Genetic engineering involves directly altering the genetic structure of an organism in order to provide that organism with traits that are deemed useful or desirable by those doing the altering. For centuries, plant and animal breeders have attempted to produce organisms with useful or desirable traits, but this kind of breeding is not genetic engineering as it does not involve directly altering the genetic structure of an organism. Genetic engineering of plants and nonhuman animals has been going on only since the 1970s.

The most straightforward use of genetic engineering involves producing a plant or animal with "improved" characteristics. In the case of agriculture, for example, genetic engineering has produced crop plants resistant to lower temperatures, herbicides, and insect attack, as well as tomatoes with a longer shelf life. A completely different kind of genetic engineering involves transplanting a gene, usually a human gene, from one species to another in order to produce a useful product.

In 1982 human growth hormone and human insulin were produced by genetically engineered bacteria. Fifteen years later corn and soybeans have been genetically engineered to secrete human antibodies for herpes simplex and for treating cancer patients. With the advent of cloning of large mammals, it has become practical for genetic engineering to implant human genes in nonhuman animals such as sheep and cattle to produce similar substances in their milk. A patent has already been applied for to mix human embryo cells with embryo cells from a monkey or ape, which could create an animal that might have kidneys or a liver suitable for transplantation to human beings. There seem to be no limits to the creatures made possible by genetic engineering, e.g., creating edible birds and mammals with minimal brain functions, including no consciousness, so as to avoid protests about the CRUELTY involved in raising and killing conscious animals for food.

Genetic engineering of plants and nonhuman animals has caused some controversy, primarily because of environmental, health, and safety concerns. However, most of that controversy was similar to concerns raised by traditional breeding practices and the introduction of plants or animals to completely new environments. Genetic engineering of plants and animals is now a generally accepted practice. The major moral controversy concerns whether to allow directly altering the genetic structure of human beings themselves. However, genetic engineering that is done by altering the somatic cells of an individual in order to cure genetic and nongenetic diseases has not been controversial. Indeed, what is known as somatic cell gene therapy is becoming a standard method for treating both kinds of diseases.

Unlike the genetic engineering that is used in plants and animals, somatic cell gene therapy alters only the genetic structure of the individual who receives the somatic cell gene therapy; the altered genetic structure is not passed on to that individual's offspring. However, now that it is possible to clone large mammals such as cows and sheep, it may be possible that genetic engineering of human beings done by altering somatic cells may also be passed on to FUTURE GENERATIONS.

Currently, somatic cell genetic engineering is limited to therapy; there has not even been a proposal to use this form of genetic engineering for enhancement. Clinical trials using human patients have demonstrated the feasibility of somatic cell gene therapy in humans, successfully correcting genetic
defects in a large number of cell types. In principle, there is no important moral distinction between injecting insulin into a diabetic's leg and injecting the insulin gene into a diabetic's cells.

The most serious moral controversy concerns the application of the kind of genetic engineering that is used on plants and nonhuman animals to human beings. This kind of human genetic engineering, usually referred to as germ line gene therapy, is regarded by some as the best means to correct severe hereditary defects such as thalassemia, severe combined immune deficiency, and cystic fibrosis. But many believe that genetic engineering to treat or eliminate serious genetic disorders, that is, the practice of negative eugenics, will lead to genetic engineering directed toward enhancing or improving humans, that is, positive eugenics. But this slippery slope argument presupposes that there is something morally unacceptable about positive eugenics, and that has not been shown. No one has yet provided a strong theoretical argument that shows that genetic engineering to produce enhanced size, strength, intelligence, or increased resistance to toxic substances is morally problematic.

Eugenics properly has a bad connotation because prior to the possibility of genetic engineering, eugenics could be practiced only by preventing those who were regarded as having undesirable traits from reproducing. Genetic engineering even allows for positive eugenics without limiting the freedom of anyone. If there were absolutely no risks at all in positive eugenics, that is, in germ line genetic enhancement, it would be difficult to imagine what would be morally objectionable about it. The moral force of the objection that eugenics is “playing God” is that we do not know that there are no risks. A proper HUMILITY, that is, recognition of limited human knowledge and human fallibility, is required for reliable moral behavior. A strong argument for concluding that genetic enhancement and perhaps even genetic therapy is morally unacceptable is that it risks great harms for many in future generations in order to provide benefits for a few in this generation.

Two standard arguments have been put forward that even negative eugenics should not be practiced. The first of these is that it will result in the elimination of those deleterious alleles which may be of some future benefit to the species. The argument is that the genetic variation of a species affords evolutionary plasticity or potential for subsequent adaptation to new and perhaps unforeseen conditions. To eliminate a deleterious mutant allele, like those responsible for cystic fibrosis or sickle cell anemia, could have some risk. It is generally agreed that the recessive gene responsible for sickle cell anemia evolved as an adaptive response to malaria.

