Ask A Biologist Vol 091 (Guest Klaus Lackner)

Hacking Nature

Hacking is a word that is often tied to something bad. However, there are times when hacking can be for something good. Think of it as a tool that can be put to use for good or bad. We also think of hacking as something only done with computers, but can we hack other things? Dr. Biology sits down with scientist Klaus Lackner to talk about how he is hacking the environment in order to pull carbon dioxide (CO2) out of the air. If he succeeds, it could help reduce CO2 in atmosphere and redirect it towards better uses.

Transcript

Dr. Biology: This is "Ask a Biologist," a program about the living world, and I'm Dr. Biology.

Hacking, a word that's often used today. It can mean something bad, such as hacking into a computer to get personal information or to do other harmful deeds. Hacking can also be used to describe pulling together a team of people to collaborate on a computer software project.

There are even hackathons and hack fests held by different groups around topics like security, technology, and gaming.

What if we turn our attention to other areas besides computers? Can we hack other things? Like, maybe, nature? If we could, what would we do that nature does not already do better than humans?

Today, we'll be talking about one area where hacking nature might be important for our planet. It involves the CO2 molecule, also called carbon dioxide. As we know, CO2 is the primary greenhouse gas in our atmosphere that is causing the planet to warm.

For today's show, my guest is Klaus Lackner. He's a professor in the School of Sustainable Engineering and the Built Environment in the Ira A. Fulton Schools of Engineering at Arizona State University. He's also the director of the Center for Negative Carbon Emissions at ASU.

His research with carbon, and how we might capture carbon dioxide from the air, is one way we might help the environment. In this case, we might be able to hack the environment, to reduce the carbon in our atmosphere. Professor Lackner, thank you so much for joining me today to talk about this important topic.

Prof. Klaus Lackner: I'm glad to be here.

Dr. Biology: When people talk about changes in climate, we talk a lot about the carbon dioxide molecule. Why is having more CO2 in the air a bad thing?

Klaus: If there's just the right amount, it's actually a good thing. There is a CO2 molecule, which is a carbon atom with two oxygens attached. It is a tiny part of the atmosphere. It used to be 280 parts per million. For every million molecules in the atmosphere, there are 280 which are CO2.

That's actually very important, because unlike the nitrogen in the atmosphere, unlike the oxygen in the atmosphere, which are the main stuff, the CO2 absorbs infrared light. That makes it different.

Dr. Biology: In what way does it make it different?

Klaus: If you think about the earth as a whole, we are having sunshine coming in. A little bit of it is reflected back out in the atmosphere. There's light bouncing right off that never affected us. Most of the light, two-thirds of it, at least, manages to get down to the ground. It gets absorbed. That light has energy.

That energy now is absorbed and turns into heat. The planet has to get rid of that heat. On average, it's in perfect balance. For all the light coming in, it has to go back out. It turns out if you have a temperature like the planet has, this energy is radiated back into space, as infrared radiation.

It's different from light in that the wavelength is a lot longer. The remarkable thing about the atmosphere is, in the visible light, in the short wavelength, it's perfectly transparent. The sunlight coming in comes all the way to the ground, but the infrared going out is stuck. The atmosphere absorbs it again on the way out.

The fact that we are not an ice ball, which the earth at some point has been, is due to the fact that we have a little bit of CO2 in the atmosphere, which is just enough to keep the temperature in.

Dr. Biology: It's that balance. A little bit of CO2 is really important. Otherwise, we're an ice ball.

Klaus: If you have too much, the planet gets warmer and warmer. The first person who actually figured this out was a famous mathematician and physicist in the early 1800s, Fourier. Fourier wrote a little treatise -- it's a little booklet -- in which he said the temperature of a planet will depend on what kind of atmosphere it has.

He had figured out the principle. He didn't know anything about CO2. He didn't know anything about infrared, really. That was all still in the future, but he got the idea right.

In the mid-1800s, Tyndall, in Britain, did a number of measurements. He said, "Well, nitrogen doesn't absorb any infrared. Oxygen doesn't absorb any infrared. The only two gases in the atmosphere which actually do are CO2 and water." The water comes and goes, with the rain, and you can't change it. The CO2, we are changing.

