WORLD ECONOMIC FORUM

Revisiting and Realizing the Promises of Synthetic Biology

BRIEFING PAPER

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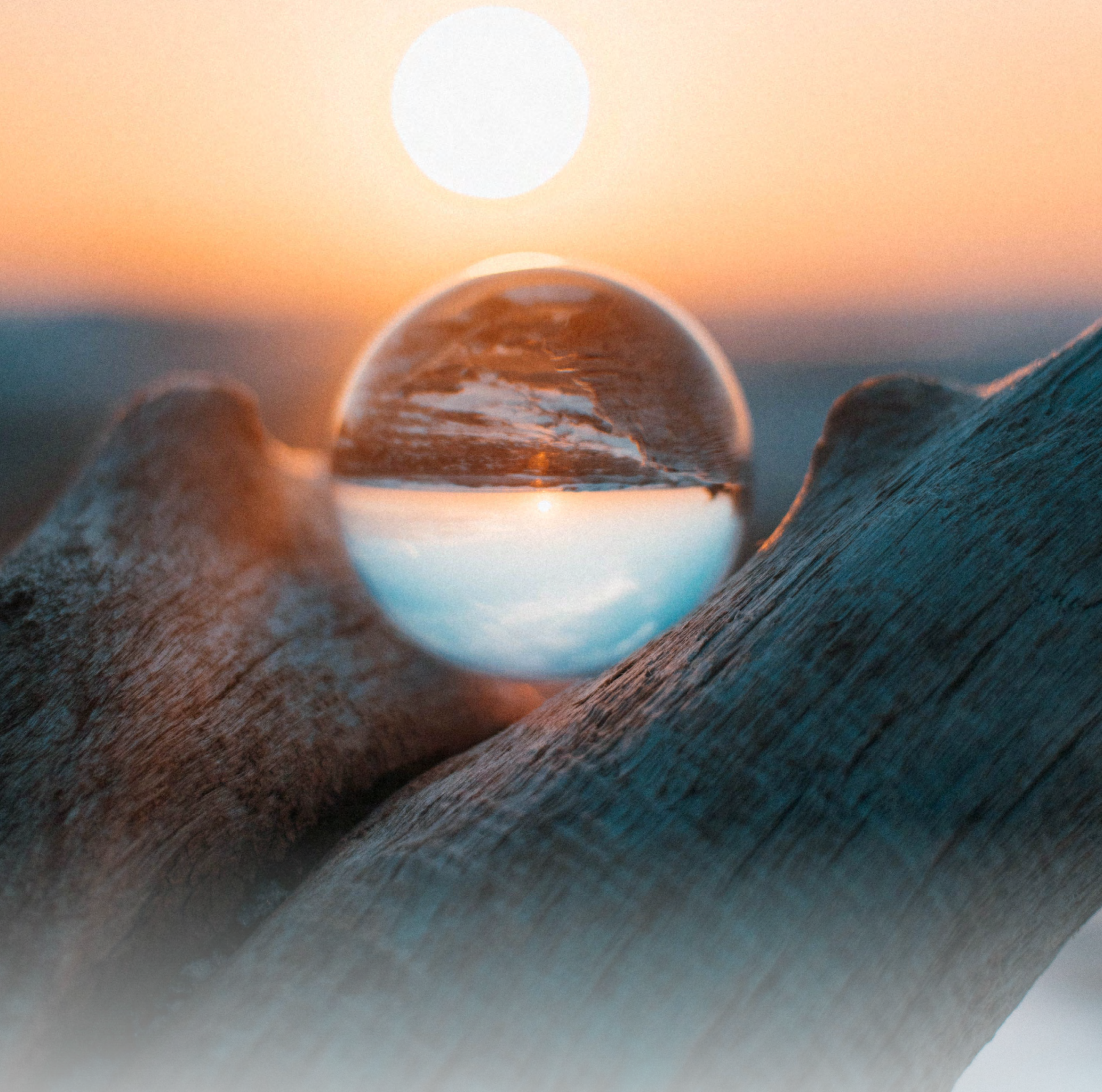

