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Partnerships with Indigenous Peoples for an ethical bioeconomy

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Biotechnology offers a sustainable route to manufacturing, but closing the loop towards safeguarding biodiversity remains challenging. Here, we explore how partnerships with Indigenous Peoples and Local Communities (IP&LC) can promote an ethical and circular bioeconomy.

Recently, scientists reported in *Nature* how biomanufacturing provides a sustainable route to an essential pharmaceutical. Liu et al. engineered yeast to produce QS-21, a potent adjuvant in FDA-approved vaccine formulations administered to millions globally[1]. Today, the commercialization of QS-21 relies on laborious extraction from *Quillaja saponaria* trees in South America, leading to ecological damage, shortages, and rising costs. Notably, the medicinal use of the tree is Traditional Ecological Knowledge (TEK) of the Mapuche Peoples[2]. With various similar products approaching the market, QS-21 can provide a model for commercializing biodiversity-derived products. But will a biotechnology-based supply chain lead to a sustainable and ethical bioeconomy? What are the emerging practices to achieve such a goal?

The World Health Organization (WHO) reports that approximately 40% of the commercial drugs today derive from plants and Traditional Medicine[3]. As biotechnology provides new supply chains to these medicines, Indigenous Peoples and Local Communities (IP&LC) raise critical considerations regarding the fair and equitable use of their TEK and the potential of synthetic biology to disrupt the local production that sustains their ways of living. This topic has historically divided biotechnologists and IP&LC. However, safeguarding the biodiversity that provides these life-saving medicines is a shared responsibility and is of interest to all parties.

Here, we present how partnerships with IP&LC can close the reciprocal loop between biotechnology and biodiversity. We explore the important ethical considerations, opportunities, and challenges of implementing benefit-sharing policies in biotechnology. As guidelines for practitioners, we highlight case studies of partnerships leading to a new wave of socially responsible businesses. By bringing technology and Indigenous leaders together, we envision how biotech commercialization can return investments to safeguard nature and its stewards through an ethical and circular framework.

Closing the Loop Between Biotechnology and Biodiversity

Biotechnology for a circular bioeconomy often focuses on technological processes like waste-to-product, renewable feedstocks, and sustainable alternatives. Yet, principles such as regenerative practices and preventing natural resource degradation are also essential to circularizing bioprocesses[4]. Economic and ethical frameworks can drive circularity in the bioeconomy to meet these sustainability goals. Through such frameworks, products derived from biodiversity and Traditional Ecological Knowledge (TEK) would return a percentage of the proceeds to their stewards and custodians (Fig. 1). Investing in IP&LC directly supports conservation and regenerative efforts, as they safeguard 40% of the world's remaining protected areas and ecologically intact landscapes[5].

The Nagoya Protocol closes the loop from biotechnology to IP&LC. It is a landmark legal framework for fair and equitable access and benefit-sharing (ABS) from using Indigenous genetic resources, establishing a global instrument to execute the mission of the United Nations Convention on Biological Diversity (CBD)[6]. Recent genomics and synthetic biology advancements have significantly expanded its scope to protect Indigenous Peoples' rights on Digital Sequence Information (DSI)[7]. These resolutions have substantial implications for biotechnologists. A perspective shift to include key considerations (Box 1) regarding the land and peoples our research relies on is crucial for a fair and ethical practice.

Data frameworks are also advancing with extensive discussion in the field of genomics but remain limited in biotech[8,9]. Emerging advancements based upon the UN Declaration on the Rights of Indigenous Peoples (UNDRIP) affirms Indigenous Data Sovereignty (IDSov) and Governance (IDGov) as integral to self-determination, establishing Indigenous Peoples' authority over data collection, ownership, and use[10]. As guidelines for practitioners, the Global Indigenous Data Alliance (GIDA) has created the C.A.R.E. principles (Collective Benefit, Authority to Control, Responsibility, and Ethics) for data protection[11].

To drive innovation forward to meet the global challenges ahead, upholding these frameworks will enable biotechnologists and Indigenous Peoples to access biodiversity and benefit from a growing bioeconomy. This commitment fairly credits the contributions of Indigenous TEK and fosters trust between IP&LC and biotechnologists (Fig. 1).

