Institute for Youth in Policy

Genetic Engineering: An Ethical Dilemma

Stephanie Wang[#1], Samantha Overhauser[#2], Jack Samet[#3], Dan Siddiqui[#4], Adrienne Yue[#5]

Public Health Department, Institute for Youth in Policy
1700 Van Ness Ave #1143, San Francisco, CA 94109

[1]stephanie.wang@yipinstitute.com, [2]samantha.overhauser@yipinstitute.com,
jack@yipinstitute.com,
adrienne@yipinstitute.com,
marielle@yipinstitute.com

***Abstract*— In this brief, we examine the current state of genetic engineering, focusing on agriculture and healthcare. We discuss the pros and cons of genetic engineering, its recent advances, and present perspectives regarding its ethicality.**

***Keywords*— GMO, genetic modification, gene therapy, CRISPR, bioethics**

I. Executive Summary

The recent rise of the genetic engineering field has brought about vigorous debate among Americans. The benefits of this field are apparent, especially for agriculture—both crops and animals—but the public worries about the safety of genetically modified food and its long term health effects. Similarly, the public is divided on the topic of human genome editing, where genetic engineering is used to alter the genes in order to prevent genetic disease or "enhance" desirable features. This has obviously been a point of contention within the American public and has been addressed by many different stakeholders.

II. Overview

For thousands of years, humans have used selective breeding to breed animals and plants with more "desirable" or unique traits. In the early 70's, scientists developed a way to streamline this process by manipulating DNA. Genetic engineering describes the emerging field surrounding this process—using recombinant DNA (rDNA), to alter an organism's genetic information. Most often, this is done by adding a gene from another species into the genome of the organism. It is important to make a distinction between gene therapy and genetic engineering as the technologies are closely related and often confused. Gene therapy seeks to correct genetic "defects" while genetic engineering is used to enhance the capabilities or traits of an organism beyond what is considered normal. The rising popularity of the fields of genetic engineering and gene therapy have been met with some serious resistance, especially in the past.

A. *Pointed Summary*

- It has been difficult for society to accept the benefits of genetic engineering and gene therapy, as there are many value and affordability issues.
- In 2019, Congress banned the use of human genome editing in embryos in the United States.
- Agricultural and biotech companies profit off of the use of genetic engineering and have seen notable economic benefits since the recent development of the field.
- There are ethical concerns surrounding the field, specifically concerning human genome editing.
- The benefits and costs of genetic engineering are widely debated among Americans.

B. *Relevance*

Genetic engineering is increasing in popularity, especially in agriculture and healthcare. In agriculture, the use of Genetically Modified Organisms (GMOs) has become popular to help farmers reduce crop loss and increase crop yields. The use of GMOs in agriculture allows genes to be

transferred from plants to animals or vice versa, hence selecting organisms with certain desirable traits and breeding them. However, a downside to this process is that other undesirable traits can manifest in the genetically modified product. Currently, over 93 percent of the corn and soy planted in the United States is genetically modified in some way, most of which is used in animal feed, ethanol, or corn syrup. Other common GMOs include cotton, canola, and soybeans. Roughly 60 to 70 percent of processed foods in grocery stores contain at least some ingredients that have been genetically modified. Most of the GMO crops grown today were developed to help farmers prevent crop loss. The three most common traits found in GMO crops are resistance to insect damage, tolerance to herbicides, and resistance to plant viruses.

Genetic modification does not occur solely in plants in agricultural production. Some genetically engineered animals have also been bred to decrease disease susceptibility and yield faster. For instance, salmon have been genetically engineered to grow larger and mature faster. In this case, a type 1 growth hormone gene was injected into fertilized salmon eggs, resulting in significantly increased growth rates for commercial production. Additionally, cattle have been genetically modified to resist mad cow disease.

