THE ETHICS OF GENETIC ENGINEERING

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THE ETHICS OF GENETIC ENGINEERING

Just as the twentieth century was a golden age of computing, the twenty-first century is the DNA age. The silicon age brought about dramatic changes in how we as a species work, think, communicate, and play. The innovations of the computer revolution helped bring about the current genetic revolution, which promises to do for life what computing did for information. We are on the verge of being able to transform, manipulate, and create organisms for any number of productive purposes. From medicine, to agriculture, to construction and even computing, we are within reach of an age when manipulating the genetic codes of various organisms, or engineering entirely new organisms, promises to alter the way we relate to the natural world.

Biotechnology, specifically genetic engineering, is already a beneficial resource, employed in medicine, manufacturing, and agriculture. We have begun reaping the practical rewards of genetic engineering such as new medical therapies and increased crop yields and so far only a few instances of measurable harm have resulted. Genetic engineering has the potential to improve our health and well-being dramatically, revolutionize our manner of living, help us to conserve limited resources, and produce new wealth. Provided that it is appropriately regulated, bearing in mind ethical concerns relating to dignity, harmful consequences, and justice, its potential benefits outweigh its harms. There is certainly no reason to reject it outright as "unnatural." Biotechnology should be understood as an extension of already accepted and well-established techniques, such as directed breeding, combined with sophisticated understanding of evolution and genetic technologies.

As with any revolutionary technology, anxieties, fears, and moral objections to the promise of genetic engineering abound. Some are well-grounded and suggest caution, while others are the product of misinformation, religious prejudice, or hysteria. We should sort out those objections based on sound science and reason from those that are unfounded. Given the relative youth of the technology and the tremendous possibilities it offers for improvement of the human condition, as well as the environment in general, careful consideration of ethical implications now can help inform and ensure

the future of the genetics era.

As indicated, some significant moral implications ought to be taken into account as we go forward with genetic engineering. Some of the moral implications that we should consider carefully are discussed below in three clusters: first, general ethical concerns, both religious and secular, about the intrinsic immorality of genetic engineering; second, the potential beneficial and harmful consequences of genetic engineering; and finally, issues of justice, especially fair access to genetic therapies and enhancements. Note that given the scope of this paper there are many other ethical issues that are not addressed, such as the ownership of genetic information. This paper concentrates on what we regard as the major ethical concerns about genetic engineering. Before proceeding to these concerns, we will briefly review the science underlying genetic engineering.

The Basic Science

Deoxyribonucleic acid (DNA) is a remarkable molecule capable of directing the development and propagation of organisms. The organizational component of every life form on Earth is wrapped up in DNA's double-stranded molecular structure. Each organism carries within its DNA the instructions for that organism's every ongoing function, folded tightly in the nucleus of most of its cells. The same DNA exists in the organism's "germline" cells, used for reproduction, as in the organism's other cells (referred to as somatic cells); however, germline DNA, as opposed to somatic DNA, is used solely to create new offspring, forming a part of the set of instructions that are combined (in the case of sexual reproduction) with DNA from the other parent.

The DNA molecule consists of four nitrogenous bases, adenine, thymine, guanine and cytosine, on a phosphate-sugar "backbone," twisting in a double helix like a spiral staircase. A subunit of DNA, consisting of a base, a phosphate group, and a sugar, is referred to as a "nucleotide." Each thymine base is joined across the "rung" of the double helix ladder to an adenine base, and each cytosine base is joined with a guanine base. This structure is both elegant and remarkable. Because of the exclusive bonding of these base pairs, replicating a strand of DNA, and thus the instructions for the organism's development and each of its cells' ongoing metabolism, can be accomplished more or

less by simply splitting the DNA strand in two down the rungs of the ladder. Each half, split along the axis of its rungs, provides a template that will recombine with loose nucleotides to form exact copies of the original strand, with the help of special "proofreading" enzymes, and some other mechanisms of cellular reproduction.

The genetic code of organisms such as humans is complex, with nearly three billion base pairs. Those three billion base pairs are arranged in different sequences, yielding approximately 25,000 genes, each of which is responsible for some trait or facet of each of us. When combined with environmental factors, variations in the coding of those genes define our unique identities. Not every trait is cosmetic. While genes convey information about features such as hair and eye color, height, etc., they also convey information about important biological functions. Errors in the sequencing of some genes can produce genetic disorders.

