TECHNOLOGIES AND SCOPES OF HUMAN BIOENHANCEMENT: FROM GENE EDITING TO MORAL BEHAVIOUR[1]

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Abstract: Issue 11 (2020) of the *Ramon Llull Journal of Applied Ethics* contains a monographic section in which four articles are published on human enhancement. Two of them (those by Alonso, Anomaly & Savulescu, and Capasso & Santoema) deal with the use of CRISPR gene editing systems for the enhancement of human capabilities. The other two (those of Conradie and Rueda) deal with different ethical aspects of using biotechnology to increase human morality. In the present article, F. Lara and M. Moreno contextualize these four contributions by pointing out the background and interpretative keys to the debates in which they are inserted.

Keywords: *Human enhancement, moral enhancement, bioenhancement, CRISPR, gene-editing systems, neuroethics*

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Recent developments in biotechnology have led to intense academic debate at the beginning of the 21st century on the possible application of these developments not only regarding the prevention or treatment of diseases but also to a hitherto unknown increase in certain human capacities and our life expectancy. This is basically what is known as the debate on moral enhancement. The beginning of the debate was characterized by a confrontation between two positions. On the one hand, that of the "bioconservatives", who were opposed to the use of technology for human enhancement because it threatened human dignity and went against nature (Fukuyama, 2003; Kass, 2002; Habermas, 2003; Sandel 2004); or because it blurred the relevant distinction between therapy and enhancement (Sandel, 2004; Schwartz, 2005). On the other hand, that of the "transhumanists", who defended a moral obligation to enhance ourselves through biological interventions, even to the point of becoming a different species (Walker, 2002; Bostrom, 2005a and 2005b).

Regardless of who was right, both positions shared the error of being formulated from overly simplistic and speculative perspectives. The parties involved in the dispute based their positions on highly theoretical arguments, often unaware of the real possibilities and risks of particular interventions and without differentiating between techniques with peculiarities that could considerably condition the debate. This led to a polarization between the pessimism of the bioconservatives, which made them distrustful of any biological manipulation, however small, controlled and beneficial it might be; and, on the other side, the optimism of the transhumanists, who paid little attention to the limitations of interventions on complex and still largely unknown biological mechanisms.

The perception of this excessive generalization of the debate and its risks is what probably led to the expansion among subsequent authors of a working method that ethically evaluates human enhancement from the particularity of both the technology used and the scope of human functionality that is intended to be increased.

For this monographic section, dedicated to human enhancement by the *Ramon Llull Journal of Applied Ethics*, four articles have been selected that are entirely in line with this more particularist methodology. Two of them deal with the applicability of a very new enhancement technique of genetic editing, known as CRISPR. The other two

are about the ethical aspects of biomedical enhancement in the specific field of human morality.[2]

BIOTECHNOLOGIES OF ENHANCEMENT: THE CASE OF CRISPR GENE-EDITING SYSTEMS

Currently, the most developed forms of human capacity enhancement are the use of drugs (neuro stimulants, oxytocin, selective serotonin reuptake inhibitors...) and brain stimulation devices. The latter can be invasive, such as deep brain stimulation, where mild electrical discharges are produced in the brain through surgically implanted electrodes. But they can also be non-invasive and the stimulation can be performed through electrical discharges or magnetic waves from outside the skull. The use of brain-computer interfaces to enhance certain human skills is also considered a possibility in the longer term.

However, the most promising techniques in this area are genetic interventions, thanks to the recent development of CRISPR[3] gene-editing systems. In particular, the CRISPR/Cas9 system offers precise mechanisms of human genome modification. For this reason, it has been widely utilized since 2014, in many basic biological studies oriented to control the expression of specific genes, gene knockout, or genome-scale screening. Recently, several CRISPR/Cas systems have been used in clinical translational studies for drug screening in disease models (organoids), gene correction or anti-virus therapies (Zhang et al., 2017: 233).

[2] Apart from the article of M. Alonso, J. Anomaly and J. Savulescu, the other three were presented at the Third International Workshop on Human Enhancement, held in Granada on the 3rd and 4th of June 2019. The workshop was organized by the BIOethAI+ Project in collaboration with the Wellcome Centre for Ethics and Humanities, University of Oxford. The main speakers were Jonathan Pugh, Hannah Maslem and Julian Savulescu. Since 2017 BIOethAI+ Project has studied some ethical aspects of moral enhancement through new developments in biotechnology and artificial intelligence. Although it has been based at the University of Granada, 19 researchers from 12 universities in different countries have taken part in it. The project is funded by the Spanish Government (FFI2016-79000-P).

