How do tiny ocean critters affect the global carbon cycle?

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Carbon is the elemental building block for all living things. Over time, carbon moves through the land, air, and oceans in a process called the carbon cycle. Parts of the oceanic carbon cycle are still a mystery. How do tiny photosynthetic microbes and bacteria in the ocean affect the carbon cycle? Why does some carbon stay in the ocean for thousands of years while other carbon moves from the ocean to the air in just seconds or minutes? By combining new methods from chemistry, biology, and data management, we are investigating carbon dissolved in seawater. Eventually we’d like to understand how bacteria in the ocean will react to our changing climate – will they help store more carbon safely in the ocean or will they speed climate change by adding more carbon to the atmosphere?

Introduction

Carbon is an important part of you and me. In fact, you can find it in all living and many non-living things. In different forms, it is found in plant and animal cells, in rocks and soil, dissolved in seawater, and in the air. Over time, carbon moves through the land, air, and oceans in a process called the carbon cycle. For example, part of the carbon cycle happens when we breathe: animals exhale carbon dioxide (CO$_2$) into the air, and plants take in CO$_2$ from the air during photosynthesis.

Carbon moves into the ocean when microscopic underwater cells, called phytoplankton (Figure 1A), grab CO$_2$ from the water for photosynthesis, just as plants on land do from the air. Even though phytoplankton are tiny, they are vast in number, and therefore have a big impact on the carbon cycle. In fact, all the phytoplankton in the ocean remove as much CO$_2$ from the air per year as all the plants on land do.

Figure 1:
Different forms of phytoplankton (A) and one of the billions of bacteria (B) that live in the ocean and help cycle carbon around.
Methods

We and other scientists are combining methods from chemistry, microbiology, and informatics (which is the science of processing and storing large amounts of data) to better understand how microbes in the ocean affect the carbon cycle. In the lab, we are using specialized machinery to map the genes of all the bacteria in a seawater sample who consume dissolved organic carbon, and to identify the genetic and chemical activity that show what the bacteria are doing. These new technologies are so powerful that we can look at millions of DNA sequences in a single water sample!

Results

More than a hundred thousand different types of bacteria in the ocean consume, digest, and excrete thousands of types of dissolved organic carbon. Most of the dissolved organic carbon is produced at the surface of the ocean, where sunlight hits and powers photosynthesis (Figure 2). Bacteria tend to gobble it up quickly – in a matter of seconds or minutes. In deeper water, the process is slower – on the scale of months or years. In the very deepest parts of the ocean, dissolved organic carbon can hang around for a very long time – on average for 6,000 years!

The types of bacteria and dissolved organic carbon in the water are intertwined: specific bacteria consume and excrete certain kinds of dissolved organic carbon, and the presence of specific types of dissolved organic carbon determines the bacterial community that can live there.

We also identified the different types of dissolved organic carbon in the ocean by using a machine called a mass spectrometer, which can identify thousands of different molecules in a seawater sample by weighing them. Our mass spectrometer can even distinguish between two substances with weights that are less than an electron apart.

This lab work produces a lot of information, which is stored, analyzed and managed in computer databases.
Discussion

The more closely we are able to look at life in the ocean, the more complexity we find. As our tools for mapping bacterial genes, identifying the molecular differences between types of dissolved organic carbon, and storing and interpreting data improve, we are able to understand more about how oceanic bacteria affect dissolved organic carbon and help control the global carbon cycle.

But there’s still a lot to learn. We think there are many thousands more types of bacteria and dissolved organic carbon that haven’t been identified yet, and we still don’t know what controls the formation of the “refractory” types of dissolved organic carbon that remain in the ocean for thousand of years. We still don’t know how climate change - and related shifts in ocean temperature, acidity, and circulation - will affect the interactions between bacteria and dissolved organic carbon in the ocean. For example, will hotter water make bacteria eat faster, and cycle carbon more quickly back to the atmosphere?

Conclusion

One complicated aspect of studying the carbon cycle in the ocean is that it requires an understanding of chemistry, microbiology, and data science. One person alone probably couldn’t master all these subjects on their own; to make progress, teams of scientists with different specialties have to communicate and work together, in a process that’s called “interdisciplinary research” (= research that combines different academic subjects).

Working in teams to decipher the natural carbon cycle is an important step to understanding the full effects that human-caused carbon emissions have on the environment.

Glossary of Key Terms

- **Bacteria** – Microscopic single-celled organisms with very simple cell structure.
- **Carbon** – An element that is part of all life on Earth.
- **Carbon cycle** – The process by which carbon molecules move and transform between the land, air, and water on Earth.
- **Carbon dioxide (CO$_2$)** – A gas found in the atmosphere, which plants take in during photosynthesis. It is also emitted by humans when we breathe and when we burn fossil fuels. It acts like the glass in a greenhouse, keeping the planet warm.
- **Carbon emissions** – Releases of carbon dioxide from the land to the atmosphere, for instance when humans burn fossil fuels.
- **Database** – An organized set of data that is stored in a computer.
- **Dissolved organic carbon** – The carbon in molecules exuded from living things that are dissolved in the ocean.
- **Dissolved organic material** – Materials containing carbon molecules which are exuded from living things, that are dissolved in seawater.
- **DNA** (Deoxyribonucleic acid) – A material in the cells of all living things that carries the creature’s genetic information.
- **DNA sequence** – A formation of DNA that determines an organism’s genetic code.
- **Electron** – Tiny, negatively charged particles found in every atom.
- **Gene** – A portion of a DNA molecule that controls physical traits.
- **Genetic code** – The total organization of DNA in a living creature.
- **Informatics** – The science of processing, storing, and retrieving large amounts of data.
- **Labile dissolved organic carbon** – Carbon at the surface of the ocean that cycles back to the atmosphere in seconds, minutes, or days.
- **Mass spectrometer** – A machine that sorts and helps identify a mixture of substances by weighing separate molecules.
- **Microbes** – Tiny living creatures, such as bacteria, that can only be seen with a microscope.
Check your understanding

1. Phytoplankton are so tiny you need a microscope to see them. How do they affect the global carbon cycle?

2. What role do bacteria in the ocean play in the global carbon cycle?

3. Climate change is expected to alter the ocean’s temperature, salinity, acidity, and currents. What would you want to investigate to find out how these changes would affect the way oceanic bacteria will process dissolved organic carbon in the future?

4. Some dissolved organic carbon gets processed and released to the atmosphere quickly, while other forms of dissolved organic carbon mix down deep into the ocean and stay there for thousands of years. If you wanted to figure out how to get more carbon to mix down deep in the ocean, what kinds of questions would you need answered first?