

Kirsten Sanford

Like, yeah.... No.

Justin Sanchez

So this is a great story. So let me tell you about Aimee Mullins because she has a great lecture on the TED website that everybody should go out and watch. So Aimee I guess she does not have both of her legs from the knees down. So she was fitted with these Cheetah prosthetic legs and she was a track star at one point in her lifetime. But ever since she had that experience of these prosthetic legs she has been developing many different types of legs that she uses in many different parts of her life.

So during this talk she had these very elegant, kind of sexy legs that she was using while she was giving her talk and she was saying that these legs were designed to increase her height from 5.8 to 6.1. And she was telling this story about how she was seeing one of her old, I guess, high school friends or something and her friend walked up to her, she hadn't seen her in a long time, she said, 'oh my God, you are so tall!' And she was like, 'well you know I have these new legs designed for me' and the person replied back, she goes 'that's not fair! It's not fair that you can do that' and this is a beautiful example of how technology, even prosthetics are being integrated into people's lives in a very meaningful way, right, that can enhance their abilities.

So you asked me this question about, can we scale time for the individual and I say, yes. We can scale time and what that will mean for somebody who is disabled is that they will be able to add a whole new dimension on their life that they did not have before. So thinking of them as being disabled I really don't think is right anymore. I think about enhancing what they – what they can use to interface with the world. So I think...

Marc Pelletier

The \$6 million man coming to fruition.

Kirsten Sanford

Or the Bionic Woman.

Marc Pelletier

Would you and woman yes, she was fantastic. I remember, I watched that too. So would you foresee the engineering going as a cerebral implant or a neuroprosthetic that connects to the sciatic nerve?

Justin Sanchez

So I believe it really depends upon what your condition is, so somebody that has a high cervical spinal cord injury, say in your neck here, you're going to want to have an implant right in your brain in controlling some kind of device. Let's say you are just an amputee, maybe you can have a prosthesis fitted to your arm and then maybe you can control that either with your peripheral nervous system or from your central nervous system from your brain. So I really believe that we tailor these technologies for the individual patients; that's where we'll have the most impact for them.

Kirsten Sanford

What about people who aren't disabled?

Justin Sanchez

Yeah, this is an interesting concept and I think it also ties back to this story that's being run on Gizmodo right now about the Cyborg Life. Now I was driving to work this morning and I was thinking about all of the stories that they have been running and I kind of had this revelation that this idea of the Cyborg, the idea of the neural prosthesis, interfacing human-machine parts with the nervous system, this is not science fiction anymore; these are popular culture ideas that are being ingrained in every aspect of our lives, right.

I mean all of the things that Gizmodo is talking about, these are things that are coming out either today or in the very short-term future. So it's just amazing when I started kind of in this business,

people were very – they just thought it was too sci-fi and didn't think that it would ever impact humanity and I think that it's happening and it's – there is no way to really stop it now, people are seeing the real potential of these types of devices and they are seeing how we can really enhance our lives, both for able-bodied and for disabled individuals. So I think it's wonderful that these things are happening.

Kirsten Sanford

Over the last 20, 30 years our understanding of the brain has really allowed us to make these leaps and bounds in our technological abilities where 20 years ago people would be like 'what; that's just a television show, that's sci-fi', but now we really understand the brain that much more.

Justin Sanchez

Yeah, that's so true. Just probing different circuits of the brain and understanding how they encode behavior and perception and how they help individuals to control their bodies, I mean there has been so much great work that has contributed to that.

The second aspect is just technology. Do we have fast enough computers, powerful enough computers and we have fabrication techniques that enable us to build these types of interfaces that we are seeing in animals and in humans now and I would say the answer is no. So the technology boom was a catalyst for all of these different things that we are seeing again in pop culture today and it's my great hope that as all of these knowledge bases improve in the future that it's only going to enhance our ability to develop these types of prosthesis. So, again it's a very, very bright future, both for technology, for humanity and for medicine.

Kirsten Sanford

Can you talk a little bit about the miniaturization of technology and how that's affecting it?

Justin Sanchez

Yeah, so the first set of neural interfaces, I guess the ones that are being deployed in laboratories right now, these have desktop computers, very specialized rack-based hardware that is used to sample activity from the brain and I think you would agree that if you want to use a device like this in the activities of daily life, you would want them to be wearable, miniaturized, low power and last for a long time, right. I mean even something as small as your cell phone, right, that you'd like to carry along with you. So there are a lot of technical challenges for doing that.

So let's say I wanted to probe a thousand neurons in the brain, you know, what kind of amplifiers would I need to extract that information, what kind of digital signal processes would I have to put on that chip in order to decode the information and turn it into a command for either a computer or a wheelchair or a prosthetic arm, right? We are advancing the technology that really needs to do that. I would say one of the biggest issue is power. How do you power these devices for long periods of time? And one thing that is just remarkable to me in science is that our battery technology, it seems like it hasn't advanced in 20 or 30 or 40 years and I was just wondering when the great advancement's going to come to make batteries that are going to be able to support these kinds of devices.