There are more than four thousand known genetic disorders. These conditions and diseases may be chronic or degenerative or even latent and undiscovered for some time, but are ultimately harmful to the organism. In some cases, genetic disorders are the result of errors which creep into germline cells because of environmental factors; some errors creep into the genome as a result of copying errors during replication. In other instances, defective genes may be passed on through generations of parents where the trait has not been fatal. In many cases, genetic diseases remain as dormant, recessive traits waiting to be passed on to offspring of parents who both happen to have the recessive characteristic.

Over time, all of these means of genetic change have resulted in the current form of humans. The process of mutation, responsible for the emergence of genetic diseases, is also the underlying mechanism of evolution. Evolution is the process of genetic change over time, as some of these changes result in a fitter version of the species more apt to survive than others, and these advantageous traits are then passed on to succeeding generations. In some cases, the errors conferred a survival advantage in some environments while subsequently conferring a condition classified as a disease in other environments, as with the hemoglobin-s gene, responsible for the sickle-cell trait, which confers some immunity to malaria but also results in anemia (Levine and Suzuki 1993, pp. 35–38).

Most mistakes in DNA replication result in errors in the production of proteins.

Somatic cell DNA is essentially a protein-making code that directs cellular metabolism throughout an organism by controlling the production of essential proteins that direct the ongoing survival and functioning of discrete cells in every organ of the body. Because of tissue differentiation mechanisms, also part of the instruction set of DNA, different types of cells in the body produce different types of proteins. Certain genes in those organs are "turned on" and others are "turned off," directing the tissues of those organs to perform their own unique functions. Genetic diseases typically involve mistakes in an organism's DNA sequence that result in disruption in the normal production of a certain protein (Griffiths et al.1997). Cancers, however, typically involve damage to somatic cell DNA that disrupts cellular reproduction itself, not just metabolism or protein production.

While the actual mechanisms of genetic diseases are complex, scientists are learning more about their causes and how to detect them. Some of the relevant DNA changes occur in the gene causing the disease; other changes, while not present in the directly relevant gene, alter the functioning of that gene; a third type of change, while not causing a particular disease, indicates that the individual with that particular sequence is more susceptible to developing the disease. Many of these changes can now be detected and scientists continue to discover correlations between between specific DNA sequences and genetic diseases. By understanding these correlations, scientists could test for the presence of a particular disease, or the susceptibility to that disease, and perhaps devise cures based upon our knowledge of these relationships (Griffiths et al.1997).

We are a long way from understanding fully the complexity of the human genome, but we are making progress in understanding how certain genes work in humans and other species, including species that serve as sources of foods and medicines.

Besides the promise of treating or curing genetic diseases, manipulating DNA can enable scientists to develop new strains of organisms, including mice that serve as models of human diseases useful for pharmaceutical testing, or sheep that secrete medicines in their milk (Rebelo 2004). New strains of agricultural crops have been engineered, by inserting genes from animals or other plants, making them resistant to cold, disease, or pesticides (Myskja 2006, p. 228). In sum, as we learn about the specific functioning of genes in various species, we are able to develop new, useful life forms; manufacture new medicines; and improve human life, health and the environment.

But these medicines, therapies, and other products of genetic engineering present ethical challenges. For purposes of understanding these challenges, it is useful to distinguish different categories of genetic intervention (Allhoff 2005, p. 40). They are: somatic gene therapy, which aims at the treatment or prevention of disease without affecting future generations, and is the least morally objectionable; somatic genetic enhancement, which aims to improve the functioning of the individual; germline gene therapy, which aims at preventing disease, but involves heritable genes; and germline genetic enhancement, which aims to improve the functioning of future generations. Germline genetic enhancement is, not unexpectedly, the most controversial form of genetic intervention. Bioethicist Ronald Green makes the point forcefully: "enhancements are always more controversial than therapies or preventions, less likely to be funded by society, and more likely to be morally and legally prohibited if the risks to individuals or society are seen to outweigh their benefits" (Green 2005, p. 104). As this paper will discuss ethical issues arising out of all four types of genetic intervention, the reader should bear in mind the distinctions among the different categories of interventions.

