Transcript

Julia Macpherson (JM): Welcome to Arctic Minded. I'm your host, Julia Macpherson, and today's episode of Arctic Minded is called *Microbes: What are they and what can they do?* with special guest Dr Srijak Bhatnagar. Arctic Minded is produced by ArcticNet, a Network of Centres of Excellence of Canada that brings together scientists, engineers and other professionals in the human health, natural and social sciences with partners from Inuit organizations, northern communities, federal and provincial agencies, as well as the private sector, to study the impacts of climate and socio-economic change in the Canadian North. From coast to coast to coast, we recognize that our work reaches across the ancestral and unceded territories of all the Inuit, Métis and First Nations people that call these lands home and who have been protectors of and share connections with these lands since time immemorial. Our guest today, Srijak, is an assistant professor of microbial ecology and computational biology at Athabasca University. His expertise in interpreting DNA sequencing data allows him to study microbes in various environments, including the Arctic Ocean. His research program focuses on studying ecosystems from a microbial perspective and leveraging microbes for a sustainable environment, with an emphasis on monitoring and remediation. He has been working on generating microbial baseline data to map the microbial biogeography of Canada's Arctic Ocean and the microbial response to Arctic oil spills. Since his first introduction to microbes during high school in India, he has found his passion in studying these invisible unsung heroes and becoming a microbe superfan. Aside from research, he is also a passionate science communicator and works with the Arctic Institute of North America to increase the awareness and uptake of DNA based knowledge and Arctic policy and decision making. Hi Srijak! Welcome to Arctic Minded. So excited to have you here today.

Srijak Bhatnagar (SB): I'm excited to be here and thank you for this opportunity and letting me talk about things that I'm passionate about.

JM: Yeah. Well, that's the whole point of the podcast. So, we're excited to have somebody who is passionate and enthusiastic here to share a little bit about your work, which focuses on microbes. So, can you tell us a little bit about microbes and what sparked your interest in studying microbiology?

SB: So, microbes are these invisible life forms that are all around us, and they are everywhere. And yet we've only started to scratch on the surface of who they are and what they can do and they are invisible superheroes. They are the underdogs. A lot of things they do go unnoticed cause it's just happening and we don't see them, so we don't think about them. And that's when I got to learn about microbes and so many cool things they do, they got me very interested in studying microbiology and looking at microbes cause the historical baggage is that we think about microbes or bacteria as those that cause diseases, but there's so much more to them than causing diseases. There are more species of microbes on planet Earth than there are animal and plant species combined.

JM: This stat that Srijak just mentioned was too crazy for me not to look up, so I did. According to the National Science Foundation, the Earth contains about 1 trillion species of microbes and only about one tenth of those have been identified.

SB: They live in such varied environments from ice to boiling waters, so hydrothermal vents. They live in the air, they are deep within the surface of the Earth. They are very hearty and they can survive so many extreme things and so many extreme environments. And they can essentially make a meal out of anything and everything. One of the cool facts about microbes is that they are the real lungs of the planet. Everyone thinks that Amazon, the Amazon rainforest, makes so much oxygen, but in reality, it's the microbes in the ocean, they're actually producing more oxygen than pretty much all the plants combined or all the trees combined on the land. And one of my favorite tidbits on how hearty the microbes are is before International Space Station, there used to be a Russian space station called Mir, and one of the reasons for it to be decommissioned is cause there was fungi, microbes, that made its way to the space station and it adapted to low gravity. It adapted to the extreme environment and it basically started growing in the space station on the windows, on their insulation, in their control panel, and started eating it up. So that actually led to an entire division in all space agencies, now called, effectively, Planetary Protection. Where not only we don't want any new life form, supposed life form, from outside coming into the planet, but at the same time, when we send out our Rovers to Moon or Mars or anywhere, we want to sanitize it so well so that we don't contaminate any new environment with the microbes from Earth. That shows that not only how hearty they are, but how adaptable they are.

JM: It's true. In 1988, aboard the Russian space station Mir, astronauts discovered fungi on their windows and air conditioners, even on control panels, and in their food and water supply. Rather than be fearful, scientists have taken advantage of the situation to study this fungi to figure out how they survived so effortlessly in a harsh environment such as outer space.

SB: So The Last of Us, again, cordyceps, it's a microbe. It's a fungi and it's actually a real thing. And it's such a cool fungi. And that actually was the inspiration behind The Last of Us because right now. It actually infects ants and what it does, it can actually control their brain and control their behavior. So it makes the ants then go climb up the tree, go underneath the leaf, hang from it and die, so then the cordyceps fungus then sprouts out of its body and then sprays its pores all over the forest, infecting other ants. So, it creates these zombie ants where once it infects them, it modifies their brain and their behavior and that was the biology behind The Last of Us.

