

BioHacking

Biological Modification and the Future of Homo Sapiens

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Social Issues in Computing
27 April 2020

Abstract

The Biotech and Genetic revolutions are advancing at a feverish pace. Where once we played dice with the selective breeding of plants and animals, we are now capable of nucleotide-level precision in the changes we can make to the source code of life. Just as the 20th century was the century of physics, the 21st century will be the century of biology. With tools like CRISPR, we will become the designer of our own design. While we advance and change the very meaning of life, we must also advance our ethical norms. As the scientists spearheading these revolutions, the future of our society and our species is in our hands.

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1. Introduction

In the early 1950s we unlocked two nuclei: fusion and the cell. It is remarkable how little these discoveries have changed our lives and how much we still resemble our ancestors from thousands of years ago. With continual advances in these technologies, we stand on the precipice of great change.

Should we be playful, excited or terrified by this? We have been capable of genetic manipulation for quite some time. For thousands of years, we have been breeding plants and animals to meet our growing needs. Recently, our tools have become orders of magnitude more powerful, more precise, and less expensive in time and materials. Where once we had to rely on chance for desirable traits, we can now precisely aim towards the changes we want.

Advances in biotechnology are rapidly opening up the world of human genetic modification. Once we start changing our traits, we will not stop. We cannot think of nature as separate from us and of ourselves as “screwing with nature.” We are nature, nature is us and nature is always changing. This makes nature natural to hack and we Homo sapiens, with tool usage as our comparative advantage, are natural hackers.

Today we expect that our next phone will be better and faster than the last, but we think of our biology as static. “I am Homo sapiens and my kids are Homo sapiens.” With technologies like CRISPR, we are rapidly moving into a world where we will be able to edit our genomes at will. Every day there are not just additional stories of applications of CRISPR, but new types of gene-editing tools. The ability to rewrite our source-code is going to cause a fundamental shift in our self-perception.

Computational biology and data science are driving the expansion of our knowledge about ourselves. As biologists and data scientists spearheading these revolutions, we bear the lion’s share of responsibility in

moving the world forward. With growing insight into ourselves, we are beginning to see some profoundly disturbing data, along with unsavory interpretations of those data. Many of our cherished values as human beings are coming into conflict with the emerging science.

Our story will play out along three trajectories: the utopian, the dystopian, and the impasse. Only through honest and rigorous conversation and by engaging with the public from the very beginning can we avoid stagnation and impasse. Through such conversation, we will each be able to move the dial a little in the direction of the utopian or a little in the direction of the dystopian. We need to infuse the conversations about values and norms into the development of these technologies while also integrating science into our social decisions. With this upcoming clash between our technological and social needs, can we use our new powers to find a graceful exit? Conversation might be the only portal available.

2. Background

The history of genetic manipulation by humans includes plant and animal breeding, GMOs, IVF, the Human Genome Project, and CRISPR.

2.1 Selective Breeding

Selective breeding of plants and animals has been practiced since prehistoric times (Buffum). Modern species of wheat, rice, and dogs are different from their wild ancestors. Maize, i.e. corn, required especially large changes from its wild form, teosinte. Sources from as long as 2,000 years ago give advice on selecting animals for different purposes, and these works cite still older authorities, such as Mago the Carthaginian (Lush). These old methods are clumsy and imprecise. We would breed species together in the hopes of generating some desired phenotypic trait. Some of our other methods were quite outrageous. We would bombard plants with radiation, find the rare plant with a desirable trait, e.g. seedless grapes, and then produce more of that plant.

With animals, we have bred swine for meat (University), horses for performance (Evans), and dogs, cats, and birds as pets. In 2013, researchers at the University of Istanbul created glow-in-the-dark rabbits (Rojhan). Sea-jelly genes were engineered into the bunnies' genomes, granting them luminescence. These bunnies were bred in an effort to create animals capable of producing medicines in their milk. We have

continued such genetic experimentation on animals, with mice being the chief test subjects.

2.2 Genetically Modified Organisms

With the invention of techniques around Recombinant DNA, we developed Genetically Modified Organisms, i.e. GMOs. These include Golden Rice (Xudong et al.), herbicide-resistant (Funke et al.) and insect-resistant (Paine et al.) crops. Recognizing the power of Recombinant DNA, the scientists involved congregated at Asilomar in the early 1970s to establish principles to ensure the safety of this budding technology (Berg et al.). However, there was no public engagement during the early developments and fear among the public has persisted since. This fear and the public's resulting unwillingness to proceed has stunted the science.

