Interview with Dr. Laura Wegener Parfrey by Clara Gimenez-Delgado and Natalie Trapuzzano

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My name is Laura Parfrey. I'm an assistant professor in Biology and a Canada research chair in Protists' Ecology. Well, my first encounter with the microbiome was when I was born, technically, but I really didn't think about it until the time when basically the world started paying attention. As I was transitioning from my PhD to looking for a postdoc, it was 2009-2010, and it was the time when the microbiome started to become a much bigger deal because we finally had tools to be able to see who was there.

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So, just being able to map the diversity of organisms meant that it opened up huge worlds. And so, as I was looking for a postdoc, I was struck by that reality that microbes are everywhere, that they're invisibly controlling many aspects of the visible biological world. And my background was in Eukaryotic microbes, things like ciliates and amoebae. And, so I was already very taken by the microbial world.

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One of my favourite things about the microbiome is that it has the power to make lots and lots of people care about microbes. So, it's kind of translated the importance of the microbial world to a much broader audience.

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The microbiome is the collection of microbial organisms that live in or on larger organisms, such as plants, animals, or the seaweeds that I study. So first, I'll just say that the microbiome isn't really one entity because it is this collection of lots of different organisms that come and go into a host. And are often different across different individuals in a population, so… when you study microbes in general, you do find a lot of new species when you look in new environments.

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But as we study, we're looking across those, all those different species of seaweeds, we're finding a lot of repeated microbes. So, the same things that are on seaweeds in one part of the world are on seaweeds in a different part of the world. And it might be different species; we don't really know what a microbial species is. But it's the same type of organism. The eukaryotes, they're called parasites, they can reproduce by binary fission, and they have some form of sexual reproduction. But we're not really sure how often they reproduce sexually versus asexually. But, usually, we think of bacteria reproducing on the scale of hours to days.

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For one type of bacteria, one lineage of bacteria, to persist, it's got to move to a different organism at some point because the hosts die. So, people have studied this in a different framework, looking at decomposition and how the communities change as decomposition progresses. And certainly, the organisms that are dominant, the bacteria that are dominant when a human is alive, are replaced by new bacteria that come in and decompose flesh, so they're really good at doing different things. Something eating tissue instead of eating the byproducts, for example.

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So, in both the human microbiome and the seaweed microbiome, it's this collection of species, so it's not one thing, but hundreds of different microbial species that come and go. Of course, some are common, and some are rare. So, a lot of the similarities have to do with those dynamics. It's a dynamic community that changes based on the conditions. On one hand, what you've eaten or drugs that you've taken. On the other hand, whether it's summer and you're exposed to hot, high tides or it's winter, and you're exposed to freezing temperatures. So, the species that are there are different, the conditions are different, but those dynamics and the fact that it's always, that it's changing and it's changing based on characteristics of the host or the environment are similar. Overall, the picture that we have is that the environment determines the similarity of the microbiome.

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Genetics play a small role. So, there are some bacteria that are determined, at least in part, by the genetics of the individual. And then diet plays a big role as well because the diet is the food that you're giving, you're introducing to the bacteria to eat. So the biggest distinction in the gut microbiome that I study on one side and the seaweed microbiome that I study on the other side is the fact that one is inside and one is on the outside, and that comes with a whole host of other characteristics.

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So, the gut microbiome is really different than the outside environment. It's much hotter. It's much more stable in terms of the temperature; it doesn't vary daily or in seasonal cycles. There's lots and lots of food, and it's anoxic - there's no oxygen.

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In utero, humans are mostly sterile. You can detect a few microbes, but it's really, really hard to do so there. There aren't very many, and they aren't very diverse. But of course, when you're born, you've come shooting out into the world and are colonized immediately by lots and lots of organisms. Who colonizes does depend on whether you have a c-section and are mostly colonized by bacteria that are found on hands and other surfaces, versus vaginal birth, you get colonized by microbes in the, from the gastrointestinal tract as well as the vaginal tract. The bacteria that are, that colonize an infant gut are initially seeded by that first colonization event. Some of the most important bacteria are transmitted from mother to infant through breast milk or through contact. They're also, the most important ones are sustained by the common food source of breast milk. So, mom produces sugars that feed not only the baby, but also the bacteria and select for particular strains, and that seems to be associated with better health of the infant and less pathogen influence. And then over time, as the baby grows and starts eating more food, and more diverse kinds of food, and then crawling and putting everything in their mouth, they're colonized by more and more different types of bacteria. Some of them just pass through and are transient, and others colonize and are there for long periods of time. So, by the age of two or three, kids have a more or less stable community.

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But the seaweed microbiome that I study in the other half of my lab is basically a biofilm on the surface of fucus or other seaweeds, and it's composed of organisms that colonize from the water column or the surrounding rocks or neighbours. And they're subject to about the same environmental conditions as the other microbes in the broader marine environment, so the same temperature, the same... roughly the same pH, and various conditions.

