FUTURE STORIES OF HUMAN EVOLUTION

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Evolution Religion

Writing dispassionately about human germline genetic engineering and its potential consequences – if any – for the human species is not for the faint of heart, especially if you're a scientist who has actually practiced the art on other organisms. So, I will state at the outset that my speculation about a technology unlikely to have any impact on humanity during my lifetime is to stimulate thought, not change the world. I am neither an advocate nor an opponent of the technology. My interest lies in understanding the deep feelings of anxiety, fear, and anger expressed by so many educated people when the subject is broached even indirectly. Where do all of these emotions come from? For some, the answer lies in spiritual beliefs. For others, it is spiritual aversions

To get a sense of how American adults-at-large think about genetic engineering, *Harper's Magazine* commissioned a telephone survey, in 1997, that began with the following question, 'If you had to choose one of the following, *who* should have the power to control the genetically linked characteristics of a child before birth.' Possible answers were 'only the parents;' 'only the doctor;' 'only God;' or 'no one.' Less than 1% chose the doctor and only 11% chose the parents. The overwhelming first choice, with 70% of the vote, was God. But 'no one' placed second with 16%.[1]

In his popular book *Human Heredity* written in 1959, Ashely Montagu the famed anthropologist, lamented the fact that 'many people still think . . . that at conception, the blood of the mother mixes with the blood of the father, and it is in this way that the offspring come to exhibit a mixture of the traits of both parents.'[2] Not anymore. Today, everyone who watches television or reads a newspaper knows that *blood* is just an old metaphor for *genes*, the true material carriers of heredity present in the egg and sperm. At the same time, belief in a super-human spirit or spirits remain as strong, in most people, as it has ever been. The two influential memes of spirituality and material genetics become intertwined in a Western culture built upon a Judaeo-Christian tradition of tight linkage between body and soul. A potential conflict between the roles played by God and genes is resolved by imagining that God *uses* genetics as a tool in the creation of each human being.

While genetic differences may distinguish us in this worldview, our genetic commonality is the God-given framework for humanity. How God created this framework is imagined differently by fundamentalist Christians and other more highly educated people. In survey after survey, 45% to 50% of Americans express the view that 'God created human beings pretty much in their present form at one

time within the last 10,000 years or so.'[3] To go beyond God's singular creation, in any way, clearly smacks of hubris to those who reject past evolution. Another 40% of Americans are willing to accept the fact that 'Human beings have developed over millions of years from less advanced forms of life,' but believe that 'God guided this process.' In this spiritually-influenced evolution conceptualization, genes have been added and altered by an external force that built up human beings piece by piece. If the force worked in the past, many emote, we should not challenge it in the present. Two-thirds of Americans explicitly choose God as the external force that should be giving out genetic gifts. A significant number, however, put their faith in 'no one,' presumably because they don't view God according to traditionalist doctrine, but they believe in a Mother Nature that can somehow pick genes better than parents. In either vision, not always consciously acknowledged, we have no right to do God's or Nature's work, even if the outcome is beneficial to the child.

According to a proclamation passed by the Council of Europe in 1982, 'the right to inherit a genetic pattern which has not been artificially changed' is essential to human dignity. French Anderson, a leader in the field of post-birth gene therapy, wrote that 'to provide a gene [in an] attempt to improve on normal [is] . . . misguided or malevolent.' As Harvard professor Michael Sandel warns, 'genetic engineering . . . [represents] a *Promethean* aspiration to remake . . . human nature, to serve our purposes and satisfy our desires. . . [But] not everything in the world is open to whatever use we may desire or devise. Appreciating the gifted quality of life constrains the *Promethean* project and conduces to a certain humility. . . The problem [with genetic engineering] lies in the *hubris* of the designing parents. [all emphases are mine]' Prometheus was a mythological Greek character who stole fire from the gods to give to humankind; as a result of his act of *hubris* (taking on powers that rightly belong to God or Nature), Zeus (the top god) had him chained to a rock where a vulture ate out his liver, which grew back to be eaten out again every day.

