Ask a Biologist Vol 008 (Guest Susanne Neuer)

A Breath of Fresh Ocean Air -

Yes, most of us know that plants and animals exchange carbon dioxide and oxygen gases, but how about the oceans - did you know that oceans breathe? Marine biologist Susanne Neuer talks about oceans, global warming, and life on not only Earth, but also the possibility of life on other worlds.

Transcript

Dr. Biology: This is Ask-a-Biologist, a program about the living world, and I am Dr. Biology.

[sound of deep breathing]

All this heavy breathing is just to point out that animals breathe in oxygen--which we also say is O^2--and out carbon dioxide, which is CO^2. These are both gases.

And plants and phytoplankton, which we'll learn about on this show, also exchange gases, but in their case they do the opposite: they breathe in or bring in carbon dioxide, and exchange that for oxygen. This makes a very nice balance for the Earth, because if we don't have those two working, it's going to be a little bit tough for either one.

But what you may not know is that oceans also breathe. Today our guest scientist will help us learn about how oceans breathe, and the role they play in the planet's ecosystem. She'll also let us know about how there can be deserts--deserts!--in the ocean.

Suzanne Neuer is an associate professor in the School of Life Sciences at Arizona State University. Dr. Neuer is an oceanographer, a biogeochemist, or what some people might call a "marine biologist." She is also exploring the outer reaches of space as an astrobiologist. Welcome to the show, Professor Neuer.

Suzanne Neuer: Thanks for having me on, Dr. Biology.

Dr. Biology: I have to start our talk off with a question I know you hear a lot: what's a marine biologist doing in the Southwest desert?

Suzanne: Well, you know, the oceans are very important, and they are very important for us even here in the desert. As you may know, three-quarters of the surface of the Earth is covered by the oceans, and as much as 98 or 99 percent of all the liquid water we have on this planet is contained in the ocean. The ocean determines our climate, determines our weather here in Arizona. So the oceans are important everywhere, just not when you live right at the coast. And we have, with all of the computers that we have available, the many data that are connected by marine scientists, by automated systems like buoys in the oceans, or by remote systems like satellites, we collect a lot of data that we can work with no matter where. We can be anywhere on the planet and work with data that are transmitted to your computer via the Internet.

Dr. Biology: So a lot of your work involves what is called "remote sensing devices." Just to give a little overview:

So, you can go out on the ocean, you can locate these devices where you need to put them to monitor things in the ocean and the environment, and they actually can send information back up to the satellite and back to your office in the middle of the Southwestern desert, where you work, you teach, you live. You can be a marine biologist without being on the ocean at that time.

Suzanne: That is correct.

Dr. Biology: If that's the way it works, tell me what these remote sensing devices do.

Suzanne: These remote sensing devices are sensors that are sitting on satellites, and the satellites orbit around Earth. So they are like big eyes in the sky. They look down on the ocean, and depending on what sensor is located on the satellite, you see different things. For example, the sunlight is reflected from the surface of the ocean, and depending on how many minute, microscopic algae there are in the water, the ocean has a little bit different color. So the more phytoplankton--we call these microscopic algae "phytoplankton"--the more phytoplankton are in the water, the water gets a little bit more green.

You can see that yourself when you are standing in front of a lake or a pond which is really green because there is so much algae in there, you see it really green. Now the open ocean never gets that green, but still the ocean color gets a little greener, and these changes in color are picked up by the satellite sensor, which is very, very sensitive, and converts it into data that tell us something about the biomass--that means how many microscopic algae there are in the water. And it converts it to maps where you see the whole of the ocean surface, and you see the distribution of these phytoplankton.

Dr. Biology: You've got this wonderful set of maps, and they're called "satellite oceanography maps." Just to give a little description, the top one looks very similar to something you might see in the evening news when they're doing the weather. It has all the different colors, from the yellows, the reds, the blues, and in this case it's talking about temperature. But instead of temperature, say, that we think about in the air, where we are, we're actually looking at the temperature of the ocean.

Down below you have yet another map that would overlay; it looks exactly the same but it is a completely different set of colors, and that one is showing us this phytoplankton again, and its distribution. So tell me the story of what these maps are helping us learn.

