INTERVIEWER: Today is Tuesday September 22, 2015. I'm Barbara Costa. As part of the MIT Infinite History Project, we're talking with Dr. Sallie W. Chisholm, also known as Penny. Dr. Chisholm is the Lee and Geraldine Martin Professor of Environmental Studies and professor of biology at MIT. She joined the MIT faculty in 1976. She is the principal investigator at the Chisholm Lab at MIT, which studies the role of cyanobacterium Prochlorococcus in the ocean's metabolism.

Discovered by Dr. Chisholm and her colleagues in 1988, Prochlorococcus is the most abundant photosynthetic microorganism in the oceans. Her research is devoted to developing Prochlorococcus as a model system for advancing our understanding of the ecology and evolution of marine microbes.

Dr. Chisholm has a Bachelor's degree from Skidmore college. And she received her PhD from SUNY Albany. She is an MIT Institute Professor and a recipient of the 2011 National Medal of Science. Thank you for talking with us, Professor Chisholm.

CHISHOLM: It's a pleasure to be here.

INTERVIEWER: Thank you. So we want to start way back when. We often start with growing up. And what was it like to grow up in Marquette, Michigan on Lake Superior?

CHISHOLM: It was a great childhood. I didn't appreciate it at the time. But we go back there now. We actually have a cabin on the lake now. So I go back and relive my childhood. But it was idyllic, sort of. We played on the lake in the summer. And we skied all winter.

And we only went to school through junior high and high school-- because it was the baby boom era, there weren't enough schools. So they split the sessions. So I went to school in the morning in junior high and the afternoon in high school and skied the rest of the day. So it was really a wonderful place to grow up.

INTERVIEWER: Was the water an important part, since you were on the lake?

CHISHOLM: Well, we just assumed that the rest of the world was like that. I mean, that was our world. So yeah, it was an important part of our activities there. But it didn't really have an influence on the direction of my career, I don't think.

INTERVIEWER: Or an environmental awareness or anything like that?

CHISHOLM: No. I think I was just a kid growing up. I didn't have great plans for my life at all at that point.

INTERVIEWER: But the '60s must've been interesting. Was that anything particular, that time period? Was there something challenging or interesting?

CHISHOLM: Yeah, I think I picked up on-- my mother was a traditional '50s housewife. And I think, in the '60s, I picked up on her unrest and that her life was not as fulfilling as it might have been. She was a really smart woman and artistic.

And as we, I had an older brother. So as we grew up-- we were in high school-- she started getting into other activities and, I think, was it was getting swept into the early feminist era then. And so that, I think, had an influence on me.

INTERVIEWER: And so, then you graduated from Marquette Senior High School. And did you immediately know what you wanted to do next?

CHISHOLM: No, I didn't. In fact, I had no ambition at all. I actually thought I wanted to be a medical technologist. I knew I liked laboratories. I liked test tubes. And I liked going to school. But I didn't really think about what was going to happen next.

But my parents kind of made it clear that I was going to go to college and go into a four-year college all the way along. So I knew that's what I was supposed to do. So that's what I did. And I applied to a number of colleges. And I only got into Skidmore and the University of Colorado.

And I was really interested in skiing. And I would have gone to the University of Colorado. But my father convinced me. He said he'd buy me a car if I went to Skidmore. So that was what made my decision. And also, my brother was at Dartmouth. And I think that made it easier to go east. Because I'd never been there, never visited it or anything. It was just an adventure.

INTERVIEWER: And so, once you were there, was it pretty quickly that you became interested in marine biology?

CHISHOLM: Well, no. Actually, I started as a math major. I had done well in math in high school. But realized that college math is very different than high school math. And I liked my introductory biology class. And so, I switched to becoming a biology major my sophomore year. But still, I didn't really realize or think about what I wanted to do after college. I was just getting through the years.

INTERVIEWER: And so, even all through college? The marine biology?

CHISHOLM: Yeah.

INTERVIEWER: Where did the marine--

CHISHOLM: Well, my senior year I did independent study. And my adviser studied lakes and plankton. So that's when I started getting interested. And I remember the first time I looked through a microscope and saw plankton from lakes. I thought that that was pretty cool. But I still didn't know what I wanted to do. And he was the one that said, you could get a PhD if you want. And it had never occurred to me that I could get a PhD.

I mean this was in the late '60s. And also, I came from a family that was very business-centered. So academic life was not part of my world, except for one of my close friends growing up. Her father was a vice-president of the local university. So I remembered hanging around their house was pretty interesting.

So when he said, you could get a PhD, I thought, well, I wasn't sure I wanted to get a job. So that seemed to be a good option. So that's what made me go on to grad school.

INTERVIEWER: Enough that you knew straight what you wanted to do? Because you have to specify.

CHISHOLM: Yeah. Actually, I started, i knew I was interested in ecology. And my adviser helped me find people that worked in limnology and ecology. And I actually started graduate school at Cornell.

But I was in love at the time. And ended up only staying there for a year. And came back to be with that person. And so, then, that's how I ended up at State University of New York at Albany. Because it was near the Saratoga Springs area, which is where Skidmore is.

And then, at Cornell, I was studying more chemistry in lakes. And it was at Albany that I switched to phytoplankton, which became my trajectory, but still in lakes. And it was only after that that I got into oceanography as a postdoc.

INTERVIEWER: How was the transition made from lakes to oceans then?

CHISHOLM: That was big. I realized in graduate school that a lot of the funding was really in oceanography and that not in lakes, which is really too bad. Because there's a lot of really interesting research to be done in lakes. But at that time, the Navy was funding a lot of oceanographic research and funding a lot of research on plankton for strategic military reasons, in terms of sensing submarines and things in the oceans.

And so, they were funding basic research though on plankton in the ocean. So there was a lot more research funding in that field. And so, I had an opportunity to go to Scripps Oceanographic Institution for my postdoc, which really launched my career in a sense. But I didn't know anything about the oceans. I had only been to the oceans about twice before that. So it was a steep learning curve to make that transition.

INTERVIEWER: And did you have specific mentors that were important to you early in your career? Anybody come to mind?

CHISHOLM: Well, my adviser at Skidmore certainly, who was one that suggested that I get a PhD. And I had a couple of teachers in high school. I just went to my 50th high school reunion. And both of them are there. Two math teachers were there. And I had the opportunity to thank them. Because they stood out.

I always say, all it takes is a few good teachers in high school or junior high to-- there was also a science teacher in junior high who had an influence on me. And that was enough. Even though the school system was sort of in crisis-- since we were only in school for half a day both times. And there was very overcrowded and everything. But a few good teachers can go a long way. So in those years, they were very helpful.

