Project Number: TAS-6594 - 43

GENETIC ENGINEERING IN HUMAN BEINGS

An Interactive Qualifying Project Report

submitted to the Faculty

of the

WORCESTER POLYTECHNIC INSTITUTE
Worcester, Massachusetts, USA

in partial fulfillment of the requirements of the

Degree of Bachelor of Science

on this day of

Tuesday, May 4th, 2004

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Abstract

The purpose of this paper is to discuss the ethics of genetic engineering in human beings in the future. We read various books, reports and essays as research, and conducted an online survey among WPI students. We divide genetic engineering into four categories, identify the topics of choice and somatic vs. germ line modifications, and then focus on four social groups as a base for our discussions and conclusions on what types of genetic engineering are acceptable.

Executive Summary

Genetic engineering is a field of science that is rapidly expanding, and the vast possibilities of modifying the human genetic code that it offers have raised many ethical questions. In our paper, we assume a future where any kind of genetic modification on humans is possible and relatively safe, and discuss the ethics of different types of modifications in order to arrive at conclusions that can help in guiding policies on genetic engineering.

For these discussions, we drew on various books, reports, and articles as research, from various renowned authors as well as possibly lesser-known sources. We also conducted an online survey among WPI students to be able to draw on realistic statistics.

We identify four different types of genetic modifications: *medical reasons*, which are those changes that are medically necessary; *medical enhancements*, which are not necessary to preserve a life or prevent severe disability; *cosmetic modifications*, which only affect the outward appearance; and genetic *performance enhancements*. We discuss the topic of *choice*, i.e. whether modifications should be allowed on incompetent persons, as well as the related topic of *somatic* vs. *germ line* modifications, i.e. modifications that are not passed to the next generation and those are. Finally, we discuss the views of four different social groups: *scientists and doctors*, *sociologists and philosophers*, *religious groups*, and the *general population.*

From our research and discussions, we arrived at the conclusion that genetic engineering is generally accepted as a positive development, and genetic engineering for medical reasons and medical enhancements is generally acceptable. However, one must proceed with caution and respect for human society when making such profound steps. We find that performance enhancements and cosmetic modifications which make one unrecognizable as a human being would disrupt our society too profoundly and are therefore unacceptable. We hope that this paper gives insight to the reasons of our conclusions.

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1. Introduction

Since the discovery of DNA, the field of genetic engineering has constantly expanded. Eventually, this science will extend to cover all areas of our life, from the medicines we take, to the food we eat, to the people we meet. The latter is one of the most important aspects of genetic engineering; this is the focus of this paper.

1.1. Definitions

We would like to clarify some of the terms we will cover in this paper.

DNA: Deoxyribonucleic Acid – Found in the nucleus of every cell, this chemical stores information about the entire organism. DNA is replicated when the organism replicates or reproduces and so its stored information is inherited.

Gene: The basic unit of inherited information, consisting of a sequence of nucleotides in a DNA molecule that carries the code for the production of a specific protein or RNA molecule.

Genome: An organism's complete collection of genetic information.

Genetic Engineering or Gene Manipulation: Direct manipulation of genetic information or transfer of genes from one type of organism to another to produce new biological structures or functions in the resulting organism.

Gene Therapy: Treatment of a disease through genetic engineering.

Modifications: Changes to an organism's DNA that introduce changes in that organism's phenotype (i.e. its visible characteristics, as opposed to genotype, which is the organism's actual genetic make-up that may include codes for traits that are not actually exhibited by the organism).

Germ Line Modifications: Genetic modifications that may or may not affect the individual, but these modifications are passed down to their descendants, thus the offspring will receive the modified versions of the parents' DNA sequence.

Somatic Modifications: Genetic modifications to an individual's genetic code, but these changes are not passed on to their descendents, so that their offspring will inherit an unmodified version of the parents' DNA sequence.

1.2. Current State of Technology

At the time of writing, we have the technology to identify certain genes and use gene therapy to cure certain diseases. As gene therapy is still experimental, only few people have actually undergone this kind of treatment. Even though more therapies are proposed every day, there is currently a general hold on gene therapy due to cases of severe side effects. For example, the case of Jesse Gelsinger, who died hours after beginning his gene therapy trial, prompted the FDA to place most gene therapy trials on hold.

Most gene therapy involves removing cells from the person and replacing the genes in them and then reinserting those cells into the person. In large multi-celled organisms, the most effective way to modify genes is to introduce a modified virus, called a vector, to insert a specific gene into a DNA sequence. The exact point of delivery is not able to be determined, so the gene may be inserted anywhere along the DNA sequence. In smaller single-celled organisms, it is possible to splice out part of the cell's DNA and replace it with another sequence.

1.3. Assumptions

This paper will deal with the future issues of genetic engineering as science progresses. There are countless discussions on the current state of genetic engineering, including ones that discuss whether to actually proceed with the development of gene manipulation. However, we want to look into a future where science has reached a level where genetic engineering is relatively safe and practical. Hence, for the purpose of this paper, we will make several such assumptions.

We will assume that it has been discovered for every gene what feature of the organism it encodes, and how these genes interact with each other.

We will assume that technology has advanced enough so that scientists can introduce a gene into a large, multi-celled organism, such as a human adult, and that gene will be placed in the desired location, replacing the DNA sequence that was previously there.

We will also assume that because of the above assumptions, genetic engineering is relatively safe and can be practically executed, as comparable to surgery.

1.4. Genetic Modification Categories

With these assumptions in mind, we have decided to divide the topic of genetic modification into four different categories:

Medical Reasons are changes to the genetic code that are necessary to preserve a person's life and/or prevent severe disabilities (blindness, deafness, paralysis, mental disabilities).

Medical Enhancements are changes that benefit a person's health, but are not necessary to save a person's life (such as increased immune system strength, or the capability to regenerate limbs), and that do not alter his or her outward appearance, unless it is to correct a physical defect (such as dwarfism).

Cosmetic Modifications are changes that only affect the outward appearance of the person, such as hair or eye color.

Performance Enhancements are changes that positively affect the person's ability to perform any task.

1.5. Overview of Discussions

Changes in the genetic code can take on two forms, somatic modifications and germ line modifications. In this paper, we will discuss the ramifications of these different types of modifications.

Closely linked to this discussion is the question of genetic manipulation of incompetent persons, i.e. those who are not able to decide on whether they wish to have the modifications performed on them, such as young children and unborn generations, or the modification of those incapacitated by an illness.

We will discuss the social and ethical ramifications of genetic engineering under consideration of the viewpoints of different groups, such as religions groups, laypersons, scientists and doctors, and sociologists and philosophers.

Finally, we will discuss the possibilities of errors in genetic modifications that could cause problems for the entire human race.

1.6. Thesis

In this paper, we shall argue that somatic modifications for medical reasons, medical enhancements, and cosmetic enhancements that do not make you unrecognizable as a human are acceptable. However, germ line modifications and performance enhancements are unacceptable. We will also argue that modifications on the incompetent are only permissible if it is necessary to preserve the life of the individual or prevent severe disability (i.e. for medical reasons).

2. Technology

Genetic engineering is a rapidly advancing field of science. This makes it hard to keep up with everything that is going on in the field of genetic engineering because it involves many different forms of technology and techniques, with new developments and discoveries being made regularly.

These sections of the report will present a brief history of the field of genetic engineering, and report the current state of genetic engineering. The last section discusses some of the problems faced and where the field of genetic engineering is going in the future.

2.1. The Beginnings of Genetic Engineering

The history of genetic engineering begins with the discovery of the gene. In 1866, Gregor Mendel published his work on the topic of heredity in pea plants. Through his work with pea plants, he was able to come up with the concept of genes (called "factors" in his work) (O'Neil). He also developed the concept of recessive and dominant genes by observing the number of plants that displayed a certain trait and if the trait skipped generations. (Yount)

In the following years, researchers made many further discoveries. In 1902, Walter S. Sutton and Theodor Boveri separately noted the parallels between Mendel's units and chromosomes, which led to the discovery of the fact that chromosomes were part of the factors that Mendel described in his work. In 1910, Thomas Morgan was able to identify the first sex chromosome related trait. With this trait, Morgan was able to identify the first gene. In 1952, Martha Chase and Alfred Hershey proved that DNA was the carrier of genetic information, giving scientists the knowledge of what they needed to manipulate and control genes. In the following year, 1953, Francis Crick and James Watson were able to identify the three-dimensional structure of the DNA molecule. (Encarta)

Genetic engineering had its beginning in 1972. Paul Berg spliced the gene from one organism into another. He did this by cutting the gene off the host's DNA and attaching it to the other organism's DNA sequence at the spliced ends. In 1973, Stanley Cohen and Herbert Boyer developed a fast way to splice DNA. They were able to combine their research to develop a system that allowed the splicing of DNA to occur much faster and with less direct human guidance. They also developed a way to use a genetically modified virus to insert a gene into bacteria, an important discovery for genetic engineering. (Yount)

2.2. The Present State of Genetic Engineering

The basic techniques of genetic engineering have not changed much since Cohen and Boyer, but there have been many additions and improvements.