[3] CRISPR stands for Clustered Regularly Interspaced Short Palindromic Repeats, which are interrupted by "spacer" sequences. This powerful gene-editing tool has been developed by repurposing an ancient immune system mechanism in bacteria (Jinek et al., 2012; Doudna & Charpentier, 2014).

There is no doubt about the advantages of the CRISPR/Cas9 genome-editing system, compared to the alternative techniques commonly used in human pluripotent stem cells (PSCs) and somatic stem cells (SSCs). CRISPR/Cas9 is easy to use and more economical than the zinc-finger nucleases (ZFNs) and transcription activator-like effector nuclease (TALEN). It is also highly efficient and faster than TALEN in editing human stem cells (Ding et al., 2013).

These advantages explain the rapid adoption of CRISPR/Cas9 system as the preferred tool for gene editing, and the growing number of publications in which CRISPR/Cas9 is the key methodological advance in developing new clinical applications (Memi, Ntokou, & Papangeli, 2018: 490; You et al., 2019: 360, 364-365).

The CRISPR/Cas9 system allows the integration of gene-manipulating capacities in one technique, in a cheap, easy-to-use and efficient way. It is a powerful tool for new researchers interested in understanding the limitations of modeling human disease and treatment options on other animals. But the comprehension of human biology still poses formidable challenges at molecular, cellular, tissue, and organismal levels during different developmental stages. In combination with organoids, embryonic stem cells (ESCs), adult stem cells (ASCs) and human-induced pluripotent stem cells (iPSCs), CRISPR systems are an essential tool to reproduce many aspects of human development, physiology, and disease in vitro, ex vivo, and xenon models (Wu & Izpisua Belmonte, 2016: 1572).

Tested on three-dimensional tiny versions of the organs they are meant to model (*organoids*), CRISPR gene-editing systems bring us closer to a plausible scenario of less risky gene therapies and cell-replacement therapies with the capacity to cure diseases at the roots. This context offers promising new clinical alternatives for inherited disorders, some types of cancer, and certain viral infections (You et al., 2019: 359).

A better understanding of epigenetic factors, and a combination of biological tools and engineering principles from synthetic biology, open new opportunities for the design, analysis, and manipulation of biological processes in humans. The gene-editing technology associated with CRISPR/Cas systems can be considered the greatest step in the last seven years towards the goals of a genuine personalized medicine program, focused on individualized variations in pathology that form the core of precision medicine (Bilkey et al., 2019: 3). The

versatility and precision of the CRISPR/Cas9 system explains why this tool has become the biggest biotech discovery of the century (Memi et al., 2018: 487).

Despite the fact the first clinical trials based on the use of CRISPR-Cas9 did not begin until 2016, they have still contributed to, and amplified the debate about their possible applications for non-strictly therapeutic purposes. The multiplexing capability of the CRISPR-Cas9 system can be harnessed to build synthetic multi-gene transcriptional programs for rewiring cell fates or engineering metabolic pathways in human cells (Zalatan et al., 2015: 339, 348). And some applications of synthetic biology have been successfully used to customize sensing and response behaviours to user-specified extracellular cues in human cells (Morsut et al., 2016: 783, 788-789).

Nevertheless, the CRISPR/Cas9 gene-editing system has clear limitations regarding the accuracy and specificity of Cas9 nuclei. These proteins can tolerate mismatches on the guide sequence, leading to off-target cleavage effects. When used in germline editing, they can produce complex rearrangements and embryo mosaicism (Fu et al., 2013: 824-825). Although new methods to improve targeting specificity are under development (Zhou et al., 2019; Tycko, Myer, & Hsu, 2016: 358-359; Gorski, Vogel, & Doudna, 2017; Shao et al., 2017; Banan, 2020), the potentially confounding effects of high-frequency off-target mutations will need to be considered for research applications.

Without significant improvements in their specificity, these nuclei cannot be used safely in the long term for the treatment of human diseases. In somatic cells, CRISPR/Cas9-editing has clear potential for success. Beyond preclinical studies, an increased efficacy could outweigh the associated risks, in a context where accurate models of human diseases have been constructed, potential therapies have been tested and validated in animal models, and genetic modification of animals have been translated into products for the agricultural and pharmaceutical industries (Shrock & Güell, 2017).

