

NASA-JPL-AUDIO-CORE

Moderator: Heather Doyle

August 9, 2017

Heather Doyle: Thank you so much, Operator. Welcome everyone. I'm Heather Doyle from the Solar System Ambassadors Program. Welcome to our Astrobio telecon about extreme life detection on Earth. And we're very luck to hear from Dr. Goordial. She actually graduated from University of Toronto in Biology. Me, too. Not from Toronto, but biology.

She has her Masters in Ecology and Evolutionary Biology also from the University of Toronto and her PhD from McGill University from the Department of Natural Resource Sciences.

So I've looked at the slides and it looks like a really great topic and I'm very excited to hear so I'll turn it directly over now to Jackie. But please- one last final reminder to mute your phone. If you don't know how to do it, you can press *6 and that will mute it. And also, don't put us on hold because sometimes hold music plays. So that will disrupt the talk as well. So, take it away, Jackie.

Jackie Goordial: Okay. Hi, everyone. So thank you for that introduction, Heather. Today I'm going to be talking about some projects that I'm working on currently that deal with looking at analogue environments on Earth to look at how we detect life in some of these analogue environments.

So if you go to slide two now, so what are analogue environments and why do we use them? Well, one of the reasons that we look at extreme environments on Earth is to look for the universal requirements for life as we know it. We only know that there's life on Earth, so this is kind of our testing grounds.

And we use this to constrain where life could exist on possible other extraterrestrial habitats.

So by examining the empirical and the theoretical limits to life on Earth, it's possible for us to narrow down the search elsewhere in our universe to look for places that could be inhabited now or where life could have been inhabiting sometime in the past. And some of this work happens in the laboratory and you can manipulate conditions. But others are other places on Earth that share characteristics of present or past conditions on other planetary bodies.

Planetary missions are very expensive and sometimes very technically challenging. And so using these analogue environments on Earth, in addition to letting us know where life can and cannot survive, also allows a good testing bed for us to look at the methodologies for how we can look for life on these other planets. And, you know, if a tool isn't good enough on Earth, it's probably not going to be a good tool on Mars.

And to kind of illustrate that idea, we can think about microbiology and how the advent of molecular tools and being able to extract the DNA from environments has really significantly allowed us to identify where life exists. In fact there are some places on Earth such as the Atacama Desert in Chile where people thought that life wasn't existing, that these soils were sterile. And now because of the advent of new methodologies, we know that that isn't the case.

What are we looking for when we say we're looking for life? Well, we're looking for biomarkers. And biomarkers or also called biosignatures are basically traces that life leaves behind. So it's really any characteristic -- elements, a molecule, a substance, maybe a morphological feature or isotopic

signatures -- anything that can be used as evidence of past life or present life and that's distinct from processes that could have been made abiotically. So I'm going to go to slide 3 now.

And so when we're talking about life on other planets, we're really talking about two different types of life -- we're talking about either extinct life or we're talking about extant life. And extant life is life that's currently existing. Maybe it's in a state of dormancy. Maybe it's alive and active. But it's present. And this idea of being alive is a lot more complex than it sounds. You know, we have a pretty intuitive idea of what organisms on Earth are alive, but it's actually not that easy to tell when we're using some of the methodologies that we use on other planetary bodies.

And so, for example when we think about Frankenstein's monster and the flick of a switch that made this kind of a shell of a being into an alive organism, how did he do that? How do we distinguish between this dead Frankenstein's monster and this alive Frankenstein's monster? And so let's go to slide 4, please.

Some microbiologists have some tools that we can use to get at these questions. Some of you may be familiar with the central dogma of molecular biology. It's basically a sequential passage of information from your genetics, from the DNA, to proteins which make up a lot of the cellular components in cells. And we can use these kind of markers, these biosensors, DNA, proteins, RNA that acts as a sensor between DNA and protein. And we can use these individual components as signals that A) there is life present but maybe it's alive.