And then, my postdoc mentor was also very-- he took a huge chance, I think, in taking me, a unknown person from limnology. And so he was very supportive in getting me to Scripps and sort of launching my career there. But he retired actually soon thereafter. So that influence sort of stopped after he retired.

But I had another mentor there at Scripps who was just brand new on the staff. His name was Farooq Azam. My other mentor was Dick Eppley. And Farooq Azam had a big influence on the way I do science. We worked together at the bench and did experiments together. And I've always been grateful for his influence.

INTERVIEWER: When did you start going out of the lab on cruises or whatever it was that got you out into the field of the ocean?

CHISHOLM: Well, when I was working on lakes, we did a lot of field work. But those would just be day trips. And I spent one summer in Point Barrow, Alaska, working on ponds there, which was really an interesting experience. But at Scripps, my first cruise was two months after I got there. It was in the Gulf of California off Baja for a month. It was a really incredible experience to be able to do that.

And we went on pretty much monthly cruises off the coast of California. So I jumped in pretty quickly to the cruising lifestyle. And at that time, it was just beginning. Women on ships was just beginning to be allowed. They hadn't quite sorted it all out yet.

INTERVIEWER: You would be the only one?

CHISHOLM: Sometimes, yeah. But it was just starting. There was just opening up for women to go on cruises. But it wasn't anything like today. There are women crew members. And it's all very, very mixed. But in those days, it was an interesting-- plus, it was the '70s.

It was the '70s! It was a pretty wild time. So we had a good time. And I must say that the people that I worked with at Scripps were very open to women being treated as equals and being part of the scene.

INTERVIEWER: Still, a month at sea as the only woman-- anyway, what was the time like when you're out for a month? What did you do?

CHISHOLM: Boy, well, cruises are different. They have different qualities. The monthly cruises were very monitoring cruises. So there's a lot of routine around the clock, just collecting samples, doing the same analysis, collecting more samples, doing the same analysis, trying to get it more efficient. But it was always a good crowd of people and a lot of camaraderie. And I enjoyed it a lot.

And then, some of the other cruises, you could actually collect samples and do experiments and do science, as you would in the lab. And so those were more stimulating intellectually. And they have different qualities with different missions. But I had a great time. A great place.

INTERVIEWER: How many were there? How many missions? Like, while you were a postdoc.

CHISHOLM: As a postdoc? Oh, I probably went on about five different cruises.

INTERVIEWER: Over what period of time?

CHISHOLM: Over two years. Yeah, so I learned a lot. I learned everything I know about oceanography from those cruises and some that came afterwards when I came here.

INTERVIEWER: And then, could you describe the Prochlorococcus and what's special about it?

CHISHOLM: I would say Prochlorococcus has great charisma. Because it has all kinds of superlatives attached to it. It's the smallest photosynthetic cell on the planet. It's less than a micron in diameter. And it's got the smallest number of genes of any photosynthetic plant.

So I would say it's the smallest amount of information that can convert carbon dioxide into living organic matter, using only solar energy. So it's the smallest. It's the most abundant. And of course, from my point-of-view, the most interesting of small-- they're called picoplankton-- in the oceans.

INTERVIEWER: Actually, we could step back. I should have asked first about the discovery.

CHISHOLM: Ah, yes. Well, when I first came to MIT, I was studying a group of phytoplankton called diatoms. And they're single celled. But they're about 30 microns in diameter. And they're very abundant in lakes and oceans, and many different species of them.

And we were studying a single species. We were trying to understand how it grew and responded to the light and the dark cycle, the daily rhythm of light and dark, since these guys are limited by solar energy. But I was always frustrated that we could study them in a lab, in cultures, but we couldn't count on finding them out in the field if we went on a cruise.

That particular species you couldn't say, well, this is what I know about it in the lab. Now, I want to go study it where it lives. Because there's so many different species. And you never know when they're going to bloom. And so, that was frustrating. But we kept working at it.

And we were interested in the cell-division cycle. And you could study that by staining the DNA in the nucleus and seeing when the nucleus replicated itself. So these cells replicate by dividing in half. So you'd see two nuclei. And then, you'd know, that cell was about ready to divide. And so, to study that, we were using an instrument called a flow cytometer that is a laser-based instrument that's used in cell biology research, and hospitals, biomedical research to study cell division and cancer cells and other things.

And so, we couldn't afford a big flow cytometer. So actually, I had a postdoc who was very clever. And he built one, based on microscope set-up. And so, we used that. But at the same time, around 1979-- I came to MIT in '76-- a colleague in Woods Hole discovered these tiny little cells in the oceans-- they're called Synechococcus-- that were very abundant and had a pigment that fluoresced orange when you shine blue light on them.

So we realized that this flow cytometer that we'd been using to study cell division could be a really powerful tool to study those microorganisms in the oceans. Because they autofluoresce. Their pigments autofluoresce. And in fact, it would be useful to study all the phytoplankton.

So we started just shooting seawater through the instrument and saw all of these-- the laser is focused on this little capillary tube. And then you inject the cells. And a cell goes through the laser. The cell scatters light. And the pigments fluoresce a color, depending on what pigment you see. And so, it turned out that this instrument that was designed for cell biology was pretty interesting, in terms of oceanography.

So we got a grant to buy one, with a money-back guarantee that, if it didn't work on a ship, they would take it back. And this one very clever postdoc, Rob Olson, who had designed this homemade flow cytometer had the courage to actually put this on a ship. And so, we set out.

And it turned out that it was really ideal for studying this Synechococcus, which was very abundant and everywhere. So we could, for the first time, while at sea, count the numbers of these things, and look at their properties and how they're distributed with depth and all of that.

So it turned out that those cells fluoresce orange. And Rob noticed that there were these tiny little things, even smaller than Synechococcus that were fluorescing red that we thought was electronic noise in the instrument and kind of ignored for quite a while. But then, it started behaving better than noise. They started changing with depth.

And so-- make a long story short-- those were Prochlorococcus, which is smaller than Synechococcus and fluoresces red instead of orange. Because it doesn't have the pigment that Synechococcus has. And so, that was the "discovery." But it turned out that it actually had been discovered twice before. But people didn't know what they had discovered. So we were lucky enough to be able to look at that earlier evidence.

There was a picture that had been published. And their pigments had been published. But people didn't realize that that was their pigments. And so, we were just lucky enough to be able to put the pieces together, that what we were seeing with the flow cytometer was this same pigment that had been observed in seawater and, also, was the cells that were in a picture that somebody had published of all the different cells in the oceans.

INTERVIEWER: And it was everywhere?

