Name: Huong Phan
Prompt: Using what you have learned from Earlham's *Principles and Practices,* the book "The End of Sex" and our various readings and discussions throughout the semester, discuss the following question: Should humanity embrace the possibilities offered by genome editing to improve our species?

The advent of human genome editing tool CRISPR-Cas9 has taken the scientific world by storm in the last few years by its potentially tremendous power of modifying our bodies to be disease-free, as well as more physically attractive and intellectually competent. Meanwhile, modern reproductive tool IVF and DNA sequencing and analyzing tool Easy PGD allow the development of various embryos outside a woman's womb and the selection of embryos with most favorable traits to be implanted. Together, CRISPR-Cas9, IVF and Easy PGD can help us not only eradicate diseases and improve physical and mental abilities in our children, but also pass down the traits generations after generations (Baltimore, *et al*. 2015). Thus, they can ultimately eliminate a significant number of genetic diseases and retain only the fittest traits in our society. As promising as the combination of these powerful technologies might look on paper, it was met with hesitance and caution from not only the public but also scientific community, due to its similarity to the widely reviled eugenics movement originated in the late 19th century and various ethical concerns. With the above context in mind, this paper will examine the pros and cons of human genome editing within medical, socioeconomic and ethical contexts and come to a tentative conclusion to how we should utilize these technologies optimally while minimizing the concerns they may cause.

The idea of modifying our DNA to remove disease-inducing genes and enhance our bodies takes root in our persistent desire for preservation and propagation of more

physically and mentally favorable traits through many generations. And eugenics, or "good births" (Greely 253), was a prominent example of that desire, facilitated by our past extremely strong association of genetics with social behaviors. Back in the late 19th century, Darwin and Mendel's theories of natural selection and genetic inheritance back then led us to believe only children that were born from healthy and talented parents are socially fit, while others with physically and mentally disabled parents could never escape from their fate of inheriting their parents' defective or diseased traits. Eugenics was divided into positive eugenics and negative eugenics (Greely 253). Positive eugenicists aimed to promote frequent reproduction between parents with favorable traits, usually those higher in the social hierarchy (Greely 253), while negative eugenicists condemned socially unfavorable traits such as "criminal, diseased, defective" (Greely 254). This negative side of eugenics was universally reviled as it rode on inadequate medical understanding of genetics and led to forced legalization of sterilization, causing ethical breach and exacerbating social injustice.

Negative eugenicists thought that contagious diseases are passed down even though bacteriologists proposed otherwise (Pernick 1997). They also had poor understanding of the extent that our genes are influenced by parents' genes, (Pernick 1997), as scientists later discovered that environmental factor may even have a greater influence on our DNA than inheritance (Chakravarti 2015). The legalization of eugenic sterilization was also a controversial issue for its unethical practice as it was practiced on thousands of adolescents without consent or uninformed consent (*Fit to Breed: Eugenics in Indiana*), violating their human rights. Moreover, university graduates from Indiana Committee on Mental Defectives

conducted a biased study to determine the population selected from Indiana's undereducated and destitute neighborhoods to undergo forced sterilization (Lantzer 2007). The significant social and literacy gap between the graduates and the residents most probably misled the elites to believe the people were genetically feebleminded. The white Americans also supported the eugenics movement, fearing that immigrants would endanger the American familial and cultural bonds (Cohen 4). The court ruling of Buck v. Bell is another example of people's discriminative reactions as a result of eugenics. Carrie Buck, a powerless woman under extremely unfortunate social circumstances for giving birth to a child out of wedlock and being born in a poor family with her mother being labeled as "feebleminded", was then labeled as feeble-minded herself and forced to be sterilized, despite demonstrating "perfectly normal intelligence" in her school records (Cohen 7). Forced sterilization law, in the hands of Nazi Germany, became a cruel tool to express extreme, deep-rooted racism by forcibly sterilizing not only the feeble-minded, alcoholic and epileptic but also the Jews, a strongly discriminated against race (Cohen 302). Thus, eugenics revealed the inherent racial and social discriminations in the society and even aggravated them. Overall, eugenics was an unfortunate cause with initial benevolent intention but terrible and even detrimental implications. Despite its negative reputation, the eugenics movement's remnants can still be felt today through our unchanging desire to select only certain favorable traits to remain in our population and eliminate those that make us physically or mentally unfit. The idea of modern human genome editing is the most direct manifestation of this desire, which potentially allows us to create more disease-resistant and improved versions of ourselves.

