Dr. Betsy Pugel interviews Dr. Gene Carl Feldman for “Straight from the Scientist’s Mouth”

[The views presented in this interview represent the opinions of the subjects. They do not necessarily reflect the views of the National Aeronautics and Space Administration.]

Betsy: Escape the playa heat as you join us for a swim in the ocean with Dr. Gene Carl Feldman from NASA’s Goddard Space Flight Center, today on “Straight from the Scientist’s Mouth.”

[music]

Betsy: So, I’m just going to start straight into the questions.

Gene: Do I sound better now?

Betsy: Yes.

Gene: Good answer.

[laughter]

Betsy: Before we start digging into the science, I noticed that you have a background that’s a bit different from the average scientist.

Gene: That’s for sure.

Betsy: Can you tell me a bit about your experiences in the Peace Corps?

Gene: Yeah, I didn’t follow the traditional route of just going to grad school and then onto a career. I took some time off after college and went to the Peace Corps. I worked as a fisheries biologist in a little island called Western Samoa [officially the Independent State of Samoa, since 1997], in the middle of the South Pacific. Got to learn a lot about the ocean, and one of the things that we used to do was go out fishing periodically, in these very small, leaky canoes, and when you’re in the middle of the Pacific Ocean in a 10-foot leaking boat, you have a lot of time to think about where you are and what you’re doing.

One of the things that I was always amazed by was [that] we could go to certain parts around the island, far away from land, you’d never see anything, but there would always be fish there, and that got me thinking as to why are there some places in the ocean that are more productive than others?

I mean, I couldn’t see any difference sitting on the surface, but obviously the fish knew that there was something unique about this one place in the ocean that was different than another place. You could go to another place; it’d look exactly the same, but you would never find fish, but you could always go back to this one location, and there'd be fish there. So, that got me thinking—this was back in 1976, '77—why are some places in the ocean more productive than others?

Anyway, that question stuck with me for awhile, and then after I got out of the Peace Corps and worked up in Alaska and did all sorts of things there, [I] found out that NASA actually launched a satellite whose very job was to try to understand why certain places in the ocean were more productive than others. It was sort of like a match made in heaven. I said, "Ah! That's what I want to figure out!"

Betsy: What kinds of things does this satellite see that might be in common with what the fish see or the fish know about the different areas of the ocean?

Gene: There are two things you really care about if you're a fish. One is, I want to be somewhere where there's nothing that's going to eat me. That's like the No. 1 thing that fish spend their days worrying about, is being eaten by something bigger than them. The other thing is, OK, where am I going to find food? If you think about what fish eat, they generally eat fish that are smaller than themselves, or if they're really little, they'll eat little plants, microscopic plants. Let's forget about seaweed. [That's] different. Let's talk about the main kind of plant life in the ocean, which are these microscopic plants called phytoplankton, and they're just usually single-celled, little plants that you need a microscope to see, and they float around in the waters, and the little larvae fish or very small fish eat these things.

We'll get into it a little bit later about why you can possibly learn anything about these microscopic plants from space, which in itself is a very strange thing, and why I, as an oceanographer, work at NASA, 'cause we're supposed to study planets. But the basic thing is, if you want to understand where the fish are, you need to understand where the food that the fish eat [is]. That's the bottom-line story on all this stuff.

[music]

Betsy: What is "phytoplankton?"

Gene: The word "plankton" actually comes from the Greek, it means "wanderer." It's not unlike the guy from "My Big Fat Greek Wedding," talking about, "This is from the Greek."

[music]

Gene: Anyway, it means "wanderer," and [the] reason it means "wanderer" is that these little things can't swim. They just drift with the current, so they wander wherever the currents take them. And "phyto" means "light." They're these little plants that life off of the light and wander around. That's what a phytoplankton is. Phytoplankton, being plants, require the sun to photosynthesize, which hopefully everyone who's listening to this has at least learned enough in college or high school [about] what photosynthesis is.

And there’s this little molecule called “chlorophyll” that traps light from the sun, and allows the plants to convert carbon dioxide and water into oxygen and carbon that they can use in their body tissue. That’s the basic photosynthetic equation.