JM: Yeah, that's so cool. It's almost like even though it's such a small organism that maybe people don't consider, it's actually like an evil mastermind in a sense that it's able to manipulate the things around it like that. That's crazy. You mentioned that we've only kind of started scratching the surface on what we know about microbes. And do you think that this is just because of the technology that's been available to us in the past? And do you think that with the new technology that we have now that will advance faster than it has?

SB: Short answer, yes. The first time microbes were ever seen through a microscope was like somewhere in the 1700s, and then we, as in humans, became aware that *ohh there are invisible life forms that live out there* and a lot of research started looking at them. And the traditional way of looking at microbes was to try to grow them in the lab and study them. And maybe only 50 years ago, the field completely transformed, when new technology, new methods came about looking at, or studying microbes, without actually looking at them under the microscope or without growing them. But actually using the DNA or RNA to study them so that you can identify what microbes there are, and that's how we came to know that only the last estimate was only about 1% of the microbes that actually exist are culturable, yet in the lab. So what we have been studying, it was like very little. And there have been leaps and bounds of progress in technology when it comes to DNA sequencing to then allow us to study more environments and more microbes. And when I say DNA sequencing, what I mean by that is DNA is the one thread that connects it all. It's a blueprint for us. Our DNA holds so much information. The same way it's for microbes. So, in an environment then you can actually go and try to read the DNA, which has its own language and what the DNA sequence it does, it reads the language of DNA and makes it available to us, and then we can try to interpret what that language is. We try to come up with tools, like Rosetta Stones for DNA, to try to interpret what the DNA is telling us. And what used to cost a lot of money, take a lot of time, and allowed us to only read a little bit of DNA, now, has changed into costing just a fraction of it, producing so much more data and doing it on an organism basis instead of looking at just one thing - to look at an entire environment so we can not only look at all the things that are in there, but everything they could be doing cause we have the DNA sequence and then go next step forward is what they are doing and how they're interacting with each other. Because at the end of it, microbes, as I mentioned, are everywhere. So, on your skin or on my skin they are doing something different. They are different microbes than what would be in the air, what would be in the water, what would be in the sea ice.

JM: You mentioned that the microbes living on my skin could be doing something different than those living on your skin. How are they able to detect their environment and how quickly can they adapt?

SB: The microbes that are on our skin have adapted already. They have evolved for surviving on our skin. In general, your and my skin is producing more or less the same chemicals. Those chemicals are signaled for these microbes. But skins can be different. Some skins can be oily, some skins could be dry, and that could also play a factor to what microbes are on the skin. But then also remember skin is a living thing. It's part of us. We have an immune system. So the microbes are interacting with that immune system as well. So it's a two-way collaboration of not only what our skin is producing that the microbes would like or would want to use, but also what they could provide for the skin. For example, they also provide a base level of immunity so that we don't have skin infections, right, because they've just occupied everything on our skin surface. But then there are gonna be subtle variation from a person to person on what their skin is. And that variation could lead to subtle variations in the microbes as well. So not just what kind of microbes are there, but how many of them are there, that's also variation that could happen. Ages ago, there was a paper had come out which actually had looked at the microbes on the fingertips. And they were able to use that information of which microbes and how many of them, to actually then start identifying that you had used the keyboard.

JM: So just like on our skin, you mentioned that there are microbes absolutely everywhere, even in some really interesting and remote places that have some environments that might be a little bit difficult to adapt to, such as the Arctic. So, can you go into how your work led you to working in the north?

