International Journal of Early Childhood Special Education (INT-JECSE)
DOI:10.48047/intjecse/v16i4.54 ISSN: 1308-5581 Vol 16, Issue 04 2024

Biotechnology and Social Values in Arab Society: Challenges and Opportunities

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Received :16/02/2024 ; Accepted : 18/06/2024 ; Published :27/07/2024

Abstract:
This paper search discusses the intersection of biotechnology with social values in Arab society, focusing on the challenges and opportunities it presents. It highlights biotechnology's historical roots, modern applications in health, agriculture, and environmental sustainability, and its impact on traditional Arab values. Religious, ethical, and regulatory perspectives are considered, showing how biotechnology can align with or challenge societal norms. The article also examines the role of education, economic development, and governance in promoting biotechnology within Arab countries. It underscores the need for collaboration and partnership, especially in research and innovation, while addressing public perception and awareness. Finally, the document raises questions about gender diversity, inclusion, and the broader ethical implications of biotechnological advances in the region.
Keywords: Biotechnology; Arab Society; Social Values;Challenges; Opportunities.

1. Introduction

Defining biotechnology and framing some of its historical aspects as they relate to Arab countries, biotechnology may be paradigmatically defined as any technique, whether old or new, that uses living organisms (or parts or derivatives thereof) to make or modify products or processes for some use. Historically, however, biotechnology is often defined as modern biotechnology – a relatively recent biotechnology that began in the mid-1970s with the invention of recombinant DNA (rDNA) technology. This new biotechnology, along with bioinformatics and other developments in the life sciences, is responsible for transforming the way many living systems are viewed and understood, providing unprecedented capacities for manipulation.

The biodiversity crisis and the biotechnology revolution are taking place simultaneously and are fundamentally interwoven, potentially bringing about unprecedented and irrevocable changes to nature, society, and our very understanding of life itself. (Folke et al.2021) Clarifying biotechnologies, their speculative biological, economic, and social contexts, assumptions, and expected outcomes are crucial to public discussions about possible biotechnology governance approaches. Some of the underlying issues of appreciation are suggested as they have arisen in the context of Arab society.

Biotechnology has applications in food and agriculture, energetics, environmental science, the basic life sciences, medical and pharmaceutical science, and biosafety in laboratories and the environment, safety testing of products prior to commercialisation. Today, biotechnology operates under the assumption that life is determined by genetic information and that a dramatic advance in knowledge, if mastered, could allow the manipulation of life in most biospheres for good global and local benefits. This perspective could foster excessive greed among developers and some investors, leading to unjust concentration of benefits.

Biotechnology has backdoor paternalism baked in its technologies and governing practices that accumulate power and knowledge among few policymakers and investors, neglecting, exploiting, and posing risk to powerless rural and urban communities without their free, prior, and informed consent. It intensifies the undemocratic globalization of agriculture, shifting responsibilities from governments, a concern for public interest and long-term sustainability, to an unaccountable private sector primarily concerned with short-term profits. It enhances the slower pace of biosafety regulation and risk assessment without which profound changes in global agriculture cannot proceed smoothly, threatening and risking uncontained biotechnologies. (Leguizamón, 2020)

As a powerful and complementary tool, participatory technology assessments identify local priorities and crops, techniques, and policies that best match them, undertakings whose success lies with the people, local biologists, experts, and organizations concerned, and are consistent with public interest, local sustainable diversity, development, and capacity-building. Based on the above, we can pose the following questions:

1. How has biotechnology been historically integrated into Arab society, and what contributions have been made?
2. What are the ethical and social challenges that arise with the advancement of biotechnology in Arab society?
3. How do Arab cultural and religious perspectives influence the acceptance of biotechnology?
4. What is the impact of biotechnology on health, agriculture, and environmental sustainability in the Arab world?
5. How can education and regulatory frameworks in Arab countries support biotechnology development?

2.Importance of the Study

The research emphasizes the critical role of biotechnology in addressing health, food security, and environmental issues in Arab society. It aims to bridge the gap between traditional social values and modern technological advancements, while also fostering sustainable economic development through innovation.

3.Objectives of the Study

1. To explore the historical development and modern applications of biotechnology in Arab society.
2. To analyze the ethical, religious, and social implications of biotechnology in the region.
3. To assess the regulatory and educational frameworks that govern biotechnology in Arab countries.
4. To propose strategies for enhancing biotechnology education and innovation through collaboration and partnerships.

4. Historical Overview of Biotechnology in Arab Society

Arabculture and its historical contributions to the field of biotechnology in Arab society were thoroughly examined by delving into the significant contributions made by illustrious historical figures throughout the ages. A comprehensive and concise overview of the historical events that played a pivotal role in shaping and driving the advancements in biotechnology in the modern Arab World was also taken into consideration.

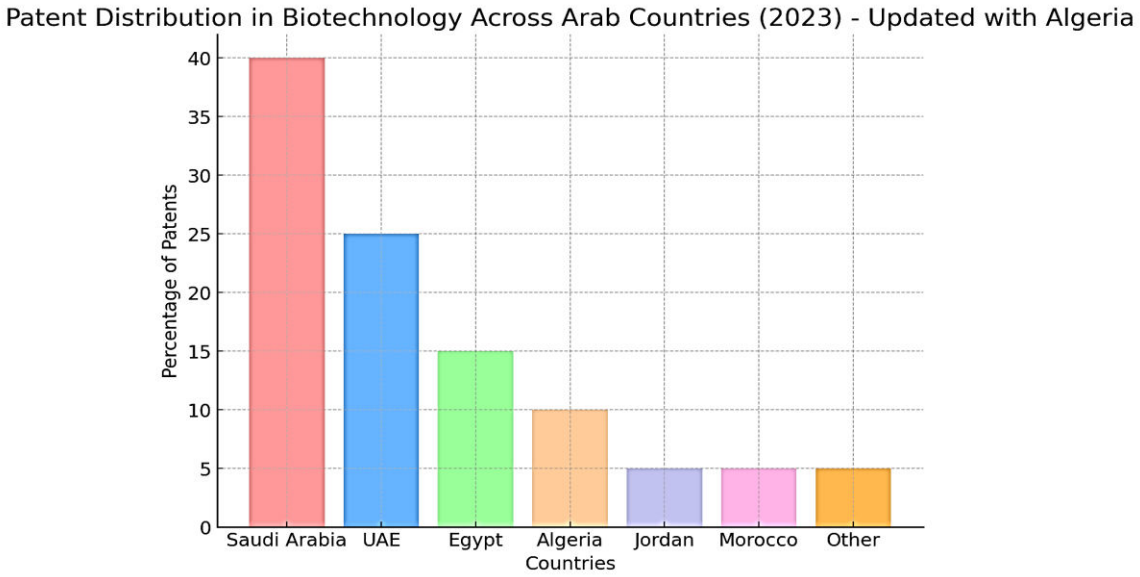
Extensive research was conducted to explore the remarkable developments in the field of biotechnology originating from various Arab World countries, with special emphasis placed on the notable holdings of patents in the biotechnology sector. Additionally, a meticulous evaluation was undertaken to discern the correlation between the prevailing social values in Arab society and the perception as well as acceptance of biotechnology, and to ascertain whether these social values undergo any alterations in accordance with the subject matter.