Suzanne: Yeah, the first map that you mentioned, on the ocean color, that's a different sensor that is on the satellite, that receives the infrared radiation coming reflected from the ocean's surface, and that is telling us something about the temperature of the ocean. On that satellite map of ocean temperature, it's only looking at the surface. We see a large gradient of temperature--very, very cold temperature around Antarctica and in the Northern Atlantic and the Northern Pacific, and then it gets progressively warmer. The warmest water temperatures, which are shown on this map in red, are right around the equator, so that's where the warmest water is.

When you compare the differences in temperature with the differences in phytoplankton biomass, you see something that is at first counterintuitive. Normally you would think from your experience from land, wherever it's warmest you have the greatest biomass, like the tropical rainforest, which is enormously, densely populated by a variety of different plants. On the other hand, in the ocean, wherever it is warmest you have the fewest phytoplankton.

But it can be easily explained by the fact that wherever you have cold water on the surface, it means it has been in exchange with deeper water which is colder and also nutrient-rich, and most of the phytoplankton in the ocean are nutrient-limited. So as soon as they get nutrients from below--through mixing with the storm process, or through upwelling, which is along the ocean, some of the ocean's continental margins, where actually water comes up from deeper down--the water is cold and loaded with nutrients, and that makes the phytoplankton really happy, and they start blooming; and in your satellite map of phytoplankton biomass you see, wherever water is cold, you see the greatest biomass. And in the map you see that, actually, in it; that's a greenish-yellowish color.

Dr. Biology: So we get a lot more food when it's cooler or cold...

Suzanne: Right.

Dr. Biology: ... and so we can have a lot more of these plants and animals which we call phytoplankton.

Suzanne: Phytoplankton are the source of, the basis of the food web. Everything alive in the ocean depends on the photosynthesis where the microscopic algae convert CO^2 into sugars. That is called photosynthesis. Another way to say that is, they fix carbon dioxide. Essentially, what you mentioned in the beginning, the breathing.

Like plants on Earth, they take up CO^2, and with the help of sunlight with, inside of the chlorophyll molecule, which is that pigment which is common to phytoplankton and plants on Earth, they make sugars; and so they build up biomass that can be utilized by sole plankton. Sometimes I compare phytoplankton, I say they're like the grass that we have on land, and the zooplankton are like the cows that we have on land, that feed on the phytoplankton. So the phytoplankton is the basis of the food web. Zooplankton feed on them, then larger zooplankton feed on the smaller zooplankton, then the fish feed on the larger zooplankton.

So the areas on the margins of the continents, which you see here is yellowish and greenish, like off Northwest Africa or off Peru, those are also regions where we have a great amount of fishery.

Dr. Biology: Let's talk just a little bit about plankton. We've been using that word, and it's actually a really great word. It's another word that the Greeks, we get it from the Greeks. It comes from "planktos" and it means "wanderer" or "drifter." There are three types of plankton, while we're talking about.

There is phytoplankton, which a lot of people might think are plants, but in reality we're talking mainly about algae, which are not plants.

Suzanne: Correct.

Dr. Biology: So be careful about that. And we have zooplankton, which are more animals. Again, all very small, microscopic. And then we have bacterial plankton. These actually fit, as you've mentioned, the food web beautifully. They are the producers, the consumers and the recyclers; and as you mentioned about, you used the word "fix, " in some cases an easy way to think about it is, they are moving energy from the sun into a plant or algae-type energy, which is then consumed--we have our consumers--by the zooplankton. Then later on, the bacteria plankton break it all back down, and that becomes reused by the whole system again.

Suzanne: Yes. Yes, yes.

Dr. Biology: Truly a food web. Since you mentioned the food web, how do they play in this term we hear so much about, "global warming"?

Suzanne: The oceans are incredibly important, and again, coming back to this analogy you used in the very beginning, I established that phytoplankton take up CO^2 and, as in all processes of photosynthesis, oxygen is being, is essentially a byproduct of photosynthesis, and that is released into the water and eventually into the air. So phytoplankton are really important in the carbon cycle of the whole global ecosystem because they take up CO^2, and as you all know, CO^2 is a very big issue right now, because by burning fossil fuels we are emitting a lot of CO^2 into the air.

CO^2 is a greenhouse gas; we now know that it is involved in the global warming that we are experiencing currently, and what happens is that the oceans take up about half of the CO^2 that we are emitting every year by fossil fuel burning, be it the energy generation in fossil fuel plants, or burning of gasoline in cars. So the oceans take up half of that CO^2, and so prevent our planet, essentially, from heating up too much. So without the oceans taking up this CO^2, the CO^2 in the air would be higher and our planet would be hotter.