CHISHOLM: Well, we didn't know it was everywhere then. We didn't really realize what we had discovered. I mean, we did. But we didn't realize the magnitude of any of it. And in fact, we got more interested in understanding it's evolutionary-- it's well-known that higher plant cells have chloroplasts and that those chloroplasts evolutionarily come from cyanobacteria, which is actually what Prochlorococcus is.

And higher plant chloroplasts have chlorophyll B. And Prochlorococcus, it turns out, had chlorophyll B. And so, we got excited. We thought, well, maybe this is like a living fossil. Maybe this is the ancestor, closely related to higher plant chloroplasts. And we thought that would be, perhaps, an interesting story. But it turned out that, through molecular phylogeny analysis, that it isn't any more closely related to chloroplasts than other cyanobacteria.

So that wasn't an interesting avenue to pursue. So we just kept studying them. And we didn't have them in culture for quite a while. So we just kept studying their distribution and where they were and how deep they went. And we'd bring up seawater and add nutrients or change the light intensity and see how--

INTERVIEWER: Right on the spot? You mean--

CHISHOLM: Yeah, right on the ship. That's the only way we could do experiments with them. But because we had the flow cytometer on the ship, you could actually do that. And you could count them independent of everything else. So we could see how they responded to light shifts and what their growth rates where if you added nutrients and all that. So we did that for several years before they were finally brought into culture.

INTERVIEWER: And again, the role of Prochlorococcus? The role of it.

CHISHOLM: In the ecosystem?

INTERVIEWER: Mm-hm.

CHISHOLM: Well, they're the base of the food web, because they photosynthesize. They can make biomass just from inorganic compounds and CO_2. And of course, they're important in drawing CO_2 from the atmosphere into the oceans. They're part of-- it's called the "biological pump" that draws CO_2 in.

And then, they get eaten as fast as they divide pretty much. So their numbers stay stable out in the oceans. So much of the carbon they fix gets respired and goes back out again. But they're an integral part of the machinery of the microbial community in the surface ocean.

So there's this thin film of about 200 meters in the surface ocean where the sunlight penetrates. And that is where all the photosynthesis goes on. And that's feeding everything, all the way down to the thousands of meters depth. That carbon in the ocean, in the surface waters, is settling down and feeding everything in the deep water. So their role-- I always say-- is to keep the food-web churning.

INTERVIEWER: And there's also variability within Prochlorococcus? Or is there a similarity throughout?

CHISHOLM: Yeah, the Prochlorococcus-- when we first found them, we thought they were all one thing. Basically, they were what we see on the flow cytometer. There was this population. And that's Prochlorococcus. And that's still true. But the first two isolates-- and the first person to isolate one was Brian Palenik, he was a graduate student here at MIT, or in the joint program with Woods Hole. And then, soon thereafter, colleagues in France isolated one from the Mediterranean Sea.

So we have one from the Sargasso Sea that was isolated at 120 meters. And then, the Mediterranean strain was isolated in the surface. And so, we started measuring their growth rate as a function of light intensity in the lab and saw that they were very different. The one that was isolated from the deep water could grow at an extremely low-light intensities. And the one that was isolated from the surface could tolerate much higher light intensities and grow faster at higher light intensities.

So that was the first evidence that there's more than one type-- we call them ecotypes-- of Prochlorococcus. And to fast forward, the punchline now is that there is extraordinary diversity. But that was 20 years of work to get there.

INTERVIEWER: You've referred to seawater as "dissolved information." Can you explain what you mean by that?

CHISHOLM: Well, maybe I should backtrack to the beginning of genomics in the story? Because that's where that comes from. Or would that get you out of sequence?

INTERVIEWER: That's fine. I was going to ask about the genome sequencing. You want to just tell the whole story?

CHISHOLM: Sure. So after we realized there were these different ecotypes, we kept isolating more different strains and found that they broadly fell into these high-light, low-light groups. But there was a continuum in between. And they all had slightly different characteristics. And there were also high-temperature and low-temperature ecotypes. So we started seeing the diversity.

And then, it was around 1990, I think-- no. Was it? I don't remember the first genome. But somewhere around there, I think, we were lucky enough to be among the first microbes to have its genome sequenced. Because it was so small and the genome was so small, it wouldn't take "long," quote, unquote-- even though, in those days, it took six months. Now, it takes six hours or something.

And we managed to get these two strains-- high-light and low-light-- their genomes sequenced. And that completely opened up the black box. And that's when, also, metagenomics was entering our field, which is not simply isolating-- well, I took another, maybe a decade, for metagenomics to get big.

So not just isolating different strains and sequencing them, but you'd take seawater. You'd filter it. You'd collect all the microbes and grind it up, chop up the DNA, so that you have it all in these little pieces that are about the size of a gene. But they're from all the microorganisms. And then, you'd have to make sense out of that.

So with the genomics entering the lab and metagenomics entering the field, it started to change the way we-- when I'd look at the ocean, I would think of all those microbes and all of the information in their genes. And that's what I started to refer to as dissolved information. It's not really dissolved. But you can't see the microbes.

And then, you start to think that that's what's running the element cycles of the globe. It's the information in those microorganisms, in their DNA, that is bringing CO2 into the ocean and oxygen out of the ocean and cycling all the elements and doing all the work of the planet. So it totally changes the way you think about it.

INTERVIEWER: And so, what have we learned, on the genomic level, about Prochlorococcus?

CHISHOLM: Well, the fascinating thing for us has been that, every time we would sequence a new genome-- which, now, you can do just-- phwoo-- like nothing. We now have 45 strains sequenced. And there will be another 100, probably, in the next year or so. But every time we sequence a new genome, we find 200 or so genes that we never saw before.

And if you compare, pairwise, every time you sequence a new genome, you quickly realize that there are about 1,200 genes that all Prochlorococcus share. That's their core genome. That's the essence of being a Prochlorococcus cell. That's their basic metabolism. But every strain has a unique set of genes, some of which are shared with others, but 200 of which we haven't seen before. So on average, they have 2,000 genes.

But it's called the pan-genome, the total number of genes in all of Prochlorococcus on the planet, is now projected-- just from our theoretical projections-- to be about 80,000 genes, which is four times the size of the human genome. And we don't know whether that's really what it is. But one of my goals is to actually measure that, to know how many total genes at this moment in time are in a Prochlorococcus cell on the planet.

But it represents an extraordinary amount of genetic capability. By traditional microbiological standards, it would be considered a single species. And so it's an enormous population that's filled with very diverse sub-species or ecotypes, as we call them. And that's what allows it to occupy the vast majority of the oceans.