In order to present a holistic view, this study also incorporates an intricate historical overview of biotechnology and the prevailing social values in the Arab World. Furthermore, insightful and analytical assessments were made on the Arab cultural critiques and historical contributions that have significantly influenced and shaped the Arab culture, outshining the Western paradigms and establishing their unique perception of the subject matter. The influential figures in the field of medicine who have left an indelible impact on the realm of biotechnology in Arab society were also exhaustively examined and listed, showcasing their immense contributions and accomplishments. (Khan, 2020)

Furthermore, it is important to note that the research questions are not only motivated, but also extensively explored and analyzed in this study. The methodology employed is highly comprehensive, ensuring a well-rounded understanding of the subject matter. In order to achieve this, a wide-ranging compilation of patents specifically from the Arab World countries in the field of biotechnology has been carefully carried out.
Hence, this study further delves into the public perception and acceptance of biotechnology within the Arab World countries by extensively examining international journals. (Laith & Alnemri, 2022) This meticulous analysis takes into account multiple dimensions, including but not limited to the subject matter, the country of origin, the year of publication, and the insights gleaned from the research findings. By summarizing these insights in a comprehensive table, the study provides a concise overview of the current state of affairs in the

Arab World countries regarding the public perception and acceptance of biotechnology. It is crucial to emphasize that a holistic approach is adopted throughout this study. By considering all the factors at play, the researchers recognize the significance of evaluating cultural critiques surrounding biotechnology, specifically within the Arab World.

The study endeavors to understand whether the perception of biotechnology differs in this region compared to other subjects. This can only be achieved by adopting a broader perspective, which not only includes the present circumstances but also explores the historical backdrop. By doing so, a more accurate understanding of the cultural critiques can be attained, shedding light on the nuances and intricacies of biotechnology perception within the Arab World.



Source: WIPO IP Facts and Figures 2023

The **patent distribution chart** reveals significant disparities in the level of innovation and technological advancement across the Arab world, particularly in the field of biotechnology. Countries like **Saudi Arabia** and the **United Arab Emirates** (UAE) stand out, holding the majority of biotechnology patents, which can be attributed to their robust investment in research and development (R&D). These countries have focused on leveraging biotechnology for advancements in health, agriculture, and environmental sustainability, reflecting their broader economic visions, such as Saudi Arabia's Vision 2030, which emphasizes innovation as a pillar of economic diversification.

In contrast, **Algeria** presents a more complex sociological picture. The country's biotechnology sector is underdeveloped compared to its peers. This can be explained by several sociopolitical and economic factors, including a slower pace of regulatory reform and limited funding for R&D. The lower patent numbers in Algeria reflect the broader challenges facing the country, such as a reliance on oil and gas revenues and less focus on diversification into high-tech sectors like biotechnology. Additionally, the educational system in Algeria, while strong in certain scientific disciplines, has yet to prioritize the advanced technical skills required to foster biotechnology innovation. This suggests a need for targeted policy changes to stimulate local innovation and investment in emerging fields.

From a sociological perspective, Algeria's position in the patent distribution also highlights issues of **scientific dependency** on foreign technologies. Unlike the Gulf states, which have actively sought international collaborations and foreign direct investments to build their biotechnology sectors, Algeria has lagged in creating similar partnerships. This highlights the broader regional disparity in terms of how different Arab countries engage with global technological trends and economic modernization. If Algeria aims to increase its share of biotechnology patents, it must engage in institutional reforms and encourage entrepreneurship in high-tech sectors.

5. Impact of Biotechnology on Health and Medicine in Arab Society

The impact of biotechnology on health and medicine in the Arab region is of paramount importance. Biotechnology provides techniques derived from living organisms, which can be used to improve plant or animal life. Medicine, a branch of the biological sciences, includes any substance used in the diagnosis, treatment, or prevention of disease. Research in biotechnology and health has leapfrogged after the genome project, which has led to the understanding of mankind's genetic makeup.

People view biotechnology with interest and concern. The interest comes from the great potential of the new science in curing diseases, leading to higher food production, and safeguarding the environment for the future. The concerns arise from the unknown aspects of biotechnology. Among the concerns are moral and ethical questions such as the blanket patenting of life and genetically engineered humans. (Ahmad et al.2022)

Arab scientists have made significant contributions to the understanding of basic genetics through their discoveries made in fruit flies by the late Sir T.H. Morgan and colleagues. These remarkable findings have had a profound impact on the development of the field of genetics, paving the way for a greater understanding of various genetic disorders. One such disorder that Arab scientists played a vital role in uncovering is "Thalassemia," a genetic condition that affects the production of hemoglobin.

While Arab scientists showcased their exceptional prowess in the realm of genetics, they did not actively partake in the field of molecular biology and biotechnology that emerged from the profound understanding of genetic material, better known as DNA. This field holds tremendous potential for revolutionary advancements, offering insights into the intricate mechanisms underlying life itself. (Khaled & Hanafi, 2024) With their profound expertise, it is only a matter of time before Arab scientists actively engage in the captivating field of molecular biology and biotechnology, further propelling humanity towards astonishing scientific breakthroughs.

There have been numerous attempts to "catch up" with the rapidly advancing field of biotechnology, yet these efforts have consistently fallen short due to the absence of a solid foundation in conscious social science. The paramount concern that arises is the pressing issue of health. Shockingly, statistics have shown that approximately 20% of all births are affected by various genetic disorders. Despite this alarming prevalence, society has made remarkably little headway in effectively informing parents about the importance of genetic counseling and the availability of screening tests.