2.3 In Vitro Fertilization

Our first steps down the path of human genetic engineering have been with IVF. This involves the extraction of human gametes after which a small number of fertilized embryos are created in a lab. After some time, these are implanted in a womb with the hope that some will take root and a child will be borne to term. The first IVF pregnancy was reported in 1973 (Kretzer et al.) but it resulted in an early miscarriage. The first IVF birth occurred in Oldham, England on July 25, 1978 (Steptoe and Edwards). Since then, IVF has grown in popularity. IVF births account for 2% of the births in the United States, 5% in Japan, and 10% in Norway and Denmark (Metzl). These numbers will continue to rise. Having taken conception outside of the human body, entirely new sets of possibilities are now open for us as a species.

2.4 Genome Sequencing

Since the completion of the Human Genome Project, the cost of sequencing has been falling towards negligibility (Wetterstrand). With this ability to cheaply read our genomes, we are starting to demystify our biology. Among other developments, we have learned how to identify Down Syndrome during pre-natal screening (Natoli et al.), and are able to diagnose various genetic disorders in fertilized embryos during IVF (Rycke and Staessen). We have also been able to identify and categorize over 5,000 single-gene-mutations, i.e. Mendelian disorders. These include sickle cell anaemia, color blindness, muscular dystrophy, and cystic fibrosis. This has opened up choices for which embryos to implant through IVF.

2.5 CRISPR

In addition to reading genomes, we now have the ability to arbitrarily edit genomes. The invention of CRISPR/Cas9, Clustered Regularly Interspaced Short Palindromic Repeats and CRISPR-associated protein 9, has opened up the world of genetic editing (Zhang, Y. Wen, and Guo). CRISPR works on genomes much like a text editor works on strings. There is a guide-RNA, the cursor, that can be placed at any desired nucleotide. From here, string of any length can be deleted or replaced by a different string. This lets us make extremely precise edits to genomes at low expense of power and time. The near-term applications of tools like CRISPR include potentially curing all Mendelian disorders, while long-term applications include rewriting large sections of human genomes to make “designer babies.” In fact, the first genetically edited babies were born in China in October 2018 (Harney, Kelland, and P. Wen). Dr. He Jiankui announced the birth in videos on YouTube saying that he edited the twin girls’ CCR5 gene to grant them increased resistance against HIV. The Russian scientist Dennis Rebrikov has announced that five of his patients have signed up for gene-edited babies (Cohen).

3. Viewpoints and Personal Opinions

The emerging biotechnologies are going to have species-wide impacts. With this realization, different people have come to different views around the various developments.

3.1 Public Engagement and Discourse

It is essential to keep the public engaged from the very beginning with new and powerful technologies and their implications for our society. While the scientists involved with Recombinant DNA showed a great sense of responsibility in the conference at Asilomar, they lacked this crucial engagement with the public. Scientists often communicate in a coded language. While this is great for idea transmission within academic communities, the general public needs the jargon translated. The public lack of understanding of this field has bred fear and uncertainty around GMOs. The ensuing lack of public support has stunted growth in this field. Indeed, a science can die from not engaging with the public.

There is, however, a strong argument to be made for the position that we should let these developments fly under the radar. Scientists are, by and large, responsible and we should let them do their work.

The near-term application of technologies like genomic sequencing of embryos during IVF include diagnoses and cures for such terrible ailments as Tay-Sachs disease. Poking the hornets' nest may cause people on one side or the other of the abortion issue to build and man new barricades. We should let this emerge in much the same way as IVF did. By the time the issue drew public attention, people in evangelical communities were already speaking in their churches of the miracle of life.

I believe that we are talking about technologies that are everyone's business and we need to respect each other enough to have this conversation out in the open. We cannot afford to make the same mistake that we did in the beginning of the GMO era. Will our conversation around genetic manipulation lead us to adaptive fears which would cause us to come up with wise restrictions for how we do our science and engineering? Or will we spend our time worrying about the wrong thing because some benign modification catches the public eye and causes a panic that shuts down the science? Can we figure out which fears are adaptive and which are maladaptive?

