Natalie Holmer Mehul Joshi
North Creek High School 2019

Works Cited

"What Are the Ethical Concerns of Genome Editing? | NHGRI." *What Are the Ethical Concerns of Genome Editing? | NHGRI*, 2017, www.genome.gov/about-genomics/policy-issues/Genome-Editing/ethical-concerns

"Researchers Use Gene Editing with CRISPR to Treat Lethal Lung Diseases before Birth." *ScienceDaily*, ScienceDaily, 17 Apr. 2019, www.sciencedaily.com/releases/2019/04/190417171025.htm

Ormond, Kelly E et al. "Human Germline Genome Editing." *American journal of human genetics* vol. 101,2 (2017) https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5544380/

Liang, Puping, et al. "CRISPR/Cas9-Mediated Gene Editing in Human Tripronuclear Zygotes." *SpringerLink*, Higher Education Press, 18 Apr. 2015, link.springer.com/article/10.1007/s13238-015-0153-5#citeas

Shwartz, Mark, et al. "CRISPR Is a Gene-Editing Tool That's Revolutionary, Though Not without Risk." *Stanford Medicine*, stanmed.stanford.edu/2018winter/CRISPR-for-gene-editing-is-revolutionary-but-it-comes-with-risks.html

Howard, Heidi C et al. "One small edit for humans, one giant edit for humankind? Points and questions to consider for a responsible way forward for gene editing in humans." *European journal of human genetics* : EJHG vol. 26,1 (2018): https://www.nature.com/articles/s41431-017-0024-z

Rossant, Janet. "Gene Editing in Human Development: Ethical Concerns and Practical Applications." *Development*, Oxford University Press for The Company of Biologists Limited, 15 Aug. 2018, dev.biologists.org/content/145/16/dev150888.long

Ma, Hong, et al. "Correction of a Pathogenic Gene Mutation in Human Embryos." *Nature News*, Nature Publishing Group, 2 Aug. 2017, www.nature.com/articles/nature23305?_ga=2.130646991.1501829565.1537833600-1889761642.1537833600.

Feng Zhang, Yan Wen, Xiong Guo, CRISPR/Cas9 for genome editing: progress, implications and challenges, *Human Molecular Genetics*, Volume 23, Issue R1, 15 September 2014, Pages R40–R46, https://doi.org/10.1093/hmg/ddu125

"A 2017 Horizon Scan of Emerging Issues for Global Conservation and Biological Diversity." *Trends in Ecology & Evolution*, Elsevier Current Trends, 10 Dec. 2016, www.sciencedirect.com/science/article/pii/S016953471630218X.

Should Gene Editing be used in Human Embryos?

Background

At the onset of the 21st century, the technology boom spurred the rise of biohacking, germline gene editing, and embryonic editing. Through this process society developed techniques to cure diseases, alter genetic makeup, and change the future. Humankind, now possess powers that were unimaginable in previous decades, however many bioethicists raise concerns that changing the genetic composition of individuals can lead to adverse consequences. On one side, people fear that a dystopian future will rise up with only super babies for the wealthy, creating a vast gap between the classes. On the other side, advocates for gene editing maintain that biohacking will spur a new age where all people are granted the pursuit of happiness with freedom from diseases. This article takes a scientific approach by weighing the risks with the benefits of gene editing technologies.

One of the prominent methods of editing genetic makeup is CRISPR-Cas9. The CRISPR-Cas9 technology allows researchers to manipulate specific palindromic sequences of specific genes by cleaving DNA and performing the requisite insertions, deletions, or substitutions of base pairs at the target site. CRISPR was first discovered in bacteria as a protective measure against invading foreign virus and phage DNA. However, today it has been

adapted for major biomedical research. It is relatively cheap and easy to use in terms of functionality. It has been demonstrated to cure mice of diseases and has immense potential to treat humans. An analogous way of thinking about it, is that CRISPR is like a search and replace algorithm that finds specific sequences of DNA and replaces it with a new template that is provided. In 2012, scientists hacked CRISPR to not only attack viral DNA but any host organism. It has pioneered a new wave of editing anything and everything but it raises the concern that the intended changes are not the only changes expressed.

The following article will explore two opposing viewpoints and then come to a single conclusion. The first viewpoint resonates with the idea that biohacking is a tool that humankind must take advantage of to create a healthier society. The second viewpoint encompasses the idea that gene editing will lead to a dystopian society. It is a rather recent debate that has sparked up over night in the 2012's. The media holds the stringent belief that germline editing will cause a land where genetic makeup will be another dividing factor among individuals as some individuals would gain an unfair advantage by manipulating their genes.