INTERVIEWER: So fair to say that genomics has revolutionized the research you're doing.

CHISHOLM: Oh absolutely.

INTERVIEWER: And I'm interested by the interdisciplinary work of your team. Because now, I'm hearing a lot of genetics. But what other disciplines are important on your team? In your lab? Or your colleagues?

CHISHOLM: Yeah, I always think of my lab as almost like a miniature biology department, in a sense. One of the goals, for me, has been to study this single organism from the genome all the way up to the level of the global biosphere, basically. I call it cross-scale systems biology. And to do that, you need people who are thinking and trained in all these different fields.

And I'm not trained even-- I mean, I'm not a molecular biologist or a genomics person. I'm an ecologist by training. So I would not have gotten into genomics without bright young PhD students trained. And actually, the first student on the first genome paper was a biology department major. So she was a molecular biologist-- or an undergraduate in the biology department.

So the team is made up of microbial ecologists, bioinformatics people, molecular biologists, environmental engineers. I've had chemists. I've had physicists. Anybody that's interested in Prochlorococcus, I'll take them. So it's been a very, very rewarding experience for me to see them work together. Because the organism unites them. It's really satisfying to see it happen when they come together around understanding this single organism and sort of bond to it.

And it works really well. And I could not have done what I have done at all. I always say, I'm the conductor and they're the musicians. I just make sure that the right people are talking to the right people and find the right teams to make something happen.

INTERVIEWER: So it's civil and environmental engineering with biology, but also much more.

CHISHOLM: Oh absolutely. Yeah. Because to understand it, you need to understand the physics of the ocean. You need to understand chemistry. I've had people involved in trace-metal chemistry, which is very complex and difficult to work with in the oceans. Because they're vanishingly low concentrations. So to study the effects of trace-metals on Prochlorococcus is really difficult.

And I've had students in four or five different PhD programs. There's the joint program with Woods Hole in biology and in chemistry. There's the environmental engineering. There's the biology department. I've had-- I can't even remember. I think there's a couple other ones. But I can't remember them. But many different PhD-- oh, the microbiology PhD program recently. That's a new PhD program, which is very cross-disciplinary in students that it admits.

INTERVIEWER: What's the civil engineering side of it?

CHISHOLM: Well, it's environmental engineering.

INTERVIEWER: I see.

CHISHOLM: Yeah.

INTERVIEWER: It's the department.

CHISHOLM: And it's the civil and environmental engineering department. But we're in the environmental end of it. So I would say that-- and we're all in the Parsons Lab. We're in a separate building, the environmental people. And I think, even though there are people working in physics, fluid mechanics, aquatic chemistry, hydrology, all these different fields, but our world views are the same. We're all interested in the natural world and how it sustains human beings.

And so, it's interesting to see the very interdisciplinary group of graduate students in the division. So some of my students are microbiologists, are doing genomics, are getting a PhD in environmental engineering. And they come out sort of with a different profile. Because they take a lot more engineering classes and fluid mechanics and other things. So that's also interesting to watch the students in the different disciplines interact.

INTERVIEWER: What is the Earth System Initiative at MIT? Does that get into the political end of things? Or is that about systems?

CHISHOLM: It no longer exists. But it was a labor of love. Well, I should say, it's slowly morphed into the new Environmental Initiative that's recently been launched. But that was an initiative that a number of us, faculty, got together and felt that MIT could really make a difference in advancing our understanding of how the planet works.

That the earth is a complex system made up of living creatures and physics and chemistry. And that between the Earth Atmosphere and Planetary Sciences Department and Environmental Engineering Department and others around the campus, that we could put together a compelling initiative designed to really understand how the planet works. And so, we worked hard to do that. And succeeded, to some degree, at bringing faculty together from different disciplines and things like that.

But I think that, at MIT, we're founded on solving problems. And even though you have to understand a system in order to solve the problems, I think that Environmental Initiative will be much more focused on solving immediate environmental problems. And that these long-term studies of how the earth works will go on, but not as focused initiative.

INTERVIEWER: And one other piece of what you have been discovering in your work has to do with viruses. Could you talk a little bit about that?

CHISHOLM: Yeah. Once we understood, got a handle on Prochlorococcus, had it in culture, had the genomes, I decided it was time to move outward and study their sources of mortality. And we knew there were viruses in the oceans. And that Sycechocossus' close relative had had viruses that infect it.

So I had a student, Matt Sullivan, who worked under the guidance of John Waterbury, who's a colleague at Woods Hole-- I should say too that I guess I haven't mentioned how important Woods Hole was in my early years at MIT and even the joint program with Woods Hole. I've graduate students in that. And John was very helpful in getting us into the virus field. So we started isolating viruses that infected Prochlorococcus.

And then, genomics was coming into the lab at that point. So we start sequencing viruses. And actually, before us even, a colleague in the UK discovered that viruses carry photosynthesis genes in their DNA. And they don't photosynthesize. So they've picked these up from the host during infection. And it turns out that there are other genes that they carry-- like phosphorus-acquisition genes-- lots of different genes that they carry that they use when they infect the host to redirect the host's metabolism. And so--

INTERVIEWER: It's symbiotic you mean?

CHISHOLM: Well, no. It's interesting you should ask that. Because the classic view of virus-host interaction is that it's predator-prey. Because the virus injects its DNA and uses the host's metabolism to replicate its DNA. And then, it bursts the host and spreads out all the baby viruses. Well, they're not babies. They're just viruses. They only have one age.

INTERVIEWER: The progeny.

CHISHOLM: Yeah, the progeny. Exactly. And so, that's the way it works with Prochlorococcus. But we started to think that, since the viruses carry these host genes, that there's good evidence that they're exchanging them. They're carrying them. They evolve in the virus. And then, they get put back in the host, in ways that we don't understand yet. But the virus almost serves as a way of creating gene diversity in some of these genes. And the virus also maintains diversity in the populations.

Because they-- and this is all speculation. There's like three people in the world that work on these viruses. So it's going to take a long time to get this nailed down. But the image that's starting to emerge is the viruses are really part of the system. And yes, that one cell may die. But that cell has a daughter cells all over the place that are genetically identical. And the viruses is playing a role in the flow of gene exchange and in maintaining the diversity of the populations, they say, by "killing the winner."

If one population is really abundant, the viruses will reduce those numbers so things are stabilized a little bit. So in fact, the whole field of microbial ecology is moving in the direction of viewing the system, the community, as a living entity, rather than a bunch of units that are competing or killing each other or whatever. It's a co-evolved system that is very metabolically interdependent.

INTERVIEWER: You referred to it somewhere-- the ocean-- as a machine? Or--

CHISHOLM: Did I? I don't think so.