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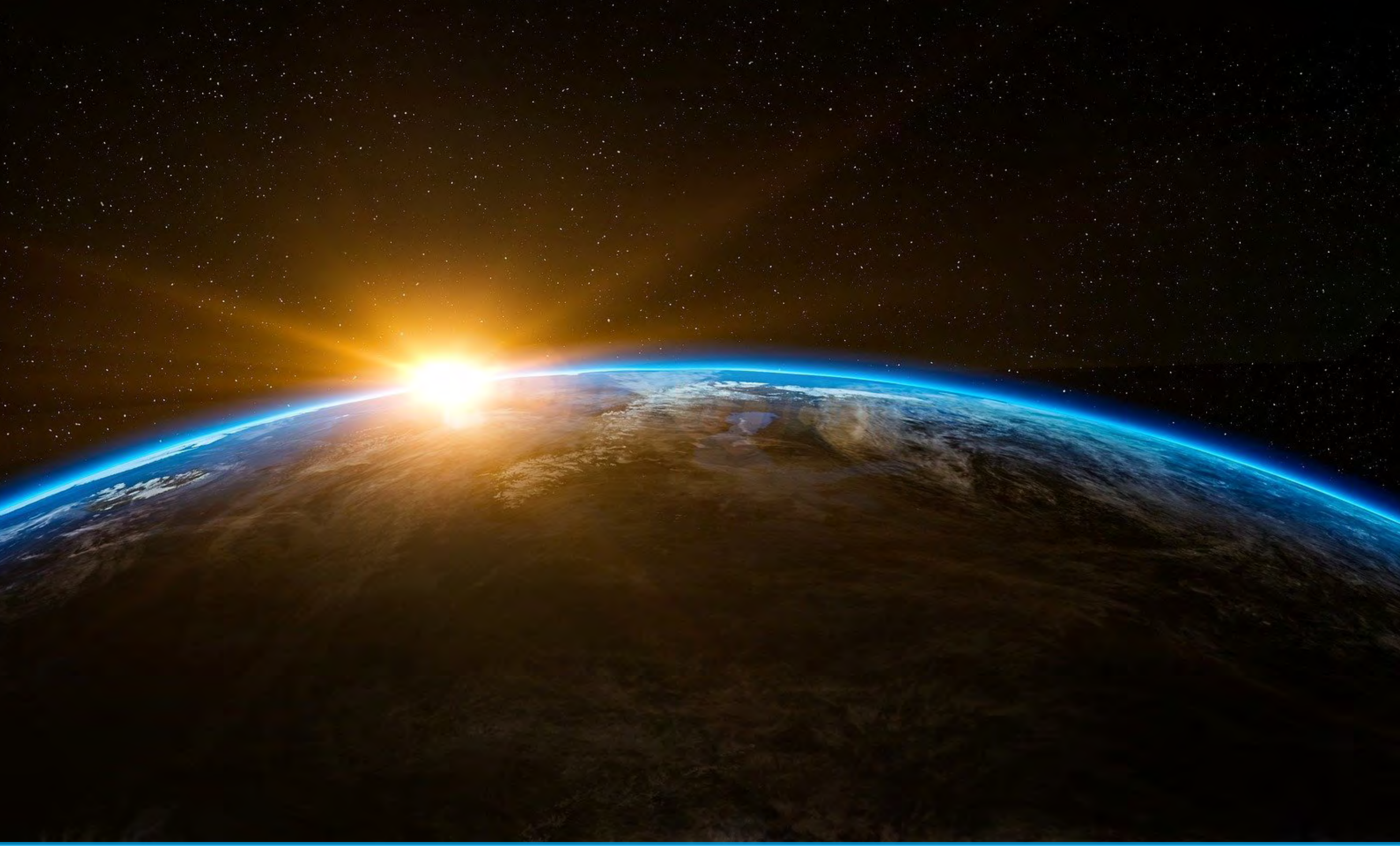
Contents

Introduction

Synthetic biology has been defining itself as a field for at least two decades.[1] It employs science and engineering approaches to design biologically based parts, novel devices and systems as well as redesigning existing, natural, biological systems. Synthesis is a powerful approach to learning about and building with the living world[2] and its applications have expanded to almost every major industry. Potentially the broadest impact area is the manufacture of bio-based products and the numerous applications of these products in health and well-being, food and feed, industrial chemicals and biofuel applications.

