What is the carbon cycle?

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Carbon is both the foundation of all life on Earth and the source of the majority of energy consumed by human civilization. Swamp ecosystems like this one in Norway are a carbon sink that take carbon out of the atmosphere. Photo: Pixabay/Public Domain

Carbon is the backbone of life on Earth. We are made of carbon, we eat carbon, and our civilizations are built on carbon. We need carbon, but that need is also connected with one of our most serious problems: global climate change.

Carbon is the fourth most common element in the universe. Most of Earth's carbon — about 65,500 billion metric tons — is stored in rocks. The rest is in the ocean, atmosphere, plants, soil and fossil fuels, like coal and oil.

Carbon flows between each of them in an exchange called the carbon cycle, which is really two cycles — one is slow, and the other is fast. As carbon shifts out of one area, it goes to the others. When carbon gases end up in the atmosphere, temperatures get warmer on Earth.

Over the very long term, the carbon cycle seems to maintain a balance. This balance helps keep Earth's temperature relatively stable. But for shorter time periods, anywhere from about 100 to 100,000 years, the temperature of earth can vary.

Over millions or tens of millions of years, the temperature may change more dramatically. Earth has undergone such a change over the last 50 million years.

Rain Moves Carbon From The Atmosphere To Rocks

Carbon takes 100 million to 200 million years to move between rocks, soil, ocean and atmosphere in the slow carbon cycle. On average, 10 million to 100 million metric tons of carbon moves through the slow carbon cycle every year. In comparison, human emissions of carbon to the atmosphere are 10 to 100 times more than that.

The movement of carbon from the atmosphere to rocks begins with rain. Carbon comes down from the atmosphere as acid rain. The acid dissolves rocks and releases other elements. Rivers carry them to the ocean.

In the ocean, coral and plankton turn those elements into shells. After they die, they sink to the seafloor, and over time, layers of shells and minerals are cemented together and turn to rock, storing the carbon in stone.

This is how most carbon-containing rock is made. The other rocks come from living things that have been embedded in layers of mud. Over millions of years, heat and pressure turn the mud and carbon into rock. In special cases, layers of carbon become oil, coal or natural gas.

In the slow cycle, volcanoes return carbon to the atmosphere. When volcanoes erupt, they vent the carbon dioxide to the atmosphere and cover the land with fresh rock to begin the cycle again.

If volcanoes raise the carbon dioxide in the atmosphere, temperatures rise, leading to more rain. That dissolves more rock, which will eventually deposit more carbon on the ocean floor.

However, the slow carbon cycle also contains a slightly faster part: the ocean. The ocean absorbs and releases carbon dioxide at the surface. Once in the ocean, carbon dioxide gas reacts to make the ocean more acidic.

Human activity has increased carbon concentrations in the atmosphere, so the ocean now takes more carbon from the atmosphere than it releases. Over thousands of years, the ocean will absorb up to 85 percent of the extra carbon, but the process is slow.

"Movement Of Carbon Through Life Forms"

The fast carbon cycle is the movement of carbon through life forms on Earth. Between 1,000 and 100,000 million metric tons of carbon move through the fast carbon cycle every year.

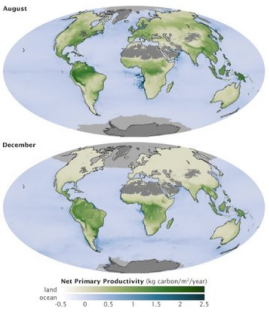
Carbon plays an essential role in life on Earth. All living things contain carbon in their cells, and carbon is an excellent source of energy.

Plants are the main parts of the fast carbon cycle. They take carbon dioxide (carbon combined with oxygen) from the atmosphere by absorbing it into their cells. This is known as photosynthesis. Plants use energy from the sun and combine carbon dioxide and water to form sugar and oxygen.

Four things can happen to move carbon from a plant and return it to the atmosphere. Plants break down the sugar to get the energy they need to grow. Animals (including people) eat the plants and break down the plant sugar to get energy. Plants die and decay at the end of the growing season. Fire also consumes plants, and carbon is released.

In all four processes, the carbon dioxide released usually ends up in the atmosphere. The fast carbon cycle is very closely tied to plant life. As a result, the growing season can be seen by the way carbon dioxide fluctuates in the atmosphere. In the Northern Hemisphere winter, few land plants are growing and many are decaying, so atmospheric concentrations climb. During the spring, when plants begin growing again, concentrations drop. It is as if the Earth is literally breathing.

Left undisturbed, the fast and slow carbon cycles maintain relatively steady concentrations of carbon. When anything changes the amount of carbon in one area, though, the effect ripples through the others.



The fast carbon cycle is visible in the changing seasons. As the large land masses of Northern Hemisphere green in the spring and summer, they draw carbon out of the atmosphere.

These maps show the amount of carbon consumed by plants on land (green) and in the oceans (blue) during August and December, 2010. In August, the green areas of North America, Europe, and Asia represent plants using carbon from the atmosphere to grow.

Graph by Marit Jentoft-Nilsen and Robert Simmon, using data from the NOAA Earth System Research Laboratory. Maps by Robert Simmon and Reto Stöckli/NASA.

Humans Speed Up The Cycle

Throughout Earth's history, the carbon cycle has changed in response to the changing climate. When the Earth gets cooler, the carbon cycle slows. The carbon in the atmosphere decreases, and that causes additional cooling. The opposite happens when temperatures rise.

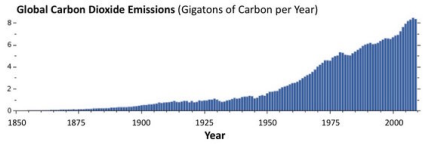
Today, changes in the carbon cycle are happening because of people. We affect the carbon cycle by burning fossil fuels and clearing land.

When we clear forests, we get rid of plants that would otherwise take carbon out of the atmosphere as they grow. We also expose soil that vents carbon from decayed plant matter into the atmosphere. Humans are currently emitting just under a billion tons of carbon into the atmosphere per year through land use changes.

Without human interference, the carbon in fossil fuels would leak slowly into the atmosphere over millions of years. By burning coal, oil and natural gas, we speed up the process. It releases vast amounts of carbon that took millions of years to build up into the atmosphere every year.

Extra Carbon Is Dangerous For Marine Life

Since people first started burning fossil fuels, carbon dioxide in the atmosphere has risen by 39 percent. That is the highest concentration in two million years. The concentration of carbon dioxide in the atmosphere has risen from about 280 parts per million to just over 400 parts per million. That means that for every million molecules in the atmosphere, around 400 of them are carbon dioxide.



Emissions of carbon dioxide by humanity have been growing steadily since the onset of the industrial revolution. About half of these emissions are removed by the fast carbon cycle each year, the rest remain in the atmosphere. Graph: NASA.

All of this extra carbon needs to go somewhere. So far, land plants and the oceans have taken up about 55 percent of the extra carbon people have put into the atmosphere while about 45 percent has stayed in the atmosphere. Eventually, the land and oceans will take up most of the extra carbon dioxide, but as much as 20 percent may remain in the atmosphere for many thousands of years.

Extra carbon in the atmosphere warms the planet and helps plants on land grow more. Extra carbon in the ocean makes the water more acidic, putting marine life in danger.