SB: As you mentioned, the microbes are everywhere and that's what brought me to the Arctic. Cause a lot about Arctic Ocean is still unknown. We don't know what all different types of microbes live there. What are the different functions they could carry out, how they connect to each other or how do they connect to the animals and other living things in the ocean and more importantly, my focus of my work was also to then specifically look at microbes that may be able to help build. As I mentioned, there is probably a microbe out there who can eat a chemical, and there are microbes out there, we know from tropical oceans, that are able to eat or degrade parts of oil or crude oil. And as we know and as our audience know, that Arctic is warming rapidly and we are having more and more sea ice free area. So that means there is an increased shipping traffic that's happening, more and more ships are passing through the Arctic, which means that there is an increased risk of oil spills in the Arctic. So, my work started with wanting to understand what happens to the oil if it gets built in the Arctic Ocean. There's a lot of studies have been done in tropical oceans, especially around Gulf of Mexico because of Deepwater Horizon spill, but the microbes that live in Gulf of Mexico, that live in temperate waters, may not be suitable or may not actually live in the cold waters of the Arctic Ocean. So, I wanted to specifically study are there microbes in the Arctic who would respond to an oil spill? So your answer, yes, there will be, but more importantly, what are those microbes and how are they working? And one important part of preparing or responding for oil spills is to know what the environment looked like before the oil spill. That was a big gap in knowledge that came out from Deepwater Horizon, was then a remediation process is done. How do we know it's done? How do we know the environment went back to what it was pre spill? And that's called a baseline. And one could do baselines using animals in the Arctic like you know, how many different invertebrates are in one square meter of sediment floor or sea floor, or how type of fishes there are and what I was trying to do is hey all of that takes so much time. Why don't we use microbes to establish baselines? We can easily sample the water column and we can easily sample the sea floor and instead of looking at and counting specific species of animal, why don't we just look at all the microbes in there, because then it gives us a microbial baseline profile. What microbes and how many of them are there? And we do it over a couple of years, and that builds us a baseline. So, if or when there's an oil spill, that happens in the Arctic, and their remediation effort or process took place, then one could use our baseline data to identify did the ocean in this part actually went back to what it looked like before also? And so that was a big effort that we led to sample the Arctic Ocean of Canada. There have been microbial surveys done of Arctic Ocean. Unfortunately, there were only places in the Canada's Arctic Ocean where samples were taken, where we have an idea of what the microbes look like, but we have the largest coastline in the Arctic Ocean, which also means given our Arctic archipelago, there is a lot more possibilities of ship related incident. And a lot more variation in what the ocean chemistry or microbiology is like. So, what we did as part of this work is we went and sampled in three different parts of the ocean on the surface about 7 meters above the sea floor and the sea floor itself. And we sat and did that at over 50 or 60 different locations. From those locations, then we picked 40, for which we then generated large amounts of DNA data to establish what the microbes look like in Canada's Arctic ocean and on the surface, in the water column, and on the sea floor. And what that also allows for is now we have this large data set that could be mined for so many different questions we were looking for *Hey, are there any microbes that can potentially eat oil?* Cause you can look at the DNA, you can look at specific parts of DNA, portions of DNA called genes, to see whether they have that capability or not. But then another person could actually go and interrogate that data set, could actually use that data set to see what are the chances of metal mercury happening in this part of the ocean. Reason for that being methylation of mercury, or the more toxic form of mercury, is actually produced by microbes. That could actually move up in the food chain. Or one could go totally with a discovery point of view of like what are the different, what are new microbes out here? As I mentioned that tropical oceans being warmer would tend to have different microbes. Then how is our ocean, or how is Arctic Ocean, unique? How does it differ from Antarctic Ocean? Is it only because of temperature or there are other factors underlying this differences that could be observed, whether it's salinity or whether it's specific composition of specific minerals? And we also then got samples of sea ice because sea ice, even though looks like nothing should be alive in there, and guess what? There are microbes in there, and those microbes have either lived directly under the sea ice where they could use sunlight to then drive photosynthesis. Or they could live inside the sea ice and what's called channels. It's just a huge ecosystem level approach that we decided to take there.

JM: My question is, so you mentioned in temperate waters, there are species of microbes that live there that are able to degrade or eat this oil, in the case of an oil spill, and that in colder Arctic waters, there also exists likely a different population of microbes there too, that have those same capabilities. My question is, is the abundance of microbes existing in Arctic waters right now enough to, like, effectively degrade oil spills? Should one happen? Or like, what are the actual applications of this, if an oil spill happens in Arctic waters and we know that there are microbes that are there that are able to degrade? But how effective is the naturally occurring population of microbes at actually doing this?