So this is a challenge that I throw out there to all the electrical engineers and the chemical engineers: better batteries, better, smaller, more powerful VSPs, better fabrication techniques for implanting these types of devices in the body.

Marc Pelletier

So like a baseball cap with a solar panel on top or glasses with transparent solar panels, so you got...

Kirsten Sanford

Or even things that are dynamically activated by the movement of your muscles, yeah.

Marc Pelletier

There you go.

Justin Sanchez

Harvesting energy from your body, that would be a great idea, right?

Marc Pelletier

I'm on to the US Patent Office right now.

Justin Sanchez

Even from vasculature or from – I mean there are any number of ways that have been proposed to do that but I would...

Marc Pelletier

Mechanical watches, you know, how they just use that motion.

Justin Sanchez

Yeah, even the motion, kinetic motion there. I would really think that the vision for the future though for these types of interfaces, having a chip maybe implanted in the brain, small, low power, wireless, sending the neural signals to some wearable type of device that's the size of a cell phone or smaller that's doing the neural decoding on that and then sending those kinds of commands either to a prosthetic limb or computer. So I think the design constraints, this is really what the target should be.

Marc Pelletier

Have you done the wireless yet using components like commercial like Eye-Fi and Eye-Fi SD card?

Justin Sanchez

[27:36] Yeah. So for the implantable types of chips, the bandwidth is too high for using just the off-the-shelf kind of components, so we are trying to develop innovative ways of sending the information out of the brain using kind of some asynchronous types of coding. I guess that's a lot of technical stuff there but you have to be really creative...

Marc Pelletier

This is this WEEK in TECH, it's okay.

Justin Sanchez

...creative with how to get that information out. So off-the-shelf components, I don't think, can be used in the implantable devices but maybe in the wearable types of devices. Again, if you have something the size of your cell phone that has a powerful enough processor on there I think that you can do some really effective neural decoding on it.

Marc Pelletier

I have got a question. You said a thousand electrodes, right, is that like the ultimate amount? Is that the necessary amount or is that overkill? Are there single neurons with different connections that can power different intent?

Justin Sanchez

So there is an ongoing debate about this, about how much neural information is really necessary for controlling a prosthesis and I would respond with that question with – it depends upon what kind of environments and how complicated your skills that you would like to be using for this type of interface. So I would say in very simple laboratory environments, yeah maybe only 10 or 20 neurons are really necessary to control a robotic arm.

But let's say I take that robotic arm into all of the different environments that I would encounter throughout the day in my life. Would those same 30 neurons be able to encode all of the information? I don't know. Would other neurons be recruited to be able to control those different aspects? I would say maybe so. And then would the properties of those neurons change as I encounter different environments? We know that there is great plasticity in the brain and there may be aspects of consolidating new aspects of the environment into those neural circuits and I would think that you would incorporate many other types of neurons. So I think looking at systems of neurons is the appropriate way to investigate these types of devices.

Marc Pelletier

I would like to take a minute to thank audible.com for sponsoring Futures in Biotech. They have over 60,000 titles now, audio books, newspapers, magazines, radio, TV programs. A huge library of great audio content and today's pick is brought to you by Justin Sanchez. So Justin said he had a pick, so let's take a second and talk about his audible pick.

Justin Sanchez

Yes, so somebody told me about this wonderful book called This is Your Brain on Music: The Science of a Human Obsession and they passed along this information to me, and I found out that there's actually an audio book of it. And I just started listening to it a few days ago and it's just amazing. Trying to – the book just really gives a very high level overview of how one perceives music and how one uses their neural systems to engage and interact with music and I think it's a must read for any music lover that's out there. So I think it's a really wonderful – wonderful pick.

Marc Pelletier

Cool. So This is Your Brain on Music: The Science of Human Obsession by Daniel Levitin.

Justin Sanchez

Levitin – one of the two.

Marc Pelletier

And edited or narrated, sorry, by Edward Herrmann, sounds like an awesome pick – music is such an – a way, an incredible way to activate the brain, right, so it sounds really, really cool. So if you'd like to download This is Your Brain on Music, head over to audible.com/biotech. Sign up for a 14-day free trial of their Audible Gold account and if you like it, you stay with the account and if you don't, after 14 days – before 14 days you just cancel but you get to keep the free book, so it's a win-win situation. So I'd really like to thank audible.com for their support of Futures in Biotech. Back to the interview.

You said you – I think you had listened to the Terry Sejnowski episode.

Justin Sanchez

Yes, that was a great episode, Terry's a great guy.

Marc Pelletier

He's great, isn't he?

Justin Sanchez

Yeah.