However, the tides are slowly turning as current research is heavily focused on unraveling the intricate genetic basis of these disorders. With an exponential growth in research, state-of-the-art facilities, and an influx of specialized expertise, it is imperative that a conscious and coordinated effort be instigated in order to construct a robust healthcare delivery system that prioritizes prevention and proactive measures. Only by doing so can we hope to diminish the devastating impact of genetic disorders on humanity.

6.Religious Perspectives on Biotechnology in Arab Society

Arab society is an excellent example of the place of culture and religion in the regulation of biotechnology. As in other parts of the developing world, in the Arab world, religiosity, culture, and ethics are major factors in how rapidly and in what ways biotechnologies have been received and implemented. In this section, we will present a few of the dominant religious perspectives on biotechnology within Arab society. We propose three major principles.

First, biotechnology is more likely to be calmly received if it affects only a small group of people and if the group acknowledges the legitimacy of the issue and the authority of the scientists who speak.

Second, despite the common perception of Islamic culture as an inflexible and resolute adversary of technological advancements, the reality is far more intricate. Islam wholeheartedly esteems technology and contemporary accountability, recognizing their paramount significance. (Abbasi, 2021) This holds immense importance, particularly when it comes to ethically important domains like reproductive technologies. Nonetheless, there exists a marked circumspection with regards to novel biotechnology, prompting Islamic scholars to ardently advocate for the establishment of a morally sound Islamic framework within which these technologies can be responsibly employed.

Once again, this stance assumes great significance not only in the discourse surrounding reproductive technology but also in the broader context of genetic manipulation and the utilization of stem cells. The sheer delicacy of these matters demands a measured and cautious approach in order to ensure alignment with Islamic principles, values, and tenets. Rest assured, Islam places a discerning emphasis on adapting to and assimilating

technology in a manner that is consistent with its moral fabric and ethical guidelines, always striving to strike a harmonious balance between progress and preservation of core beliefs. (Qorib & Afandi, 2024)

Thirdly, it is crucial to acknowledge that ethical and religious issues should be given utmost importance and regarded primarily as an internal matter within the Arab community. In order to find effective resolutions, it becomes imperative to update religious rulings in a manner that aligns with scientific advancements, ethical considerations, and medical perspectives. By doing so, we can ensure a comprehensive approach that is both morally and intellectually sound. Moreover, it is important to emphasize that the involvement of external entities should only be sought if substantial conflicts persist or if the international community continues to express criticism. In such instances, it may be appropriate to establish collaborative efforts and partnerships between various faiths and secular organizations within regulatory and ethical bodies.

This inclusive approach can foster greater understanding, promote harmony, and contribute towards the development of equitable solutions. It is essential to maintain an open dialogue and engage in respectful discussions to address these complex issues. By encouraging sincere conversations and promoting a culture of acceptance, we can pave the way for constructive transformations within Arab society. The goal should be to establish a framework that respects and recognizes the diversity of perspectives while upholding the values of justice, compassion, and progress.

The path towards resolving ethical and religious dilemmas lies in a holistic approach that amalgamates the tenets of faith, the principles of ethics, and the knowledge of science and medicine. By embracing a multidisciplinary perspective, one that acknowledges the changing dynamics of societies and the evolving needs of individuals, we can create a robust foundation upon which resolutions can be built. (Ghaly, 2024)In conclusion, it is essential to prioritize the recognition of ethical and religious issues as internal Arab matters. By employing an updated approach to religious rulings that incorporates scientific, ethical, and medical considerations, we can proactively seek resolutions that are in harmony with contemporary advancements. Only in exceptional circumstances, such as persistent conflicts or external criticism, should we engage in partnerships with diverse faiths and secular institutions. It is through collective efforts and a commitment to dialogue that we can pursue viable solutions that uphold the values of unity, respect, and progress.

7. Biotechnology and Agriculture: Addressing Food Security

Since the dawn of tailor-made offspring, it was clear that biotechnological applications would provoke a fundamental reevaluation of combinations of food security, fertility, genetic diversity, commercialization, and ownership of genetically modified organisms (GMOs). (Saini et al.2020) It challenged the search for and redefinition of new social values and social structures to align with new biotechnological practices. Understood as a collection of latest, current, and future techniques concerning natural organisms, be they domesticated or wild, biotechnology prohibits itself from breeding and focuses on transformation, replacement, or extraction of parts, i.e. genetic modification of biota.

Such transformation, replacement, or extraction is based on the knowledge of the genetic code as the basic structural building block for work with natural organisms. It forms a standardization to guide the development of the instruments and methods used in biotechnological practices, thereby emerging as virtual technocratic biota to govern the fragments of living nature biotechnologies work with. These governing capacities expose reproductive biota to bias - a good plant, an unhealthy organism, a wild flower - alongside fatal risks in the advent of planetary biota.

Such wider biotechnological understanding acts itself upon reproduction by putting concepts such as non-nativeness, pathogenicity, weediness, homogeneity, subservience under global standardized cultural and socio-economic conditions or unbalanced evolutive chances, geographical pervasion of pest resistance, invasion of transgenesis in the wild, disaggregation of genetic resources from the locus of their creation, and even planetary transformation and assemblage of biological and geological sites.

This bracketing of postmodernity, of the diverse legislative landscapes of garden variety social values, is addressed by the analysis of the genetic transformation processes pragmatically, thereby clearing the way to explore a very basic query: are post-applied (biotech) conversion processes transforming themselves into such asymmetric and coercive commodification? And especially, are they encouraged, determined by one-community dominant action? All of these biotechnical processes reconsider the terms of reproduction and the delicately forged social values and structures on which they rest upon.

This challenge extends to practical, pragmatic endeavors - future biotechnologies, how globally to live with GMO technology? Despite a small share of cultivated surface area, GMOs have sparked a heated public debate in most countries of the world. It is regrettable that, in Arab countries, little research has been devoted to the social and ethical issues surrounding GMOs.

8. Biotechnology and the Environment: Balancing Innovation and Sustainability

In the realm of biotechnology, like in any new field, there exist various obstacles related to technological progress that take into account the societal values such as social justice, religion, and ethical principles. These obstacles are particularly prominent in the Arab world, where societies are generally conservative and uphold deeply rooted traditions. Nevertheless, the proposed emerging biotechnologies have the potential to alleviate issues like disease, famine, and pollution, even though they may conflict with some of the societal values.