So if I as a microbiologist were to go into an environmental sample, there's some things that I could look for that would very clearly be alive to me. So

one thing would be if I saw cells dividing or growing, that's a clear sign to me that this is something that's alive. Maybe I could measure respiration. Maybe my cells are breathing, breathing oxygen and exhaling CO₂ like we do. There's a disequilibrium there that's measurable. That would be another clear indication that something's alive.

Like I said, RNA is the messenger between DNA and proteins. And we know now in the environment that RNA is very short-lived. So when you find RNA, it's a pretty good indication that something active is happening in your sample.

But, just the presence of DNA or proteins don't necessarily mean that something is alive. And so when we look at things like preserved cells, when we look at permafrost, for example, which is a very, subzero, permanently below zero degrees Celsius frozen soil sample, sometimes we'll find cells. That doesn't necessarily mean that those cells are alive. When I want to preserve cells in the lab, I throw them into the freezer and permafrost is very similar to that.

So just finding cells doesn't mean that that cell is alive. And similarly, just finding DNA isn't an indication of life -- though it is a good biomarker that life is present, whether or not it's still alive or not. Slide 5, please.

So today I'm going to talk to you about two projects in analogue environments and I'm going to talk about how we look for live -- active life and biomarker life -- in situ using equipment that we can take into the field with us that's portable, that's lightweight, that has low energy requirements. And these have very clear applications to potential astrobiology missions.

So what we're doing here is we're testing inner analogue environments on Earth -- methods that we hope could be used in a useful manner elsewhere on other planetary bodies.

And the first work I'm going to talk to you today about is in permafrost located in the Canadian High Arctic. Slide 6, please.

So to give you just a quick view of where we're about to go, we're going to Expedition Fjord It's sort of 80 degrees north in the Canadian High Arctic. You can see Montreal is down there. That's where I was located when I was doing this work. And it's basically a straight shot north.

It was really fun. So slide 7, please. So the Canadian High Arctic has a lot of different sites that are considered very good analogues to Mars. Today, I'm only going to be talking about ice wedges and permafrost and go into details about that. But there's several different analogue types in the Canadian Arctic.

And so if you look at these on the left-hand side, those two photos, you'll see this sort of polygonal terrain. This is a view from the helicopter on the top and then a view from the ground on the bottom. And in this polygonal terrain, there's sort of depressions in the ground. And these depressions are indicative of underlying ground ice deposits in the form of ice wedges.

And these are one of a very common and obvious comparison to make to the terrain on Mars, which are some photos on the right-hand side. So on the top you see some images from the South Pole and on the bottom from the Phoenix Landscape. And there's some very similar geometric patterns created on these landforms and they possibly are also due to ground ice. So let's go to slide 8 please.

And so we went to the Canadian High Arctic and on this permafrost polygonal terrain that we think are very similar to Mars, we decided to test something called our MICRO life detection platform. And we were both looking for, you know, possibly extinct life, but we were also looking for extant life. We were looking to not only measure the presence of life, but also try to detect if it was alive.

And we used a couple different tools, and I'll go through all of these tools in a little bit more detail. But this is an overview of the system that we used for basic life detection -- we chose to use DNA as a biomarker. And for that we used a pretty new technology called the Oxford Nanopore MinION. This is a portable DNA sequencer. It fits into your pocket. It's actually smaller than my iPhone that I'm talking to you on right now. It's a very neat device and I'll talk a little bit more about that.

But we also wanted to look at viable life, growing life. And so for that we used two different things -- one was a microbial activity assay. In this case, we were able to spot colored wells whenever we could detect an active microorganism. And we also tried to culture and isolate some microorganisms. And that idea is again this idea that if we can detect growth, then we can be pretty certain that it's alive.

And then we used those two methods of detecting alive microorganisms. And because we had the portable DNA sequencer, we were able to extract DNA from these samples and learn about their genetics and get information from their genetics.

All of these tools are preexisting. They're very lightweight. Some of these are tools that were developed for environmental microbiology and have been used

for a number of years and now we're just starting to look at how they could be used for astrobiology. So slide 9, please.