Ethical Concerns

1. Objections to Genetic Engineering as Inherently Wrong

Some people object to any tinkering with the genetic codes of humans, or even of any life form. Some religious critics perceive genetic engineering as "playing God" and object to it on the grounds that life is sacred and ought not to be altered by human intention. Other objectors argue from secular principles, such as the outspoken and ardent Jeremy Rifkin, who claims that it violates the inherent "dignity" of humans and other life-forms to alter their DNA under any circumstances (Rifkin 1991). These arguments, while perhaps well-meaning, are not supported by sound logic or empirical evidence, as will be demonstrated here (Epstein 1999). Religious objections assume the existence of some creator whose will is defied by genetic engineering, and secular objections assume that life in its "natural" state, unaltered by human intention, is inviolable because of its inherent dignity.

a) Religious objections to genetic engineering

Arguments based upon life's sacredness suggest that altering life forms violates the will of a creator (Ramsey 1966, p.168), but they fail for want of internal theoretical consistency or because they rest on question-begging assumptions. If a creator does exist, most philosophers and theologians agree that either the creator's will is expressed in every facet of its creation, or that consistent with the creator's will mankind has free will, which includes the ability to create technologies (for a contrary view, see Prather 1988, pp.138–42). Thus, either genetic engineering can be seen as an expression of the creator's will—since it forms part of creation—or it is the result of our having been imbued with free will.

Granted, there are those who would claim that genetic engineering constitutes a misuse of our free will. Of course, determining what constitutes a misuse of our free will in defiance of divine directives depends on interpretation of those supposed divine directives. This is a problem with all moral theories premised on God's commands: what anyone believes to be commanded always depends on some human's interpretation of those commands. "Defying God's will" always means defying some person's interpretation of God's will. The difficulty of discerning a deity's wishes in the context of genetic engineering is compounded by the fact that none of the major religions' sacred writings speak to this issue. The Bible, for example, is silent on recombinant DNA. Furthermore, those who suggest that genetic engineering violates God's will must also view selective breeding of agricultural products, both plants and animals, as similarly contrary to God's will. If they do not view selective breeding as violating life's sacredness, then they must explain how it is qualitatively different from genetic engineering, which is in many ways only a quantitative or methodologically distinct process. The speed and predictability of the changes brought about by genetic engineering do surpass the speed and predictability of changes accomplished by selective breeding techniques, but that seems a poor argument for saying the former is contrary to God's will, while the latter is acceptable. Is it God's will that modifying nature is acceptable, but only provided we proceed slowly and haphazardly?

Our entire culture exists by virtue of human inventiveness and our modification of nature. Even religious sects that reject modern technologies nonetheless embrace some

technologies; the essence of technology is to alter the human relationship to nature. Clothing, agriculture, and weaponry have existed since before the dawn of civilizations, and each alters our relationship with nature. These technologies express a rejection of the "natural" order of things, and result from human consciousness and intentionality. In fact, embracing these technologies has altered human evolution, enabling us to venture outside of the savannah, and live in a variety of climates, defending ourselves from inclement environments and dangerous predators. Without these technologies, it is likely that humans would look very different, with different strengths and weaknesses from those we see now, and would have remained in relatively restricted environments instead of populating six out of the seven continents (and the seventh to a limited extent). As such, the history of our tinkering with the natural is long, and its results generally lauded by religious and secular alike.

Technologies such as antibiotics and contraceptives have interfered with the natural order of evolution, preventing the conception of millions of human beings, and enabling the survival of others who might have died through exposure to diseases. These technologies have affected not only human populations, but also numerous species where humans have interfered through medicines, contraception, and selective breeding. Those who oppose the alteration of genomes of humans and other species based upon some notion of the inviolability of natural processes must provide an ethical justification of the use of medicines, contraception, and selective breeding which somehow sets them apart from conscious, more targeted alterations at the genetic level. The technical difference between genetic engineering and these other mechanisms of altering the natural evolution of various species is the difference between a blunderbuss and a rifle. The blunderbuss approach we have historically taken, by the use of contraception, antibiotics, and selective breeding, results in unanticipated consequences: medical and social problems may result from selecting for certain traits by breeding, or by ensuring the survival of potentially unfit members of the species through the use of medicines, or even by preventing generations of potentially fit members of a species being born. Moreover, these techniques are not always reliable in achieving their desired results. By contrast, genetic engineering is a rifle that can be accurately focused on a desired target. Admittedly, genetic engineering may have undesired side effects as well, but, as

indicated, this does not distinguish this technique from currently accepted methods.

b) Secular objections to genetic engineering

Secular objectors to genetic engineering must defend the claim that the dignity of an individual member of a species, or of the species itself, is tied to its untampered-with evolution to its present state (Rolston 2002). This claim seems difficult to defend in light of the great infirmities—arguably indignities—that occur because of evolution, which is utterly indifferent to the suffering that results from many genetic disorders. Wholly innocent creatures lead lives of illness or degradation, or die prematurely because of genetic diseases. Where is the dignity in Lesch-Nyhan syndrome, a genetic disorder that results in uncontrollable self-mutilation (Preston 2007)? The dignity of individuals suffering from such infirmities is dependent not on their "natural" state, but on overcoming shortcomings or hardships.