For example, scientists can now splice a gene into multiple versions of the same virus. The viruses are exposed to the cells of the organism that they are going to modify. The viruses then infect the host cells, and the new gene is added to the host genome instead of the normal viral life cycle, in which the virus uses the host cell to replicate itself. The host cell now has the new gene permanently inside its genome. Thus, when the host cell divides, its daughter cells will inherit the new gene. (Walters)

In addition, scientists have developed a computer-controlled machine that can read a DNA sequence much faster than the scientists could. (Double Helix) This allows scientists to look at the DNA of organisms that they have modified to see where they made the change, and if it has damaged any of the other genes in the organism's genome.

The methods in which humans are genetically modified fall into two general categories. The first method is that in which cells are removed from the person, and those cells are exposed to a viral medium. The second method is that in which a viral medium is injected into the person, which delivers the new gene to all cells of the host. Each of these processes has several advantages and disadvantages. (Walters)

The processes in which cells are removed from the host, genetically modified, and then inserted back into the host have several advantages. One advantage is that specific cells can be targeted, i.e. the scientist can remove the cells that they want to modify and then modify only those cells. Another advantage to this process is that the cells that are exposed to the viral medium can be tested to see if the cells have taken the gene before they are implanted back into the host. (Walters)

The disadvantage for the just mentioned process is that it can be applied only to a limited number of cells at any given time. A large number of cells cannot be removed from the host, for it could cause undesired side effects. In addition, this process cannot be used on cells that would be dangerous to remove, such as nerve and brain cells.

The second process, in which a viral medium is injected straight into the host, has several advantages. One advantage of this process is that it can expose every cell in the host to the viral medium. Thus, this process has the ability to modify an organism as a whole. Another advantage of this process is that it can be used on cells that would be difficult to remove form the body, such as nerve and brain cells. (Walters)

A disadvantage of injecting a viral medium into the host is that it is currently very hard to control which cells are affected. When the viral medium is injected into the host, it will start to modify any cell that it came across. This causes the modification of cells that were not intended to be modified. It is also very difficult to tell how many of the cells are taking to the new gene and producing the desired results. (Sokolove)

2.3. The Future of Genetic Engineering

In today's world, genetic engineering is already used successfully in many applications. Many medicines and plants have been successfully created and enhanced by genetic engineering. A few genetically related human diseases are also in experimental treatment at the moment (Adams). Genetic engineering is still an imperfect science that is trying to overcome some major problems.

One of the problems that genetic engineering is trying to overcome is the inaccuracy of the gene insertion. With much of the genetic engineering that is done today, a foreign gene that is inserted into the host DNA strand though a viral medium may cause problems. The problem is that the gene can be inserted anywhere in the host DNA sequence. If the foreign gene were to be

inserted in the middle of one of the host genes then the host gene may not function properly or fail, and this may have life threatening repercussions on the host. (Adams)

One of the ways that geneticists are trying to overcome the problem of insertion is to develop a viral measure that will insert the new gene in one specific place in the human DNA sequence. One such virus that is being investigated is the Adeno AV5 virus. This virus has some control over where it inserts the new gene. Many scientists are working with this virus to make it a much more effective medium for genetic engineering. (Adams)

Another problem that geneticists are trying to overcome is their lack of knowledge of what every gene does. We still do not know what every one of the 30,000-35,000 genes of the human genome does (Double Helix). We also do not know how each gene works with each other to develop traits that are more complex.

The problem of not knowing what a gene does is being overcome with many independent trials and research. One way that researchers are finding out what genes do is by comparing the genes of many people who have a common trait. Many researchers are looking at genes that cause diseases. The researchers look at genes that cause diseases by comparing the genetic information from one person with the diseases and the information from many other people with the same diseases. If the researchers find a common gene between the people with the diseases, then that gene is the gene that causes the diseases. In addition, if the researchers find that the people with the diseases do not have one type of gene, and then the researchers can conclude that that gene prevents the disorder. (Adams)

At the moment, many scientists are concentrating their research on genetic disorders in the hope of saving human lives. The type of research that scientists are doing could then later be applied for other traits such as height and eye color. Scientists will eventually start looking for the

genes for height and eye color when genetic diseases have been mostly eliminated. This will eventually lead to the discovery of what every gene in the human genome does.

Money is also one of the problems that must be overcome. Due to the technology and time involved, the price of one genetic treatment could be in the tens of thousands of dollars. This would place the cost beyond the reach of most people. Scientists are working on ways to make their processes faster, easier, and cheaper. Some scientists hope that genetic engineering will be like vaccines; expensive at first but over time it will become cheap enough so that it will be practically free. (Adams)

Another problem that geneticists are trying to solve is how to remove a gene from an organism and replace it with a different gene. It is one thing to just be able to insert a gene into a cell, but it is quite a different thing to remove a gene and insert another to take its place in the DNA sequence. Scientists are trying to find better viruses that have the ability to knock a gene out of its place in the DNA sequence and insert a new gene in its place. (Adams)

Even given the problems stated above, the future of genetic engineering is still promising. Scientists will eventually find solutions to all of the problems. With all the problems solved, many scientists hope that genetic engineering will become common in the medical profession and that it will allow people to live happy and healthy lives.

One of the major situations that scientists hope that genetic engineering will improve is overcoming genetic diseases. Many diseases are caused by genetic errors. Some of these genetic diseases are cystic fibrosis, hemophilia, sickle cell disease, Tay-Sachs disease, multiple sclerosis, and Huntington's disease. Scientists hope that they will be able to prevent or cure such diseases from happening by inserting genes that will prevent the diseases or replacing the genes that causes the disease.

Another problem that is being addressed is muscle degeneration due to old age, cystic fibrosis, or any other muscle destroying disorders. H. Lee Sweeney and Elisabeth Barton have been experimenting with mice. The mice have been given gene therapy so that they will produce increased levels of IGF-1 (insulin-like growth factor-1). IGF-1 is a protein that promotes muscle growth and repair. The mice have greater than normal muscle size and strength and they do not lose their muscles as they age. Barton and Sweeney hope to use their research to help the elderly by preventing the muscle degeneration of old age and other muscle deterioration diseases. (Sokolove)

2.4. Conclusion

Genetic engineering holds the possibility of helping millions of people. Genetics started with a man working with some pea plants and has grown into an international industry. Genetic engineering has grown from just a few people in some universities to thousands of people in industry and government.

As the technology advances, the use of genetic engineering will become more common. When a suitable viral vector is found, genetic engineering will start to be used more often because genetic engineering will have become safer. Once we discover what all the genes in the human genome do, we will be able to prevent many diseases and make our lives healthier.

3. Genetic Modification Categories

In order to be able to better classify different types of modifications, we have identified four uses of genetic engineering. Part of the purpose of this division into categories is to be able to identify to what extent generic engineering is acceptable to different people.

3.1. Medical Reasons

There are many medical issues affecting humans. Some of them are the cause of simple mistreatment of oneself, others the cause of bacteria, viruses, or foreign substances. Yet others stem from errors in the genetic code – even though the body has grown according to its genetic code, this code itself is incorrect. In such cases, the only way to treat the cause of the disease is to correct the code through genetic engineering. Examples of such diseases are congenital blindness, deafness, mental disabilities or sickle-cell anemia. Furthermore, it may be possible to treat other kinds of sicknesses genetically, possibly even with much more success than conventional medicines.

As an example, while it may be possible to treat the flu with antibiotics, this is usually not necessary and there are larger risks associated with this treatment (such as the possibility of breeding a strain of the flu that is resistant to antibiotics), therefore it is usually considered unreasonable. However, in the case of a life-threatening organ failure or disease (such as gangrene, which sometimes can only be stopped by amputation), extreme steps must often be taken to preserve that individual's life.

In any case, it is the task of the doctor – and, in non-emergency cases, of the individual him or herself, family, relatives, or even the law – to decide what is medically necessary and what is reasonable. The person or the people making the decision must weigh the expected outcome of the treatment with its cost and risks (such as possible side effects or putting too much strain on the body).

It is these cases, where it is determined to be medically necessary and the only way to preserve an individual's life or to prevent or treat severe disabilities, that genetic engineering would have a *medical reason* to be used.

3.2. Medical Enhancements

As stated in the above section, there are many possible areas of use for genetic engineering for medical purposes, but many where it may not be the only option to treat a disease. In addition, there are many conditions that a person may live with, but that could be optionally treated (such as dwarfism). Furthermore, there are many possible enhancements that may be made to an individual's health (not performance – see below), such as giving them increased immune system strength, or the capability to regenerate a lost limb. Generally, these changes do not affect the outward appearance of the person, unless they correct such a physical defect. These are the kind of genetic changes that we categorize as *medical enhancements*.