So this is a picture of us using the Oxford Nanopore MinION in the field. So here I have it just hooked up to my laptop. On my laptop I can in real-time see the genetic information of the sample that I'm sequencing. It's hard to make out the actual sequencer in this picture but it's shown there at the bottom. And it's like as you can see the power requirement is pretty low. It just plugs into the USB port on your computer. It's highly portable. If you could go to slide 10.

And some people may have a GIF that's showing an animation and some people may have a PDF. But this image is to illustrate what exactly is driving the technology behind this new sequencer. It's a very new technology.

Basically, what it consists of is a bunch of tiny nano-sized pore forming proteins and what they do is you have your strand of DNA goes through that tiny pore sized protein base by base and it reads as it goes through there's an electrical current that's being passed through the pore.

And every time a nucleic acid base goes through that electrical current, there's a drop in the current. And each of those drops in the current has a signature. There are four nucleic bases. Each one has a different signature. And so you can sequence your DNA and find out what exact bases you have based on those drops in current.

What's interesting about this idea and this means of sequencing is that right now we use it for DNA but it's conceivable and it's being shown in the lab with synthetic nucleic acids -- nucleic acids that don't really exist that we've kind of made up -- but they also have signature drops in their current.

And so if we were able to take this type of technology to another planet, what we hope is that even if it's something that we haven't seen before, if it was going through this pore that maybe we could be able to still detect patterns due to drops in current as molecules go through these pores. It's very exciting technology. This is fairly new but it's in the news a lot and it's definitely something to keep your eye on. I'm personally very excited about it. So slide 11.

So we took this out to the field in the Canadian High Arctic and what you have to do for this type of sequencer, you have to extract through DNA first. And for is, there is no automatic DNA extractor yet that really exists.

So we had to do this all by hand. It's fairly involved to prepare that DNA for sequencing. You have to clean it up, make sure there's nothing that's inhibitory to the sequencing process in it. And then you put it in your machine.

And when we go to places like the Arctic, we don't really have reliable internet access. It's very sporadic. We had satellite internet, but on a cloudy day it wouldn't work. Sometimes someone would have to take the Ski-Doo out and manually move around the satellite dish to try and get it to work.

And so this actually quite accidentally mimicked a fake astrobiology mission. We were trying to do a sequence in the field, send that data via the internet to another computer to get a computer to analyze that data, tell us what nucleic acid we had, give us that genetic information, and then we wanted to download it back to ourselves, downlink that data back to us and analyze.

At the time, when we did this in 2016, the capabilities with the technology -- again, this is a pretty new technology -- the capabilities to take that genetic information and immediately identify which microorganisms are in your sample, that didn't exist then. But since then, those technologies have been developed and those capabilities have been developed.

So conceivably if we were to do this this year again, we would be able to go to the Arctic, sequence our sample, and then right away find out we have a bunch of e coli, we have a bunch of X, Y, and Z species within our sample. As a microbiologist, this makes me very excited. I'm very excited about this technology. Slide 12, please.

So this is the data that we got back from our soil sample. So we were able to obtain the data in the Arctic but when we came back that's when I started analyzing this data and really finding out what was in our sample. And one of the first things I did was I looked for what domains of life are in my sample. And I found that using this technology, we were able to detect all of the domains of life.

So this technology was good enough to detect even viruses. There was a very small amount of viruses in our sample, but it was sensitive enough to pick up viruses and discern them away from bacteria, eukaryotes, and archaea.

Because we were getting large, massive amounts of genetic information from this, we were also able to find out what genes were present in our samples. And so from those genes, I can assign function. And so these are very small, that's a very colorful pie chart on the bottom. And this gives you a little bit of a taste of what different functions were present in the sample So there were genes involved with protein metabolism. There were genes involved with stress response.

And so we can compare this genetic information that we were finding in our samples with genetic information in the databases and we can start to assign function to them. Very interesting for us. So slide 13 please.

And so that was all well and good, but just getting at the genetic information gives us an idea of the potential things that could be going on in the environment, but doesn't actually tell us that it is going on. Like I said, permafrost is basically a frozen environment. It's very much like a freezer. It just tells us that there's DNA there. It doesn't tell us if it's alive.