SB: Yeah. So, the first thing to consider is, are there any microbes that could degrade oil? The short answer is yes, there are. And they look very different from those that are in the tropical ocean. Now one thing to consider here is normally, if there is no oil seep in the ocean, there isn't that much oil around. So, these microbes tend to be lot fewer in numbers, cause there's just not enough food for them, their food being oil. And what we did in the lab as part of experiments, is we took the Arctic sea water, we gave it crude oil, and because now there is food, those Couple of microbes, those handful of microbes, then started growing rapidly, cause now there is food. So, think of the fishes and the seals. So, seals eat the fishes. If there aren't that many fishes around, there will be very few seals barely able to survive and hang around. But if the fish population goes up, now, there's a lot more food for seals to eat, so their population will also go up. In this case of oil spill, the food is not living. It is oil and there isn't that much in the ocean. So, while they are around, there's a lot fewer of them. But as soon as an oil spill might happen, or how we did in the lab where we simulated the oil spill, then their population would bloom, because now there's a lot of food and that is a response to oil spill. That is a way of also detecting microbially detecting oil seeps in the ocean. And all of a sudden, in one place you see a lot of microbes that can eat oil, that means that there is a source of oil somewhere in there. So, this is how, in real life scenarios and also happen, microbes will respond to it, they will grow very rapidly and they will start eating the oil. Realistically, they won't eat all of the oil. Oil is a complex mixture of different chemicals. They prefer certain chemicals over other chemicals, but what we showed is that they are our allies in response to oil spill. They will work with us to clean up some of our mess. And we can encourage them, we can help them, if the policy allows. But even if we do nothing, they will respond to oil spills. So there have been oil spill offshore Newfoundland and Labrador, where the sea was so rough that no oil spell clean up effort could be done. What ended up happening, because the sea was so rough, the oil dissipated. And one of the reasons for that oil to actually go away from the water would be the microbes ate it and converted it into a different chemical, most likely into carbon dioxide, and it went out of the water. Here is an example, and knowing how remote and difficult Arctic ocean can be, it is important for us to know and acknowledge that microbes play a role in our oil spill response and they will pay an outsize role in remote areas and remote locations, where a human response to an all spell might be delayed for many reasons, whether it's remoteness or inclement weather, but the microbes are there and they are doing their thing. They are having a buffet cause we just dumped a whole bunch of food for them.

JM: So when you're saying that the microbes are able to degrade oil or eat the oil, what is that process like? Are they actually transforming it into a different chemical like you said? Because I'm just wondering about bioaccumulation, because I imagine that they're at the bottom of food chains for many different species. And I'm wondering if oil, like, there's a worry about it bioaccumulating and magnifying up a food chain, and what that would mean for, like, other predatory species or even the people living who fish and consume animals out of that water.

SB: Yes. So, bioaccumulation is a real risk around oil spill. A large part of that is because of filter feeders where contaminated seawater would pass through their bodies and oil could stick around. And then different components of oil could then become, they are fat soluble, they are oil, so they could then move up in the food chain. When it comes to microbes, they like certain portions, certain chemicals within the oil itself. They like certain fractions of oil. And there are two ways they could degrade it. They could degrade it all the way to turn it into carbon dioxide and releasing it into the air, either as a single microbe or as a community working together. Or they could modify it to be able to detoxify it, so the bacterial cells, the microbial cells, could survive around and those modification means that they have changed the chemical structure of the certain fractions of oil to make it less toxic for themselves. Now, what happens to those modified fractions? I'm not sure.

JM: So what are the some of the challenges that you have faced in this field of work?

SB: A lot of this work has been done on Amundsen, which is the Canadian Coast Guard ship. As part of ArcticNet, you would know and many of our listeners would know, Amundsen is actually a Coast Guard ship that does ice breaking in the Saint Lawrence River during winter time, and is only available during summer time. I cannot emphasize the outsized impact Amundsen has had on our work. It has allowed us to sample throughout the Arctic Ocean. It has allowed for us to sample different depths of Arctic Ocean. It has provided technology to do so many things. As I mentioned, it's only available during summer and it's only available during in a short time. So, one of the biggest challenges that many ocean-based researchers have is access. With Amundsen, there is a huge cost associated of trying to take a lab on to Amundsen, trying to ship a lab. I'm based in Calgary, so I have to ship... We have to ship pallets and pallets of stuff, pallets and pallets of equipment to Quebec City, to put it on the ship, we have to establish the lab and then we have to tear it down and move it again. This is akin to a nomadic lifestyle, where you move from place to place to place doing, earning your living, making or getting your food. Imagine if we had science ship that was also an ice breaker. What that would allow is it would simplify so much of the work, it would reduce so much of cost, so much of time expense where everything that's needed for research is already on the ship, is already there around the clock. And so that the ship then can allow for sampling around the year. Provided in the Arctic, some of the Arctic is not going to be navigable during the winter time, but that is not to say that the field season could be expanded to be much longer. A lot of our data set has come from a couple of months during the summer time when the Amundsen is available, but that means there's a resolution that's lacking during the winter time. A couple of ways around that is to community-based monitoring, where community members could go out onto the sea ice, drill a hole, sample at least surface water and sea ice for us, but to do it across the Arctic would require a lot of money to have a proper framework, a proper support in place to do community-based sampling across the Arctic Ocean. So that was one of the challenges. One of the biggest challenges we had was to work with the schedule of Amundsen of when it's available. I am deeply grateful for Amundsen Science to be able to so smoothly and swiftly actually operate the operation because I have seen the complexity of it. Bu then also imagine having one of the largest coastlines in the world. We span three different oceans, so it is not unfathomable that we could have a science ship on two or three coasts of Canada that then allows for more researchers, more research, and more frequently with less time and money.

