« MODERN MEDICINE HAS CONSIDERABLY REDUCED THE TRAGIC TOLL OF NEGATIVE SELECTION. BUT SUCH ACHIEVEMENT OF OUR INDUSTRIALIZED SOCIETIES (...) BRING LONG-TERM ACCUMULATION OF DELETERIOUS TRAITS. »

« SOLUTIONS TO LIMIT THOSE DELETERIOUS TRAITS WILL BE BASED ON THE USE OF COMBINED ADVANCES, AMONG OTHERS, OF BIOTECHNOLOGY, ROBOTICS AND NANOTECHNOLOGY. »

CHAPTER 3

Human enhancement and evolution

J. AGUILAR-RODRIGUEZ AND A. REZAEE VAHDATI

«HUMANKIND IS ABOUT TO ENTER A NEW PHASE OF EVOLUTION.»
J. Craig Venter

The biological sciences are evolving at an unprecedented pace. Following the discovery of DNA and the rise and spread of digital technology, the biosciences are experiencing spectacular advances that are expanding our comprehension of the living world and our ability to control it. Humankind is at the door of a new era of biological design, an era dominated by powerful technologies capable of improving not only the world in which we live but also our own bodies and minds. If such biotechnological interventions in or on human beings come to pass, we might finally be able to domesticate the process that has created us and that is continuously modifying us: evolution.

EVOLUTION IS SOMETIMES DEFINED AS A CHANGE IN THE COMPOSITION OF THE TRAITS OF A POPULATION OVER TIME.

One of the causal mechanisms for most (but not all) of this change is natural selection. Natural selection is the process by which inheritable traits that favor survival and reproduction increase their prevalence in a population from one generation to another. In other words, traits that favor their individual carriers become more common in a population (positive selection), while deleterious traits become rarer (negative selection). Beginning with a given population, after many generations, natural selection may lead to the creation of subpopulations displaying different traits. Now, imagine that this natural selection process acts over millions of years: ultimately, traits between subpopulations might become so dissimilar that each subpopulation becomes "something" quite different. In other words, by means of natural selection, they diverge to such an extent that they can no longer interbreed, transforming them into new species. This process is called speciation. All living beings that inhabit the Earth descend from a form of life that lived more than 3.5 billion years ago: the "last universal common ancestor" (LUCA). Since LUCA, life has unceasingly branched out through speciation to finally create all the species that lived and that are currently living on Earth.

As is true of any other biological species, we humans are also the product of evolution through natural selection. However, in our case, human culture has also played a crucial role during our own evolutionary process.

THE ADVENT OF CULTURE HAS SHELTERED US FROM THE HARSH ENVIRONMENT FACED BY OUR PREHISTORIC ANCESTORS. MITIGATING MANY ENVIRONMENTAL PRESSURES THAT MOLDED OUR TRAITS IN THE PAST.

However, the advent of culture has also created subtle selective forces that have participated in the forging of modern human beings, such as "lactase persistence", which is the ability to digest lactose into adulthood. Lactase is an enzyme that allows us to break down lactose (a sugar present in milk). Active during childhood, lactase is normally switched off as children grow older. However, the persistence of this enzyme during adulthood has become a common trait in certain human populations. This persistency correlates with the domestication of dairy animals over the last ten thousand years. In other words, the increase in the frequency of individuals showing lactase persistence constitutes an adaptation driven by the consumption of non-human milk beyond infancy. This trait is highly beneficial for populations with diets containing high levels of dairy products and clearly illustrates how human culture can influence the presence – and/or absence – of certain human characteristics.

Although human beings have been forged by evolution through natural selection (among others causes), we may wonder whether we are continuing to evolve. Some commentators – such as the geneticist Steve Jones, the naturalist Sir David Attenborough and the late paleontologist Stephen Jay Gould – have expressed doubt about such contemporary processes of evolution (Gould 2000; Bellutz 2008; Furness 2013). They claim that human beings do not actually evolve anymore because modern medicine has considerably reduced the tragic toll of negative selection by correcting the deleterious effect that some traits may have on individuals.

Medical interventions have been extremely successful in improving human living conditions, even for those individuals carrying traits that may cause serious morphological, behavioral and physiological problems (e.g., hemophilia and diabetes, among others). However, it would be an oversimplification to assert that improved living conditions have stopped the evolution of the human species. Although many societies have reduced mortality rates by means of advances in medicine and social policies, many developing countries in which fatal diseases (e.g., malaria) remain and impose strong selective pressures. As a consequence, at least in these countries – which account for the majority of the global human population – natural selection continues to select traits that confer survival and reproductive advantages.