So we decided to use this microbial activity assay as a means of visually and rapidly being able to see if cells are alive. And so, for here all we did was we took our permafrost soils, we shook it up with some water, and then we put our water samples into each well of this 96 well plate.

So what you're looking at here is each different well has a different carbon substrate in it. And if there's a microorganism that's capable of eating that substrate, there's a chemical reaction that happens that turns that well purple as a byproduct of respiration. And so very quickly, over the matter of one day -- 24 hours -- we can look at our wells and I can say there's a microorganism in this sample -- or several microorganisms in these samples -- that are capable of eating glucose, et cetera, et cetera.

And so this is pretty easy to do. It's again very lightweight. This requires again very little power. And it's visual and it's fast. So this is a potentially very powerful tool that could be used on future missions. We know that very similar types of chemistry are being used for activity assays, such as the BioSentinel mission. In this, the BioSentinel mission is the pink cell on the bottom. It's a very similar chemistry.

And in this case, they have inoculated all of their wells with a yeast and they're testing the effects of radiation on yeast cells as they are in space. And so, what they're looking for is to make sure that their yeast are causing the colored wells because of the yeast die they won't form a color forming well. And so it's almost like the opposite of what we were trying to do. They're trying to test if something's dying. We were trying to test if something's living. So if we can go to slide 14, please.

And so this is again some more genetic information. So we look three purple wells -- we did everything in triplicate -- three purple wells that contains the amino acid L-serine. I chose this because it's a very interesting thing in an environment when you have a microorganism that can eat an amino acid. That means usually those types of organisms are scavengers. They tend to be very stress tolerant. And so I was interested in finding out what could be living in this, what could be eating this amino acid in the permafrost.

And so I took the wells and I extracted the DNA from them and then using the MinION in the field -- all this work was done in the field -- using the MinION I sequenced those wells. And so what you're seeing here in these bar charts are the microorganisms that were found in those wells. And as you can see, it's mostly composed of one single organism. So that's a pseudomonas species. And so that pseudomonas, it looked like was very happy in the L-serine.

And for me as a microbiologist, now I can start to focus in on that pseudomonas and try to understand why that pseudomonas was capable of eating L-serine. Okay. And so can we go to slide 15, please.

The third kind of life detection system that we were looking at is something called the CRYO-ichip. And this again is a very lightweight, fairly low-tech device. It again consists of 96 wells. And the goal here is to try to culture microorganisms.

And so culturing microorganisms is actually very difficult to do in the environment. There's over 99% of microorganisms in any given sample are simply not culturable. We haven't figured out a way to do it, which means that we're really missing out on most of the microorganisms in any environmental sample. And some new technologies have been developed over recent years, and one of those technologies is the ichip.

And what the ichip does is it has a diffusible substrate in it. So if you look inside of these wells, you can kind of see a clear gel-like substance. That's something similar to agar. It's a gelling gum. And there's no added nutrient sources here whatsoever. We don't add a carbon substrate. We don't add any nutrients. We just add a solid matrix. And we incubate this chip in the field. And the idea is that we're letting the nutrients from the field diffuse into our solid substrate. And we have a micron filter over that so that microorganisms from the environment do not diffuse in. only nutrients can diffuse in.

And we inoculate the top with our environmental sample and we wait. Sometimes it takes about a week. Sometimes it takes a year. So when we went last year, we left some of these in and this year we will go keep coming back to see if we've been able to retrieve or isolate any new microorganisms.

And hopefully you can make it out on your images. Online it's a little bit hard to see but inside of each of these wells, there's a circle. And those are colonies of microorganisms. And we're hoping that these are new strains that no one has cultured ever before because we're using these novel technologies.

As a microbiologist, I'm really interested in culturing new strains because these are a potential source of new enzymes, new genetic information that we haven't had access to before. The ichip, for example, isolated a recent microorganism that was the first in 25 years that was capable of producing a new class of antibiotics. So this method is really proving useful in the discovery of new substances that can be useful for humans, but also just for isolating new microorganisms. And hopefully could be useful for isolating organisms on other planets.