This argument is false for two different reasons. The first concerns the nature of genetic maladies. For maladies based on the inheritance of recessive alleles, it is not the presence of two mutant alleles that causes the malady, rather it is the absence of a normal allele. As long as a normal allele is present, the mutant alleles do not cause a genetic disorder. Even if the situation of heterozygote advantage, as in the case of sickle cell anemia, were common, which it is not, gene therapy for recessive disorders will work even though the mutant and nonfunctional alleles still remain. However, when it is possible, not merely to add a gene, but to replace a nonfunctional mutant allele, nonfunctional alleles will no longer remain. This kind of gene replacement procedure will expand the range of candidate genetic maladies subject to gene therapy to those caused by dominant alleles. But no evolutionary problem is caused by eliminating dominant genes that cause serious genetic disorders such as Huntington's disease.

Almost all genetic disorders are caused by recessive genes and it seems quite unlikely that there will
be any serious attempt to eradicate these genes from the human gene pool, even if it becomes possible. The technology required must be applied on an individual basis with rather limited accessibility. Because it is a surgical procedure, germ line gene therapy would be done in a medical setting and on a voluntary basis. So although many couples might qualify for gene therapy, only a small number would elect to participate. Finally, the vast majority of deleterious alleles that are recessive are maintained in heterozygous condition by carriers. Since there would be no reason to perform gene therapy on heterozygotes, the frequency of deleterious alleles would still be maintained at high levels. For example, if germ line gene therapy involving gene replacement could be developed for Tay Sachs and was used to treat all homozygous Tay Sachs embryos (which occur at a frequency of 1/2,000), the frequency of the Tay Sachs allele in the entire population would decrease only from 0.01000 to 0.0099 over one generation.

The second argument is that since it is impossible to draw a nonarbitrary line that distinguishes positive from negative eugenics by defining what a genetic disorder is, even genetic therapy may cause more serious maladies in future generations than it prevents for the present generation. However, genetic conditions like hemophilia, cystic fibrosis, and muscular dystrophy all share features common to other serious diseases or disorders, such as cancer. An objective and culture-free distinction can be made between genetic conditions that everyone counts as diseases or disorders and those that no one does. Even if there are some borderline conditions, it is theoretically possible to limit genetic engineering to those conditions about which there is no disagreement. If genetic engineering is used only to cure serious genetic maladies such as Tay Sachs, it is extremely unlikely that more serious genetic maladies will be created in the future.

While there is no theoretical reason for not using germ line gene therapy, there is a persuasive argument, based on real world considerations, that concludes that all forms of germ line genetic engineering involving humans should be prohibited. This argument, similar to the argument against genetic enhancement, claims that even genetic therapy risks great harms for many in future generations, and that there is not sufficient harm prevented to justify these risks. Not only is genetic therapy, like genetic enhancement, permanent during the entire lifetime of the affected individual, but the transgene also becomes heritably transmitted to countless members of future generations.

Facts about basic genetic phenomena are now being discovered. For example, five human genetic disorders have been found that are based on mutations involving expandable and contractible trinucleotide repeats. This baffling and novel mechanism for producing mutations was totally unpredicted and there is currently no complete explanation for its cause. Similarly, geneticists have only recently discovered another novel and unpredicted phenomenon, genetic imprinting. For a small but significant fraction of genes, in humans and other species, the expression of the gene during early embryonic development varies according to its paternal or maternal origin. The biological role of imprinting, and the molecular mechanism responsible for selective gene expression, remain mysteries. But the effect of genetic imprinting and trinucleotide expansion, in terms of carrying out germ line gene therapy, may be critical. Problems may not be discovered until the third or fourth generation. It seems quite likely that more new unpredicted future findings about basic genetic phenomena will be discovered which carry similar risks.

Given even this small possibility of significant harm to many, an analysis of risks and benefits indicates that germ line gene therapy would be justified only in cases of severe maladies. Further, germ line gene therapy would be justified only if there were no less radical way of preventing these
severe maladies from occurring. However, pre-implantation genetic screening, in which embryos are first produced by in vitro fertilization, does provide such an alternative. At an early blastocyst stage of development, when the embryo is at the eight or sixteen cell stage, a single embryonic cell is removed and screened, genetically, for the presence of defective alleles. If analysis reveals that the fetus would develop a severe genetic malady, the embryo would not be implanted. If analysis reveals that the embryo has no severe genetic malady, uterine implantation would be carried out so that normal development would occur.

Pre-implantation screening will eliminate essentially all severe genetic maladies that can be eliminated by genetic engineering. For those with religious or metaphysical beliefs that prohibit destroying any fertilized human egg, it should be pointed out that genetic engineering usually involves creating more fertilized eggs than one plans to use, since implanting of any fertilized egg, including a genetically altered one, is often not successful.