But germline editing raises complex issues concerning the liability of those who authorize and develop the intervention, the irreversibility of its effects, and how the future generations are affected (Memi et al., 2018: 496). Potential immunogenicity and activation of the P53 pathway are also possible side effects (Haapaniemi et al. 2018; You et al., 2019: 366, 368). For the time being, there is a broad

consensus about the high-risk associated with the potential use of CRISPR/Cas gene-editing systems in the human germline (Lanphier et al., 2015).

THE POTENTIAL OF CRISPR/CAS9 TECHNOLOGY FOR GENETIC ENHANCEMENT

Due to its versatility, simplicity and efficiency, the CRISPR/Cas9 technology has been applied in research for the genetic enhancement of farm and pet animals. Among other traits, the interventions were designed to improve resistance to viral infections, thermogenic capacity, and to reduce the accumulation of fat mass (Zheng et al., 2017; Cyranoski, 2015).

In beagle dogs that lack Myostatin (MSTN), a CRISPR/Cas9 system was successfully applied to edit specific genes with high efficiency and minimal mutagenic activity (Cong et al., 2013). Spontaneous mutations of MSTN –a negative regulator of skeletal muscle mass- cause muscle hypertrophy without severe, adverse consequences in many species, including dogs. The CRISPR/Cas9-engineered beagles that lack Myostatin expression obtained double muscular mass than their non-engineered littermates. The step from myopathy therapy to athlete enhancement seems less unlikely than other options in the usual science-fiction scenarios. This case gives some clues about the necessary evolution of basic assumptions in the ethical debate and regulatory documents.

In conclusion, the technological limitations and risks associated with the CRISPR/Cas gene-editing systems are so far significant enough to restrict its use in humans to very specific circumstances. The *Regulatory Framework for Clinical Trials That Use Heritable Genome Editing* suggested by Steffin, Hsieh, & Rouce (2019: 48) emphasizes some interesting recommendations:

1) Absence of reasonable alternatives. 2) Restriction to preventing a serious disease or condition. 3) Restriction to editing genes that have been convincingly demonstrated to cause or strongly predispose to the disease or condition. 4) Restriction to converting such genes to versions that are prevalent in the population and are known to be associated with ordinary health with little or no evidence of adverse effects. 5) Availability of cred-

ible preclinical and/or clinical data on risks and potential health benefits of the procedures. 6) Ongoing, rigorous oversight during clinical trials of the effects of the procedure on the health and safety of the research participants. (...) 10) Reliable oversight mechanisms to prevent extension to uses other than preventing a serious disease or condition.

This volume includes two contributions focused on the status of gene editing technologies as potential tools for some forms of human enhancement. Marcos Alonso, Jonathan Anomaly, and Julian Savulescu, in "Gene Editing: Medicine or enhancement?", explore in detail the status of gene editing technologies like CRISPR. They argue that gene editing is both a conventional medical technology and a potential human enhancer. For the public debate, different applications of the CRISPR gene-editing systems may require separate considerations in terms of regulation or policy. Readers will find a good selection of interesting cases, including the case of the Chinese twins whose embryos were edited with CRISPR by Dr. He Jiankui and his team.

The concept of preventive medicine is developed in several contexts of discussion, considering how social norms and public policies can affect future generations, but also the negative consequences of anti-gene editing prejudices and the inconsistencies in regulatory frameworks. The authors provide key elements for a more informed discussion about gene editing applied to human enhancement.

Marianna Capasso and Ilaria Santoemma ("Genetic Enhancement and the CRISPR-Cas9 case: an attempt for an Agency Approach") consider the potential use of CRISPR-Cas9 technology for human enhancement, framed within the *Agency Approach*. They explore both the biological and the philosophical implications of concepts like *poiesis*, *autopoiesis*, and *sympoiesis*, trying to understand their role in the ethical discussion of poietic (intentional) and autopoietic (unexpected) processes of modifications on genomes. The birth of twin girls resistant to HIV, after using CRISPR-Cas9 for germline editing from He Jiankui's team, is one of the cases they analyzed, considering the individuals involved and the impact on the scientific community and the society. They propose some guidelines for a multi-level system in which scientists should take responsibility for the mediation through which they act, and also for the values they chose to implement.