In addition, several studies have characterized natural selection in human populations from industrialized countries, suggesting that it remains in effect. For instance, the "Framingham Heart Study" – an ongoing medical health survey on all Framingham inhabitants since 1948 (Massachusetts, USA) – has consistently measured changes in citizens' so-called health markers such as blood pressure, cholesterol, blood sugar levels and body weight. Surprisingly, scientists have found certain correlations between health markers and the number of descendants. For example, women with lower blood pressure and cholesterol levels tend to have more children. These results might support the proposition that human evolution has not ground to a halt in contemporary populations and that we humans remain under the tight control of the "natural forces" that have made us.

Moreover, there is another side to the story. Medical progress and progressive social policies have substantially reduced the efficiency of negative selection (i.e., the decrease in traits that are not favorable in a given environment).

Nevertheless, authors such as James Crow (1997) and Bill Hamilton (2002) both evolutionary biologists –

believed that:

«THIS ACHIEVEMENT OF OUR INDUSTRIALIZED SOCIETIES DOES NOT OCCUR WITHOUT COSTS BECAUSE IT LEADS TO THE LONG-TERM ACCUMULATION OF "DELETERIOUS" TRAITS.»

Normally, natural selection ensures that the recurring input of deleterious traits in each generation is balanced by the selective elimination of such traits. According to these authors, by reducing the latter, medical interventions favor the steady accumulation of such deleterious traits in individuals who live in industrialized countries. The immediate effect of such deleterious traits can be minimized – or mitigated – by medical interventions. However, these authors believe that this situation will be unsustainable in the long-term and that it might become problematic for the long-term future of the human species.

In this sense, authors such as Alexey Kondrashov (2012a, 2012b) and Michael Lynch (2010), both geneticists, share a rather stark vision of the future of humanity. They have both recently suggested that the residents of developed countries are accumulating deleterious traits because they are less subject to negative selection. According to their arguments, it is probably the first time in human history that this accumulation is occurring at such a high rate. Lynch believes that future human beings in wealthy countries will likely be "(...) different in just two or three centuries, with significant incapacitation at the morphological, physiological, and neurobiological levels" (Lynch 2010, 966).

One may wonder whether these authors are harbingers of doom or whether they may be – at least partially – correct in their assessments. Experimental evidence supports their claim that accumulated deleterious traits can affect a population quickly and detrimentally. For instance, when fruit flies – a commonly used animal in experimental biology – are bred in conditions of relaxed selection, they display a rapid accumulation of deleterious traits and soon exhibit a decline in their ability to survive and reproduce. Another example is "intracytoplasmic sperm injection" (ICSI), an in vitro fertilization technique that is frequently proposed for men who display few or no spermatozoids in their semen. A single sperm cell can be collected and artificially injected into a mature egg, thereby forming an embryo. The newly created embryo is then transplanted into a woman's uterus, in which it will continue its development through the end of gestation. However, a caveat of this technique is that boys conceived through ICSI can inherit their father's severe sperm problems, making them infertile as well, which clearly indicates how deleterious traits that would normally have been removed from human population can persist over generations due to medical intervention.

A crucial question emerges here: will we be able to find solutions for eliminating – or at least limiting – the unwanted effects related to the accumulation of deleterious traits in human populations? We may hope that, in the near future, our scientific and technological abilities will be powerful enough to diagnose, repair, or – at the very least – limit the effect of deleterious traits. After all, sterile boys conceived through ICSI could use the very same technique to overcome their sterility. In that sense, the advent of CRISP/Cas9 is promising. This is a rapidly advancing technique that endows scientists with the ability to easily alter the genomes of living cells – including germ line cells, i.e., sperm and egg cells. Alterations in these cells are particularly important for evolution because changes in their DNA are inheritable. This technique has previously been used to edit the DNA from fertilized eggs in monkeys.

Moreover, such a technology, which is able to reverse detrimental traits, might also be used to introduce changes to express "desirable" traits, allowing individuals to have greater control over their biological destiny.

SUCH "IMPROVEMENTS" WILL LIKELY BE BASED ON THE USE OF COMBINED ADVANCES OF. AMONG OTHERS. BIOTECHNOLOGY. ROBOTICS AND NANOTECHNOLOGY.

Biological bodies could therefore become a combination of organic and artificial parts. Modified individuals may live longer, show increased cognition, be physically stronger and be better looking compared with unmodified people.

However, the technological challenges required to modify human beings using biotechnology, including by means of CRISP/Cas9, will not be small. The main problem is that the effect of an introduced change can vary substantially from person to person – and from environment to environment. This phenomenon will make it practically impossible to accurately predict the effect of most modifications, at least in the near future. Moreover, the improvement of a trait can be the cause of unwanted deficits in related traits. For example, individuals with eidetic/photographic memory typically also have synesthesia. The stimulation of one of the five senses leads to an automatic reaction in another, i.e., hearing a particular sound triggers seeing a specific color. Because of these problems, the modification of human beings in the near future is more likely to originate from the fields of robotics, nanotechnology and pharmacology.