Implementing Benefit-Sharing in Biotechnology

Opportunities. One promising pathway for biotechnologists to implement benefit-sharing is the Cali Fund, approved recently at the 16th Conference of the Parties (COP16) to the CBD in Cali, Colombia[12]. This mechanism promotes companies using Digital Sequence Information (DSI) from nature and TEK to contribute 1% of profits or 0.1% of revenue to support biodiversity conservation. The Cali Fund establishes a benchmark for benefit-sharing (e.g., 1% return to IP&LC), which can guide the application of other models, such as royalties, milestone payments, and data-sharing licensing fees with IP&LC[6]. Additionally, the UNDRIP affirms Indigenous Peoples' rights to co-develop with external parties. Agreements based on this principle enable IP&LC to own IP, hold equity, and participate in the governance of biotech-based businesses as co-owners.

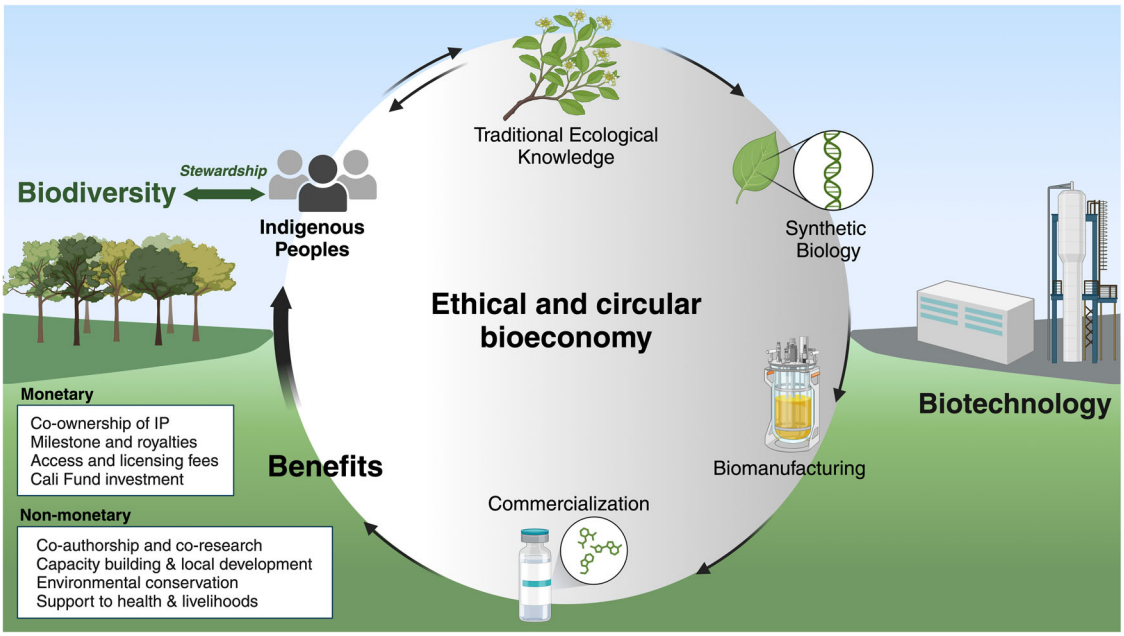

Fig. 1 | Circularizing the bioeconomy through partnerships and benefit-sharing. Indigenous Peoples and Local Communities (IP&LC) steward most of the world's key biodiversity assets. Partnering with them allows for ethical access to nature's genetic resources and safeguarding the ecosystems they steward. Synthetic biology and biomanufacturing leverage these resources to deliver sustainable and scalable supply chains for products derived from biodiversity. Benefits from biotechnology commercialization can be shared and returned to IP&LC through non-monetary and monetary agreements. Products may be co-developed through co-ownership of intellectual property (IP) and co-authorship agreements. Shared benefits can be allocated to environmental conservation, local development, capacity building, equitable distribution of medicines, and more. In each step of this framework, Free, Prior, and Informed Consent (FPIC) is fundamental to protecting Indigenous Peoples' rights. FPIC upholds Indigenous Peoples' authority to approve or decline projects affecting their lands, resources, and knowledge systems. This consent must be secured to ensure ethical collaboration. FPIC is a commitment to Indigenous sovereignty, reinforcing their self-determination and control over how their biological and cultural knowledge is used.