This, Sandel warns, may be the fate of future humankind if we don't mend our ways. The best response was given by the great geneticist J.B.S. Haldane: 'The chemical or physical inventor is always a Prometheus. There is no great invention, from fire to flying, which has not been hailed as an insult to some god. But if every physical or chemical invention is a blasphemy, every biological invention is a perversion.' Haldane voiced this retort in 'a paper read to the heretics' of Cambridge, England on February 2, 1923.[4]

Anderson, the Council of Europe, and Sandel seem to be claiming that a child with genetically enhanced better-than-normal protection against cancer and other common diseases (for example) will be worse off than a normal child. Francis Collins, a medical doctor and, in his own description, a serious Christian doesn't buy it: 'To say that genetic engineering is unacceptable across the board because of its potential for creating some ethical dilemmas is the most unethical stance of all. It's to basically say, here is a powerful approach which could alleviate human suffering, but we're not going to do it because we're worried about the misuses that might occur. I find that completely unacceptable from every possible point of view, most profoundly, [from] the theological one.'[5] In fact, when safety issues are overcome, it is not each individual use of the technology that causes anxiety in many learned people. It is their fear that humanity will alter what God or Mother Nature created as his or her final masterpiece. Mark Frankel, Director of the Program on Scientific Freedom, Responsibility and Law at the American Association for the Advancement of Science expresses this fear when he writes, 'Existing methods of enhancement, from pharmacology to advanced music lessons, are aimed at the current generation of adults and children. They are not biologically intrusive in a manner that will significantly shape our evolutionary course.'[6] Bill McKibben, an environmentalist who worried about *The End of Nature* in a previous book, explores his hope in *Enough* that our emotional instincts will overcome our rational ones so that humankind will remain unchanged: 'our gut revulsion at the coming 'enhanced' world is consciousness trying to save itself.'[7] And French Anderson proclaims, 'Our genes do not belong to just ourselves. The gene pool belongs to all of society. No individual has a right to intentionally change the gene pool without the consent of society.'[8]

A few critics fear that biotechnology will 'risk a fatal interruption' in a future evolutionary destiny that *should* occur.[9] The conservative *New York Times* columnist William Safire wrote, in his condemnation of human reproductive cloning, 'the continued interplay of genes . . . is central to *humankind's progress*.' The feminist legal scholar Lori Andrews lamented similarly, 'there is a concern that [human] cloning will *interfere* with evolution.' In his admonishment to physicians who want to prevent transmission of mutations responsible for cystic fibrosis, sickle-cell anemia, and Tay Sachs from parents to their children, anti-biotech advocate Jeremy Rifkin writes, 'a rich reservoir of genetic diversity is essential to maintain the viability of a species against ever-changing environments and novel external challenges. . . recessive traits and mutations are essential players in the evolutionary schema. They are not mistakes, but rather options, some of which become opportunities. Eliminating so-called

'bad' genes risks depleting the *gene pool* and limiting future evolutionary options. Recessive gene traits are far too complex and mercurial to condemn as simple errors in the code.' [10]

To gain insight into the confusion between science and spirituality that underlies all fears of evolutionary *interference*, we need to understand the germ of truth at the scientific core. The most important environmental factor that has actually caused significant genetic change in human populations during the last thousand years is competition with other living things. We long ago won the battle against large organisms – lions, tigers and bears – but many people are still killed and maimed by microscopic viruses and bacteria. And genes providing protection against particularly virulent microorganisms can often increase in frequency among people living in endemic areas. One recently discovered example is a gene named CCR5. About 10% of the people in Northern Europe today carry a variant of CCR5 that appeared in about 1200 AD as a mutation in a single man.[11] Over the following centuries, this genetic variant provided the man's descendants with protection against bubonic plague, which swept across Europe several times, killing a quarter of the entire population in the worst outbreak between 1347 and 1350. The same CCR5 variant, by chance, also provides protection against infection with HIV, the virus that causes AIDS. But thousands of other genes, well-known to scientists, provide people with protection against thousands of other infectious viruses and bacteria. They all began as mutants, most before our species came into existence. Because they were beneficial, these immune system genes were eventually passed into all living descendants. The general public never hears about these genes because every healthy person shares in their protective properties.