Aside from agriculture, genetic engineering also has significant implications in healthcare and medical technology. Currently, genetically engineered bacteria and other microorganisms are used to produce human insulin, human growth hormone, blood clotting proteins, and other pharmaceuticals, and these applications are projected to increase in the future. Furthermore, genetic engineering is heavily relied on for treatments to diseases like hemophilia, infertility, dwarfism, and the development of immunotherapy for cancer treatment. In recent years, genetic engineering has also become popular in the production of drugs and vaccines for diseases like Ebola, Zika, leukemia, lymphoma, and blindness.

This type of genetic modification is referred to as gene therapy and is the application of genetic engineering and genetic modification to cure diseases in humans. One form of gene therapy is germline editing, where the defective gene is edited at its earliest stages of embryonic development. This prevents the defective gene from replicating in the other cells of the organism before it is changed. Because this therapy prevents the defective gene from replicating before it is fixed, it also prevents the defective gene from being passed down to the patient's offspring, inducing a generational effect. In somatic editing, only the genes of a particular group of cells are targeted, hence only inducing genetic modification in the patient without the possibility of passing it down to his or her offspring. With the rise of CRISPR technology, gene therapy has transitioned from a mere idea into a promising course of treatment currently in clinical trials for diseases like cystic fibrosis, heart disease, diabetes, hemophilia and AIDS.

C. Current Stances

Due to the up-and-coming nature of genetic engineering and its various risk factors, there exists a rigorous ethical debate around its use. In agriculture, the benefits of using genetically modified crops include tastier foods, more nutritious foods, decreased use of pesticides, increased supply of foods, longer shelf life, reduced costs, increased crop yields, medicinal benefits, and foods with more desirable traits. Shepherded by the Green Revolution, the use of GMOs in agriculture has not been without its drawbacks. These include the potential for foods that cause allergic or toxic reactions, harmful genetic changes, and the inadvertent transfer of undesirable traits between one organism to another.

However, perhaps the most heated topic of contention surrounding the use of genetic engineering is in humans and other intelligent organisms. With the rise of CRISPR gene editing technology, which greatly increases the ease of base editing in correcting errors in DNA, society has the difficult dilemma of grappling with the future of genetic engineering and gene therapy. Germline gene editing, especially, has many risks, such as off-target mutations, targeting the wrong gene, and mosaicism, in which only some copies of the gene are altered. The severity of these drawbacks has

caused scientists to approach gene therapy with caution.

D. Tried Policy

The development and introduction of products modified using biotechnology is largely regulated by the Coordinated Framework for the Regulation of Biotechnology (CFRB). Under this framework, the Environmental protection Agency (EPA), Food and Drug Administration (FDA), and the U.S. Department of Agriculture (USDA) are expected to approach the regulation of these products in a scientific and unbiased manner. In addition, the FDA has a voluntary Plant Biotechnology Consultation Program, where they allow developers to work with them on a product to evaluate safety.

Since the 1980's, when the CFRB was established, the U.S. has seen innovations in the Genetic Engineering field that require legal response - specifically the recent rise of CRISPR technology. CRISPR—mentioned in the prior section—can be used to alter the genes of embryos in order to avoid certain traits or "enhance" others. In 2019, a congressional committee voted to reinstate the ban on creating genetically modified babies after weighing the societal risks and benefits. In fact, human genome-editing is banned by laws and regulations in most countries, even for those who undergo stem cell research.

III. Policy Problem

A. Stakeholders

Due to its wide scope of impact, the rise of genetic engineering has effects on a wide range of stakeholders. For instance, agricultural businesses benefit from the commercialization of GMOs. Farmers in both developing and developed countries have benefited economically from the rise in GMO distribution, which has added 122 million tons and 230 million tons respectively to the global production of soybeans and maize since the mid-1990s. Farmers who use improved seeds and grow GMO crops have seen significant economic benefits amounting to $14 billion in 2010 alone and $78.4. billion from 1996 to 2010.

