BIOLOGICAL OCEANOGRAPHY

Some phytoplankton like it hot

Phytoplankton drive productivity in the global ocean, but are sensitive to changes in temperature. Research now demonstrates how phytoplankton cells respond to an increase in seawater temperature and uses this knowledge to predict the resultant impacts on global marine biogeochemistry.

Jack A. Gilbert

The implications of increasing average global temperatures for life are difficult to predict with any certainty; even more uncertain is how any response by organisms will be manifest. Microbial marine phytoplankton are the trees and grasses of the ocean, therefore it is vitally important that we understand how a warming ocean may change their physiology to allow prediction of the consequences. Key to achieving this are scientific models that encapsulate how phytoplankton respond to changes in temperature, and therefore enable us to extrapolate the outcomes of such responses to the global ocean. Writing in *Nature Climate Change*, Andrew Toseland and colleagues[1] ask explicitly what happens to these oceanic productivity engines if annual average sea surface temperature is increased by 5 °C.

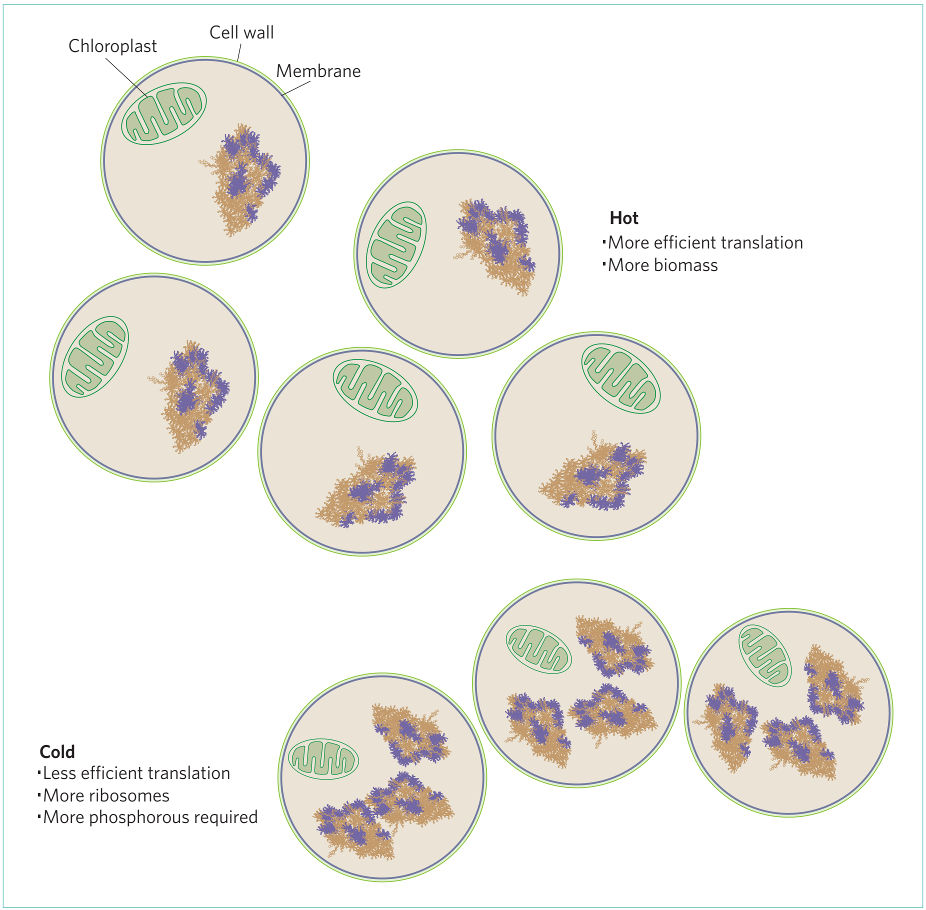

Figure 1 | Temperature-dependent physiology. Phytoplankton have heightened ribosomal efficiency at temperatures experienced around the equator. At colder temperatures they can supplement the reduced efficiency of each ribosome by building more ribosomes. Ribosomes are extremely phosphate rich, shown here in orange (with protein in purple), and hence at colder temperatures a cell needs more phosphorus to make more ribosomes.

The world's oceans cover 72% of the planet's surface and harbour microscopic plants and bacteria known as phytoplankton, which are responsible for ~98% of the oceans' primary productivity[2] and the majority of its geochemical cycles[3]. Despite considerable investment in understanding how land-based primary productivity may be affected by climate change, we still lack fundamental evidence of how this will be manifest in the oceans. A single group of phytoplankton — diatoms — have been estimated to contribute >25% of global carbon fixation[4]. However, recent evidence suggests that this carbon sink is being threatened by steadily increasing water temperatures[5]. To determine the impacts on marine productivity, and therefore nutrient cycling, it is important that we identify how temperature influences phytoplankton physiology. Toseland *et al.*[1] demonstrate this by combining evidence from phytoplankton metatranscriptomes (total community gene transcription) and biochemistry to create a model that encapsulates how phytoplankton alter their cellular chemistry in response to temperature change. The model can then be used to predict any impact on nitrogen (N), phosphorus (P) and carbon cycles.