Viewpoint 1: Support Gene Editing in Embryonic Stages

Despite the controversy behind it, many believe that gene editing in the embryonic stages of development presents the scientific community with a critical tool in helping to create a more healthy society. Through the use of developing CRISPR-Cas9 gene editing technology, it is believed that important research can be done to not only further the understanding of embryonic growth and development, but also correct inherited genetic disorders, and help families with reproductive issues.

Although genome editing is a relatively new resource for science, its application to embryos has the potential to benefit science in a variety of ways. Janet Rossant tells of how CRISPR can quite simply be used in embryos or human cells as a basic research tool to help further our understanding of normal human development (Rossant 2018). Currently, CRISPR editing technology has been used in many different species such as mice and humans, and according to research done by Kelley Ormond and her team, has been successful (Ormond et. al 2017). This has in turn "already accelerat[ed] the pace of many areas of biology as researchers use genome-editing methods to more quickly and cheaply study the function of genes in model organisms" (Ormond et. al 2017). When used as a research tool in embryos, CRISPR technology presents scientists with a ready method to expand their knowledge of gene expression and inheritance, which in turn helps understand the importance of embryonic development.

Genome editing can also pose as a benefit to embryos by using CRISPR technology to target and replace mutated genes that would otherwise manifest into potentially fatal conditions. When used in embryos purposefully with the intent to correct disease, gene editing can be viewed as a tool to better maintain the health of future generations. Research has shown that CRISPR is exceptionally efficient at targeting genes in human zygotes, and that mutant alleles can be almost entirely repaired through gene editing technology (Ma et. al 2017). The successful application of this technology suggests promising results as the technology expands. Further research related to the utilization of gene editing in embryos has been presented to the scientific community already, and has helped establish guidelines so that certain "oversight mechanisms" would be in place, keeping research regulated (Rossant 2018). The "National Academies of Sciences, Engineering, and Medicine" published these guidelines in their piece called *Human*

Genome Editing: Science, Ethics, and Governance, which provides an overview of all kinds of gene editing (ie: somatic vs embryonic), which compartmentalizes the legality of different levels of experimentation in different countries into one publication. This has allowed science to have a basis for their advancements to follow in accordance with the progress of other countries. With these in place, ethical regulation is possible.

Finally, gene editing in embryos can be beneficial to helping families reproduce successfully. Technologies are being evaluated to provide alternative methods that meet the needs of different families that by already existing reproductive methods do not (NIH 2017), and as CRISPR technology expands, it is hypothesized that "genome-editing methods could be incorporated into human-assisted reproduction procedures" (Ormond et. al 2017). These situations are already being applied to families where parents are homozygous for a disease-causing allele, or they object to some elements of already existing methods (NIH 2017). By using genome-editing technology to assist with reproduction, parents can find ways to begin families in through effective new technology.

In summary, genome editing in the early stages of development can help the scientific community understand critical stages of human development, save developing embryos from potentially fatal mutations, and serve as resource for parents to utilize when trying to start a family.

Viewpoint 2: Oppose Gene Editing in Embryonic Stages

In addition to the religious objections, many have to experimenting with and utilizing gene editing on embryos, many find that there are substantial scientific-based ethical pieces that

justify the opposition of this process. With this in mind, it can be argued that gene editing in embryonic stages should not be supported, as it raises concerns regarding the concept of eugenics (improving the human population through controlled breeding), it utilizes underdeveloped technology that is still new to the medical community, and it interrupts the natural process by which population diversity occurs.

The involvement of science in the human reproductive process brings the concerns of normalizing eugenics in society. The scientific community risks overstepping into the sensitive idea of enhancing embryos for desirable traits, as opposed to just fixing harmful mutations. In an attempt to prevent this, The National Academy of Sciences (NAS) and National Academy of Medicine (NAM) proposed a set of praised guidelines suggesting the involvement of gene editing in embryos. Of these principles, it was repeatedly recommended to discourage the "[e]xtension of human gene editing… beyond the treatment or prevention of serious disease, to genetic enhancement strategies" (Rossant 2018). Further, some believe that the research and study of human embryos outside the body-- known as *in vitro*-- "will inevitably lead to the technology being used in the clinic" (Howard et. al 2018), which will snowball into the idea of creating "designer babies" (Rossant 2018). It has been proposed that "concerns about enhancement should be managed through policy and regulation" (NIH 2017), however these regulations are inconsistent and have yet to be established as "laws" and not "guidelines."