Nature itself is indifferent to our dignity, and so altering nature cannot violate our dignity. In fact, it dignifies us to use the talents we have to alter our environment and our biology to improve our lives and those of the disabled. Technology in any form is an outgrowth of our intellectual abilities: at its best, it allows us to overcome natural shortcomings. Home heating and air conditioning violate the natural order, yet allow us to thrive in climates we otherwise could not survive. Few would argue that overcoming that natural disadvantage violates our inherent dignity.

Those who argue for drawing a line at altering the genome of humans or other organisms must give reasons both for regarding DNA as somehow special and apart from the rest of the natural world *and* for arguing that conscious manipulation of DNA is morally impermissible. There are some reasons to support "genetic exceptionalism," the point of view that DNA is unique, but those arguments do not necessarily imply: a) that because of this uniqueness there are absolute bars to altering it; or b) that if it is acceptable to alter the DNA of non-humans, it is nonetheless unacceptable to alter that of humans. Uniqueness does not itself imply any moral duty. In fact, every human being is "unique" by virtue of DNA, environment, and upbringing, but our moral duties toward each do not depend upon that uniqueness. Neither of the assumptions above can be sustained by logic or empirical evidence, and, as indicated previously, we have been

tinkering with genes in plants, animals, and even human beings, through selective breeding for millennia. Thus, the uniqueness of DNA has never forbidden us implicitly or explicitly to modify what we encounter in nature (Myskja 2006, 228).

Selective breeding can, over time, express genetic traits that are desired and suppress genes (and thus their phenotypes) that are undesired. Selective breeding manipulates the genome of a species, or subclasses of that species. As those who are familiar with various breeds of domesticated animals or plants, breeding for certain traits also has resulted in some instances in new and unanticipated infirmities. Genetic engineering allows for more selectivity in determining traits and in weeding out harmful traits or infirmities. It is arguably just a matter of degree rather than a qualitative difference in kind that separates selective breeding and genetic engineering. Those who oppose genetic engineering on moral grounds must make a coherent case that it is qualitatively different from selective breeding, or they must similarly oppose the selective breeding which has resulted in almost every aspect of our modern agriculture.

One of the problems in evaluating arguments based on "dignity" is in defining this concept. Many toss this word around without any explanation of its meaning. An extended and precise explanation of this concept is beyond the scope of this paper. It is sufficient to note that two leading philosophers with profoundly different ethical systems nonetheless had an understanding of the concept of dignity that does not seem to preclude genetic engineering. Immanuel Kant, insists that our moral duty is to treat other humans as ends in themselves, and not as means to any particular end. As Kant stated in his *Fundamental Principles of the Metaphysic of Morals*:

> In the kingdom of ends, everything has either *value* or *dignity*. Whatever has a value can be replaced by something else which is *equivalent*: whatever, on the other hand, is above all value, and therefore admits of no equivalent, has a *dignity* ([1785]1949, p. 51).

John Stuart Mill derives his theory of liberty from basic principles of human autonomy and self-determination. It is our autonomy and inalienable right to dispose of ourselves as we please that gives us dignity as human beings, distinct from creatures incapable of reasoning and intentional action (Mill [1859]1947). Under either of these understandings of dignity, modifying our genes either to rid ourselves of infirmities or to improve

ourselves is not inherently wrong.

The principle of human dignity supports democratic institutions and notions of moral equality (Kurtz 2000). As an empirically based principle, its justification lies in such facts as the more-or-less equal capabilities of humans, when nurtured through education, family, and supportive social institutions, to direct their own lives and share in self-governance, material support, and betterment. We are dignified because we have a tremendous capacity for cognition, creativity, growth, and emotional fulfillment. The notion of human dignity has a long historical tradition, being embraced by diverse philosophers such as Kant and Mill, and modern scholars and ethicists continue to regard this concept as important, as evidenced by the work of John Rawls. Rawls interprets human dignity as implying that we enter into a social contract treating each individual from the position of equality: "for in this situation men have equal representation as moral persons who regard themselves as ends and the principles they accept will be rationally designed to protect the claims of their person" (Rawls 1999, p.157). We have dignity in a way in which no other animal does, which is not to say that other animals lack dignity. (Creatures have their own dignity, inherent to their species and capacities). We are the only creatures we know capable of art, science, literature, architecture, and transforming our environment to accommodate our physical limitations.