3.3. Cosmetic Modifications

Aside from changes that have a medical background, many people like to change their outward appearance – some, to make themselves more attractive, others, to show their individuality and uniqueness, often to make a statement about themselves or their views. With genetic engineering, the possibilities for this would be extensive, and permanent. Furthermore, these changes would be "real" – they are not accomplished by applying cosmetics to the skin, or under the skin, but by instructing the body to make the change to itself. Any such changes that affect only the person's outward appearance are what we classify as *cosmetic modifications*.

3.4. Performance Enhancements

Performance enhancers are already well known to us today, for example in the form of amphetamines or steroids. While these drugs have negative side- and aftereffects, performance enhancements through genetic engineering – similar to cosmetic modifications – are permanent, and, if the genetic code is modified correctly, without side effects. Such *performance enhancements* could be increased mental activity or strengthened muscles.

4. Discussions

4.1. Somatic vs. Germ Line Modifications

4.1.1. Introduction

Genetic engineering falls into two basic categories: somatic genetic engineering and germ line genetic engineering. The main difference between somatic modifications and germ line modifications is that germ line modifications will be passed on to the children of the person who received the modification. Thus, the germ line modifications will become a permanent part of the person's descendants' DNA. (Walters)

The following sections will go into detail on somatic genetic engineering and germ line genetic engineering. The sections explain the advantages and disadvantages of somatic genetic engineering and germ line genetic engineering. The first section deals with somatic genetic engineering. The second sections deals with germ line genetic engineering. The results of somatic genetic engineering and germ line genetic engineering will be referred to as somatic modifications and germ line modifications, respectively. Also, in every section when referring to the children or child of the genetically modified, the term children or child refers only to the children or child born after the modifications were done.

4.1.2. Somatic Genetic Engineering Introduction

Somatic genetic engineering is genetic engineering that affects only a person's somatic cells. Somatic genetic modifications that the person receives will not be passed on to the person's future offspring. (Walters)

Somatic genetic engineering can involve every cell in a person's body except for the cells that are or will produce germ cells. Germ cells are the cells in a person's body that hold the genetic information that is to be passed on to the next generation. The two types of germ cells are

the sperm and egg. Somatic genetic engineering therefore can affect every cell in a person's body except for the sperm or egg cells. (Walters)

Somatic modifications have several advantages and disadvantages. Some of the advantages for somatic modifications are: allowing a person and their children to choose the genetic modifications that they will receive, preventing possible genetic errors to be pass on to future generations, and somatic modifications can be performed at almost any time in a person's life. The disadvantages of somatic modifications are that they must be performed for every generation if it is necessary, and can only be performed after the person has developed in the womb to the point were their sex cells (their germ cells) are developed and are independent from the other cells in the person's body.

4.1.3. Somatic Genetic Engineering Advantages

Somatic modifications allow a person to choose what genetic modifications they will receive. A person can receive a genetic modification, and as long as the modification cannot be passed on to the person's descendents then that is a somatic modification. A somatic modification also prevents the children of the person who had the modifications performed from being forced to inherit the modifications. Thus, somatic modification allows a child to choose the modification that they will have themselves. (Walters)

If a gene were to cause side effects in the person in whom the gene was implanted, but not for years later, the person will also have to deal with the problems and the children of the person will not have to deal with the problem. Somatic modifications allow for a single person to deal with the problem instead of future generations having to deal with the problem too. (Walters)

Somatic modification can be performed on a person at almost any point in their life since the germ cells are independent from the development of the somatic cells. This allows a person to

be somatically modified at a time that they see fit. Thus, when a genetic disorder does appear, they can deal with it at that time. (Walters)

4.1.4. Somatic Genetic Engineering Disadvantages

One disadvantage of somatic modification is that it has to be performed on every generation to correct a genetic disease. Many diseases are passed on from generation to generation. Families with these diseases would need to undergo somatic genetic engineering every generation to prevent the diseases. This could become very expensive for families since they know that they will have to modify every child that is born. The number of people who need the somatic modification will also increase as the family grows; thus, more resources will be needed to modify the family with every generation. (Beyond)

A further disadvantage of somatic modification is that it can only be performed on a person who is developed enough so that their sex cells are independent from the rest of the person's development. Somatic modification can only be performed on a fetus after the germ cells of the fetus are impendent from the somatic cells. Any genetic modifications that are performed on a child that is this young will most likely result in changes in the child's germ cells, thus causing the modification to actually be a germ line modification. The inability to performed early somatic modifications may leave a child with irreversible damage if germ line modification were not allowed. (Walters)

4.1.5. Germ Line Genetic Engineering Introduction

Germ line genetic engineering is any form of genetic engineering in which genetic modifications are be passed on to the children of the genetically modified person. The germ line modifications may or may not affect the person, i.e. the modifications may only arise in the children of the people who were modified.

There are several advantages and disadvantages with germ line modifications. One of the advantages of germ line genetic engineering is that it is an effective way to remove genetic diseases. Another advantage of germ line modifications is that they can be performed on very young fetuses. One disadvantage is that germ line modifications do not give the children of the genetically modified people the possibility to choose to have or not to have the modifications. Another disadvantage of germ line genetic engineering is that the modifications will forever be in the genome of the offspring, unless they are removed again later. It is impossible to tell the long-term effects that the modifications will have on the genome as a whole in the future generations.

4.1.6. Germ Line Genetic Engineering Advantages

Germ line genetic engineering allows for effective treatment of genetic diseases. Replacing a diseased gene with a healthy gene can treat genetic diseases. If the disease is treated with somatic modifications, the children of the person that got the modification will have to undergo genetic modifications themselves to prevent the disease. Treating genetic diseases with somatic modification is inefficient, since a germ line modification can treat the disease once and the children of the person with the disease will not have to worry about the disease. Germ line modification can be performed once, and the disease would no longer be present in the family, and thus further modifications to treat the disease will not be needed. This is more efficient and requires fewer resources since the treatment would only be needed to be performed once. (Beyond)

This form of treatment is advantageous to families with limited income since they will only need to pay for the treatment once. It could become very expensive if the parents need to pay for their treatment and the treatment for their children. In addition, performing genetic engineering is a time taking and resource draining process, especially if it has to be repeated.

Germ line modification allow for a one-time modification thus using a minimal amount of resources.

If a person were to perform genetic engineering on a young fetus, it is very difficult to ensure that the modifications will not become part of the fetuses' germ cells. A fetus is a very small organism in which many of the cells are still dividing and do not have a precise function yet. Thus, a modified cell can become almost any type of cell in the body, including germ cells. To modify a young fetus is to ultimately change the fetus's germ line.

4.1.7. Germ Line Genetic Engineering Disadvantages

A disadvantage (which was also counted as an advantage) of a germ line modification is that the children of the modified person inherit the modification. This denies the children of the modified person to have a genome free from genetic modifications. The child may want to have a genetically unmodified gnome. (Walters)

The child could also not like the modification that they were forced to receive from their parents. The child will then need to undergo genetic engineering to reverse the original modifications. This will create a strain on the resources to undo all of the modification that the child has received.

Another problem with germ line modifications is that a child does not have a 100 percent chance of receiving the modified gene. If a gene is implanted in a person's germ line and that person has children, the children will have a 50 percent chance that the modified gene will make it into their genome. If a gene were to be added to a person so that it suppresses a disease causing gene, there is a chance that an added gene and the disease causing gene will be separated when the germ cells turn into sperm or eggs, and thus one will still need to deal with the disease causing gene in the child that will develop from that egg and sperm. (Walters)

If the implanted gene were to have unwanted side effects that only appear if a person is born with the gene, then the children of people who had germ line genetic engineering will suffer because of it. Now the child will now have to be genetically modified to counteract the unwanted side effects. This is not an efficient use of resources since the child will suffer unnecessary and have to be genetically treated.

It is also very difficult to perform a germ line modification on a developed female. A female has all of her germ cells already produced before she was born and she does not produce any more. To modify her germ cells you must go and directly modify all of her eggs.

One of the biggest disadvantages with germ line modifications is that given enough time and germ line modifications the entire human genome will be altered. The result that will come to be is that certain genes are completely eliminated from the human genome and new genes are added. An overall change in the human genome like the one previously described will lower the genetic diversity of the human race. This may have unforeseen consequences.

An example of a gene that is typically not good to have is sickle-cell anemia. Sickle-cell anemia causes the production of abnormal hemoglobin. The abnormal hemoglobin then deforms blood cells so that they will be sickle shaped, thus blocking tiny blood vessels. When the blood vessels are blocked, they starve the body of oxygen and cause pain, illness and sometimes an early death. (Yount)

There is however an advantage of having the sickle-cell anemia in the genome. People who carry sickle-cell anemia gene have an unusually high resistance to malaria (Yount). Malaria is a serious blood disease that can cause death.

With new diseases, such as SARS, appearing all over the world there may be genes in the human genome that on their own cause problems but give the person who has that gene a greater resistance to certain infections. If a very contagious and deadly disease were to appear, the only

people who may be able to fend off the disease are people with a certain type of genetic code. If that gene is removed from the human genome then every one in the world will be equally susceptible to the disease.

