## Abstractions

**LAST AUTHOR**
Protozoa were thought to be the primary predators of marine bacteria, but phytoplankton now look set to rival them for poll position. These photosynthetic marine microorganisms dominate the oceans and form the basis of many oceanic food webs, and their sheer numbers drive global cycling of carbon and nutrients. On page 224, Glen Tarran from the UK-based Plymouth Marine Laboratory, and his colleague Mikhail Zubkov of the National Oceanography Centre in Southampton, UK, quantify the surprising degree to which phytoplankton consume ocean bacteria — a phenomenon that could have implications for climate change.

**Did you stumble across phytoplankton's predatory behaviour?**
Somewhat, yes. We've known for more than 50 years that some marine microorganisms are mixotrophs — that is, can derive metabolic energy either by photosynthesis or by grazing on other organisms — but the phenomenon wasn't thought to be widespread. However, that wasn't our initial focus. We set out to quantify how open-ocean protozoa consume bacteria. During our experiments, we developed a method to sort protozoa and phytoplankton and, to our surprise, found phytoplankton grazing on bacteria as much as the protozoa were.

**How many bacteria do phytoplankton consume?**
Our work shows that phytoplankton are responsible for between 40% and 95% of the bacteria consumed in near-surface ocean waters in the North Atlantic near Iceland. We found similar numbers near the Cape Verde Islands off Africa's west coast, suggesting that this phenomenon is widespread.

**What are the next steps?**
Next month we will embark on a voyage across the Atlantic, from the United Kingdom to the Falkland Islands, looking for mixotrophy among phytoplankton as we pass through areas of varying temperature, nutrients and ocean dynamics. Our goal is to quantify how important mixotrophy is to global carbon cycling. Eventually we'd like to plug our data into global climate-change models.

**Have we misunderstood marine food webs?**
No, we've simply been limited in our ability to quantify their dynamics. Mike Zubkov and I have spent 10 years developing techniques to determine microbial dynamics. Mike is the big-picture guy forging new radioactive methods; I bring things down to Earth with the nuts and bolts implementation of the techniques. The open ocean is still a frontier, and we plan to further explore the role of phytoplankton in ocean nutrient dynamics. ■

## MAKING THE PAPER

### Abraham Stroock

**Synthetic tree shows how plants transport water against gravity.**

The towering coastal redwoods of northern California have long inspired awe in scientists and laymen alike. *Sequoia sempervirens* can grow to a height of more than 100 metres, ranking as Earth's tallest trees. When Abraham Stroock first visited a sequoia forest a decade ago as a graduate student in engineering at Harvard University, his thoughts turned to a question that had puzzled biologists for hundreds of years: how do these giants transport water all the way from their roots to distant leaves? Ten years later, Stroock, now an assistant professor of chemical engineering at Cornell University in Ithaca, New York, has the answer. He and graduate student Tobias Wheeler built a 'synthetic tree' — a microfluidic device that mimics the water-transportation capabilities of nature's tallest plants.

"I knew enough about biology to know that a cell is about 10 micrometres across, and enough about capillary phenomena to estimate what the capillary pull of a structure like that would be," recalls Stroock of his first encounter with the redwoods. "And the result would have been a miserably small tree." Biologists had long grappled with the same conclusion that capillary action alone couldn't account for water transportation in plants. Most accepted a passive 'wicking' model in which evaporation from the leaves pulls a long chain of water molecules up from the ground in a process known as transpiration. Stroock and Wheeler are the first to reproduce this phenomenon in the lab, with a microfluidic system in which chemically cross-linked hydrogel membranes represent natural root and leaf membranes, and are joined together by a fluid-filled microchannel that represents a plant's xylem capillaries (see page 208).

Their creation is no *Sequoia* — owing to materials and fabrication limitations, Stroock and Wheeler are working on a scale of tens of centimetres, not tens of metres. "But you can extrapolate from our system and see that you could get water transport against gravity over more than 100 metres," Stroock says.

The biggest challenge for Stroock was "how to convince a chemical engineer to work on the problem for his PhD". The solution? Wheeler hails from Sebastopol, California, and grew up with an appreciation for the giant native trees. "The transpiration process really is a collection of chemical engineering processes, mediated by membranes and changes in phase, heat and mass transfer," says Stroock. "If you bring the process into a synthetic system, it becomes a chemical engineering problem." With two engineers motivated by grand biology, Stroock says, "we were able to stick it out and make it work".

Stroock has also collaborated with plant physiologists, and says that this new system will be used as a research platform to tease out further details of the transpiration process — such as how trees recover from inevitable failures of the system, when the long columns of water within the xylem break, leaving a vapour space. But as an engineer, Stroock has an eye on biomimetic applications as well. These include the possibility of designing artificial root systems that can extract and purify water from deep, sparse deposits. And because the synthetic tree can transport thermal energy as well as water, it could be used to design sophisticated heat-transfer devices similar to the heat pipes used to cool a laptop's motherboard, "but on an architectural scale" to cool buildings and other large structures. ■

## FROM THE BLOGOSPHERE

Chemists love periodic tables! But the latest incarnation "really is quite different", writes Neil Withers, an associate editor of *Nature Chemistry*, at the Sceptical Chymist (http://blogs.nature.com/thesceptical-chymist/2008/07/periodic_table_of_videos.html).

Martyn Poliakoff and his colleagues at Nottingham University, UK, in collaboration with video journalist Brady Haran, are creating entertaining short videos about the properties of each element. At their Periodic Table of Videos site (http://www.periodicvideos.com/), they explain that tables charting the chemical elements have been around since the nineteenth century, and that their aim is to create a more modern version.

As this issue went to press, the most-viewed among the 118 videos were sodium, helium and potassium. Phosphorus, mendelevium and mercury were also highlighted as worth a look. Viewers can subscribe to a YouTube feed to be notified as new videos are created.

Those keen for further elemental education might like to check out a video, Chemical Party, over at Nature Network (http://network.nature.com/forums/ukpolicy/2318). ■

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