Consequently, pre-implantation screening eliminates the need for germ line gene therapy. The number of cases in which both parents are homozygous for a rare deleterious recessive allele, such as cystic fibrosis, is vanishingly small. Genetic engineering, then, is necessary only for improving or enhancing people by adding new genes for strength, intelligence, or for resistance to pathogens or toxins. Genetic engineering to add improvements rather than to eliminate defects may give rise to serious social and political problems.

Gene therapy will be, for the foreseeable future, a very expensive procedure. Thus, only the wealthy will be able to afford it. Germ line gene therapy probably comes as close as is humanly possible to guaranteeing that those families who can afford it will be able to perpetuate their social and political dominance. Thus, together with cloning, it may give rise to a genetically stratified society as envisioned in Huxley's *Brave New World*. Once this technology is well developed, it could be used by those societies in which those in power are not governed by ethical restraints. People may be genetically engineered to provide various tasks, e.g., as warriors. Imagine a group of people engineered to be resistant to various poisonous gases, e.g., sarin. However, these concerns, although genuine, are speculative.

On the other hand, we know from experience that cutting edge TECHNOLOGY, including genetic technology, generates pressures for its use. Consequently, it is likely that if genetic engineering were permitted, it would be used inappropriately, that is, it would be employed even when a comparable outcome could be accomplished using a less risky method. There is justified concern that genetic engineering advocates will make claims that the risks are less than they really are, and the benefits are greater than will be realized. It is at least disconcerting that proponents of germ-line gene therapy do not talk at all of the far less risky alternative of pre-implantation screening.

If every scientist, administrator, and venture capitalist involved in applying and commercializing genetic engineering were appropriately thoughtful, there would be much less reason to prohibit its development and application for those rare cases in which it could be the therapy of choice. However, based on the real world risks that were just described, there is insufficient potential benefit to justify any human genetic engineering. Until certain knowledge of the real risks and benefits associated with human genetic engineering has been obtained, the potential risks to all of the descendants of the patient outweigh any benefit to a very small number of persons who might benefit. In the event of an unanticipated harmful outcome of genetic engineering using mice or corn,
the transgenic organisms can be killed, but clearly this option cannot be used with humans.

It takes only a few scientists who have convinced themselves that they know that the risks are only imaginary, and that the benefits are real, for human genetic engineering to become a field in which scientists compete to be first. Prospects of national and international recognition, of prizes, awards, patents, and grants, of all measures of status, wealth, and POWER, are potent incentives to overstate successes and benefits, to take unacceptable risks, and to dismiss valid objections. The extraordinary loyalty of scientists to one another, their reluctance to interfere with any research project that their scientific colleagues wish to pursue, make it very likely that some misguided projects will be carried out.

Technology that is not needed to prevent great harm, and poses even a small possibility of causing great harm to many people, cannot be justifiably used to provide benefits to only a few, even if those benefits are great. The presence of the less risky alternative procedure of pre-implantation screening of embryos changes the moral situation. In cases where no great harm is being prevented and a great number of people may be put at significant risk, caution must prevail. Even if there is no chance of completely stopping germ line gene therapy, it may be possible to delay it long enough that the technology is developed that enables scientists to repair a gene rather than replace it. Similarly, it might have been better if the building of nuclear power plants had been delayed until they were designed so there would be no chance of a nuclear explosion or meltdown. Indeed, it may have been better to postpone building them until acceptable plans for disposing of nuclear wastes had been developed.

The human genome project involves mapping the entire genome, that is, showing where each gene is located: not only which chromosome it is on, but where it is located on that chromosome. It also involves sequencing each gene, that is, showing how each gene is built up from the base pairs that make up a gene. Most defective genes involve a change in a few of these base pairs, often only one. Gene repair involves changing the base pair or pairs that are causing the problem. This form of genetic engineering has far less potential for disaster or misuse than the kind of genetic engineering now being considered. Further, the concept of gene repair reinforces the difference between gene therapy and gene enhancement. It would be inappropriate to regard making any change in a gene as repairing it unless that gene is both different from the standard form or allele and results in some genetic malady. Limiting human genetic engineering to the repairing of genes would dramatically lessen the risks of such engineering while not preventing any of its therapeutic benefits.

See also: AGRICULTURAL ETHICS; ANIMALS, TREATMENT OF; BIOETHICS; BIOLOGICAL THEORY; ENVIRONMENTAL ETHICS; EVOLUTION; FUTURE GENERATIONS; HARM AND OFFENSE; LIBERTY, ECONOMIC; MEDICAL ETHICS; NATURE AND ETHICS; PUBLIC HEALTH POLICY; REPRODUCTIVE TECHNOLOGY; RISK; SLIPPERY SLOPE ARGUMENTS; TECHNOLOGY; TECHNOLOGY AND NATURE.

Bibliography


https://search.credoreference.com/content/entry/routethics/genetic_engineering/0

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