The concept of human dignity is perfectly compatible with genetic engineering. Recognizing human dignity often means taking steps to ensure that where nature impedes human potential, everyone's human potential may be achieved to the fullest. The disabled and the infirm should be aided wherever possible, and consistent with their stated goals, to achieve their potential, consistent with the principle of avoiding harm to others. Indeed, recognizing the inherent dignity of our fellow human beings suggests that we are impelled to pursue genetic engineering research, to the degree that it can help to develop therapies and treatments for those who suffer or develop natural or accidental limitations (Bostrom 2003). Nor do enhancements pose an inherent threat to human dignity. Self-improvement is usually lauded, not condemned.

Clearly, some limits on genetic engineering also may be required by human dignity. Actions that diminish the capacities of others to achieve their potential are affronts to human dignity. Enslavement is the most extreme example, but less extreme

diminutions to human dignity abound. Treating others as means to a personal end, for instance, rather than as an end in themselves (also contrary to Kantian ethics) diminishes the dignity of the one who is used, and impacts the dignity of the user. Genetic engineering requires special attention to issues of equal access and even some restrictions on its applications where they may threaten subordination of some humans. Any invention used to diminish critical human capacities, such as cognitive functioning, would be unethical. Thus, while some people might benefit from a small race of humans genetically engineered to be slaves with diminished mental capacities this would clearly and egregiously violate human dignity (see, generally, Cooley 2007). However, these objections effectively raise the issue of harms resulting from the misuse of genetic engineering, not the inherent immorality of genetic engineering. The next section of the paper will discuss the potential harms and benefits of genetic engineering and the last section of this paper will expressly address the problem of justice as it relates to genetic engineering.

2. Benefits and Drawbacks of Genetic Engineering

a) Benefits

Genetic engineering has already supplied us with products that alleviate illness, clean up the environment, and increase crop yields, among other practical benefits to humanity and the ecosystem. For example, the first genetically engineered life form to be granted patent protection was developed by Ananda Chakrabarty, who genetically engineered a common bacterium into *Burkholderia cepacia*, a variant that digests petroleum products. He obtained a patent for his new life form, and helped establish the Supreme Court precedent that, to this day, enables inventors to patent genetically engineered life forms (*Diamond v. Chakrabarty* 1980). The bacterium cleans up oil spills and has proven to be both safe and useful. Since this precedent, tens of thousands of patents have issued for genetically engineered life forms.

Genetic engineering has also helped create thousands of organisms and processes useful in medicine, research, and manufacturing. Genetically engineered bacteria churn out insulin for treating human diabetes, production of which would be substantially more expensive without the use of genetic engineering. The OncoMouse (U.S. Patent

#75797027) was the first genetically engineered mouse to be patented for use as a model for cancer research. Numerous other "knock-out" mice have followed, each missing certain critical genes, or expressing certain genetic diseases, so that medical researchers can test drugs and other treatments for human genetic maladies without risking the lives of human subjects, and reducing the numbers of experimental animals sacrificed for science in the process. Gene therapy, in which manufactured viruses can deliver repairs to somatic cells with genetic defects, is making strides to correct genetic diseases or defects in fully grown humans.

Genetically engineered foods produce pest-resistant and drought-resistant crops, reducing the need for pesticides and fertilizers, and increasing yields in a world with an ever-growing need for food. Much of the so-called "green revolution" of the past few decades has been fueled by standard chemical technologies. New pesticides and remote sensing have enabled reductions in the amount of hazardous chemicals entering the ecosystem, and allowed farmers faced with an ever-expanding human population to meet the food needs of a planet. Nonetheless, insects and fungi, through evolutionary dynamics, develop resistance to pesticides. Moreover, even the best modern pesticides enter the food chain and the ecosystem, harming generations of humans and animals alike. Even in European countries like The Netherlands, farmers have recently had to switch from soil-growing plants to hydroponics due to the accumulation of toxic salts from fertilizers and pesticides (Levine and Suzuki 1993, p.176). The promise of new genetic engineering technologies includes the development of pest-resistant strains of crops that would require little-to-no pesticides, or robust drought-resistant plants that can grow in harsh environments without irrigation (Levine and Suzuki 1993, pp.185–86).

