WORLD ECONOMIC FORUM

Global Future Council on Synthetic Biology

Realizing Geographical Diversity in Synthetic Biology

The Next Critical Frontier to Deliver Impact and Equitable Futures

BRIEFING PAPER

February 2023

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1 Introduction

To realize the full potential of synthetic biology, all benefits must be equitable and delivered globally.

Innovation in synthetic biology, a field of science that involves redesigning organisms for useful purposes by engineering them to have new abilities[1], is heavily concentrated, with North America, the United Kingdom, Europe and China playing leading roles. These regions are also the primary beneficiaries of synthetic biology technologies, such as health, agricultural and industrial innovations despite much of the value of synthetic biology being derived from the genetic material of organisms that are sourced worldwide.

This leaves a gap between where the resources are extracted and the benefits yielded, while ignoring overall equitability. With synthetic biology maturing as a cornerstone of the Fourth Industrial Revolution, the focus needs to be on how to realize all its potential by leveraging the full creativity and capability of the global research community, as well as delivering its benefits globally[2].

As we explore new systems of innovation, we have an opportunity to purposefully include equity and social considerations in the development of synthetic biology[3,4]. Synthetic biology drives innovation in the "bio-economy", an economy based on activity involving the use of synthetic biology in the production of goods, services or energy alongside materials harvested from the natural environment and information derived from living organisms.

These new "living" building blocks can be applied to a wide range of products in food, health, agriculture and even IT – such as more nutritious food, improved medicines, higher yielding crops and more advanced disease suppression and detection. As biological information and assets are sourced globally, synthetic biology provides an opportunity to not only imagine but also to build a future through equitable innovation.

Diversity, equitable partnerships and local autonomy

The World Economic Forum's Global Future Council on Synthetic Biology[5] identified that leveraging the strengths of geographic diversity in innovation must be a key pathway in advancing the potential of synthetic biology[6]. At the core of this pathway is the appreciation of diversity, equitable partnerships and local autonomy. In this briefing paper we examine how present and/or absent these values are in the history of synthetic biology and how focusing on them will help to deliver on the promise of synthetic biology[7] as the field evolves and matures.

2

Recognize and leverage strengths of geographic diversity

Greater inclusion in the synthetic biology research community would dampen the brain drain of local talent.

Nature, biodiversity and the genetic code are valuable economic resources. That value has the potential to be unlocked in ways that better utilize local knowledge and provide greater benefit to local populations if development takes place closer to the source of genetic resources. The geography of ownership and sovereignty over genetic resources is complex and often contested. In the context of synthetic biology, this is especially true of digital DNA sequence information (DSI) that can be shared globally. Fair governance of DSI and the technology using it is crucial for enabling more democratic paths of innovation in synthetic biology.

This is highlighted in the discussions on the inclusion of DSI in the Nagoya Protocol[8,9] on access and benefit sharing, addressing the live debate about nuances of balancing open access to knowledge with ensuring that benefit is shared equitably with data providers[10]. Biodiversity – the source of genetic resources for bioengineering – is greatest in the Global South, making its inclusion a key advantage for synthetic biology.

A lack of geographical diversity in innovation is reflected by the uneven spread of publications in synthetic biology. The Global South remains under-represented in publications even though it represents some of the most biodiverse regions in the world. Currently, out of 24,000 academic papers referencing synthetic biology[11], only 1,128 are from low and middle-income countries[12], excluding China. These figures arise despite synthetic biologists emphasizing inclusive access to infrastructures and components (DNA sequences and genetic modification resources) from the origins of the field. Open sharing of synthetic biology technologies is well documented[13,14] and responsible research and innovation has become an integral part of major national and regional initiatives[15,16].

Utilizing innovation in a wider range of regions offers opportunities to leverage geographic advantages and to capitalize on a broader pool of talent, perspectives, knowledge and ideas. Examples of other benefits to expanding geographies engaged in synthetic biology include accessing warmer tropical climates that yield better growth of organisms that convert sunlight and carbon dioxide into valuable products and increased food security by optimization of crop yields. Numerous reports have demonstrated the innovation advantage of diversity[17,18]; there is no reason to believe synthetic biology is any different.

Much more can be done to increase inclusion in the synthetic biology research community. This can also dampen the brain drain of local talent, with the Global South currently losing its best and brightest to North America, the UK and Europe.

3

Form equitable partnerships to enable geographic diffusion of synthetic biology

Equitable international collaboration is vital to empower true partnerships between developing countries and established economic powers.