This uptake of CO^2 is not only due to the photosynthesis by the phytoplankton. It is also due to the fact that gases--any gas, not just CO^2--is dissolved in the water. You may know that the colder water is, the more gases can be dissolved into it. So coming back to our satellite map of ocean temperature, you know that the coldest water is up in either Arctic or Antarctic, and that's exactly where a lot of the CO^2 that is produced by us, by fossil fuel burning, is sucked back into the ocean. And oftentimes in these high-latitude oceans, the water doesn't stay at the surface but sinks down to the depths of the oceans and then flows along the ocean floor. So we have a really great mechanism of taking up CO^2 in this case, and transporting it down to the deep ocean.

So it is both mechanisms--it is photosynthesis by the phytoplankton, which is very important, but it is also the dissolution of the CO^2 in the cold water of the world ocean, which helps, taking up the CO^2. So the phytoplankton not only take up CO^2 through photosynthesis, but they also make oxygen, so oxygen is a byproduct of photosynthesis. That's the same for phytoplankton as it is for plants on land; but one of the things we have to be aware of is that half of the oxygen that is in our atmosphere, that we are breathing, comes from the phytoplankton in the ocean.

Dr. Biology: The other thing we want to be careful about is, if we keep warming things up, since everything is more efficient with cooler water--the phytoplanktons are better there, and the water works better at breathing for us--if we keep warming things up we run into this problem where we don't breathe as well, and it does warm the planet, and it becomes this chain that we want to protect.

OK, we talk about going out into the ocean, and even though you are in the desert, you do go out in the ocean.

Suzanne: Yes.

Dr. Biology: How often do you go out?

Suzanne: I used to go out quite a bit. Before I came to ASU I was located at a university in Bremen, which is in Northern Germany, and I was responsible for a project that required a lot of going out on cruises, and I was gone maybe three to four times a year. These were cruises that lasted anywhere from two to five weeks, I would be out at sea. So I used to go out very often. Now, being at ASU, I work more with data that I have collected previously, or that have been collected with satellites, but I was out two years ago in the North Atlantic on a cruise.

Probably in total I spent, like, two years on the ocean.

Dr. Biology: With all that time on the ocean, do you ever get seasick?

Suzanne: I usually do get seasick. In the very beginning of a cruise, in the first one to two days, I am feeling queasy. Then, of course, it always depends how high the waves are, how much the ship moves. But it usually takes one to two days for me to develop my sea legs, and then it's all OK and I can work as if I was on land.

Dr. Biology: You know, at the beginning of the program we also talked about deserts, and deserts being in the ocean. There seems to be an awful lot of water in the ocean; how can there be deserts in the ocean?

Suzanne: Yeah, that is really something that is very curious. So as you remember, I was talking about the uneven distribution of phytoplankton in the ocean, and I explained before that it was very much related to, where you have cold temperatures you have more nutrients, and where you have warm temperatures there are fewer nutrients. So we have, actually, areas in the ocean where there are very few phytoplankton, and these are usually in the middle of the ocean, very far away from land; and on that satellite map you see, instead of having greenish colors, you see very dark blue colors.

So these are huge expanses. We also call them "the gyres of the ocean." So these are the centers of the oceans. What I have argued before, I have said, "OK, cold water needs a lot of nutrients, and these centers of the oceans have very warm surface temperatures. Consequently, these have very few nutrients." And phytoplankton, of course they have enough water, but out there in the centers of these vast regions of the oceans, far away from land, they actually are limited, they have few nutrients.

So while the deserts around us, here in Arizona, are clearly limited by the supply of water, in the ocean, the deserts, the phytoplankton are limited by the amount of nutrients they get. So there is very little cold water that is mixed in from below, so very little nutrients that come up, and so there is very few phytoplankton.

Dr. Biology: There is a very little amount of things that are living.

Suzanne: Yes, because the phytoplankton, as you recall, is the basis of the food web, so if there are fewer phytoplankton, it means there are also fewer zooplankton, and fewer bacteria, because there is not so much organic matter that they can degrade. So yeah, it is, everything is less, it's true.

Dr. Biology: Right, so we're not talking about water when we talk about deserts, then, we are actually talking about living things. That's more of a definition of a desert, and that is how we can have deserts in the ocean.