Genetic engineering also holds the promise of creating new, more productive strains of farm animals for meat and milk production. These new strains may be more resistant to infections, reducing the need for large, unhealthy doses of antibiotics (McCreath 2000, pp.1068–69). They may also be engineered to produce more meat, so we need not slaughter as many animals, or they may produce milk or other products with vital nutrients otherwise not found in those products, ensuring a healthier source of such nutrients. Eventually, as envisioned in Margaret Atwood's *Oryx and Crake* (2003), animal variants used as food sources might even be engineered without anything more

than an autonomous nervous system, arguably eradicating many of the ethical concerns involved with the wholesale slaughter of large mammals for food.

b) Drawbacks

Of course, we need to assess our actions in light of both short and long-term consequences to the biosphere. Although the scientific consensus is that genetic engineering poses few, if any, short-term threats to the environment, long-term threats, known and unknown, must be considered as we move forward with research and genetic technologies.

As mentioned in the brief introduction to the science underlying genetic engineering, somatic-cell and germline genetic engineering differ in important ways. Somatic cell therapy seeks to repair damage to cells that are not gametes. A creature with a genetic disease could theoretically be cured by somatic-cell therapy, and some advances have recently been made. One of the principal disadvantages of this process is its complexity. Repairing a fully grown organism means altering the genetic makeup of living cells.

Genetic engineering has made the most progress in germline alterations where the gametes of the organisms contain the altered DNA, and thus the organism's offspring carry the altered traits. This is the sort of engineering which has resulted in nearly every major scientific breakthrough and technological offshoot of genetic engineering (Myskja 2006). Altered bacteria, knock-out and other experimental animal models, and commercially available crops are among those that have resulted from germline genetic engineering.

Altering germ cells is a process that requires caution. Fertile organisms with altered germ cells may propagate beyond our control. This has happened with some genetically altered crops which have, in some instances, cross-fertilized non-engineered crops and spread their altered genes. This happened with Monsanto's "Terminator" corn, which renders its offspring infertile: farmers who chose not to use Monsanto's seeds nevertheless suffered the effects of infertile crops and could not use a portion of their crops to reseed because they had interbred with "Terminator" corn (U.S. Patent # 5723765, Control of Plant Expression). Seeds of neighboring non-genetically modified

crops were “terminated” by cross-pollination, although the effects seem to have been limited to the first generation (Ruiz-Marerro 2002).

Moreover, because of the complexity of most genomes, all the consequences of a particular gene’s alteration often cannot be predicted. In particular, how a genetically modified plant or animal might interact with other living things cannot be known for certain until it is placed in the wild, and, at that point, effective control over these interactions may not be possible. The controversy surrounding Bt-corn illustrates some of the possible dangers from genetically modified organisms. Bt-corn has genes from the bacterium *Bacillus thuringiensis* (Bt) spliced into it. The alteration is effective against the European corn borer, thus eliminating the need for excessive use of pesticides. The corn was shown to be safe for human consumption, but had an unanticipated and unintended consequence. In 1999, a Cornell study showed that the corn produced a toxin fatal to the larvae of monarch butterflies and this toxin could be found in the corn’s pollen (Losey et al. 1999, p. 214). Furthermore, as is often the case with plants in the wild, pollen from Bt-corn spread to surrounding plants, including milkweed, which is a source of nutrition for the butterfly larvae. Fortunately, subsequent studies have shown that the toxin is not sufficiently concentrated in field conditions to pose any significant harm to monarch butterfly populations (Sears et al. 2001). Nonetheless, no one had anticipated this problem, which illustrates how difficult it is to rein in the spread of pollen and thereby, in some cases, the spread of altered genes.