Historically, systems of global development and the mental models that underpin them can be problematic. This is most acute in the framing of populations in emerging economies as a set of passive beneficiaries of capacity-building initiatives[19]. One part of correcting this situation involves overcoming blind spots in how innovation is conceptualized in the bio-economy and how different forms of knowledge and problem solving, such as the application of local knowledge, are rendered invisible or undervalued. To meet local needs, the products, services and research underlying their development need to respond to the local context and culture. Yet the process of extracting, outsourcing and commodifying data that rightfully belongs to local communities has been under way for millennia[20]. This has resulted in local innovators building and instituting stringent measures to safeguard against access to data derived from their local communities[21, 22].

Having stewarded this biodiversity for millennia, local communities have sophisticated knowledge spanning agriculture, aquaculture, forestry, medicine, celestial navigation, spirituality and more. Yet many of those communities find themselves limited in the expertise and laboratory infrastructure (including high throughput bioengineering facilities, known as biofoundries[23]) necessary to reclaim, organize, protect and exploit data that rightfully belongs to them[24].

Challenges can be solved through prototypes of new data governance systems. Thoughtful ethical guardrails, data-sharing restrictions and privacy safeguards are needed to ensure proper use, while overly complicated barriers to sharing data or unclear benefit-sharing mechanisms could risk limiting both scientific and capacity-building progress[25]. Having shared data commons, where DNA sequence information, know-how and other resources are made public, can safeguard responsibility globally while allowing communities to not only occupy a seat at the consensus building table but also receive a larger portion of royalties and intellectual property. For example, piloting the concepts of “data trusts” and “data cooperatives”, where a steward manages data on a collective’s behalf, could facilitate sharing knowledge of biotechnology efforts.

It is paramount that capacity is built with a focus on increased autonomy for research and innovation. This entails the identification of mutually beneficial opportunities that transcend geographic boundaries and promote the sharing of resources. These could include laboratory equipment, essential materials, data analytics, knowledge and people. Such approaches will be important to fast-track innovation, data sharing and new product development, ensuring that technologies are readily available to students, researchers, business executives and regulatory agencies everywhere. Partnerships need to be established with all innovation stakeholders, creating enabling conditions for the technology to flourish in local but globally linked contexts. These arrangements also need to be reflected in the applied intellectual property regimes.

The future products and services that emerge from synthetic biology must be responsive to societal differences, cultures and needs. The requirement to co-create these enabling conditions with communities and local institutions substantially extends the effectiveness and longevity of synthetic biology. All stakeholders will need to be involved in creating enabling conditions for growth in the local context over time.

At a national and regional level this will mean embedding relevant dialogue and education[26] in synthetic biology at all levels, changing research cultures and generating labour market conditions that allow fair access to jobs in the field.

4

Increase local autonomy for research and innovation

Greater benefit for all can be unlocked if diverse geographies can participate in the discovery and development of synthetic biology.

Synthetic biology capacity-building initiatives need to aim for re-education in scientific dependency and foreign funding and growth of a qualified workforce and local job prospects. Common approaches are training by international lecturers, or overseas exchanges or capital infrastructure investments, which fit well into self-contained and short-term grant programmes. However, transporting people to developed countries is not enough; local innovation is essential to providing effective frameworks for solutions and ensuring local benefits[27]. The loss of developing countries' brightest talent to developed countries compounds the issue and prevents those countries from building local capability.

There is insufficient financial capital to provide necessary infrastructure in emerging economies, as observed in the patterns of foreign direct investment[28]. The evidence base for exclusion of the Global South from synthetic biology or biotech more broadly is limited by lack of data on key innovation-related metrics. For example, the journal Nature reported record financing of biotechnology in 2020[29], but the accompanying data consolidated North and South America and excluded Africa. There is a need to actively continue and expand research and analysis so we can describe the nature of investment activity in the global synthetic biology sector, including the tracking of patterns of R&D, expenditures, investments, patents and talent.

Without investing in addressing the structural challenges facing synthetic biologists in emerging economies, it will be difficult to make systemic and sustainable progress. While labs conducting some aspects of synthetic biology can be established at relatively low cost, the investment and infrastructure required to engineer biology at scale is limited to wealthy research labs in developed economies. Operational costs can be far higher in emerging economies where supply chains and support ecosystems are yet to be developed. Low numbers of job opportunities and low salaries in many emerging economies are also deterrents to pursuing higher studies and research in synthetic biology even where educational opportunities exist.[30]

To stimulate a "pull" into the local workforce through job creation requires substantial investment of time and financial capital to support professional training, as seen in countries such as the United States, Australia, UK, Germany, Japan and Switzerland[31] with ample government funding and well-managed doctoral and post-doctoral programmes. If done successfully, pipelines for a qualified workforce to develop and commercialize synthetic biology products can be established.