Almost all the thousands of genes that protect people in some way have no negative side effects and are not detectable in anyone who carries them. But there are a tiny number of exceptions. The first discovered and best known are variants in blood proteins that provide protection against malaria, still common across tropical regions of the world; the most prominent of these protective variants – carried by 5% of Americans of African descendent – causes sickle-cell anemia when inherited from both parents. A mutation in another gene provides people with protection against typhoid fever, which was prevalent in sewage-infested Medieval cities; this mutation is carried by 5% of present-day Northern European descendants and causes cystic fibrosis when inherited from both parents.

Contrary to what Rifkin claims, each of these protective mutations *did* occur as a simple random error in the code. Random errors occur all the time, and the vast majority are not beneficial in any way whatsoever now or tomorrow. Neither individuals nor populations save up mutations for future use.

Although Rifkin is fond of using the 'gene pool' as a scientific-sounding metaphor for a whole-species spirit, the term is just an abstract mathematical function invented by population biologists to add up the varieties of genes carried by groups of individuals. With each generation, the constitution of gene pools change as some individuals reproduce and others don't. While the size of a gene pool might be important in assessing the survivability of an endangered inbred species, the human species is far from endangered and far from inbred. Indeed, if 95% of the people in the world today were vaporized by a meteorite, the remaining human population and gene pool would still be greater than at the time of Christ's birth, and greater than that of any other comparably-sized mammal ever in existence.[12]

In evoking the image of a species spirit, Rifkin and Anderson conflate *individual* well-being with *population* well-being. Population well-being makes sense for conservationists who aim to prevent the extinction of plants and animals. From this perspective, the survival of any particular individual is not important. One endangered giant otter is the same as the next endangered giant otter, as long as enough of them reproduce to maintain a population of anonymous otters into the future. In contrast, it is precisely the well-being of individuals that matters most in a humanitarian society. If a new plague threatens people, an ethical and effective society will find a way to *protect* them and their children. In the face of malaria, cholera, tuberculosis, and AIDS, developed countries don't rely on genes carried by a fraction of individuals to maintain a future population. They rely on clean water, sewage treatment, education and the products of medical research to provide maximal protection and treatment to all of their citizens today. In the US, where malaria was eradicated over a century ago, worthless malaria protection genes cause only *grief* with the birth of 50,000 children each year who suffer from sickle cell anemia. Similarly, people in the US and Europe do not benefit from any genetic protection against typhoid fever, but they do suffer the birth of children with cystic fibrosis.

Another common misperception is that genetic adaptation will be required for human beings to survive in a changing climate. Our species history over the last 10,000 years shows otherwise. Human populations with minimal genetic differences have survived and prospered simultaneously in incredibly diverse environments. Bedouins roamed the dry Arabian deserts under a baking sun; the Inuit dwelled among snow packs above the Arctic Circle; Amazon tribes prospered in a humid rainforest filled with dangerous animals; and New Yorkers now live in a jungle of steel, brick, concrete, and glass. We survived through past eras of global warming and Ice Ages, and thus we – ourselves – could prosper in cold and warm, dry and wet, places as well. Cultural adaptation is much quicker, and modern

technology increases the power of adaptation immensely, bringing warm coats and heat to cold zones, and air conditioning to hot ones. Local climate-changing technology, of course, requires large energy inputs, mostly provided by fossil fuels today. An important fact to keep in mind is that daily global energy use today is comparable to less than 0.01% of the daily energy provided to the Earth by the sun. It's a good bet that as fossil-fuel sources become exhausted in the future, economic considerations will drive the development of efficient technologies for capturing solar energy, directly or indirectly from windmills or tides. In addition, physicists have great hope in the future feasibility of harnessing the nearly unlimited and clean energy of nuclear fusion.

The mythology of future evolutionary *interference* is also abetted by false analogies between future evolution and progress, and between evolution and development. Unfortunately, even some scientists use the words *development* and *evolution* interchangeably. For the sake of clarity, *development* should be limited to the process by which an individual organism matures from a simple embryo into an adult animal, mostly according to a predefined developmental program present in the embryo's DNA. There is no question that chemical and physical disruptions can *interfere* with the developmental process. And if biological evolution were simply *development* writ large, the potential for evolutionary interference might thus be inferred. Nevertheless, while the progressive outcomes for our species and its members may seem the same, the processes are fundamentally different. Most importantly, organisms do not contain any future evolutionary program. Neither is there a master plan lurking in any species as a whole. Faith in the *natural* evolutionary process as an agent for the betterment of humankind derives fundamentally from faith in a species spirit – an *élan vital* – directed by God above or within Mother Nature herself.