Germ line genetic engineering can eventually homogenize the human genome, thus removing diversity. Diversity allows for change and evolution in a species, thus if there is little diversity the species will change little and evolve slower. Germ line genetic engineering will remove chance from human evolutions and thus it may disallow some new mutant gene to arise and take its place in the human genome for better or for worse.

4.2. Choice

The question of choice is the question of whether we are allowed to make decisions for others, even if it is a question of life and death. As we have seen from the discussion of genetic germ line changes, even modifying oneself may affect others. We would like to divide the discussion into two categories along these lines: First, the question of what medical decisions we are allowed to make for others, and second, the question of non-medical changes (performance enhancements and cosmetic changes). Finally, we will touch on some general issues that apply to both questions.

4.2.1. Medical Reasons and Enhancements

For the discussion of medical decisions, we would like to illustrate two different scenarios: the case of an unborn or young child where genetic screening has uncovered a genetic error, and the case of a grown human who is too ill to make conscious decisions for him/herself.

In the case of an unborn or very young child, the problem lies in the question of what the child's future will hold. Is this modification really necessary to save a life or prevent disability that would strongly reduce the quality of life? Are we allowed to make the decision for our child considering that we cannot assume any medical treatment to be completely safe? Moreover, if the

child is very young, will this change be a germ line change and be passed on to his or her children? These are all questions that one must ask before making a decision – because, as with many other questions concerning their children, parents do have the responsibility to make decisions. They must consider how the child will be affected in the future and not fall into the trap of making the decision only for their own benefit.

When it comes to the case of an adult suffering from a disease or disorder that has rendered him or her incompetent, the issue is not as clear-cut. Here, someone else must make a decision for a person who would normally be capable of making decisions. Most commonly in such cases, a certain family member or members who are closely related to the person will be able to make such a decision. However, there may be cases where this is not possible, normally because such a family member cannot be found. On a different but related topic, that of withholding life support for terminally ill patients, the law has already found two models for such cases. The decision that is attempted to be made is based on one of two questions: first, what is of the greatest benefit to the patient (this can be a purely medical evaluation), or, second, based on what is known about this person, what would the patient have decided. (McThenia)

4.2.2. Performance Enhancements and Cosmetic Changes

Medical reasons and enhancements have a strong case for modifying incompetent humans – the fact that a modification of these people will in fact allow them to have a better quality of life or to live in the first place. However, performance enhancements and cosmetic changes are a much different topic. These kind of changes are not only questionable in the first place, they are mostly a matter of personal choice – both types of modifications would be performed by people on themselves for various purposes that, when compared to such things as medical reasons, can hardly be called a necessity.

As an example, take an adult who decides that to stand out, and who modifies his skin color to display a variety of colors. If this person has these changes made so that they affect his reproductive cells as well (i.e. germ line changes), then his children will also display some form of skin coloration – something of which it may turn out the child does not want, or, worse, is discriminated against for.

Instead, performance enhancements and cosmetic changes should only be made as somatic changes. Otherwise, their offspring would be unfairly affected – the modification was not necessary for the child, and the parent does not know how the child will be affected.

A more practical reason to argue against making choices about others' genetic code for others is the minute, yet still present, chance that certain modifications will cause mutations or some other kind of undiscovered side effect in the future. Considering our assumptions, the chance may be small, yet we still acknowledge it, meaning that one needs to minimize the chances of hurting others with one's choices.

4.3. Social Groups

In viewing the question of what society would see as acceptable uses of genetic engineering, we examined four different social groups for their opinions on the various types of genetic engineering. These groups are: scientists and doctors, who are the ones researching and performing the genetic engineering; sociologists and philosophers, who study society and whose ideas shape the views of society; religious groups, who also shape the moral fabric of society; and the general population. Most of the opinions expressed herein were extracted from a sampling of these social groups and should of course not be taken as the view of all people mentioned.

4.3.1. Scientists & Doctors

Two of the most influential groups in the future development of genetic engineering of humankind are scientists and doctors. Scientists and doctors develop the techniques and processes

that allow for genetic engineering to take place, and their recommendations influence what kind of genetic engineering the law will allow. This section will discuss the possible points of view that scientist and doctors have.

4.3.1.1. View on Medical Reasons

Many scientists and doctors are trying to find ways to cure and prevent diseases with genetic engineering, and this has led to the development of many such programs. These programs have tried to set up many standards and protocols that ensure the safety and privacy of their patients.

The consensus on which types of diseases can be candidates for genetic engineering is at the moment that genetic engineering can only be performed on patients with a fatal illness where other treatments have failed (Adams). This consensus ensures that healthy people will not receive genetic modifications, for at the moment genetic modifications are still dangerous to perform (Adams). In addition, this will help ensure that the people who need this treatment to live will receive it and those resources are not spent on frivolous things.

Scientists and doctors tend to view genetic engineering for medical reasons as an acceptable use of genetic engineering. It is important for doctors to help preserve life and genetic engineering will be a great aid for them. Doctors will be able to treat genetic disorders when all other treatments have failed, thus being able to save someone's life. Scientists and doctors view genetic engineering for medical reasons as a natural extension of current medical practices (Walters).

4.3.1.2. View on Medical Enhancement

Some scientists and doctors are at work on genetic engineering programs whose results fall into the category of medical enhancements. Many of these scientists and doctors are doing

this type of research to aid the health of people. Many of them are working on ways to help the body deal with problems on its own and not to suffer from normal maladies.

An example of this type of research is the research of H. Lee Sweeney and Elisabeth Barton of the University of Pennsylvania. As stated in a previous section of this paper, Sweeney and Barton are using genetic engineering to cause mice to produce increased levels of insulin like growth factor-1 (IGF-1). IGF-1 is a protein that promotes muscle growth and repair. The proposed use of this treatment is to help elderly people and people suffering form muscle wasting diseases to keep and grow muscles to help them move around and avoid injuries. (Sokolove)

Many scientists and doctors view genetic engineering for medical enhancements as a form of medical treatment. Thus, they wish for genetic engineering for medical enhancements to be performed to aid in the health of society.

4.3.1.3. View on Cosmetic Modifications

Very few scientists and doctors are working on genetic engineering for cosmetic modifications. Since genetic engineering is still experimental it would, at the moment, be morally wrong to perform unnecessary genetic modifications. With any genetic modifications at this time, there is a chance that unwanted side effects might arise from the modifications that will affect the health of the person. Thus at the moment scientists and doctors have the point of view that genetic engineering for cosmetic modifications is wrong since it may affect the health of the person in a negative way.

Once genetic modifications are safe to use, the opinion on genetic engineering for cosmetic modifications will probably change. There will no longer be a moral objection for genetic engineering for cosmetic modifications on the grounds that it is dangerous. This will most likely lead to scientists and doctors to view genetic engineering for cosmetic modifications as

morally not wrong as long as it does not drain resources from the people who need genetic engineering to live.

4.3.1.4. View on Performance Enhancements

Almost no genetic engineering research is being performed for the sole purpose of performance enhancement. Much of the genetic engineering research that is being done is to correct deficiencies in the human body that cause a loss in health. Many scientists and doctors know that if their research on non-performance enhancement were to be performed on normal healthy individuals then the person's performance many be enhanced to beyond the human norm (Sokolove).

Some scientists and doctors do not mind their research being used for the purpose of performance enhancements as long as their research still benefits those who need it. When some people pay for the genetic modification, some of the money will be used in further research, making genetic engineering better and cheaper (Adams). Another opinion that scientists and doctors hold is that any genetic engineering for performance enhancement is misusing their research for selfish goals instead of humanitarian goals.

4.3.1.5. View on Somatic Genetic Engineering

Many scientists and doctors view somatic genetic engineering as the best way to perform genetic engineering (Adams). This form of genetic engineering can be used to perform every type of genetic engineering and it does not affect society as a whole.

The current norm of scientists and doctors is to perform only somatic genetic engineering on humans (Adams). Scientists and doctors know that genetic engineering is still dangerous to perform, and so it is unethical to perform genetic engineering on a person and have the modified genes pass on to future generations were they can cause problems (Walters). Somatic genetic engineering is the only option to prevent that from happening.

4.3.1.6. View on Germ Line Genetic Engineering

Many scientists and doctors believe that any form of germ line genetic engineering on the human beings should be done with extreme caution (Adams). Scientists and doctors must know that the gene will not have any ill effects after a few generations (Adams). It is impossible to tell if germ line genetic engineering will have any ill effects in the long run. Thus, at the moment, scientists and doctors have decided not to perform any genetic engineering with the purpose of doing germ line modifications.

4.3.1.7. View on Genetic Engineering in General

Scientists and doctors are the people who are making genetic engineering possible. They hope to be able to use genetic engineering to help humanity overcome some of the most dreadful diseases and ailments. They vary greatly on their opinions of how to use their research and treatments. They also know that they must take things slowly for they know that things can go very wrong. Thus, scientists and doctors generally view that genetic engineering is a good thing but it must progress very carefully to ensure that no errors happen.

