

DISRUPTIVE: BIOINSPIRED ROBOTICS Pt. 3

Host Terrence McNally interviews Conor Walsh. Podcast published July 27, 2015.

McNally:

Hello, welcome to DISRUPTIVE the podcast from Harvard's Wyss Institute of Biologically Inspired Engineering. I'm your host, Terrence McNally.

The mission of the Wyss Institute is to: Transform healthcare, industry, and the environment by emulating the way nature builds.

Our bodies — and all living systems — accomplish tasks far more sophisticated and dynamic than anything yet designed by humans. By emulating nature's principles for self-organizing and self-regulating, Wyss researchers develop innovative engineering solutions for healthcare, energy, architecture, robotics, and manufacturing.

They focus on technology development and its translation into products and therapies that will have an impact on the world in which we live. At the Wyss, folks are not interested in making incremental improvements to existing materials and devices, but in shifting paradigms. In this episode of DISRUPTIVE, we will explore: BIOINSPIRED ROBOTICS.

Many of the most advanced robots in use today are still far less sophisticated than ants that "self-organize" to build an ant hill, or termites that work together to build impressive, massive mounds in Africa. From insects in your backyard, to creatures in the sea, to what you see in the mirror, engineers and scientists at Wyss are drawing inspiration to design a whole new class of smart robotic devices.

We're going to explore this exciting territory in a three-part episode of DISRUPTIVE, featuring three members of the Wyss faculty, CONOR WALSH, ROBERT WOOD, and RADHIKA NAGPAL.

Walsh's Bio

Today's guest, CONOR WALSH is Assistant Professor of Mechanical and Biomedical Engineering at the Harvard John A. Paulson School of Engineering and Applied Sciences, founder of the Harvard Biodesign Lab, and a Core Faculty member at the Wyss Institute. His research focuses on applying disruptive technologies to the development of robotic devices for augmenting and restoring human performance. He leads a team of researchers on the DARPA Warrior Web project whose long term goal is to develop fully portable wearable robots to assist the disabled and able-bodied.

Conor received his B.A.I and B.A. degrees in Mechanical and Manufacturing engineering from Trinity College in Dublin, Ireland, and M.S. and Ph.D. degrees in Mechanical Engineering from MIT. He has been the recipient of over a dozen invention, entrepreneurship, and student mentoring awards including the MIT

\$100K business plan competition and the MIT Graduate Student Mentor of the Year. Walsh established the Harvard Medical Device Innovation Initiative that provides students with the opportunity to collaborate with clinicians.

Welcome, Conor Walsh to DISRUPTIVE...I like listeners to get a feel for the people behind the work and ideas we talk about. Could you share a bit about your personal path?

[02:40]

Walsh's Personal Path

Walsh:

Growing up I just always wanted to do cool things, and I guess that's why I decided to become an engineer. Enjoyed gadgets, technology, all those types of things. But I think it was really when I got to my undergrad where I started taking more engineering courses that I got a hands-on feel for what it was like. I did my undergrad in Trinity College in Dublin and I was part of this unique program where for the first two years you didn't specialize and pick a discipline. So you took mechanical engineering classes, electrical engineering classes, computer science classes, even civil engineering classes.

I think it was really that broad exposure at the start of my third level education where I was like, "I kind of like all of this and I'm not really sure which part I want to focus on more." When I was going through undergrad, I liked the idea of working on smart mechanical devices that had some electronics, some software component to it, and that was really, my first passion, before I even knew I wanted to be a roboticist.

Robotics isn't a very big field in Ireland, but during my undergraduate I read a *Scientific American* article on exoskeletons, some of the work that was being done by Professor (Homayoon) Kazerooni at Berkeley and Steve Jacobson at Sarkos, which was part of an early DARPA exoskeleton wearable robotics program. And I was really inspired by that, and I was like, "This is just super cool." There was nothing like that going on in Ireland whatsoever at the time, so that's what kind of triggered the thought, maybe I'll apply to graduate school in the US.

From there I applied to a bunch of different places and I ended up going to MIT. At MIT I was excited about exoskeletons, but there wasn't so much work going on there at that time. Then just coincidentally, Professor Hugh Herr, a faculty member in the Media Lab there, sent out an email saying he was looking for a few graduate students who want to work on a new exoskeleton project that he was starting. And I was like, "Can't believe the timing, that works out pretty well." So I applied for a position in his lab. That was back in 2004 when I started working on exoskeletons and wearable robots for the first time.

McNally:

You say he was in the media lab, so already it sounds like there's some kind of cross-fertilization going on.