In 1897 or '98, Arrhenius, a Swedish chemist actually, started to work this through, and he calculated how much warmer the earth will get, if we double the CO2 in the atmosphere. He got it just right.

The bottom line is there's nothing really new in the greenhouse effect. We understand it quite well, and the planet will get warmer. The next big question is what will that do to the planet?

Dr. Biology: And reasons for it getting warmer. Where is the CO2 coming from, the extra CO2?

Klaus: Since the end of the Ice Age, the CO2 in the atmosphere has been constant. It has been around 280 parts per million. Then with the beginning of the Industrial Revolution, the CO2 in the atmosphere is starting, first slowly, then faster to go up. The reason this is happening is because we are burning fossil fuels.

We have burned coal, then we discovered oil, and now we use natural gas, and those three things add to the atmosphere. As a matter of fact, since we still can account for all the coal and oil and gas we put out, at least approximately, we actually know that the CO2 should have gone even more. Some of the CO2 which we put out has gone somewhere else.

Most of that is probably in the ocean because the ocean dissolves that CO2. It's carbonic acid. If you bubble CO2 into water, it becomes slightly acidic. That's where the CO2 goes that doesn't stay in the air.

Some part of it also has gone into biomass. We have grown trees, we have more leaves on trees because it's warmer and there's more CO2, but then we also cut down a lot of trees. In the total probably the biomass has lost.

Dr. Biology: We've increased the amount of carbon dioxide in the air?

Klaus: Yes, and substantially. We started at 280 parts per million, and we are now at 400 parts per million. When I started to work on this in the early '90s, it was 360 parts per million, and it is now going up by a little more than two ppm every year.

The general consensus right now is, and people can argue about the details, that things become awkward, or possibly harmful, at around 450 parts per million.

Now, there are outliers on both sides. There are some people who say we really should have stopped at 350 parts per million. Other people say, maybe, 550 is manageable, but I think there's hardly anybody who says he can do this indefinitely.

As you put more and more CO2 out the effect will get larger and larger. Once you put it there, most of it will not go away.

Some of it will go in the ocean, some of it will go into biomass, but it's fair to say that half of it is still there in a couple of hundred years from now. To get rid of that last quarter, you probably talk tens of thousands of years.

Dr. Biology: This is a perfect time for me to mention, you're working on a way to remove some of that extra carbon dioxide?

Klaus: Yes, and part of the reason I got involved in this is I am very much convinced that we need a lot of energy for today's 7 billion people, possibly in the future 10 billion people, to have a decent standard of living.

Right now, the vast majority of this energy comes either from coal or oil or gas. We can argue whether or not we run out. The answer is, of course eventually we will run out.

Did we make a very big mess beforehand? Will we run out in the next decade? In a hundred years from now? Or will we run out in 500 years from now? That's a hard question to answer, but if you look at how much coal is in the ground, we definitely will not run out in the foreseeable future.

In the 1980s South Africa, because of its appalling apartheid policies, was actually embargoed by the rest of the world. Specifically, they had no access to oil, but they have internally plenty of coal.

They demonstrated back then that you can take that coal and convert it into gasoline, which tells me that in some way or another if we were actually sure there is no more oil, we might actually start going after the coal.

What concerned me was, if you look at the budget from the other side, and says, "How much CO2 can we possibly afford to put in the atmosphere?" We have way too much fossil carbon to make this work. We are not resource limited, in my view, in the sense that we run out of fossil carbon. We are environmentally limited.

Dr. Biology: To actually put it, maybe, in this view is we have too much of this.

Klaus: We have too much of it?

Dr. Biology: For our own good.

Klaus: For our own good. Or we have to figure out how to not get into trouble. Very clearly, we either abandon fossil fuels, or we figure out how to balance the books. This is where I started. We will have to have a net zero balance of carbon emissions. If we emit, we have to take it back.

What has changed, from my perspective, in the last decades, is that we look better and better at having other alternatives. They are still decades away. By now, we have put out so much CO2, that we may not have a choice, but to get it back and put it somewhere.

We already are too late to say, "We just stop." If we stop today, we will live with a 400 ppm climate.

If by magic, I could say, "We, from here on out, will hold the line at 400 ppm. Next year, you are allowed a little bit of emissions, because the ocean will take a little."