Suzanne: Correct.

Dr. Biology: Well that makes sense. Well, you have been doing this for quite a while. What have you seen happening to the ocean since you began your research?

Suzanne: I have been fortunate that I could be involved in a station in the North Atlantic in one of those deserts; and I have been working at one of those stations--stations in the ocean, for oceanographers, meaning that these are locations in the oceans where people go to, frequently, to measure parameters in the ocean, be it temperature or phytoplankton biomass, or how many nutrients there are. We also have equipment out there in the deep ocean that, for example, measures how many particles fall out of the upper water and fall down to the deep ocean. So these stations are really a little bit like monitoring stations, where we can keep track of changes that are happening over many years. Usually there are many nations involved with these, since oceanographic research is very expensive.

A few things that we have been monitoring, for example, is if the ocean has been warming up. During this past decade that we have been working there, we have seen, actually, a rise of the surface water temperature.

Dr. Biology: How much on average? I know it varies.

Suzanne: It is, it varies because there are also natural variabilities that, the overall large-scale variability overplays over the natural variability. So we may be seeing a warming in terms of maybe half-a-degree Celsius, which is maybe a degree Fahrenheit. It doesn't seem very much, but for an oceanic food web which is very much used to very stable conditions, this is really a lot.

The other thing we have been seeing, because when the CO^2 dissolves in the water part of it forms carbonic acid, and so one of the consequences of the ocean taking up CO^2 is that the ocean becomes slightly more acidic, and that is--some of the phytoplankton get in trouble when the water gets a little bit more acidic, because some have carbonate shells, and you may know that if you drop vinegar onto carbonate, maybe some carbonate rock or chalk even, you'll see it fizzing, it dissolves. So the phytoplankton that have carbonate shells actually do a lot worse when the PH drops.

Dr. Biology: Not a healthy environment.

Suzanne: Not a healthy environment for them, and then there are all kinds of changes within the food web, because if they do worse, the ones with the carbonate shells, others may do better, and so you may see a shift in the composition of the community. It's like when you are out here in the desert, like let's say the saguaros become less, but instead you get more sagebrush. That can happen in the ocean, and because of the food web, the zooplankton are all dependent on having a certain type of phytoplankton. Then they have to adapt, and those that do not, that cannot adapt, they essentially starve.

Dr. Biology: And die, right. So is global warming responsible for many of the things you've seen, and--let me just add this little extra bit to it--do you think humans are a large part of global warming?

Suzanne: In the past couple of decades, the scientific evidence has been rising. Not only do we experience global warming, but the activity of humans, mainly by burning fossil fuels such as oil and coal...

Dr. Biology: Driving our cars.

Suzanne: Driving our cars, and a lot of it also is burning of tropical rainforests, where a lot of carbon is stored, that has contributed to global warming we are witnessing. In fact, the scientists speak now of a 90 percent certainty that we contribute part of the global warming that is happening.

Dr. Biology: Tell us a little bit about your work in astrobiology.

Suzanne: Yeah, this is an interesting story. So, a while ago, I've become interested in one of the moons of the planet Jupiter. One of the moons, the name is Europa--it has nothing to do with the continent Europe, it is called Europa after the Greek goddess Europa--it's a very curious moon. It is about the size of Mars--a little bit bigger than our moon--but it is covered in an icy shell, and some spacecraft that have been observing

Europa and Jupiter system in the '70s and '80s actually discovered that there may be a liquid ocean underneath the icy shell, and that is an incredibly exciting discovery because liquid water is one of the great prerequisites for life as we know it. So people have become very curious about the possibility of having water underneath the ice, or even life within the ice of Europa.

And because we cannot go easily to Europa--it's very far away and it is very expensive to do these missions--we have begun to look into systems on Earth that are the most related, most closely related to this ice on Europa. Of course, Europa has incredibly low temperatures, and we fortunately don't have that anywhere on Earth, but we have become interested in the Arctic sea ice as an analog--meaning as a similar system--than what we are seeing that the icy shell of Europa is like. My group has started to look into Arctic organisms that are... so when the Arctic ice forms every winter, around the continent, for example, of Alaska, some of the phytoplankton in the ocean become enclosed in the ice; and when ice freezes it is the fresh water that freezes out first, and what is left behind is very saline--brine, essentially.

Dr. Biology: Very salty.