Evolution Ethics

Traditional cultures seem so entrenched, so eternal, so much a part of a people's heritage that the introduction of a culture-altering element can be viewed as a crime against society. Cultures can, however, undergo very rapid changes that are quickly eliminated from cultural memory. Pizza and spaghetti with Bolognese sauce seem quintessentially Italian, while *pomme frites* (French fries) have always been eaten by the French, and boiled potatoes are a traditional component of a German dinner. But whatever the Italians, French, and Germans were eating before 16th century European explorers returned home from the Americas, it

couldn't have contained either tomatoes or potatoes since neither existed outside the New World. For the same reason, rice could not have been part of the Mexican diet, and pigs could not have been raised by natives of South America or the Caribbean before Columbus arrived.

Many other characteristics of so-called "traditional" cultures are foreign-born and more recently incorporated than commonly realized. An ironic example for people who find French wines superior to American varietals is that the roots of all French grapevines are American in origin.[13] In the late 19th century, a tiny but lethal root-infesting aphid began to spread across European vineyards. The only way to save the French wine industry was to transplant American vines into the soil, and then graft on French branches to produce grapes.

Can a society's genes change as rapidly as its cultural memes? The short answer is almost certainly not anytime in the foreseeable future. Some disease-protective genes have, indeed, increased in frequency among certain populations over the last several thousand years, but the primary defenses used today by developed countries against infectious diseases are cultural inventions. This is not to say that we are guaranteed permanent cultural protection. In theory, a newly emergent microorganism could defy attempts to control it and wreak havoc as the bubonic plague did before the availability of antibiotics. Then protective immune genes would provide some with a better chance of survival, and the frequency of such genes would increase in future generations. In sub-Saharan Africa, where societies' leaders have been neither ethical nor effective in dealing with the current AIDS epidemic, very few people are protected by the genetic variant found in 10% of Northern Europeans. But even if the same percentage were protected, the dependence upon a genetic variant to 'overcome' a disease is equivalent to sacrificing the majority who, by chance, are not genetically-endowed with protection. This is both senseless and immoral when preventive public health strategies and medicines are available. Thus, if natural selection in favor of HIV resistance genes or any other disease protection gene occurs, it will be a tragedy for humanity, not a triumph. Even in this worst case scenario the genetic basis of humanity itself would not be fundamentally altered because disease resistance genes have nothing to do with our ability to communicate with each other and create culture.

The contradiction between modern humanity and natural evolution lies within the fundamental mechanism through which all evolutionary changes occurred in the past. Genes – good, bad, or indifferent – are inherited randomly without any consideration to the specific needs of their direct

recipients, let alone future generations. But in every plant and animal population, certain mutant genes provided individuals with the ability to survive and reproduce more effectively, or kill off other members of their species who did not carry the same variants. Even in the context of cultivation and domestication, certain randomly-appearing mutant genes increased the likelihood that particular plants or animals would be selected by a breeder to parent the next generation. Darwin grasped the equivalence in mechanism and outcome of *artificial* selection brought about by conscious human choice, and *natural* selection that occurs independently of human beings. He used the dramatic changes produced in cultivated species as the main pillar of evidence for his theory of evolution.

People themselves don't have to play by the same rules. First, in liberal democracies, a modern ethic of universal rights to life and liberty prevents people with one kind of a gene from curbing the reproductive output of those with a different kind of gene. Second, in developed countries, with broadly available healthcare and social services, the vast majority of people have an equal opportunity to find partners and reproduce. Third, while all other creatures are slaves to their genes and the reproductive instincts they evoke, men and women alone can consciously choose to limit the number of children they bear. In highly developed countries, the vast majority fail to live up to the reproductive potential encoded in their genes, and in Europe, North America, and Japan, native populations are even in retreat. With a widespread conscious choice to forgo babymaking, mutations that enhance aspects of higher mentality and creativity responsible for the development of human culture and ethics – intelligence, morality, beauty, talent, self-awareness – do *not* provide people with a reproductive advantage over the norm. A mathematical protégé or brilliant musician or selfless provider of refuge services will *not*, on average, have more babies than an auto mechanic. Since babymaking statistics are the only currency used by natural evolution, modern humanity seems fundamentally incompatible with natural evolution of the genes that define the critical features of humanity itself.