Previously, researchers have focused on the influence of temperature change on individual components of phytoplankton physiology or on how the ratio of N:P is changing in marine organic matter (for example, refs 6–9). Toseland *et al.* shed light on how phytoplankton cells allocate available resources (specifically N and P) so that they can maintain their productivity from the poles to the tropics. The authors employed metatranscriptomics to determine the distribution of phytoplankton and which genes they were transcribing (transcripts) in the Arctic, Antarctic, North Atlantic, North Pacific and equatorial Pacific. They show first that the changes in the relative abundance of transcripts that are destined to make cellular protein (and hence biomass) — in a process called translation — are positively correlated with temperature. Experimental studies in the laboratory show that the translation apparatus of two diatom species worked most efficiently when grown at temperatures close to average equatorial surface waters, and were less efficient at Arctic temperatures as the cold slowed down the molecular machinery. However, Toseland *et al.* observed that actual cellular productivity in the Arctic and Antarctic was not as repressed as it should be, despite the colder water. They attribute this to a considerable increase in abundance of the cellular translation machinery that helps to build protein, so called ribosomes, which are bound in P-rich RNA (Fig. 1). Hence, to overcome the low water temperatures (average of 2 °C) and concomitant reduction in efficiency, these cells just make more protein factories to maintain their productivity. As this requires more P, the N:P ratio in their cells is reduced.

This information led to the development of a physiological model of the phytoplankton cell that described how much available P and N the cell would use for creating protein, versus how much it would put into creating RNA. The problem is that RNA uses more P, which is often a limiting nutrient in the world's oceans[3]; therefore if the cell diverts its resources to create more RNA-laden ribosomes to overcome their reduced efficiency, it needs more P than cells found in warmer water at the equator. The authors placed their model cell in a computer-generated model ocean that replicates the changing temperature, nutrient availability and amount of light that real phytoplankton cells would experience across the global ocean. The model validated the hypothesis that under low temperatures the cells invested more in their cellular machinery to overcome the inefficiency of their factories; whereas under higher temperatures the cells invested in photosynthesis and hence biomass.

In further work they artificially raised the average sea surface temperature by 5 °C, and observed what happened to the phytoplankton cell. As the polar sea warmed up, the phytoplankton cell reduced the production of P-rich ribosomal RNA, changing the cellular N:P ratio, which by definition fundamentally alters this ratio in organic matter. Why does this matter? If the N:P ratio increases then the cell has an increased N requirement, which will cause N to become a limiting resource. Nitrogen limitation could reduce photosynthetic productivity causing an increase in carbon flux from the surface ocean to the atmosphere, thereby resulting in a significant reduction in carbon sequestration by the ocean. Potentially this could result in a catastrophic positive feedback loop, as more atmospheric carbon equals more warming[9].

Although this model represents one of the most sophisticated methods for capturing and predicting the result of rising temperature on global oceanic primary productivity, it still has limitations. For example, it doesn't take into consideration the changes in atmospheric carbon levels, which could bolster photosynthetic efficiency and inflate predictions. The model also doesn't account for cyanobacteria, the other major phytoplankton group in the ocean, nor the interactions with other non-photosynthetic bacteria. Future work should focus on the integration of these efforts to create a comprehensive model that will enable us to predict the real outcome of climate change and global warming in this essential system. ❐

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AGRICULTURAL IMPACTS

Big data insights into pest spread

Pests and diseases reduce agricultural yields and are an important wildcard in the evaluation of future climate impacts. A unique global record of pests and diseases provides evidence for poleward expansions of their distributions.

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Food security depends on our ability to effectively manage crop pests (arthropods and pathogens). Because of the important effects of weather variables such as temperature and precipitation on crop pests, scientists have for some time hypothesized that where climate change results in a more (less) favourable environment for pest establishment, losses to unmanaged pests are likely to increase (decrease)[1]. But evidence that ranges have shifted under climate change is often anecdotal, and the availability of long-term data sets of pest occurrence is limited[2,3]. In this issue of *Nature Climate Change*, Bebber and colleagues[4] present an analysis of decades of reported pest distributions, concluding that pests have moved towards the poles over the past fifty years, in line with expectation under climate change.

One of the interesting aspects of this analysis is its reliance on 'big data'. The data set that Bebber and colleagues[4] analysed, although not challenging in terms of sheer storage and computational requirements, has been assembled over some time as many, many individuals reported where and when they found particular pests. In their popular book, Mayer-Schönberger and Cukier[5] discuss three aspects of big data that present challenges for scientists. The first is a shift towards using large amounts of data from different sources, often collected for different purposes. The second is an acceptance of 'messiness', where having large amounts of data may make up for introducing increased sources of variability, and potentially even for introducing bias (more on that later). The