[music]

Gene: Chlorophyll happens to be green, so here’s the million-dollar buyoff here. If something is green, and it’s in the ocean, and you have a lot of it, it turns the water a color. So what we measure from space is actually the color of the ocean, and here’s the real take-home message. For most of the world’s ocean[s], the thing that determines the color that you can see from space is the amount of phytoplankton in the water. The more phytoplankton, the greener the water; the less phytoplankton, the bluer the water. It’s that simple. You really don’t have to be a rocket scientist to understand that.

Betsy: How big is a phytoplankton?

Gene: How big is a phytoplankton? Really small. Really, really small. Most of them are single-celled. You have some idea how big a cell is. You can’t just see it with your naked eye, but they’re microscopic. Sometimes they form chains. There’s one called a diatom that forms these long chains. There are others that are bizarre shapes. There’s another one called coccolithophores—no laughing out there—that covers itself in calcium carbonate. The white cliffs of Dover are made up of eons and eons of coccolithophores that have fallen to the bottom of the sea, gotten buried, compacted, and then uplifted out of the water. All the white cliffs of Dover are nothing more than calcium-carbonate shells of these little, microscopic phytoplankton.

Betsy: They’re not big chunks of rock.

Gene: No, they’re not rock. They’re from—they were originally created from living matter. A really important thing: probably going to get to this, but, why should we care about the ocean?

We live on land. The ocean is kind of something that’s kind of just out there. Most people don’t think about it unless they happen to go to the shore. But if we’re thinking about global change, if we’re thinking about the global carbon cycle, if we’re thinking about carbon dioxide in the atmosphere, the common thread through all of this is carbon.

Over 99 percent of all the carbon that’s ever been taken up by organic matter on this planet is buried in marine sediments. It’s kind of a hard thought to get your brain around, but if you think about it, as long as there’s been life on this planet, carbon is the key building block. We’re a carbon-based life form. I think that’s from what? Star Trek, or something like that. We’re carbon-based life forms, so carbon plays a really, really important role in life as we know it on this planet.

Over 99 percent of all the carbon that’s ever been taken up by organic matter is buried in marine sediments, which says that if you really want to understand the role of carbon in the global carbon cycle, in global warming, the ocean is where you need to look, because that's where the long-term reservoir of all this stuff is, which means that that's where most of the life, most of the activity that messes with the carbon takes place. It's in the ocean.

Betsy: Can you talk a little bit about the carbon cycle for the listeners out there who are not familiar with it?

Gene: OK. Most people, if they hear the term "carbon cycle," think it's some fancy, expensive Italian bicycle that you race on. It's not. The carbon cycle, just like the water cycle, is the pathways through which an element or something is transported from one place to another, from one state to another. So, the carbon cycle—let's just use photosynthesis as one example.

Carbon dioxide, which is a gas, CO_2. One carbon [atom], two oxygen [atoms]. It's a gas. It's everywhere. It dissolves in the ocean. It's in the atmosphere. We exhale it every time we breathe out. That carbon atom is the source, pretty much, of all the organic carbon that we see, and the first intermediary step in that is photosynthesis. As I said before, when a plant photosynthesizes, it captures light from the sun with this molecule that's called chlorophyll, and then it takes water, which is H_2O, and then through the magic of the Krebs cycle [a process that combines H_2O and CO_2 to create other carbon compounds] and all this other stuff, it takes the CO_2, strips out the carbon (which is what it wants), combines it with a little bit of the water, and produces a carbon-based sugar molecule. And the byproduct of that, it releases oxygen.

So, lo and behold, if it weren't for the plants, we wouldn't have oxygen to breathe, so they're kind of important.

So now that carbon has gone from a CO_2 molecule, [which] was running around the atmosphere or dissolved in the water, into something that you can eat, or something that something else can eat, or something that creates your body tissue.

Then what happens is, OK, we're running around happily, and we get to be 80, 90 years old, and we die. We get buried back in the ground, and we decompose, and that carbon [from our bodies] gets respired by bacteria, and [they release] CO_2 back into the atmosphere.

So, that's sort of the cycle. It's this carbon being taken out of one state, in this case, gaseous, turned into body tissue, and then released at some point.

