▲ The author measuring methane emissions from a peatbog in northern England. *D Reay*

comment

microbes as climate engineers

Human activity is a big factor in global warming and politicians around the world are trying to agree some control measures. But as **Dave Reay** reveals, they cannot afford to ignore the role played by microbes in climate change.

'The Anthropocene' is the name given by Nobel Laureate Paul Crutzen to the epoch we now live in. Ours is an age where global climate is increasingly determined by humankind, one where our species continues to alter the composition of the atmosphere and the energy balance of the planet. Arrogant organisms that we are, it is easy to view this as something entirely novel in Earth's history – evolution's newest top consumers breaking the environmental shackles and dictating global climate. In truth of course, micro-organisms have been at it for billions of years. From the first molecule of oxygen released by a cyanobacterium in the turbulent oceans of a young Earth, to the methanogen-made CH_4 belched from the warm bogs of the Carboniferous, microbes have long helped determine the composition of Earth's atmosphere and its climate.

Both natural and human-induced fluxes of CO_2, CH_4 and N_2O are dominated by microbiology. In the sea, CO_2 uptake by phytoplankton provides the pump for the annual drawdown of 90 billion tonnes of carbon from the atmosphere, with microbial decomposition and respiration returning much of this to the atmosphere. On land, the huge amount of carbon stored in soils and vegetation is under continual attack from microbes, the balance between primary production, respiration and decomposition resulting in the uptake of around 120 billion tonnes of carbon each year, and the loss of about 119 billion tonnes.

For CH_4, the flagella-print of micro-organisms on the atmosphere is even more apparent. The world's wetlands pour over 100 million tonnes of CH_4 into the atmosphere each year as a result of microbial methanogenesis. This amount would be far greater if it was not for the significant proportion used by methanotrophic bacteria before it can escape into the atmosphere. The CH_4 that does escape is still not free from their attentions; high affinity methanotrophs utilize atmospheric CH_4 at a rate of ~30 million tonnes each year. Along with additional CH_4 release from gas hydrates and microbial methanogenesis in the oceans, the world's termite population produces an additional 20 million tonnes of CH_4 every year courtesy of the methanogenic bacteria in their guts. Aside from energy-related sources like fossil fuel extraction, most human-induced CH_4 emissions come from ruminant livestock, rice cultivation and landfill, adding around 150 million tonnes to the atmosphere annually, all derived from the methanogens that thrive in these carbon-rich environments.

N_2O has a sobering global warming potential of 298 (this is the warming produced per kg of a gas over a 100-year time horizon relative to 1 kg of CO_2). Again, it is microbes that dominate global emissions. For every tonne of reactive nitrogen that human activities add to the biosphere, between 10 and 50 kg end up being emitted into the atmosphere as N_2O.

It is not only via reactive nitrogen that we are changing microbial greenhouse gas emissions. Through our post-industrial emissions, we have enhanced global warming. Average temperatures have risen by 0.7 °C in the last 100 years, with a projected increase in the 21st century of between 2 and 4.5 °C. From enhanced soil carbon decomposition rates to elevated wetland methanogenesis, the impact of these microbially mediated feedbacks on further climate warming in the 21st century is potentially huge.

The role of microbes as climate engineers is evident, as is their potential to exacerbate the problems of enhanced global warming driven by our burning of fossil fuels. But all is not lost in the world of climate microbiology. In the abundance and diversity of microbial life on our planet may lie the roadmap by which we can better navigate the Anthropocene. Through a better understanding of microbial decomposition of organic matter, there is the potential to alter land-management practices to conserve or even enhance soil carbon storage. By inducing increased primary production in the oceans, by adding iron or reactive nitrogen, there exists the possibility of sequestering more CO_2 from the atmosphere. Already the methanotrophs in landfill cover soils are playing a vital role in intercepting the vast quantities of CH_4 produced below, cyanobacteria are being explored as providers of hydrogen fuel, and vats of phytoplankton are being grown as the feedstock for biofuels.

Microbes will continue as climate engineers long after humans have burned that final barrel of oil. Whether they help us to avoid dangerous climate change in the 21st century or push us even faster towards it is dependent on just how well we understand them.

Dave S. Reay
School of GeoSciences, Crew Building, West Mains Road, University of Edinburgh EH9 3JN
(**t** 0131 650 7723; **f** 0131 662 0478; **e** david.reay@ed.ac.uk)

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