4.3.2. Sociologists & Philosophers

Sociologists and philosophers have shaped how society has thought of the world and how society functions. Sociologists and philosophers also shape views on how genetic engineering should be performed. Genetic engineering will affect how people interact with each other and how society runs. Sociologists and philosophers ask and try to answer the questions of how genetic engineering will affect humanity and the relationships between people.

4.3.2.1. View on Medical Reasons

Most sociologists and philosophers view genetic engineering for medical reasons as an acceptable and good use of genetic engineering. They would view genetic engineering for medical reasons as good use of genetic engineering since it will allow the lives of people to be

saved and thus it is a good action. Sociologists and philosophers have agreed that life should be persevered under normal circumstances. Thus genetic engineering for medical reasons will help to preserve life and as such a good action. (Walters)

4.3.2.2. View on Medical Enhancements

Sociologists and philosophers have different ideas on the use of genetic engineering for medical enhancements. Some philosophers and sociologists have viewed genetic engineering for medical enhancements as a normal and good extension of medical reasons. They view medical enhancement as a way to improve the health of society, making the lives of people better (Sokolove). This will also allow people to worry less about their health, allowing them to give their attention to other aspects of their lives.

Other sociologists and philosophers view medical enhancements as a technology with the potential to disrupt normal society. One of the reasons that medical enhancements are a problem is that sociologists and philosophers view that medical enhancement as a way to disrupt the normal life cycle of society, in which the older generation gives control to the younger generation. With medical enhancements, the old generation may still be in good enough health so that they will not give control to the young generation, thus disrupting the normal influx of new ideas that the younger generation brings with them. This will cause society to stagnate as the old ways will not give way to the new ways at the rate that is normally happens. This will also cause the younger generation to not be motivated to grow better since they have no way place to advance since the older generation is still in their positions thus leaving no room for advancement. (Beyond)

4.3.2.3. View on Cosmetic Modifications

Many philosophers and sociologists view the idea to use genetic engineering for cosmetic modifications as a potentially bad use of genetic engineering. They hold the view that genetic

engineering for cosmetic modifications is an unnecessary use and as such should not be performed.

Sociologists and philosophers view genetic engineering for cosmetic modification as damaging to the diversity of looks that society has. They believe that many people in society will try to change themselves so that they fit the current tread of what is beautiful in society. Sociologists and philosophers feel that people will no longer have unique features that make them recognizable as them; people will start to homogenize their looks. In addition, they feel that people will stop trying to look into themselves for their inner beauty since it will be easy to make their outer selves more beautiful. This many lead to cause society to become even more superficial (Beyond).

4.3.2.4. View on Performance Enhancements

A common view that sociologists and philosophers have on genetic engineering for performance enhancements is that it should not be allowed. They believe that genetic engineering for performance enhancements will dehumanize humans and human achievements. Philosophers and sociologists also believe that people will start to be judge on what is in their genetic code and not who they are.

Many sociologists and philosophers believe that when people use genetic engineering for performance enhancements, people start to lose what it means to work hard to make them better. When someone can just get an injection to get any physical trait, they will no longer need to work hard to make themselves stronger, faster, and smarter. Then, having theses traits will no longer be a sign of hard work and sacrifice but a sign of having a good genetic engineer. Any great feat that a person has done will be seen as the great design of a genetic engineering and not of the person doing the feat. People will become like machines, parts can be added to so that the machine can perform a function. (Beyond)

People may start to judge others on the genes that they have and not who the person is. It will be as if people were judging a car by the parts in the car than the car as a whole. People will be judged basis on their genetic information, which is only natural potential, and not on how hard they work and how much they have grown beyond what they were given. In this type of world an individual's self worth and public stature is determined on what his genetic code says that they can do and not what they can actually do. A person has become only what their body is, and nothing more (Beyond).

4.3.2.5. View on Somatic Genetic Engineering

Sociologists and philosophers believe that somatic genetic engineering is the only form of genetic engineering that should be performed. Sociologists and philosophers think that somatic genetic engineering has the ability to help humanity, but not change humanity. Philosophers and sociologists want to make sure that humanity does not make any changes to itself that will later be viewed as a mistake. (Beyond)

With somatic genetic engineering, we can help people without the risk of permanently changing the human genome. If the human genome is changed enough it may cause problems with humanity. We may find that we have made a mistake when we have changed our genome and now have to deal with a huge problem instead of having to deal with a few people that had the genetic engineering in the first place. (Beyond)

4.3.2.6. View on Germ Line Genetic Engineering

Philosophers and sociologists think that germ line genetic engineering should not be performed. Germ line genetic engineering has the potential to change humanity permanently. If we change humanity permanently, problems can arise from all the germ line genetic engineering mixing with each that we will not be able to correct. Also, germ line modification may homogenize the diversity of the human gene pool and that can have consequences that may not

be known for a long time. All the genetic defects that we have may have some unseen benefits that will not be known until they are gone. (Walters)

4.3.2.7. View on Genetic Engineering in General

Sociologists and philosophers believe that genetic engineering should proceed with extreme caution. Genetic engineering to benefit the health of an individual is acceptable but genetic engineering to make an individual perform better should be avoided. In addition, germ line genetic engineering should be avoided. Sociologists and philosophers believe that humanity should think out the consequences of any type of genetic engineering before it is done.

4.3.3. Religious Views

Many religious groups have contributed to the various debates on genetic engineering topics as early as 1973. Since then, they have dealt with issues such as genetics, cloning, and genetic patenting, in the form of books, pamphlets, essays, conferences, and letters to the President and his advisors.

Most religiously oriented texts offer insight into the ideals and morals that stem from the different religions, and they seek to apply these to the topics of genetic engineering. "One of the contributions religious perspectives provide is to offer broad frameworks of understanding and commitment so necessary to deal with these complex issues." (Chapman)

Religions have shaped the morals of society from the very beginnings, and therefore theology is an important resource when studying these issues. This is a fact recognized by many people – for example, the National Bioethics Advisory Committee invited religious thinkers to its discussions for exactly this reason. (Chapman)

However, while theological writings can make people more aware of issues such as the nature of human uniqueness and dignity, there are several issues that must be overcome. In many cases, it is not appropriate to try to apply statements about morals and ethics from religious texts

directly to issues of genetic engineering, because, for example, the question of whether or not cloning is acceptable is a very new question. As a result, religious texts are often very general and abstracted, and writers must struggle to put theological statements into plain English. (Chapman)

In turn, the result of these difficulties in describing religious views, most texts are limited to more general or ideological analyses, as described above, rather than actually formulating policy suggestions. Most groups recognize the need to actually solve the dilemmas presented by the evolving genetic technology, and some have called for public discussions in order to formulate public policy on these topics. For example, Judaism generally uses the idea that interpretation of the holy texts can be achieved through public discussions (Chapman).

One of the more distinguished authors of theological analyses is Ronald Cole-Turner, who looks not just at the questions of what genetics can learn from theology, but what theology can learn from genetics.

In this sense, Cole-Turner describes theology as a field that can learn from new scientific discoveries. What can religion learn from biotechnology? Cole-Turner argues that "the divine art of creating" is accomplished through scientifically proven processes such as evolution through random mutations. This in turn however presents the question, if God controls mutation, and all that He creates is good, what about the mutations that affect people negatively? The answer to this question is that without these mutations, there would have been no evolution, in fact, no life at all. With the randomness of mutation, there can be bad things that happen as well. In other words, God takes risks in creating life.

Concerning the question of genetic engineering, Cole-Turner takes a position that is also held by several other authors as described by Chapman, relating genetic engineering to what is stated in Genesis 1-2: that humankind shall have dominion over the creatures of the earth. It may be meant to be that humans further their own evolution through their technology, as He still holds

control over these processes. However, this raises the following central questions: are we even supposed to change our own genetic code, how far can we go, and what does God intend for us to do?

Another interesting point is the idea that humans were created in the image of God. Are we, humans, as we know ourselves, the image of God, or are we simply in a transient stage of our development, with genetic engineering being another tool to further our development?

These religious thinkers are generally acknowledging the idea of genetic engineering being a possibly good thing, something that humankind may be intended to do. However, genetic engineering also gives us the power to "play God," and we do not know if this is really how God wants to further his creation. Hence, we must proceed with caution and with great awareness for the responsibility we carry.

As stated before, religious thinkers have rarely contributed actual policy suggestions, and we should not make any presumptions on such questions. However, religious groups can and have made significant contributions to the discussions surrounding genetic engineering.

4.3.4. General Population

In order to infer the reception of genetic engineering by the general population, i.e. those members of society not belonging to the previously analyzed groups, we draw on two resources. First, a survey conducted among students of our college over the course of approximately three weeks, and second, the results of several external surveys presented in The Ethics of Human Gene Therapy by LeRoy Walters and Julie Gage Palmer.

In this section, we would like to analyze the results of these surveys. The full results of our survey may be viewed in the appendices, and the results of the external surveys analyzed by Walters and Palmer may be viewed in the appropriate bibliographical reference.