There is a need to develop convincing business cases and analyses that appeal to financiers. This should include programmes and investments that build the capacity and agency of populations including consideration of accessibility to and financing of the infrastructure and tools required by synthetic biology. Policy-makers need to adopt a long-term focus in the design of equitable and sustainable frameworks for resource allocation.

Fortunately, new modes of thinking are gaining ground. For example, the Dasgupta report[32] centres a radical focus on long-term thinking about global economics: prioritizing financial projections that span at a minimum 10 generations into the future, forcing us to redefine the measures of economic success in relation to nature. We need to return to the question: what creates value? To avoid confusing value extraction with value creation, we urgently need to rethink where wealth comes from – which activities create it, which extract it, which destroy it?[33]

5 Conclusion

Synthetic biology is the next frontier for equitable futures.

The COVID-19 pandemic has made interventions to expand the geographies of innovation in biotechnology an urgent issue and synthetic biology is now a key focus of many governments in emerging economies. The speed, development and deployment of an arsenal of new COVID-19 vaccines and diagnostics is testimony to the success of synthetic biology and biomedical research[34] but also proof-positive that inequities in both innovation and access are an ongoing point of conflict for global health and development.

The potential benefits of synthetic biology are manifold[35], ranging from applications in agriculture to health. But are we realizing the full potential of synthetic biology? Wealthy nations have been at the forefront of synthetic biology and the role of those in developing and emerging economies with abundant biodiversity wealth have often been overlooked. Greater benefits for all[36] can be unlocked if local populations can participate in discovery, prioritization and development of synthetic biological innovations. Only then can geographic diversity and equitable innovation be fully leveraged to truly advance the promise of synthetic biology.

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Acknowledgements

The World Economic Forum would like to acknowledge the valuable contributions of the following people in the development of this document:

Seth Bannon
Founding Partner, Fifty Years

Roel Bovenberg
Senior Science Fellow DSM, Honorary professor University of Groningen, Royal DSM

David Bray
Distinguished Fellow, The Henry L. Stimson Center

Jane Calvert
Professor of Science and Technology Studies, The University of Edinburgh

Matthew Chang
Professor, National University of Singapore

Natsai Chieza
Founder and Chief Executive Officer, Faber Futures

Marileen Dogterom
Professor, Delft University of Technology

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

Eyal Emmanuel
Chairman, CRISPRIL Consortium, Evogene Ltd.

Cristina Guerra-Giraldez
Vice-President, Board of Governors, International Centre for Genetic Engineering and Biotechnology

Antoine Gourévitch
Managing Director and Senior Partner, Boston Consulting Group

Margaret Karembu
Director ISAAA AfriCenter; Chair, Africa Science Dialogue

Jason Kelly
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Faisal Khan
Co-Founder and Chief Executive Officer, Peshawar 2.0

Emily Leproust
Chief Executive Officer, Twist Bioscience Corporation

Chenli Liu
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Meagan Lizarazo
Executive Vice-President and COO, iGEM Foundation

Gillian Marcelle
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Wataru Mizunashi
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Ryan Morhard
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Kristala Prather
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Jerome Ravetz
Fellow, Institute For Science, Innovation and Society, University of Oxford