Marc Pelletier

So he was explaining that the honey bee has a single neuron that controls everything, almost everything including the three-mile journey from the hive to the flower, and – which is equivalent

for a human from L.A. to San Francisco. All the memory from all that voyage is maintained in a single neuron, right, and all the, 'oh, is that a tasty flower.'

Justin Sanchez

Right.

Marc Pelletier

What's the color of that flower, what time a day, what direction; I mean it's an incredible amount of memory from a single neuron. So I guess there is some support.

Justin Sanchez

Yeah, I think there is some support and what I think it all boils down to is this concept of the neural code. Now people like to express the neural code. They called it a code because they think that there's something hidden in the collective activity or firing properties of these neurons but I would say in general that we have not really defined how all neural systems really encode information, right. And our ability really is to develop new signal analysis techniques to process this information that's represented in the firing on and off of a neuron into I want to move in a particular direction or I desire a certain aspect of reaching and grasping or I perceived a certain aspect of my environment.

So I think that there's a lot more work that needs to be done in terms of that neural decoding concept. And really to get at that we need to probe neural systems in animals and in humans and we need to develop new analysis techniques, new signal processing algorithms for exploiting that kind of information.

Kirsten Sanford

[33:39] Yeah, do you think that there's a lot that's still missing in the signal processing that – I mean we're looking at frequency, at the timing of firing. What aspects – are we really looking at summation of different neural firing? What things are we possibly missing?

Justin Sanchez

Right, so this is a complicated question. Let me see if I can break it down into a couple of steps. So in the processing of this neural activity, we need algorithms that take in multivariate signals. So I mean that multiple inputs, let's say a thousand inputs, and then convert that information into either movement, direction or movement speed, or it could be movement intent or something like that, right. So we have this huge – this algorithm that we have to put between these two things that need to define the functional relationships between the two.

And to compound that problem even more is that there is this idea of nonstationarity in the data, meaning the statistical properties of the neural firings or the neural activity may not be constant over time. So I think a lot us know if we're trying to fit, let's say, curves to data, we expect that data, the statistical properties of that will be fixed for the time that you're analyzing this. For neural interfaces right, we're in dynamic environments; they are changing, our neural system is changing, the environment is changing.

So signal processing, people working and developing single processing algorithms have not really embraced that concept completely yet. So I think that we need to develop algorithms that evolve over time, that symbiotically work with the user in an adaptive way, and this is something that we are actually developing in some of our work here, that – not necessary having the static decoding algorithm but having this algorithm that evolves and grows with the user over time. We're developing a mathematical....

Marc Pelletier

You're in the department of pediatrics, right?

Justin Sanchez

Yes, that's exactly right.

Marc Pelletier

In the department of pediatrics, a child's mind to an adult mind are completely different and is the brain – so I don't know developmental neuroscience here; so is the human brain – develop change in the organization, I guess every time you learn something.

Kirsten Sanford

Plasticity.

Marc Pelletier

Yes, there is huge plasticity.

Justin Sanchez

Yeah, every time you learn something there could be some changes in the synaptic efficiencies, some reorganization.

Marc Pelletier

I'm thinking more morphology, developmental morphology, expression of proteins between the ages of six and fifteen. When does an adult mind actually happen?

Justin Sanchez

That's a good question.

Marc Pelletier

I can tell my kids.

Justin Sanchez

Yes, that's really interesting. One concept that we really embrace a lot is the concept of reinforcement learning, is that you can adapt or modify your neural representation based upon the rewards that you get back from the environment or the consequences that you get back from the environment. And we're trying to build computer algorithms that are really based upon reinforcement learning and that enable the system to again grow and learn over time as the neural system would actually grow and learn over time. So learning through reinforcement I think is a real central principle of both just for individuals in general and for developing the next generation of neuroprosthesis.

Marc Pelletier

I have a tangent question for you.

Kirsten Sanford

I was going to ask something also from the chat room. Someone was wondering whether it would be more beneficial to give the neural implants or prostheses to young children, if that would be more beneficial because of the way that they learn. Is it better? Will they incorporate the prosthetic more readily than an adult?

Justin Sanchez

Maybe so. I mean maybe those younger children have less kind of barriers in their mind, just so to speak. But I have an interesting story, a lot of the human neuroprosthesis at least that we have tested so far at Florida here have been in pediatric patients. And what's remarkable is that when I put one of these kids in front of the computer screen and say okay we're going to do a brain machine interface to control a computer cursor, they look at it like controlling a video game. So in that sense it's very natural for them to say, okay, I'm going to think about doing something, it's going to affect the computer screen.

I would say if you put this task on somebody who, let's say, didn't really grow up in the computer revolution it may be a little bit more foreign to them so they would have to kind of adapt themselves a little bit more to incorporate it. So I say, yes, I'd say the easier you are to really incorporate technology into your lifestyle, the easier it will be to control these prosthesis.