[05:00]

Walsh:

The Media Lab at MIT is this really interesting place. It started out mainly focusing on IT type of stuff when it was founded, and I'm not actually sure when, but it's kind of morphed to also be doing interesting work on hardware as well. At the time when I started there, Hugh's group was really one of the main groups focusing on hardware and more mechanical engineering type things. It was a really interesting environment where there were more artistic people, people thinking about music, all kind of together. It kind of forces you not to think about things in traditional types of ways, where you look at, I'm okay, I'm in the mechanical engineering department or the electrical engineering department. I guess that's just coincidentally been kind of a theme throughout my education, where I managed to find myself in places that are maybe not totally traditional, and I think that's influenced me in a good way I would say.

McNally:

I would think people could go to MIT or to Harvard and spend their time in a little silo. And you - either by nature or luck - have managed to avoid that.

Walsh:

Yeah, and who knows what the real reason is. Maybe it's because I'm not very good at picking things. Maybe it's because I don't want to specialize in one thing. I've never really thought about it too much or tried to figure out why it happened, but it's definitely something that leads you down interesting roads and opens up interesting opportunities.

[06:25]

Soft Wearable Robots

McNally:

Though it may not be what most people, even today, think of when they hear the word robot, you've been drawn to the soft, wearable... What does that mean, that robotics can be soft and wearable, what does that open up for us?

Walsh:

I guess the field of wearable robots definitely started from thinking about, how do we apply robotic technology that was designed for industrial settings - so, factory automation - to the area of exoskeletons? It looks really cool and people look like they can have superhuman strength; but some of the practical challenges for implementing them, both from a technology point of view but also from a cost point of view, have limited their adoption into the market.

I think from a technology point of view they're really amazing and they, with traditional types of robots, have already seen real world applications that are very exciting and real. Now there's a number of different companies commercializing rigid exoskeletons, mostly targeted at medical applications for people who are fully paralyzed making them able to walk. But there's also the military application or the industrial application - how do you help people carry heavier loads or perform tasks where the risk of injury is reduced?

[07:42]

And so with all of that as a background, when I got to Harvard - again just by coincidence - there was a number of faculty here working on this emerging field of soft robots.

I think it's a rapidly emerging sub-field of robotics, where people are thinking, how do you use soft materials and a lack of rigid elements to be able to create robotic structures that even move, crawl, swim, etc. or grasp. I guess, because I had previous experience in exoskeletons, I really saw that there was a unique opportunity to apply that area of soft robots to applications where you really had an intimate coupling with the human body.

So the way I think about soft wearable robots is that it really opens up new possibilities, new market opportunities and new application areas, where you're not looking to fully support people. You're not looking to help a paralyzed person stand up. You're not trying to help someone carry two hundred pounds. But you're basically trying to say, how do I use this small and flexible robot that can move, but not apply too much force, and find application areas where that action could be beneficial for people.

So we look at grasping. If someone has a very weak hand, could you put a glove on them that has some soft-robotic components that would allow them to grasp objects? We look at walking and say, okay, if someone can walk but just not very well, can we help give them a little boost at key moments while they walk, to help allow them to walk maybe 50% faster? And while that doesn't sound like that big a deal, it's those small types of gains that can lead to big functional improvements for people that allow them to be able to be more independent and have a higher quality of life.

McNally:

I would assume that they change their whole perception of who they are and what they're capable of. I know one of the things you've said is we're not replacing them, we're not starting from scratch, but increasing their stamina, increasing their possibilities.

Walsh:

Exactly. I think that's the key thing. And to do that with a rigid, traditional type of robotic system is hard. I think that's really where soft robotics - because it's so lightweight and flexible - gives you new possibilities that you wouldn't otherwise be able to do.

[09:50]

Soft Exo-suit or Exo-skeleton

McNally:

Conor, with the soft exo-suit or exoskeleton...Can you share the story behind that?

Walsh:

Sure. So it was about three years ago, in 2012, just as I was starting at Harvard, there were a bunch of other faculty here, and Rob Wood, Radhika Nagpal and Gene Goldfield had already started working in this area of soft wearable robots. I guess for me, I'm more of an applications type of guy. My initial thought was, "Wow, can we actually deliver enough assistance with one of these devices so that we can actually have a positive effect on their mobility?"

