

## ETHICAL REFLECTIONS ON THE IMPACT OF GENETIC ENGINEERING ON BIODIVERSITY

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**Abstract:** Genetic engineering, the manipulation of an organism's genetic material, holds significant promise for advances in medicine, agriculture, and environmental management. However, its application raises profound ethical considerations, particularly concerning biodiversity, and the variety of life in all its forms and interactions. On one hand, genetic engineering can enhance biodiversity by introducing novel traits into species, thereby increasing genetic variation, however, the impact of genetic engineering on biodiversity is multifaceted and contentious. Concerns include the potential for genetically modified organisms to crossbreed with wild relatives, leading to genetic contamination and possible loss of natural genetic diversity. There is also the risk that genetically modified species might out-compete natural species, resulting in a reduction of biodiversity.

This paper uses the exposition method to discuss the concepts of genetic engineering and biodiversity while it uses the analytic method to engage in an ethical reflection of the impact of genetic engineering on biodiversity. This paper contends with the problem that while genetic engineering holds promise for enhancing certain aspects of biodiversity, it also poses risks that necessitate careful management and regulation. Ensuring that genetic engineering practices are aligned with biodiversity conservation goals requires a balanced approach, integrating scientific innovation with ecological and ethical considerations. This paper argues that it is important for researchers and policymakers to carefully assess the potential environmental impacts of genetic engineering to minimize negative consequences on biodiversity. It concludes by recommending environmental risk assessments and regulatory frameworks in ensuring the responsible and sustainable use of genetic engineering technologies.

**Keywords:** Genetic Engineering, Biodiversity, Ethics, Reflection, Genetic Variation.

### INTRODUCTION

Genetic engineering, a realm where the boundaries of human ingenuity intersect with the intricacies of life itself, stands as a beacon of hope for overcoming the limitations of our genetic makeup. The ability to manipulate genes, once confined to the realm of science fiction, has now become an integral part of our scientific reality, offering promises of eradicating diseases, enhancing agricultural yields, and even shaping the course of human evolution. At its core, genetic engineering embodies the quintessential human endeavor to transcend the constraints imposed by nature. Through the manipulation of genetic material, scientists wield the power to eradicate hereditary diseases, alleviate suffering, and potentially enhance human capabilities beyond the bounds of natural selection. However, with this power comes an inherent responsibility to navigate the ethical contours that accompany such transformative technologies.

Genetic engineering, the manipulation of an organism's genetic material through biotechnological means, has emerged as a revolutionary tool with profound implications for agriculture, medicine,

and environmental management. This technology enables scientists to introduce, remove, or modify specific genes within an organism's genome, creating genetically modified organisms (GMOs) with desired traits. As genetic engineering continues to advance its impact on biodiversity — the variety and variability of life on Earth — has become a critical area of study and debate. Integral to this scientific marvel is its ability to redefine biodiversity. This redefinition becomes imperative in the face of threats and challenges to biodiversity conservation. Biodiversity is fundamental to the health and stability of ecosystems, providing essential services such as pollination, nutrient cycling, and climate regulation, all of which support human well-being.

Biodiversity is essential for ecosystem health and stability, providing a wide range of ecosystem services, including pollination, pest control, and nutrient cycling. It also offers resilience against environmental changes and shocks. The relationship between genetic engineering and biodiversity is complex and multifaceted, with potential benefits and risks that need to be carefully considered.

One of the primary benefits of genetic engineering is its potential to enhance biodiversity by introducing new genetic variations. For example, genetically modified crops can be engineered for increased resistance to pests, diseases, and environmental stresses such as drought. These modifications can reduce the reliance on chemical pesticides and fertilizers, promoting a healthier environment and supporting a wider variety of species. Additionally, genetic engineering can help conserve endangered species by enhancing their genetic diversity and resilience.

Despite these potential benefits, genetic engineering also poses significant risks to biodiversity. Production of genetically modified crops can lead to unintended ecological consequences, such as the potential for genetically modified genes to transfer to wild relatives through crossbreeding. This can ultimately lead to an alteration of the genetic makeup of natural populations and potentially reduce their genetic diversity. Moreover, GMOs may outcompete native species, leading to a decline in local biodiversity. The widespread adoption of genetically engineered crops can also reduce genetic diversity within agricultural systems, making them more susceptible to pests, diseases, and climate change, among other effects.