The tension between these two factors has created opportunities for discussion, research, and policy development, ensuring that values are honored while societies can potentially benefit from the technology. These current challenges and future opportunities regarding biotechnology in relation to Arab societies during the early stages of biotechnology are examined.

The changing landscape of the environment is a growing concern for scientists and the public alike. The advancement of science in general has facilitated environmental degradation, global warming, and overuse of non-renewable natural resources. Recent public attention has turned to the negative consequences resulting from technological advancement, such that new technologies, at their inception, are now scrutinized concerning their impact on society as a whole and the environment. Biotechnology, like any emerging field, is not immune from this scrutiny. Life patents of higher-order organisms, a consequence of biotechnological advancement, have manifested concern regarding ethicality, social justice, and environmental hazard. The Arab world is increasingly becoming aware of the importance of environmental issues too. (Dawoud et al.2020)

Cities such as Rabat, Tunis, and Cairo were founded thousands of years ago along with the subsequent civilizations that flourished in the region. The coalescence of various values of societies in the Arab world such as religion, tradition, customs, and social values shaped the course of the development of Arab societies and cities.

The subsequent countless layers of ruins in cities such as Amman, Petra, Cairo, Damascus, and other cities in the Middle East testify to this particular course of development. Rapid advancement of the environment, on the other hand, in the last decade represents a sudden jolt to the social constructs imposed by the values that are tightly held by Arab societies. The mutual dissatisfaction between the proponents of biotechnology and the masses, on the other hand, can contribute to a broader public understanding of biotechnology in its conflict with Arab landscapes. As Arab societies grapple with the rapid changes brought by modernization and technological advancements, the clash between tradition and progress becomes increasingly apparent.

This clash is emblematic of the delicate balance between preserving cultural heritage and embracing the opportunities of the future. The landscapes of Arab cities bear witness to the ongoing struggle between the forces of tradition and the demands of innovation. (Moscatelli, 2023) Amidst this complex tapestry of historical layers and social values lies the intersection of biotechnology and Arab landscapes.

The proponents of biotechnology advocate for scientific progress and breakthroughs that can revolutionize various industries, including agriculture and healthcare. However, the masses, deeply rooted in their traditions and customs, often resist these changes, fearing the erosion of their cultural identity. This clash between the proponents of biotechnology and the conservative values held by the Arab societies illuminates the need for increased public dialogue and understanding. By bridging the gap between these opposing perspectives, a mutually beneficial path towards the integration of biotechnology into the Arab landscapes can be forged. It is through this process of engagement and education that a harmonious coexistence between tradition and innovation can be achieved, honoring the rich heritage of the past while embracing the promises of the future.

9. Biotechnology and Education: Bridging the Skills Gap

Biotechnology education has become an incredibly pressing and burgeoning challenge within Arab society. It is of utmost importance to equip students with the extensive knowledge, diverse skill sets, and unrivaled competences necessary to not only develop and evaluate biotechnological approaches, but also apply

them effectively to various pivotal domains that shape our existence, such as bio-safety, food production and security, climate change mitigation, poverty alleviation, bio-energy exploration, and so much more.

Within Arab society, the demand for comprehensive biotechnology education spans across all educational tiers, ranging from undergraduate studies that cater to future farmers, local health workers, scientists, teachers, policymakers, economists, and numerous other professions, to adult education that targets present farmers, health workers, scientists, teachers, and countless others. Furthermore, the necessity for public education in pre-tertiary schools as well as other platforms cannot be overstated.

The urgency to address this challenge lies in the belief that a well-educated society in biotechnology will pave the way for advancements and breakthroughs that could revolutionize various sectors, leading to sustainable development, economic growth, and improved quality of life. It is imperative to foster collaboration and synergy among Arab biotechnologists hailing from different nations in order to thrive in this dynamic educational undertaking. To effectively confront the challenges encountered in Arab biotechnology education, it is highly recommended to establish a groundbreaking project that either consolidates an umbrella organization to oversee Arab biotechnology education programs or establishes a pioneering Arab center solely dedicated to the advancement of biotechnology education.

This project should incorporate both theoretical knowledge and practical applications, offering state-of-the-art laboratories, cutting-edge research facilities, and engaging training programs. The umbrella organization or Arab center should prioritize networking opportunities, facilitating partnerships between universities, research institutes, governmental bodies, and industries. Such collaboration would generate a vibrant academic and professional community that encourages knowledge exchange, research collaboration, and the development of innovative solutions to address the pressing issues faced by the Arab society. Moreover, a comprehensive curriculum should be designed, catering to the diverse needs and interests of learners at different educational levels.

The curriculum should integrate interdisciplinary subjects and hands-on experiences, enabling students to acquire a holistic understanding of biotechnology and its applications. This will empower them to tackle pressing challenges and contribute to the sustainable development goals of their respective countries. In addition, scholarships and financial aid programs should be established to ensure equal access to biotechnology education for talented students who may face economic barriers.

This will promote inclusivity and create opportunities for individuals from different socio-economic backgrounds to excel in this field. Furthermore, mentorship programs should be developed to guide and support students throughout their educational journey, encouraging their personal and professional growth. (Surana et al.2020)To ensure the sustainability and impact of the umbrella organization or Arab center, partnerships with international biotechnology organizations, academic institutions, and industry leaders should be forged.

This will facilitate knowledge transfer, expose students to global best practices, and promote collaboration on regional and international research projects. In conclusion, the expansion and advancement of biotechnology education in Arab society is vital for the future development and progress of the region. By investing in comprehensive and inclusive educational initiatives, establishing a groundbreaking project that consolidates efforts, and fostering collaboration among biotechnologists, Arab society can unlock the immense potential of biotechnology, addressing societal challenges and contributing to a brighter and more sustainable future.

Biotechnology education can play a crucial role in bridging the skill gap in society, facilitating economic growth and promoting local development. However, achieving this requires a careful and strategic approach that takes into consideration the unique needs and perspectives of the local stakeholders. (Hojeij, 2024) The ability to bridge the skills gap effectively is closely linked to a country's economic advancement and its proximity to modern biotechnology. In many Arab countries, the heavy reliance on imports highlights the urgent need for swift access to contemporary biotechnology advancements by both public and private institutions.

By providing essential guidance and support before granting public access, these institutions can significantly benefit from gaining early insights and making informed decisions. Failure to develop national competencies in biotechnology can result in the inefficient allocation of precious resources, leading to a detrimental loss of sovereignty through blind adoption and dependence on external sources. Thus, it becomes

imperative to establish comprehensive public biotechnology education programs that focus on imparting knowledge and fostering a deeper understanding of modern biotechnology and its diverse applications.