In the 21st century, scientists have gained a better understanding of what our genes encode and DNA mutated variations that cause various genetic diseases. They also have discovered a few technological tools to edit the human DNA in order to cure genetic diseases such as cystic fibrosis and improve our immune system to fight against fatal diseases such as HIV-AIDS (Editing humanity; Genetic Engineering Will Change Everything Forever – CRISPR). The most brilliant tool of all is called CRISPR-Cas9, which has the ability to cut the DNA sequence at precise intervals (Doudna; Shannon). Originally discovered as a bacterial defense mechanism against virus, Clustered Regularly Interspaced Short Palindromic Repeats or CRISPR, accompanied with Cas9 protein, has been exploited as a human genome editing tool to potentially eliminate any genetic diseases in humans as well as enhance our physical traits and intellectual abilities (Sternberg and Doudna 2015). This gene editing system called CRISPR-Cas9 consists of CRISPR, which contains repeated DNA sequences with “unique spacers sequences” in between (Sternberg and Doudna 2015), and Cas9 protein, which makes a guide RNA that is able to search, cut targeted DNA parts and paste new ones in (Sternberg and Doudna 2015; Editing humanity) for the DNA to produce properly functioning proteins for our bodies (Shannon), thus removing inherited genetic diseases or strengthening our immune system. This provides a much more effective treatment than drugs, which only provides a mitigating effect for our bodies instead of addressing the genetic cause of the diseases (Corn). In the lab, CRISPR-Cas9 was proven to be able to correct the mutated DNAs that cause Sickle Cell disease (Corn) and cystic fibrosis (Shannon). It can also help us fight against cancer by modifying immune T-cells so that they can produce PD-1 protein to “develop an immune response against cancer attacks” (Cyranoski 2016). Moreover, CRISPR-Cas9 can also alter the animal cells

to remove contagious diseases or to preserve those that are valuable to humans. With this powerful technique, mosquitoes can be engineered to be malaria-resistant so that they will not transmit the disease to humans, as well as bees, an essential pollinator of most of our food sources, can be altered towards adopting cleaner hygienic behaviors for better chances of survival (Reardon 2016; Kahn). All the above examples are evidence to the robustness of this mechanism, which possesses the ability to completely transform the traditional medicinal approach of lessening human's sufferings and enhancing our physical capacities.

Furthermore, modern reproductive techniques like IVF and Easy PGD allow parents to manually create multiple embryos at the same time in the lab and select their favorite embryo based on the results of genetic testing. In Vitro Fertilization, or IVF, is the process of artificial fertilization of eggs by sperms outside a woman's womb. Usually used by infertile couples who wish to conceive, it is a tedious and even possibly dangerous process to women (Greely 9). It requires them to undergo through a series of hormonal injections to control the ovulation and maturation of the eggs before the eggs can be fertilized through combination with sperm in a petri dish and developed into embryos (Greely 53 - 54). The embryos are then selected through a process called Preimplantation Genetic Diagnosis, or PGD. It is a technique that retrieves and sequences the DNA of early embryos' cells, then analyzes how healthy the embryos are and decides which embryo is worth being developed to become a baby (Greely 2). Though it may currently be an "expensive, unpleasant, and even dangerous" procedure due to its association with IVF, with technological advancements, PGD will eventually evolve to become Easy PGD, which costs much less and gives very precise information about "disease risks,

physical characteristics, behaviors and other traits of the child that the embryo would become" (Greely 2 - 3). Easy PGD can be achieved through the development of induced Pluripotent Stem Cells (iPSCs), allowing the generation of eggs from skin cells and thus “avoid (avoiding) most of the cost, almost all the discomfort, and all of the risk of IVF” (Greely 12). From the results given by Easy PGD, parents can make an informed decision to choose the embryo they think is the fittest for implantation. Better yet, with CRISPR-Cas9’s existence, parents can not only choose the embryos with the most advantageous genetic traits but also may be able to edit the embryos’ DNA.

The combination of modern cutting-edge gene editing and reproductive technologies, with our desire to select more favorable traits and less socially unfit traits can revolutionize the future of human reproduction through germline editing. It involves editing the DNA of human embryos to get rid of inherited genetic diseases such as cystic fibrosis or insert genes that gives rise to favorable traits from big beautiful eyes to formidable intelligence, then transfer the edited embryos to be developed into babies. As it allows us to modify “the genetic makeup of every differentiated cell in an organism”, it ensures the edited traits are “passed on to the progeny” (Baltimore, *et al.* 2015). Thus, not only can CRISPR-Cas9 alter the individual somatic cell in human adults and animals, it can also alter the genes of early embryos, which means the edited genes will be inherited by all successive generations (Baltimore *et al.* 2015). Though CRISPR-Cas9 can currently edit embryos with only very limited success (RadioLab: CRISPR; Editing humanity), it is highly likely to eventually improve and successfully engineer germline cells to consist of no inherited diseases and probably

enhanced physical and mental traits, potentially changing our future population forever.