The controversy surrounding genetic engineering and biodiversity is further compounded by ethical, legal, and social considerations. Questions about the long-term impacts of genetic modifications, the right to patent and control genetically engineered organisms, and the socio-economic effects on small-scale farmers and indigenous communities add layers of complexity to the debate.

Although it is widely assumed that the potential agricultural, medical, and industrial benefits, afforded by genetic engineering, greatly outweigh the inherent risks surrounding such a powerful technology, most of the moral and ethical concerns raised during the inception of genetic engineering are still actively expressed today. These concerns will be the focus of the discourse in this paper as it engages in an ethical appraisal of the effects of the biotechnological wonder known as genetic engineering on biodiversity.

This paper has four sections. The first section is a conceptual exposition of genetic engineering; the second part focuses on a conceptual overview of biodiversity; the third aspect discusses the revolutionary impact of genetic engineering while the fourth section takes a cursory look at the effects of genetic engineering on biodiversity from an ethical spectrum. Finally, this paper posits certain recommendations that can plausibly balance the potential benefits of genetic engineering with the need to protect and preserve biodiversity.

### **Conceptual Clarification of Genetic Engineering**

Genetic engineering is the use of molecular biology technology to modify DNA sequence(s) in genomes, using a variety of approaches (Lanigan, Kopera, Saunders 2020). Genetic engineering is a field of biotechnology that involves manipulating the genetic material of living organisms. Genetic engineering, also known as genetic modification or recombinant DNA technology, involves altering the DNA of an organism to introduce new traits or characteristics. It can also be said to be the deliberate modification of an organism's genetic material by artificial means, typically involving the insertion, deletion, or alteration of specific genes to achieve desired traits or characteristics (Christian et al. 2010, 757-761).

Genetic engineering, also known as genetic modification or genetic manipulation, involves altering the genetic material of an organism to achieve desired traits. This technology has broad applications in medicine, agriculture, and industry. The foundation of genetic engineering was laid with the discovery of the structure of DNA by James Watson and Francis Crick in 1953. The advent of recombinant DNA technology in the 1970s marked the beginning of genetic engineering as we know it (Ajoykumar, Singh, Shackira 2021, 421-450). The first genetically modified organism was created by Herbert Boyer and Stanley Cohen in 1973 (Sverdlov, 2014, 242-245).

Genetic engineering is applied in numerous fields including research, medicine, industrial biotechnology, and agriculture. In research, GMOs are used to study gene function and expression through loss of function, gain of function, tracking, and expression experiments.

In general, genetic engineering refers to all the techniques used to artificially modify an organism in order to produce a desired substance (such as an enzyme or a metabolite) that is not naturally produced by the organism or to enhance a preexisting cellular process (Pyne, Sukhija, Chou, 2014). Similarly, genetic engineering involves modifying the genetic composition of living organisms through artificial means, such as recombinant DNA technology, gene editing, or transgenic methods, with the aim of producing organisms with desired characteristics or traits (Ajoykumar, Singh, Shackira 2021, 421 - 450). Its process involves selectively altering the genetic information of an organism by introducing foreign DNA or making changes to an existing DNA sequence, often to enhance its capabilities, improve its performance, or confer new functionalities.

Broadly speaking, genetic engineering revolves around the deliberate manipulation of an organism's genetic material using various biotechnological techniques. This manipulation typically involves altering, adding, or deleting specific genes within an organism's DNA to introduce new traits, improve existing ones, or achieve desired outcomes (Christian et al., 2010, 757–761). Genetic engineering encompasses a wide range of applications across different fields, including medicine, agriculture, industry, and environmental conservation. In essence, it's about harnessing the power of genetic information to modify organisms for beneficial purposes, such as developing disease-resistant crops, producing pharmaceuticals, treating genetic disorders, or creating biofuels.