The potential benefits of synthetic biology are manifold – but will they be distributed equitably? Wealthy nations have been at the forefront of synthetic biology and the livelihoods of those in developing and emerging economies have often been overlooked. As we learn to engineer the living world, how can we ensure it is a world in which we want to live? If synthetic biology is to realize its full potential, it must have values at its core.[3] This report looks at synthetic biology's embodiment and advancement of equity, humility, sustainability and solidarity over time: four values that are important in realizing its future benefits and minimizing its potential negative consequences. We then provide recommendations on how policies could direct the future trajectory of synthetic biology to benefit all people and the planet.



1 Equity

Equity is an ethical concept grounded in principles of impartiality, distributive justice[4] and fairness. Equity in synthetic biology involves many factors, not least ownership and resource flows including who pays, who profits, who is taking risks and who is exposed to them. Examples of inequities include disparities that constrain the ability of researchers in the Global South to innovate with biological engineering and the unequal accession to leadership opportunities faced by women,[5] people of colour and other under-represented groups in the field.

From an early point in its history, synthetic biology has included discussion of democratization of access to technology and responsible ways of doing and deploying science.[6] There is also a strong ethos of sharing and a commitment to "open source" approaches at an academic level.[7] Disciplines like design[8,9] and sociology[10] have brought constructive criticality to synthetic biology, raising issues of equity such as structural factors that might exclude different types of knowledge.

However, looking back over discussions of equity in synthetic biology, its identification and definition are complicated by its many dimensions: geography, gender, ethnicity, seniority and economic power to name a few. The focus of most equity initiatives so far has been limited; e.g., gender equity in specific contexts, global access to research tools and inclusion in educational initiatives. Looking ahead, deeper questions will need to be asked. For example, what structural changes would be needed to enable researchers in the United States and Kenya to make the same use of equally accessible DNA encoding a biosensor? We also need to move the conversation beyond equitable access to research, towards equitable development and use of products, leading to more equitable benefits and opportunities.

As much as these future challenges are daunting, there are currently huge opportunities to act and expand the accessibility of synthetic biology to more parts of the world and to new talent, fostering more equitable innovation, discovery and business.

2 Humility

Considering humility in synthetic biology, we are inspired by the concept of technologies of humility proposed by Sheila Jasanoff.[11] In summarizing this thinking, she states:[12] "For every new technology, we must leave ourselves time to ask how it can best serve humankind. We will find the answers only by remaining critical and by supplementing the forces of government, the market and ethics with a more humble approach to innovation."

The question is not *could* but *should* synthetic biology be used as a solution in a given scenario. There is significant hubris about what is possible and sometimes poor recognition of what can be achieved in the immediate term,[13] which risks both failure of delivery and loss of trust in the technology even if progress finally is delivered – perhaps years later than promised. Synthetic biology-based biofuels are an excellent example of this (see Sustainability). Other technologies, such as gene drives to control pests or disease vectors like mosquitoes by spreading genes that result in "self-destruction" of the population, should be explored with humility and recognition of the social, ecological, economic, ethical and political context of their use, regardless of their promise as a technical solution.[14]

Humility does not fit easily with academic and entrepreneurial activities. Their structural frameworks of funding, recognition and reward encourage and incentivize over-claiming and over-promising, particularly about the potential economic benefits of the field. In addition, technological fixes are often prioritized above understanding complex socio-technical realities. However, the complexity of biology requires humility: synthetic biologists have over time turned to working *with* these systems, harnessing evolution and adaptation even if this does not always fit easily with the philosophy of the engineering roots of the discipline, which emphasizes systematic control. The interdisciplinarity of the field is also a positive indicator that there is capacity to recognize the value of a plurality of knowledge and perspectives.