This dramatic incident underscores the potential for significant harm to the environment from genetic engineering, especially in this nascent phase where we are often unable to predict the consequences of germline genetic enchancement. Germline alterations, as opposed to somatic alteration, affect the gametes and thus propagate alterations, in unpredictable ways, to future generations of the altered species. Once a germline alteration is introduced into a species, evolution takes over for successive generations. Evolution, as we know, is unpredictable. The complexity of calculating potential successive generations exceeds our present knowledge about genes and their interactions not only epigenetically, with the environment, but also generationally, with other members of the species with which the progeny may interbreed. It requires that scientists and commercial producers of genetically altered life forms take particular care

to explore all the possible effects of their products, not just on humans, but upon the biosphere as whole. Currently, we have only educated guesses and interpolation from past examples of genetically altered species, but over time, as computing technology improves, those guesses will be refined. In the meantime, germline alterations should be carefully introduced in isolated communities so that generational effects can be evaluated for the dangers of a release of altered organisms in the wild.

Another dramatic example of specific harm from genetic engineering is the case of Jesse Gelsinger, who died shortly after an experimental gene therapy treatment for a genetic liver disease (Corzin and Kaiser 2005, p.1028). Although that case involved a research trial of an experimental protocol, it is conceivable that future gene therapies might introduce harmful effects into the gene pool, not necessarily resulting in death, but affecting future generations. The important lesson learned from this and other actual harms caused by experimental and even commercial genetic engineering is that the relationships between genes and phenotypes are far more complex than we currently understand. It behooves us to do adequate research and risk calculus for germline alterations that may affect all successive generations of a species.

New bioinformatics and modeling technologies should enable greater caution. Laboratory testing as well as field experience should be employed to forestall further harm to the biosphere. Assessing the actual risks of genetic technologies is fast becoming a major concern for scientists working in this area:

> The basic features of general risk assessment of GMOs [genetically modified organisms] are understandably different from those associated with chemicals. Genetically modified organisms are living organisms and therefore, unlike chemicals that may become diluted, GMOs have the potential to disperse to new habitats, colonize those sites, and multiply. Their novel activities, including the production of metabolic products, enzymes and toxins will occur as long as the GMOs remain metabolically active. Once established, living organisms cannot be recalled (Seidler et al 1998, p. 112).

One voluntary organization currently compiling and disseminating data for use in risk assessment is the International Centre for Genetic Engineering and Biotechnology (ICGEB) (www.icgeb.org). The organization has 55 member countries, not including the United States, who jointly fund research centers in India, South Africa and Italy, with

headquarters in Trieste. The organization maintains databases of genetically modified products in use, adverse field reports, and relevant statistics, as well as biosafety training and risk assessment tools for scientists engaging in genetic engineering research and applications.

As the tools for data gathering and modeling for genes, organisms and populations improve, so too should the practical use of risk assessment. Appropriate risk assessment will help minimize adverse consequences.

3. Justice and Equity

Ethical principles and concerns about justice should act as a check on technological advancement. As distinct from science, which ought to be free to investigate any area of nature without restriction, technology brings scientific advancements that impact both humanity and the planetary environment for good or for ill. Apart from direct benefits or harms that may result from genetic engineering, which we have already considered, there is also the problem of how genetic engineering may affect the distribution of social goods as well as political rights. Such issues are often referred to as problems of distributive justice. This paper cannot take on the task of defining and defending a comprehensive theory of justice; however, we will take as a given that great disparities of wealth and power are not, all other things being equal, desirable. They are especially undesirable if they result in great disparities of political power.

With the onset of genetic engineering, there is a concern that genetic interventions, especially genetic enhancements —or the reverse, deliberate genetic disabling—may exacerbate already existing inequities as well as creating new ones. In evaluating these concerns, we need to bear in mind that genetic engineering is still young. Some of the possibilities discussed, such as creating new species of superhumans or subhumans, seem highly unlikely, at least for the foreseeable future. We are a long way from developing H.G. Wells-style Morlocks to serve as our slaves (Green 2005, p.101). Nonetheless, although mad-scientist examples seem extreme, they are used by those who argue against the morality of using genetic engineering, and because many of these examples are within the range of technical possibility, they serve as useful illustrations

for the underlying principles.

Beyond science-fiction examples, immediate issues involving access and social stratification impact on current notions of justice and should be worked out in public debate, perhaps legislation (Mwase 2005). As with any new and expensive medical technology, non-socialized medical regimes in which genetic interventions become available will likely result in stratification of services and beneficiaries. There will be the class of those who can afford access to new technologies, and those who cannot. This will not be a unique situation, for already a number of elective and even necessary medical procedures are unavailable to the segment of the population that cannot afford them, or has inadequate or no health insurance. Inequality of access raises obvious social justice concerns where treatments or services are medically necessary which might not be available to everyone because of cost (Alhoff 2005).

