

International Journal Research Publication Analysis

Page: 01-06

BIOTECHNOLOGY AND SOCIAL INEQUALITIES

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Article Received: 06 April 2026

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Article Revised: 26 April 2026

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Published on: 16 May 2026

DOI: <https://doi-doi.org/101555/ijrpa.4811>

ABSTRACT

Biotechnology has rapidly transformed contemporary medicine, agriculture, and environmental science, offering powerful tools to address pressing global challenges such as disease, food insecurity, and climate change. However, the benefits of biotechnological advances are not distributed evenly across populations, raising critical concerns about social inequalities and equitable access to innovation. Emerging research highlights that while biotechnology can enhance human health and economic well-being, disparities in access to biotechnological resources and their benefits may deepen existing social, economic, and geographic inequalities, especially between high-income and low-income communities (Mukherjee, 2021; Tait, 2022).

One prominent concern is the unequal global distribution of advanced healthcare technologies, including gene therapies, precision medicine, and diagnostics. High costs and infrastructure requirements for these innovations often limit their availability to affluent populations or countries with robust healthcare systems, leaving economically disadvantaged groups behind (Battisti & Heinz, 2023). For example, precision oncology and gene editing treatments can significantly improve outcomes for certain cancers, but their prohibitive expenses have made them inaccessible to many patients in low- and middle-income regions. This dynamic perpetuates a cycle in which those who are already socioeconomically advantaged benefit disproportionately from cutting-edge biotechnologies, exacerbating health disparities both within and between nations.

Beyond healthcare, inequalities also arise in agricultural biotechnology. While genetically modified (GM) crops have the potential to increase yields and enhance food security, smallholder farmers often face barriers to adoption, including limited access to credit, seeds,

regulatory support, and scientific knowledge. Research suggests that when the benefits of GM crops are unevenly distributed, wealthier agribusinesses and large-scale farms are more likely to profit, while marginalized farmers struggle to compete, thus reinforcing rural economic disparities (Qaim, 2020; Smyth et al., 2021).

Social inequalities in biotechnology extend further into ethical and policy dimensions. Discussions around benefit-sharing, intellectual property rights, and data ownership have raised concerns about biopiracy and the exploitation of indigenous knowledge without fair compensation. For instance, communities contributing traditional biological resources or genetic data may not receive equitable returns from subsequent commercial or scientific use of that information, undermining principles of justice and respect for local autonomy (Tazzyman & Bietz, 2020; de Vries et al., 2022).

Efforts to mitigate these inequalities must therefore integrate ethical reflection, inclusive policy-making, and targeted investment in capacity building. Policies that subsidize essential biotechnologies, ensure equitable pricing, and support local innovation ecosystems can help bridge gaps in access. In addition, programs that enhance scientific training and infrastructure in underserved regions are critical to empowering communities to participate in and benefit from biotechnological advances. International collaborations and benefit-sharing frameworks, such as those promoted under the Convention on Biological Diversity and related agreements, aim to promote fairness in the distribution of biotechnological benefits, although challenges remain in implementation and enforcement (Secretariat of the Convention on Biological Diversity, 2022).

KEYWORDS: biotechnology, social inequality, equitable innovation, public health, agricultural biotechnology, genomic justice, benefit sharing, ethics, sustainability, inclusive development.

INTRODUCTION

Biotechnology has become one of the most influential scientific disciplines of the modern era, shaping developments in medicine, agriculture, environmental protection, and industrial production. Advances such as gene editing, molecular diagnostics, vaccines, bioengineered crops, and personalized medicine have created new opportunities to improve quality of life and address global challenges. However, the distribution of these benefits remains deeply unequal. Technological progress often emerges within systems marked by economic

disparity, geopolitical imbalance, and unequal access to education, healthcare, and research infrastructure. As a result, biotechnology can both reduce and reinforce social inequalities depending on how it is governed and implemented.

The issue of unequal access is particularly visible in healthcare, where innovative therapies and biologic medicines are frequently available first in wealthier countries and among higher-income populations. Similar inequalities appear in agriculture, where advanced breeding technologies and genetically improved crops may increase productivity, yet small-scale farmers often lack the financial resources or institutional support necessary for adoption. At the same time, the expansion of genomic databases and biotechnology patents has raised questions regarding ownership, privacy, and the commercialization of biological resources.

