Ananya Mettu

The Ethics of Genetic Engineering

"...in the early fifties, when the great breakthroughs in science followed one after the other so rapidly, there wasn't time to take stock, to ask the sensible questions…there were all these new possibilities laid before us…by the time people became concerned…it was too late…There was no going back." These words, from the novel *Never Let Me Go* by Kazuo Ishiguro, describe a fictional dystopian world in which humanity takes genetic engineering technologies too far, creating a dark and unethical system that raises human clones for the sole purpose of harvesting their organs upon reaching adulthood. In the novel, humanity saw the immense potential of new technology and chose to adopt a "full steam ahead" approach with little thought to the potential repercussions, until it was simply too late to go back. Through envisioning this frightening future, Ishiguro warns of the necessity of extreme caution with technological advancements, particularly genetic engineering (Ishiguro 257-258). Genetic engineering, "the artificial manipulation, modification, and recombination of DNA or other nucleic acid molecules in order to modify an organism or population of organisms," is a technology currently at the forefront of innovation ("Genetic Engineering" [Britannica]). It has a wide variety of potential applications that fall into two broad categories: somatic genetic engineering and germline genetic engineering. Mary Todd Bergman, correspondent for the Harvard Gazette, explains that somatic genetic engineering is for individuals after they are born, only changes a specific type of cell, and does not affect future generations, whereas germline genetic engineering is for an early-stage embryo, alters all the cells in the embryo, and affects the individual's offspring and future generations (Bergman). Due to this wide range of applications, it becomes crucial to recognize the wide range of ethical perspectives on genetic engineering in an effort to minimize the potential for physical harm and moral infringement caused by this technology. Considering the current knowledge of the benefits and risks of genetic engineering, somatic genetic engineering can be regarded as ethical while germline genetic engineering cannot.

Though genetic engineering is a novel technology that has primarily come to the public eye in the past decade, it originated much earlier. According to a video by Kurzgesagt, a highly reputable science channel founded by author Philipp Dettmer that seeks to present scientific topics in the form of engaging videos, humanity has attempted to edit DNA ever since discovering its existence and function ("Genetic Engineering Will Change Everything Forever"). Nevertheless, the first recognized form of genetic engineering was in the 1970s with Stanley Cohen and Herbert Boyer's research into genetic engineering in bacteria (Cohen et al.). From here, the technology evolved. In recent years, genetic engineering has advanced remarkably quickly, particularly with the invention of CRISPR, a method of genetic engineering discovered in 2012 by scientists Jennifer Doudna, Emmanuelle Charpentier, and Feng Zhang. As Amy Maxmen, Harvard graduate and award-winning science journalist, describes in an article published in the magazine WIRED, this method programs "guide" RNA molecules to direct a nuclease, a type of enzyme, to cleave DNA at a specific spot (Maxmen). Additionally, according to a video from TED-Ed created by biology professor Andrea M. Henle, PhD, "template" DNA directs the cell to repair this broken DNA strand in a specific way, a process called "homology directed repair" that can repair genes or even create new ones ("How CRISPR Lets You Edit DNA"). It would not be an overstatement to say that CRISPR has been revolutionary for the world of genetic engineering. It is immeasurably more powerful, effective, and precise than its predecessors, as it can edit a much wider range of DNA sequences and is applicable to any type of cell. Additionally, it is much easier and cheaper than genetic engineering methods of the past, making genetic engineering technology more accessible than ever before ("Genetic Engineering Will Change Everything Forever"). With these tremendous advancements, however, discussion of the ethics of this technology has risen to the forefront of the scientific community, more pressing than ever.