These educational efforts should cater to a broad spectrum of learners, offering basic proficiency courses for the middle class and specialized, high-level instruction for the elite. By implementing robust educational initiatives, countries can encourage investments in new biotechnology and facilitate the harmonious collaboration between biotechnology institutes and various industries. To effectively address the needs of the nation, public biotechnology education should be standardized and implemented on a national scale, ensuring equitable access and broad-reaching impact.

10. Regulatory Frameworks and Governance in Arab Countries

There are substantial differences among Arab countries in their legislative systems and governance structures for biotechnology. Some countries have enacted laws but have yet to establish rules and regulations, while others lack any pertinent legislation. In some cases, draft legislation has been produced but not yet enacted. (Hasim et al.2020)

In addition to legislative variables, the number of government authorities involved in the implementation of biotechnology legislation varies from one country to another and can be grouped into three categories: (1) a single authority government agency; (2) a multi-agency; and (3) a research institution established by the government, with a regulatory role regarding biotechnology and its potential impacts on biodiversity, natural resources, and human life.

All legislative frameworks and procedures should be constructed and modified to implement proper biosafety mechanisms clearly, transparently, and simply. All Arab countries should establish an independent national agency with legal expertise and technical knowledge to deal with biotechnology issues. Governments should consider establishing a national center for biotechnological policy formulation and enhanced cooperation among Arab countries. This would ensure that the concepts, opportunities, and facts of biotechnology are well understood by policy makers involved in relevant decisions on intellectual property rights, biosafety systems, and the conduct of research activities.

Consideration should be given to establishing a comprehensive and inclusive biotechnology advisory panel, comprising experts from various disciplines, to provide governments with invaluable technical advice on a wide range of relevant public projects or policies. This panel would serve as a crucial resource, offering insights, recommendations, and innovative solutions to enhance the understanding and utilization of biotechnology in a responsible and sustainable manner. (EFSA et al.2022)One major aspect that warrants careful attention is the development of intellectual property right legislation.

It is essential to draft this legislation with meticulousness and precision to prevent any inadvertent infringement on the interests and traditional knowledge of indigenous peoples. Special provisions should be carefully crafted to safeguard the rights of these communities, including measures such as disclosing the origin of intellectual property derived from indigenous knowledge and ensuring fair compensation for its utilization. Furthermore, proper management protocols must be put in place to effectively govern the resources used by traditional breeders. Transparency and accountability should be paramount to ensure the replicability and traceability of their practices.

This will not only foster a sense of trust and equity among traditional breeders but also facilitate the wider dissemination and adoption of their invaluable knowledge and techniques. By considering these key aspects and implementing appropriate measures, governments can foster a conducive environment for the harmonious integration of biotechnology with societal needs and values. (Han et al.2024) Such careful considerations will lead to sustainable development, equitable sharing of benefits, and the preservation of indigenous knowledge, while harnessing the full potential of biotechnology for the betterment of all.

There are certain trends in Arab countries to ratify the Convention on Biological Diversity and establish legal and technical biosafety mechanisms to regulate biotechnological research and trade.

Updated Regulatory Frameworks For Biotechnology Including Algeria

	Country	Has Regulations	Biosafety Mechanism	Governance Type	Source
1	Saudi Arabia	Yes	Established	Multi-agency	Strategy& Report on Saudi Arabia's Biotechnology Sector (2023)
2	UAE	Yes	Established	Single Agency	Hayat Biotech Report on Biotechnology and Life Sciences in UAE (2023)
3	Egypt	Yes	Established	Multi-agency	WIPO Patent Cooperation Treaty Yearly Review (2023)
4	Algeria	No	Not Established	None	WIPO Patent Cooperation Treaty Yearly Review (2023)
5	Jordan	Partial	Not Established	Single Agency	WIPO Patent Cooperation Treaty Yearly Review (2023)
6	Morocco	In Progress	Partial	In Progress	WIPO Patent Cooperation Treaty Yearly Review (2023)

The **regulatory framework table** provides an insightful lens into how various Arab countries manage and govern the burgeoning field of biotechnology. The presence of established frameworks in countries like **Saudi Arabia** and the **UAE** reflects a proactive governmental approach toward fostering innovation while ensuring biosafety. These countries have developed multi-agency regulatory bodies to oversee the application of biotechnology, balancing innovation with the need for safety and ethical considerations. Their clear and structured governance models have facilitated growth in the sector by instilling confidence among investors and researchers alike.

Algeria, however, presents a contrasting scenario. The absence of a clear regulatory framework and biosafety mechanisms signifies a significant gap in the country's approach to biotechnology governance. This lack of regulation not only impedes domestic innovation but also acts as a deterrent for foreign investments in the sector. Sociologically, this can be interpreted as part of a broader hesitancy within Algerian governance structures to fully embrace rapid technological advancements, potentially due to political conservatism or bureaucratic inertia. Moreover, the absence of biosafety mechanisms suggests that Algeria might face difficulties in balancing innovation with ethical and environmental concerns, which are becoming increasingly important in global biotechnology governance.

Algeria's regulatory weaknesses may also reflect broader issues of **institutional capacity** and **policy prioritization**. While other Arab countries have recognized biotechnology as a key driver of future economic growth and have thus crafted policies to support it, Algeria's focus remains on traditional industries like hydrocarbons. This creates a lag in diversifying its economy and promoting high-tech sectors. For Algeria to catch up, it will need to not only establish robust regulatory frameworks but also invest in educational and research institutions that can drive the innovation needed to compete regionally and globally in biotechnology.

11. Biotechnology and Economic Development in the Arab World

Indisputably, biotechnology is paramount for fulfilling the Arab national aspirations and sustaining its economic development. There are current concerns about the Arab world's economic viability and opportunities for sustainable economic development. Biotechnology may deliver industrialized countries' promises of an information-based economic era. In fact, biotechnology offers opportunities for developing countries having natural resources like land, water, plants, animals, and genetic resources to maintain, enhance, and commodify such resources.

The Arab world, with its rich resources and diverse experiences, is currently facing dire needs when it comes to the creation of biotechnology prospects. (Mohamed et al., 2021) In order to tackle the existing

economic challenges and pave the way for a prosperous future, it is imperative to conduct a thorough viability analysis of biotechnology within the Arab world. This analysis should be given immediate attention from various stakeholders, including scientists, planners, decision-makers in academia, as well as the public and private sectors. Biotechnology holds immense significance for the Arab world, as it has the potential to shape its future economic viability.