Despite CRISPR-Cas9's capacity to develop our future population's resistance against almost all diseases in the world and increase our species' fitness, scientists are still cautious about its applications due to its medical uncertainties, potential socioeconomic implications and ethical issues. Medically, CRISPR-Cas9 is not yet a foolproof mechanism, with its off-target effects leading to possible damage of healthy cells and cell mosaicism (Lanphier *et al.* 2015; Greely 182). Modifying germline cells can also incur unintended consequences for future generations (Baltimore *et al.* 2015; Lanphier *et al.* 2015) as a result of scientists' "insufficient knowledge" on epigenetics and any genetic associations between different diseases in the same patient (Venter; Baltimore *et al.* 2015; Lanphier *et al.* 2015). However, it is only a matter of time before these medical concerns disappear thanks to greater demand for better medical treatment approaches and rapid pace of technological advancement. The more severe repercussions actually lie in the technology's socioeconomic perils and ethical concerns as its power to weed out any genetic diseases can lead to slippery slope towards human enhancement and creation of designer babies (Baltimore *et al.* 2015; Venter; Genetic Engineering Will Change Everything Forever - CRISPR).

People who support genome editing in human enhancement, called transhumanists, argue that the technology will more likely to alleviate inequality in the world as once the children of poorer families are enhanced, they will have the opportunity to "be brought up to everyone" (Masci). However, I personally believe human genome

editing technology may actually exacerbate the existing huge inequality between the rich and the poor instead and cause discrimination to deepen even further in our society. With greater financial ability and better knowledge, the wealthier class is more likely to gain access to the sophisticated technology than the lower-income class and to modify their embryos to have their chosen favorable physical and intellectual traits. This can worsen social immobility as the rich would have an even greater advantage to gain higher-paying jobs due to their enhanced intelligence, while non-modified lower-income class would have a lower chance of breaking out of their poverty cycle. In addition, the implementation of the technology may cause social prejudice against the non-modified people that would be diagnosed with possibilities of genetic conditions even before their births. Their potential is likely to be discouraged and hampered, since others may see them as genetically inadequate to achieve their aspirations. This is evident in the movie “Gattaca”, which portrayed how Vincent’s parents discouraged him from reaching his dreams and how he was rejected by employers because he was a non-modified, or “invalid” person. The naturally conceived people in the movie also resigned to their fate as lowly cleaners who should not dream of anything out of their capacity. On the other hand, an engineered child, if they learn about his or her parents’ choice to enhance them, may face unnecessary pressure to grow up to be as athletic or as smart as they expected. Parents would probably feel more disappointed if their modified child cannot meet their expectation than they would do for a non-modified child, and this may hurt the relationship between parents and child. Moreover, the application of human genome editing for enhancement may also lead to implications that the lives of non-modified people may not be as worthy as those of enhanced people (Greely 246), that our value as humans are only defined by the strength of our genes and the

path towards living a life someone else expected us to, instead of our social perspectives and endeavors to overcome challenges and live the way we find meaningful for ourselves. There is also a possibility that human gene editing technology will one day be able to cure virtually all diseases in the world. Hence, with a much lower mortality rate in the future, world population may keep increasing exponentially and deplete all of Earth's resources.

Gene editing technology for human enhancement also raises serious ethical concerns, as it involves changing a supposedly inherent part of ourselves and going against the forces of nature that clashes with religious beliefs such as those of Catholics and Islam (Masci; Greely 274). Moreover, as human embryo modification is unable to seek the embryo's consent, it also raises the question whether it is ethical for parents to determine their children's destiny by their own before their children were even born, limiting the choices for their children's future (Greely 229). I personally think it is not ethical for parents to do that. I believe all humans, are entitled to their own major life decisions and embryos deserve to be treated like humans though they are not technically humans yet at that point. Parents only have the right and responsibility to guide their children towards what their children choose to accomplish. However, in my opinion, the most important ethical question is whether it is acceptable to satisfy individuals' desire for enhancement in the expense of the whole population's detriments. As discussed above, though non-therapeutic enhancement can bring a lot of benefits to individuals such as better appearances and intelligence, it can cause many severe problems to the rest of our society. While I do believe that we, as individuals, all deserve to have the freedom to choose to improve themselves to become "much smarter, stronger and healthier" (Masci), I

think it would be unethical to prioritize individuals' benefits over collective benefits by allowing the application of genome editing technology in altering one's physique and intellectual ability.