But there's a really interesting point, and this is something that everyone needs to understand. Let's think about the carbon cycle on land for a second, and the guys in the desert probably won't ever see this because there's nothing growing out there, but if you live in a place like New England, where there's a fall and a winter and a spring and a summer, every spring, the leaves start coming out on the trees, and the grass starts growing, and all these little plant molecules are taking carbon dioxide out of the atmosphere. The trees get bigger, and everything gets green, and it's wonderful.

And then fall comes, and everything changes color, and all the leaves die, and they all fall to the bottom of the forest or in your lawn. And then winter comes, and then spring comes, and, lo and behold, [there are] no more leaves around. They're all gone. What happened? During the winter and spring, a lot of that organic matter that was taken up in the spring and the summer is decomposed, so all that carbon dioxide that was taken up by plants during the growing season on land is released back into the atmosphere.

So, I'm probably going to get shot by all the land people here, but, if you really want to understand the global carbon cycle, if you really want to understand global warming and where CO2 is going, and greenhouse gases, the rainforests and the land vegetation [are] not where it's at, because that's not a long-term storage of carbon. That stuff just comes and goes every year. There's a cycle.

The oceans are where it's happening, as far as long-term sequestration of carbon. That's really the place where one needs to look if you want to look at the geological role of life on this planet in regulating how we can survive. As I said earlier, over 99 percent of all the organic carbon is in the ocean, so that's the place to look.

The land is great. Rainforests are wonderful. They have all kinds of cute, little, fuzzy creatures, but if you really care about carbon dioxide in the atmosphere, if you really care about greenhouse gases, that's not the long-term solution.

Betsy: What kind of technology are you using to look at the oceans?

Gene: NASA uses satellites that are essentially big light meters in space. Everyone that used to have one of those old-fashioned cameras with a light meter on it, if you point it at something bright, the little needle would move way up to the top, and if you pointed it at something dark, the little needle would move down. What we use in remote sensing, which is essentially a means of observing something from afar, are big light meters in space that look at different parts of the spectrum, so we have something up there that maybe has eight different wavelengths that it looks at. It'll look in the blue. It'll look in the green. It'll look in the red. It'll look in the yellow. It measures how blue, how green, how yellow, how red the light coming back from the Earth is.

We see color because of the way that the light that comes from the sun, which is sort of ubiquitous in all kinds of different wavelengths, is affected by what it strikes. And there are two processes. One: The color can either be reflected off of something, or the material can absorb color selectively. For instance, if you look at something and it's green, it's green because it absorbs blue and red and all that and reflects light in the green.

Remote sensing, in our case, of ocean color or land vegetation is nothing more than measuring how green or how blue something is. It's really pretty basic.

Betsy: Do you have to worry about clouds getting in the way or interference from other sources?

Gene: Remote sensing is a pretty tough job, and remote sensing of things on the Earth is even tougher. If I'm going to go send a sensor off to Venus or Mars, and everything I know about that planet has to be derived from what my sensor is telling me, then that's "truth." There's no little Martian going, "Waitaminute, no, that's wrong!"

On Earth, if I'm looking at a piece of land in Kansas, and my satellite algorithm is telling me that that's a wheat field, I've got Bob Dole sitting down there going, "No, that's soybeans." Ground truth on remote sensing is really tough, because we know what the right answer is, so it's a really hard job. The advantage of doing it from space is that it allows us to take that giant step back.

The oceans are really, really hard to study, if you are trying to do it hands-on. The land is a little easier. First of all, there's not as much land as there is ocean, so it's smaller. Two, it doesn't move. So, if you want to go back and study the same tree year after year, you can go back to that same tree. It's not going to move.

[music]

Gene: … The oceans are huge. Not only do they cover 75 percent of the surface of the Earth, but if we want to talk about the living space on this planet, over 95 percent of the living space on this planet is in the ocean.

[music]

Gene: Life exists in the ocean all the way from the very surface to the very, very, very bottom. Cool, cool story. Let me tell you a cool story. Life on land exists in this thin veneer. You have worms that live maybe a few inches below the surface of the soil. You have birds that will nest at the top of trees. So, on the land you've got this veneer of maybe a couple hundred feet where things can live.