Although both the percentage and absolute number of people living within liberal democracies has grown dramatically over the recent centuries, it never has, and still doesn't, encompass all. In some repressive societies – most visibly in today's Middle East – institutionalized polygamy allows a few ruling men to monopolize the reproductive capacity of multiple women. Genetic variants could play a significant role in determining who gets to have multiple wives – and, thus, more babies – in these societies. In addition, large portions of humanity still live in underdeveloped countries where genes can also play an important role in determining success in life and reproduction. Simultaneously, in

developing countries like India, the population is expanding rapidly. If these population growth trends continue, the balance of genetic variants could shift slowly, and the traits associated with different racial groups today could become more or less common in the global community. But does any of this matter for the critical features that define humanity at large? The answer depends on the total population size, the continuation of travel links among all communities, and the general persistence of civilizations with technological capabilities at or higher than those in existence today. Simple statistical analyses show that when a population size is larger, it takes longer (more generations) before an advantageous new mutation can spread throughout. The emergence of *Homo sapiens*, 100,000 years ago, was only possible because it occurred within a founder population of fewer than 10,000 individuals living in East Africa. As long as a single interbreeding world community exists with 300 million or more members (just 5% of the number today), mathematical calculations show that natural evolution of the human species in any significant way can *not* occur before the Earth as a whole loses the capacity to support life in a few billion years, when our sun burns out.

A few caveats are in order. In theory, modern civilization, along with its high level of scientific knowledge and technology, could be destroyed by an external catastrophe or a human-induced disaster, both of which have been repeatedly portrayed in popular films and science fiction novels. Perhaps it's naïve optimism that leads me to believe humanity can avoid these hypothetical civilization-destroying scenarios, as long as the Earth supports life. The process of racial and cultural divergence – underway for the last 50,000 years in isolated geographical locations – has been reversed by global communication and transportation. Continued globalization will blur the lines further, which will ultimately benefit those in today's poorest societies. A single incredibly diverse humanity could emerge after hundreds or a few thousand years. Karl Marx – whose naivety about the malleability of human nature is now broadly recognized – may have been remarkably prescient in his 1848 observation and prediction that what we now call a global marketplace '. . . draws all, even the most backward, nations into civilization. . . It compels all nations, on pain of extinction, to adopt the bourgeoisie mode of production . . . In one word, it creates a world in its own image.'[14]

Pessimists, however, point to the collapse of nearly all pre-modern civilizations as historical evidence that the modern global village must collapse eventually as well. In this regard, the first years of the new millennium do not seem encouraging, with challenges to democracy from fundamentalists of all religious faiths on all continents. But the collapse of all the individual empires around the pre-

Modern world were just negative blips along an upward spiral. When viewed from afar, the last 10,000 years of global human history is a record of continuous cultural, technological, and ethical advancement.[15] By extrapolation, even if the worst catastrophe befalls us, the resulting upheaval will not last long enough to have any significant impact on the evolution of humanity. In any future scenario (other than complete human extinction), cultural and technological knowledge will survive somewhere, and in a few generations, people will re-organize their industries and re-establish their democracies.

Throughout the nearly four-billion-year history of life on Earth, it has always been the individuals at the top end of one inheritance curve or another who have driven evolution. The ones in the middle were out-competed and became extinct; those at the top became the middle of the next wave; and new mutations created new individuals at the top ends of new curves in a never-ending game of one-upmanship called natural selection. But with the eventual globalization of modern civilization, rare individuals at the top of any curve will have no greater chance at reproducing than those in the middle, and in the game of natural selection, reproduction is the only way to score. Our species seems to have reached a unique point in evolution where it has turned around and stopped the Darwinian forces that always mattered in the past, perhaps forever. So does this mean we are at the end of the evolutionary line?

