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# Possible future evolutionary consequences to *Homo* as a result of the implementation of biotechnology

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Abstract: Biotechnology has become one of the most powerful forces on the planet, since it is capable of altering life processes at a molecular level. Since human bodies are dynamic biological systems, medicine requires to understand the evolutionary antecedents of *Homo*, especially in relation to neurohormonal regulation. Furthermore, increasing human dependence on biotechnology has led to relaxed natural selection in *Homo*, with subsequent increase of genetic load. In this paper, we speculate on the possible consequences of the application of parsimoniously derived biotechnologies onto the biological system of humans, with special attention to three areas: 1. human brain augmentation; 2. biotechnology and public health; 3. relaxed natural selection and genetic load. Human ability to manipulate and alter the structure and function of the body may not only make natural selection redundant but will be guided by a teleology whose purpose will seek to improve upon nature's design.

Key words: brain augmentation, brain-machine interfaces, cosmetic neurology, relaxed natural selection, genetic load, bioethics.

Original article



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## Introduction

Human bodies are dynamic biological systems. According to systems theory (von Bertalanffy 1957) a change to any function or any element of a system elicits changes in other elements of that system. Human technologies are constructs resulting from discoveries of basic properties of objects reached by the process of abstraction – isolating essential properties of objects and relations of those objects to others from all possible properties and relations. This approach in science is known as the rule of parsimony, 'Ockham's Razor', the simpler, the better (Tornay 1938; Burgess 1998). Construction and use of technologies to control the world was crucial for humans becoming the dominant vertebrates (Laland and Seed 2021). However, when it comes to the use of technologies directly interfering with biological processes of ecosystems and individual organisms, problems occur because biological entities are systems, hence not abstract isolated entities (Bateson 1973; Charlton 2008; Saniotis 2011). Therefore, what was successfully abstracted from to produce technological objects and processes, comes back to interact with these processes and results of those interactions are largely unpredictable because they were abstracted from, not included, into the design of technologies. Vertebrate brains, including human ones, are processing information along multiple intersecting pathways stimulated by external sensory inputs and modulated by physiology of organisms (Saniotis and Henneberg 2011a). Therefore, they are complex systems.

In this paper, we speculate on the possible consequences of the application of parsimoniously derived biotechnologies onto the biological system of humans, with special attention paid to three areas: 1. human brain augmentation; 2. biotechnology and public health; 3. relaxed natural selection and genetic load.

## Unknown evolution: brain augmentation

Since the early Neolithic period humans have been able to genetically alter dozens of plant and animal species for their benefit. Although genetic manipulation of plants and animals was pivotal for human population increase during the 1st epidemiological transition, which later gave rise to civilisations, proposed genetic engineering of humans may have future evolutionary and public health consequences. While biotechnologies have received much theoretical attention, there have been relatively few studies assessing biotechnologies from an evolutionary viewpoint. Numerous biotechnological companies now develop, facilitate and spread various kinds of biotechnologies on a global scale. Their impact is both profound and increasing (Tab. 1).

Proponents of biotechnologies such as brain-machine interfaces (BMIs), cosmetic neurology and genetic engineering aim at augmenting human brain's abilities. This includes the idea of downloading the brain into robots (Bostrom 2003) or replacing it with a nanotech brain (Kurzweil 2000). Currently, novel BMIs are being developed to provide movement for quadriplegics or amputees (Shin et al. 2012; Bouton et al. 2016; Sharma et al. 2016; Wojtalik et al. 2016; Bundy et al. 2017). Within the next fifty years various brain chips will be developed to prevent or reduce the onset of neurodegenerative diseases (i.e. Alzheimer's disease, Parkinson's disease, multiple sclerosis) and brain trauma (i.e. stroke). These may include nano/neuroprosthetic devices (Saniotis et al. 2018, 2020) to enhance cognitive and neuromotor functions.