Additionally, GMOs have contributed to significantly reducing greenhouse gas emissions from commercial agriculture. In 2010 alone, the use of GMOs resulted in the reduction of 19.4 billion kilograms of carbon dioxide from the atmosphere, which is equivalent to the reduction of 8.6 million cars from the road for one year.

In healthcare, pharmaceutical companies have become major stakeholders in the rise of genetic engineering and gene therapy. Companies like BioNTech and Moderna have earned $580 million and $803 million in revenue, respectively, in 2020. BioNTech, for instance, focuses on creating vaccines and immunotherapies, relying on genetic engineering for conditions like COVID-19, cancer, and influenza. Moderna, on the other hand, focuses on mRNA vaccines for infectious diseases, COVID-19, and rare diseases.

B. Risks of Indifference

Despite the groundbreaking potential of genetic engineering, it must be well-regulated, especially in healthcare. Otherwise, serious ethical breaches may result. One high-profile case of unethical use of genetic engineering occurred in Shenzhen, China. Scientist He Jiankui of the Southern University of Science and Technology claimed to be the first to create genetically-engineered babies with CRISPR. His team performed "gene surgery" on embryos created from their parents' sperm and eggs to protect the children from HIV, which causes AIDS, because the children's father is HIV-positive. This individual is under an investigation by a local medical ethics board. Jennifer Doudna, who helped discover CRISPR technology, says the claim reinforces the need to restrict the use of gene-editing technology to certain situations where there is an unmet medical need.

C. Nonpartisan Reasoning

Genetic Engineering is widely controversial in the American political conversation. About half of Americans are concerned about the health effects of foods with genetically modified ingredients. This is understandable—the science is complex, it's costly, and it's unfamiliar. On the other hand, the benefits

for farmers are compelling; the drop in crop loss could increase the food supply as our global population rises.

When it comes to human genome editing, there is a similar divide. Funding and encouraging research into this topic could be the key to curing certain debilitating genetic disorders. However, the critics of this practice are concerned about its value to our society as compared to its affordability and effectiveness. Clinical effectiveness has been a great point of contention as there is no universally accepted patient-centered outcome that can be used to evaluate these therapies. In addition, there is little long-term experience with gene therapy, so the safety risks are largely unknown. Although these therapies can be costly at times, they could potentially offset costs by replacing long-term treatments currently in place for genetic diseases.

IV. Conclusions

The benefits of Genetic Engineering in agriculture are undeniable - we've increased our food supply and made it easier for farmers to increase their crop yield. GMOs will likely continue to be used despite criticisms, due to the benefits for stakeholders.

The emerging field of gene therapy is harder to evaluate as there is little long-term evidence of substantial benefits and a general lack of concrete research done. However, the benefits that have been discovered show promise that perhaps the days of genetic disease are behind us.

V. Acknowledgement

The Institute for Youth in Policy wishes to acknowledge Marielle DeVos, Luke Drago, and other contributors for developing and maintaining the Policy Department within the Institute.

References

[1] Bergman, Mary Todd. "Harvard Researchers Share Views on Future, Ethics of Gene Editing." Harvard Gazette, Harvard Gazette, 28 Oct. 2019, https://news.harvard.edu/gazette/story/2019/01/perspectives-on-gene-editing/.

[2] Brookes, Graham, and Peter Barfoot. "Economic Impact of GM Crops: The Global Income and Production Effects 1996-2012." GM Crops & Food, Taylor & Francis, 2014, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5033197/.

[3] Center for Food Safety and Applied Nutrition. "How Gmo Crops Impact Our World." U.S. Food and Drug Administration, FDA, https://www.fda.gov/food/agricultural-biotechnology/how-gmo-crops-impact-our-world.

[4] Center for Food Safety and Applied Nutrition. "How Gmos Are Regulated." U.S. Food and Drug Administration, FDA, https://www.fda.gov/food/agricultural-biotechnology/how-gmos-are-regulated-food-and-plant-safety-united-states.