[In] the ocean, life exists from the surface to the very bottom, and the deepest part of the ocean is the Mariana Trench, about 7 1/2 miles down. If you were down at the bottom of the Mariana Trench, the pressure on your body would be equivalent to 50 jumbo jets pressing on you. It's really not a great place to live [for people]. Humans have only been down there one time, in … history. In 1960, two guys, Don Walsh and Jacques Piccard, put themselves in a 6-foot titanium sphere, closed it up, and were lowered down to the bottom of the Mariana Trench, 7 1/2 miles down. It took them I don't know how many hours to get down there, and these two guys are crammed in this little titanium sphere, I think it was 6 [feet] in diameter.

The pressure was incredible. They get to the bottom. They turn on the light, and there sitting on the bottom is a flounder looking back at them, happy as could be, couldn't care less. And you've got to think. My God, this thing is living at the bottom. It's never seen light, and it's perfectly happy.

The point of that is you've got this huge volume of living space in the oceans that really is what this planet is all about. We call it "Earth," but really, it's "Ocean." That's the thing that most people really don't understand, because it's alien to us. You stand on the shore and look at the ocean, and all you see are the waves. You really don't know what's down below the waves, and that's what we, as humans, really need to get a grasp on, because half of the air we breathe, half of the oxygen we breathe, comes from the plants in the ocean. We never think about that. But the plants in the ocean are responsible for half the photosynthesis on this planet. So, half the oxygen we breathe is because of those little guys in there [phytoplankton], but we never think about it.

[music]

Betsy: At what depth do they live at, in the picture that you just described?

Gene: Phytoplankton, because they're plants, require the same things that the grass that grows on your front yard does. They need water. OK, water in the ocean, not a problem. … Plenty of that. They need carbon dioxide because of photosynthesis. Plenty of carbon dioxide in the ocean, and when that runs out, there's more of it in the atmosphere. … They need light. Light's a really critical thing for plants. The light in the ocean is decreased as you go down in the depths. So, in clear oceanic waters, there's enough light down a couple hundred feet for plants to grow. In really turbid coastal waters, it doesn't penetrate that deep because there's a lot of other muck in the water. And the most important thing is, they need nutrients: nitrates, phosphates, silicates, trace nutrients like iron. And this is the most important thing because, the place where most of those nutrients are, are in the deeper, cold waters. That's where they're kind of recycled, and that's where there's this huge reservoir of them.

So, anytime that there's a physical process that brings that cold, nutrient-rich water up near the surface, you're going to stimulate phytoplankton growth. It's sort of like when the chemlon truck comes to your yard and dumps the chemicals on it. All the little grass going, "Oh, boy! Oh, boy! We can grow now!" And they just start growing like crazy. They turn green. Same thing in the ocean, but it's a more natural process, where you'll have winds blowing across the water. You'll have currents moving that [bring] this cold, nutrient-rich water near the surface, called upwelling. There are places in the ocean where this upwelling is persistent. So it's like there's a continual supply of nutrients that keep this, this first level in the food web nourished, which then allows the fish populations to grow.

Some of the most productive regions in the ocean where the fisheries can really, really sustain a lot of human fishing activity—coast of Peru, coast of South America—[have] this continual upwelling process that just continually nourishes the phytoplankton. It's like going to an all-you-can-eat buffet. They can just go there all the time and just stuff themselves.

[music]

Betsy: Are there things that are happening in the environment that are reducing the amount of phytoplankton that contribute to the [size of the] fish population.

Gene: One of the really important things about trying to understand the Earth is knowing that it changes at different time and space scales. You can't go out just one time and measure something and then from that make a determination of how the ultimate state of the world is. It's like when you go to a doctor. If your arm fell off and you go to the doctor, yeah, they can see there's a real chronic problem. But generally what you do is you go year after year. You get an annual physical. It's not just to give the doctors more money, but they will measure certain key parameters about your state of health at that particular time, and then they'll check that the next year. And if you do this over time, what a doctor is able to do is see how the key vital signs that indicate your state of health have changed over time.

That's what we, NASA, do with the Earth. We are measuring the key vital signs of this planet and trying to understand over a long period of time how are they changing. We know that there's natural variability at all different times and space scales, but we also know—and there's a consensus now, thankfully, that is finally agreed—that we, as creatures on this planet, are also impacting the way the Earth is changing.