For me there's a big difference between creating a very nice proof of concept device that has a bunch of actuators on a person, but then how do you actually take that and test it in a real world type of setting? One of the key challenges with these types of systems is, without the use of a rigid exoskeleton, how do you anchor to the body and allow these artificial muscles or actuators to attach at various locations, so that when they pull on the person that they don't just kind of pull your pants down or pull the suit away, but anchor with some degree of stiffness to a textile that is worn by the person.

[11:04]

We got a bunch of different inextensible elements like seatbelt webbing. We figured out how can we wrap these on a person's legs so that we can anchor to the body but that it doesn't restrict them when they're trying to move. Because you could put somebody in a strait jacket that's a very good fit, but then they're not going to be able to walk.

So the basic idea was, what's the architecture, what's the layout of these inextensible elements of fabric that go on the legs that allow you to apply forces but don't restrict a person at other times in any other way? So we spent about six months putting together a first prototype. We're a mechanical engineering type of robotics research group, so we have to get sewing machines, and we started off with just a single sewing machine and no one who really knew how to use it. People gradually trained themselves how to use the sewing machine. The first prototypes we built weren't very pretty.

Basically about three years ago, we were able to prove the concept where we put together one of these first prototype of the soft exo-suit and had someone walk on a treadmill, and we monitored their oxygen consumption. What we found was, when you get the timing right - the timing of when you deliver a assistance to the person -you can actually reduce the amount of oxygen that they're consuming. And you're able to do that by applying forces through this soft suit, and you're able to do it by applying forces that are not very very high. So we're not talking about giving 100% assistance to the wearer, we're talking about 15-30%.

[12:27]

McNally:

I've heard you use the metaphor...You compare your approach to pushing someone on a swing...

Walsh:

Yeah, so the way we think about walking is that - or the way others think about walking - is that it's a very dynamic process. When you're walking, your body is

acting like this pendulum at various times, where there's a lot of exchange of kinetic and potential energy. And so it's analogous in a way to a person on a swing, where as they swing forward they're getting a lot of kinetic energy, and then as they reach the peaks on each side, they're storing that in potential energy, and then gravity is helping them accelerate again. And if you think about someone on a swing, if you wanted to really keep someone moving, the right time to do that is right at the top of one of those crests, where you can just give them a little tiny tap and it keeps them oscillating back and forth.

Walking is very similar, where there's kind of key moments during the walking cycle when the muscles in the body are giving these boosts or these impulses to someone when they walk, and the timing of that is very critical. So with our exo-suits, we're essentially trying to deliver those same impulses the way the muscles are trying to keep the person dynamically walking very, very efficiently. And so the way we think about it, it's the actuation. Being able to apply the forces is very important, but then the other thing with these soft exo-suits is, what's the minimal and simplest approach to monitoring a person's movement? What sensors can you have in the system to detect where they are in the walking cycle, so that you can always deliver that assistance at the right time?

McNally:

...What your sensors are picking up and transferring and acting on...?

Walsh:

Exactly. So we have a little microprocessor in these systems that reads in that sensory information, and then it tells the motors when to pull to deliver that assistance to the joints.

McNally:

It strikes me that when you start doing that, that's where you're getting much closer to simulating biology...

Walsh:

I think that is one difference... With the soft systems, we really are trying to have this, it's almost like an extra muscular layer that's on the outside of the person but is really affixed to them through this kind of textile architecture that we're designing.

McNally:

It also needs the nuances of the sensing and the input that is not... rough. It's so subtle.

Walsh:

The timing is critical. And we take a lot of inspiration from human walking, and there's a lot out there in the literature, but the reality is that people don't fully know exactly how the body still does some things in terms of walking. How do the muscles and tendons interact? How do they work together to try and store energy in soft tissue so the muscle has to do less work? I think there's still a whole lot of unanswered questions there.

I think in addition to the applications that we're doing, the technologies that we're building provide unique experimental platforms, that will then allow us to perturb the person and see how they react and respond to assistance, and maybe we'll end up learning more about people as a result.

[15:12]

Soft Robotic Glove

McNally:

Working backwards almost...

In June you released news of a soft robotic glove that could someday help people suffering from loss of hand motor control and regain some of their daily independence. What's the story behind that one?

Walsh:

That's using a slightly different type of technology, but it definitely fits in the same category of soft wearable robots. The actuation scheme that we used there is the silicon type of actuators. They're hollow silicon tubes - rectangular tubes or circular tubes - that when you pressurize them, they end up creating these complex motions that would be very hard to achieve with a traditional type of rigid robot.

When I came to Harvard, George Whitesides and Rob Wood were really doing some very interesting work in this area. Basically we saw the opportunity to integrate these into wearable applications - the actuators as they stand actually look quite like fingers.