As with cosmetic enhancements presently available, genetic enhancements threaten to create a class division between the "haves" and "have-nots." Even now, cosmetic surgery confers some tangible economic and social benefits on those who can afford it. While a genetic underclass of slaves seems far-fetched, consider, for instance, parents who decide they want their child to be a NBA (National Basketball Association) player, so they select for traits conferring height, stamina and intense athleticism. Such a genetically enhanced individual will enjoy benefits that no amount of training could provide for the most motivated, unenhanced person. In such a possible future, one of the means by which poor yet motivated people now move from an underclass position to one of economic security may well disappear, given unfair competition from players whose parents could afford genetic enhancement. Similar scenarios can be envisioned for a range of abilities, including intelligence, musical ability, physical attractiveness, etc.

Although possession of these traits now confers some social and economic advantage, it is now the result of chance and evolution (which is largely unpredictable). In a world where genetic enhancement is available but not readily affordable, only the rich will be able to stack the deck in favor of their children.

Of course we face similar social-ethical issues with other technologies, but in the realm of genetic modification, decisions are more complex. Cosmetic enhancements are not hereditable, but the possibility of a new genetic aristocracy is both technically

feasible and troubling. However, we must also recognize that it will be difficult to coordinate and establish rational oversight and regulation of germline modifications in humans while respecting both autonomy and the need to guard against social injustice. There is a presumption that self-improvement is permissible, if not laudable, even when it provides someone with a competitive advantage for herself and her offspring. We would regard as unacceptable legislation prohibiting someone from going to law school or medical school merely because she comes from a wealthy family and can easily afford the tuition. If use of one's money for a superior education is permissible, can we confidently say that use of one's money to alter one's genes to obtain a higher IQ for oneself and one's offspring is impermissible? For now, the technology is nowhere near marketable, so we have time for a clearheaded dialogue about the social justice issues associated with genetic modification by choice.

And there is a range of options that have been offered and need to be considered. Some authors, like Mehlman, argue for preemptive action, imposing rigorous restrictions on germline enhancement before it obtains a foothold:

> Bearing in mind that the consequences of unregulated wealth-based access to genetic enhancement could mean the destruction of the liberal state, it will be far too late to wait to act until after…the consequences have taken place (Mehlman 2005, p. 81).

Others counsel against hasty action: "I am opposed to the preemptive strike approach; its use in the area of biotechnology is as troubling and questionable as it is in the area of international relations" (Lindsay 2005, p. 32). One point on which most authors agree is that distribution of benefits as opposed to the nature of enhancements is the moral issue. The technology should not be completely banned or prohibited, but managed justly to ensure a stable and equitable social structure. It will be our job to monitor both scientific developments and governmental actions to maintain maximum social benefits.

Conclusion

Bioengineering has the potential to transform our lives in many positive ways. Rejection of this new technology on the ground that it is unnatural or inherently immoral is unwarranted and seems to be based on little more than an instinctive adverse reaction. Biotechnology is an extension of already accepted and well-established techniques, such as directed breeding, but with the distinct advantage of producing more predictable and more rapid results. There are risks involved with this new technology, but provided that it is appropriately regulated, its potential benefits outweigh its harms.

Legislators and other responsible decision-makers should not implement regulations that unduly restrict implementation of genetic engineering. In particular, existing mechanisms that ensure the safety of testing protocols should be sufficient for somatic genetic therapies for humans. With respect to germline enhancements for plants and animals, we recommend a better coordinated effort among relevant regulatory agencies, such as the Food and Drug Administration and the Department of Agriculture, to ensure there are no gaps in the regulatory framework. Enhanced organisms should be rigorously evaluated and tested in isolated conditions prior to their release in the wild. Germline alterations for humans should not be prohibited outright, certainly not in advance of their availability. However, given the special risks posed by human germline alterations, each proposed alteration needs to be carefully evaluated, not just with respect to immediate benefits and harms, but also with respect to the effects that the proposed alteration may have on our social structure and the distribution of social goods.

Some have compared genetic engineering to a Pandora's box. If mythological analogies are appropriate, the Center for Inquiry believes a better one would be a comparison to the gift of fire from Prometheus: genetic engineering can provide immense benefits provided it is used prudently and carefully regulated and controlled.[*]

[*] Note that minor wording changes have been made to the initial posted version of this position paper.

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