SCOPES OF HUMAN ENHANCEMENT

Enhancement technologies, such as CRISPR-Cas9, could be applied to different scopes of human functionality. One of them is related to physical exercise. Biotechnology has within its reach the ability to provide us with, for a short period, more reflexes, strength, speed or resistance. Scientists at Case Western Reserve University in Cleveland genetically manipulated mice as early as 2007 to overexpress the gene responsible for glucose metabolism in skeletal muscles (PEPCK-C). The result was a super-mouse that could run continuously for 6 hours, compared to a maximum of 10 minutes for an unmodified mouse, and without any negative health effects (Hanson et al. 2007).

The plausible possibility of applying changes of this kind to human nature, forces us to consider whether it would be correct to do so. Although this increased functionality would have a significant impact on our daily physical tasks (making life easier in terms of professional or mere physical well-being), the debate in this area of enhancement has usually been about the consequences regarding competitive sports. In principle, allowing an athlete to use biotechnology to improve performance would be a further example of sports doping. Therefore, in the prevailing belief that doping is a form of cheating, bio-physical enhancement should be censored and banned. Even so, some authors wonder whether it is not possible to distinguish between acceptable forms of physical enhancement and others that do amount to cheating. Others even question whether physical enhancement contravenes itself the *ethos* of sport (Tamburrini & Tännsjö 2011; Miah 2016).

Another scope of enhancement is the cognitive one. The great progress made by the neurological sciences and biotechnology together allows us, already with few adverse effects in some cases, to considerably increase capacities such as intelligence, memory, attention or learning. Our different neurological information processing systems could be greatly improved with substances such as modafinil, with transcranial stimulation devices (magnetic or electrical) or with new genetic editing techniques (Sandberg 2011). In the debate on this scope of bioenhancement, concern about personal and social effects has predominated, in particular about the counterproductiveness of seeking improvements in positional goods or about a possible inequality in the implementation system (Sandberg & Savulescu 2011).

Enhancements could even reach the realm of our emotions. This could be achieved by administering to healthy people some of the neuropharmacological substances that currently have a therapeutic purpose. The psychiatrist P. Kramer (1993) told how his patients, already cured of depression, asked him to continue prescribing Prozac so that they could "feel better than good". For some authors, the increased energy and self-confidence produced by neuro stimulants would bring us not only pleasant states of mind but would also help us to have new and valuable personal relationships as well as to strengthen those we already have. It would also decrease, it is said, some conflicts and social problems (Liao & Roache 2011).

Other authors stress the benefits of possible uses of biotechnology in experiencing emotions that are logically required by the context of a situation, but from which we are naturally prevented from experiencing. For example, when a woman lacks maternal feelings after childbirth. Despite the positive effects that could result from such emotional enhancements, one might nevertheless wonder whether the enhanced person would not lose some of their authenticity. One reply could be that what is really alienating is that one cannot control her emotions (Kahane 2011).

MORAL ENHANCEMENT, FREE WILL AND RESPONSIBILITY

But the area of bioenhancement that is most controversial, in terms of public opinion (Riis et al., 2008), is that of moral behaviour. In principle, it might be strange that this generates some rejection. Is not moral development what we pursue in ourselves and for others? Is this not what we seek with education, rehabilitation of criminals or different forms of social awareness? Moreover, if these traditional forms of moral development are not usually effective and when they are, they are only effective in the long term, then why not use interventions to modify the neurological determinants of morality?

At present, various treatments could be applied to change the moral attitude of human beings. For this purpose, we could use substances such as propranolol, oxytocin, selective serotonin reuptake inhibitors, modafinil or methylphenidate. Transcranial stimulation devices or, more recently, some of the CRISPR/Cas systems would also be useful. Separately or jointly these techniques could influence some relevant aspects in moral conduct, like the reduction of the implicit racist tendency (Terbeck et al

2012), the reduction of the aggression (Almeida et al. 2005, Miczek et al. 2007, Coccaro 2012), the increase of a sense of justice (Crockett et al. 2008, and Wood et al 2006) or the increase of empathy (Barraza & Zak 2009, Hurlemann et al. 2010, Rilling et al. 2011).

Why then, can the use of these forms of moral enhancement be controversial, even when they entail no health risks? Experts agree that the main reason for this lies in the possible threat that this type of enhancement would pose to individual freedom, either by directly reducing free will (Harris 2011; Diéguez & Véliz 2019) or by requiring forced implementation (Persson & Savulescu 2008).

