Hannah Shafaat Looks Deep into the Oceans and Gets Answers

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SPEAKERS

Doug Dangler, Eva Dale, Hannah Shafaat

E Eva Dale 00:00

From the heart of the Ohio State University on the Oval, this is Voices of Excellence from the College of Arts and Sciences with your host, David Staley. Voices focuses on the innovative work being done by faculty and staff in the College of Arts and Sciences at The Ohio State University. From departments as wide ranging as art, astronomy, chemistry and biochemistry, physics, emergent materials, mathematics, and languages, among many others, the college always has something great happening. Join us to find out what's new now.

Doug Dangler

Professor Hannah Shafaat received her BS in Chemistry from the California Institute of Technology, and PhD in Physical Chemistry from the University of California, San Diego. After earning her doctorate, Dr. Shafaat studied at the Max Planck Institute for Chemical Energy Conversion, and then joined the Ohio State University's Department of Chemistry and Biochemistry in 2013. In 2017, she received the Department of Energy Early Career Award, in 2015, the National Science Foundation Career Award, and in 2018, a Sloan Research Fellowship. So, welcome to Voices from Arts and Sciences, professor Hannah Shafaat.

H Hannah Shafaat 01:11

Thank you.

Doug Dangler

So, tell me about the work that you're doing. Tell me about the Department of Energy Early Career Award, how does one win that?

Hannah Shafaat 01:19

So our work for the Early Career Award is on alternative energy and learning how nature has evolved ways to take things like carbon dioxide and turn this waste product into a useful fuel.

Doug Dangler

Okay, so what are some of the mechanisms for how it does that, some of the things that you're studying how it, it makes it happen?

Hannah Shafaat 01:42

So at the core of a lot of these very ancient organisms, and organisms that still live in deep sea vents or fairly primordial conditions, are a lot of different enzymes that have metals in them. And these enzymes operate anaerobically. So, in complete absence of air, they're, in fact, very sensitive to air. But we're trying to understand how some of these enzymes work. Many of them use nickel, nickel ions at the core. And so we're trying to take lessons from those enzymes, use nickel, and do a lot of these reactions, but do them in very simple and robust scaffolds that will make the reactions not as sensitive to air, or oxygen tolerant, so we can think about using them on a on a larger scale.

Doug Dangler

Okay. So, what are some of the things that you found recently working with them and ways that you're finding new energy pathways?

Hannah Shafaat 02:34

So one of the things that we've learned fairly recently is we're trying to do CO2 reduction, and CO2 reduction to carbon monoxide specifically. And we've learned that in addition to needing to put a catalyst inside a very structured environment, we also need a way to get electrons in and out of that catalyst very, very quickly. And in fact, both of those things working together are important to create a catalyst or an enzyme system that's completely selective for CO2 reduction.

Doug Dangler

So when you reduce CO2 to carbon monoxide, what happens to it then? Where does the carbon monoxide go, because that's also a bit of a poisonous issue.

Hannah Shafaat 03:12

That is certainly a poisonous issue. And so the other half of the DOE grant actually looks at taking that carbon monoxide and turning it into a fuel, basically doing a carbon-carbon bond forming reaction, which is the next step in the natural pathway. Nature takes CO_2, make CO and then takes that CO, and immediately makes Acetyl-CoA, which is essentially a biological fuel, out of that CO. So we're trying to take that CO and again, do a very similar type of reaction to make a liquid fuel.

Doug Dangler

Okay. So when you make the liquid fuel then, what's the next step down the pathway? And I know this is probably out in the future, but if you have that, where do you take it from that step?

Hannah Shafaat 03:53

So the next step, the fuel that we're right now focusing on are things like acetate, which can be a fuel, it's actually something that's liquid, that you can imagine putting into the infrastructure. What we really want to do is understand how we can do these reactions, so then we can use that to essentially design catalysts that can do this on the industrial scale.

Doug Dangler

Okay. So when you say it happens in nature, tell me about the places where this happens in nature, what kind of environments are around the production of something like that?

Hannah Shafaat 04:24

So, a lot of these organisms that do this kind of reaction, they live in deep sea vents or volcanic trenches, very anaerobic volcanic trenches that are bubbling up in the mud. Organisms that do that are sometimes found in the anaerobic guts of people, not so much, but certainly, we know cows produce a lot of methane and methane is another, the enzyme that uses that is also a nickel-containing enzyme. So, a very similar type of pathway.

Doug Dangler

Okay. So when you're studying something like this, then how often do you get to compare to say the, the reactions that happen at a vent, do you - you don't yourself travel there? Which would be fun.

Hannah Shafaat 05:07

Unfortunatly not, not yet

Doug Dangler

Or the, you know the guts of the cow, because at Ohio State, we do have the cannulated cow, you know, it's open and you can look at and reach into, but you know, probably not something you're going to do.