3 Sustainability

Many synthetic biology policies reference environmental sustainability and also sustainable development, which is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs".[15] Increased sustainability compared to existing manufacturing is viewed as a key advantage of many bio-based products,[16] particularly in the chemical and petrochemical industries, which are the largest contributors to global demand for fossil fuels.[17]

For this reason, biofuels were a yardstick for the early synthetic biology field.[18] Upon reflection, the broad consensus among synthetic biologists was that promises were made regarding advanced biofuels that could not be realistically achieved in the given time frame and that the field lacked appropriate humility. While technologies like biofuels still hold great potential, there are multiple questions on policy, finance and governance that need to be addressed, such as how we assign value to sustainability, maintain realistic expectations of the timescales that are required for sustainable technologies to mature and design systems that can prioritize their longer-term impacts.

This is not to say there have not already been sustainability success stories. Alternatives to fossil-derived molecules for fuel have since come to the market alongside bio-derived plastics and innovations to improve crop yields and manufacture drugs with less waste.[19] These achievements have galvanized consistent interest and investment in sustainable bio-based approaches as well as significant policy attention.[20,21,22] The enthusiasm for sustainability is also clear among early career researchers such as teams in the International Genetically Engineered Machines (iGEM) competition.

Moving forward, synthetic biology holds the potential to drive many sustainable outcomes but provides at best only part of the solution. Grand sustainability challenges which synthetic biology can address include replacing fossil-derived feedstocks; inventing truly sustainable plastics; developing scalable methods for CO_2 capture and storage; and reinventing meat production. We should take into account that technology can sometimes support unsustainable consumption when it is not accompanied by strategies to address the underlying reasons or models that drive consumption. We must assess which strategies – biological and otherwise – can deliver at sufficient scale to make a lasting difference for these sustainability challenges.

4 Solidarity

Solidarity is identified in the United Nations Millennium Declaration[23] as a fundamental value of international relations whereby those who are negatively impacted or benefit least deserve help from those who benefit most. Solidarity aims to decrease social divisions and exploitation, actively promoting the welfare of all those who are less advantaged.[24] International solidarity is necessary to ensure that in a post-COVID world we are able to narrow rather than widen some of the gaps in terms of how synthetic biology (and other technologies) benefits different groups of people and different parts of the planet.

The origins of synthetic biology saw scientists and engineers co-defining a new field, terminology and applications, including human practices, ethical, legal and social aspects and concepts such as responsible research and innovation, which should have left the field well placed to model solidarity. However, despite some progress in embedding human practices as a norm within the field, the existing systems have continued to support scientists who focused on technological and scientific development decoupled from social considerations. Educators, researchers and others attempting to understand and shape the future of the field from different perspectives have struggled to gain the time, attention and budget to enable equitable participation in discussing new directions and policies, yet efforts to change norms and cultures within a field require sustained efforts to avoid a return to the status quo.

The result is that embedding solidarity as a value that shapes the trajectory of synthetic biology is still a work in progress. Synthetic biologists need to engage and collaborate directly as part of a truly global ecosystem to address needs in many different communities, including in developing countries. Otherwise, synthetic biology technologies risk a lack of support in countries that could benefit the most from them. Social divisions might be increased by the mixed feelings on synthetic biology already held by the public,[25] opinion leaders and lawmakers.[26]

One key question in advancing solidarity in synthetic biology and beyond is how to develop a broader global science and education community that shares knowledge, technology and know-how and avoids technology nationalism in countries that "have" preventing the benefits reaching countries that "have not". This scenario is unfolding at present in the light of COVID-19 vaccine roll-outs. Many of the vaccines are based on technology advanced through synthetic biology approaches, and the World Health Organization and partners are calling for global solidarity to ensure that developing countries have access,[27] in the face of existing intellectual property regimes, insufficient global supply and export controls.

5 Recommendations

Looking back teaches us that synthetic biology is not panacea, rather it is enabling production of new knowledge and disruptive approaches to challenges and problems. The consideration of where synthetic biology does and does not serve equity, sustainability, solidarity, humility and what has been effective or counter-productive in the past can inform us as we look ahead. Our preliminary recommendations are:

1. **Increase international collaboration between countries on synthetic biology policy, research and applications that leverage the skills and resources of all participants.**

   This includes coordination of technical infrastructure, tools and platforms. We particularly recognize that specific policy alignment may be needed for applications of synthetic biology that have effects beyond national boundaries (e.g., ocean bio-remediation, gene drives to control invasive pests) and social or economic downstream impacts that divergently affect different international stakeholders (e.g., changing land-use patterns due to requirements for fermentation feedstocks).