Some thinkers have postulated that radical technological interventions in our biology may transform us into "something different" from what we are. In other words, they believe that large-scale application of technology in or on human beings might make them evolve into "something else", a "new species" of hominids. Is it plausible? To answer this question, we first must understand how Homo sapiens – the humans we are now – appeared on Earth. We humans are the result of millions of years of evolution. Fossil records indicate that our first hominid ancestors lived approximately seven millions years ago in Africa. These first hominids were quite different from us and looked more like apes. We may wonder what made them evolve into the highly intelligent species that we are.

There are various compelling theories that address this question. One theory is perhaps more convincing than the others. During the nineteenth century, Charles Darwin – the first person on Earth to coherently propose that species have evolved through natural selection – thought that bipedalism set our ancestors onto the path of becoming what we are now. By releasing their hands from locomotion, these primitive humans could use them as tools. According to Darwin, "Man could not have attained his present dominant position in the world without the use of his hands, which are so admirably adapted to the act of obedience of his will» (Darwin 1871, 135).

In addition, the taming of fire is arguably considered one of the pivotal events in human evolution. Cooking helps us digest food more rapidly and efficiently. Such a reduction in the time spent feeding and digesting led these primitive humans to invest more time and energy resources in new activities. It is also believed that it helped humans allocate more energy for thinking and resolving day-to-day problems. The act of thinking is energy consuming. Whereas the modern human brain represents approximately 2.5% of our body weight, it consumes approximately 20% of the body's total energy budget. Therefore, the energy that is saved by the shorter period of time we require to digest our food can be redirected for brain activity, which may have had an impact on the improvement of our intellect. Therefore, cooking by fire might be another example of how technological advances have modified our biology.

Furthermore, approximately 2.5 million years ago, a shift in the evolution of hominids occurred. At that time, Africa experienced unusual climate instability that consisted of sequential changes between dry and rainy climates. These climate changes resulted in the extinction of many species and imposed new and strong selective pressures on the hominids, which were forced to adapt to survive. Those who developed more sophisticated hunting strategies (i.e., weapons) survived and had descendants.

Roughly knowing how Homo sapiens appeared, we may now explore whether the large-scale application of technology in or on human beings, together with substantial socioeconomic differences, might make them evolve into a "new species" of hominids. Many science-fiction writers have speculated about a possible future speciation for humanity. For instance, in The Time Machine (1895), H.G. Wells imagined humans evolving into two different and opposing species: "Elois" and "Morlocks". The first are beautiful frugivorous creatures who are, by nature, childish, stupid and weak. They are the descendants of wealthy humans who lived comfortably in a utopian Earth as the result of the systematic application of technology. The second species are hideous albino creatures that prey on the "Elois" and live in underground and mechanized cities. They are the descendants of the poor working classes. Wells' imagination notwithstanding, given the time it has taken to "make" the humans who we are, it is highly improbable that technological modifications of our biology will soon lead to speciation. Moreover, speciation implies the creation of an initially homogenous subpopulation, i.e., populations that share identical traits. In addition to the technological modifications that may be necessary to repair deleterious traits, individuals may wish to have traits according to their personal preferences, therefore leading to more diversity than unity between individuals.

COMBATING THE ADVERSE EFFECTS OF DELETERIOUS TRAITS – AND ENHANCING OTHER TRAITS – WILL BE COSTLY. WILL THIS ABILITY BE RESTRICTED TO A RICH MINORITY?

Or will it instead be accessible to anybody who may wish to use it? Should we worry about a schism between the enhanced rich and the unenhanced poor, similar to that between the "Elois" and the "Morlocks"? Conside-ring the current social and economic differences between individuals, the possibility of emphasizing some of our traits – such as cognitive capacities or lifespan, for instance – will probably not be available to all. Many people in today's world do not have the luxury of having enough to eat, whereas others live under harsh dictatorships that may not allow people access to the relevant technology. Industrialized countries struggle with unemploy-ment and income inequality (for example, the 2011 census data (www.census.gov) showed that half of the U.S population lives in poverty or near poverty). We believe that crucial socio-ethical issues related to human "enhanced evolution" would mainly concern the justice aspect of its application.

We have evolved from other animals, but evolution is not over for us. Evolutionary changes continue and will continue to occur in human populations. Some of these changes are the product of cultural and technological advances, but we do not have any control over them at present. We are changing in ways that we may not consider desirable. Nonetheless, it is possible that, in the near future, we may achieve greater control over our own evolution with the help of technology. It may be possible that we will be able not only to stop unwanted changes but also to introduce desirable changes. Technology will undoubtedly accelerate human evolution. What is more doubtful is the extent to which we will be able to control such a process and to select the evolutionary trajectories we may take.

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