Unnatural Evolution?

Until just thirty years ago, inheritance could not be controlled directly. Genetic variants appeared randomly and were only recognized by their effects on isolated plants and animals after birth. Then, and only then, could breeders intervene by selecting which individuals to use for the next generation of mating. During the late nineteenth century and early twentieth century, some intellectuals proposed controlling human reproduction in the same way to counteract a 'weakening of the human gene pool' caused by a lenient civilization that protected those born with genetic defects. They claimed that the species could only be saved through societally-imposed eugenic restrictions on individual babymaking. Today, modern liberal democracies reject the application of such selective techniques to human beings. Law-abiding adults are allowed to decide for themselves whether to have babies or not and, upon birth, all viable children are accorded a right to life. But ironically, the beliefs that drove eugenics – a misunderstanding of evolution, and the conflation of individual well-being with a whole-species well-being – also lie at the heart of modern opposition to genetic engineering.

The difference between the old genetics and the new genetics is often missed, but it is critically important in terms of any evaluation of the technology by academics and lay people alike. In the same survey of Americans that uncovered 86% support for the right of God or 'no one' to control genetically linked characteristics *in the abstract*, people were presented with a subtly different multi-part follow-up question that referred to a child of their own who was already on the way: 'If you were *expecting* a child, how important would controlling the following [genetic] characteristics be to you.' The first characteristic was 'immunity from disease;' 84% said that genetic control was either 'very' or 'somewhat important.' The second characteristic, 'intelligence,' garnered a 64% positive response as well. These are the kinds of responses that scare Professors Francis Fukuyama, Michael Sandel, French Anderson, Leon Kass, Bill McKibben and other intellectuals from the right and left who think that a shortsighted predilection for benefiting one's own child is an unwarranted challenge to God or Mother Nature who will rise up and punish humankind for its transgression.

As I write these words, a generalized method of genetic engineering is nowhere near ready for utilization in human reproduction. The reasons are several-fold. First, practically no one *needs* genetic engineering for their children to survive. If two people have the genes required to reach adulthood, combinations of their genes should produce children who will be at least as healthy as they are (except in very rare cases). Second, although the generic human genome is decoded, scientists have just begun to scratch the surface in terms of knowing which genetic variants give some children significant advantages over others in most biological realms. The single variants responsible for thousands of simply inherited diseases have been uncovered, but the genetic influence on characteristic differences among 'normal' people is usually attributable to multiple variants at many genes interacting with environmental factors. These complex traits have yet to be teased apart into individual genetic and environmental components. As a result, general modifications large numbers of potential parents might eagerly desire cannot yet be put on the design table. A third brake is the fact that optimization of a genetic engineering protocol for safe human use will be an extremely expensive undertaking, and without a large target population or governmental backing, it won't be financially feasible. Fourth and finally, as Leon Kass – chairman of President Bush's Council on Bioethics – correctly observed, 'man does not live by rationality alone.' Whether our emotional impulses represent deep spiritual wisdom, as he believes, or are the products of evolution, as I believe, they inform the decisions most people make and cannot be ignored. The balance between individual autonomy and societal values is a delicate one.

As long as a majority of citizens are strongly opposed to the use of a controversial technology that is not required to save existing human lives, the principles of democracy will bid scientists not to proceed.

Some intellectuals think this situation will last forever. But forever is a long time, especially considering the speed at which genetic technology has advanced. It was not until the mid-1970s that a method was invented to look directly at DNA differences between people. A molecular biologist had to work hard for three days to get results on a single blood protein encoding gene from forty people. Now the U.S. National Institutes of Health expects $1,000 kits to be available by 2015, to decipher the complete sequence of individual people. In just forty years, genetic diagnosis technology will have advanced from looking at one letter of the DNA sequence to looking at all three billion letters, for about the same cost, and much less labor and time.