2. **Those creating bioeconomy policy or funding research and development should embed design thinking, social and economic science and a plurality of perspectives early on.**

   Existing close ties to designers and social scientists can be leveraged to help understand how to build values of equity, humility, sustainability and solidarity into the technology itself alongside better ways to measure and model the value (economic and otherwise) of innovation ecosystems enabled by synthetic biology.

3. **Provide regular fora for public and private investors in synthetic biology to discuss their innovation models and strategies, address social and environmental issues and prioritize support for initiatives that will advance equity, solidarity and sustainability.**

   The United Nations Sustainable Development Goals (SDGs) could be adopted as rallying points for efforts in applying synthetic biology to solve the most pressing problems.[28]

4. **National and regional policy initiatives that seek to embed synthetic biology into broader bioeconomy strategies should deliberately include a wider range of voices.**

   Current conversations on shaping the future of synthetic biology and of resource allocation are dominated by a small number of nations and people. Diversifying and including new perspectives would enrich many discussions and potentially lead to more equitable outcomes. Amplifying voices from frontier and emerging economies is also necessary to advance synthetic biology strategy at a truly global level. This recommendation will involve asking how we can share the achievements and potential for synthetic biology to change the world for the better in ways that demonstrate humility and realistic expectations.

5. **Include consideration of how we finance equity, sustainability and solidarity in the development, deployment and impact of synthetic biology in the design of all policy and funding instruments for the bioeconomy.**

   Specifically, research funders, institutions, companies and investors should revisit the structural frameworks of financing, funding, recognition and reward that encourage and incentivize over-claiming and over-promising in academia and industry. More inclusive and expansive measures of success for future activities, initiatives and investments in synthetic biology are required.

These recommendations are pressing because of global interest in the potential of synthetic biology to address urgent issues across many sectors including climate change, circular economy, healthy living for all and a healthy planet. We must ensure that those guiding ad resourcing the upcoming wave of investment in synthetic biology learn from the past. The future of synthetic biology should centre on equity, humility, sustainability and solidarity at its core as the world rebuilds from COVID-19.

Contributors

David A. Bray
Distinguished Fellow, Stimson Center; Executive Director, Commission on the Geopolitical Impacts of New Technologies and Data

Roel Bovenberg
Senior Science Fellow, Royal DSM, honorary professor Synthetic Biology and Cell Engineering, University of Groningen

Matthew Wook Chang
Director, Singapore Consortium for Synthetic Biology; Associate Professor of Biochemistry and Dean's Chair of the Yong Loo Lin School of Medicine, National University of Singapore

Natsai Audrey Chieza
Founder and Chief Executive Officer, Faber Futures

Juergen Eckhardt
Senior Vice-President; Head, LEAPS, Bayer

Chenli Liu
Professor and Director, Shenzhen Institute of Synthetic Biology, Shenzhen Institute of Advanced Technology, Chinese Academy of Science

Jenny Molloy
Senior Research Associate, Department of Chemical Engineering and Biotechnology, University of Cambridge

Megan J. Palmer
Executive Director, Bio Policy and Leadership Initiatives; Adjunct Professor, Department of Bioengineering, Stanford University

Kristala L. J. Prather
Arthur D. Little Professor of Chemical Engineering, Massachusetts Institute of Technology

Elissa Prichep
Lead, Shaping the Future of Health and Healthcare, World Economic Forum

Claudia Vickers
Director, CSIRO, Synthetic Biology Future Science Platform, Adjunct Professor, Queensland University of Technology and Griffith University

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World Economic Forum
91–93 route de la Capite
CH-1223 Cologny/Geneva
Switzerland

Tel.: +41 (0) 22 869 1212
Fax: +41 (0) 22 786 2744
contact@weforum.org
www.weforum.org