However, it is important to note that, apart from a few exceptional cases such as Egypt, Tunisia, and Morocco, biotechnology is not widely pursued across the region. Consequently, its probability of success remains relatively low. This can be attributed to various factors, including biological, political, and economic constraints that arise from globalization, environmental concerns, issues related to intellectual property rights, and the monopolization of agricultural technologies by transnational companies. Given the critical importance of biotechnology, there is an urgent need to prioritize its development in the Arab world.

This entails addressing the aforementioned constraints and fostering an environment conducive to the advancement of biotechnological research and innovation. By doing so, the Arab world can unlock its full potential and overcome the challenges it currently faces, paving the way for sustainable economic growth and prosperity. (Rastegari et al., 2020)

Biotechnology strategies of upstream endeavors must be faced by downstream ones. For most Arab countries, a pragmatic strategy is to follow a 'take it or leave it' policy with regard to foreign proprietary technologies. Countries like Egypt, Tunisia, Algeria, Morocco, and Jordan may have the luxury of pursuing a more 'make it or break it' strategy. The Arab world must globalize biotechnology efforts more actively and seriously pursue its full-spectrum endowment. Biotechnology prospects like using native genes and plants in vaccines and human drugs, animal draught bioengineering, desert plants aquaculture indoors and in farmlands, and euphorbiums and daisies in oils and seeds are presented. The Arab world and its biotechnology prospects are profiled.

12. Challenges and Opportunities for Biotechnology Startups in the Arab World

Biotechnology has widely been recognized as a pivotal tool in propelling the development, innovation, and economic expansion of the Arab world. In an effort to thoroughly investigate the sustainability of technology-based startups and delve into the abundant opportunities and challenges of biotechnology in the region, extensive research was conducted. This encompassing exploration encompasses stakeholders involved in the intricate web of Arab biotechnology ecosystems, providing a comprehensive and objective overview of biotechnology's vital role in the Arab economy. By delving into the complexities of the Arab biotechnology landscape, both the impediments and hurdles obstructing startup growth are meticulously examined. Consequently, the key to fostering and stimulating startup growth in the Arab world lies in fostering enhanced integration between the various stakeholders within the biotechnology ecosystem and cultivating a more robust and proficient biotechnology scientific workforce.

Biotechnology is undeniably one of the most groundbreaking and transformative technologies to emerge in recent years. It encompasses a wide array of life science-related fields, encompassing the realms of genetics, biology, cell biology, and molecular sciences, all working harmoniously to extract invaluable knowledge that is then translated into cutting-edge services and products. The scope of opportunities within biotechnology is vast, encompassing active involvement in domains such as therapeutics, industrial applications, environmental conservation, agricultural advancements, and so much more. Many experts argue that this technology stands as one of the most pertinent solutions for expediting innovation, driving development, and fueling growth. (Fabris et al.2020)Crucially, biotechnology has been widely recognized as an indispensable technology to address and surmount the challenges brought upon by rapid demographic growth.

As our global population continues to surge, the need for sustainable solutions becomes increasingly urgent. Biotechnology holds the promise of helping humanity overcome these challenges by enabling the discovery of quality water and food sources, fostering the creation of healthy environments, and developing cures for diseases that have proliferated due to urbanization and lifestyle changes. These challenges, which have come to define the 21st century, necessitate active engagement in emerging technological areas, including but not limited to biodetection, biocatalysis, bioremediation, bioprocess engineering, biomonitoring, biosensors, biomanufacturing, bioproduction, genomics, and an extensive array of other cutting-edge disciplines.

To truly tackle these complex challenges, it is crucial to embrace a holistic approach that encompasses efforts across both the abiotic and biotic realms. The intricate interplay between these realms is the foundation upon which biotechnology can flourish and deliver transformative outcomes. By uniting scientific expertise, technological advancements, and a deep understanding of the natural world, biotechnology emerges as a beacon of hope, propelling us forward in our quest for a brighter and more sustainable future (de2022) .

While Arab science-based ecosystems have been extensively studied in recent years, there is still a significant lack of comprehensive and in-depth surveys focusing on teaching and research in the field of biotechnology. Furthermore, there is a scarcity of independent assessments that explore biotechnology activities across different Arab countries. Consequently, there is a considerable gap when it comes to a unifying, comparative, and comprehensive analysis of the challenges, hurdles, and opportunities faced by the Arab biotechnology ecosystems.

This absence of a holistic examination hinders our understanding of the impact these ecosystems have on the growth and success of biotechnology startups. It is imperative to gain a thorough comprehension of the biotechnology landscape in the Arab world in order to develop targeted and effective policies that cater to the unique needs of Arab biotechnology startups. By bridging this knowledge gap, we can formulate recommendations that promote their development, foster their growth, and ultimately ensure their long-term sustainability. (Baylis et al., 2020)To achieve this, it is essential to embark on comprehensive research endeavors that delve into the intricacies of the Arab biotechnology ecosystem, scrutinize the current state of teaching and research in biotechnology, and shed light on the potential areas of improvement. This multifaceted approach will enable us to gather invaluable insights and generate data-driven strategies to elevate the Arab biotechnology sector to new heights.

13. Public Perception and Awareness of Biotechnology in Arab Society

Biotechnology, a rapidly emerging field, encompasses various scientific applications utilizing living systems or biological organisms to develop products and technologies. Arab societies are crucial stakeholders in a biotechnological era due to their unique challenges and needs. (Capell et al.2020) Education and awareness regarding biotechnology encourage public discussion and participatory decision-making, influencing perceptions of benefits and risks, and underscoring the need for equitable governance amidst divided benefits. Public perceptions of biotechnology are intertwined with values and involve examining opinions across its scope, including agricultural, biomedical, environmental applications, and emerging technologies.

Interest in public perceptions of biotechnology was ignited in the late 1990s, sparked by crop biotechnology controversies, especially in industrialized nations. It gained footing in developing regions, including the Middle East. Despite interest, studies on Arab societies remained scarce, with limited focus on public perception linked to social values and a lack of knowledge-based research to assess awareness levels among various societal groups. Such assessments can help build human capacity in biotechnology and promote public discourse around ethical investment in biotechnological fields.