Now one last point here, one thing that we're striving to do is that we're trying to build the neural decoders in as natural a way as possible. So when the user thinks about, let's say, imagines moving their arm, we want them to use that kind of control command to control the prosthesis. We don't want them to think about some kind of abstract idea in order to control the prosthesis. And that's really where that reinforcement learning may come in to be really handy, is that if you can train the algorithm in the same way that you would, let's say, a natural neural system, maybe you can come to this kind of symbiotic middle ground where it's easier for the user to control the prosthesis.

Kirsten Sanford

Fascinating.

Marc Pelletier

[39:05] The question I had was – now this is impossible to answer right now. There is no science, probably, behind it, is if a patient was an expert and had learnt – they were a pianist and they'd learnt all their scales and the twelve positions and major / minor, they had the memory of it and the muscle memory of it. Could that muscle memory be translated to a prosthesis?

Justin Sanchez

I think so.

Marc Pelletier

Through a brain-machine interface? Or would it require relearning from scratch because it's in the brain, if you got the right section of the brain. Go ahead.

Justin Sanchez

I think there are several fMRI studies in patients where they have shown, let's say, you ask a patient 'imagine moving your arm in a predefined path' or something, and they find that the areas that become activated in the brain are the same as those that you would use for your natural limb. So I think that the neural substrates are still there. The, I guess, maybe the engrams of those activities are still there, whether you are functionally using your arm or not. And I think that there are also other studies that show that there can be great remapping of these circuits depending upon the environments that the individual encounters.

Marc Pelletier

Well, I just saw a talk at the Neuroscience meeting in Chicago and it was Eric Kandel. He was the Nobel Laureate in 2000 for memory and he gave some of the unpublished data in his talk that's coming out. And we're going to have him on in May to talk about it.

Justin Sanchez

That's tremendous.

Marc Pelletier

He is got some...

Kirsten Sanford

I have to be on, I have to be on! I want to talk with him.

Marc Pelletier

All right, all right.

Kirsten Sanford

I study memory.

Marc Pelletier

So guess who else is going to be on that show. It's going to be Susan Lindquist, who's been collaborating – she is my favorite scientist, American scientist. She is just absolutely incredible. And what they were working on is – well she is a prion expert. So a prion is an unfolded protein that forms a fiber and they found that the brain has these prion like proteins and that they can aggregate and I'm not sure they were forming fibrils, but it was the aggregation that was the basis of long-term memory potentiation. And they actually modified the prions recombinantly and were able to actually accelerate memory – learning by two-fold. So they created these intelli-mice, right; super-mice that would learn twice as fast. Now I'd say that it's pretty neat, but – so you could actually potentially look at local regions of protein expression in metabolism, find out where the memory was stored or those – maybe access that proteomic information and guide your electrodes to the right neurons that have those memories.

Justin Sanchez

Yes, I think –

Marc Pelletier

Maybe this is 50 years ahead, but do you think something like that – could you imagine yourself poking an electrode at the right neuron, because that one you can tell has memory?

Justin Sanchez

I saw some very interesting work recently, it was some monkey work where the investigators were stimulating part of the brain called the striatum and – while monkeys were learning how to do certain kinds of tasks. And they find that if you stimulate the right neurons that the animal will be able to learn faster than an animal that was un-stimulated. So I completely agree that if you go from a cell-molecular perspective or just modulate thorough stimulation that really enhancing these abilities is a possibility in the future.

Marc Pelletier

I guess the gap between electrophysiology and molecular biology, I mean it's a fairly large gap compared to proteomics to genomics, right?

Justin Sanchez

Yes.

Marc Pelletier

Where one is just the simple – it's the fundamental biochemistry difference of course, but one uses the same kind of analytical techniques and the same bench style but if you're going with electrophysiology I guess it would be really interesting to see – so you are in your early 30s by the time you're in your 120s because of the...

Justin Sanchez

Right.

Marc Pelletier

...those nutraceuticals that are going to come out from Sertravis [ph]...

Justin Sanchez

That's right.

Marc Pelletier

Right. Wow; really cool to see what kind of – how molecular biology, molecular genetics can merge with the electrophysiology.

Justin Sanchez

That's right. And one thing that I think we should even advocate to the audience here is that there needs to be a stronger advocacy for people in each of these areas to cross-pollinate their ideas and work on grand challenges. I think that there is a great tendency in academia right now to just compartmentalize yourselves in areas that you are just – very fine focused. But something at least that plays a big part in my life, I want to address grand challenges of the nervous system, of humanity, all of these aspects and it really requires multi-disciplinary kind of collaboration and I think the more we advocate it and the more we kind of bring in the forefront this idea to bring people together I think it can only benefit us all in the future.

Marc Pelletier

We will talk after the show.

Justin Sanchez

That's right.

Marc Pelletier

[44:12] We have got some projects that I guess we shouldn't talk about per se but could be used – some of your technologies could be used to monitor the development of therapeutics in the area of neuroscience and that's kind of – I am very excited about that and one of the reasons why I keep calling you.