INTERVIEWER: I'm not sure. I thought--

CHISHOLM: I don't think of it that way.

INTERVIEWER: --I saw that, but--

CHISHOLM: I think of it as an organism. I think of it-- yeah-- as a super organism. And then, the inhabitants are finely tuned and co-evolved. And that's what gives it its stability.

INTERVIEWER: And just to pull back and now talk a little bit about MIT. What attracted you to join the MIT faculty in 1976?

CHISHOLM: Oh, well, I had finished my postdoc. And at Scripps, in those days, you could only be a postdoc for two years. Because it was so beautiful. It was right on the beach. And everybody would want to stay there forever if they could. So two years, and you had to find a job. So I had to find a job. And so, I applied.

There was an ad in this department, describing somebody that was very much like me. And so, I decided to apply. And applied a bunch of other places and got some other offers. But I had another mentor at Scripps who had gone to Harvard. And he said, you don't turn down MIT. So I was sort of terrified to come here. But another option was a oceanography department in Canada, which would've been a much more relaxed lifestyle, and a small marine lab in Maine.

So I kind of knew, yeah, I probably shouldn't turn down MIT. But it was an odd fit, you know, Civil and Environmental Engineering Department. I was the only biologist. I was the only woman. And that's where the Woods Hole connection was huge. I felt there were colleagues there that I knew. And I felt at home with that connection. And so, I decided to give it a shot. And--

INTERVIEWER: Who were your early mentors or connections that were important?

CHISHOLM: Well, in the department, there was a chemist, Francois Morel, who's no longer here. He went to Princeton. And he was breaking into biology. And he saw that that's where the action and the excitement was. And so, he had some students working on phytoplankton. And so, the two of us kind of formed a group and, together, built over the years what we called the aquatic sciences group.

So I was still the only biologist. But there were chemists. And then, in Woods Hole, there was a man named Bob Guillard who maintained a phytoplankton culture collection there. That was very helpful to us in the beginning.

And at Harvard, a fellow named Jim McCarthy, who's still a professor there. He also encouraged me to take the job. Because he had been a graduate student at Scripps with my same mentor there. So I had a few connections that made it welcoming.

INTERVIEWER: And how has MIT changed during the time that you've been on the faculty? Any key moments or critical junctures that come to mind?

CHISHOLM: Interestingly enough, my immediate environment, my physical environment, has not changed a bit, which is the Parsons Lab. It's exactly the same building. It was renovated once over the years. But certainly, MIT has changed dramatically.

Noteworthy of course, is the number of women. The number of women students-- when I first came in '76, there weren't that many undergraduate women. There were enough, but not like now where it's almost 50%. I don't know what the percent was but-- and certainly very few women faculty and no women administrators at all. So that's changed dramatically.

But also, since genomics, the last, say, 15 years or so, I think my field has become much more recognized at MIT. We really used to be very much in the back waters.

INTERVIEWER: So to speak.

CHISHOLM: Yeah, so to speak. But genomics and molecular biology, as applied to oceanography, has made some of the things we work on so much more tractable that it's become a very exciting time in the field. And also, the Moore Foundation has poured a tremendous amount of money into marine microbiology. And that completely changed my life in the last 15 years too. It really made us able to run labs of a critical size and take risks and do things that we wouldn't have been able to do before just on NSF funding.

INTERVIEWER: Is funding difficult? Or--

CHISHOLM: It hasn't been. It traditionally always used to be. Well, when I first started, it wasn't too difficult. Things weren't that expensive. The Navy was investing a lot in basic research in biological oceanography. And NSF had had more money. So it wasn't too bad. But in the middle years, funding did start to get harder to get. And of course, you start to build a bigger lab and do more expensive things.

But I've always managed to do fine. But when the Moore Foundation entered the scene, that's when we really, really could do things. And it was tremendously exciting. And I could have a much larger lab. And have these people from diverse disciplines all working on Prochlorococcus.

And most importantly, we could take risks. And there's no question that the discoveries we made because of that were because of that kind of funding. They wanted us to take risks. They wanted us to tackle hard things. And now, the Simons Foundation has picked up in their funding the field.

So I've just felt incredibly lucky that, at this stage of my career-- because, you know, fields have these arcs. And usually, you enter an exciting field when you're young. And then, more often not, it will pass. By the time you're later in your career, that field's been replaced by something else.

The arc of my career is kind of the other. The field was just moving along steadily for years but not making many major breakthroughs. But now, toward the tail end of my career, it's just exploding. Which it's really exciting to see that happen.

INTERVIEWER: I'll say. And by the way, talking about MIT and the changes over time, could you talk about your participation in the committee that conducted the study on the status of women in the MIT faculty of science back in the 1990s and 2000s? What was that experience? What brought you into that? And what was that like at the time?

CHISHOLM: Yeah, that was extraordinary. And I have to say, that was definitely one of the most memorable periods at MIT. And what started that was Nancy Hopkins. It was a phone call from Nancy Hopkins saying, describing something that had happened to her and saying that she felt the situation for senior women faculty-- she was focused on-- just that they weren't getting their share of the pie.

And she just started calling. I think there were, maybe, 13 or 14 of us at the time. And she was focused on the School of Science. But I had a joint appointment in the School of Science. So I was on her call list.

INTERVIEWER: What was your experience before her call? What were you feeling?

CHISHOLM: Well, actually if I go back. When I first came here, even though I was the only woman-- and even though there weren't that many women at Scripps-- I was just one of those people that-- I was just doing my work. And I liked being one of the guys. And I wasn't plugged in to feminist issues or anything.

I think I enjoyed being surrounded by men. And I mean, I was young and I was single. And so, I was just working toward getting tenure and having a good time. But then, after I got tenure, I think--

INTERVIEWER: Which was at what point?

CHISHOLM: That would have been seven years after '76, so 1983 I guess. Actually, it's interesting. Memories are coming back. There was a group of colleagues. I lived in Newton. And one of my colleagues-- Keith Stolzenbach on the faculty in our department-- lived in Newton. And they had a carpool. They were all men. And they asked me to join their carpool. But they were all married man with kids. And so, they were 8:00 to 5:00.

And I was young, and I was single. And I said, I'm not going to go home at 5 o'clock. I go out and party. But they said, OK, but we have breakfast every Friday at the Hyatt. So at least join us for breakfast. So I said, OK, that would be fun. And it was sort of strange. I was the only woman. But they were these wonderful guys. They're still, to this day, my friends. We still have breakfast--

INTERVIEWER: Of different disciplines?