What we need to do is understand, one, what's the natural variability; two, what's the additional impact that we as humans have on this planet are producing; and three, more importantly what's the biological impact of those changes. We can go look for life on other planets, that's great and it's all exciting to do that, but for me personally, the life on this planet is enough of a wonder that I'm very happy just to try to understand this unique place that we call home.

For whatever reason, the physical processes, the chemical processes, the geological processes that all took place on this planet somehow created an environment in which life could flourish. As far as we know, there's no other place anywhere that's like that. So, it's pretty damn special. And I think what we need to do is understand how that unique combination of factors not only created the life that we have, but is able to support the life that we have, and we'd damn well better learn how the environment may be changing that could somehow impact the ability of the Earth to support life as we know it.

That's really, really an important thing to do, because we as humans, unlike any other creature that's ever lived here, have, within the last couple of hundred years, developed the ability to alter the planet on a global scale. And that's kind of scary if we do it without knowing what the consequences are.

[music]

Gene: The thing that I've really been struck with is how resilient nature can be if left to its own devices, to recover from what is essentially natural variability, natural disasters. The classic example for me of what happens when humans muck up the system was back in 1972. There was this major El Nino, which shut off the supply of nutrients to the coasts of Peru and Ecuador. The first thing that happens during an El Nino is the cold water upwelling decreases, so the area of cold water shrinks, and all the little anchovies that are used to living in the cold water all kind of aggregated into these little pockets.

The fishermen who didn't know any better, I mean, it wasn't their fault, thought, "Wow, this is great! All the fish are really congregating for us to collect in our big nets." And they did. In the 1972 period I think they caught something like 10 or 12 million metric tons of anchovies.

Betsy: So, it was a good year for pizza.

Gene: It was a really good year for pizza if you happened to be a Peruvian fisherman. Problem was that, because they didn't realize what was happening, that was all the fish there were, and they pretty much wound up catching all the fish in the whole area because they all aggregated, because they didn't fully understand it.

And what happened the next year when El Nino was gone and the [normal] system was back again, there were no fish. There were plenty of phytoplankton, but there were no fish to eat because the fisherman had caught them all [last year]. There were no eggs that had been laid and no fish to come back.

Between the regulators who manage the fishery and the scientists, they realized finally what the deal was with El Nino and its relation to the fishery. So now, if there's an El Nino, they realize there's going to be natural mortality of the fish. Some fish are going to die just because there's no food around. But enough [fish] will survive, if they [people] leave them the hell alone, to come back the next year and breed. So now when there's an El Nino, the fisheries managers come in and say, "Stop fishing. You're not going to be able to catch as much this year because we need to protect the fish to come back next year." So it's a really good positive example of how science and management can work together when you want to understand how the natural system works.

But unfortunately, I don't think there are enough good examples to really show how humans have to change their behavior in response to natural variability, to protect the environment.

Betsy: We often think of responding to climate change and global warming by doing something, but what you're describing is more not doing something, and not doing something is a consequence of understanding the natural rhythms of our planet.

Gene: Exactly. You just brought up a really good term, the natural rhythm.

[music]

Gene: One of the big problems that I think we as humans, in today's technological society, face is that we have lost touch with the natural creatures that we are. We isolate ourselves from the environment. If it's too cold, we turn up the heat. If it's too warm, we turn up the air conditioning. We don't go to sleep when the sun goes down. We just turn the lights on. If you don't understand the natural rhythms and natural cycles the way that we are connected to the natural system, then how can you respect the natural system and what it's trying to tell us? I think that's, in my mind, one of the biggest things that we need to teach our kids.

[music]

Gene: We are creatures that live in a natural world. We have to understand the natural world. That's what we, NASA, do. We're not regulators. We're not managers. Our job is to try to understand, observe, allow humans to understand their natural place in this world that we live in. I think it's through understanding that roll that we play, where we fit, what are our niches, that we'll be in a better position to really appreciate what we should or should not be doing and how the things that we do on this planet may be altering it in ways that really are not beneficial to us as inhabitants of it.

Betsy: So using technology as a way of understanding those natural patterns, as opposed to—oftentimes people look at technology as something that should be pushed away or shunned. What you're describing is the use of technology for the purposes of understanding nature and then allowing us to live in a more natural way in line with the technology we face day to day.