Justin Sanchez

I think it's wonderful; it's really great to think about all these potential applications in the future.

Marc Pelletier

Cool, how about we take some of the – so it was a really good idea Kiki to go into the chat room, I have never actually done it other than participate in the chat room.

Kirsten Sanford

Yeah.

Marc Pelletier

But how about we take some questions from the chat room. This is – I don't know if there's anybody watching in chat room, but we've got like 400 people.

Kirsten Sanford

Yeah I am taking a look at it. There are some people in there, don't know that there are necessarily any questions right now.

Marc Pelletier

It's a lag.

Kirsten Sanford

But maybe now that we've asked for questions, people will bring them up. I was thinking maybe we could jump to, since you brought up a tangent, Marc, I had another tangent about phantom limbs, oh there is Leo. Hi, Leo.

Justin Sanchez

I see Leo.

Leo Laporte

Hello.

Kirsten Sanford

Hi!

Marc Pelletier

Okay, phantom limbs.

Justin Sanchez

Hello.

Kirsten Sanford

Hi.

Leo Laporte

They didn't give me chance to put my makeup on.

Kirsten Sanford

Get ready. So I am interested in the idea of phantom limbs and so people who have amputations have this feeling that there is still a limb there even long after it's gone. How does this feed into the – under our understanding of how the brain works and for application to prosthetics?

Justin Sanchez

Yeah so the interesting I think concept behind your question is, let's say, we were to add a prosthetic limb to somebody who had a phantom pain, would that phantom pain actually go away?

Kirsten Sanford

Go away, yeah.

Justin Sanchez

Yeah, would the brain reincorporate that prosthetic limb into its representation of the world and say yeah this is a part of me now and I don't have that kind of missing sensation that I had before. And I don't know if anybody has even investigated that but I think it would be interesting and intriguing line of research in the future.

Kirsten Sanford

Yeah, I think – I think it would be, I think, the most interesting thing that comes out of it is the plasticity of areas of our brain. I know – I think it's V. Ramachandran or Ramachandran I think is how you have to say his name. But...

Marc Pelletier

He is at the Salk Institute, right?

Kirsten Sanford

Yeah, and he has done some really interesting work and – from what I remember, it suggests that areas of the brain that are adjacent to the area that used be responsible for that limb kind of encroach, so maybe it's the neurons that are responsible for proprioception or the sense of touch on your nose are now encroaching on the area that used to be your arm and so when something makes your nose tickle, it gets transferred to the area that used to be your arm and – and so if you – it's your nose you can make the phantom limb go – phantom arm go away.

Justin Sanchez

Yeah, so this remapping – it's a very interesting concept because there have been lots of examples like that in just basic physiology but even in prosthesis you can remap somebody's neural activity to any number of types of devices, right? And again you have representation for that in your brain. The question for biotech I think, is let's say, as individuals start interfacing their neural activity to computers and maybe even to the Internet, how would that influence our perception of how we interact with people, how we interact with the environment. It's just very, very intriguing possibilities for the future.

Kirsten Sanford

Yeah, someone in the chat room, Steve123 are you going to ask that one.

Marc Pelletier

Yeah.

Kirsten Sanford

Yeah, he says are there any ethical considerations about all this and I think if you get into the Internet – there are so many different places but maybe you could address them.

Justin Sanchez

Yeah –

Marc Pelletier

Maybe you could give some worst and best-case scenarios.

Kirsten Sanford

Yeah.

Justin Sanchez

[48:03] Yeah. So I think somebody always asks the ethical question when you talk about neuroprosthesis because it is such a powerful technology and I know that if I had a family member of mine that was suffering from a disability, there would be no question in my mind that I would develop that neuroprosthesis for them, right? These are people's lives that we are talking about here and we need to do everything we can to develop technologies to help improve their lives. That's a simple premise of human nature and of medicine.

And for that purpose alone I think that neuroprosthesis should be developed. I think that with any technology it can be used in any number of ways for positive or for negative and we as a society need to ensure that it gets use in the appropriate ways. And that's the kind of the value system at least that I live my life by, I mean I've devoted my life to this area of research and I think it's very virtuous and it should be done in the right way, and we should have the appropriate checks to make sure that it's done in the right way. And that's about our humanity, it's about helping people.

Marc Pelletier

Well there is no question the repercussions, the medical repercussions, I mean if you look at human frailty, right? We have got disease, infectious disease, while we can talk about the pharmaceuticals, possibly genetic intervention, vaccines, but collisions, trauma; really there is no treatment that can put an arm back, right?

Justin Sanchez

That's right.

Marc Pelletier

Well there may be.

Kirsten Sanford

Once we figure out the lizard's tail trick, right?

Marc Pelletier

The lizard – yeah exactly – well the salamanders, the lizard tail too I think geckos can do it.