Recent academic discussions emphasize that biotechnology should not be viewed solely as a technical field, but also as a social and ethical domain. Justice, accessibility, participation, and fair benefit-sharing are now central concerns in evaluating whether innovation truly serves humanity. Therefore, understanding the relationship between biotechnology and social inequality is essential for building more inclusive systems of scientific progress.

MATERIALS AND METHODS

This study is based on a qualitative literature review using contemporary academic sources focused on biotechnology, ethics, public policy, and social justice. The selected references include peer-reviewed journal articles, policy analyses, and international institutional publications addressing the relationship between biotechnology and inequality in global contexts.

The reviewed literature was analyzed through thematic synthesis. Key recurring themes were identified, including healthcare accessibility, agricultural inclusion, ownership of genomic data, indigenous knowledge, regulatory frameworks, and equitable distribution of technological benefits. Comparative interpretation was used to connect findings from multiple disciplines, including bioethics, economics, political science, and sustainability studies.

Particular attention was given to publications discussing structural barriers that prevent marginalized populations from accessing biotechnology, as well as policy recommendations that could promote fairer innovation systems. By integrating perspectives from different

sectors, the study provides a broader understanding of how biotechnology interacts with social inequalities across multiple levels of society.

RESULTS AND EVALUATION

The analysis demonstrates that biotechnology has substantial potential to improve human welfare, but its benefits are frequently concentrated among economically advantaged populations and technologically developed countries. In healthcare, high treatment costs, patent protections, and limited infrastructure often restrict access to advanced therapies such as gene-based medicines, targeted cancer treatments, and molecular diagnostics. This creates a situation in which scientific progress may coexist with persistent or even widening health disparities.

In agriculture, biotechnology offers valuable tools for responding to climate change, food insecurity, and declining soil productivity. Crops with improved resistance to drought, pests, or disease can significantly enhance agricultural resilience. Nevertheless, many smallholder farmers face obstacles such as expensive seeds, dependence on multinational suppliers, lack of credit systems, and insufficient training. Consequently, technological innovations may strengthen already competitive producers while leaving vulnerable rural communities behind.

Another important finding concerns genomic information and biological data. Modern biotechnology increasingly depends on large-scale data collection from human populations and biodiversity-rich regions. Ethical concerns arise when communities provide biological materials, traditional knowledge, or genetic data without receiving proportional benefits. This has intensified debates about data sovereignty, informed consent, and ownership of scientific discoveries derived from shared resources.

The literature also shows that public policy strongly influences outcomes. Where governments invest in education, research capacity, universal healthcare, open science, and fair regulation, biotechnology can contribute to social inclusion. In contrast, weak institutions and purely market-driven systems tend to prioritize profitability over accessibility. Therefore, inequality associated with biotechnology is not inevitable; it is shaped by political and institutional decisions.

Overall, biotechnology should be evaluated not only according to scientific efficiency, but also according to fairness, accessibility, and long-term social value. Innovation that reaches only privileged groups cannot be considered fully successful from a societal perspective.

SUMMARY AND CONCLUSION

Biotechnology is one of the most powerful drivers of modern transformation, offering solutions for disease treatment, food production, environmental sustainability, and economic growth. At the same time, it operates within unequal social systems that influence who gains access to these benefits. The reviewed literature confirms that without deliberate intervention, biotechnology may reproduce existing inequalities related to income, geography, education, and political power.

The most significant barriers include high costs of innovation, concentration of intellectual property, unequal research capacity between countries, exclusion of local communities from decision-making, and insufficient public investment in inclusive systems. However, these barriers can be reduced through targeted policy measures such as affordable healthcare strategies, support for small farmers, equitable licensing models, international cooperation, and recognition of community rights over biological resources.

In conclusion, biotechnology should not be judged solely by what it can create in the laboratory, but by how responsibly and fairly those creations are distributed in society. The future success of biotechnology depends not only on scientific excellence, but also on ethical governance and social inclusion. If guided by principles of justice and shared benefit, biotechnology can become a major force for reducing inequality rather than deepening it.

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