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Abstractions

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LAST AUTHOR
Biologists have wondered for more than a century why separate sexes exist when many plant and animal species reproduce through self-fertilization (selfing). Two theories had emerged to explain why cross-fertilization, or outcrossing, might be beneficial to species despite the cost of a separate gender. One theory is that it reduces the probability that harmful mutations will become fixed in all future generations as a result of inbreeding. The other is that it boosts the chance that two beneficial mutations arising in two different individuals will appear in future generations and allow them to adapt to new environments. Now Patrick Phillips, an evolutionary biologist at the University of Oregon in Eugene, and his colleagues have tested the effects of new mutations and environmental change (see page 350) by breeding 50 generations of the nematode *Caenorhabditis elegans*, an organism capable of both selfing and outcrossing. He tells *Nature* more.

Why are you interested in this question?
Sexual reproduction is a major feature of life on Earth and it's so common we take it for granted. But, in fact, it requires explanation.

What makes *C. elegans* the ideal model system for this kind of study?
Producing each new generation of *C. elegans* took only about 4 days, so this part of each experiment, following 50 generations, lasted less than a year. This would be a difficult study to do in plants because it would take a huge amount of time and space. Yeasts wouldn't work because most don't self-fertilize. We know so much about the genetic basis of sex determination in *C. elegans* that we can use specific mutations to yield strains that either only self-fertilize or only cross-fertilize. Other animal species can't be tested because no such mutations exist that alter the mating system in the right way to conduct the study.

How did you test the 'adaptation' theory?
We exposed *C. elegans* to *Serratia marcescens*, a bacterial pathogen that kills the worms. After 40 generations of worms, neither the groups that only selfed nor the groups that outcrossed at low levels could adapt to the pathogen. But the high-outcrossing populations did.

Do species alternate from selfing to outcrossing?
They don't seem to be able to. When you take worms from different selfing lineages and cross them together, their offspring are sicker. If this happens in other species, it could explain why, once selfing occurs, it rarely moves into outcrossing, even though outcrossing may be more beneficial for the species. ■

MAKING THE PAPER

Samar Khatiwala

Using maths to map the ocean's carbon sink through time.

Samar Khatiwala's description of the 'ocean carbon problem' is deceptively simple. A scientist, he says, cannot simply scoop up a water sample and tell how much of the carbon in it came from carbon dioxide released by human activities and what fraction is the naturally dissolved carbon. But he and his colleagues have now found a way to tackle the problem, using not-so-simple maths (see page 346).

The oceans absorb roughly a quarter of the CO_2 released into the air from the burning of fossil fuels, making them the most important sink for this greenhouse gas. Previously, scientists tried to back-calculate the amount of anthropogenic carbon in the oceans by subtracting the level of natural carbon from the total dissolved carbon. But that involved assumptions about poorly understood biological and geochemical processes acting on natural carbon — and resulted in much disagreement between calculations.

As a result, Khatiwala, an oceanographer at the Lamont-Doherty Earth Observatory of Columbia University in Palisades, New York, and his colleagues, decided to ignore the natural carbon and measure only the signal of the carbon released by humans.

Because the amount of carbon in the oceans from this source is tiny compared with the amount of natural carbon, they decided to treat it as a conservative tracer — something carried passively through the ocean by circulation. They knew that a differential equation called the advection-diffusion equation describes how certain chemical tracers move around the ocean, and that this equation can be solved using a Green's function, named after the nineteenth-century British mathematician George Green. "If we could treat man-made CO_2 as a conservative tracer in its own right, then we could apply all this mathematical machinery to the ocean carbon problem," says Khatiwala.

To be able to do this, they first had to infer the ocean's Green's function from observations of the distribution of other conservative tracers. The next piece of the puzzle was obtaining measurements of the ocean-surface history of carbon released by human activities. This history turned out to have a simple relationship to the amount of anthropogenic carbon in the atmosphere, data that go back to the start of the industrial period.

With all the pieces in hand, the team reconstructed the amount of anthropogenic carbon in the oceans from 1765 to 2008. The study revealed that the Southern Ocean around Antarctica absorbs a much bigger chunk of emissions than was previously appreciated, about 40% of the total. It also showed that the ocean's uptake rate has increased sharply since the 1950s, when emissions started rising. But this increase slowed between 2000 and 2008, while emission rates rose by a factor of three.

"That means more emissions are remaining in the atmosphere, as a smaller proportion is taken up by the ocean. That was really very surprising," says Khatiwala. There are competing hypotheses as to why the uptake rate is falling off; Khatiwala says he favours a fairly simple explanation — the limits of ocean chemistry. "As the ocean absorbs more carbon it becomes acidic and can hold less CO_2. Plus, ocean uptake is a relatively sluggish process. If emissions grow too rapidly, then the oceans cannot keep up." ■

FROM THE BLOGOSPHERE

Published research articles are now available to rent, writes Frank Norman on his Nature Network blog, Trading Knowledge (go.nature.com/GKNUa8). Norman, head of library services at the Medical Research Council's National Institute for Medical Research in London, reviews a new business model for publishing.

"When I buy a pair of shoes, I try them on first to see if they fit and look OK. Similarly when buying some items of clothing," writes Norman. "Information is not like other goods though. If you open the box to read the information, then you have consumed the information already. This ... makes buying and selling information resources a tricky business."

When online journals first arrived, Norman thought that publishers would sell sections of articles at a fraction of the full price. Instead, most journals chose to sell full articles at substantial prices and with only the abstract as a preview. But, Norman notes, a California company called DeepDyve (www.deepdyve.com) now offers article 'rentals'. For 99 cents, researchers can preview, but not save, a full article for 24 hours using DeepDyve's reading software. ■

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