Xu Xun
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Endnotes

1. https://www.genome.gov/about-genomics/policy-issues/Synthetic-Biology
2. https://www.weforum.org/agenda/2021/04/synthetic-biology-potential-people-and-the-planet-gtgs21/
3. https://www.weforum.org/reports/revisiting-and-realizing-the-promises-of-synthetic-biology
4. de Koning, C. (2020). *The co-constitution of technologies, organisations, and institutions in the process of commercialisation: the case of CRISPR*
5. https://www.weforum.org/communities/gfc-on-synthetic-biology
6. https://faberfutures.com/projects/bio-stories-2/
7. https://www.weforum.org/reports/revisiting-and-realizing-the-promises-of-synthetic-biology
8. https://en.wikipedia.org/wiki/Nagoya_Protocol
9. Bagley, M., & Rai, A. (2013). The Nagoya Protocol and Synthetic Biology Research: A Look at the Potential Impacts. In *Virginia Public Law and Legal Theory Research Paper* (Issues 2014–05). https://scholarship.law.duke.edu/cgi/viewcontent.cgi?article=5916&context=faculty_scholarship
10. The WEF GFC on Synthetic Biology will further explore this topic in a focused piece: The Data Commons group will be unpacking this in great detail
11. As indexed by by lens.org and accessed on 1 Sep 2021 via this lens.org search
12. Low and middle income countries were defined by the OECD DAC list. Breakdown by region was Asia [excluding China]: 653; Latin America: 357; Africa: 118)
13. Calvert, Jane. "Ownership and sharing in synthetic biology: A 'diverse ecology of the open and the proprietary?." BioSocieties 7.2 (2012): 169-187
14. Rai, Arti, and James Boyle. "Synthetic biology: caught between property rights, the public domain, and the commons." *PLoS biology* 5.3 (2007): e58
15. Brian, Jenny Dyck. "Special perspectives section: Responsible research and innovation for synthetic biology." Journal of Responsible Innovation 2.1 (2015): 78-80
16. Kahl, L. J. (2015). Realizing positive network effects in synthetic biology. *Journal of Responsible Innovation*, 2(1), 137-139
17. https://www.weforum.org/agenda/2019/04/business-case-for-diversity-in-the-workplace/
18. Hofstra, Bas, et al. "The diversity–innovation paradox in science." Proceedings of the National Academy of Sciences 117.17 (2020): 9284-9291
19. Scheid, B. P. (2021). Shifting the power in global development : Should we stay or should we go now? William + Flora Hewlett Foundation Accessed on March 26, 2021, from https://hewlett.org/shifting-the-power-in-global-development-should-we-stay-or-should-we-go-now/
20. Dunbar-Ortiz, R., "Not" A Nation of Immigrants": Settler Colonialism, White Supremacy, and a History of Erasure and Exclusion." Penguin Random House. (2021)
21. Fox, K., "Game of Bones: Power, Ethics, and Emerging Technology in Paleogenomics Research." ELSI-Hub. (2021)
22. Fox, K. "Lei niho palaoa and digital tools to safeguard against the illicit use of ancient DNA." Hawaiian Archeology. (2020)
23. https://academic.oup.com/synbio/article/6/1/ysaa026/6039187
24. Fox, K. & Hawks, J., "Use ancient remains more wisely." Nature. (2019)
25. Global Futures Council on Synthetic Biology (2021). https://www.weforum.org/agenda/2021/12/why-sharing-data-and-benefits-is-crucial-for-bioeconomy/
26. Bio Stories (2022). World Economic Forum & Faber. Futures https://faberfutures.com/wp-content/uploads/2022/06/FaberFutures_WEF_BIOSTORIES_2022.pdf
27. De Koning, C., Hellman, T., Govaerts, B., Gandrup-Marino, K., Ludbrook, L. (2022). Founders & Funders: Purposeful Innovation. https://www.sbs.ox.ac.uk/events/founders-and-funders-purposeful-innovation
28. World Investment Report 2020, UNCTAD
29. https://www.nature.com/articles/s41587-021-00817-7
30. Salary Explorer. (n.d.-a). *Pharmaceutical and Biotechnology Average Salaries in China 2021*. Retrieved 26 March 2021, from http://www.salaryexplorer.com/salary-survey.php?loc=44&loctype=1&job=41&jobtype=1
Salary Explorer. (n.d.-b). *Pharmaceutical and Biotechnology Average Salaries in United States 2021*. Retrieved 26 March 2021, from http://www.salaryexplorer.com/salary-survey.php?loc=229&loctype=1&job=41&jobtype=1
SalaryExplorer. (n.d.). *Pharmaceutical and Biotechnology Average Salaries in India 2021*. Retrieved 26 March 2021, from http://www.salaryexplorer.com/salary-survey.php?loc=100&loctype=1&job=41&jobtype=1
31. Phillips, T. (2020). *The Top Countries for Biotech Firms and Research*. ThoughtCo. Accessed on 26 March 2021 from https://www.thoughtco.com/ranking-the-top-biotech-countries-3973287

32. Dasgupta, P. (2021). *The economics of biodiversity: The dasgupta review*. London: HM Treasury. https://www.gov.uk/government/publications/final-report-the-economics-of-biodiversity-the-dasgupta-review

33. Mazzucato, M. (2019). The Value of Everything: Making and Taking in the Global Economy

34. Whyte, D. (2021). *COVID-19 vaccines are a victory for public research, not 'greed' and 'capitalism.'* The Conversation. Accessed 16 April 2021 from https://theconversation.com/covid-19-vaccines-are-a-victory-for-public-research-not-greed-and-capitalism-158164

35. https://www.weforum.org/reports/revisiting-and-realizing-the-promises-of-synthetic-biology

36. https://www.weforum.org/agenda/2021/11/synthetic-biology-can-benefit-all-expert-explains-how/

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