There are several techniques in genetic engineering which are recombinant DNA technology, CRISPR-Cas9, gene cloning, gene therapy, and RNA interference. Recombinant DNA Technology involves combining DNA from two different sources wherein a gene of interest is inserted into a vector (usually a plasmid), which is then introduced into a host organism (Pyne, Sukhija, Chou, 2014). This method is used to produce insulin, growth hormones, and other pharmaceuticals. CRISPR-Cas9 is a revolutionary technology for gene editing and allows precise, targeted changes to the DNA of living organisms. It consists of a guide RNA and the Cas9 enzyme, which together can cut DNA at specific locations (Ledford 2016, 156–159). Gene Cloning is issued to produce multiple copies of a gene of interest. It is essential for studying genes and producing proteins in large quantities while gene therapy involves inserting genes into an individual's cells to treat or prevent disease. RNA Interference, on the other hand, is a method of silencing gene expression. It is used in research and therapeutic applications to knock down the expression of specific genes.

### **A Conceptual Overview of Biodiversity**

Biodiversity, or biological diversity, refers to the variety of life on earth, encompassing the different species of plants, animals, fungi, and microorganisms, the genetic differences within these species, and the ecosystems they form. Gaston and Spicer (2004) defined biodiversity as the “variation of life at all levels of biological organization”. On the other hand, the Food and Agriculture Organization of the United Nations (FAO) defined biodiversity in 2019 as “the variability that exists among living organisms (both within and between species) and the ecosystems of which they are part.” In lucid terms, most biologists often define biodiversity as the “totality of genes, species and ecosystems of a region” (Carrington, 2021).

Biodiversity is crucial for the stability and resilience of ecosystems, providing numerous benefits to humans, such as food, medicine, and ecosystem services. There are levels of biodiversity which are genetic diversity, species diversity, and ecological diversity.

**Genetic Diversity:** This level of biodiversity refers to the variation of genes within species. Genetic diversity is important because it enables populations to adapt to changing environments and helps ensure species' survival. For example, different genetic traits within a crop species can make some individuals more resistant to pests, diseases, or climate extremes.

**Species Diversity:** This is the variety of species within a habitat or a region. It includes not just the number of species, but also their relative abundance and their ecological roles. A high level of species diversity increases ecosystem productivity and stability, as different species can perform various ecological functions and contribute to overall resilience.

**Ecosystem Diversity:** This encompasses the variety of ecosystems within a particular area or on the planet as a whole. Different ecosystems, such as forests, deserts, wetlands, and oceans, provide different habitats and support different communities of organisms. The diversity of ecosystems contributes to the wide range of services they provide, from climate regulation to water purification.

Biodiversity has profound effects on humanity and nature in its entirety. Biodiversity ensures natural sustainability for all life forms as species interact with each other and with their environment in ways that create a balanced ecosystem. Predators, for example, control the population of herbivores, which in turn influences plant life. By this, the ecological balance is important in nature.

Biodiversity is also a source of economic wealth. Many plants and animals are sources of food, medicine, and raw materials, for instance, many pharmaceuticals are derived from compounds found in plants and animals. More so, it underpins ecosystem services that benefit humans, including pollination of crops, water purification, climate regulation, and soil fertility. These services are essential for human survival and well-being. In addition, biodiversity has aesthetic, spiritual, and recreational value. Many cultures around the world revere certain species and ecosystems, and biodiversity is a key component of the natural landscapes that provide inspiration and recreation (Zohary, Hopf, Weiss, 2012).

### **Genetic Engineering: A Scientific Marvel**

One of the primary benefits of genetic engineering is its potential to enhance biodiversity by introducing new genetic variations. In agriculture, crops are engineered for traits such as pest resistance, herbicide tolerance, and improved nutritional content. Certain tree species can also be used as feedstocks for bioenergy production (Baulcombe, 2010, 761–810). Achieving this requires the introduction or modified expression of genes to enhance biomass production in a sustainable manner (which has become a reality with genetic engineering). Moreover, tree genetic engineering has advanced to the point at which genes for desirable traits can now be introduced and expressed efficiently; examples include biotic and abiotic stress tolerance, improved wood properties, root formation, and phytoremediation (Carrington, 2017). It enhances traits in livestock for better productivity and disease resistance. Genetic engineering offers the opportunity to improve not only forage and turf crops but also bioenergy crops by allowing the introduction of foreign genes from unrelated species and the down-regulation or up-regulation of endogenous genes (Hughes Queresh, 2014). This enhances renewable energy in the form of biofuels. The upsurge in industrialization and the human population has led to increasing energy demands mostly met by fossil-oriented energy carriers, resulting in the emission of pollutants and greenhouse gases. The environmental and public health damages caused by these emissions have triggered a global transition toward replacing fossil fuels with their renewable and green counterparts making biodiesel a promising alternative to fossil diesel (Hughes Queresh, 2014).