3.2 Designer Babies

We have many bugs in our genetic code. These cause our children to die from genetic diseases and our elderly to suffer from the likes of dementia and Alzheimer's. Having already identified thousands of genetic disorders, we know what to look for when sequencing the embryos during IVF. We will know, for example, if a child, if carried to term, will die of Tay-Sachs. Data from European countries show that couples that receive a diagnosis of Down Syndrome from a pre-natal screening at three months, up to 93% choose to abort (Natoli et al.). From this we can impute that almost no one will choose to implant an embryo that we know would be a child who would suffer and die from a genetic disorder.

The scary side of this is that we will make choices about our children based on factors beyond just their health. We will know the probabilities of personality traits, intelligence, height etc. and will choose according to the cultural and economic norms of the day. Take sickle cell anemia as an example. If you carry two alleles of the trait, you will likely die. However, if you are a recessive carrier, then you have much higher resistance against malaria at some cost to your hemoglobin's ability to carry oxygen (LaMonte et al.). This trait emerged as a desperate adaptation to the deadly threat of malaria. However, malaria is nonexistent in the United States and sickle cell anemia is seen as a disease. If we select out the gene for sickle cell anemia

through embryo-selection, we would be left vulnerable to a reemergent malaria. We have no idea what other recessive traits we are carrying that could help our species survive some forgotten threat.

We do not know what trade-offs we have made through the course of our evolution. To borrow from finance, we might be on a interior point of the efficient frontier. We might be able to take two traits that are involved in a trade-off and optimize for both to reach a point of the efficient frontier where the trade-off actually starts to bind. So far, we understand some of the variables involved in our genetics but we do not understand most of them. We used to say that there's a gene for that: the short gene, the tall gene, the smart gene etc. We now have a poly-genic hypothesis that most of our traits are mediated by many genes, and often each individual gene contributes very little (B. D. Editors). Understanding these tradeoffs requires a far greater understanding of genetics.

China's biophysicist He Jiankui is responsible for the birth of the first known genetically-edited babies in the world. His "achievement" was initially lauded in China's *People's Daily* as "a triumph of Chinese science." (The article has since been removed from the online archive of the *People's Daily*.) There was swift international condemnation of his actions (Harney, Kelland, and P. Wen). The event was controversial for a number of reasons. The consent of the parents was misinformed. He Jiankui did not obtain approval from the hospital. The father had HIV while the mother did not. In a country with advanced medicine such as China, or the United States, there are many ways for such a couple to have a child who will not inherit HIV. He Jiankui targeted the CCR5 gene to make it similar to a mutation that some europeans have. The mutation is two disrupted copies of the gene, granting the carrier increased resistance to HIV but making them more susceptible to the West Nile virus. He Jiankui was not trying to solve an existing problem but was trying to make an enhancement.

A few months later, a report came out that mice with the same CCR5 mutation were faster at maze-running (Regalado). This sparked rumors that the babies were engineered to be smarter. Soon after, a study analyzing data of almost half a million people from the UK Biobank was released, which found a link between people with the same CCR5 mutation and their lifespans (Wei and Nielsen). People with the mutation were living shorter lives. It is clear that our knowledge of genetics is limited and we do not know how editing even one gene would affect our phenotypic traits.

The age of human genetic modification has begun. The third Chinese genetically-engineered baby has probably already been born. The Russian scientist Dennis Rebrikov has announced that he has five parents lined up. This number is going to go from 2 to 3 to 8 and exponentially grow from there. Within a decade, we will almost certainly have thousands of genetically-engineered babies.

3.3 Differences in National Cultures

National cultures around these technologies also differ. We need to worry about the nations that are the most gung-ho about exploiting these technologies. We need to worry about biology becoming the next battlefield in an undeclared geo-political war. China is the major concern.

Let us first visit the positive story from China. China is building massive datasets by collecting information about its people. While these datasets can be used to do a lot of things that most people consider good, though China is also using them to oppress its people. These datasets will enable their analysts to develop actionable insights about how cancers form, predisposition to certain diseases, and responses to certain treatments. This is going to be an immense boon for Chinese healthcare and could also help the rest of the world. China has many things. They have a lot of money, incredibly talented people, a nearly unrestrained scientific culture, very few limits on what the government is prepared to do, and a national ethos that aims to make the 21st century China's century. These are translating into very aggressive applications of revolutionary science with biologists and data scientists at the forefront.