So we thought - could we integrate these into a glove and have it be a device that could actually assist someone increase the amount of grasp strength that they have? That could be interesting for healthy people to be able to hold on tighter for longer. But really to start with, we're thinking about, could we design a technology that allows someone who has lost the use of their hand and has lost the ability to grasp objects, to be able to restore that, so that they could be able to be more independent? It's a similar type of concept. We're not trying to overpower the person, we're trying to put a light, flexible actuator on them that in this case, when pressurized, has a similar type of motion to what they would be trying to do so that it works very naturally and synergistically with them.

[16:51]

McNally:

Can you talk about how you involve the glove's potential users in every step of testing and development?

Walsh:

Because my lab is such an applications-focused lab, we often start with problems, and you don't really know problems unless you get outside the lab and start to talk to people. So three or four years ago, when we were starting to think about this

area of upper extremity assistive devices, we actually started an IRB-approved study that allowed us to go out to patient's homes, talk to them, see how they are living at the moment without assistive technologies, understand what some of their challenges are, and give us an insight into what technologies could be practical in that setting and what technologies may not be practical.

That was really how we started, and then, once we honed in on the idea of soft robotic glove to assist with grasping, as we were developing prototypes even at the earliest stage, we were bringing them out to patients and saying, "Hey, what do you think about this?" And this wasn't a full prototype, this was a work in progress and we got really lucky with some fantastic participants that were happy to work with engineers, and realized that these weren't finished products and were able to say, "Well, I liked this part... this would be very hard to put on...I'm worried if I wore this I won't be able to feel what I'm grasping..."

Little things like that would be impossible for an engineer or a researcher to think about themselves. But it's this interaction with the real end-users that forces you to have more constraints than you would otherwise put on yourself, that allows you to maximize your chances of the technology you're developing having impact down the road.

McNally:

Right, instead of the esoteric perfect ideal that sits on a shelf, you're saying this is only of value if it's actually used. One of the things I know you found is that appearance is an important factor in whether they'll actually use it.

Walsh:

We definitely got that feedback from patients in general. They're always very excited about it, but they also want to have it look cool. I think with these technologies it always ends up being a trade-off between how much benefit is it giving you, versus how does it look versus how difficult is it to use and interact with? Because if something gives you amazing abilities, you'll sacrifice more of those other things. It's always trying to get that balance right between cost and benefit, which I think is really important.

[19:08]

Latest Developments, What's Next

McNally:

What are some of the latest developments and what's next?

Walsh:

We've achieved proof of concept, where we've shown that we can use this device to help patients grasp objects and that they wouldn't otherwise be able to do. And now it's basically how do we make it smaller, lighter and smarter? And think about developing it to the point where we could actually use it in a small pilot trial of eight-to-ten patients, hopefully that we would do by the end of this year. And the goal there is to really demonstrate across a number of patients that it creates a significant benefit in their independence and quality of life. That would be the

proof of concept step that we would then hope some commercial partner – whether it’s a startup or another company in the space - would want to then take that technology and help us bring it to market.

[19:52]

Culture of Translation at Wyss

McNally:

And that step that you’re talking about of demonstrating those sorts of things, that’s a step that an academic institution usually wouldn’t get to, right?

Walsh:

Yeah, I think it’s a challenge. Often times you have graduate students and post-docs that do really amazing work but they want to go on to an academic career or they want to go and do something else, so projects often don’t make it outside the lab. But the really exciting thing about being part of the Wyss Institute - in addition to the graduate students and post docs, we have a lot of staff here that are also working on the projects with us. They provide the institutional memory and they also provide the industrial experience, so they can really think about, what really needs to be done in order for this to be a product in the future? You’re not going to solve everything within Harvard, but at least you’re making sure that that transition can be smoother and easier.

[20:41]

So for us, we really think about projects in three different phases. The first is kind of skunk works research, let’s just do lots of different things and see what looks exciting. Then once projects start to have potential, we build teams around that, and we call those platform projects. Then we say okay, over the next year we really have a goal from going from proof-of-concept to something that we could use in a number of patients and demonstrate it in a larger more scaled-up way. And then the last step is these institute projects, where we have the opportunity to then say, “Okay, we have a technology that looks really exciting.” We know there’s commercial interest, because we’ve been talking to people along the way, what’s that remaining gap that exists to accelerate that towards the market? And that could be technical stuff, business development stuff, marketing stuff.