So if we go to slide 16, there's a close-up of one of those wells that's being removed from the chip. And you can see single colonies on there. From these plates, when we went in the field, we were able to get 106 isolates -- which is a lot. And about 70% of these we were able to culture again afterwards. We were able to kind of take them off of this unconventional media and then put them on more conventional media and they grew successfully.

But the other 30% we just could not get them to grow at all after this. So we isolated them the first time using this method, but we weren't able to subsequently keep them going. And those are the strains that we're really interested in. And those are the ones that we're trying to sequence to learn more about their genetic information and try to understand what we could be doing differently to be culturing them.

And so if you go slide 17, one of those isolates that was of interest, is a new strain we sequenced with the MinION. And we didn't get the full genome of it. We got about two million base pairs and the closest *Pedobacter* genome is five million. So we don't have the whole genome of this strain, but we have tons of genetic information about this.

So we were able to identify 800 genes inside of its genome. But there's over 6,000 hypothetical proteins here that we have no idea what they're actually doing. And so using these methodologies are really helping us understand things about life here on Earth that we don't really know yet. Slide 18, please.

But what about the microorganisms that we can't culture? How do we know that they're alive? Those two methodologies for testing active life -- both the microbial activity assay that has colored wells and the CRYO-iplate of culturing microorganisms -- both of those means require the growth and replication of microbial cells in our assays. But what do we do if we're not able to get ourselves to growing culture? What do we do then? So slide 19.

And so for that, I'll take you into some of the work that I'm currently doing here at Bigelow Labs for ocean sciences, which is located in Maine. I'll show you some preliminary data. We're pretty early on in this project but it's very exciting stuff. And here I'm going to be taking you to Atlantis Massif, which is in the middle of the ocean. It's in the mid-Atlantic ridge where the lost city hydrothermal field is. So hopefully you can see that arrow. And these are samples that were drilled in December of 2015 on a three-month cruise. And so slide 20, please.

So the Atlantis Massif is basically a huge underwater mountain range. So here you can see this. It ranges from about 800 meters below the sea floor to about 5,000 meters in the fracture zone. And what they did on this cruise was very interesting. It was the first time that seabed floor drills could ever be used. So they weren't able to drill from the ship. They actually dropped the drills onto the sea floor and then the drills were able to drill into the ocean crust and then they retrieved cores from there.

And so what we're talking about is drilling into the ocean crust, drilling into rock at the bottom of the ocean beneath all of the water, beneath all of the sediment.

And if we go to slide 21, and one of the reasons we were interested in the rock and why we're interested in the rock is that there are certain types of water rock interactions that can create food for microorganisms. This is a process called serpentinization. Serpentinization is very interesting for a number of reasons. One of it's that it generates a little bit of heat, but most importantly it generates methane and it generates hydrogen.

And so here's an example of some serpentinite from Atlantis Massif if you want to get an idea of what the rocks underneath the bottom of the ocean look like. And so what we were looking for was within these rocks, can these rocks support life? We know that there is potentially food there, but we don't know if there's any active microorganisms. We have an idea that microorganisms are probably present, but do they form an ecosystem? Are they actually doing anything in these rocks? Slide 22, please.

And this serpentinization is really fascinating for a number of reasons. But when you look at in the astrobiology context, it's been in the news in the context of Enceladus, which is a moon of Saturn. So this Saturnian moon has an ice-covered ocean with plumes. And these plumes we're finding are containing the chemical signatures of water rock interactions, in the rock kind of oceanic crust that look to be very similar to what we see on Earth in...

Heather Doyle: Okay everyone. We're going to see if this workaround is going to work. Jackie's going to speak through my phone, because the Operator was trying to call her but her phone doesn't have any service. So she has Facetimed me. So

Jackie, if you want to say something and then everyone let us know if you can hear her.

Jackie Goordial: Hey, can you guys hear me with this really wacky workaround?

Woman: Yes, we can.

Heather Doyle: So yes, they can hear you.