Food insecurity and malnutrition are currently among the most serious concerns for human health, causing the loss of countless lives in developing countries. To be healthy, our daily diet must include ample high-quality foods with all of the essential nutrients, in addition to foods that provide health benefits beyond basic nutrition. Even maintaining the amount of food per capita what we are getting today will be a mounting job in the future because of the continuing loss of arable lands and the prevalence of unfavourable environmental conditions including drought, salinity, floods, diseases, and so on. In order to ensure food security for future generations, the world must produce 50% to 100% more food than at present in spite of the predicted adverse environmental conditions (Baulcombe, 2010, 761–810).

According to Malzahn, Lowder, and Qi, (Malzahn, Lowder, Qi 2017, 433–450) adverse environmental conditions, such as drought, flooding, extreme heat, and so on, affect crop yields more than pests



and diseases. Thus, a major goal of plant scientists has been to find ways to maintain high productivity under stress as well as develop crops with enhanced nutritional value - this drive is now possible with the production of genetically modified crops. Genetically modified crops have proven to be powerful complements to those produced by conventional methods for meeting the worldwide demand for quality foods. Crops developed by genetic engineering can not only be used to enhance yields and nutritional quality but also for increased tolerance to various biotic and abiotic stresses (Datta, 2013, 76–101).

With genetic engineering, new crop varieties that can thrive in diverse environments and resist pests and diseases have been produced, thereby enhancing crop diversity. It helps in the production of crops with a capacity to withstand extreme weather conditions, thereby maintaining agricultural biodiversity. Genetic engineering also makes bioremediation possible. Bioremediation is the creation of organisms that can detoxify polluted environments, aiding in the restoration of ecosystems (Kumar, Shahi, Singh, 2018, 115-136). In addition, it engineers the development of plants and animals that can re-establish themselves in degraded habitats, thereby promoting ecological balance.

Genetically engineered pest-resistant crops reduce the need for chemical pesticides, benefiting non-target species and overall biodiversity while the creation of crops that utilize nutrients more efficiently, reduces the environmental impact of agriculture and supports diverse ecosystems. Above all is the conservation of endangered species. Genetic engineering can drive the rescue of many endangered species via the introduction of genetic diversity into endangered populations to improve their viability and resilience (Caro et al. 2022, 45–60).

### **Ethical Reflection on Genetic Engineering and Biodiversity**

The ability of scientists to interfere with nature and alter the genetic makeup of living organisms has been the focal point of many concerns surrounding genetic engineering. Without a doubt, this promising biotechnology is laced with crucial issues in various spheres. However, the fulcrum of ethical discussions in this paper will be based on biodiversity.

The widespread adoption of genetically modified crops can lead to monocultures, reducing genetic diversity within agricultural systems and increasing vulnerability to pests, diseases, and environmental changes. In other words, genetic engineering can engineer the production of specific crops and lead to loss of various crop species. Similarly, genetic engineering can ultimately lead to the loss of local varieties with traditional and locally adapted crop varieties being displaced by genetically modified varieties and invariably leading to a loss of genetic diversity.

It can also inadvertently create pests and weeds that may develop resistance to genetically modified traits (e.g., pest-resistant crops), leading to the emergence of “super pests” or “super weeds” that are harder to control (Pillay et al. 2022, 10–15). Genetic engineering is capable of impacting soil health through microbial alteration. The use of genetically modified crops can affect soil microorganisms, potentially altering soil health and nutrient cycling processes.

More so, the introduction of genetically modified organisms into an ecosystem can disrupt existing food webs and ecological relationships, potentially causing cascading effects. Genetic modifications could alter the behavior or characteristics of a species, potentially leading to imbalances in predator-prey relationships or competition for resources (Briggs, 2020). In a nutshell, introducing genetically modified organisms into ecosystems can disrupt natural interactions and relationships, potentially leading to changes in biodiversity and ecosystem dynamics.