For our survey, we paralleled the topic of genetic changes for cosmetic modifications and performance enhancements with the already well-known topics of cosmetic surgery and performance enhancing drugs, respectively.

For the case of performance-enhancing drugs, even though there are supporters of these kinds of drugs in general, over 70% of respondents stated that these drugs should either not be used at all or only to correct deficiencies. This is close to the number of respondents that stated that they would not modify their own genetic code to enhance their performance (64%). These numbers reflect the general opposition that we experience in the everyday world to performance enhancers in sports and academics.

For the case of cosmetic surgery, 33% of respondents stated that extensive plastic surgery was acceptable. However, only 23% stated that they would change their own genetic code for cosmetic purposes. In addition, a majority (58%) stated that only cosmetic modifications that stay within "normal" human parameters are acceptable (changes of hair color, skin tone, or body size, for example). We can see that even though cosmetic changes are generally accepted, most people still are hesitant to perform more extensive changes on themselves. This most likely reflects that cosmetic modifications, under the assumption that they are acceptably safe, are a matter of personal choice.

Interestingly, close to half of the respondents said that they would pass their modified genetic makeup to their children – this would indicate that they would let their children be affected by their choices, even cosmetic modifications that they may have made to themselves. This result is also reflected when it comes to curing genetic diseases – just over 60% of respondents stated that they would pass genetic modifications on themselves to treat genetic disorders to their children. This is understandable, as these people would not want their children affected by the genetic disorder – which is in turn reflected in the response to the questions

whether respondents would genetically modify their newborn child to correct a deficiency: 72% of respondents would agree to such a modification.

However, it is also necessary to view the opinions of respondents when it comes to risks. Most respondents (78%) stated that they would not proceed with genetic modifications of any kind of there was still a risk that the changes would affect them or future generations negatively. This may reflect peoples' insecurity when it comes to taking personal risks, but it also reflects the realization that choices that one makes about germ line genetic changes also affect future generations.

Finally, for the question of medical enhancements, respondents seemed generally willing to perform genetic modifications for medical enhancements (64% said they would modify their own genetic code for medical enhancements). Our survey did not ask any more questions regarding medical reasons (except when it concerned making changes to others), but this is where the external surveys do cover these questions. Specifically, in these surveys respondents were overwhelmingly approving and willing (about at or over 80%) to undergo gene therapy to treat or cure genetic diseases (Walters & Palmer, 45). The same even applied when asked about gene therapy on a child. The next set of questions concerned germ line changes. Here, respondents were more reluctant when it comes to preventing a non-fatal birth defect in children: 66% of respondents were somewhat or strongly approving.

It seems that for medical reasons, people are much more willing to perform gene therapy. This is understandable, as when presented with a choice of life or death – either one's own or that of one's child – it is natural to choose whatever will save a life. However, since not everyone agreed to gene therapy, it seems that there is still some resistance to the idea of modifying the human genetic code. When asked whether changing the genetic makeup of humans is morally

right or wrong, respondents were almost split in half (52% said that it was not morally wrong, 42% said it was morally wrong, and 6% were not sure) (Walters & Palmer).

To study a specific group of students, who we expected to have differing opinions of on genetic engineering, we selected all students who had indicated to be a major in a biology-related field, approximately one third of the total respondents. Interestingly, their opinions did not vary a great amount from those of the total pool of respondents; however, there was a noticeable general trend *against* genetic engineering mainly for performance enhancements and cosmetic changes. However, the responses to the question of whether the respondents would enhance themselves medically had more responses that were positive. These results may reflect the general awareness of those in biology-related fields of not only the risks of genetic engineering, but also ethical issues surrounding this topic.

From these surveys, we can attempt to draw conclusions about the opinions of social groups who may not deal with such questions regularly. Genetic engineering for medical reasons seems to be a generally accepted idea. It is taken to be just another form of medical advancement, which, when used only for such purposes, is a significant step of progress in medical science. The topic of medical enhancements is unfortunately an often ill-defined one, and hence the responses (and most likely opinions) of the general population are varied. It is understandable that while many people see the many possibilities of genetic engineering, others may object on moral grounds, or on practical ones: if this kind of modification were possible, what about cost and practicability? It is the many possibilities of genetic engineering that people respond to when it comes to other kinds of enhancements. Cosmetic changes are viewed much in the same way as already existing cosmetic possibilities: while some may disapprove of other's choices, they are not necessarily strongly against the use of genetic engineering for something that is being done already. However, any kind of "unnatural" performance enhancers are already viewed as unjust

and the same applies to genetic performance enhancements. Finally, the question of germ line modifications may be somewhat unclear. Many people would agree to pass modifications such as medical enhancements on to future generations, without realizing the possible risks for future generations of making germ line modifications.

4.3.5. Society as a Whole

From the discussions in the previous sections, some generalizations can be drawn. Most groups tend to agree that genetic engineering, while one must be cautious, is considered acceptable for medical reasons, because here the benefits of preserving human life outweigh the possible consequences. While the views on medical enhancements cover a wider range of opinions, there are not many strong voices against it. On the other hand, performance enhancements are commonly opposed, as they promote inequality. Cosmetic modifications also have a wide range of opinions, however, as other kinds of cosmetic changes are already commonly accepted, this kind of genetic engineering will most likely fall into the same kind of acceptance.

4.4. Consequences of Genetic Engineering

4.4.1. Genetic Problems

As genetic engineering progresses and humans are increasingly modified, the chances for errors will also increase. Errors may arise for a variety of reasons, which may include modified genes breaking down, unknown interactions with other genes, genetic incompatibility (infertility), and spontaneous mutation.

4.4.1.1. Modified Genes Breaking Down

When new genes are introduced or genes are modified, it is possible that over time, the gene will stop having the desired effect. This is the result of the changed gene, which may have been artificially produced, not being stable or having as strong chemical connections to the

original or host gene. When a gene breaks down, it may stop functioning correctly and unknown and potentially extremely dangerous side effects may arise. (Walters)

4.4.1.2. Unknown Interactions with Other Genes

The human genetic code has been fine-tuned over hundreds of thousands of years through evolution, and there are many complex interactions within the cells of the body and the different organs of the body, all of which are controlled by the genetic code and the proteins it encodes for. Although we are assuming that this will have been extensively researched in the future, it is still possible that when a gene is modified, there could be unexpected interactions between this gene and other existing genes.

This is even more prudent when there is more than one modified gene introduced into the DNA sequence, for the interactions between these two new genes and the original genes may still be unknown. If one modified gene were to produce one trait and another modified gene were to produce another trait, and the traits are counterproductive to each other, unknown side effects may arise.

4.4.1.3. Genetic Incompatibility

As modified genes are introduced into human germ line cells, it is possible that the cells are modified in such a way that they are genetically incompatible with another human's germ cells. This would have a strong impact on the human race since these people will no longer be able to have children.

4.4.1.4. Spontaneous Mutation

Mutation is the key to evolution. If mutations happen, genetic engineering may just try to screen out these changes without knowing if the mutation is good or bad. This means that evolution itself will be controlled and not natural.

4.4.1.5. Discussion on Effects

If a modified gene breaks down, it will only affect the person it was changed in. However, if this person has had a germ line modification and has children, then it is very likely that the children will also experience this problem. All parties involved would have to undergo genetic modification to combat the genetic breakdown, which in turn may have its own side effects later.

Unknown interactions are a problem especially when they are germ line modifications – one person with modified genes and another person with modified genes may be perfectly healthy on their own, however the mixing of these genes in the offspring may produce unknown effects.

The above problems become serious when germ line modifications are used, because in this case they will affect future generations. With only somatic modifications, any problems that do arise would affect only the individual that had the modifications done, knowing the risks associated with them. For this reason we conclude that germ line modifications should be avoided unless medically necessary (such as treating a very young fetus).

4.4.2. Social Consequences

When a great and powerful tool is introduced into society, the society assimilates it into its fabric. Genetic engineering is such a tool. Genetic engineering has the possibility of changing how people view each other and interact with one another.

While genetic engineering for medical purposes could increase the overall health of society, people may start to judge each other on what their genetic information is and how much they are modified (Kalbian & Shepherd). Natural gifts and abilities would become a thing of the past because they would be achievable by anyone through genetic modifications. Other possible side effects exist in any competitive aspect of life.

Each form of genetic engineering has a different effect on society, and we will discuss these here.

4.4.2.1. Medical Reasons

With genetic engineering, it would be possible to cure almost any kind of disease, many of which are life threatening today even when treated with conventional means. Some of the consequences that would arise from the use of genetic engineering for medical reasons are: fewer deaths due to genetic diseases, fewer cases of disabilities, and longer life expectancy. The introduction of this tool bears a great similarity to the introduction of other medical enhancements such as vaccines and antibiotics.

With fewer deaths due to genetic diseases, there would be a lower need for long-term health care for the population, thus freeing resources to pursue other goals. With fewer disabilities, there would be less of a need to create special programs and laws for those with disabilities. Disabilities may become a thing of the past, allowing everyone to live normal, fulfilled lives. With the overall life expectancy increasing, families would be able to stay together longer, hopefully allowing younger generations to benefit from the knowledge of their elders.