Gene: Exactly. In this case, ignorance is not bliss. It really isn't, because if we don't understand our environment, if we don't understand the forces of nature and how they work together to shape the environment in which we survive and thrive, then how can humans be expected to understand the consequences of their actions?

When the early pioneers moved out onto the prairies, they clear-cut everything.

[music]

Gene: No way at that point did they realize, "Well, if I cut down all of these trees, it's going to impact the global carbon cycle and CO2 in the atmosphere is going to build up, and then we're going to go into global warming." They had no idea. They just needed—they knew they needed to clear the land to plant crops.

Nowadays, we know the consequences of a lot of our actions, but unfortunately, economics still rule. We need to be careful that we balance our ability to sustain our populations with the bigger responsibility that we have to sustain the planet. Oftentimes those two are competing needs. If you've got hungry people that need to eat, we need to get food for them. If the most efficient way to get the food is to farm, there is a consequence to that.

It's a delicate balance, and unfortunately I don't think we've been doing it really well. And there's also another aspect of it, which—the developed countries are developed because they pretty much ignored the environment for many, many, many years, and did whatever they needed to do to develop themselves economically and technologically

Now we're at a point where the developed countries are telling the developing countries, who want to do the same thing, don't do that. In some ways it's a form of environmental racism, if you really think about it.

So there needs to be a little more sensitivity, I think, on the developed countries' part to recognize [that] we did all this stuff. We cut down all of our forests. We burned all of our coal. We're gas-guzzling SUV lovers like crazy. We should not be telling some poor, little Brazilian rainforest guy that he cannot cut down his one acre of trees because it's going to hurt the environment. We have to be really sensitive about that. There needs to be a compensation somehow.

Betsy: What kind of steps can our listeners take to help maintain or improve the health of the oceans?

Gene: Question No. 1 for your listeners: What is the biggest source of oil [pollution] in the ocean? Fill out your answer. I bet 90 percent of you say oil spills from those bad oil tankers. Wrong, OK? Ten times more oil goes into the ocean every single year from little Joe six-pack living in Kansas, changing his oil and dumping it on the ground or down the sewer or in the forest. Or that leaky oil that you've got dripping out of your car, one little drop every mile. That eventually gets washed into a river, washed downstream, and into the ocean. Ten times more oil goes into the ocean every single year from human activity like that, many of which we don't even know, than all the oil spills that all the big, bad oil companies could ever have produced.

So, yeah, those [oil spills] are bad. They're not good. They're localized disasters, but in the grand scheme of things, they're trivial. What's the old biblical saying about looking for the thing in your own eye before you look in somebody else's eye? There's stuff that you can do that can change the world. Recycle your oil when you change your oil, if you do it, or make sure you go to a place that recycles the oil.

Don't put so much fertilizer on your lawn. That stuff is ultimately going to wash off into the streams, and it's going to fertilize the near-shore waters [and] create way too much phytoplankton that when they die, the little bacteria are going to decompose and take all the oxygen out of the water and create these things called dead zones. Dead zones are there because we humans are pumping too much nutrients into the coastal waters. Nature's going to do what it's going to do; the phytoplankton are going to grow because it's like, "Wow! We're at the buffet! We can keep growing." But they die and they overwhelm the natural system.

Again, it's humans throwing nature out of balance. The key is balance. The natural system wants to be in some kind of natural balance among all of the different elements, and yeah, there are going to be perturbations, things that change from one year to the next. That's a natural system. I mean, 18,000 years ago, we were in the middle of an ice age. Humans had nothing to do with that, but we're at the point now where there are enough people on this planet, and we have the technology that is powerful enough that we can actually impact the climate of this planet.

That's a pretty, pretty sobering fact when you think about it, if we don't know how to do it correctly.

Have fun in the desert. Play nice. Wear your sunscreen.

Betsy: Definitely.

Gene: OK.

Betsy: Thank you very much.

Gene: You're very welcome.

[music]

Betsy: For more information on the health of our oceans, check out the link to our show on the Burning Man Web site [www.burningman.com]. You'll find links to further educate and empower yourself on environmental issues that come straight from the scientists' mouths. You can also find further information at www.nasa.gov/goddard. G-O-D-D-A-R-D.