Genetic engineering has a wide variety of potential applications, both tested and theoretical. Its most notable applications include gene therapy in adults to correct disease-causing genetic mutations, early-stage embryo editing to remove inherited genetic diseases or conditions from the family lineage altogether, and "designer babies" with enhanced genes that code for desirable traits ("Genetic Engineering" [Britannica]; "Genetic Engineering Will Change Everything Forever"). Despite its highly appealing benefits, however, genetic engineering carries high levels of risk. Current methods of genetic engineering are far from perfect, and the risks include "off-target impacts," which are unintended effects on other genes that may cause new genetic diseases or conditions, and mosaicism, which is a phenomenon where not all copies of a gene receive intended edits (Bergman). Additionally, as a result of its novelty, genetic engineering simply carries inherent risk. Dr. Hank Greely, professor of law and medicine at Stanford and leading expert on "the ethical, legal, and social implications of new biomedical technologies," states that there must be further research into genetic engineering technologies before they can be deemed safe, as scientists do not yet know everything about their potential risks (Greely).

Despite this, in 2018, Chinese scientist Dr. He Jiankui used germline genetic engineering to create the first genetically modified babies with CRISPR. He was attempting to edit their genes to lower their risk of contracting HIV. Though the babies were born healthy, he faced a near-unanimous backlash from the scientific community. Greely, for one, calls Dr. He's actions "grossly reckless, irresponsible, immoral, and illegal" considering the current amount of research on the topic and the lack of knowledge about its potential risks (Greely). Indeed, it is for these reasons that germline genetic engineering is currently banned in the United States and many other countries (Belluck). However, regulation as a whole is still trying to keep up with all the recent advancements in technology. As Bergman writes, "Progress in this field has been so rapid that the dialogue around potential ethical, societal, and safety issues is scrambling to catch up" (Bergman). Though some of the applications of genetic engineering, particularly germline genetic engineering applications, remain theoretical at the moment due to technological limitations, it remains crucial to consider ethics and regulation. It is likely that technology will continue to progress at an unprecedented rate, and these theoretical applications may not be as far off as they seem.

Considering the current knowledge on genetic engineering, somatic genetic engineering can be considered ethical. It is widely considered to be safer than germline genetic engineering. It only affects one type of cell, and the changes are not passed onto future generations, meaning that if the procedure were to go wrong, it would not affect the individual's offspring (Groch; Bergman). The principal application of somatic genetic engineering is somatic gene therapy, which seeks to correct disease-causing genetic mutations by replacing these genes with unmutated versions. As Pam Belluck, Pulitzer Prize-winning journalist, writes for The New York Times, somatic gene therapy can cure diseases caused by a specific known mutation or set of mutations. This includes Huntington's disease, cancers caused by BRCA genes, Tay-Sachs disease, cystic fibrosis, sickle cell anemia, and, in some cases, early-onset Alzheimer's (Belluck). Gene therapy has tremendous potential for application, too; according to Dave Bond in his book

Genetic Engineering, around 1 to 2 out of every 100 babies are born with a genetic disorder (Bond 27). Considering its vast potential to alleviate intense suffering and its relatively low level of risk, somatic genetic engineering should be regarded as ethical.

Though any form of genetic engineering carries a certain degree of inherent risk, the benefits for somatic genetic engineering outweigh the risks. Somatic gene therapy has immense potential to change an individual's life for the better, meaning that it would be unethical to withhold this treatment, according to Dr. Lovell-Badge, professor of genetics and embryology at the Francis Crick Institute in London (Belluck). Similarly, Joseph et al. concluded in a study on the ethical perspectives of genetic engineering that, "Any [moral] issues that arise are outweighed by the medical benefit of disease eradication that is promised by genome editing" (Joseph et al.). Moreover, somatic genetic engineering is a relatively low-risk form of genetic engineering as all changes stay with the individual, and as scientists proceed to conduct research on it, they will minimize the level of risk involved even further.