It is important to note, however, that the validity of the first objection, regarding free will, will depend on what we mean by a genuine moral enhancement. It is true that directly expecting that individuals behave correctly through biological interventions, or even that they are highly motivated to do the right thing, probably implies replacing autonomy with strict biological determinants. This is what could be derived from proposals that endorse the use of treatments such as those mentioned above to increase certain motivational dispositions, such as empathy, altruism or sense of justice (Persson & Savulescu 2008), or to attenuate counter-moral emotions, such as racial aversion or violent impulses (Douglas 2008, 2013).

But this is not a proper way to understand moral enhancement. We believe it is based on a very simplistic conception of morality. Morality is more than being generous or willing to collaborate with others. For someone to make progress in morality they must also be able to properly interpret each situation and deliberate on how to orient their emotions and motivations. Namely, morality, in addition to feeling, is also largely a matter of having reasons to act. Many of us think that these cognitive and rational aspects should not be forgotten when theorizing about the possibilities of the current techniques of moral enhancement (Harris 2016; Earp et al. 2018; Focquaert & Schermer 2015; Schaefer & Savulescu 2019; Lara 2017). In that way, we are also demanding a much less passive role for the individual in the process of enhancement than is usually granted in interventions aimed at changing only attitudes (Lara 2017).

In short, bioenhancement can pose a threat to autonomy only if it is alien to that part of human beings that precisely converts them into moral agents, characterized then by maintaining an active and ultimately deliberative role in the sphere of moral decisions.

This coincides in part with what Niel Conradie maintains in his article in this volume "Enhancing Responsibility and Responsible Enhancement: Moral Bioenhancement and the Actual-Sequence Account of Moral Responsibility". He maintains that if we base ourselves on the most widespread conception of moral responsibility, as expounded by Fischer and Ravizza, moral bioenhancement should be permissible not on the conditions of whether it increases some attitude or motivation, but rather because it does not degrade a capacity, namely that of moral reasons-responsiveness. In other words, intervention in the biology of the individual will be acceptable only if it does not diminish his capacity to govern himself according to moral reasons in which he can perceive a normative force. Conradie justifies this because it is this capacity that defines the individual as a moral agent and that, therefore, allows us to conceive of them as someone to whom, by their actions, blame or praise can be attributed. Finally, the author assumes that there are forms of bioenhancement that could meet the requirement of not deteriorating that capacity and that could even increase it.

COERCED ENHANCEMENT AND THE THREAT OF CLIMATE CHANGE

The second major source of ethical controversy about moral bioenhancement has to do with the strategies for implementing it. If this enhancement were acceptable, presumably its implementation would not be questioned if the intervention had the consent of the individual being enhanced. But unfortunately, this strategy based on consent is not viable. It is foreseeable that those who would request the intervention will be those who need it the least and that those who behave immorally will not consent to be morally enhanced (Harris 2016; Torres 2017). The problem is that this foreseeable fact would not only prevent the good social consequences that could be derived from the enhancement but would also worsen the situation by promoting the figure of the free-rider, the person who only pursues things in their benefit at the expense of the altruistic behaviour of others (Glannon 2018; Lara 2017).

Because this, it is worth considering whether situations could occur where it would be justified to bioenhance individuals without their consent, either to increase their autonomy or to avoid great harm to others.

This first possible way of justifying the imposition of moral bioenhancement, because it increases the autonomy, is what Niel Conradie advocates in his article here. He starts from the fact that this type of intervention is desirable (when it seeks to modify capacities) because we have moral reasons for promoting moral agency in ourselves and others as much as we can. From this, it follows the feeling that we should morally educate children and to rehabilitate wrongdoers. But the author goes further and argues that given the difficulty in clearly distinguishing from his theoretical framework between a reason to minimize harm and a reason to maximize it, the demands of moral responsibility do not exclude the fact that sometimes moral bioenhancement may be even mandatory.

A universal imposition of bioenhancement could also be directly justified by the dire consequences that failure to do it could have for everyone. This is what Persson and Savulescu (2008, 2012) intend when they insist on the fearsome risks of facing the great challenges of today from our natural limitations in making moral decisions. They point out how, when making decisions, we concern most notably on beings and issues close to us, in comparison with the disinterest we show for the greater suffering of strangers or for the greater damage that can be caused in the medium and long term. This leads us in many cases to discriminate against those who do not belong to our group or to make entirely irrational decisions.

