Interview with Dr. Curtis Suttle by Graeme Niedtner and Manfred Nissley

[00:00] CS: I'm Curtis Suttle. I'm a professor at the University of British Columbia that works in the Biodiversity Research Centre. I'm interested especially in viruses and their interactions with the microorganisms in seawater.

[00:11] CS: As a boy, I was on a sailing trip around the world with my mother and stepfather. We were the first Canadian family to sail around the world on a sailboat. During that four-year journey we stopped at an island on the Great Barrier Reef. There was a research expedition there that they were looking at how life survived in the ocean. They were looking at mangroves and saltwater crocodiles and dugongs. As an eleven-year old, I was running around the beach, talking to all these scientists, and I said when I grow up I want to work on the diversity of life in the ocean. I want to work on all these different organisms and all these different animals. That sort of set me on this path of going down the road and trying to think about diversity of life in the oceans. And, like most folks, I was interested in the charismatic megafauna.

[00:56] CS: As I got older and I went onto university I became really interested in why there was so much life, how could you have so much life, and I wanted a way to kind of think about those ideas. Like, how could we have a hundred different species in a drop of water and how could they all coexist together? So, I wanted to try and start doing things experimentally. That kind of set me on this path about trying to look at biodiversity and what life exists in the ocean and got me working on smaller and smaller things. So, that led me down this path working from plankton, working at experiments in bottles of water and trying to look at the mechanisms behind why there were so many different types of life that were able to coexist.

[01:34] CS: In my PhD, I had been working on these ideas that you could look at what resources were available to organisms and if different organisms needed different resources, that you could control organisms by the availability of what was there. After I got my PhD I went to the State University of New York at Stony Brook to look at some of these questions. While I was there, there was a graduate student in the lab and she was finding all of these viruses in water. All these little virus particles and prior to those [02:00] observations, nobody really thought viruses existed in water and there was actually scientific papers written on why we wouldn't expect to find any viruses in water and in seawater.

[02:08] CS: When I took a faculty position then at the University of Texas in Austin at the Marine Sciences Institute, I thought viruses, because they're obligate pathogens, and they can only reproduce by infecting organisms and maybe viruses were really important in controlling all of this biodiversity. And so that led us on this path to thinking about it and there was anecdotal observations that viruses might be very important. I was interested especially in viruses which infected the photosynthetic organisms. There were, in the scientific literature, anecdotal observations that people looking at things under an electron-microscope and seeing virus particles inside individual cells, these are single cell organisms. There were reports in the literature of phytoplankton blooms that disappeared overnight and they couldn't see any reason why they disappeared overnight. The third observation there was a professor at the University of British Columbia and his graduate student, Jolie Mayer. For her PhD work, she had isolated a virus which infected one of these photosynthetic microorganisms. So, when we went to Texas, I said let's just try an experiment and see if we can isolate a virus which infects a photosynthetic organism; and the first experiment worked and we were able to isolate a number of different viruses. So all of a sudden we began finding all of these different viruses which infected specific groups of organisms, and so that led us down the path about viruses and their interactions with the microorganisms in seawater.