Conversely, however, germline genetic engineering cannot currently be considered ethical. The stakes for germline genetic engineering are high, as future generations inherit all gene edits. Any mistakes in the procedure would not only affect the individual, but also all of their offspring. There are two primary uses for germline genetic engineering: germline gene therapy and "designer babies." Germline gene therapy is similar in function to somatic gene therapy; however, the crucial difference is that germline gene therapy is conducted in still-developing embryos (Bond). The main benefit of using germline gene therapy over somatic gene therapy is its potential to eradicate a genetic disease or condition from an entire future family lineage, as all changes affect the individual's offspring. The other principal usage for germline genetic engineering is "designer babies," a largely theoretical concept in which genetic engineering is used for non-medical purposes to enhance the genes of a baby. Many suspect that, as technology advances, humanity will be able to "design" traits in babies such as eye color, height, and even, theoretically, intangible traits such as intelligence, though whether this is possible is still under discussion (Belluck). Considering current knowledge, germline genetic engineering should be regarded as unethical. It is unconsented, as the affected individual would still be an embryo at the time they receive these procedures. This is inherently unethical, as a choice that they did not make would have the potential to determine their entire bodies and lives. Moreover, germline genetic engineering is an incredibly "slippery slope," according to Kurzgesagt. The line between using genetic engineering for medical purposes and enhancement purposes can be easily blurred ("Genetic Engineering Will Change Everything Forever"). Thus, if germline genetic engineering were permitted in any form, it would be difficult to enforce restrictions on it as it could easily be used in other contexts. Overall, it is clear that germline genetic engineering is highly unethical due to the lack of consent and the level of risk involved.

Although some may argue there is an ethical obligation to permit germline genetic engineering, particularly for germline gene therapy, in order to alleviate suffering, this does not take into account the full picture. Germline genetic engineering is simply too risky to be allowed. An alternative would be for individuals with genetic diseases to seek somatic gene therapy once they are born and grow older. This would be a much lower-risk and more ethical way to alleviate the suffering caused by a genetic disorder, and they would be able to consent to this procedure. Similarly, in the context of "designer babies," the risks greatly outweigh the benefits. Although there is an appeal to being able to select traits and enhance genes in a baby, this would come with tremendous socioeconomic costs. According to MIT-educated journalist Erik Sherman, writing for Forbes, parents "would want to ensure their children had the best of advantages through genetic improvement," but only the wealthiest parents would have access to this technology, meaning that the most well-off in society would become even more well-off. Their enhanced abilities would allow them to become even more successful, intensifying income inequality to unprecedented levels (Sherman). Additionally, allowing "designer babies" would be heavily editing the gene pool of humanity. According to Sherryn Groch, journalist at The Sydney Morning Herald, diversity is crucial to humanity's survival as a species, so much so that humans are vulnerable without it (Groch). Although any type of genetic engineering would edit the gene pool of humanity, this concern is much more relevant in the case of "designer babies" as they would likely have heavy genetic engineering (Belluck). To create "designer babies," scientists would need to edit countless genes, as a wide variety of genes control traits like height, eye color, and especially more intangible traits like intelligence. Thus, the genetic engineering involved to create "designer babies" would be extremely heavy, meaning that editing the gene pool of humanity is of utmost concern.

At the moment, somatic genetic engineering should be considered ethical as its benefits outweigh its relatively low level of risk, but germline genetic engineering should not, as it is simply too high-risk. The clear solution is to permit only somatic genetic engineering and proceed with caution. Governments should implement carefully considered regulation on somatic genetic engineering by consulting with scientists and experts who can determine what is safe considering the current amount of research. It must be noted that this solution is limited by the lack of research on the subject. In the future, there will certainly be much more information on the potential uses and risks of genetic engineering, as well as methods for minimizing its risk and regulating its use. For now, however, it is essential that governments approach somatic genetic engineering with extreme caution. *Never Let Me Go* warns of the grim dangers of recklessness when it comes to technological advancements that have the power to alter the future of the human species. These technological advancements that were once relegated to science fiction are rapidly becoming reality, making it more essential than ever to consider their ethical implications.

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