Socio-economic concerns raise ethical issues on equity, justice, and accessibility to the benefits of genetic engineering. The adoption of genetically modified crops might favor large-scale agribusiness over smaller ones and traditional farmers, potentially exacerbating social inequalities and consequently, agricultural biodiversity. There is also the danger of monopolization by large biotech companies and the hoarding of genetic benefits. This can be exacerbated by intellectual property rights such as the patenting of genetically modified seeds, which will in turn limit farmers' access to diverse seed varieties and traditional practices (Erwin, Gendin, Kleiman, 2015). In much broader projections, genetically modified organisms might cause changes that are difficult or impossible to reverse, with unknown and unintended long-term consequences for biodiversity.

In a broader sense, biodiversity has intrinsic value and instrumental values which are important bastions of nature. Its intrinsic value, independent of its utility to humans, presupposes the inherent worth of all living beings and ecosystems. Hence, my opinion, is that the homogenization of species or ecosystems through genetic engineering undermines this value. Moreover, biodiversity is instrumental to as many biological processes in nature as can be imagined. Biodiversity provides essential ecosystem services, such as pollination, nutrient cycling, and climate regulation. These biological processes are crucial for human survival and well-being, as well as continuity in nature. This necessitates a responsible approach in the use of genetic engineering procedures and processes. In addition, ethical reflections are imperative in a bid to ensure equity and justice vis-a-vis the distribution of benefits and risks. Genetic engineering often benefits large corporations and wealthy nations, potentially exacerbating global inequalities. Indigenous communities and developing countries, which often harbor rich biodiversity, may bear the risks without reaping proportional benefits.

As argued by Melian (Melia 2004), the rights of future generations are one that isn't elusive. The ethical principle of intergenerational justice emphasizes the responsibility to preserve biodiversity for future generations. Thus, genetic engineering decisions made today will have long-term impacts, necessitating careful consideration of their sustainability and reversibility.

In the final analysis, genetic engineering holds significant promise for enhancing biodiversity and addressing some of the most pressing challenges facing our world today. However, it also presents substantial risks that require careful management. As we continue to explore and harness the power of genetic engineering, it is imperative to prioritize the preservation of biodiversity, ensuring that technological advancements contribute to a sustainable and resilient future for all life forms.

### **Conclusion**

Genetic engineering holds immense potential to revolutionize various fields, from healthcare to agriculture. However, it also poses significant ethical, safety, and socio-economic challenges that must be addressed. As technology advances, ongoing dialogue among scientists, policymakers, and the public is crucial to ensure that genetic engineering is used responsibly and equitably.

Ethical reflections on genetic engineering and biodiversity necessitate a balanced approach that considers both the potential benefits and risks of the technology. Genetic engineering requires a framework that integrates principles of beneficence, non-maleficence, justice, and respect for the intrinsic value of all life forms. Policy decisions should be guided by thorough ethical analysis, precautionary measures, and inclusive dialogue with diverse stakeholders to ensure that the applications of genetic engineering advance human welfare without compromising the integrity of our planet's biodiversity.

### **Recommendations**

Mitigating the negative effects of genetic engineering on biodiversity involves careful regulation, monitoring, and research. To this, this paper presents the following recommendations:

1. Environmental impact and risk assessment protocols should be developed.
2. Preservation of the genetic material of native and wild species in gene banks to safeguard against genetic erosion.
3. Promotion of agro-biodiversity through the use of diverse crops and livestock breeds to reduce dependency on genetically engineered varieties and maintain agricultural biodiversity
4. The creation and use of controlled environments to prevent genetically modified organisms from interacting with wild species.
5. Stakeholders' engagement process including scientists, farmers, Indigenous communities, and the public in discourses and decision-making processes regarding genetically modified organisms.
6. Protection of natural habitats that might be affected by the introduction of genetically modified organisms to ensure ecosystem resilience.
7. Encourage agricultural practices that integrate genetic engineering with sustainability principles to minimize environmental impact.
8. Scientists, technologists, and relevant agencies involved in genetic engineering should respect and adhere to international agreements like the Cartagena Protocol on Biosafety, which governs the movement of genetically modified organisms across borders.

9. More importantly, the development of alternative technologies and practices that may achieve similar benefits without compromising biodiversity.

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