Jackie Goordial: Amazing. Okay.

Woman: Sounds good.

Jackie Goordial: Well, there's 15 minutes left and I'm sure you guys have some questions based on the stuff I already presented. So I'm going to maybe just present one more slide. So let's just skip over to slide 25 really quickly. I'll give you a snapshot of the work that I'm doing right now and then let's take some questions, try to shake off the technical difficulties that I'm having.

So here on slide 25 like I said I'm trying to get active cells but without a culturing them. So what I'm doing is extracting those cells away from the rock. This consists of kind of shaking them off really gently, trying to get them to unattach from the rocks. And then I'm using a methodology called BONCAT -- which you can see in slides 23 and 24 -- but briefly what they consist of is feeding your samples a fake amino acid that in cells that are actively making new proteins, they will incorporate by accident this fake amino acid into their proteins.

This fake amino acid will fluoresce if you do a certain type of chemistry on it. And we can start to use some of the new technologies that go down to the

single cell to sort only those cells that are fluorescing away from the rest of the cells. So this is in the diagram on slide 25. We use a flow cytometer. Basically, it will shoot a laser at each individual cell. Each cell goes through this line one by one. It shoots a laser at it and if it fluoresces, it puts it in the fluorescent pile. And if it doesn't it puts it in the other pile.

And I can take that pile of cells that I know are active because they're fluorescing -- they've incorporated this fake amino acid -- and I can start to probe questions like which microorganisms are in here? What adaptations do they have that are allowing them to live in the crust at the bottom of the sea floor?

Like I said, this project is pretty new. We're only in the beginnings of getting our results. But I will share with you that we are finding life in these serpentinizing rocks at the bottom of the sea floor. They're very low diversity. They're very low biomass, but they are indeed active. And they're very different than the community, like the entire community.

And so what we're learning from this kind of methodology is that yes, there are microbial cells there but only a small amount of those microbial cells are actually doing anything or seem to be active under current in situ conditions.

So if we go to slide 26 -- the conclusions -- so here I just want to wrap things up and say most of the methodology here presented here are preexisting. You know, we didn't really reinvent the wheel. But some of them are very new. This flow cytometry method is fairly new. The Oxford MinION is very new. But these are pretty lightweight and they have low energy requirements. So these are really good candidates for astrobiology missions.

The MinION in particular is a very exciting tool and it can be integrated with other microbiology based assays for life detection. But one of the major drawbacks with this is that we need to figure out automated systems. And this isn't as easy as it sounds. Something as simple as DNA extraction isn't universal. There are different types of extractions that work on different types of samples. There is no one type of DNA extraction that works on all types of samples.

So when we think about how to automate things like this, these are the types of problems we need to think about. And of course, low biomass samples are a huge obstacle. I personally think that future missions should be looking for extant life -- life that's alive, but even signs of past life would be very exciting. But I feel, and there's a number of us that feel, that there really is a need for a direct and unambiguous life detection instrumentation in addition to biosignature instrumentation.

And with that, I'll take any questions. So yes, thank you. Thanks. The funding bodies who've helped fund this work are on slide 27. And I would especially like to acknowledge Dr. Lyle Whyte at McGill University in Montreal, Canada and Dr. Beth Orcutt at Bigelow Labs for Ocean Sciences here in Maine. Thank you.

Ed Mahony: Aloha. Ed Mahony from Maui, Solar System Ambassador. There's a meteorite -- Zagami Katsina from Nigeria that is evidenced from Mars, that it came from the planet Mars. It's a Shergottite, Eucrite, and a Chondrite meteorite. Would a sample of that be something that the doctor could research and study and see if there's anything in it?

Jackie Goordial: You're talking about the, I can never remember the numbers, but the infamous biosignature, one that's very controversial. We could. We could use some of

these techniques, although I think that there are perhaps more robust and technically more precise genetic tools that could be used to look for life.

So the MinION for example is very handy because it is portable. That's one of its strengths. And it seems to be fairly accurate. But it really doesn't have anything on - like it really compared to the tools that we're using in the laboratory, it's just not at that caliber yet.