A note about the distinction between what scientists call 'formal genetics' and 'molecular genetics' is required here. Formal genetics has its roots in the pea experiments performed by Gregor Mendel in the nineteenth century. Formal geneticists identify groups of people who do or do not express a disease or other genetically-influenced characteristic. Then they search for genetic variants that show up in one group but not the other. In 1989, a team led by Francis Collins first applied this approach successfully to the identification of genetic variants that cause cystic fibrosis. Initially, Collins had no idea how the gene worked. But formal genetics made it clear that people or embryos with one type of variant would become diseased, while others would not. In theory, without knowing anything else, a genetic engineer could replace one version of this gene with another and prevent disease. However, once a genetic correlation is made, molecular geneticists jump in to study the product of the gene and understand how variation causes the disease.

Each individual (other than identical twins) is born with different degrees of genetic advantage and disadvantage at *starting points* along thousands of bell curves that specify different aspects of health and talent. Genes are certainly not the only things that matter in life. There is no doubt that inadequate environments can restrict the expression of a person's natural potential. In fact, across the world today, circumstances of birth and other arbitrary life events – rather than genes – play a far greater role in determining health, social status and income level for a majority of people. Furthermore, people vary widely in how well they use what they inherit under any circumstances. We all know 'under-achievers' and 'over-achievers' . However, in a truly vigorous meritocracy, where environmental advantages and disadvantages are minimized, inherited components of appearance, abilities, emotionality, and

personality come to the fore in determining who succeeds and who fails in all aspects of life. So notions of equality become elusive. In the U.S. today, some middle-class children of modest means can perform well enough in public schools to get need-based scholarships to the best universities where they out-compete classmates who attended private preparatory schools. But other Americans born with both modest means and capabilities are unable to thrive.

Genetically influenced complex traits will depend on difference in not one gene, but rather, different *constellations* of genetic variants. Complex genetic constellations will only be identifiable when all genes are compared in very large numbers of people, an impossibility just two decades ago. But, in fact, a British government and foundation consortium has begun a project called the BioBank in which they plan to study 500,000 people in all possible ways for a thirty year period. BioBank is not alone. Pharmaceutical companies are also studying very large numbers of people so they can develop an individualized approach to healthcare based on genetic constellations. If this information were used in conjunction with genetic engineering (which is not the intent of current researchers), parents could provide their children with the same advantageous genetic attributes that some other lucky children inherit naturally. Meanwhile genetic engineering technology – practiced on animals – advances in magical ways. Regions of the DNA sequence varying in size from thousands of letters to just a single letter can be precisely targeted for alteration. Genes have *already* been inserted into the mouse genome with failsafe switches; give the animal a special potion to drink and all copies of the gene self-destruct In 2001, another unexpected finding (called RNA interference) provided a powerful engineering tool for eliminating the effects of misfiring genes.[16]

It's nice to hope that a future globalized society will provide the means for all people – not just those within a rich country's borders – to live free and healthful lives, taking advantage of the benefits that biotechnology can provide. But the econometric tool of *future discounting* should dispel any belief that hope for a *distant* future can be translated into present-day action. If we assume conservatively that our base of knowledge and technology continues to increase by just 5% each year, then our current-day techno-scientific tools will represent less than 1% of the technology available a century from now, and less than 00.0001% of the technology available in 300 years.[17] Clearly, it makes no sense to worry about, or try to control, a society so far in the future that we can't possibly understand it. Instead, the focus of biomedical research and treatments should be on the well-being of individuals in the world

today and the planet and society they leave to their children, grandchildren, and great-grandchildren, but not beyond.

Nevertheless, we can still be intrigued by ideas and questions we have little hope of resolving. It is fun to wonder whether human beings will ever find evidence for intelligent life elsewhere in the universe, and it is fun to ask whether genetic engineering could *ever* change the nature of humanity. Leon Kass presented, what I think, is the most straight-forward philosophical argument against the possibility: 'Man is the peak, both in possessing the *highest*, and also in possessing the *complete range* of, faculties of soul [according to Aristotle's definitions]. Even looking to the future, what could be higher than man? . . . Granted, we could be, and might in time become, more intelligent, more alert, less forgetful, more energetic, etc. but can we imagine for ourselves or for our souls anything really new . . . the story of the ascent of soul may already be complete.'[18] Kass' views emerge from his belief in the traditional Judeo-Christian conceptualization of the human soul as the divine endpoint of God's creativity, for 'on the seventh day God ended his work,' according to the book of Genesis (2:2). But our genes, at least, show no evidence of being at the end of any line. Yet like Kass, I can't imagine what it means to be 'higher' than man. But we should be humbled by the fact that not even *Homo erectus* could have imagined what it was like to have the mind and language instincts of a normal *Homo sapiens.* If there is such a thing as a post-*Homo sapiens*, *Homo sapiens* can't possibly perceive its nature from our vantage point today.