In the United States, we have many self-imposed, and in many cases rational, restrictions on which boundaries we are willing to push. But is it prudent to hold back in this way if China will not restrain itself? In other words, does it become ethical to compete because lack of competition means ceding the game to a less ethical actor? We are having the same conversation around Lethal Autonomous Weapon Systems. By developing these LAWS we lay the foundation for humans being wiped out, but by not developing them, we empower any other country that *is* developing them. While we need to be competitive on these technologies, we cannot lose our humanity in their pursuit. This is a societal race. The first country with a genetically enhanced human will not be the victor. The first country to figure out how to use the resources of its society as a whole to realize its objectives, whatever those may be, will win this race.

3.4 Eugenics and Selection

The word eugenics is used as a cudgel. When someone starts talking of eugenics, the response is “oh I’m against eugenics.” This is appropriate because so many terrible things have been done in the name of eugenics. Perhaps we need a new word; something like “selection.” Yet when we talk of selection, we are immediately in Mengele territory, selecting who lives and who dies. When you are in a situation in which there are some embryos in a dish and you have to pick one implant, what are the criteria by which you make the choice? If you say that you want a child who is not going to die of some terrible genetic disease then that *is* selection. This is a normative choice set not in some abstract, objective world, but our current reality.

With our choices set to change the future of human life, we have good reason to be terrified. There are still many people alive today who fled from Nazism to our country. If we asked the Nazis what they were doing, they would have said that they were implementing Darwinism. To make an extreme understatement, many jewish communities were on the losing end of a eugenics experiment writ large, gone mad. And yet we are uncomfortable with the fact that eugenics has never been properly defined, and so does not really mean anything. Mate selection is another form of genetic selection but if you decide that dinner and a movie is eugenics, then you have erred in drawing the line. At the same time, we cannot have a free-for-all and let a hundred flowers bloom only to see what the experiments produce. It is not clear where good selection ends and bad selection begins. In some way, we have been lying. There is no way of drawing such a line. In much the same way as in the abortion debate in which neither the pro-choice nor the pro-life camp makes sense, neither the pro-hacking nor the anti-hacking position makes sense. We are left with a permanent struggle along these spectra of choices.

It would be wrong for us to say that we will not employ genetic modification. Who wants to have a kid who will die of some terrible genetic disease when we have the technology to save that kid? Who wants to see their parents suffer from dementia if we can remove the very possibility of that condition? It would be insane for us to not use these powerful tools that will let us do unimaginable good just because these tools are also dangerous. With that logic, we would not be using cars, plows, or any other technology, for that matter. This is the position of the Amish: it’s a slippery slope. Some slippery slopes are great. We solve one disease and learn from that how to solve another disease. Dinner and a movie is a slippery slope to love

and marriage.

We need to find a good place in the middle. On the one hand He Jiankui is a villain and the danger of Nazi Germany is obvious. On the other hand we are excited about the idea of freeing people from the risk of breast cancer and perhaps even enhancing cognitive ability. However, is such sobriety even possible? These technologies are becoming cheaper and more powerful. This usually means that the technology is moving into someone's garage. There is a growing do-it-yourself biology movement (Kolodziejczyk). There was recently a Swedish man who created a functional nuclear reactor using the radioactive elements from hundreds of discarded smoke detectors (Taylor). Criminalizing such ventures and holding panels on ethics will neither stop nor slow this trend. So far, the high cost of genetic modification, our lack of power and knowledge, and our clumsiness have allowed us to hide from these most dangerous questions. With these barriers crumbling, we will soon have to confront ourselves.

3.5 Ethical Norms in Light of Genetic Differences

In 1953 when the double-helix structure was elucidated by Watson and Crick and then in 1963 when the genetic code was figured out by Marshall Nirenberg, scientists were shocked that we only pretended to care about our identity as spelled out by nucleotides. We never really accepted what they found. Every time the scientists started talking about identity and characteristics, they found that we were so attached to our pre-genetic understanding of ourselves that we would not give it up. Even today, we will fight anyone tooth and nail who tries to tell us that our characteristics are really a consequence of information technology as developed by natural and sexual selection. In many ways, we are incapable of updating our culture to assimilate the knowledge that we gained seventy years ago.