Hannah Shafaat 05:20

No, we're much more on the sort of lab side of things really trying to, we work not in collaboration, but in close conversation with people who actually do work on these native enzymes, and try to go back and forth, letting them know what we've learned, seeing what the new results that they found are. There's a couple of conferences that we go to where we end up seeing each other, and we can sort of shoot ideas back and forth.

Doug Dangler

That must be an interesting kind of conversation, when you've got people that are from such different kind of chemical and biochemical backgrounds coming together to talk about it. What is the way into the conversation, you say, okay, you work with cows,and I work in the lab, how does that play out when you're at a conference talking to somebody?

Hannah Shafaat 06:05

So it's a little, a little closer than the the cows themselves. Most of these people work on the isolated, the organisms, and they actually culture and ferment these just, either bacteria or archaea, culture them anaerobically in their labs. So they work on the actual bacteria, and try to, and get the proteins out of the bacteria to then study them. Whereas, we work more in the lab making new proteins and trying to study them. So it's, the people that I mostly talk with are still biochemists, but they work with very hard to work with organisms.

Doug Dangler

Okay. So tell me about a day for you in the lab, you get in in the morning, and you say, okay, this is what I'm going to do as a researcher at Ohio State.

Hannah Shafaat 06:50

So one of the really fun parts of the job is that every day seems to be very different, because our research spans from the biochemistry and molecular biology to physical chemistry and spectroscopy, and we even do some calculations, some days are very lab heavy and wet lab heavy, where you work with bacteria, we're purifying proteins out of those bacteria, we characterize the proteins sort of using some sort of standard protein chemistry. But then we also do a lot of spectroscopy, so I have a laser lab, where we shoot our proteins, basically, with a laser to see what the structures are. We also do a lot of electrochemistry, to see if we can turn our proteins on using just electrons. And then yeah, some days you end up studying and working up data and also doing calculations on the proteins themselves to try to figure out how they work.

Doug Dangler

When you have somebody come into your lab, what's the favorite piece of equipment you show them if they're not familiar with what you're doing? You say, we're doing a lot of cool stuff, but you've got to see this laser in action - what is the most fun for you to show other people?

H Hannah Shafaat 07:54

The coolest, the most unique piece of equipment that we have is a resonance Raman system that we've personally set up in the lab, and it's a very unique instrument. So, resonance Raman spectroscopy is a specific kind of spectroscopy that looks at vibrations of molecules. And it's what I did during my graduate work, but we've set up a unique resonance Raman system where we can actually change the wavelength. So by tuning a knob, we can actually change the wavelength that comes out of the laser, and then that gives us the ability to look at a lot of different types of systems. And so that's perhaps our coolest piece of instrumentation where then we couple that into, there's other instruments associated with that, the camera and the spectrograph. But the laser part of that is pretty fun.

Doug Dangler

About how long does it take to set something like that up? How much time did you have just saying, here's the idea of what we want to do with these, we want this tunable system between having that idea and actually getting it to work in the lab and doing what you want?

H Hannah Shafaat 08:53

It took us about six months from the time the laser was installed to getting it to be this functional system, where we could actually collect the spectra that we wanted to collect. And I worked pretty closely with a student that I had at the time, he's recently graduated, and he and I set that up basically together.

Doug Dangler

When you finally got it to do what you wanted, and you saw that it was working, what was your reaction? I'm curious in the lab, like, do you scream eureka? Do you run down the hallways? What is your reaction, is it just a quiet smile and you go on?

H Hannah Shafaat 09:28

No, it's very cool. It was so exciting when we had our first spectrum. And, I guess my reaction was to get everyone else in and say, look, look, we can actually see something, it works! And that's, the excitement with us is really being able to, I have a great group of students working together as a team and to be able to show them that the instrumentation works, and we haven't just been drawing things out on paper and whiteboards forever and then also that we can now use this to do some really cool characterization.

Doug Dangler

Then, when you go to conferences and talk about this, how do other people react to it? Do they say, I'd like to see the schematics to it? Do you get to share that kind of stuff with it? How do you give that kind of information to other people in the field?

H Hannah Shafaat 10:08

So depending on the audience, I often like to show a schematic of it in my talks, because it is kind of a unique system and then explain why we went through all this trouble to create the system because it's a little bit more finicky than a normal resonance Raman instrument. But there's a lot of good reasons for having it, and so I typically like to show the schematic and then with true laser people and resonance Raman people, I talk a little bit more about what we did and why we made the decisions that we made for selecting this particular laser system.

Doug Dangler

When you go back to say, family reunions, or you meet up with people from high school, how do you explain it to them, and what's their usual reaction when you say this is the cool stuff that I do?

H Hannah Shafaat 10:52

I normally take a broader approach when I go back and talk with friends from high school or, because I normally put it in the context of we're looking at alternative energy, we're trying to do alternative energy reactions, and we're trying to do it in the way that nature evolved originally to do these reactions. So, we're basically rebuilding and recreating these reactions within proteins.