The unfortunate part is the ocean will take every year less. In a matter of decades, your CO2 emission has to go to zero, to hold the 400 ppm line, or very, very close to zero.

Dr. Biology: Your research is, "How do we get it back out of the air?"

Klaus: My research is right now focused on how to get it back out of the air. A larger picture I'm worrying about is what do we do with all that carbon we collected?

Dr. Biology: Let's start with the first one. How do we get it out of the air?

Klaus: A tree can do it. If you look at a tree, a tree stands out there in the wind. It sees sunshine. All those leaves absorb CO2. We said, "Well, we need something like a leaf so the surface has to be sticky for CO2." It binds C02. Then at some later time, we take the CO2 back off.

Over the last ten years, nearly, we are working on a process where we use a material that when it's dry, really likes CO2. When it's wet, it gives it back.

Dr. Biology: You use that for storage?

Klaus: No, we use it for capture. It's a temporary thing. My first goal is to stand in the dry, desert air here in Phoenix, and let the surfaces we created, these filters, if you wish, the air moves over it and things stick to the surfaces. In our case, it's the CO2, and when they're dry, it sticks very well.

Then we collect our filters in a box, make them wet, and now the CO2 level in the box goes up to about five percent. The material now, when it's wet, doesn't want the CO2 anymore, and that's [inaudible 00:12:58] .

We can pull that out, and now we have a stream of five percent CO2. We can upgrade to 100 percent CO2, because that's what a power plant would be doing.

We now have a problem which is very similar to them, where we directly feed it into a greenhouse, where somebody might want the CO2, or we figure out how to have the CO2 react with minerals to form carbonates.

That's how we would throw it away. We either use it, or we find a way of thinking of it as a waste.

Dr. Biology: Do you see that as a storage method, or do you see that just as a waste?

Klaus: I ultimately would think of it as a waste. I think we actually, philosophically, haven't quite gotten to this point, in our discussions. I give you a simple example how it changes the way you think about the problem.

Let me say hypothetically, I don't smoke, but let's assume I did smoke. I have the horrible habit of throwing the cigarette butts out along the highway as I go along. I come to you and say, "Since you complained about it, I have figured out how to reduce my cigarette butt production by 20 percent, because I'm smoking longer cigarettes. Aren't you proud of me?"

Are you? Not really. You would say, "Look, you made a mess beforehand. Yes, you make a smaller mess, but you're still making a mess. You need to properly dispose of these things. You can't just throw them out of the window of your car."

The same would be true for sewage. The same would be true for the garbage at home. By simply phrasing the problem as a waste problem, it becomes very clear you shouldn't litter. You shouldn't dump CO2 into the atmosphere, period. To the extent that it ended up there, you are responsible for taking it out.

It's not good enough to increase efficiency. I don't want to discourage that. By the way, the waste disposal way of looking at it, clearly doesn't discourage it. If I look out of the window, when the garbage truck comes by, it has written in big letters, "Reduce. Reuse. Recycle." It's motivated by the fact that, otherwise, the garbage has to be landfilled. That costs money.

Everybody agrees it's better not to make it. That's where the reduce comes in. If you can avoid landfilling it, because you still have another use for it, please reuse it. If you can't reuse it the same way, maybe you find another use for it, which you would call recycling.

That's all good, but it's driven by the fact that it's a waste you wanted to get rid of. Here too, the CO2 is the waste product of making energy. Unfortunately, it's a very, very, large waste stream.

Here in the US, we produce about 15 to 20 tons of CO2 per person, per year. We don't use materials at that scale, with the one exception, that's water. Everything else, we use at much, much smaller rates.

I'm very skeptical that we find lots of uses for CO2, which absorb this enormous stream of CO2, which comes from our energy consumption. The only exception is if we make fuel again. In that case, we are not using fossil fuel anymore.

Dr. Biology: If you don't use fossil fuel, then you're not adding to the CO2 in the atmosphere. Then if it's used as energy, now we have a whole new other option for getting our energy.

Klaus: Envision a world, which uses solar energy. Sometimes you have sunshine, and sometime you don't. You, on average, want to have enough energy. Sometimes you will have too much. When you have too much, make fuel. You collect CO2 and water. So to speak, with the energy, you "un-burn" it.