People would be able to live longer and healthier lives, with less suffering from these genetic problems. This is why we view genetic engineering for medical reasons as acceptable.

4.4.2.2. Medical Enhancements

When medical changes are not made to preserve a person's life or cure a disability, but to improve the health of a person, the possibilities for medical enhancements are endless. People could be made to be resistant to outside influences, live longer, or have great medical capabilities.

With these possibilities, there are several consequences that could arise. For example, the possibility of longer life could change the social life cycle, possibly disrupting relationships

between old and young. Or, one would no longer have to be fearful of diseases such as AIDS, malaria, or SARS.

With a longer life due to medical enhancements, the life cycle of the society, the older generation giving way to the new generation, can be severely altered. If people live longer, and are still in good health, they may not wish to leave their jobs. This will cause the younger generation to have no jobs to fulfill, thus not allowing them to influence society as strongly. In addition, the total population of the planet would rise, contributing to the problem of overpopulation. (Beyond)

On the other hand, society has already adapted to people living longer and healthier, and other forms of medical enhancements. It is the general realization that these medical enhancements benefit humans that makes society actually strive to adapt.

However, the benefits of this kind of enhancement are obvious – the elimination of disease and less concern about injuries – and so we believe that even with the possible side effects, society will be able to adapt and ultimately this kind of genetic engineering is acceptable.

4.4.2.3. Cosmetic Modifications

We view cosmetic modification as a parallel to cosmetic surgery, and therefore believe that effects of genetic engineering for cosmetic modifications will be similar to those of conventional cosmetic surgery. Even though we are often taught to be happy with the way we are, many people decide they would still like to be different, and genetic engineering offers endless possibilities of making such changes.

Genetic engineering has the possibility of making cosmetic modifications easier and less painful, thus more people would be willing to undergo modifications.

We think that making extensive modifications, ones that drastically change the shape of the body from what we recognize as "human," is too extreme of a modification, an opinion that is

underlined by our survey results. This kind of modification would cause humans to not be able to recognize one another, strongly upsetting social relations.

4.4.2.4. Performance Enhancements

Performance enhancements are possibly one of the forms of genetic engineering that can have one of the greatest effects on society. They influence all forms of life that involve one human competing against another, from jobs, to sports, to how society views individuals. One of the consequences of performance enhancements may be that people judge each other on what performance enhancements they have. The human spirit for hard work, achievement, and sacrifice would be lessened since people would just be able to get any trait that they want added to their abilities. Since performance enhancements would most likely be expensive or not applied to the entire population, certain classes of individuals would then gain an unfair genetic advantage over the rest of the population. Any form of competition between two humans could almost be viewed as a competition between two manufactured robots. (Beyond)

In today's society, people judge each other on what they do, what they say, and how they look. With genetic engineering, people could gain skills that classically are held only by people with these gifts, or by people who acquired these skills through hard work. With the possibility of genetic engineering, one could no longer be certain how a person acquired his or her skills; he or she may just have had a performance enhancement. Thus, having gifts or having done hard work would no longer be important. In turn, humans would no longer strive to work hard to acquire their skills because they would not be recognized. Instead, people may begin to judge one another solely on what enhancements they have had done, which is simply a result of how much money and time they have spent on getting themselves modified. (Beyond)

Since genetic engineering may be relatively expensive, only people of wealth would be able to afford them. Since the wealthy could now be stronger and more intelligent than the rest of

the population, they would be able to shift the balance of power towards themselves even more. With the wealthy having greater natural talents, they would be able to keep and achieve higher levels of jobs, thus normal, unmodified people, would be more likely to take lower position jobs and thus make less money, which in turn means that they would not be able to afford the enhancements. (Kalbian & Shepherd)

Above, we used the analogy of two robots competing to describe the competition between two genetically modified humans. To illustrate, we would like to use the example of a baseball batter and a pitcher. The batter may have his eyes' accuracy and hand-eye coordination increased, thus giving him a better chance to hit the ball. To counteract this, the pitcher may have his arm modified so it is stronger and quicker to throw a faster ball. In turn, the batter may have his arms strengthened, and so on. This scenario is as if two engineers are designing robots to compete; the human factor has been removed from the competition. It is no longer the humans' talents or skills; it is their performance enhancements that are allowing them to perform their task. (Beyond)

Performance enhancements create genetic discrimination and destroy the human spirit of hard work and sacrifice to gain achievements. The human factor is removed from human activities; it is now just genetic modifications performing. Some people may be in favor of performance enhancements because they strive for power or simply an edge over their competitors; however, this power is gained unfairly. We believe that it is this inequality that speaks against allowing performance enhancements.

5. Conclusion

In our paper, we have shown how genetic engineering can be used for various purposes, which we have categorized into acceptable and objectionable purposes. Based on our discussions of four different uses of genetic engineering and the analysis of the views of four different social groups, we draw our conclusions on the uses of genetic engineering.

Humans strive towards preserving their lives, and we should responsibly and ethically use the technology available to us for that purpose. Hence, we find genetic engineering for medical reasons to be acceptable. It has the capability of saving lives that would otherwise be lost to genetic disorders and diseases.

Because we believe that humans have control over their own body, medical enhancements and cosmetic modifications are a tolerable use of genetic engineering. However, there are also limits to these changes. Cosmetic changes can theoretically be very extensive, with possibilities for changing one's body to appear as that of another species altogether. We find that this level of modification would upset the order of humankind so strongly that it is unacceptable to make such extensive modifications. In addition, one must be careful not to cross the line – as unclear as it may be – into performance enhancements when making medical enhancements, and we suggest a "better safe than sorry" policy, i.e. one that forbids enhancements that border on performance enhancements.

Performance enhancements create unfairness in human interactions. They can also upset the balance of society, and can easily be used to create an unbalanced population; with power being defined as one's genetically modified abilities. As such, performance enhancements should not be allowed.

An important question when it comes to any kind of genetic engineering is whether the individual knowingly decides to proceed with the modifications, with a full understanding of the

risks involved. As stated above, we believe that all humans have control over their own body, however not over other people. Therefore, we find it unacceptable to modify other individuals, be it an unborn child or an incompetent adult, including any germ line changes to oneself. The only exception is in the case of a medical reason, where it is necessary to modify someone else's genes to preserve their life or prevent a severe disability that would render them incompetent, however such a decision must still be made responsibly.

We have found that germ line modifications violate the right to free choice of an individual, thus they are unacceptable. In addition, germ line modifications may have the potential to homogenize the human genome, thus reducing genetic diversity of the species. Germ line modifications may have dire effects that cannot be known at the time of the modification.

At the time of the research and writing of this paper, the human applications of genetic engineering are only in their infancy compared to the views of the future. As this area of science progresses, it should be continuously evaluated to ensure that it is only responsibly and ethically used. We hope this paper gives usable guidelines for future applications of genetic engineering in humans.

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Appendix: Survey Results

Survey first announced on 3/31/2004, results as of 4/20/2004, 83 total responses.
The survey was presented in the form of an interactive website and was announced through electronic mail to the entire undergraduate student body of the Worcester Polytechnic Institute. Please contact the authors for raw survey results.
Note: Percentages indicated with "*Bio*" are the selection of responses where the Major is a biology-related field (27 total responses)

- Age
  - **1.2%** (1) 17
  - **18.1%** (15) 18
  - **30.1%** (25) 19
  - **19.3%** (16) 20
  - **16.9%** (14) 21
  - **4.8%** (4) 22
  - **2.4%** (2) 23
  - **2.4%** (2) 25
  - **4.8%** (4) No Response

- Major
  - **2.4%** (2) AE
  - **9.6%** (8) BB
  - **6.0%** (5) BBT
  - **3.6%** (3) BC
  - **8.4%** (7) BE
  - **3.6%** (3) BME
  - **1.2%** (1) BT
  - **7.2%** (6) CE
  - **1.2%** (1) CEE
  - **3.6%** (3) CM
  - **9.6%** (8) CS
  - **16.9%** (14) ECE
  - **13.2%** (11) ME
  - **1.2%** (1) MGE
  - **2.4%** (2) MIS
  - **3.6%** (3) PH
  - **1.2%** (1) Society Technology, Policy
  - **4.8%** (4) No Response

- Class Year
  - **20.5%** (17) 2004
  - **14.5%** (12) 2005
  - **26.5%** (22) 2006
  - **33.7%** (28) 2007
  - **4.8%** (4) No Response

- Religious Affiliation
  - **2.4%** (2) Agnostic
  - **1.2%** (1) Agnostic/Secular Jew
  - **9.6%** (8) Atheist
  - **2.4%** (2) Baptist
  - **1.2%** (1) Buddhist
  - **13.3%** (11) Catholic
  - **8.4%** (7) Christian
  - **1.2%** (1) Christian Orthodox
  - **1.2%** (1) Congregationalist
  - **1.2%** (1) Hindu
  - **2.4%** (2) Lutheran
  - **1.2%** (1) Orthodox
  - **1.2%** (1) Protestant
  - **3.6%** (3) Roman Catholic Christian
  - **1.2%** (1) Unitarian Universalist
  - **2.4%** (2) United Methodist
  - **45.8%** (38) No Response