CHISHOLM: Yeah. And we still have breakfast on Fridays on occasion. We've lost one member. He died last year. But anyway, one of them was very into women's issues and was reading all kinds of things. And another one's wife was studying with Carol Gilligan at Harvard. And so, they would be talking about this stuff at breakfast. And I remember reading Carol Gilligan's book *In a Different Voice*-- I think it was called back then.

Anyway, I started thinking, something's registering here. And my colleague in the department, I think he was kind of encouraging me to get enlightened on what I was experiencing myself. But I also sat in on Evelyn Fox Keller-- she taught a seminar on her book *Gender and Science.* I think that was the book then. I'm pretty sure that's what it was. She had written a biography of Barbara McClintock, who won the Nobel Prize, and about her early studies and her early career.

Anyway, that experience-- I realized what I was experiencing. And luckily, probably, I didn't realize it all the time I was working toward tenure. Because I would have wasted of a lot of energy on it. But that was when, I think, my feminist needle just went from here to here. And so, that was soon after I got tenure. So then, fast forward.

So I started reading and reading the literature and realizing that it was exhausting to be trying to keep up with everything in the field at the same time, the micro-inequities; the studies of women having to be twice as good as men to achieve the same thing; the double-blind studies of CVs, showing exactly the same CV. If it's got a woman's name, that candidate will be judged lesser and all of that. And you never quite believe it applies to you.

But still, I realized that this was something that I had to really understand. And also, I started working with the women graduate students to help them at least appreciate what was happening around them. And anyway, so then fast forward to Nancy calling. And she called all of us and said, have you experienced any of these things or a feeling that maybe you're not getting the same share of the pie as some of the men?

INTERVIEWER: And you were? You weren't just reading about it? You were experiencing it?

CHISHOLM: Well, not tangibly. I couldn't point to a particular-- because I've always felt MIT has been very good to me. But I tend to look at the positive. I feel like MIT gave me my career. And I've felt that I had been fairly treated. And I certainly didn't have less space than other people. I think I probably had more space than other people.

But it's sort of a general sense of not being part of the club, just always being a little bit outside of-- noticing-- I always described it as, you're playing a game, like a football game or something. And they have the play-book. And we don't.

And that's the way it felt. Because you'd just be taken aback by learning something, some deal that was worked out or whatever. But I never had in my own experience-- couldn't put my finger on anything. But it was just that general sense that, yeah, it's not the same playing field. It's not the same playing field.

INTERVIEWER: And you felt that study really made a difference in terms of--

CHISHOLM: Well, yeah, I mean--

INTERVIEWER: --not just perceptions but in reality?

CHISHOLM: Absolutely. And the most exciting thing about that was, first of all, I met other women faculty. Because they're was, like, one of us in each department. We didn't really know each other. But I'll never forget the first time we all got together. And everybody was not wanting to look like the whiner. I mean, we're all accomplished, full professors at MIT. We made it. We're not really short-changed or anything.

And then, people started sharing stories. And before long, a half hour went by. And we were all on the same page. And it was just very-- you felt, finally, you've found your tribe, kind of. But then, the best thing about it was the response of the administration. They listened.

Bob Birgeneau-- I'll never forget the time we got an appointment. He was the dean at the time. And we all got together. And we marched to his office, not expecting anything to happen. Because so many women at other universities have tried to launch some of these equity studies and things. And it just gets put in a filing cabinet or something. And we all sat around his big conference table. And he listened. And he listened earnestly. And the same was Bob Brown and Chuck Vest.

It was just-- was very proud of MIT. It was just a really satisfying experience. We felt heard. And then, the study-- and changes were made, significant changes. And if you look at MIT now, just, it's amazing how. But it takes that constant vigilance to keep the numbers of women increasing.

INTERVIEWER: So now, just to present day, the Chisholm Lab at MIT, students doing research there-- could you just talk about what a typical day might be like at the lab? And what work is going on now?

CHISHOLM: Sure. I'm sort of embarrassed to have it called the Chisholm Lab. But that's--

INTERVIEWER: Your lab.

CHISHOLM: Yeah. That's the way we identify within the department. There's the Polz Lab and the Chisholm Lab and the whatever.

INTERVIEWER: Fair enough.

CHISHOLM: Yeah. I know that that's what it's called. You probably should call it the Prochlorococcus lab, but anyway--

INTERVIEWER: Chisholm's easier.

CHISHOLM: Yeah, exactly. Well, they do all the work. So a day in the lab-- we have people now. We have lots of cultures that we are taking care of, that we keep isolating more of. And--

INTERVIEWER: Are you still going on cruises?

CHISHOLM: I don't go. But the students do. And not a lot. Because we have freezers full of samples from all over the world. And what I've worked on the last couple of years, as I've gotten funding now to analyze all of these samples, we're doing metagenomics on all these samples.

And we can now do single-cell genomics. So we can grab a single Prochlorococcus cell from a sample from all over the oceans and sequence its genome. We don't do it. But we send it to a facility. So that's one big project we have going now.

I've decided there's several things I want to accomplish before I-- I don't say retire-- but before I wind down. And one is to really nail down this pan-genome by sequencing the samples in our freezers that are across all these gradients of different oceans and different ocean characteristics. So that we can map Prochlorococcus genome content onto the traits of the different oceans and really understand what's driving their evolution and their diversity. So that's a big project that we're doing now, which is funded by the Simons Foundation.

And the other thing I want-- one thing that we can't do with Prochlorococcus is genetics. So if we want to understand the function of a certain gene, we're not able to knock that gene out, which is a standard tool in any kind of modeled system that anybody uses in the lab. And because it's been just incredibly recalcitrant to any kind of manipulation. It does not want us to mess with it.

And it doesn't evolve very fast in the lab. We've resequenced, 10 years later, the same strain. And it just doesn't change. Because I think it's just this tiny little cell with this tiny little genome, all of which is essential to it. And it doesn't want to be messed with. But we're working on it. Because I think we need to be able to do genetics.

Because my other goal is to have a lot of people adopt the system, so that it will become-- like, E.coli is sort of the standard model microbe that people do a lot of molecular biology research on. So I want Prochlorococcus to be the model microbe for microbial ecology research and have a lot of people study it from a lot of different angles, so that it will live on and be famous, as it should. But in order to do that, we need to crack the problem of being able to do genetics with it, so that we can manipulated it a little.

INTERVIEWER: Although, that's what the viruses are doing, aren't they?

CHISHOLM: That's what the viruses are doing, yes. And then, everybody says, why don't you use viruses to do that? And I've had a couple people work on it and try. And it's actually quite difficult. And so, now I have somebody working on it from a different angle. So we're doing that.