Studies in neuroethics and evolutionary psychology explain these deficiencies in human beings as an example of the little usefulness of our current abilities or predispositions for a social context very different from that in which, as an adaptation mechanism, such abilities and predispositions arose. These appeared in an environment of small communities that required immediate and reciprocal group cooperation. But they are not valid for a globalized, anonymous and increasingly technologically advanced society, in which the harmful behaviour of the free-rider is more difficult to detect and punish.

Moreover, in a society with widespread access to the Internet that allows terrorists to easily obtain weapons of mass destruction, traditional morality is even more inefficient –according to Persson and Savulescu– not only to ensure better coexistence but also to guarantee the survival of our species. Nor does it help much, that the liberal democratic system in our societies is always based on national interests, being then incapable of dealing with serious global threats such as world hunger

and climate change. For all these reasons, these authors conclude, moral bioenhancement is urgent and can be demanded even against the will of individuals.

It is precisely this confidence in resolving important threats such as climate change through moral bioenhancement, that Jon Rueda criticizes in his article published in this volume under the title "Climate Change, Moral Bioenhancement, and the Ultimate Mostropic". After evaluating the difficulties of a possible scenario in which people voluntarily take a safe and cheap drug that would make us act in the face of the climate catastrophe that is approaching, he also considers the inconveniences of another scenario in which the intake of the drug would be mandatory, as Persson and Savulescu have proposed. Rueda considers this second scenario unfeasible because it would be difficult to justify it from the liberal scheme that predominates in our societies and because the risks and cost of the required control mechanisms would be very high.

Rueda's ultimate aim is to show that the debate on moral bioenhancement cannot be reduced to the sphere of ethics and that it must always be accompanied by the political implications that its implementation would entail. He even suggests that to solve the major problems that currently concern us, the ethical study of moral bioenhancement must be dealt with in conjunction with other essentially political aspects. Precisely concerning the problem of climate change, Rueda highlights, for example, the usefulness of the debate on moral bioenhancement to help us design more effective political strategies from greater knowledge of our limitations as moral beings.

CONCLUDING REMARKS

The advance of science has made it a not-so-distant possibility to quickly and effectively satisfy our omnipresent desire for self-improvement. It is undeniable that this possibility must be meditated upon and discussed. But we are convinced that this can only be done adequately from a consideration, free of prejudices, of the particularities of each of the technologies and of the human functionalities that are intended to be enhanced.

There are great differences between non-invasive enhanced biotechnologies with reversible or limited effects, such as treatments with certain substances or transcranial stimulation devices, and others that could imply

substantial changes in the biology of a subject and their future descendants, as occurs with genetic editing systems. One of these differences would be the greater effectiveness of these systems, recently reinforced by the successful development of the CRISPR/Cas system9. However, this technique still poses serious risks and limitations, especially if used in the human germline. The fact that this has not stopped certain scientists from using it on humans, as demonstrated by the recent case of the Chinese twins, raises the need to establish, in all countries, a clear, coherent and demanding regulation in this regard, but one that leaves the door open to possible applications of this technology on human enhancement, always from risk avoidance and an informed and unbiased discussion.

But the special features are not only in the different enhancement techniques. They are also in the objectives. As the surveys show, people do not think that the biotechnological modification of physical or cognitive abilities is as controversial as that of emotional or moral attitudes. This makes sense because the enhancement of these attitudes may imply an alteration of the identity of the individual at the deepest level, in the freedom of that individual to choose values, something that would not occur if we talk about enhancement in physical or cognitive skills. But moral enhancement does not always have to entail this undesirable effect. Everything will depend on what we mean by moral enhancement. Thus, the free will should not be compromised if what we intend to promote directly with biotechnology are not attitudes such as empathy or the sense of justice, but rather skills of the moral agent, such as knowledge of relevant data or deliberation.

Another important issue related to moral bioenhancement is that of its implementation in a context where the modification of individuals' behaviour to face the great global challenges is so urgent. Would the moral bioenhancement of individuals be acceptable if we could solve, for example, the emergency posed by climate change? Regardless of whether it is ethically justifiable to impose an intervention with such significant effects on the identity of the individual, there are important implementation constraints that must be taken into account, especially in terms of the risks and cost of control mechanisms. This would not invalidate the ethical debate on moral bioenhancement but it should help us to extract from that debate the keys to develop a more efficient policy to face important challenges, such as climate change.

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