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And so, on balance, the microbes that are on the seaweed microbiome are much more similar to what we find in the environment. And the life cycle, the cycle for a microbiome is really, strongly tied to the lifecycle of the host organism. The fucus, the reproductive structures, are probably mostly sterile or they're not, they settle on rocks, and as the fucus grows, the microbes are colonizing very rapidly from the environment or from neighbours or from the surrounding rock biofilms.

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And fucus, just like plants, grows throughout its lifetime, so very different than animals. And the new tissue is always colonized by microbes. The most likely route for that is the microbes on the tissue, just on the older tissue, colonize the new tissue. And so, you have a cycle of the fucus microbiome sort of perpetuating itself, and we see some similarity in the ‘who's there’ over the lifecycle of that individual plant. But it's exposed to this really dynamic microbial environment, and so there are other things that come in all the time from the neighbours or from the water, from rocks. And so, we see quite a lot of variability over time.

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And then as we move from March now through April and May, we know that the microbes that are in the water column change as it gets warmer and there's more light, algal species bloom to take advantage of those nutrients and we see microbial communities changing. Over time, we also see changes in the fucus microbiome, and that's actually one of the strongest signals, is this change over time. And especially in the late summer, when we have really hot temperatures that in the afternoons when we have low tide events, the fucus microbiome changes a whole lot. So it's basically, probably a stressful drought event and many of the microbes can't survive in those conditions, so they're replaced at that time. And then as it goes into the fall, it becomes cooler and less extreme temperatures again and the same, you get the same bacteria colonizing again that would have been there in March.

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If you looked more similar to a given seaweed, you had more similar microbes. So, the species that have the same morphology or just general shape have more similar microbes present on them. The shape of the seaweed does determine, to some extent, what microbes are present.

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Is there a way of transferring those, either the whole microbiome or just those quote-unquote "parasites" that are associated with good health? People are trying both of those things. The first case is, it's under fecal transplants. And so that's done somewhat, to some extent, in a medical realm to treat specifically Clostridium difficile diarrheal infections, where doctors transplant whole fecal samples into people that are sick, and it's been shown to be really effective in curing that disease. People are trying it in a range of other diseases. Sometimes it works well; sometimes it doesn't. Doctors and the general public are scared of introducing pathogens accidentally. So that's, that fear has slowed down fecal transplants as a broader tool.

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And on the other side, there are scientists that are trying, that are introducing those, quote-unquote, “parasites” into people that are sick and asking if they get better. And, in some cases, there's promising evidence, especially in animal models, showing that introducing worms especially can make diseases less bad or cure people from diseases. It's usually animals, though, and it's usually preventative, so if you had the worm first, then you're less likely to get a severe case of the disease. And that probably works through changing the immune system. So, better understanding what is normal and what is the nature of this association where we are seeing healthy people having more parasites.

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There are studies that have looked at this measuring the amount of transfer in roller derby, some participants hitting each other or not. And there is transfer. Whether or not someone else's microbes colonize your skin depends on a lot of things. It depends on your skin, like how many microbes are present there. It depends on the nature of the other person's coming in. I will say that when we start thinking about the microbiome from the perspective of the microbe, it totally makes sense that they would transfer from one person to another because that's how they're growing their population sizes. And so that's access to a new pool of resources.

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Why we think the microbiome is important to hosts? We know that because people have grown, especially mice, without any microbes and they call that "germ-free" and they're born by c-section in a bubble. So, it's like totally isolated from the outside environment, and the mice grow up without any contact with bacteria. And that has big consequences for their health. Their intestines don't develop nearly as much. So, normally intestines have lots of folds and projections, and that increases the surface area that microbes are colonizing and space for digestion. In mice born without microbes, without contact to microbes, they have much less surface area. The immune system also doesn't develop properly, so the immune system has evolved to depend on those microbial signals that were basically always there. So, if it doesn't have them, it doesn't develop normally.

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Certainly, the microbiome will be affected by climate change because, when we look really broadly, we see the microbes change on a seasonal cycle. They're very strongly affected by basics of climate and the abiotic environment. So, temperature and salinity differences will have, do have a big impact on the microbes that are present. And as those things change with climate change, we will see that the microbial communities change as well.

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But we don't know yet if that has if it will have an impact on the biology of the host or not. Climate change could either be worse because of the microbiome, if the host is really dependent on particular microbes that disappear with climate change. If those microbes can't stand hotter temperatures or different changes in the pH. But a more likely scenario is probably going to be that there are many different microbes that can fulfill key roles for the host. And as we see climate change progress, it gets warmer, and the pH goes down, we'll just see different microbes that are fulfilling that role for the host –a new microbe that does the same thing, but can live at hotter temperatures, will take over that role, effectively.

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What I would like to be known –especially in a case where we have rapid climate change and other changes that are perhaps catastrophic– an important thing to know about the past would be that the microbiome has always been changing, it's always been dynamic, that there is not one “best” or that there's not one state that we should be trained to return to. An understanding of the dynamics of the system are important to keep in mind.

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Embrace your microbiome.