Tab. 1. List of top 10 biotechnologies being used in the developing world. Modified from Acharya et al. (2004)

| Top 10 biotechnologies to improve health in developing countries |
|---|
| 1. Molecular diagnostics |
| 2. Recombinant vaccines |
| 3. Vaccine and drug delivery |
| 4. Bioremediation |
| 5. Sequencing pathogen genomes |
| 6. Female-controlled protection against sexually transmitted infections |
| 7. Bioinformatics |
| 8. Enriched genetically modified crops |
| 9. Recombinant therapeutic proteins |
| 10. Combinatorial chemistry |

High brain bandwidth optimisation may be achievable leading to improved inter-neuron transmission (Saniotis et al. 2018; Kurzweil 2000). Improvements in neuropathological markers, albeit beneficial in improving our current knowledge of cortical processes, have yet to recognize their evolutionary precursors (Saniotis et al. 2014). Furthermore, neuroscience has yet to produce a theory for assessing neurohormonal regulation of higher cortical processes (Saniotis et al. 2018).

Pharmacological approaches to brain augmentation have been ongoing over the last few decades. Giurgea (1972), who first coined the term "nootropic" to mean a substance which can initiate enhancement of cognitive abilities, has yet to spread. While substances such as methylphenidate (Ritalin) Modafinil and dextroamphetamine (Adderall) have been widely researched, they have failed to enhance human intelligence.

Chatterjee (2016) offers a poignant vignette regarding the prescribing of pharmacological substances to a businessman in order to improve his study of Arabic language. Notwithstanding this, several authors have argued that there are short term and long-term effects of psychostimulants such as anxiety, cerebrovascular disease, nausea, depression, higher stroke risk, psychosis, seizures and Parkinsonian symptoms (Lappin and Darke 2017; Lappin and Sara 2019).

Short-term adverse effects of psychostimulants include cerebrovascular disease, anxiety, initiation of mental illness, insomnia, diarrhoea and nausea, their long-term consequences include higher stroke risk, cognitive impairment, and psychosis, stroke, Parkinson's disease and seizures (Ballon and Feifel 2006; Sahakian and Morein-Zamir 2007).

The effectiveness of current synthetic psychostimulants lies in their ability to amplify neurochemical alterations (Smith et al. 2017; Lappin and Sara 2019). It has been argued that the modern brain is unable to efficiently metabolise the toxic substrates of synthetic psychostimulants – a poignant example of evolutionary mismatch (Saniotis et al. 2014). If this is the case, the current prevalence of psychostimulants may have the potential to dysregulate neurohormonal mechanisms in *Homo*. Despite evidence of methamphetamine induced epigenetic alterations (Smith et al. 2017; Jayanthi et al. 2018; Limanaqi et al. 2018; Krasnova et al. 2020), more research needs to be conducted in relation to cause-effect dynamics between genetic and epigenetic aspects and possible long-term changes.

However, the desire for brain augmentation must also be critiqued due to recent brain evolution where it has been reported that during the Holocene period (last 10,000 years) the human brain has actually shrunk by approximately 10% (100–150 ml) (Brown 1992; Henneberg 1988; Ruff et al. 1997; Saniotis et al. 2020). This reduction in brain size has come at a time when civilisations and their concomitant technologies and science have arisen (Henneberg and Steyn 1993) (Fig. 1).

Second, there has been a decline in genotypic intelligence in various countries, resulting in lowered average values of intelligence quotients (IQ). For example, from 1975 to 2003, 11–12 years old children from the United Kingdom had an IQ decline by 12 points (Shayer et al. 2007), while Danish conscripts in 2004 had had a decline in IQ by 1.6 points (Teasdale and Owen 2005). More recent research (Bratsberg and Rogeberg 2018) has noted a decline of the "Flynn effect" in the Norwegian population. The Flynn effect refers to the increase of IQ during the 20th century (Flynn 2009; Pietschnig and Voracek 2015). This time period witnessed a rapid rise of IQ in several western nations by approximately 3 points per decade (Shayer et al. 2007). However, the last two decades have seen a reversal