[5] Center for Food Safety and Applied Nutrition. "Science and History of Gmos and Other Food Modification Processes." U.S. Food and Drug Administration, FDA, https://www.fda.gov/food/agricultural-biotechnology/science-and-history-gmos-and-other-food-modification-processes.

[6] Center for Health Ethics. "Gene Therapy and Genetic Engineering." Gene Therapy and Genetic Engineering - MU School of Medicine, https://medicine.missouri.edu/centers-institutes-labs/health-ethics/faq/gene-therapy.

[7] Communications, Purdue Agricultural. "Study: Eliminating Gmos Would Take Toll on Environment, Economies." Study: Eliminating GMOs Would Take Toll on Environment, Economies - News - Purdue University, https://www.purdue.edu/newsroom/releases/2016/Q1/study-eliminating-gmos-would-take-toll-on-environment,-economies.html.

[8] Constance, Joseph. "Small Biopharma Gene Therapy Companies Emerging in Gene and Cell Therapy." BioSpace, BioSpace, 3 Sept. 2020,

https://www.biospace.com/article/small-biopharma-companies-emerging-in-gene-and-cell-therapy-/.

[9] Eugene H. Kaji, MD. "Gene and Stem Cell Therapies." JAMA, JAMA Network, 7 Feb. 2001, https://jamanetwork.com/journals/jama/fullarticle/193525.

[10] Funk, Cary. "About Half of U.S. Adults Are Wary of Health Effects of Genetically Modified Foods, but Many Also See Advantages." Pew Research Center, Pew Research Center, 31 July 2020, https://www.pewresearch.org/fact-tank/2020/03/18/about-half-of-u-s-adults-are-wary-of-health-effects-of-genetically-modified-foods-but-many-also-see-advantages/.

[11] "Global Economic and Environmental Benefits of GE Crops Continues to Rise." BIO, https://archive.bio.org/articles/global-economic-and-environmental-benefits-ge-crops-continues-rise.

[12] Hampson, Grace, et al. "Gene Therapy: Evidence, Value and Affordability in the US Health Care System." Journal of Comparative Effectiveness Research, vol. 7, no. 1, 2018, pp. 15–28., https://doi.org/10.2217/cer-2017-0068.

[13] Liu, Shuang. "Legal Reflections on the Case of Genome-Edited Babies - Global Health Research and Policy." BioMed Central, BioMed Central, 14 May 2020, https://ghrp.biomedcentral.com/articles/10.1186/s41256-020-00153-4.

[14] Mayo Clinic. "Gene Therapy." Mayo Clinic, Mayo Foundation for Medical Education and Research, 29 Dec. 2017, https://www.mayoclinic.org/tests-procedures/gene-therapy/about/pac-20384619.

[15] National Human Genome Research Institute. "Genetic Engineering." Genome.gov, https://www.genome.gov/genetics-glossary/Genetic-Engineering.

[16] Ossola, Alexandra. "20 Companies Changing Genetic Medicine." Quartz, Quartz, https://qz.com/2006089/20-companies-changing-genetic-medicine/.

[17] Phillips, Theresa. "Genetically Modified Organisms (GMOs): Transgenic Crops and Recombinant DNA Technology." Nature News, Nature Publishing Group, 2008, https://www.nature.com/scitable/topicpage/genetically-modified-organisms-gmos-transgenic-crops-and-732/.

[18] Plumer, Brad. "How Widespread Are GM Foods?" Vox, Vox, 3 Nov. 2014, https://www.vox.com/2014/11/3/18092748/how-widespread-are-gm-foods.

[19] PRABHUNE, MEENAKSHI. "Full Stack Genome Engineering." Synthego, https://www.synthego.com/blog/alison-van-eenennamm-podcast.

[20] Stein, Rob. "Chinese Scientist Says He's First to Create Genetically Modified Babies Using CRISPR." NPR, NPR, 26 Nov. 2018, https://www.npr.org/sections/health-shots/2018/11/26/670752865/chinese-scientist-says-hes-first-to-genetically-edit-babies.