You take the oxygen out of the H20, and one of the oxygens out of the CO2. Now you have CO and hydrogen. Chemists call that syngas or synthesis gas, which is the starting point of making plastics, and making fuels. The energy you put back in, by using a solar panel.

Now you have new fuel. The energy in this fuel came from your solar panel. You can drive a car, or fly an airplane. That airplane then consumes that energy. In the process it produces, again, CO2 and water. You take that back out of the atmosphere, and the cycle is perfectly closed.

Dr. Biology: You actually mentioned fuels and plastics. That's actually an important point, because the fossil fuels aren't used just for gasoline, or some kind of a product that we're going to use for powering things.

Klaus: Yes, you can get the plastics from the same source, but you have to put the energy in. Energy, once you took it, is gone. That's what makes the CO2 truly a waste product. That coal, oil, or gas was a carbon form with lots of energy. You took the energy out by sticking an oxygen onto it.

If you want to get the energy back in, you have to take the oxygen back off. That's, in effect, what biology does. One way of closing this cycle -- this is something we are working on here, with Bruce Rittman and his group -- is we say, "Algae would like to do photosynthesis. They convert sunlight, CO2, and water into biomass, into storage, into bio-oils, into energetic carbon compounds." That can be done.

If your algae grow inside a bioreactor, they need CO2, which they cannot take out of the air, even if they are in an open pond. They would like to see more CO2. Either way, we can come along and say, "We collect CO2 out of the atmosphere. We feed it to the algae. The algae now make fuel."

Dr. Biology: We have an algae farm connected to your apparatus, that actually pulls the CO2 out. You feed the algae. The algae produce the fuel. This sounds great. It means if we get this all working, we have algae farms.

We have your mechanism of feeding them CO2. Sounds like a great idea, the same thing with the solar panels. If this all works, do we need to worry about carbon emissions anymore?

Klaus: Yes and no. The problem with the surface of the planet is it has a certain amount of carbon, some of it in the ocean, some of it in the air, some of it in the biomass. We come along, and we add to that. There are huge fluxes, by the way.

There's a huge amount of carbon dioxide, going from the ocean into the atmosphere, and back. There's a huge amount every year, which goes into all the leaves in the plants, which then fall back on the floor and rot. Those are big numbers shifting back and forth.

Dr. Biology: Part of the carbon cycle that...

Klaus: That's part of the carbon cycle. The total amount of carbon, in the ocean, in the atmosphere, in the biomass, doesn't change. On average, these groups don't change. There's big fluxes in and out. On average, nothing changes.

Now we come along, and we steadily, every year, add carbon dioxide to the atmosphere, which was not in this part. It came from underground, deep underground, where for millions of years, it hasn't been touched.

Dr. Biology: The balance has been thrown off.

Klaus: We are constantly throwing the balance off. If you look at it, every year, if you go to Hawaii, every year the CO2 in the atmosphere goes up and down, 6 ppm all by itself.

The reason is every summer all the photosynthesis in the Northern Hemisphere sucks out the CO2. Every winter, respiration wins, and it all comes back into the atmosphere. If we weren't around, every year there's this saw tooth, peak to peak, there's a 6 ppm every year.

Dr. Biology: It's just that that peak, that band, is shifting.

Klaus: Now the band is shifting. It used to shift by 1 ppm a year, then by 1.5 ppm a year, then by 2 ppm a year, and now it's 2.2 ppm a year. That's us adding new carbon into the system, which simply wasn't there before. We are changing the balance.

My argument is, for every ton of carbon coming out of the ground, another ton has to back in. You still need air capture, because for every ton of CO2 going into the air, another ton has to come out.

You could do this biologically. You could grow trees, but then the amounts we are talking about look like more than all the world's agriculture. That's your challenge, but you need to balance that part.

The other part you balance is, we will end up at 400, 500, 600 ppm, wherever we manage to stop. What do we do with what we already have done? If you had had this conversation in 1980, I would have said, "Look, you need to stop. That's the end of the story."

Now, I'm going to tell you, "We are now at 400 ppm. Realistically, you are not going to stop before 450 ppm."

Dr. Biology: It's like a giant train.

Klaus: It's a giant train.

Dr. Biology: You can't stop it right away. It doesn't stop on a dime.