Suzanne: Very salty, right. So these phytoplankton have learned to live, over winter, essentially, in these brine channels; and they are very, very curious, because they are essentially, over winter, in this brine, and then the next spring when the ice melts they can seed the water column and essentially start a new bloom there. So we are studying some of these organisms that we find in the ice, and look at how well they are adapted to life in cold temperatures and high salinity. And we are finding that some of them are really very well adapted, and so we are saying life can be adapted to these extreme environments that for us would be way too cold and way too salty, but they are adapted to it, they can deal with it, and they can survive it. And so not only do we learn something about the organisms that live in the ice, we also learn about possibilities of life if it ever existed or exists on an icy moon such as Europa.

Dr. Biology: Right. You actually brought up a really interesting word. You said, "Extreme, " and a lot of these organisms have a named, called "extremophiles," and there are other ones besides the ones that are in the very cold. There are some that live in very hot temperatures. So this is going to be a study for a lot of people that are doing astrobiology: since you can't go to Mars, you can't go to Europa very easily, find something that's similar, see what can survive there.

Tell me, since you've actually been studying the depths of the ocean, and you are in some ways into the stars, when did you first want to be a scientist? Where did you get started in this?

Suzanne: I have wanted to be a marine biologist since I was maybe 13, 14 years old, and it all started by having the opportunity to go on summer vacations back... of course, I grew up in Germany, and many Germans, they go down to the Mediterranean, to Spain, in summer, because they like the sun and we don't get too much sun in Northern Germany. I had the opportunity as a child, as a young teenager, to snorkel around in the

Mediterranean, and I saw the life in the ocean that you can only see when you have a mask on and maybe a snorkel in your mouth. And so I started falling in love with ocean life.

Then I also became very interested in microscopic life, and I started jobbing around as a teenager, and then I saved money and I bought my first microscope--I think I had that when I was 14, 15 years old--and I bought a camera, and I bought an adapter. Back then, of course, it was all a lot of money for me. So I started very early, going into, liking marine environments but also doing some microscopy, then, of some ponds that were around where I grew up. So I knew very early on that I wanted to do marine biology.

Dr. Biology: Yeah. "Microscopy" is such a fun word, and I am actually a microscopist and we always define that as "anybody who can say the word 'microscopy.'"

What if you weren't a biologist? What would you be?

Suzanne: I probably would want to be a doctor. Actually, there was a time when I was just being done with high school and starting to study biology, where I worked as a nurse helper in the hospital, and I found that very rewarding, being able to help people who were sick. So for a while I was doubting. So I think that if I hadn't become a marine biologist I might have become a doctor.

Dr. Biology: What advice do you have for young scientists? Because not everybody gets to start out young, some of them actually start out a little bit later, but what do you think is the best thing?

Suzanne: Yeah, you definitely don't have to start early to become a successful scientist. In fact, I know a lot of successful scientists who tried out different things and came into science relatively late. So you don't have to become interested as a teenager. But if you do, if you do become interested in science, one of the things you may want to do is to find other teenagers who are interested in science, and maybe join a club in your high school, a science club, talk to science teachers, maybe get in touch through your high school, through your science teachers, with programs which make link you with labs at a close-by university, where you can then maybe visit a lab or maybe work with a student in a lab, get some hands-on experience.

You know, the whole thing is not to be on your own and trying to do it on your own, but find like-minded people, friends. Talk to science teachers who may help you out, try to get your hands wet. Maybe there are summer programs that you may find, where you can actually go to labs. If you are interested in marine biology, there are programs for high-schoolers where you can actually get your hands wet and see if that is really the thing for you. Because the scientists who are now in school, in middle and high school, are probably the ones who will be finding out a lot about the future progress of the world; and the scientific problems we are encountering right now will be researched and maybe be solved by the next generation of scientists, who are now in school.

Dr. Biology: Well, Suzanne Neuer, thank you so much for visiting with us today.

Suzanne: You're welcome.

Dr. Biology: You've been listening to Ask-a-Biologist, and my guest has been Professor Suzanne Neuer from the ASU School of Life Sciences. The Ask-a-Biologist podcast is produced on the campus of Arizona State University. Even though our program is not broadcast live, you can still send us your questions about biology using our companion web site. The address is AskABiologist.asu.edu, or you can just Google the words "Ask-a-Biologist." I'm Dr. Biology.