Kirsten Sanford

Yeah.

Marc Pelletier

So is that – is the driving force behind neuroprosthetics is the fact that we're sometimes – I guess people win the Darwin Awards for a reason, I hate to get goofy on this but...

Justin Sanchez

That's a great question. I think that right now our ability to engineer electronics and interfaces that are effective immediately, I think that that's – of the immediate future. I think that designing replacement parts for the body, again connecting that to that Gizmodo the Cyborg Life set of stories, they ran a story about how there are some individuals out there that are growing artificial limbs – not limbs but artificial let's say ears and heart valves and things like that and I think maybe in the future maybe they could be able to regenerate different kinds of limbs and there may be technology that could interface those back with the body.

But again those are your natural appendices and one may choose to go that route, but back to this idea of could one expand their ability to interface with their technology in a very meaningful way? I think that you will still need a neuroprosthesis in order to do that, right?

So just simple interacting with your hands or with your eyes with technology in some ways limits you and I think that if you can expand your horizons through technology, you should try to do so.

Kirsten Sanford

Through an iPhone app. I bet there will be something in the iPhone App Store for \$1.99.

Marc Pelletier

God, or \$0.99. So anyway, it might be a good time to introduce Leo, the infamous Leo Laporte, welcome to Futures in Biotech.

Kirsten Sanford

Hi, Leo.

Leo Laporte

Hey, how are you?

Justin Sanchez

Hey, Leo, how are you?

Leo Laporte

You know why I am here, right. I come bearing gifts.

Kirsten Sanford

Gifts.

Leo Laporte

As in a Ford ad.

Marc Pelletier

Okay, I appreciate it. I totally appreciate their support.

Leo Laporte

Well, and I thought yeah, we're really thrilled to have them on in the network, and I thought that it would make sense for me to do the ad as I am since I'm the one who is driving a Ford and has this great Ford Sync stuff in the car and I just love it.

I just drove to San José last night and back up, I gave a speech down there. And don't be jealous, don't be jealous. Colleen says she is jealous, it is so much fun, this Ford Sync stuff is – I mean the idea is it's hands-free Bluetooth, hands-free music. It has – every Ford Sync car has a USB port as well as an audio jack. So there's no MP3 player that won't work with it – and many will work like the Zune or the iPod with a USB connector – and in fact you can even put a USB key in the USB connector. The Ford Sync sees the MP3s on there, indexes them and then you can control it with your voice. You could say things like play the Beatles and it will play the Beatles. If you're listening to Beatles, you say play similar – it will play songs of a similar – that have a similar genre.

Marc Pelletier

My desktop won't do that.

Leo Laporte

I know it's really slick; that is – I was talking about this...

Kirsten Sanford

I want it!

Leo Laporte

...on this WEEK in LAW and there are 18 states that prohibit you from holding your cell phone while you're driving and more and more all the time and so you really do need some sort of hands-free. This thing – you've got buttons on the wheel, so you never take your hands off the wheel. It's all voice, so you don't have to take your eyes off the road, you press the button, it goes "poonk" and you can say navigation, even if – by the way this is really cool, even if you don't have a navigation screen, the Ford Sync has turn-by-turn directions.

So you tell it the address, and it will walk you through; it will say turn left here, turn right and it even knows as it can memorize your routes, like to work and to school and it will tell you there is traffic, go this way because it gets the traffic from Sirius, I mean this thing is really powerful, Microsoft designed. I think it's Windows CE, in my sense. I am not sure. You don't see CE but it's a little computer in there and I wanted to tell people about this and I wanted to remind them that now through December 8th they have a chance to win a free nano or a Zune.

You can go to syncmyridepodcast.com, you'll get to read about Ford Sync and find out how you can enter to win, so syncmyridepodcast.com or if you want to use Twitter you can enter just by tweeting with the hashtag [#syncmyridepodcast](https://twitter.com/syncmyridepodcast). So you say something like 'Hey, thanks Ford for supporting Futures in Biotech' [#syncmyridepodcast](https://twitter.com/syncmyridepodcast), you'll automatically be entered to win. They are giving away a Zune or Nano every single day through December 8th. So if you are listening right now, tweet say 'I love Futures in Biotech, thank you Ford!' and the pound sign [syncmyridepodcast](http://syncmyridepodcast.com) or go to syncmyridepodcast.com for more information.

Marc Pelletier

So, can I upgrade my Volkswagen to do this?

Leo Laporte

No, Ford, Lincoln or Mercury. Sorry.

Marc Pelletier

All right, a Ford, Mercury or Lincoln.

Leo Laporte

I don't think – somebody else asked me this, I don't think they have aftermarket and they really should because this is...

Kirsten Sanford

Sounds great.

Leo Laporte

Yeah, it really is the best and I am saying this absolutely sincerely. I've used all of them. We have a Toyota and I've used their built-in stuff. There is nothing this good, this smart, this convenient. It really...

