I'm Ursula Goodenough and I'd like to talk about the carbon cycle or the history of carbon. So carbon has a history in the universe. It wasn't here in the beginning and it shows up first in the detritus of dying stars that undergo nucleosynthesis and they take helium atoms and squish them together to make carbon, which has six protons in its nucleus. This carbon then spews out throughout the atmosphere and when our solar system started, most of the carbon in it took the form of carbon dioxide, which formed spontaneously in the presence of oxygen, and it is a major component of the atmospheres of all the planets. Carbon dioxide is not a good source of building blocks for molecules, but the carbon within carbon dioxide is excellent; it has the ability to form chemical bonds with other carbons and with nitrogen. And in order to do this, energy has to be put in. This doesn't require life. There are energy carbon-carbon and carbon-nitrogen type bonds that are found in molecules that are in asteroids that come in from outside the solar system. So this can be done just with energy from stars. For the formation of life on Earth, the idea is that another place where carbon-carbon bonds were formed is in the depths of the oceans in deep sea ocean vents where there's lots of high temperature and pressure, enough energy to form these carbon bonds. And scientists have simulated these conditions in the lab and have found that they can make sugars like pyruvate and formate just under deep sea conditions. So the notion is that a primal soup developed of energy-rich carbon molecules in the early Earth and that this primal soup then fed into the original origin of life. There's not, however, enough of this fixed carbon in the primal soup to generate all of what we see here. Another way of fixing carbon had to be invented and this has come to be called photosynthesis. The first photosynthesis was thought to have been invented about three and a half billion years ago by bacteria-like organisms. And the process involves two independent parts: one is called the light reaction and one is called the dark reaction. The light reaction is the part of getting the energy to make the bonds and this comes from the photons that are streaming onto the planet from the Sun. These protons excite molecules that are called pigments and their electrons get to higher energies, and then as the energies fall, the electrons and their companion protons form energy-rich molecules like ATP and NADPH that are necessary for the next part, which is the dark reaction. The dark reaction involves taking those energy-rich compounds and feeding a cycle that includes a key enzyme called RuBisCo, which is the most abundant enzyme on the planet Earth. We are steeped in RuBisCo here. And RuBisCo is able to take carbon dioxide as a gas and couple it to a five-carbon sugar to make a larger sugar. And that's the basis for then getting carbon-rich compounds into the system that go on in modern organisms to form via enzyme-catalyzed reactions, the amino acids, the nucleotides, the sugars, all of the compounds that go on to build life forms. When the pigments give up their electrons, they need more electrons to come back in to fill their place. In early life, these electrons came from hydrogen sulfide and other donors but about two to two and a half billion years ago, organisms called cyanobacteria arose that could get these electrons out of water. And this was obviously a great idea because there's water everywhere. In the course of getting the electrons out of water, oxygen is released and so the atmosphere began to get more and more filled with oxygen, which is sometimes referred to as the oxygen holocaust because oxygen is a very reactive molecule and must have done a lot of damage even to the cyanobacteria that were producing it. This problem was solved by an invention called respiration, whereby oxygen receives electrons going back to water and, in the course of that, you make more ATP and other energy-rich compounds. So the oxygen came to be a great idea but there was a period in there when it was a problem. So today, what we have is photosynthesis, almost all of it oxygen-evolving because these cyanobacteria became the chloroplasts that we see in all of these organisms. And this oxygenic photosynthesis creates what we now call plants and algae. Other organisms then evolved that eat these plants and algae and used the energy-rich carbon compounds to build themselves. And then other organisms came along that eat the plant-eating animals and used these carbon bonds for their energy sources and their building blocks. What we have in the end then is a planet that is totally dependent on sunlight. If the Sun went out, life would stop and where abundant forms of fixed carbon are everywhere. Now, what happened during the course of this is that, while there was lots of CO2 in the early atmosphere, photosynthetic organisms took a lot of this carbon dioxide out of the atmosphere to make what we have around us. Also, lots of organisms use carbon to make their shells and the shells in the forms of various kinds of carbonates sink down to the bottom of the ocean to form limestone. Dead organisms over hundreds of millions of years were subducted down deep into the Earth via plate tectonic cycles. And this carbon energy-rich source became converted, given the heat and pressure under the Earth, into coal and petroleum. So that was another way that carbon was removed from our atmosphere. What has happened in very recent times is that we have developed ways to bring that carbon back out and use it and burn it, releasing carbon dioxide. Carbon dioxide is what's called a greenhouse gas. It traps heat and so, as carbon dioxide levels rise on our planet, we get increased temperature and the capacity for lots of climate change. But for me, in addition to being concerned about that, I'm also very concerned about the fact that we're taking all of this wonderful petroleum from the center of the Earth or beneath the Earth-- center is iron-- and we are burning it. We're putting it into carbon dioxide which is, to my mind, really stupid. This petroleum is used for making plastics, it's used for other things. It's a very valuable resource for the planet, and we should be using it very sparingly.