For me as a faculty member, that’s why I’m very excited to be at the Wyss, because I don’t have to do all that. There are people here that help with those types of things, and I think it’s a really unique environment that allows you to push technologies further than you normally would in an academic setting.

[21:43]

Open Source Dissemination of Research, Soft Robotics Toolkit

McNally:

You’re really committed to open source dissemination of research results. Can you talk a bit about that notion and the Soft Robotics Toolkit?

Walsh:

Sure. Soft robotics is such an emerging field that there's no real good textbook out there on it. It's not something that's as deterministic that you can put in a textbook, where you just have equations that you learn and example problems that you solve. A lot of it has to do with hands-on design and fabrication. So what we realized is that there would be an opportunity to create an online community where researchers at Harvard and at other universities all over the world could upload their designs, their 3D-cad files, and their descriptions on how they make these. We even encourage people to submit multimedia tutorials, so if you're making something in a lab you could take a video and narrate it and upload it.

So what we're trying to do is for the different projects that we work on, uploading them on to this shared portal that then allows other people to be able to learn from each other and build on each other's work.

The question is how do you incentivize people to do that, 'cause everyone's busy. So one way recently that we've tried to do that is to create some competitions. So there's a lot of material on there that we've uploaded to try and get it started, and then we've launched two competitions. One competition focuses on - do something really cool with the material that's on there already. This is open to anyone in the world, teams or individuals, and we have a bunch of different prizes.

At the moment we've got 18 different teams that have uploaded pretty detailed cool designs that range from robotic grippers and quad copters for picking things up, to teddy bears that hug you back when you hug them ...so lots of creative ideas that people have come up with. Then they have to as part of this competition, upload their designs, so that other people can see what they've done and how they've built it. So with this, we hope that it will eventually - once we hit critical mass - be a large community of people that want to share their work and learn from each other, and I think it's something that we hope to continue to scale going forward.

[23:42]

The Future

McNally:

Finally, Conor, if you could stand in the future, say twenty to twenty-five years from now, where do you think all of this is going - the stuff that you're working on and thinking about? What does the future look like?

Walsh:

You know, in terms of robotics as a whole...Wearable robots, flying robots, personal robots are going to become more and more ubiquitous in ways that we don't really understand or imagine. I think we're kind of at this tipping point at the moment, where we see the Hollywood view of how these things work, but I think there's going to be this gradual influx of robotics into our lives, where they'll start with more practical applications and then lead to more and more exciting possibilities in the future.

I think if we look at robots in our personal lives, there's really not too many at the moment. The Roomba from iRobot is one that many people might have in their homes. But I think you're going to see more and more drones flying around in the future. I really do feel that, whether it's in a rehabilitation clinic or in the community, people are going to be walking around with some types of robotic devices. If you think about what technology these people have today, it's canes and wheelchairs and pieces of plastic that act as braces.

I think technology has a habit of just creeping in everywhere eventually, and I think with hardware it's a little bit harder. Internet over the last twenty years has really transformed society in ways now that we just take for granted, but I think hardware is catching up and people are understanding how to develop more integrated systems that work more robustly, especially when interacting with humans. So whether it's self-driving cars or wearable robots or flying robots, these things are just going to start to become so common... In twenty years you won't be surprised when you see robots every day, you'll actually just take it for granted.

McNally:

And my guess is, some of the things that will unfold, we won't think of as robots. But they will be robots, right?

Walsh:

Yes, a robot is defined as something that has actuators, so things that can move; things that can sense their environment or themselves; and then some kind of intelligence on board that synthesizes all that information to tell it what to do. I don't know where that will take us, but you're going to see more and more of that in society.

[25:51]

McNally:

You've been listening to DISRUPTIVE: BIOINSPIRED ROBOTICS. I'm Terrence McNally and my guest today has been Conor Walsh.

We invite you to listen to the other two segments of this episode – with ROBERT WOOD and RADHIKA NAGPAL. We'll talk with Wood about his work with tiny flying robo-bees and self-assembling robots inspired by origami and pop-up books. Nagpal's team built a swarm of a thousand robots who can without direction organize themselves into the shape of a starfish and Radhika is as passionate about living a whole life as she is about breakthrough science. You can find both those podcasts at iTunes or SoundCloud.

You can also find them at the Wyss site – Wyss is spelled “W-Y-S-S” and the site is wyss.harvard.edu – [w-y-s-s - Harvard.edu](http://w-y-s-s-harvard.edu) You can also learn more there about the innovative work of the Institute. There's an extensive library of articles and videos.

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free to share far and wide. I look forward to being with you again soon.