Molecular biology holds a vast potential for tackling climate change and biodiversity loss. Yet, it is largely absent from the current strategies. We call for a community-wide action to bring molecular biology to the forefront of climate change solutions.
That biological processes can profoundly impact planetary climate is well established. We owe the rich biodiversity on this planet to the massive oxygenation started by microbial photosynthesis circa 2 billion years ago. And, paradoxically, the fossil fuels, the use of which caused the current crisis, are themselves the product of photosynthesis. Although molecular biology has provided great insights into these and other essential processes of life, it is missing from the frontline strategies for climate change solutions. This is concerning, as molecular biology is essential to monitoring ecosystem health, development of optimal intervention strategies, and the invention of tools to implement them.

To understand the key areas in which molecular life sciences can make an impact, the European Molecular Biology Laboratory recently hosted a scientific workshop under the All4Climate Italy 2021 programme. Existing and potential solutions were identified (Fig 1), which together span challenges to four planetary boundaries [1,2]: global warming, loss of biodiversity, biogeochemical flows, and manufactured pollutants [3]. Below we outline some of the strategies discussed in the meeting and potential pathways to their realisation.

One of the key areas of potential impact is changes to current food and agricultural systems that can considerably mitigate greenhouse gas emissions [4]. Molecular biology could help through developing novel foodstuffs that provide balanced nutrition while maintaining sensory appeal. Engineering and breeding of crops for, e.g., enhanced nutrition and drought- or salt-tolerance, will be essential to maintain food security. In agricultural practice, modulation
of soil, gut and rumen microbiota could help reduce methane emissions from cattle and nitrous oxide emissions from intensified land usage. The balance in global N₂ flows could be restored by replacing chemical fertilizers with microbial solutions to boost direct N₂ fixation. In polluted ecosystems, some of which are already pushed beyond their tipping point, engineered, or evolved microbial communities could be deployed to clear the pollutants.

In the fuel and chemical sectors, the vast biochemical diversity of organisms [5, 6] should be tapped for uncovering and engineering novel enzymes and carbon converting pathways. Using these, synthetic biology could help replacing fossil fuels and petrochemical-based materials with renewable resources based on photosynthesis and through valorising waste streams [7, 8].

Another opportunity for impact is a targeted ecosystem modulation. Molecular characterization of inter-species interactions and computational models built on these could help us predict complex ecosystem dynamics and guide interventions to counteract the negative effects of anthropogenic emissions. Plants and environmental microbiomes could be modulated to enhance their capacity to capture CO₂ and methane. This way, the gap between the carbon sequestering capacities of natural and planted forests could be reduced through model-guided promotion of biodiversity. Similar approaches could halt biodiversity loss in the ocean and promote CO₂ fixation by phytoplankton and algae, with further capacity boosting through rational genetic engineering [9, 10]. Genomic and metabolomic markers could be developed as biomarkers for monitoring ecosystem health and provide early warnings of tipping points [11]. Integrating these modulation approaches with land usage, marine resources and economic policies would enable better adaptation of local communities to climate change and the implementation of countermeasures for restoring ecological balance.

How can we realize molecular biology solutions? First and foremost, we should aim, by working collaboratively across the globe, to put molecular life science firmly onto the agenda of the United Nations Framework Convention on Climate Change (UNFCCC). The potential of the solutions should be communicated in ways that are accessible to policymakers and the general public. Biologists should be introduced to opportunities in climate science, and climate scientists to the opportunities offered by molecular life science. This interdisciplinary research could be facilitated through creating dedicated programmes and funding schemes. A greater connection between research and industry is also needed, where industrial players are involved early on to help identify the most promising solutions, and to realize their potential by scaling up and integrating them into economic chains. For this to happen, the molecular life sciences need greater focus from governments and industry alike to develop the needed infrastructures and ambitious projects that link molecular and cellular researchers with those investigating planetary health.

Many more and better ideas than discussed here will no doubt emerge as more scientists get involved in this mission. The immediate task is to call for a community-wide action; we hope that this Perspective will help to achieve this. All of us can start by conducting research in a sustainable way. We may also need to change the mode of research that we are comfortable with, yet what better cause can there be than the emergency presented by climate change, which threatens our very existence? The remarkable response to the COVID-19 pandemic has illustrated what can be achieved by investment into molecular life sciences, combined with industrial, political, and societal participation. Let us use this momentum and tackle the challenges of climate change and biodiversity loss head-on.

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