And I have another-- I always say Prochlorococcus is the gift that keeps on giving. Because it points us in the directions we should be going. We don't really have to have ideas. Because it's always showing us something that we should study. And one of the recent things is that it makes vesicles. It buds off these little lipid-bound vesicles that it puts out into the seawater.

And through studying Prochlorococcus doing that-- the postdoc working on that went out into the ocean. He said, well, if Prochlorococcus is doing that, I wonder if other microbes in the oceans are doing it? So he studied it in seawater. And lots of different bacteria are putting these little vesicles-- they're packets of-- they have DNA in them. They have RNA in them. They have protein in them. They have all kinds of stuff. You talk about dissolved information.

And they're trying to tell us something. We don't have any idea what their functions is. So he's trying to carve away at that problem, which is really challenging. And then, the other thing that you'll find people working on, if you walk into the lab, is we're working on the bacteria that they grow with. And it turns out, Prochlorococcus-- it took us years to get them free of-- when you isolate them from the oceans, they're always heterotrophic bacteria, the ones that grow on carbon, they can't photosynthesize-- that come along with them.

And it's just been really difficult to separate them. But we finally figured out how to get them pure Prochlorococcus. And so, now we're putting them back together to try to understand what the conversation is, why they didn't like to be separated. So there's a lot of work going on that. And that's part of this co-evolved network. We think that their metabolisms are very tightly linked.

And they'll grow without each other, but-- well, the heterotrophic actually needs the carbon that Prochlorococcus makes. But it's also fulfilling a role. It's actually reducing oxidative stress in Prochlorococcus. So we're trying to understand that pairwise combination. And of course, the big question is all of them out there and how they're all interconnected and--

INTERVIEWER: So you're not running out of things to do.

CHISHOLM: No. We're not. We are not running out of things to do.

INTERVIEWER: I'm going to switch gears a little and talk to you about the children's books.

CHISHOLM: Ah.

INTERVIEWER: So if you could just tell us how that even came about that you're writing children's books.

CHISHOLM: Well--

INTERVIEWER: And what about.

CHISHOLM: Yeah, sure. Well, Molly Bang, who is my co-author and the illustrator of these books, is a friend of mine. She lives in Woods Hole. I've known her for a long time, probably 30 years maybe. And so, I watched her. And she's a accomplished children's book writer and illustrator. And I watched her make these books over the years. And at the same time-- I think I'll have a drink.

So at the same time, I was frustrated about how little people understand about how the earth works. And [CLEARS THROAT] excuse me. There was a Harvard-Smithsonian study of education. And they interviewed MIT and Harvard graduates at graduation day. And they said, here's a seed. Here's a log. Where did the weight of this log come from?

And none of them, at least none of them on the film-- you can find this on the web-- said, from the air, not recognizing that photosynthesis is the basis of making biomass on the earth. And it's drawing carbon dioxide out of the air with solar energy. And that's what made this log from this seed. And also, teaching an introductory biology class, I recognized how little time was spent on photosynthesis.

And so, I said, well, if we write a children's book, parents will read it. And at least, children will learn it. And parents will read it. And maybe they'll remember that they did learn it in the seventh grade, but forgot. Because I don't think that people can appreciate things like global warming and CO2 in the atmosphere and all of that if they don't understand the role of the biosphere in regulating the carbon dioxide in the atmosphere through photosynthesis. So that was kind of the motivation.

And so, Molly and I decided to write the first book, which is on photosynthesis on land. And by the time we finished that, had left out the phytoplankton. I said, we got to do the phytoplankton. So the second book is photosynthesis in the oceans. And then, the third book is called *Buried Sunlight.* And that's about fossil carbon, fossil fuel, and how long it took to bury it, and the problems with burning it now.

INTERVIEWER: Which I'd like to talk about more as well. Have you taken a stand, in terms of global warming and that whole issue? Have you spoken out on environmental issues? Have there been things that your research has led you to want to communicate with the general public about?

CHISHOLM: Well, I feel strongly about helping the general public understand the basics of how the earth works. I feel that if they understand that, they will make sound choices about things like global warming and things like that. So that's my top priority. The only thing that I've been pretty outspoken about is geo-engineering, which is the proposals-- and it started with the geo-engineering proposal that we might fertilize the oceans to draw CO2 out of the atmosphere.

And that emerged from-- I was involved in, actually, the first ocean fertilization experiment that was a scientific experiment. It was funded by NSF. And it was designed to study whether iron limited phytoplankton growth in the oceans. And it was a very small-scale experiment. And we were out there studying Prochlorococcus response to this added nutrient.

INTERVIEWER: And pardon me, but why iron?

CHISHOLM: Well, it turns out that iron can be the limiting factor for phytoplankton in some regions of the oceans. And in those regions, there's lots of nitrogen and phosphorus around. And those are usually considered the limiting factors, just like in your house plants when you fertilize them with Miracle Gro or something.

And so, people wondered, well, why aren't the phytoplankton using all that nitrogen and phosphorus in those regions? Because there's other regions where it's just sucked down to nothing. And the hypothesis was it was because, in those regions, it's actually iron that's limiting. And that if you add the iron, the phytoplankton can use all the nitrogen and phosphorus. And then, they'll bloom.

And so, to test that hypothesis-- which is attributed to John Martin, who actually was a close friend and colleague of mine, which is how we ended up on that cruise-- the idea was to just make a small tiny patch of iron-enriched waters out in the Equatorial Pacific and see if that created a bloom. Well, the press got a hold of that.

And I have to say, John Martin had encouraged this interpretation by saying, give me a tanker of iron, and I'll give you an ice age, suggesting that you could broadly fertilize the oceans and draw CO2 out of the atmosphere and cool the earth. And there was some evidence from paleo-oceanography that, maybe, this had happened in the earth's history.

Anyway, so entrepreneurs got a hold of this. And there were these proposals to commercialize ocean fertilization to draw CO2 atmosphere and have the phytoplankton suck it up and settle to the bottom of the ocean and that that would ward off global warming. And so, I wrote a couple of articles saying that this is just not a good idea. And again, people were ignoring all the unintended side-effects of doing something like that. So I've been pretty outspoken about "cures" that are worse than the disease.

INTERVIEWER: What concerns about the changes in pH in the ocean? Are there--

CHISHOLM: Yeah, like everybody, I'm concerned about the trajectory that we're on, which is another reason I wrote the third children's book. Not that children can do anything about it, but their parents will read it.

And it just very simply points out how long it took to bury that fossil fuel. And that most of our environmental problems-- a lot of them that boil down to us accelerating processes that are natural processes, but the earth isn't equipped to handle them at the rates that we make things happen. And I think if people understand that, they will think more carefully about the choices that we make. But I don't get involved in political activism and all of that.