Klaus: As a matter of fact, if you could do magic, and from here on out, every new power plant we built, every new car we buy, all of the things we have, will stop producing CO2.

All the old equipment is going to run out its natural life. You end up putting more CO2 into the atmosphere than we can tolerate.

I think we have possibly already created a debt large enough, that we will have to deal with it. We have to pull the CO2 back, in order to come back down.

Dr. Biology: Not just stopping, because the train's moving on. We're going to go beyond where we are now, no matter what. Now, we have to have a mechanism to reverse it, basically. All the work you're doing on that will help with that process.

We have a mechanism of bringing it out of the air. We have a mechanism to turning it into fuel, which is the algae farms, which is one possibility and then, as you said, the solar panels.

Is there something that a person should still be doing today? If we want to slow the train down, we all have to be part of the process. If we don't work on slowing the train down, you're going to have a whole lot more work, trying to put it back in balance.

Klaus: It's worse than that. People have said any capture is sort of nefarious, because it allows the excuse, "We don't need to do anything now. We can solve the problem later." I disagree with that.

The reason I disagree is, yes, a little bit it's true, but in a way we're already too late. If we keep going too far, we will do damage we cannot undo.

We can get the atmosphere back to, let's say, 400 or 350 ppm. If the glaciers melted in the meantime, they won't freeze overnight, just because we decided to do this. There are real damages we create, by letting this thing go too far.

The more you slow down now, the more you manage to solve the problem right away, the less damage you will do.

I would argue another point, why air capture is actually helpful in this discussion. Think about it this way. The air capture differs from every other way of getting CO2 back, in that it doesn't really need the direct cooperation of the polluter.

If we come along and say, "We can do air capture at an affordable price." Right now the coal plant operator can say, "Look, we understand there's climate change. We understand it's not a good thing. We also know that you need energy, and you need to be able to afford it.

"It's going to be so horribly expensive, that you don't even want us to do this. We keep researching the problem, but we can't really introduce it yet."

If on the other hand, you have air capture, we can say, "OK, you don't have to cooperate. We will just do it, and all you have to do is pay the bill." You'd be surprised how fast they figure out how they can deal with the CO2 from the smokestack more cheaply than taking it out of the atmosphere.

The other thing we're after is the CO2 which has already been put out. That could be, by far, our biggest application. We will have to come back.

If we come back by 100 ppm, which I think is quite likely, we will have to find a place to store CO2, a disposal site, if you wish, or disposal sites, big enough to accommodate more CO2 than the world emitted between 1900 and 2000.

Dr. Biology: Where are we going to put it all?

Klaus: That, to me, is one of the biggest questions. Where do we put it? That's why I'm so keen on developing mineral sequestration, where you take rocks, which really respond to acid, and then form salts.

We can make a mountain of that stuff, and put it away. In the end, you make mountains, but we also have mined mountains of coal, and we have mined mountains of dirt, over the coal, which we had to put aside. It turns out those mountains are bigger than the mountains we will make, when we make carbonates.

Dr. Biology: You've been talking a lot about balance. Let's go through the details. In particular, quickly, what is it when we talk about balance that you're looking for?

Klaus: The atmosphere, the biosphere, and the ocean, have a balanced carbon budget, which takes literally hundreds of thousands of years to change. Therefore, as long as we keep adding into this box, we have to subtract the same amount.

For every ton of carbon coming out of the ground, another one has to go back. For every ton of CO2 we put in the atmosphere, we have to figure out how to get one back out.

With those two rules, you are forced into thinking about the problem, in a balanced budget kind of approach.

Dr. Biology: From a biological standpoint, we always talk about equilibrium, that steady state, where things work optimal. Our bodies are always looking for an equilibrium. We want to have a constant temperature within a very few degrees.

You know what happens when your body temperature rises too high. You end up feeling very sick. It can't go very far. Actually, it can be very deadly.

The whole biosphere is basically a living organism. We want to make sure that we deal with that equilibrium.

Klaus: By technical means, we bring it out of balance. Therefore, technical means can help us getting it back into balance.

Dr. Biology: Tell me, you said you have some experiments running in the desert now?