BOX 1

Key considerations for biotechnologists working with biodiversity, Indigenous Peoples and Local Communities, and Traditional Ecological Knowledge-derived technologies

Land: Where do the knowledge or genetic resources (e.g., physical samples, digital sequence information) I am working with originate?

Peoples: Do any peoples or communities steward or rely on these natural/genetic resources, knowledge systems, or practices?

Data collection and disaggregation*: How were the samples collected, and did these communities consent** to their collection?

Data storage*: How is the data stored, and who may access and benefit from it?

Engagement and collaboration: Are there foundations, institutes, representing organizations, or individuals from these communities with whom I can engage?

Equitable and fair benefit-sharing: If the resulting discovery is deployed for profit or not, are there monetary or non-monetary benefits (Fig. 1) that can be shared with the communities?

*Part of Indigenous rights to Data Sovereignty (IDSov) and Governance (IDGov)

**Part of Free, Prior, and Informed Consent (or FPIC) of Indigenous self-determination rights

Beyond monetary returns and co-ownership, reciprocal capacity building offers an avenue for benefit-sharing[6]. Transferring knowledge, resources, and skills enables IP&LC to engage actively in co-research, co-development, and co-commercialization. Capacity building can include training in synthetic biology, building laboratory infrastructure, or fostering Indigenous-led research. Such initiatives position IP&LC as engineers rather than beneficiaries of biotechnologies.

Another key non-monetary benefit-sharing approach, particularly in drug development, is ensuring equitable distribution of medicines,

including free access for the communities that contributed to their discovery[6,8]. For researchers who may not commercialize their technology, co-authorship through collaboration also offers a tool to credit Indigenous TEK[6]. Without their knowledge, there would be no digital data, scientific discovery, or novel technology.

Challenges. Despite remarkable progress in benefit-sharing and Indigenous Peoples' rights-based approaches, several gaps may guide future practices and policies. Importantly, the lack of commitment to the CBD protocols from biotech powerhouse nations such as the USA significantly risks ethical industrial development. For signatory nations, a critical limitation is the lack of Indigenous-led verification mechanisms to ensure companies comply with established protocols. Gaps in the documentation and recognition of TEK may also hinder efforts to establish fair ownership. Additionally, IP&LC's lack of legal representation and financial instruments limits the ability to engage in complex negotiations with biotech companies. Established practices advocate for providing the necessary legal support, issuing open calls to all communities to foster voluntary participation, facilitating decentralized meetings, and offering multiple opportunities for dialogue on legislation, approval processes, and benefits—ensuring the establishment of fair agreements. For biotech companies, implementing benefit-sharing can be challenging. Our field must invest in infrastructure to engage with established frameworks, technical support regarding ethical approaches, and incentives for equitable partnerships, making benefit-sharing a standard practice across the industry.

Biotech-based Businesses Advancing Ethical Practices

New companies are increasingly implementing innovative commercial strategies. For example, Variant Bio uses genomics to discover new therapies from humans with exceptional health-related traits. Variant established agreements with Indigenous Peoples and committed to benefit-sharing 4% of revenue plus 4% of equity value with partner communities that have shared their DNA and health information. Variant Bio is also committed to providing partner communities with free therapy access. Recently, Variant described guidelines on implementing benefit-sharing through a case study in Madagascar, emphasizing community consultation to identify the needs and priorities of local stakeholders to guide the allocation of benefits[13].

Another example is Basecamp Research, which builds the world's largest ethically sourced database of DNA sequences. Committed to benefit-sharing, Basecamp is developing artificial intelligence (AI) models trained on biodiversity data[14]. Recently, the company partnered with the government of Cameroon to ensure that revenues from AI-driven discoveries are allocated through royalties, setting a new precedent for benefit-sharing. While emerging AI applications have significant benefit-sharing implications, the delivery mechanisms remain unclear. This opens the path for unprecedented innovation in the design and implementation of legal and ethical frameworks.

Global pharmaceutical leaders can also drive ethical practices by setting bold Environmental, Social, and Governance (ESG) and Sustainable Development Goals (SDG) agendas. Biomanufacturing is poised to drive innovation to effectively meet these targets. An ethical and circular bioeconomy to return investments to biodiversity in partnership with stewards will bring social responsibility and sustainability, enfranchising IP&LC in biotech-based supply chains.