A long-term investment in biotechnology could provide Arab societies with the opportunity to surpass technological dependency and political and socio-economic instability. However, public fears of biotechnological fields, such as genetically modified (GM) crops, biopharming animals, or emerging field applications like cloning phones or stem cell research, need to be addressed. Additionally, a knowledge-investment gap highlights the need to invest as much effort and resources in addressing concerns regarding the ethical and social implications of biotechnology as in research and development, as Arab countries boast some of the least knowledge-based public discourse on GM crops among countries with small-scale field trials. (Hillman and Baydoun2020)

Public awareness or perceptions of biotechnology are sometimes perceived or processed via mass media, educational background, or personal experiences, which can later significantly influence individuals' understanding, perspective, and even acceptance of biotech applications. Therefore, it becomes crucial to actively and accurately communicate information about biotechnology to the public in order to foster a comprehensive understanding and support for its potential benefits. To ensure the responsible development and utilization of biotechnology, it is vital to encourage a societal sense of ownership and engagement regarding biotechnology investments in academia and research. By involving the public in the decision-making processes

and encouraging their participation, we can potentially safeguard the public interests and ensure that the benefits of biotechnology reach all segments of society.

However, it is important to acknowledge and address certain ethical and social concerns that arise in relation to biotechnology. These concerns, although they may seem irrational or trivial from a purely scientific perspective, play a paramount role in shaping public opinions on recent biotechnological advances or applications. (Kendal, 2022) By understanding and effectively tackling these concerns, we can bridge the gap between scientific advancements and public perception, fostering informed discussions and decisions on biotechnology's future.

In conclusion, public awareness and perceptions of biotechnology are not solely based on scientific information, but are influenced by various factors such as mass media, educational background, and personal beliefs. To foster a comprehensive understanding and acceptance of biotech applications, it is crucial to actively engage the public, address ethical and social concerns, and promote a sense of ownership and responsibility. By doing so, we can ensure that biotechnology is developed and utilized in a manner that benefits society as a whole.

14. Gender and Diversity in the Biotechnology Sector

Diversity, equity, and inclusion (DEI) are of utmost importance within the biotech sector, spanning across companies and investors alike. The focus of DEI efforts has predominantly been on underrepresented groups within the industry. In order to further promote inclusivity for these marginalized groups, this paper delves into a comprehensive analysis of "diversity" across various dimensions including race, gender, sexual orientation, disability, socioeconomic background, and geographic location. (Birhiray & Birhiray, 2023) The presence of diversity and intersectionality has a significant impact on corporate innovation strategies and alliance networks within the biotech realm. Biotech companies that prioritize maintaining gender diversity within their executive teams are more inclined to engage in extensive technological exploration, resulting in the integration of a wider range of technologies and applications.

Similarly, executive team diversity in terms of ethnicity and race stimulates these firms to embrace a broader spectrum of technologies. It is worth noting that the interconnection between executive team diversity and corporate innovation is greatly influenced by the geographical context in which these biopharma firms operate. For instance, those situated in prominent biotech clusters such as Massachusetts, California, and New York exhibit varying sensitivities towards diversity.

Presently, there is a growing societal and political momentum pushing for corporate accountability in addressing systemic inequalities and misconduct. This document sets forth a roadmap outlining strategies for fostering equity, transparency, and accountability at the intersection of the biotech industry and social values. Its ultimate goal is to create a future that is not only healthy, safe, and just, but also sustainable. DEI is becoming increasingly recognized as a major emerging sustainability concern within the biotech sector. (Perra et al.2022)

Efforts to tackle systemic inequalities and the distribution of power and control in global matters, such as the pandemic response, have been championed by international organizations, governments, NGOs, and civil society organizations through the implementation of stringent regulations and guidelines. Biopharma companies have taken notable strides in safeguarding DEI principles and spearheading the development of pharmaceuticals to combat COVID-19. Furthermore, there is a growing realization that diversity, equity, and inclusion, as well as deliberate exclusion, play a pivotal role in shaping the understanding and response to various crises and risks, including pandemics and climate change. As a result, DEI advocacy has emerged as an urgent and equal priority alongside biomedical and sustainability initiatives within the biotech industry.

The expansion of diversity, equity, and inclusion (DEI) in the biotech sector has become a paramount concern for both companies and investors. It is vital to prioritize the inclusion of underrepresented groups within the industry. To ensure inclusivity for marginalized communities, this paper ventures into an extensive analysis of diversity across multiple dimensions, including race, gender, sexual orientation, disability, socioeconomic background, and geographic location. The existence of diversity and intersectionality significantly influences corporate innovation strategies and alliance networks within the biotech field.

Biotech companies that place importance on maintaining gender diversity within their executive teams are more inclined to engage in extensive technological exploration. This results in the integration of a broader

range of technologies and applications. Similarly, executive team diversity in terms of ethnicity and race encourages these firms to embrace a wider spectrum of technologies (Shuwaikh &Dubocage, 2022) .

The impact of executive team diversity on corporate innovation is heavily influenced by the geographical context in which these biopharma firms operate. For example, those located in renowned biotech clusters like Massachusetts, California, and New York exhibit varying degrees of sensitivity towards diversity. Currently, there is an escalating societal and political momentum driving corporate accountability in addressing systemic inequalities and misconduct. This document presents a detailed roadmap that outlines strategies for fostering equity, transparency, and accountability at the intersection of the biotech industry and social values.

The ultimate aim is to create a future that is not only healthy, safe, and just, but also sustainable. DEI is increasingly recognized as a significant emerging sustainability concern in the biotech sector. International organizations, governments, NGOs, and civil society organizations are championing efforts to combat systemic inequalities and the distribution of power in global matters, such as the pandemic response (Cabello-Medina et al.2020) .

This is achieved through the implementation of stringent regulations and guidelines. Biopharma companies have taken commendable steps in upholding DEI principles and leading the development of pharmaceutical solutions to combat COVID-19. Furthermore, there is a growing acknowledgment that diversity, equity, and inclusion, as well as deliberate exclusion, play a pivotal role in shaping the understanding and response to various crises and risks, including pandemics and climate change. As a result, DEI advocacy has emerged as an urgent and equal priority alongside biomedical and sustainability initiatives within the biotech industry.