[03:29] CS: Viruses are really special. They're only protein and nucleic acids and they can be DNA or RNA. But, they're absolutely obligate pathogens. In other words, the only way that they can reproduce is by infecting another organism and they're typically highly host specific. When we started working on them, we didn't know much about them, but it turned out there are tens of millions of viruses in a millilitre of seawater. Just to put that into perspective. If you took a virus particle and you scaled it to the size of a pinhead, [04:00] so you could see it, and I was scaled to the same amount, I would be 150 kilometres high. And then just to give you an idea of how many viruses there are in the ocean, if you took all those viruses and you stretched them end to end, it would go ten to the seventh light years or further than the nearest sixty galaxies. And they're very important in the sense that they exist by infecting other organisms and so it turns out that about 20% of the living material by weight is infected and killed by viruses everyday in the oceans. And those microbes produce about half of the oxygen on the planet. So, if we sort of think about these ecological roles of viruses, then it becomes apparent just how important they are. And if we were to kind of drill down a little bit more and there is this group of viruses that we call giant viruses, and they were a fairly recent discovery. And what we didn't know, we had actually we had isolated the first giant virus ever when I was at the University of Texas. But we didn't know it was a giant virus because we had so much trouble working with it. We have to go back in time when the technologies for working with nucleic acids and DNA, were much much more primitive than they are now. And so we couldn't get any information by this virus. I had two or three or four different PhD students and post-doctoral people start to work on this virus and we couldn't get any nucleic acids out of it. And so we just kept carrying this virus with us for more than a decade with people keep trying to work on it, but we couldn't get any information out of it. And then there was a group in France that all of a sudden found a new group of viruses called giant viruses which were extremely different than other viruses and once we had a little bit of that information and the technologies for working with nucleic acids improved, we were able to go back and find that this was a giant virus.

[05:54] CS: So a giant virus, the difference is not only is the virus particle five or ten [06:00] times larger than a typical virus the amount of genetic information that it contains is enormous relative to other viruses. So, in fact it contains as much nucleic acids in many cases as cellular life does, so a bacterium for example.

[06:17] CS: When you start looking at these nucleic acids, they're very very different. These giant viruses are taking genetic information from all kinds of different organisms and incorporating it into their own genomes, which, leads to a whole bunch of questions about giant viruses and their role in the evolution of life. Are these kind of like melting pots of genetic exchange? There's been questions about, "is this another branch of life," because they're so different than other organisms. So some people think these might have been self-replicating organisms originally, that lost the ability to reproduce, just like all parasites do. Obligate parasites, you know, they're still considered life, but they cannot grow unless they infect another organism. There's lots of examples of that. So, the question is, is that what was going on here or were these originally tiny viruses that just kept adding genetic information? So, they have very interesting implications in terms of life and the evolution of life.

[07:14] CS: People don't think viruses and biodiversity in the same sentence, but that's very relevant because viruses maintain biodiversity, including giant viruses, because they're so host specific. So, giant viruses when populations get large, they propagate very rapidly and by doing so they reduce those populations and essentially give space for other organisms to rise. So, so they maintain biodiversity that way by killing the most abundant and fast replicating organisms. But they're also the nucleic acids, it's really interesting. If you look at viruses, and in particular giant viruses, and you look at the genetic information that they contain, it's very different than the genetic information in cellular organisms. Viruses use double stranded DNA [08:00], single stranded DNA, double stranded RNA, positive sense RNA, negative sense RNA, they have RNA-DNA hybrid viruses. They've got all these different ways of containing their genetic information. So, if we think about the fact that the origin of biodiversity is genetic diversity, so, in other words if we have no genetic diversity, if we were all clones of each other, we'd have no biodiversity, we'd have no ecosystem diversity. So, in fact the underpinnings of biodiversity is genetic diversity, and if we look at where much of the genetic diversity on the planet arises, it's in viruses and viruses in the ocean being so incredibly abundant encompass much of this biodiversity. So, if we sort of think about viruses in that perspective and giant viruses in that perspective, that much of the biodiversity on the planet is encompassed in giant viruses.

[08:49] CS: Giant viruses, they are special in a number of ways. One is they are special because of the size of their genomes. Their genetic information comes from many different places. They infect specific groups of microorganisms and those are the microorganisms that are our relatives, what we call the eukaryotes. If we look at those interactions, it's really become apparent again that they've coexisted for a long long period of time. And, so one of the really interesting aspects that has come out in the last few years, and which we were a part of discovering, was the fact that there are other viruses which actually are dependent on giant viruses for their own replication. Viruses infect cellular life, and so giant viruses infect cellular life which is what we call protists, or, or single celled eukaryotes. Well, it turns out that when these giant viruses infect these cells, they produce something that we call a virus factory. And now it turns out there are small viruses which are absolutely dependent on this replication, this giant virus, the small virus will replicate and actually kill the giant virus, and it turns out [10:00] the protists have coopted this system and made a part of their own immune system. They're able to encompass the DNA of these small viruses into their own genome rather than having to depend upon this small virus finding them and killing this giant virus. They're actually able to release these small viruses into their own cellular material, which will attack and kill the giant virus and save the Protista microorganisms.