- Ethnicity
  - **8.4%** (7) Asian
  - **1.2%** (1) Black American
  - **65.0%** (54) Caucasian
  - **2.4%** (2) Mediterranean
  - **22.9%** (19) No Response

- Family Income (as entered)
  - **1.2%** (1) 15000
  - **1.2%** (1) 20000
  - **3.6%** (3) 25000
  - **2.4%** (2) 30000
  - **1.2%** (1) 35000
  - **4.8%** (4) 40000
  - **1.2%** (1) 45000
  - **4.8%** (4) 50000
  - **1.2%** (1) 52000
  - **6.0%** (5) 60000
  - **2.4%** (2) 70000
  - **3.6%** (3) 75000
  - **3.6%** (3) 90000
  - **4.8%** (4) 100000
  - **1.2%** (1) 120000
  - **3.6%** (3) 130000
  - **2.4%** (2) 200000
  - **50.6%** (42) No Response

1. What is your opinion on cosmetic surgery?
    a. **0%** (0) No cosmetic surgery should be performed at all – *Bio: 0% (0)*
    b. **45.8%** (38) Only reconstructive surgery is okay (to correct physical defects and repair damages) – *Bio: 51.9% (14)*
    c. **21.7%** (18) Simple elective cosmetic surgery is okay (collagen injections, breast enhancements, etc.) – *Bio: 22.2% (6)*
    d. **32.5%** (27) Extensive plastic surgery is okay (face reshaping, limb extension) – *Bio: 25.9% (7)*

2. What is your opinion on the use of performance-enhancing drugs? (for sports and/or academics)
    a. **32.5%** (27) Should not be used at all – *Bio: 48.1% (13)*
    b. **42.2%** (35) Only drugs that correct deficiencies are okay – *Bio: 33.3% (9)*
    c. **10.8%** (9) Only drugs with a short-term effect (i.e. that do not change the body) are okay – *Bio: 11.1% (3)*
    d. **8.4%** (7) Only drugs that have been proven to have no side effects are okay – *Bio: 7.4% (2)*
    e. **6.0%** (5) All performance enhancing drugs are okay – *Bio: 0% (0)*

3. If genetic engineering were as safe as plastic surgery, would you change yourself? (multiple answers allowed)
    a. Medical Enhancements (changes that benefit health but are not medically absolutely necessary)
        i. **63.9%** (53) Yes – *Bio: 74.1% (20)*
        ii. **36.1%** (30) No – *Bio: 25.9% (7)*
    b. Cosmetic (changes that affect appearance)
        i. **22.9%** (19) Yes – *Bio: 22.2% (6)*
        ii. **77.1%** (64) No – *Bio: 77.8% (21)*
    c. Performance Enhancements (changes that affect your ability to perform certain tasks)
        i. **36.1%** (30) Yes – *Bio: 29.6% (8)*
        ii. **63.9%** (53) No – *Bio: 70.4% (19)*

4. Would you modify your genetic makeup (in any form – cosmetic, performance-enhancing, or medical) if your children would inherit those changes?
    a. **50.6%** (42) Yes – *Bio: 51.9% (14)*
    b. **49.4%** (41) No – *Bio: 48.1% (13)*

5. You have been diagnosed with a serious genetic disease, and you plan on having children. Would you…
    a. **61.4%** (51) Genetically treat (modify) yourself, and pass these modifications on to your children – *Bio: 55.6% (15)*
    b. **20.5%** (17) Genetically treat only yourself, so the changes are not passed on to your children, so that your children can decide for themselves – *Bio: 25.9% (7)*
    c. **18.1%** (15) Not use genetic engineering and use other forms to (attempt to) treat the disease, such as medication – *Bio: 18.5% (5)*

6. What would you consider going "too far" in terms of cosmetic modifications? (listed from least to most extensive)
    a. **14.5%** (12) No cosmetic changes at all – *Bio: 11.1% (3)*
    b. **10.8%** (9) Hair color, skin tone – *Bio: 7.4% (2)*
    c. **16.9%** (14) Body size / shape (taller, thinner, etc.) – *Bio: 25.9% (7)*
    d. **38.6%** (32) Forked tongue, extra finger, cat's pupils – *Bio: 33.3% (9)*
    e. **8.4%** (7) Extra limbs, pigmentation changes – *Bio: 22.2% (6)*
    f. **8.4%** (7) Unrecognizable as human – *Bio: 0% (0)*
    g. **2.4%** (2) No Response – *Bio: 0% (0)*

7. Your newborn child is diagnosed with deficiency (deafness, blindness, mental deficiency, etc.). Would you…
    a. **27.7%** (23) Let nature take its course and consider possibilities of medication or surgery – *Bio: 33.3% (9)*
    b. **72.3%** (60) Allow genetic modifications on your child to correct the deficiency – *Bio: 66.7% (18)*

8. If there were a certain small risk associated with modifying your genetic code, a risk that these changes might affect yourself or your future generations in a negative way, would you proceed with the modifications?
    a. **21.7%** (18) Yes – *Bio: 11.1% (3)*
    b. **78.3%** (65) No – *Bio: 88.9% (24)*

9. Assuming that genetic engineering will initially be very expensive (virtually unaffordable by the middle-class population), should insurance companies cover it so that it becomes available to the entire population?
    a. **42.2%** (35) Yes – *Bio: 37.0% (10)*
    b. **57.8%** (48) No – *Bio: 63.0% (17)*

- Selected Comments (edited for spelling)
    - "If insurance would cover it... I'm assuming it would cover just those instances listed as medically necessary..." *(Bio)*
    - "Severity is a big issue when dealing with genetic disorders, if something may increase the need for you to walk with a cane when you're older, it's less of an issue than if you are incapable of moving under your own power." *(Bio)*
    - "For question 8, in general I would say no, but given a significant health problem which were to be fixed, and a small enough risk, I would proceed. For question 9, I think it is important to note that, although I said yes, that only the procedures which would correct medical/health problems should be covered by insurance, NOT enhancements of any kind."
    - "For question 5, if I had been diagnosed, I would not plan on having children." *(Bio)*
    - "Mandatory coverage for these procedures by the insurance companies might be the fastest stimulator of price reduction. This coming from the fact that the procedures would both, receive research money from the insurance companies to

reduce the cost, and the increased number of patients receiving them would help spur this research."

- "Although it's great to say I'd be all for genetic modification for medicinal purposes, it is dangerous and would negatively impact the human race as a whole as it alters the progression of evolution and throws the Darwinistic theories completely out the window. The balance of nature would be disrupted as it cannot combat mutations and genetic divergence if we keep screwing around with it. Of course, there are those bound to want not so natural modifications, and those adjustments will prove to be detrimental to their genetic line. I guess they'd be doing us all a favor though and getting out of the gene pool for good." *(Bio)*
- "I do not like the idea of genetic modifications for trivial things, i.e., to enhance looks, athletic performance, etc. But in the case of benefiting a person's overall health, whether due to a genetic disease like diabetes, or a genetic defect, like blindness, I think it would be unethical to cautiously explore the use of genetic engineering as a treatment option." *(Bio)*
- "I think in helping to cure diseases that would be obviously beneficial, but as far as cosmetic or performance-enhancing qualities, it's like 'cheating' unless there is a certain physical or mental handicap that causes more suffering than higher quality of life."
- "I'd like to argue that cosmetic surgery is not safe. It's not as if breast augmentation is as easy as getting a new pair of shoes. Cosmetic surgery is definitely risky and can have many unwanted complications. [...] I feel that cosmetic surgery is ok to reconstruct what was damaged (for instance fire victims) but I would not personally fix a physical defect that I was born with. Also, if I were diagnosed with a serious medical disease, I would adopt one of the many healthy children that have no parents, assuming I even want kids. I also don't feel that the examples for body modification are necessarily in order from least to most extensive. I'd say that a forked tongue is more like a piercing, and that surgery to change one's body shape is more extensive and also much more damaging to the way which people view their natural bodies. Consider the consequences of perpetual improvement to the human shape. To me, this means devaluing the natural human body even more than it is in today's society, as well as creating a social pressure for more drastic body modification simply because the option is there. For women, who are already expected to strictly control their appearance, options for more drastic body modification will mean more pressure and consequently more shame for their unmodified form, continuing social trends that should be stopped rather than encouraged."
- "My answer to question 6 is a conditional. If a person wants to make them self far from human that's fine, as long as it is not for the purpose of harm, like becoming a beast to kill."
- "I have friends with CF and similar genetic diseases. I think it would be important to erase genetic diseases if possible, but to mutate someone's genetic code to create something that couldn't occur naturally is unacceptable."