15. Collaborations and Partnerships in Biotechnology Research and Innovation

With the rapid growth of biotechnology research and innovation across the globe, Arab countries seek to explore the opportunities and challenges for valuable partnerships and collaborations for their biotechnology sectors. Recent trends in the fields of biotechnology research and innovation can be viewed as both threats and opportunities for Arab nations. An in-depth analysis of recent trends in biotechnology research (publication and citation trends) and innovation (patent trends) suggests that the biotechnology capacities of many Arab countries are growing at a rapid pace.

However, given the exponential growth rates of countries in Europe and Asia, several Arab countries have an immediate and urgent need to boost collaboration efforts in biotechnology research and innovation. This need arises due to the potential threats posed by the dominance of these regions in the field of biotechnology and the evident opportunities for knowledge exchange and enhanced technological growth through collaborations. Moreover, a closer and comprehensive analysis of recent biotechnology research and patenting trends reveals both possible threats and unprecedented opportunities for Arab nations.

The threats lie in the fact that the Arab countries might face difficulties in catching up with the advanced biotechnology research and innovation being conducted by leading nations. (Vafaei et al.2021) These nations have already established extensive biotechnology networks, colossal research infrastructure, and secured intellectual property rights through patents. The Arab countries, on the other hand, still need to overcome some challenges such as limited funding, inadequate research facilities, and a fragmented research landscape to fully exploit the potential that biotechnology holds for their economies. However, amidst these challenges, there are immense opportunities waiting to be seized by Arab nations. Collaboration in biotechnology research and innovation acts as a catalyst for accelerated growth and development. (Attah-Boakye et al.2020)

By establishing fruitful alliances and working in harmony with renowned biotechnological centers around the world, Arab countries can harness the benefits of shared resources, expertise, knowledge, and cutting-edge technology. This collaboration will not only enhance the research capabilities of Arab nations but also lead to the creation of novel solutions to local and global challenges, such as food security, healthcare, sustainable agriculture, and environmental conservation. Furthermore, the expansion of biotechnology research and innovation in Arab countries can also contribute to the national agendas of economic diversification, job creation, and skills development. The creation of biotechnology hubs and clusters would attract foreign direct investment, facilitate technology transfer, nurture entrepreneurship, and generate high-value job opportunities for the growing young population in Arab nations.

On top of that, the establishment of a robust biotechnology ecosystem will foster the growth of small and medium-sized enterprises (SMEs), which are considered the backbone of any thriving knowledge-based economy. In conclusion, biotechnology research and innovation present both challenges and opportunities for Arab nations. The exponential growth of biotechnology capacities in Europe and Asia necessitates the urgent need for enhanced collaboration efforts in the Arab region. While there are threats involved, the immense opportunities for knowledge exchange, technological advancements, and socioeconomic development through biotechnology collaborations should not be overlooked. By leveraging international partnerships and taking advantage of available resources, Arab countries can cultivate a vibrant and pioneering biotechnology sector that contributes to the sustainable development and prosperity of their nations (Sánchez et al., 2024) .

Turkey, Brazil, and Iran are the top three countries that Arab nations need to watch carefully in biotechnology research. Of concern are Jordan, Morocco, Egypt, Tunisia, and Saudi Arabia as they fall behind in international publication collaboration. Additionally, a focus on public-private partnerships may present an attractive opportunity for Arab countries. International patenting collaboration patterns further suggest that Arab nations need to be more proactive in forming new partnerships and networks in biotechnology innovation. Notwithstanding this, some new partnerships that may be used as a basis for forming new networks can be identified. Among advanced economies, Singapore and South Korea emerged as possible new partners. Continued reliance on existing partnerships with France and the United States is also a possibility.

Arab countries should strive to be more proactive in capitalizing on the abundance of partnership opportunities that may arise from the flourishing biotechnology sector in Asia and Europe. It is evident that there are challenges ahead for Arab nations to fully maximize these growth opportunities and establish new partnerships and networks in biotechnology research and innovation. However, conducting a thorough analysis of recent trends in biotechnology research and innovation offers valuable quantitative insights into the biotechnology research and innovation profiles of Arab nations (Seo et al., 2020) .

This comprehensive understanding serves as an initial stride towards formulating pertinent biotechnology research and innovation policies and strategies to propel the Arab countries forward in this field. It is imperative that Arab nations recognize and harness the potential that lies within the biotechnology industry, as it holds the key to unprecedented advancements and collaborations on a global scale. By embracing these opportunities and actively engaging in research and innovation endeavors, Arab nations can position themselves as influential players in the biotechnology landscape, leading to greater economic growth and development in the region.

16. Conclusion and Future Directions

Education and capacity-building encompass a broad range of applications, from international development, health, and the environment to disaster preparedness, humanitarian assistance, and community development. This complex and multi-faceted field is constantly evolving and adapting to meet the needs of society and respond to major global developments. In this context, it is essential to pursue a moral and ethical growth path, as well as to promote new concepts of solidarity and social values. Furthermore, it is crucial to ensure the sustainable financing of biotechnology education and capacity-building programs.

This publication primarily addresses value and value struggle processes that may be articulated across societal, political, and commercial domains. It argues that it might be useful to better articulate discourses on social academia and commercialization's negative social consequences in order to think through the social shaping of biotechnology outside frameworks that primarily focus on fault lines. Building on these arguments, it is suggested that there might be exciting opportunities for social academia to engage actively with changes underway within scientific and technological developments.

In terms of future research, a need exists to further study the Arab world's prominent public health concerns and their biotech interventions. In addition, the social and ethical assessment of biotechnological innovations ought to be examined in Arab settings. A view towards greater independence could usefully be pursued in both these areas. Taking into consideration sociocultural and economic contexts, institutional settings, and the role of people's perceptions of biotechnology in Arab countries, it is essential to examine discourses and frames of reference regarding biotechnology from the viewpoint of social sciences. Research topics could therefore include, but are not limited to, the Arab world's perceptions towards biotechnological innovations.

Moreover, it is essential to seek the involvement of scientists in participative, policy-oriented activities in order to enable scholarly expertise to be taken in steps beyond narrow academic confines. Educating consumers is also of vital importance so as to make them better equipped to accommodate societal expectations. Publications ought to reconsider implications of past claims of biotechnology's ethical neutrality.

The Arab world's ambivalence towards modernization should be better grasped. The effects of scientific achievements on Arab ethics ought to be clarified. Furthermore, privacy protection, discrimination, and unequal access issues should be considered within the ambit of biotechnology's social, ethical, and political considerations. Crucially, it is imperative to ask for what ends social scientists think into Arab biotechnologies.

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