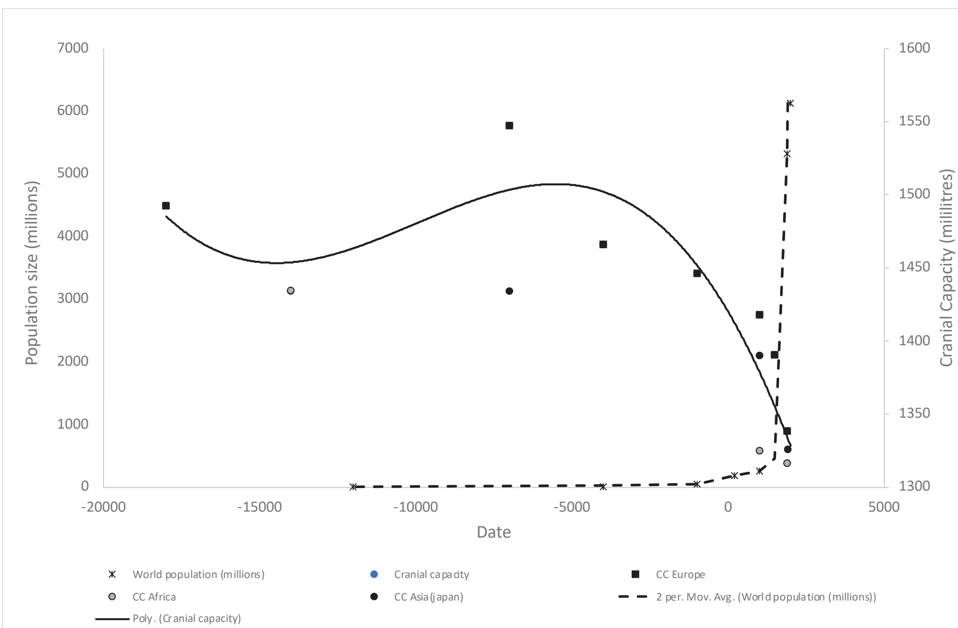


Fig. 1. Changes in the brain size (cranial capacity) on three continents and the world population during the last 22, 000 years. Data for cranial capacities from: Henneberg and Steyn (1993, 1995) and Data for World population from UN sources and Gapminder (www.gapminder.org)

of the Flynn effect (Dutton et al. 2016). A decline in IQ has deleterious consequences across the spectrum of human scientific, economic and other areas of life. This is a concern since decline in IQ has come at a time when humanity is facing serious global challenges such as biodiversity loss, climate change, ecological degradation, growing wealth inequity between developed and undeveloped nations, food insecurity, pandemics and the erosion of democratic governance.

Third, a major problem with brain augmentation technologies (which have yet to become a reality) is that science has yet to know the evolutionary antecedents of the human brain. This makes 'tweaking' the brain environment problematic. Saniotis et al. (2014) offer a poignant caveat on this theme when they note that while nootropic agents may offer possibilities in maximising human cognitive performance, this should not go beyond the brain's evolutionary capacities. On account of the brain's complexity, it is yet unclear how the brain may respond to such substances. Consequently, we should err on the side of caution since nootropic agents may lead to unbalancing the delicate neurohormonal environment (Saniotis et al. 2014). We should remember that there are several psychiatric disorders which exemplify "neurochemical aetiologies" (i.e. bi-polar disorder, schizophrenia, major depressive disorder, obsessive compulsive disorder) (Knable and Weinberg 1997; López-Figueroa et al. 2004; Berk et al. 2007; Saniotis et al. 2014). For instance, alterations in multiple neurotransmitters (i.e. dopamine, acetylcholine, GABA, serotonin, glutamate) are involved in schizophrenia (Brisch et al. 2014); dopaminergic and serotonergic pathway changes are associated with bi-polar disorder and manic depressive disorder (Benedetti et al. 2020); glutamate is implicated in obsessive compulsive disorder (Shugart et al. 2009; Wang 2010) while depletion of serotonin, dopamine and norepinephrine are linked to major depressive disorder (Hasler 2010).

Furthermore, tampering with the brain's neurohormonal regulation poses an ethical quagmire. Do extant humans have the right to change the brain in a way which may affect future evolution of the human species? Additionally, there is the possibility that in the future enhanced humans will have an unfair advantage over non-enhanced humans in all sectors of society. The question remains whether brain augmentation will become mandatory for future humans? Will brain chips be necessary in order to deal with the sheer volume of information necessary to live in a high-tech world? If so, will human reliance on augmentation technologies further affect genotypic intelligence? One lesson that history has taught us is that technology is often a twin edge sword and that our reliance on it may expose us to unforeseen consequences – the atom bomb being science's biggest caveat par excellence.