INTERVIEWER: Do you still teach at graduate and undergraduate levels then?

CHISHOLM: Just undergraduate.

INTERVIEWER: Undergrad.

CHISHOLM: Yeah.

INTERVIEWER: And why is that important to you?

CHISHOLM: I love the MIT undergraduates. I think they're the most interesting kids. I shouldn't call them kids, young people. But they're all individuals. And they're all multifaceted. And I enjoy-- I teach part of one of the Institute core biology classes. So I enjoy bringing the ecology message to those students, since ecology is not very visible on the MIT campus.

In fact, there's only one class on ecology, which was the one I've been teaching for 38 years in our department. And so, I enjoy at least having that exposure to a large number of the undergraduates, to show them that there's this scientific field called "ecology," that's a strict natural science, and we actually do experimental work, and there's all this exciting genomics going on.

INTERVIEWER: In all different disciplines--

CHISHOLM: Yeah

INTERVIEWER: It's attacking.

CHISHOLM: I've managed, over the years, to seduce a few of them to going into the field. Because I think it could benefit from some of their talent.

INTERVIEWER: And you've been awarded some wonderful awards. And I wondered if you want to reflect on the three most recent ones at all-- the National Science Medal, the Killian Faculty Achievement Award, and your appointment as MIT Institute Professor-- in the aggregate? Or was there anything about any of them that is particularly striking and defining?

CHISHOLM: Well, yeah, they're overwhelming. And I always credit Prochlorococcus and all of these incredibly bright MIT graduate students and postdocs I've had. I always say, I must have done something. But I feel sort of unworthy. Because it's really the team of these bright people.

I always say, if you took my career and you put it somewhere else, I don't think it would have culminated in this. But I do take credit for keeping the focus, keeping the direction.

INTERVIEWER: Being the conductor of the orchestra.

CHISHOLM: Yeah, being the conductor of the orchestra and recognizing, years ago, that if we focused on Prochlorococcus, it had a lot of really interesting things to tell us. But the National Medal of Science, just, that was a real shock. Mostly because my field has always been a little bit back-watery. So it wasn't something that was on my radar screen at all.

And so, that was a shock. And I still haven't quite embraced the idea. And the Killian Award-- I felt incredibly grateful. How lucky can you be to have that toward the end of your career? Especially, again, because my field-- and I've always been a little bit an odd-ball at MIT. I'm a biologist in an engineering department. And so--

INTERVIEWER: I'm thinking big and small was also used as part of your praise, that you think both big and small.

CHISHOLM: Yeah. And I guess I will take credit for that, even though I never could have done it without these incredible students. Because I remember distinctly going and talking to Gabrielle Rocap-- she was the one who stewarded the genome. And I said, Gabrielle, we could get this genome sequenced. I said, I'm not doing it without you. And I said, are you in? And she said, oh sure. No problem.

So they have had my back all the way along. And so, I feel very, very lucky to have had all of them. And the Institute Professor again, that was just a total-- not something I ever imagined would happen. So I'm feeling very grateful and very lucky at this point.

INTERVIEWER: Good. And now, looking more broadly, we're looking at MIT's 100th anniversary of moving to Cambridge from Boston. And you've been on the faculty for about a third of that hundred years.

CHISHOLM: Whoo!

INTERVIEWER: Well, many of us have been around that long. How have MIT and Cambridge, would you think in your estimation, impacted each other during that time? Do you have some thoughts about that?

CHISHOLM: Wow, I have never thought of it that way. I've been here a third of the time? Oh my god. Well, there's been enormous change, obviously. I remember when I first came to interview. I stayed in a hotel in Harvard Square and took the subway here, got off in Kendall Square, had coffee at the F & T Delicatessen, which was this little train car with sawdust on the floor. And that was all there was around here.

And I was sitting there waiting till my appointment. And the whole area on this side of campus was just nothing. And so, over the years, I've watched all the biotech industry grow up and all the buildings around our building, the Stata Center and the McGovern, all of the molecular biology. And our building is still the same building sitting there.

So yeah, enormous changes in the campus and the industry. I guess that the biotech industry is just enormous. And again, an interesting thing to watch, in the context of our field. Because we don't have any products. We don't have any--

INTERVIEWER: Manufacturing.

CHISHOLM: Yeah, we don't have any patents and companies and all of that. But I always say, but we have exciting questions. So yeah, I think for me, I've never lived in Cambridge. So the influence on the rest of it-- but certainly, it's a totally different world.

INTERVIEWER: So then, you've talked about current projects leading into future dreams. Anything else about challenges for marine biology and genomics for the future? Or the legacy of your work? Or just, as you look ahead, what are your final thoughts about where this could go?

CHISHOLM: Well, as I look ahead from my own point-of-view, my own goals-- as I said-- would be to have Prochlorococcus have a home in many, many different labs around the country. And also, selfishly, I would like it's primary home to be at MIT.

So I would hope that, some time, we might have another faculty member who works on it. But I don't know. Because as I say, I have freezers full of samples and cultures. And also, I just think it's only begun to show us the exciting things that we could learn from it. But whether it stays here or expands to other-- some of my former students and postdocs are already carrying the torch. But I think I need to get a lot more established out there.

But I also see exciting times for a coming together of-- the field of biology, years ago when I first came here, was this completely split between cellular and molecular biology, and ecology and evolution. And slowly but surely, they have been marching together, in large part because of genomics and microbial, molecular ecology.

And so, I guess, what really would excite me would be to see that really come together in what's sometimes called the "new biology," where we see that you can't just study organisms in isolation. They're all part of communities of organisms. They're all in an ecosystem. And they're all shaped by the environment in which they evolve. And we're learning that now in human health.

There's this huge initiative on the human microbiome, studying the bacteria all over our bodies and the influence that those ecological community-- we are an ecosystem. There's no doubt about it. So I think, over the next decade, that the field of biology will start to be transformed into a much more integrative-- on the one hand, you have biological engineering and synthetic biology, where people are working on making life from scratch.

And on the other hand, I think we'll have people studying ecosystems as living systems that can be understood in an entirely new way. So it's going to be a really exciting time I think. And I hope to be around to see it.

INTERVIEWER: That's an excellent way to end, unless you have any other thoughts?

CHISHOLM: No, just again to express my gratitude to MIT. Because it's been a great place to me.

INTERVIEWER: Wonderful. Thank you so much for giving us this time.

CHISHOLM: Thank you.

INTERVIEWER: --this time.

CHISHOLM: Thank you.