Doug Dangler

What do you see as the future for the work that you're doing? What do you think, you know, given the stuff that you've done recently, five years down the line, what are you hoping to be the best case scenario for what you're working with?

H Hannah Shafaat 11:30

Well, five years isn't actually that long in the scientific scheme of things. But, I'm really hoping that we'll be able to make our CO2 reduction much more efficient. In addition to making it that we'll be able to make our CO_2 reduction much more efficient. In addition to making it selective, we need to make our enzymes go faster and lower over potential so, more efficiency. And then also really, the dream is to have a system where we've combined the two and we're able to do that complete reaction, CO_2 conversion, all the way up to a liquid fuel in one system.

Doug Dangler

Okay, how did you get into science? What's your superhero origin story? Before you came here, you've done a lot of amazing work with these other institutes and then you came to Ohio State and have been very successful, but what led you into that?

H Hannah Shafaat 12:14

So I've been interested in science and math basically my whole life, and my dad's an engineer and he really instilled that interest in us, both me and my brother, my brother and I, are scientists or chemists, in fact. And so, from a young age, I was building things with erector sets, and doing mousetrap car competitions, and, and all of that, and then in high school, I was able to, essentially take an independent study advanced math and physics course. And that allowed us to develop things on our own and, and write about a project. And I think that's what got me into college, where I really started getting into research, actually, in my freshman year. And that's when I knew when I started getting in a lab and working in that research setting. That's when I knew I really wanted to do this.

Doug Dangler

What was it about the research setting that was so exciting when you were there? What were some of the things that you thought, this is what I like to do, and I don't think I can do it anywhere else but in in the science lab?

H Hannah Shafaat 13:12

There's a couple of things. One is the idea that you're doing something that's never before been done. So you don't know if it's going to work, and if it works, the reason it works is because you figured out how to make it work. So you're answering these questions that have never before been answered, that, to me is just so exciting. And the ability to do the kinds of, the flexibility, I wanted to be a PI to have the flexibility to pursue the kinds of chemistry that I was interested in or became interested in. As things change, you get interested in different topics, or maybe a project goes a different direction than you thought, and having the flexibility to do that is what was really attractive about academia.

Doug Dangler

So what would you say to kids that are thinking about going into sciences? And sometimes they think, man, it's really hard to do, am I as smart as a professor at The Ohio State University, can I get into it? How would you tell them to think about getting into sciences?

Hannah Shafaat 14:06

I think the sooner you can get involved at some level, whatever degree is accessible, the sooner you can get involved in, in science or in research or just interacting and seeing what it's like, the better. So there are a lot of opportunities for high schoolers to get involved in research during the summer. We actually have a couple of high schoolers every year come into our lab, and there's a lot of labs will open their doors to high schoolers to get involved. But really the, the sooner you can see firsthand what it is like, I think that's the best way to figure out if that's really the right direction for you.

Doug Dangler

When the high schoolers come into your lab, what kind of things do they get to do? Do they get to turn the knob for you know, finding that band that you're interested in with spectroscopy? What do what are the cool things that they get to do? No, they don't get to turn that off?

Hannah Shafaat 14:55

They I mean, they can turn the knob if that's the direction that their project is going, but typically, the high schoolers work closely with either a graduate student or a postdoc. And then we have a subset of the project that's, that they do. And so they learn how, they learn how to grow protein, and do the biochemistry and all of that. And then they learn how to do something with that protein. And so, the high schoolers in the past have worked on our hydrogenase mimic where they're able to actually make the hydrogenase mimic, which makes hydrogen gas actually, and characterize it and see how it works. And so, it's usually a project that's their own project, but within the purview of either a graduate student or a postdoc.

Doug Dangler

Tell me about some of the changes you've seen in your high school students or your grad students, when you're working with them to see maybe some growth. I'm curious about somebody that's working as a PI, you get to watch somebody grow, change over a number of years, and what that's like for you.

Hannah Shafaat 15:50

That's a lot of fun. It's been, I've had my my first graduate students now, this is the end of their fifth year, and it's been a lot of fun seeing them sort of grow and change and develop chemical intuition and develop their own ideas. It's, I really enjoy when they come to me with their own ideas that they've found from reading some other paper that's related and they think they want to try this with their system and is it going to work and it's great to let them pursue some of their own ideas that are related. That part is a lot of fun.

Doug Dangler

So, Dr. Hannah Shafaat, thank you very much for talking. And where can people go for a little bit more information about your work in your lab?

Hannah Shafaat 16:25

Thank you! So our research website is actually linked directly from the OSU Department of Chemistry and Biochemistry webpage. You can find my profile there and then our own specific research page will pop up.

Doug Dangler

Okay, well thank you very much and Go Bucks.

Hannah Shafaat 16:46

Go Bucks.

Eva Dale 16:47

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