Our new-found ability to look under the hood is challenging many of the myths that we have developed over thousands of years. We love the idea that you can be anything you want. "The world is your oyster." "Just set your heart to it, kid, and you'll go places." This is almost never not true. Take running, for example. Running is a standard human action that we have evolved with. We would run our prey to exhaustion in the hunter-gatherer era. Yet there is nothing that most of us can do to become a champion marathon runner. Between 1897, when record-keeping began, and 1987, no one from either Kenya or Ethiopia had won the Boston Marathon. Since 1987, while it has not exactly been total domination, a

disproportionately large number of the champions hail from a very small group of people from the same valley in Kenya and Ethiopia (W. Editors). They are from a single tribe of four million people, the Kelengin, and usually from a single Kelengin-subtribe of one million people, the Nandi. This is genetics. While we each have a genetic-range of possibility and we should each aspire to be on the top end of that range, whatever that means in the context of our potential, if someone does not have the genetics to be the worlds fastest marathoner, or swimmer, or abstract mathematician, they are simply not going to get there.

In the example of marathon runners we went from a situation of wide diversity - in which victory really was up for grabs and it really was about athleticism - to a situation in which we have found the special people who are wildly well-adapted to radiate heat, which is the limiting factor in endurance-running. The world was not connected enough to bring in competitors from the Horn of Africa, and there was no prize for winning marathons. With this infrastructure in place, has there been a negative impact on this sport that many no longer feel motivated to enter or even watch? In general, what would happen if we have genetically-engineered people in sports? In many ways, this has already been happening. For example Michael Phelps, in addition to having an extreme work ethic, and excellent training and coaching, is genetically well-adapted to swimming (Siebert). He is tall and slim with a long torso and short legs, which decrease viscous drag in water. His arms are a few standard-deviations too long for a man his height and his palms and feet are so large so as to act as flippers. Together, these traits give him greater ability to propel himself through water. If we were to analyze our top performers in various sports, we would find that they too are genetically optimized for the tasks that they perform.

We have, rightfully so, a fear of living in a Plato's Republic-type society, but we also do not want to live in a society in which the mission-critical functions are not being performed by people who are best suited to handle those functions. There is the old joke about the German chef and the Italian policeman. Having the wrong person in the wrong job would and has hurt societies. In the movie *Gattaca*, Ethan Hawke plays a man who was born in the old-fashioned way. He wants to get into the space program, pulls a lot of tricks, and in the end, he succeeds. We watched this movie and said "isn't it so great that that guy was so determined!" Should Ethan Hawke have been arrested for his own safety because we do not want non-genetically-enhanced people in the space program because they cannot, for example, survive the radiation

of space? If we find some person in a refugee camp who has the potential to be the next Mozart, should we ensure that that person receives the resources and assistance necessary to fulfill their potential and enrich all our lives? Acceptance of the idea that genetics probabilistically predicts life is going to fundamentally change the stories that we tell ourselves.

Unfortunately, this clarity is hard to maintain when we move on to the next example. Let us look at the number of female chess players among the best chess players in the world (USCF). We find that at the top level of chess, only about one player in a hundred is female. It is only a single protein, SRY, that determines whether a proto-human-being develops as male or female. However, when it comes to sex, we are uncomfortable accepting the same story of genetic-optimization for chess that we have for marathon running. It might be that increasingly more data point to a similar conclusion about chess that we have about marathon running. However, I do not know what kind of a society I would be living in if I were comfortable saying that there are genetic disparities in cognitive ability between the sexes.

Another dangerous example is that of Ashkenazi jews who represent one-quarter of one percent of the world's population but have won about 25 percent of the Nobel prizes in physics. Is this the result of thousands of years of the community's smartest people, the rabbis, having as many children as possible, as opposed to the sworn celibacy of catholic priests? It could also be that the mathematical ability required for work in moneylending, which christians and muslims are forbidden from doing by religious doctrine, was selected for in jewish communities over thousands of years. Only very recently did this ability become incredibly rewarding in a world dominated by information technology and computer programming. While we might accept that a small group of people from a geographically special region in Kenya and Ethiopia have a genetic advantage in marathon running, as soon as we kick it over into the realms of chess and physics, our thoughts start feeling slimy.

These examples exist in the realm of our most taboo and difficult topics. With the example of chess, it may be that the disparity is due to an obsessive trait rather than intrinsic cognitive ability. Perhaps if you want to be at the top of the chess pile, you have to be completely obsessed with chess. Several studies have shown that men rate more strongly on obsessive traits than do women, though some studies disagree (Mathis et al.). It may also be that the rule-set of chess is such that men are better adapted to it. We might easily see

a game with a different rule set, call it chess-prime, for which women are better adapted. It would not at all be surprising to see the upper echelons of chess-prime be dominated by women. For example, speed-chess has a significantly different distribution of people at the highest level as compared to classic chess. We have to ask ourselves whether we even want such things to be investigated. With our current knowledge of genetics, we cannot make the indisputable claim that certain groups are just genetically well-adapted to chess.