Finally, synthetic biology-based supply chains have set a historical precedent for social responsibility. The microbial production of artemisinin established a novel model of royalty-free IP licensing for the equitable distribution of anti-malarial treatments, delivering 51 million treatments in Africa[15]. This landmark stands as both a technical and ethical milestone. As innovative frameworks advance, biotechnology is positioned to lead in social responsibility. We envision the biotech commercialization of biodiversity-derived medicines, such as QS-21, vinblastine, or opioids, hold immense potential to set new standards of ethical practices within the industry.

Conclusion

Biotechnology has the potential and responsibility to be a global leader in sustainability to protect the very means of our innovation: nature. Partnerships with Indigenous Peoples and Local Communities can close the reciprocal loop between biotechnology and biodiversity towards an ethical and circular bioeconomy. These frameworks and practices will foster a new era of innovation that prioritizes the stewardship of nature, ensuring that our research and technologies serve both the planet and its peoples.

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Author contributions

M.C.T.A., W-N.F., R.P., U.E., T.B.Z., J.D.K., and K.L. conceptualized the manuscript. M.C.T.A. conceived the original draft. M.C.T.A., W-N.F., R.P., U.E., T.B.Z., J.D.K., and K.L. provided feedback, reviewed, and edited. All authors contributed and approved the manuscript.

Positionality statement. M.C.T.A. is an Amazônida (Amazonian) rooted in the culture of her mother's Kambeba heritage and her father's European descent. Born and raised within the Indigenous diaspora of Manaus, in the Amazon rainforest in Brasil, M.C.T.A. embodies the complex intersection of Indigenous and colonial legacies. This dual heritage shapes her visions, driving a commitment to weaving together ways of knowing and fostering reciprocity and mutual respect between the worlds she carries. W-N.F. is a citizen of the Kara and Kichwa Nations, Aþya Yala (Americas). As an ancestral land trustee of the Chįchup'amp' Clan, W-N.F. holds relational affiliations with the Kutakachį Pueblo and the Chįchup'amp' Ayll'u. With a lifelong biocultural governance experience across pluricultural and multinational contexts, W-N.F. is deeply engaged in the semipermeable transboundary spaces of the Andes and Amazon bioregions. R.P. is of Mexican American heritage, was born and raised in traditional Ohlone, Esselen, and Rumsen territory, and claims no affiliation to a specific Indigenous nation, tribe, or people. U.E. is of Afro-Caribbean and Mexican heritage, was born and raised in traditional Ojibwe, Odawa, Potawatomi, and Taino land, and claims no affiliation to a specific Indigenous nation, tribe, or people. T.B.Z. is a North American political economist raised across several states and Central Europe, advancing nature-positive economic systems that value both ecosystems and their stewards. She leads cross-sector, multidisciplinary efforts to unlock finance, build enabling policies, and drive innovative technology to address environmental threats and advance conservation priorities. Her work reflects a commitment to bridging divergent perspectives into rigorous, action-oriented strategies for climate and nature. J.D.K. is an American scientist who grew up on a farm in Nebraska. A pioneer in synthetic biology and metabolic engineering, he has led a research group for over thirty years, focusing on engineering microbes to produce sustainable chemicals, biofuels, and affordable medicines. J.D.K. led the team that achieved the landmark commercial application of synthetic biology by producing the anti-malarial drug artemisinin in microbes. His career reflects a lifelong commitment to leveraging biotechnology to address global challenges. K.F. is a Kānaka Maoli scientist and the first Native Hawaiian to receive a Ph.D. in genomics. His multi-disciplinary work focuses on genome sequencing technology, genome engineering, and Indigenizing biomedical research by advancing equity and ensuring the ethical use of Indigenous data. K.F. is a pioneer in Indigenous data sovereignty and the implementation of benefit-sharing in biomedical research.

Competing interests

J.D.K. has a financial interest in Amyris, Demetrix, Maple Bio, Lygos, Napigen, Berkeley Yeast, Zero Acre Farms, Ansa Biotechnologies, Apertor Pharmaceuticals, ResVita Bio, and Cyklos Materials. K.F. is an advisor for Variant Bio and Vice President of Wise Ancestors. RP is the Co-Founder and Co-Director of Science for Open Fung. All other authors declare no competing interests.

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