



# Is Genetic Modification a Valuable Bioengineering Tool or an Unethical Way to Change Our Natural World?

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**Abstract-** Genetical modification has existed for centuries, tracing back to ancient practices of selecting better crops to cultivate or choosing stronger cattle as breeding stock. As technology advances, hybrid plants and animals have been developed, genetically modified crops have been planted. Public disquiet began to emerge that humans are disrupting the laws of nature by creating artificial species. These concerns intensified when gene-editing technologies began to be applied to the human body. Despite genetic modification's overwhelming medical benefits, opposition arose due to concerns about unequal access. Fears that only the wealthy will be able to enhance their offspring have led to accusations that genetic modification is exacerbating social inequality. Providing humanity with a means to improve itself, genetic modification is undoubtedly an extremely valuable bioengineering tool. The changes it brings to the world are truly beneficial and meaningful. As with all powerful innovations, misuse can lead to adverse consequences. The risk necessitates in-depth evaluation and comprehensive legislation on each application. Making the technology affordable and accessible to the public would alleviate many of the unethical concerns on social inequality and societal separation. We must take responsibility to guide, monitor, and regulate the ethical application of genetic modification, rather than dismissing the unparalleled value of this transformative tool.

**Keywords:** Genetic Modification, Gene-Editing, Bioengineering, Social Inequality, Unethical Concern.

## I. Introduction

A new world is unfolding, one where modified plants and animals are increasingly common, genetic diseases are cured, and even extinct species may roam again. The application of gene-editing technologies, an advanced form of genetic modification, makes this possible. As technology progresses, the possibilities of gene modification seem endless. People enjoy the benefits of transformed agriculture, genetic medicine, and synthetic biology, but at what cost? Are we losing ethics, morality, and social fairness as the exchange?

## II. Historical Background of Genetic Modification

Genetic modification is not new. With the definition of genetic modification as any process that manipulates an organism's gene pool, or the sum of the genes in any population that reproduces by breeding, people have been developing this technology for centuries (Beck et al.). Humans have been using it to manipulate genetic traits for millennia through the application of selective breeding or artificial selection. They cultivated sturdier crops, bred animals with desirable features, well before scientists clarified the molecular mechanisms of heredity. In the 20th century, mutagenesis enabled creation of desirable traits and new species. For example, researchers used ultraviolet radiation and Ethyl MethaneSulfonate (EMS) to accelerate mutations and improve crop varieties (Chen et al.). In 1970's, gene-editing emerged as a new tool to edit DNA sequences and control how organisms grow and function, while producing pest-resistant crops and disease-resistant livestock. The modification of DNA in human cells was made possible with the invention of CRISPR-Cas9 tool in 2012 (Podcast). CRISPR-Cas9 is an enzyme system naturally exists in bacteria to defend against viruses, where CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) recognizes the viral DNA and Cas9 (CRISPR-associated protein 9) destroys it (Doudna et al.). Scientists use this tool to edit DNA at specific locations. Relying on this technology's high accuracy and ease of use, researchers developed genetic therapy (Isaacson et al.).

## III. Public Perception and Ethical Considerations

Public acceptance of genetic modification exists at different levels. People easily forgive unconscious genetic modification, such as our ancient ancestors' selective breeding, as most tend to view it as humanity's developed life experience of surviving challenging conditions. Many even view it as an extension of evolution: humans within the food chain are simply accelerating the natural selection process (Rangel). Large populations also embrace plant hybridization (Goulet). Cross breeding two different plants can produce a new species with traits



from both parents, strengthening the offspring adaptability (Aziz). Acceptance of this practice may rely on the fact that both parents are natural species. On the other hand, with the knowledge of DNA (DeoxyriboNucleic Acid) as the genetic information carrier, intentional DNA editing has sparked heated debate.

#### IV. Genetic Modification in Agriculture

##### 4.1 Benefits

Genetic modification involving DNA editing within our food system provided the first controversy. GMOs (Genetically Modified Organisms) have transformed agriculture, by increasing crop resistance to pests and diseases, leading to higher yields and less pesticide use (Ahmad). For example, Bt crops contain genes which produce insecticidal proteins, improving yields and reducing pesticide use (Smyth et al.). They are also more resistant to varying climatic circumstances (Icoz et al.). On a global scale, production of GMO crops has provided more affordable food and reduced global food insecurity. In addition, due to the consistently high GMO crop yields, GMO farmers realize higher incomes (Brookes et al.), leading to their increased financial security. Beyond quantity, GMOs also improve food quality. For instance, GMO soybeans have lower trans fats, the known substances linked to obesity and heart disease (Smyth et al.). Furthermore, by using less chemical pesticides, beneficial insects are better preserved, potential water source contamination is reduced, and tilling is decreased (Midtvedt et al.).

##### 4.2 Risks and Controversies

Despite these benefits, the increasing use of GMOs in crops has raised serious concerns about the unintended impact on environment and human health. For example, researchers associate herbicide-resistant crop with the loss of North American monarch butterfly habitat (CBAN), as these crops prevent the growth of “milkweed”, the sole food source for monarch caterpillars. Herbicide-resistant GMOs can also lead to the evolution of “super weeds”, more resistant to current pesticides, calling for stronger ones (Damalas et al.). Some of the GMOs can transfer antibiotic resistance to human gut bacteria, posing a significant public health risk. Other health risks are associated with allergic reactions. Studies showed that introducing allergenic genes into non-allergenic plants may create new allergens (Shekhar et al.). For instance, when a gene from a Brazil nut was introduced into soybeans, nut-allergic consumers reacted adversely when they consumed the genetically modified soybeans (Anilakumar et al.). This illustrates how genetic alterations can introduce new health threats.