Does it even make sense to talk about the *possibility* of a posthuman being? Spiritual people are often disturbed by the very question because it reeks so strongly of a hubristic challenge to God or Mother Nature. Whereas pragmatically minded molecular geneticists dismiss or ignore it because to themit reeks of a spirituality and magic, antithetical to the practice of good science. However, to paraphrase Kass, 'can we imagine' that a technology nearly within grasp, whose benefits could be preserved and amplified – ever so slightly – with each generation, could possibly *not* change humankind after thousands or millions of years? Experts tend to overestimate what technology can do in the short term, and underestimate the long term because, as Arthur C. Clarke wrote in 1962, 'any sufficiently advanced technology is indistinguishable from magic.' Air conditioners, airplanes, antibiotics, automobiles, cameras, computers, cyberspace, genetic diagnosis and engineering, iTunes and iPods, in-vitro fertilization, magnetic strips on credit cards, MRI scans, radios, refrigerators, telephones, television, vaccines, and a multitude of other biological, chemical, and physical technologies would

have all seemed like magic if described to even the most educated people of past generations. No doubt, magic will happen in the future as well. What a shame we won't be around to experience it all.

Notes

[1] *Harper's Magazine* poll conducted between 10.29/97 and 11/2/97. Telephone survey of 1002 men and women over 18. Margin of error is +/-3%.

[2] Montagu, A. (1959) *Human heredity,* World Pub. Co., Cleveland,.p.52

[3] The Gallup Poll. August 24-26, 1999

[4] Haldane, J. B. S. (1924) *'DAEDALUS or Science and the Future' A paper read to the heretics, Cambridge on Feb. 4, 1923,* E. P. Dutton, New York.

[5] Transcript of PBS documentary, 'Faith and Reason.' Accessed from the following website on June 14, 2004: <http://www.pbs.org/faithandreason/transcript/margaret-body.html>

[6] Frankel, M. S. (2003) *Hastings Center Report,* **33,** 31-36.

[7] McKibben, B. (1989) *The end of nature,* Random House, New York; McKibben, B. (2003) Audio Renaissance,, New York.

[8] Stock, Gregory and Campbell, John, editors (2000) *Engineering the Human Germline*, p.47.

[9] Rifkin, J. (1998) *The Biotech Century : harnessing the gene and remaking the world,* Jeremy P. Tarcher/Putnam, New York. p.146

[10] Rifkin, J. (1998) *The Biotech Century : harnessing the gene and remaking the world,* Jeremy P. Tarcher/Putnam, New York. p.146

[11] Dean, M., Carrington, M. and O'Brien, S. J. (2002) *Annual Review of Genomics and Human Genetics,* **3,** 263-292.

[12] The current human population size is 6.2 billion. Subtracting 95% of this number leaves behind 310 million. The estimated size of the total human population in 1 A.D. was 170 million.

[13] Christy Campbell, *Phylloxera: How Wine Was Saved for the World* (New York: HarperCollins, 2004).

[14] Marx, K. and Engels, F. (1964) *The Communist Manifesto,* Washington Square Press, New York,. p.64-65

[15] Wright, R. (2000) *NonZero : the logic of human destiny,* Pantheon Books, New York.

[16] Elbashir, S. M., Harborth, J., Lendeckel, W., Yalcin, A., Weber, K. and Tuschl, T. (2001) *Nature,* **411,** 494-8.

[17] The *discount factor* is the future worth, in proportional terms, of a present-day commodity. It is calculated as $1/(1+r)^n$, where r is the annual rate of depreciation, and n is the number of years in the future.

[18] Kass, L. (1985) *Toward a More Natural Science : biology and human affairs,* Free Press, New York.