Taking all of its promises and perils into account, I think we should embrace genetic engineering technology for therapeutic treatment of diseases only when it reaches a good degree of efficacy, while we should never embrace it for non-therapeutic enhancements, for its costs to society in the long term are disproportionately high compared to its benefits. Meanwhile, because of its potential tremendous health benefits, there will probably be enormous demand for this technology's clinical applications, leading to greater demand for research to improve its safety and efficacy. Governments will respond to the enormous demand for genome editing by funding the research efforts, and will most likely be unable to restrict the use of genetic engineering technology, for that will violate one's freedom of choice. Thus, despite its various concerns and possible implications, genome editing technology is very likely to keep improving and eventually be widely adopted in the future. Because of its inevitability, I think that it is now not a problem of whether we should embrace the technology, but how we should embrace it so that its social costs can be reduced. Since human genome editing technology can cause a major social revolution, we should be willing to come to a consensus as a society about the extent of application of this inevitable human genome editing technology. And if one day technological advancements really make human enhancement possible, we should have then evolved to be a community where we have respect for all individuals and see everybody as our equal, regardless of whether one is genetically modified or not.

Bibliography

Baltimore, David, et al. “A prudent path forward for genomic engineering and germline gene modification.” *Science*, vol. 348, no. 6230, 3 Apr. 2015, pp. 36-38.

Chakravarti, A. “Perspectives on Human Variation through the Lens of Diversity and Race.” *Cold Spring Harb Perspective Biol,* 2015;7:a023358.

Cohen, Adam. *Imbeciles: The Supreme Court, American Eugenics, and the Sterilization of Carrie Buck*. Penguin Press HC, 2016.

Corn, Jacob. “The end of genetic disease | Jacob Corn | TEDxBerkeley.” *YouTube*, uploaded by TEDx Berkeley, 18 Feb. 2016, https://www.youtube.com/watch?v=grf3RxryRto.

Cyranoski, David. "Chinese scientists to pioneer first human CRISPR trial." *Nature*, vol. 535, 28 Jul. 2016, pp. 476-477.

Doudna, Jennifer. “How CRISPR lets us edit our DNA | Jennifer Doudna.” *YouTube*, uploaded by TED, 12 Nov. 2015, www.youtube.com/watch?v=TdBAHexVYzc.

“Editing humanity.” *The Economist,* 22 Aug. 2015, www.economist.com/news/leaders/21661651-new-technique-manipulating-genes-holds-great-promisebut-rules-are-needed-govern-its. Accessed 30 Nov. 2016.

Fit to Breed: Eugenics in Indiana. IUPUI: Indiana University-Purdue University Indianapolis, 2007, www.iupui.edu/~fit2brd/. Accessed 29 Nov. 2016.

“Genetic Engineering Will Change Everything Forever – CRISPR”, *YouTube*, uploaded by Kurzgesagt – In a Nutshell, 10 Aug. 2016, www.youtube.com/watch?v=jAhjPd4uNFY.

Greely, Henry T. *The End of Sex and the Future of Human Reproduction*. Harvard University Press, 2016.

Kahn, Jennifer. “Gene editing can now change an entire species -- forever | Jennifer Kahn.” *YouTube*, uploaded by TED, 2 Jun. 2016, www.youtube.com/watch?v=OI_OhvOumT0.

Lanphier, Edward, et al. "Don't edit the human germ line." *Nature*, vol. 519, no. 7544, 26 Mar. 2015, pp. 410-411.

Lantzer, Janson S., and Stern, Alexandra M. "Building A Fit Society: Indiana's Eugenics Crusaders." *Traces of Indiana and Midwestern History*, Winter 2007, pp. 4-11.

Masci, D. “Human Enhancement: The Scientific and Ethical Dimensions of Striving for Perfection.” *Pew Research Center*, 26 Jul. 2016, www.pewinternet.org/2016/07/26/human-enhancement-the-scientific-and-ethical-dimensions-of-striving-for-perfection/. Accessed 12 Dec. 2016.

Pernick, Martin. "Public Health Then and Now." *Am J Public Health,* vol. 87, no. 11, 1997, pp. 1767-1772.

“RadioLab: CRISPR.” *YouTube,* link has been removed.

Reardon, Sara. "Welcome to the CRISPR zoo." *Nature*, vol. 531, no. 7593, 10 Mar. 2016, pp. 160-163.

Shannon, Stephen. “Can Gene Editing Techniques Like CRISPR-Cas9 Be Used to Replace Mutated Genes in CF?” *Cystic Fibrosis News Today*, 16 Apr. 2015, www.cysticfibrosisnewstoday.com/2015/04/16/can-gene-editing-techniques-like-crispr-cas9-be-used-to-replace-mutated-genes-in-cf/. Accessed 30 Nov. 2016.

Sternberg, Samuel H., and Doudna, Jennifer A. "Expanding the biologist’s toolkit with CRISPR-Cas9." Molecular Cell, vol. 58, no. 4, 21 May 2015, pp. 568-574.

Venter, J. Craig. “Craig Venter: We Are Not Ready to Edit Human Embryos Yet.” *Time*, 2 Feb. 2016, www.time.com/4204210/craig-venter-gene-editing/. Accessed 1 Dec. 2016.