Klaus: We have a small device, which has been collecting CO2 since September, not in large quantities. Our main goal was to figure out how sensitive are we to the weather. Keep in mind, we are moisture-sensitive. We love when it's dry. We don't work so well when it's raining.

Dr. Biology: How soon would you predict -- this is the optimistic view -- having these in large-scale production, these scrubbers?

Klaus: Once you have the will to do it, the economic structure's in place, that actually people can make profit on it. You give it a couple decades, and it moves from being a small thing, to being fully established.

Dr. Biology: Your prediction would be twenty years.

Klaus: My prediction is there will be a latency time, which has to do with how fast we can convince the world that it's necessary. At the end of that latency time, to go from practically nothing, to being full scale, is on the order of two decades. Keep in mind, you haven't solved the problem yet.

At the end of the two decades, you have a fleet in place, which can pull the CO2 down. I have a hard time believing that that fleet will be much larger in its capacity than what we emit today.

Dr. Biology: We want to make sure that we reduce, right now, so that when we get to the 20 to 50 years, that we actually have less work to do, and we have less damage that has occurred. That part is something that even if you fix the atmosphere, it's not something you can fix overnight.

It's important as an individual to figure out how to reduce your carbon footprint. At the same time, we work on this mechanism. The shining light at the end is that there is a potential to pull the CO2 back out. That's the key to me.

Klaus: We could start it right away. If I could make regulations, I would say, "There's a very simple rule. If you want to dig up a ton of carbon, you show me a ton of carbon which has been put away." The moment you do that, I think air capture will become important.

Dr. Biology: On Ask a Biologist, I always ask three questions of my scientists. We'll start with the first one. When did you first know you wanted it to be a scientist?

Klaus: In high school. I think when I had physics classes, I got really excited about this and really interested. And then, at that point, I knew I wanted to study physics, which I ended up doing.

Dr. Biology: Now, I'm going to do something that it's usually harder for my guests. I'm taking everything away. You can't be a scientist, you're at a university, so I'll take away teaching because I know a lot of my guests have tried to slide into teaching.

This is where you get to expand. You get to do anything or be in any kind of career. What would you do, or what would you be?

Klaus: A lot of the things I'm interested in are about systems, and one of the things I realized the world will need is far higher levels of automation. I would be working on automating all sorts of processes, fascinating ones. Self-driving cars and machinery like that.

I think that also helps in what I'm doing because these machines have to be small and sit in large numbers somewhere, and they better be automated because you couldn't afford the people who do it. I'd be in an industry like that.

Dr. Biology: For the last question, what advice do you have for a budding young scientist, a young budding ecologist or someone that is really interested in the environment?

Sometimes it's even the person that already had a career, but they always wanted to switch over, you can think of any of those. What advice would you have for them?

Klaus: I would emphasize the fundamentals. If you understand the systems, understand the underlying basics, that most of these things also means math, chemistry and physics, and biology. If you understand those things, you can do a lot of things.

Learning what is today hard, may be fun, but it turns out by the time you finished, it's last year's news. If you know the basics, you can get into the next big thing much more easily than if you were an expert of the last big thing.

Dr. Biology: The fundamentals, having a really strong foundation and the ability to learn new things and adapt, that's the piece that you're...

Klaus: Yes, I gave a convocation speech some time ago to people who had just gotten their PhD and I said, "What you really learned is how to learn."

Dr. Biology: Well said, well said. With that, Klaus Lackner, thank you very much for visiting with me today.

Klaus: You're welcome. It was a pleasure.

Dr. Biology: You've been listening to Ask A Biologist, and my guest has been Klaus Lackner, professor in the School of Sustainable Engineering and the Built Environment in the Ira A. Fulton Schools of Engineering. This is at Arizona State University. And he's also the director of the Center for Negative Carbon Emissions, also at ASU.

For those of you who might want to explore more about his work and the Center, pop on over to - engineering.asu.edu/cnce.

The Ask A Biologist broadcast is produced on the campus of the Arizona State University and is recorded in the Grassroots Studio, housed in the School of Life Sciences, which is an academic unit of the College of Liberal Arts and Sciences.

Remember, even though our program is not broadcast live, you can still send us your questions about biology using our companion website. The address is askabiologist.asu.edu. Or you can just Google the words, ask a biologist. I'm Dr. Biology.

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