Marc Pelletier

How's the voice recognition?

Leo Laporte

It's excellent. Now there is two – there's two settings, there is standard and advanced and the guy when I bought the car said you can use standard and it's fine, but I thought well hey advanced is free, so I set it on advanced and it's been really, really good. I can say call Colleen on her cell phone and it will do that. I could say – I dialed the number when I was calling in this morning, I said call 707-666-1333 and it dials it. So I mean it's very good and this is...

Justin Sanchez

Does it do MP3s also? I mean there has been – many a times I've been scrolling in my MP3 Player while you're trying to drive, right?

Leo Laporte

So it will read a Zune, it will read an iPod or even just you can put a USB drive in there, you can put – and it will – as long they're MP3s with tags, you have to have the MP3 tags which most people do, it's automatic. It knows the name of the song, you can say I want Huey Lewis and the News and it will play, you can tell it the name of the song. It's really cool.

Marc Pelletier

You know I'd like to tie this into Futures in Biotech a sec here, because here is an interface that allows you to connect to your computer with your intent through voice. And we have Justin Sanchez here who's a neuroprosthetic specialist. So could you see this interface, could you – do you think, Justin, you could tie in your neuroprosthetics into this and use it to – use your mind to control the brakes?

Justin Sanchez

Yeah, so it's interesting right.

Marc Pelletier

Sorry to -- but that's part of...

Justin Sanchez

Could you envision in like 50 years having a neural implant that you could send out your intent to change tracks or hit the brakes or any number of things, right. It's a very intriguing idea of something that may come out in the future.

Marc Pelletier

Time for a trip to Detroit. Thank you, Leo.

Kirsten Sanford

I'm waiting for the thought initiated...

Leo Laporte

She sounds like the Cylon Sync. You have to unplug the USB and plug it back in again, I am sorry.

Kirsten Sanford

Oh man.

Leo Laporte

I like that effect. The Sync lady sounds much nicer. She sounds cybernetic. I think voice recognition is the next, is the final frontier, it's the next frontier. The Sync stuff is in a constrained vocabulary, so it kind of has a very limited vocabulary. So you could do a much better job, but I think independent speaker voice recognition is just around the corner. I was talking to an expert on this, who said we have the algorithms; it is not a question of how, it's a question of horsepower.

Marc Pelletier

Mustang?

Leo Laporte

As a matter of fact – what is it, 315 at 5,000rpm; yeah, that's all you need. In fact I am out of here.

Marc Pelletier

Thank you, Leo.

Kirsten Sanford

Thank you. Do I sound better? No more Cylon?

Marc Pelletier

Yeah, you sound a lot better.

Kirsten Sanford

Oh wonderful, yeah I was going to say that I can't wait for the brain-car interface, you just think about where you want to go, you think about what song you want to hear and the car just does it.

Justin Sanchez

That would be perfect.

Marc Pelletier

[58:01] Or a plane. A plane is the way to go, a glider, motor glider. I'd like to ask you one – my final question then we could end with a question from Dr. Kiki. So and I asked Eric Kandel and it was kind of a stupid question, it was probably one of most embarrassing questions I've ever asked a Nobel laureate, is will there come a time when we have a USB interface in the back of our head where we can learn. So I was in college for 19 years, right. Now they call me doctor, it was 19 years of college. Is there any way we can, without necessarily going with a pharmaceutical approach, that Kandel is working on, to improve learning and to – do you see that happening? Our ability acquire information with your – the other direction, to the neural center.

Justin Sanchez

Yeah. So I see two possibilities; the first I would hope that you wouldn't in the future have a USB plug in your brain. I hope it would be completely subcutaneous, you wouldn't even know that it was there.

Marc Pelletier

Okay.

Justin Sanchez

But I think that there is evidence again for stimulation, that you can modulate neural circuits to help enhance your memory, but the idea that I think is more interesting, at least from a research point of view, is that could one develop a series of artificial neurons that could either store or produce memories that you could interact with directly with your brain. And I know that there are several groups that are out there right now kind of playing around with this kind of idea. Again you're having supplementary neurons, manmade neurons that could either store or send memories back to your brain.

Kirsten Sanford

Oh! That's a fascinating idea, I mean I can...

Marc Pelletier

We can talk about that on December 18th, by the way, I think right.

Justin Sanchez

Yeah, that's right, that's right.

Kirsten Sanford

Cool.

Marc Pelletier

December 18th, okay, but go ahead Dr. Kiki, how about you take the last question.

Kirsten Sanford

Well I was just going to just play off of that one a little bit, the knowledge of how memories work is when you remember something your neurons are basically replaying that – playing the situation so that that's why memory can be so malleable as you replay something you can actually change the memory by adding different inputs during that period of time that you're replaying it. So that that could actually get into, if you are affecting a memory as it's replaying how can you add to it and accentuate it.