There is a cautionary tale to be told here. Harvard University's math department was almost entirely male until the late 1980s. They had a desire to see women do well but there was no track record, so they would only admit one woman every year. One year, the single female student decided to defer, so the following year there were two female students in the department. They formed a support group and both did extremely well. With the opening of the floodgates, many more women have graduated from Harvard's math department and have gone on to have successful careers. While there are still injustices to be mended, the situation is improving (Jackson). It would have been easy for us to tell a soft tale of "oh there are these genetic differences and we're looking at the tails of distributions..." While there is no way to hide from data, we cannot glibly assign an explanation when our knowledge of the real causes is so lacking.

In the end, there are no dispassionate arbiters. We often pretend that we are objective and that we can make objective conclusions. And yet, relatively minor alterations to methodologies can yield wildly different results. We need humility and modesty in our approach to what may seem, at first blush, to be extremely disturbing interpretations of the data. We have to proceed in a scientific fashion and we cannot afford to think only of social consequences. At the same time, we must keep the social consequences in mind and avoid proceeding blithely with science.

4. Conclusion

The genetic revolution has produced, and will continue to produce, fundamental changes in our society. For one, our healthcare systems are going to evolve. We will move away from the present systems of generalized healthcare towards personalized, precision-healthcare. Your doctor will require knowledge specific to *you*. This will include access to your health records, biometric information and, most of all, genetic information. With the cost of genome sequencing trending towards zero, everyone is going to be sequenced as a prerequisite

of entering the healthcare system. With this move towards precision-medicine, there will be billions of people whose genetic and phenotypic information will be in massive Big-Data pools. We will use these datasets to increasingly demystify our biology and eventually move towards predictive medicine, healthcare, and life.

The shift towards IVF forecasts further changes to how we reproduce. We will probably see an end to procreative sex. Once we take conception outside of the human body, we will be able to apply all of our gene-editing tools in many incredible ways, but also in ways that will scare a lot of people. One fear is that we will make decisions about the future of our species based on what feel like eternal truths, but which are in fact transient fashions. If we asked people today, many would say that they want a kid with good health, who would live a long life, be intelligent, and maybe tall. These traits are fine to have and people who have them are thriving in our current environment. However, our genetic diversity is not just some nice-to-have thing. It is the sole survival strategy of any species. We will have to consciously choose to maintain this diversity that we have inherited. We will have to identify what we mean by diversity and we will have to celebrate it. Otherwise, our species will court existential risks.

If only that were the full extent of the danger. Individual actors now have the power to wreak havoc on a scale that previously attainable only for nations. We are in the age of DIY bio-hacking. Technologies like CRISPR/Cas9 will soon be cheap enough that students will edit genomes for highschool biology projects. In 2017, a group of Canadian researchers used the tools of synthetic biology to create an active version of horsepox, a relative of smallpox (Kupferschmidt). They achieved this with \$100,000 and little specialized knowledge of virology. Today we could do this for \$50,000 and in five years, perhaps only \$5,000. With these biological Lego bricks, we will have the tools to remake life. Just as we have the tools to do incredible good, we also have the potential to do great evil.

We can moralize all we want, but this going to play out, ironically, according to a system of selective pressures. Selection is not only about biology. Anything that has the three properties of variability, heritability, and differential success is going to behave in a darwinian fashion. The social interpretation of this is that variability constitutes the human value of diversity, heritability has to do with what we call privilege, and differential success is inequality. The maddening thing about biology is that we take this cherished value of diversity, we subject it to privilege, it produces inequality, and we take that inequality as the feedback into

the system. With bio-hacking we are going to move from obligate-heritability to facultative-heritability. In effect we will become the designer of our own design. We will break evolution and biology at a fundamental level. After 3.8 billion years of evolution by random mutation and natural selection, we are about to turn a corner. Will we see a Cambrian explosion of successors to Homo sapiens? We cannot accurately imagine where this will go over the next centuries and millennia. What we can say is that we have, over many thousands of years, developed ethical codes that help us live better lives. At the very least, we need to fight to make sure that our best individual and collective values are integrated into the decision-making process.

“We are gods but for the wisdom.” - Eric Weinstein.

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