As gene editing technology expands, the rules and regulations behind it must change as well. Currently, "[t]here are both national and international policies that regulate embryo research and interventions in early human development" (Ormond et. al 2017). This causes problems when attempting to establish a baseline for all gene editing to follow so that the

scientific community can work collaboratively. Biologists today are constantly "impacted by the rapid advances in the technology of CRISPR/Cas9 gene editing" (Rossant 2018). The policies that regulate this research present science with some challenges, as "[d]ifferences in these policies include the very definition of what constitutes a human embryo reproductive cell" (Ormond et al. 2017). Inconsistencies seen throughout gene editing technology brings challenges when attempting to gather research and uniformly regulate embryonic testing.

With the influx of gene editing technologies many fear that species will become more susceptible to death and plague. With shifts in the genome the overall diversity of a population decreases making disease spread easily as most individuals have the same genetic makeup. One researcher alludes to this fact in his dissertation, "[gene editing causes] unwanted negative effects on biological diversity and the environment" (Sutherland 2017). From a reasoning point of view, this makes sense as with a greater genetic variation within a population the overall resistance of the population would be increased as the strength is not in one individual but in the composite body as a whole. From a different perspective, researcher Oz Barazani points to the fact that "crops with higher levels of genetic diversity tend to sustain their species for thousands of years compared with crops that have lesser biodiversity". Therefore, genome editing in the embryonic stage proves to be a terrible idea because the edited genes would be passed down through reproductive cells and the overall diversity of the population would decrease over time.

Conclusively, genome editing for somatic cells in the embryonic stages of development should not be supported, as it opens the gates to the concept of eugenics, it is currently inconsistently regulated, and it eliminated the natural diversity caused by human evolution.

Personal Stance: Natalie

Gene editing in embryos has at first look many attractive benefits that cause an individual to be drawn to its utilization. “Viewpoint 1: Support Gene Editing in Embryonic Stages” presents the ideas of unlocking more understanding about our early development, eliminating certain debilitating diseases and conditions before birth, and helping couples with fertility issues have families; all of which are absolutely astounding revolutions that technology of today has reached. However, as mentioned in “Viewpoint 2: Oppose Gene Editing in Embryonic Stages” the almost unlimited potential of this technology leads one to think more of the dystopian consequences of leaving science with the potential to legally create people with any traits they desire. Germline and embryonic editing leaves the fate of society’s diversity in the hands of those that choose to use this technology. Further, in the article “Human Germline Genome Editing” by Kelly E. Ormond et. al, it is suggested that because gene editing is such a recent revelation in the scientific world, “[r]igorous basic scientific research covering multiple generations should be conducted to determine the potential medical and scientific issues before any consideration of translational research for human germline genome editing.” It seems that this technology is too new to even begin to think about using, and therefore more research must be done to ensure the technology is developed in an ethical way to determine if transgenerational germline editing should even be pursued as an appropriate method of genetic experimentation. The controversy behind the ethical conflicts of gene editing in embryos leads one to investigate the less transgenerational applications of gene editing, where editing will not affect future generations. With this as an alternative to embryonic gene editing, medical solutions can still be sought to fix debilitating conditions after birth, without interfering with the development of humans.

Personal Stance: Mehul

Embryonic gene editing is no doubt a controversial topic and prior to making a conclusive decision it is important to weigh the risks with the benefits. In viewpoint 1 our authors synthesize the argument that embryonic editing is a beneficial tactic that must be utilized in society. It has the potential to treat disease, change inherited sequences that are not favorable to genetic evolution, and help families that have reproductive issues. Although on paper these things seem like a favorable benefit to society, after properly addressing the risks with the benefits it becomes clear that gene editing is not as beneficial to the environment as the advocates hope it to be. This is in part due to the argument synthesized in viewpoint 2 as with embryonic gene editing the genetic variation within a population decreases for a particular trait and the treatment is still relatively new. Therefore, before we as a society attempt to expand the rings of gene editing we should take caution as the ramifications of the treatment are still unknown. Furthermore, embryonic gene editing may cause unintended consequences that mess up the evolution cycle as this would be the first time that humankind has the power to change the course of genetics. Before we as a society dive into this field we must understand that all good things must come to an end and with this powerful technology there will eventually come a place where if everybody is special then nobody is. In other words, with this technology the uniqueness factor that distinguishes people from one another would be stripped from the rungs of time.