Justin Sanchez

Yeah, I mean, there is some great research questions that are out there, just the sequence of the replaying of the memories has been shown to be important, how would you interject the memories in there and what would happen if you do interject, would it disrupt somehow any of your previous stored memories or would it enhance those kinds of memories and how would this affect your perception of the world and your interaction with other – all these things I think are very fascinating and are really untapped frontiers in the nervous system. So, yeah, another thing we should advocate for the audience out there is...

Marc Pelletier

Don't try this at home?

Justin Sanchez

Well no, not that, but seek out advanced degrees. Go, seek out these tough questions about our bodies and our brains and try to find solutions to them. Use your talent out there to help improve what humanity has to offer. These are what make life so interesting.

Kirsten Sanford

Or listen to programs like Futures in Biotech, you know.

Justin Sanchez

That's right and get inspired and do it in your garage or something, right. A lot of the great discoveries in history had been done in the garage, so...

Marc Pelletier

Didn't you have a Ph.D. candidate or a request from India that had listened to the show and called you...

Justin Sanchez

We sure did. I am glad you brought that up. I got an email from somebody from India that said they listen to Futures in Biotech and I said yeah, 'I listen to this show and I wanted to pursue an advanced degree in this area, I thought it was very interesting'. So this is very wonderful that we are reaching out to the community and having an impact.

Marc Pelletier

Well, we're going to continue this discussion in parts. It's going to be a four-parter. On December 4th, we're going to have Justin Sanchez back and it will be at, what time – 12:30 PM Pacific Time.

Kirsten Sanford

Pacific.

Marc Pelletier

So that will be the 50th episode of Futures in Biotech. So we're going to do a panel show and bring on some of the regular guest-hosts that have been on and we're going to talk about the top stories in the last year. So I'll give you the final word, if there's anything – or we can extend it into our conversation as well on December 18th, when we're going to talk about – we're going to go more into brain-machine interfaces but more into ultra-low power bioelectronics on December 18th, it's going to be wild, from a professor at MIT. So I'd like to really thank Dr. Kiki for guest-hosting today. You had some really great questions. I am sure Justin is sitting here, fatigued, drained – we've been drilling him with questions.

Kirsten Sanford

Just one more question!

Justin Sanchez

I say you got to get tough. It's great. It's a character-building experience, that's what I always tell my students. You've got to build character every day.

Kirsten Sanford

At least challenge your neurons a little bit, right?

Justin Sanchez

That's right.

Marc Pelletier

So, we can visit you or watch you on Dr. Kiki's Science Hour which is on Thursday, so what time?

Kirsten Sanford

3 to 4 PM Pacific Time on twit.tv, so live.twit.tv. 3 to 4 PM Pacific, 6 to 7 Eastern for Dr. Kiki's Science Hour. I also have This Week in Science which airs live on kdvs.org every Tuesday morning 8:30 to 9:30 AM Pacific Time.

You can also catch us on the iTunes and Twitter, Dr. Kiki, d-r-k-i-k-i.

Marc Pelletier

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Congratulations on joining the TWiT network. It was really great to have you on.

Kirsten Sanford

Thank you. Yeah, I am very excited and I hope to be able to help expand the science in the TWiT world.

Marc Pelletier

Well we'll have to call it TWiST, right? This Week in Science and Technology.

Justin Sanchez

Great, wow!

Kirsten Sanford

That's great.

Marc Pelletier

The new network name; TWiST.

Kirsten Sanford

A whole new network, yeah.

Marc Pelletier

Science first, technology next. This is engineering too, right?

Kirsten Sanford

It is. Science and engineering.

Marc Pelletier

Exactly, they go hand in hand. So I'd also like to thank Dr. Justin Sanchez, Assistant Professor of Pediatrics, Neuroscience, and Biomedical Engineering at the University of Florida. Thank you very much for coming on.

Justin Sanchez

Thanks so much for having me. It's always so fun and I love reaching out to the community and talking about interesting topics and technology and how it's going to impact our lives. So it's really wonderful. Thanks so much for having me.

Marc Pelletier

Especially, I called you two hours ago.

Justin Sanchez

That's right.

Marc Pelletier

It's great.

Justin Sanchez

My hands were bloody!

Marc Pelletier

And I called and said 'Justin, can you come on the show?' That's awesome. I really, really appreciate it.

I'd also like to thank the people that make this possible; Leo Laporte, Dane Golden, Colleen Kelly, Erik Lanigan and the rest of the team at the TWiT Cottage.

I'd also like to mention that transcripts are available for the show and you can get them at futuresinbiotech.com and they are made available by the kind folks at Pods in Print. If you need transcripts done, even the most technical, they can really handle it.

And lastly, I'd like to thank Phil Pelletier and Will Hall for the opening and closing themes. For Futures in Biotech, I am Marc Pelletier.