[10:27] CS: When we sequenced the first of these small viruses, which we call Mavirus, it didn't look like any other viruses at all, which is really puzzling to us. It turns out what it looked like were what are called transposable elements in the genome of higher organisms, and some higher organisms are very large percentage of their genome was encompassed by these small viruses. Our hypothesis was, that was the origin of these transposable elements in higher organisms was in fact small viruses which had been incorporated into the genomes of their hosts and then could escape and jump out and give them protection against these giant viruses. The outcome of that may have been that many of these giant viruses went extinct. Then these viruses had no purpose anymore and then they just became transposable elements and just ended up jumping around in the genomes of the host organisms. And so, from the evolution perspective, it's really interesting because these viruses, this is a way that the viral genetic information has gotten into the genomes of the cells. If we look at our own genomes, about eight percent of our own genomes are viruses that have got stuck, and those viral genes encode for things like a major protein that's in the placenta of mammals. There'd be no mammals if it weren't for the fact that some viruses got stuck on our own genome from one of our ancient ancient ancestors, a few hundred million years ago, similar with our nervous system. It turns out that some of the major proteins in our nervous system originated from viruses.

[11:55] CS: So, life is incredibly interconnected, so we have all of these exchange of genetic [12:00] information that goes back and forth between viruses and not only giant viruses, but giant viruses are very much a part of it. If we cast back, to what viruses are doing in the ocean. Avogadro's number, if you remember that, Avogadro's number of infections per second in the ocean, which is about ten to the twenty-fourth infections per second. And so people will often say, well the chance of genetic information being transferred from a virus to a host it's very unlikely, right, it would happen so rarely. But if something is happening ten to the twenty-four times every second, it can still be a very rare occurrence, but it could still be happening all the time, with that many, because when we have so many events occurring. It's like looking for, you know, the Higgs Boson, or something like that, right! It's, [laughter,] it doesn't mean just because it's rare that it's not happening at all.

[12:48] CS: When we think about viruses, what I really want people to think about is not, in fact, that they make us ill and that we're afraid of them. If there was something to take home in the long term, and if we were kind of to shift the conversation a bit, would be the recognition that viruses are just a very much a part of all life on the planet, that without viruses we actually would not exist. Without viruses, there would be no mammals. Without viruses, we would not have nutrient and energy production and cycling that we have on the planet because they're absolutely crucial to being able to, to maintain life on the planet. So, without death there is no life, right? And so viruses they're incredibly beneficial. They prevent a single organism from dominating the planet, which would result in their own destruction ultimately and that's true of microbial life, it's true of plants, it's true of all animals, right? And so disease, if we think about it we always think about it in a very negative way. It's nice to think about viruses just being part of the cycle of life on the planet, as opposed to just being a pathogen that should be avoided at all costs. Of course we want to avoid the viruses [14:00] which infect us, but that's such a small proportion of the viruses that are out there. And so what I would really like people to think about are the beneficial effects.

[14:09] CS: Viruses are likely really important in our own immune systems. So, viruses that we inhale come into our lungs, and those viruses infect the bacteria that we also inhale, and they will cause the death of those bacteria. By infecting the bacteria that come into our lungs they produce lots more viruses which stay in our lungs and infect more of these bacteria that come in. They're almost like a first line of defence in our own bodies. People don't have a very holistic view of viruses. They have a very specific view of, you know, viruses need to be avoided, I need to be afraid of viruses. But as we sit in this room, we probably inhaled a million viruses each of us, right, that we've shared amongst us, but are also just circulating in the air. For the most part, they don't harm us at all, but in fact they will have a role in terms of maintaining the diversity and life on the planet as a whole.