Despite these concerns, GMOs offer overwhelming benefits. When evaluating the decrease of monarch butterflies, the butterfly population needs to be compared to the scenario when chemical pesticides are used to achieve the same crop yield. If the butterfly population with no pesticide usage is used as the control, the result is misleading which unfairly puts GMOs at fault. The potential evolution of superweeds and antibiotic resistance needs close monitoring. The optimized process of using certain GMOs in certain environments tends to achieve the best benefit-to-risk ratio. Clear traceability provides a viable way to avoid exposing allergens to allergic populations. In addition, no matter if the DNA is altered by intentional human intervention or not, the model gene-editing technique has the same effect as the traditional unconscious genome amelioration methods: the later generations are becoming better and stronger. Judging by how artificial a method is, not by the actual effect it brings, to reject the gene-editing technology amounts to an inappropriate and inconsistent evaluation process.

#### V. Genetic Modification in Medicine

##### 5.1 Therapeutic Applications

While GMOs draw some negative comments, the most significant opposition to genetic modification is leveled at human-cell DNA editing. The invention of the CRISPR-Cas9 tool in 2012 made this process easily adaptable. By directly fixing the defective genes, CRISPR offers great hope to treat over 8,000 monogenic diseases, such as sickle-cell anemia and cystic fibrosis (Harris et al.). FDA recently approved the first CRISPR drug, Casgevy®, to treat sickle cell anemia, opening the floodgates for gene-editing therapies. Prior to this, the only treatment available was frequent blood transfusions or bone marrow transplants. With CRISPR to permanently correct the disease-causing genome mutations, the curing process can become as simple as a one-time treatment. In cancer treatment, CRISPR is being explored to locate and disable specific genes which promote cancer growth, replacing the grueling chemotherapy and radiotherapy (Chehelgerdi et al.)

##### 5.2 Ethics and Safety

The enhancement application provokes a variety of arguments, as human enhancement aims to increase human capacities above normal levels (Savulescu, et al.). Most populations understand the preventive parts of the benefit, which eliminate genes related to certain diseases. Editing these genes removes the health risk, prior to the emergence and development of the associated diseases. However, the public fears unnecessary enhancements, like to intelligence or fitness, which heightens social inequality. As gene editing might be



restricted to the wealthy, in the long term, this would create a genetically segregated society, widening the gap between social classes, significantly exacerbating existing social inequality.

Genome design means to alter the genomes in human embryos to “perfect” unborn babies. This is the most controversial application of genetic modification. The first genetically edited babies, conducted by Jiankui He and his team, created massive ethical discussion and global concerns. The procedure modified the CCR5 gene to give the babies immunity to HIV (Newcomb et al.). With the scientists’ desire to generate stronger human beings, the public began to question the human features of the next “produced” generations.

## VI. Addressing Public Concerns and Future Direction

Genetic modification’s benefits are undeniable. Part of the public’s fears comes from the lack of confidence in this newly emerging technology. With the acknowledgement of the series of pre-requisitions for a genetic modification to happen, the public may feel more comfortable facing this new bioengineering field. Genetic modification is never an isolated decision. Before it happens, structural biologists have solved the three-dimensional gene structure, to the atomic level; bioinformaticians have revealed many new species, for the cause-effect analysis; bioengineers, engineered the proteins for high efficiency and specificity; and finally, clinical researchers have conducted numerous experiments, both in-vitro and in-vivo, to observe the receptor/patient response (Stanford University). With such a robust system, the genetic modification selected to be used on humans attains high confidence of success. For example, Alzheimer’s disease is currently not a candidate for genetic modification, as we still do not know for sure which gene causes it in many patients. We have a meticulous science system, with stringent governing procedures and comprehensive risk analysis. Better communication between scientists and the public, just like how smoothly knowledge is shared within the scientific community, can help relieve society’s concerns and boost public confidence in new technologies.

Scientific advancement makes the impossible possible, driving human culture to today’s level. But almost all-important scientific breakthroughs cause debates. These debates do not stop technological advancements, rather, they help refine the technology, facilitating the advancements. With the concern that DNA editing is irreversible, scientists are exploring other genetic modification methods without editing human DNA. Epigenome editing is one of the potential routes (McCutcheon et al.). It modifies the gene expression, turns on or off the problematic genes, makes the gene modification reversible, and stops a change being passed down to future generations. Scientists take public feedback positively, continuously sharpening the technology to better meet human needs.

## VII. Conclusion

Genetic modification is a valuable bioengineering tool. The awarding of the 2020 Nobel Prize in Chemistry to Jennifer Doudna and Emmanuelle Charpentier on revealing CRISPR-Cas9 technology testified to the positive impact of this tool. They truly handed an unrivaled tool of controlling life to us. We have never been more confident that we can save people afflicted with genetic diseases, struggling under tremendous burdens, and helpless when natural disasters occur. However, genetic modification must be pursued with responsibility and caution to ensure that it serves the public. Rigorous regulations and ethical guidelines must be established to protect health, biodiversity, and social justice, while guiding science to move forward for society’s greater good. Within these regulations, genetic modification will never be an unethical way to change our natural world.

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