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Small organisms with big climate impact

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To coincide with the 28th United Nations Climate Change Conference (COP28), taking place in Dubai, United Arab Emirates, we present a set of specially commissioned commentary and review articles that call attention to the outsized impact of microbes on the environment.

We present a focus issue on microbes and climate change to coincide with COP28 in Dubai, United Arab Emirates. This issue highlights how climate impacts the spread and emergence of infectious diseases and microbial ecology, and argues the urgent need to include microbiologists in climate discussions.

The first COP meeting was held in Berlin, Germany, in 1995, with the goal of turning the tide on anthropogenic climate change. Since then, annual meetings have led to the Kyoto Protocol, which acknowledged the human contribution to global warming and outlined objectives for the reduction of greenhouse gas emissions from developed countries, and the Paris Agreement, which aimed to keep the rise in average global temperatures from exceeding 1.5 °C above the pre-industrial mean.

These agreements are hard-won diplomatic achievements. But agreements on paper have arguably failed to make a noticeable impact. The past year was the hottest on record[1], with numerous instances of deadly extreme temperatures, drought and wildfires around the globe. The stakes are high going into Dubai, especially because the programme at COP28 includes preparation for the first Global Stocktake[2], a 5-yearly checkpoint on actual versus target greenhouse gas emissions and progress towards the goals of the Paris Agreement. The focus is on climate action that enables concrete changes to prioritize relief and recovery efforts for people impacted by climate change, to safeguard food and water systems, and to protect nature. In line with this, our focus issue aims to call attention to the most pressing links between microbes and climate. Anchoring the issue is a Feature article by journalist Virginia Gewin that highlights how microbes and microbiologists are effectively omitted from climate discussions, including COP28. With the content included here, we hope to put a spotlight on microbiology at this critical point.

Among the most important issues to consider is how climate change alters and exacerbates the spread of pathogenic parasites, bacteria, fungi and viruses. One key example, covered in a Comment article by Erin Mordecai, is how extreme weather and deforestation pave the way for outbreaks of vector-borne diseases such as malaria, Zika, dengue and Lyme disease. Similarly, Diann Prosser and colleagues describe in another Comment article how shifting weather patterns alter bird habitat ranges and migration patterns and can lead to the spread of highly pathogenic avian influenza. These changes can also trigger the emergence of pathogenic traits in previously benign species, as described in a Comment article by Arturo Casadevall, which illustrates how adaptations to global warming provide an opportunity for novel fungal pathogens to emerge. A clear theme across these pieces is that reversing environmental degradation caused by warming, flooding and deforestation is essential for maintaining human, animal and environmental health, and that climate agreements must ensure accountability and enforce commitments in order to make an impact.

Preparedness for the spread of infectious diseases is also key, but strategies must be climate-conscious. In their Correspondence piece, Nidhee Jadeja and co-authors assert that climate and health strategies must take vaccination into account, especially in low- and middle-income countries that are particularly affected by both disease burdens and climate change impacts. While vaccine programmes are essential to reverse the growing spread of infectious diseases, extreme temperatures and weather and humanitarian crises hamper the consistent and equitable delivery of vaccines. The authors argue the need for innovations in thermostable vaccine technology and for collaboration between vaccination programme strategists, epidemiologists and climate researchers, building a case for a One Health approach for the most effective future vaccine delivery systems.

A sustainable future depends not just on preventing the spread of pathogens, but also future-proofing beneficial microbiomes and harnessing their potential. In a Comment article, Jingjing Shi and Madhav Thakur outline how climate extremes destabilize fungal–bacterial interactions with potential feedbacks that ripple out to the ecosystem level with implications for biodiversity and productivity. In another Comment article, Eleonora Egidi and co-authors argue that microbial community dynamics hold predictive power that can be used to assess how vulnerable an ecosystem is to environmental perturbations, as well as to track the progress of recovery efforts. In a Review article, So Young Choi and co-authors synthesize the myriad ways

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microbial metabolism could be co-opted to yield greener alternatives for the synthesis and breakdown of plastics. Together, these pieces highlight the potential of microbe-mediated environmental management strategies and the need for more research in this emergent field.

International collaboration and cooperation on field-based studies will be essential for addressing the issues outlined above, but researchers in low- and middle-income countries often go unrecognized for their contributions[3], and poorly planned studies can do more harm to the environment than good. The Nagoya Protocol was introduced in 2014 to bind researchers from signatory countries to sustainable scientific practices that protect biodiversity, while also fairly sharing the knowledge and benefits leveraged from the use of genetic resources and respecting Indigenous people and traditional knowledge. In a Comment article, Hassan Salem and Martin Kaltenpoth outline the sobering track record of the Nagoya Protocol, owing to an incompatibility with the biology of microorganisms. To equitably move forward, the authors argue that regulations should be streamlined and simplified.

This focus issue of *Nature Microbiology* closes out the eighth year of the journal. On our fifth anniversary in 2020, we expressed a commitment to expand our scope into microbial research that addresses the issues of global change and sustainability[4]. Since then, we have published research and commentary covering all domains of life across environmental systems, from how ecosystem degradation contributes to the spread of emergent viruses and fungal pathogens to calls to arms to use aquatic and terrestrial microbiomes as biodiversity safeguards. We direct readers to a collection of recent climate-focused papers curated from our archives.

The content presented in this focus issue clearly demonstrates the central role played by microorganisms in climate, so it is surprising that microbiology is rarely mentioned at climate meetings. In her Feature article, Virginia Gewin argues that microbiologists must demand a seat in climate discussions, with the hope that they can play a larger role at COP29. For our part, we will continue to champion the best environmental microbiology research and provide a platform for researchers in the pages of *Nature Microbiology*.

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