Earl Kyle: Yes, I have a question. This is Earl Kyle, Solar System Ambassador in Rochester, Minnesota. What's the wavelength of the laser that was show in slide 25?

Jackie Goordial: Twenty-five. That's interesting. So we can set different wavelengths. So depending on the dye that we're using, we will target different wavelengths. So if we have one that's in the 400 range. You know, we can de-laser these ones fluoresce at their excitation is at 488. We have some in the 600s as well. So it's really something that you can change and adapt to your experiment.

Adrienne Provenzano: Sure. Okay so this is Adrienne Provenzano, a Solar System Ambassador, and I had two questions. One, you used the term "communities" a lot. I wanted to know a little bit more of what that means in the microbiology context. And then the other thing is I wanted to know if any of this instrumentation is being currently tested on the International Space Station or testing in a microgravity environment is something that would help your work.

Jackie Goordial: Sure. Okay. So I'll address the first one first. So this idea of communities, so most of our environmental systems are not monocultures of microorganisms. They're communities that are composed of multiple different individuals and species. So much in the same way that, you know, when you go out into a

forest you have different types of shrubs and trees existing, the same thing happens with the microorganisms. In any given soil sample or water sample, you have tons of different microorganisms. There are multiple different species in there and they're all interacting with each other. And so that's what I mean by community.

So it's very rare when you'll have only one organism that kind of takes off on you. And when that happens, it's usually because there is something that that particular organism can do that is allowing it to outcompete all of the rest of the community around it. That's something that happens for example in infections and things like that.

And your second question about the International Space Station, if we go back to slide eight, so Oxford MinION is on the International Space Station. We have sequenced DNA in space. So that's there already. That's very exciting.

This is, you know, potentially useful for things like let's say your astronauts are there and maybe they're catching a cold. Maybe there's some sort of illness that might be happening. If you have a portable DNA sequencer on the International Space Station, you could potentially sequence your microorganism and identify what organism is making someone sick. Is this a potentially serious thing? Is this taking over? So that's already there being used right now.

And the Microbial activity assay, that is also something that in a different form, that yeast experiment I was describing, is also being tested in orbit around microgravity. And so that's also being tested.

I think right now, we're still in a pretty developmental phase with some of these experiments, but it certainly would be good to test them in microgravity

and in other analog environments. So for example to be more specific, when we look at this Oxford Nanopore MinION, I was describing the pores that make up how it sequences. Well, those protein pores are very susceptible to things like freezing or mechanical destruction. And so you can kind of envision how maybe on a long space that that's not an appropriate medium for an astrobiology mission.

And so there are researchers now that are trying to make nonprotein-based but nanopore sized molecules out of things like graphene. And so these are technologies that are currently being developed. They aren't out yet, but things like that will benefit from being tested in things like microgravity. Fluids will move differently under these conditions, and those things remain to be tested.

Adrienne Provenzano: Great, thank you. I knew that the DNA had been sequenced on the station, but I didn't realize it was the same equipment. So that's interesting...

Jackie Goordial: Yes.

Adrienne Provenzano: That's great. Thank you.

Jackie Goordial: Yes. All right.

Heather Doyle: All right. Well I remember in college -- it was not that long ago, maybe just over ten years ago -- that the DNA sequencers were the size of a refrigerator. So this is pretty fascinating for me. But because of technical difficulties, I guess I'll say that that will be the last question that we'll take. But please do email me any other further questions at HDoyle@jpl.nasa.gov and I'm happy to forward them on if Jackie's okay with that.

Jackie Goordial: Yes, please send me all of your questions. I will be very happy to answer them. Again, I apologize for these technical difficulties.

Heather Doyle: Well thank you so much for your time. And our next telecon is going to be tomorrow at 1:00. And it's called Taking Earth's Temperature. So I hope to hear you all then. Thank you so much and sorry also for the technical difficulties, but this was a great talk, Jackie. Thank you for taking the time to speak with us.

Jackie Goordial: All right. Thank you.

END