## Misuse of Biotechnology and public health

Illegal and unethical aspects of biotechnologies are no longer an intellectual concern of bioethicists but a reality. Misuse of genetics was evident in the early twentieth century by the Soviet scientist Ilya Ivanov who attempted to create a human-chimpanzee embryo – a "humanzee" (Rossiianov and Kirill 2003). The depraved medical experiments of Nazi physicians (Mellanby 1947; Roelcke 2004) and the decades long Tuskegee experiment in the United States further exemplify contravention of ethical practice (Tobin 2022). Although stringent international rules and regulations forbid the use of non-therapeutic gene technology, increasing commercialisation of genetic material is testing ethical boundaries (Borry et al. 2018).

Recently, the Chinese scientist Jina-kui He claimed to have produced the first children using germ line gene editing. According to He, twin girls were designed to have a natural immunity against the HIV virus. However, He was able to circumvent Chinese and international regulations banning clinically based gene-editing methods on human embryos (Zhejiang 2019).

For many bioethicists He's cavalier behaviour is the 'stuff of nightmares'. The question beckons, if a scientist can create designer babies in a country which explicitly proscribes gene editing on human embryos, what can we expect from countries where there are less distinct guidelines on this kind of biotechnology? The apparent ethical failings in this case demand not only better scientific governance by all interested stakeholders, but also a change in our thinking regarding genetic engineering and its socio-political and evolutionary consequences.

## Biotechnology, relaxed natural selection and genetic load

Humans in the 21st century CE are facing multiple global challenges such as climate change, ecological collapse, loss of arable land, diminishing water resources, over population and environmental pollution. In the last twenty years approximately thirty novel pathogens have arisen such as MERS-CoV, SARS, Ebola and the recent coronavirus (SARS-CoV-2). Many global problems are seemingly insurmountable and will affect our current way of life. It has been conjectured that these multiple challenges could be solved via synthetic biology. Various authors (Ehrlich 2000; Savulescu 2003; Saniotis 2007a,b) have stated that the use of transgenic technologies in humans could be a way for adapting to long term climate change as well as leading to greater ecological awareness. Additionally, our evolved human perceptual systems are inefficient in detecting our current social and environmental challenges (Ehrlich 2000).

Could genetically augmented humans be better equipped in responding to them? The answer to this question remains open to debate. What can be answered is that humans have since the advent of the Holocene period been actively engaged in genetically modifying plants and animals in order to improve food procurement and animal domestication. Second, gene therapies and genetic screening are two current ways in which our genetic gaze is being focused to the human realm. Although, many genetic therapies are still in an emerging state of development their use is imminent.

Increasing human dependence on biotechnology has led to relaxed natural selection in *Homo*. To illustrate this point only approximately 50% of neonates survived past 15 years of age prior to the Industrial Revolution (mid 19th century). Later the survivorship increased tenfold mainly due to improvements in public health, diet and medical intervention. Consequently, child mortality has decreased between 1890 and 2017 by >50% (from 12.6 million to 5.4 million) (Budnik et al. 2004; Saniotis and Henneberg 2011b; Roser et al. 2013). (Fig. 2).