JM: So, my first question is about community-based monitoring and I'm wondering if this is something that you have used in your research in the past. And my second question is on the subject of being limited to sampling in the summer on the Amundsen. So, because we know that microbes and pretty much all living things respond to changes in their environment, such as temperature and salinity, and everything that you had mentioned earlier, does this almost lead to a limitation for knowing what the actual composition of microbes in the water are in the winter, and is this something that you investigate? Still just by simulating it in a lab? Or how do you kind of get around not being able to sample in the winter? And your answer might be through community-based monitoring, which means you have one answer for both but, I don't know.

SB: So the duration for which our project has been running, we haven't been able to carry out community-based monitoring, but that's something we are very interested in and that allows us to build capacity in the north to train folks about not only about sampling, but also talk about microbes and talk about all these invisible life forms and how they are connected to us and how they influence us in our life. So that's a dream of mine to actually have a large community-based monitoring program. But as again, it comes with the caveat of having funding. In addition to community-based monitoring, what I would actually like to have research facilities up in the north where the samples could go be processed and the data could be generated there as well. That this allows for not just sample collection happening by the community members. And the samples being sent to cell, but actually samples being processing up in the north. There are facilities that are being built, an example that comes to my mind is Cambridge High Arctic Research Station, but also Nunavut Research Institute could take part in that. So, the future I want to be part of is where I don't bring the samples back, or the samples don't come to my lab in the south, but the samples actually are process and analyze up north. And then I do the part of supporting it. In terms of variation from season to season, yeah, that is one of the big limitations we have of what we have done is all of our work has been done during spring to summer time, maybe a bit of late fall. But there are six seasons in the Arctic. We don't have data for all the 6th season. From what we know about the microbes, the microbe's community profile would change from season to season depending upon what's happening in terms of temperature and salinity or other physical chemical parameters. Even how the land influences it, because in spring, with the snow melts, there could be a lot of different compounds and chemicals could be moving into the ocean, and how do they affect the microbial community? We don't know just yet. So, a community-based monitoring program there would be very helpful where Northerners, people who live there, people who have the right to the land and the water, people who have a stake in the knowledge that may be generated, or information that may be generated. They are there around the year. If there is a capacity up there, if there is a training, then they could actually carry out the sampling around the years. So, then we have an idea of what's happening from season to season to season. What we had tried to do is from going from we know nothing, to now we know at least something. Yes, that something is about specific times of the year, but that's a start.

JM: Yeah, for sure. So how would you say working in the North has changed your perception of microbiology and genomics, and what would you like to see changed in the next 10 years?

SB: Having worked in the Arctic and mostly in Arctic Ocean, I went with microbes are so awesome and so cool to now, microbes are phenomenal. They are in our polar oceans, but I know that I could rely on them to clean at least part of an oil spill. I could rely on them, even in an extreme environment, to carry out phenomenal processes, some of which are of benefit to us, including cleaning up some of our own messes. What it has led me to is then wonder about other microbes cause, as I mentioned, microbes live in anything and everything and anywhere and everywhere. And now I've been wondering about what are the microbes that are inside a narwhal’s gut, what are the microbes that are in the eiderdown, let's say, or the eider nest and what are the microbes that are in the Greenland shark, like on its skin. And so, I've been wondering, there are cold water corals. And now I'm wondering, what are the microbes that form symbiosis with the cold-water coral? That's the downside of being a microbiologist or an environmental microbiologist, because now there is like, there is so much work that could be done in multiple lifetimes and to find the focus of like what should be my next question? In terms of what I want to see changed or what I want to see in the next ten years in the Arctic is to have Northern researchers that are based in the North, working in facilities that are operating in the North. Where people like me, who even though live in the South but love the North and want to work in the North, can go, can live there can from time to time, and work with the people there and be part of the community.

JM: Based on everything we've talked about today, it seems like the field of environmental microbiology is one that is rapidly evolving and has more applications than I ever would have thought. Thank you so much for being a guest on Arctic Minded, Srijak. It's great to speak with scientists who are passionate about their work and eager to share it with others. Thank you for listening and be sure to follow ArcticNet on X and Instagram, and Like our Facebook and LinkedIn pages for the latest ArcticNet news and opportunities.