Invisible carbon pumps

A group of oceanic micro-organisms just might prove a surprising ally in the fight against climate change.

UNDERSTANDING how the oceans absorb carbon dioxide is crucial to understanding the role of that gas in the climate. It is rather worrying, then, that something profound may be missing from that understanding. But if Jiao Nianzhi of Xiamen University in China is right, it is. For he suggests there is a lot of carbon floating in the oceans that has not previously been noticed. It is in the form of what is known as refractory dissolved organic matter and it has been put there by a hitherto little-regarded group of creatures called aerobic anoxygenic photoheterotrophic bacteria (AAPB). If Dr Jiao is right, a whole new "sink" for carbon dioxide from the atmosphere has been discovered.

The main way that carbon dioxide is absorbed by the ocean is through photosynthesis by planktonic algae. These algae are the basis of most food chains in the sea—being eaten by tiny animals that are, in turn, eaten by larger ones. When all these creatures die, their remains (those bits that are not immediately eaten, anyway) sink to the sea floor, where some are eaten and some are buried indefinitely. These remains are known in the jargon as particulate organic matter.

Some of the organic compounds the dead creatures contain, though, dissolve out of them and into the water. This dissolved organic matter was not, until recently, thought to be an important component of the total. But Dr Jiao noticed something odd about its distribution in the sea. It would be expected to correlate with the distribution of planktonic algae—the ultimate drivers of biological productivity. But it does not.

The reason, it turned out, was that previous researchers had been tracking only a small fraction of the total—the portion composed of molecules such as sugars and L-amino acids that can be metabolised easily by living things. They had missed a whole host of molecules that cannot easily be metabolised. These included D-amino acids, which are mirror images of the L-variety normally found in living things, and compounds called porins, lipopolysaccharides and humic acids. Because they are not metabolised, these molecules are referred to as "refractory". Only when this refractory material is taken into account does the chemical map match the planktonic one.

A refractory puzzle

The reason this matters is that 95% of dissolved organic matter seems to be refractory. Dr Jiao estimates that the amount of carbon stored by the oceans in this way is equal to the amount in the atmosphere, in the form of carbon dioxide.

It was discovered ten years ago that AAPB produce refractory molecules when they metabolise sugars and L-amino acids, but it is only recently that the scale on which they do so has become apparent. That started happening in 2006, when Dr Jiao developed a technique called time-series observation-based infra-red epifluorescence microscopy, or TIREM for short, that is able to measure the amount of AAPB in the oceans accurately.

TIREM has shown that AAPB are ubiquitous, and constitute 7% of the oceans' microbes. Moreover, they grow up to five times faster than typical bacteria—in part because, as the "photoheterotrophic" in their name suggests, they can both photosynthesise and derive nutrition from the remnants of other organisms. Which is more important to them, though, was not clear until Dr Jiao and his colleagues began their research. After sampling waters from the Pacific, Atlantic and Indian oceans at all latitudes, they found that the amount of AAPB in the water is controlled mainly by the level of planktonic algae in the region, rather than by the amount of light. They therefore suspect the main source of food for AAPB is dissolved organic matter released by phytoplankton. The question is, how is some of this converted into refractory compounds?

It is possible that AAPB release such compounds during their normal metabolism. That would be odd, though, since it would be a waste of valuable carbon. Instead, Dr Jiao thinks refractory compounds are made and released by these bugs mainly in response to viral infections. Indeed, he has found that AAPB are particularly prone to such infections and his team have isolated a virus that seems to be specific to this type of bacterium. At the final stage of the infection, the viruses destroy the cells they have infected, a process that provides a rich source of refractory compounds.

Based on these findings, Dr Jiao and his colleagues propose that AAPB, and possibly other, similar microbes, have a predominant role in pumping carbon into a pool of compounds that cannot be turned back into carbon dioxide by living creatures, thereby building up a large reservoir that keeps carbon out of the atmosphere. If that idea is confirmed, it will need to be incorporated into the computer models used to understand the Earth's carbon cycle and its effect on the climate. But it also raises a more radical thought. The newly discovered microbial carbon pump could provide a novel way to extract CO2 from the atmosphere, should that ever be deemed necessary to combat climate change.

At the moment, the most plausible way of making the sea absorb more of the gas is to seed it with iron. A lack of this metal is commonly the brake that stops the growth of planktonic algae. Experiments that add iron to the sea have had mixed success, though, and may cause harmful algal blooms and ocean acidification. If AAPB could be recruited, they would provide an alternative way of getting the sea to lock up CO2. How that might be done is obscure at the moment, for the organisms are still barely understood. Moreover, there would surely be side-effects to stimulating their activity. Those side-effects, though, might be more bearable than the ones associated with iron seeding. Only further research can find that out.

In the meantime, there are many questions to answer. For example, Dr Jiao and his colleagues want to map the abundance, composition and distribution of refractory molecules in more detail. They want to understand what makes such compounds refractory and whether they can be made more or less so. They also want to know exactly how viral infections stimulate production of the molecules.

To address these questions, scientists from China and elsewhere are rushing around the oceans from ice-cold polar regions to the Indo-Pacific Warm Pool, the warmest marine waters in the world. If progress can be made, this curious discovery may turn out to be a powerful ally in the fight against global warming.

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