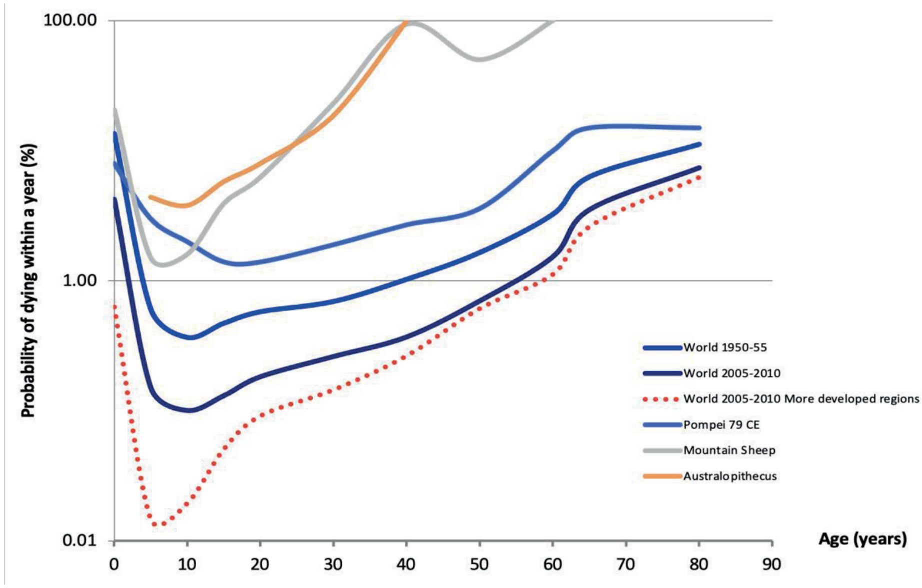


Fig. 2. Probabilities of dying within one year by age in various human populations over time compared to that of a mammal (mountain sheep). Data from the *World Health Organisation* (labelled "World" and Saniotis and Henneberg 2011b)

Although modern biotechnology has allowed more humans to reach reproductive age this has come at a cost of enabling less adaptive alleles to be circulated into the human gene pool. This accumulation of fitness reducing alleles in *Homo* has resulted in genetic load with subsequent reduction in human fitness according to earlier standards of what is fit (Agrawal and Whitlock 2012; Saniotis and Henneberg 2020). For instance, recent studies by You and Henneberg (You and Henneberg 2016, 2017) of 190 countries have identified an association between accumulated deleterious mutations due to relaxed selection and incidence for several kinds of cancer and type-1 diabetes.

Moreover, since the last quarter of the twentieth century there has been an increasing shift from curative medicine towards medical technology modifying the structure and function of the human body (Ehrlich 2000). While this shift is currently being facilitated by improvements in cosmetic surgical techniques, gene therapies are being proposed to eventually dominate body augmentation. There is no little doubt that western societies' fixation with youthfulness and concomitant disparaging of aging will continue to inform biomedicine's refocus on improving upon countering the body's physical and cognitive limitations.

## Conclusion

Relaxation of natural selection combined with increasing genetic load means that humans will become more dependent on biotechnologies in many areas of life. Biomedicine's movement from therapeutic to prosthetic techniques is changing discourses on the human body, since this movement embodies the idea of transformation (Saniotis and Henneberg 2017).

The novelty of brain augmentation technologies will require more medical effort in understanding the evolutionary antecedents of *Homo*, especially since our knowledge of neurohormonal regulation of the brain is still unclear. Although, there have been some developments in neuroprosthetics in the last generation, these devices have mainly focussed on increasing a recipient's motor control. It may be years before machine-brain-interfaces can be developed to enhance higher order abilities, if at all. A similar challenge is facing cosmetic neurology – the use of pharmacological substances in order to "enhance" human cognitive abilities. Despite research into various touted nootropic substances, there is currently no substance that is a verifiable brain enhancer. One reason is that our knowledge of neurotransmitters and their interaction with neural circuits is relatively poor. Consider that medical science has yet to find a pharmacological cure for devastating mental disorders which have been earlier discussed. Perhaps, advancements in artificial intelligence in combination with gene technology, nanotechnology and virtual reality technology could lead to a substantial modification in human cognitive abilities. However, this is speculative as we have little knowledge on how the human brain has been shaped during evolution. Lastly, there is a possibility that any attempt in tweaking the brain at genetic and molecular levels may result in the incidence of new mental disorders or provoking already prevalent mental disorders.

Second, novel biotechnologies must be conducted within existing ethical guidelines. The introduction of non-therapeutic biotechnologies will, by their nature, be antithetical to evolution. Human ability to manipulate and alter the structure and function of the body will further relax natural selection making extant humans more dependent on medical interventions.

### Conflict of Interest

None

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None

### Authors' contribution

A.S.: Conceptualisation, data analysis, writing of the first draft, critical revision; F.M.G.: data analysis, critical revision of the manuscript and literature, contribution to the writing of the second draft; M.H.: conceptualisation; data analysis, critical revision of the manuscript and literature, contribution to the writing of the second draft, supervision.

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