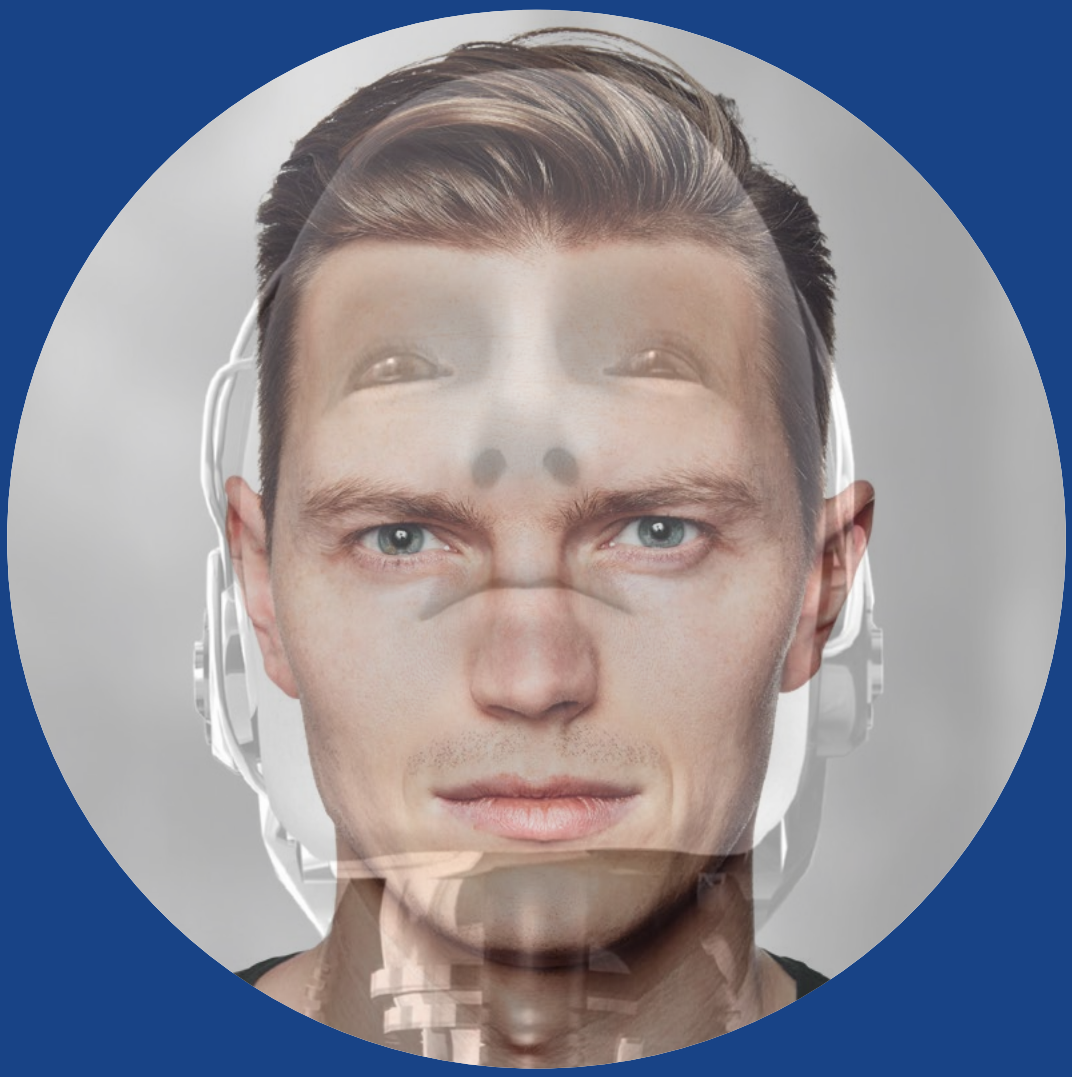

The Next Step

EXPONENTIAL LIFE

Tackling Climate Change Through Human Engineering

S. MATTHEW LIAO

Opening image:
Department of Water and Power (DWP)
San Fernando Valley Generating Station,
Sun Valley, CA, USA.

S. Matthew Liao
Center for Bioethics | New York University, New York, USA

S. Matthew Liao is Arthur Zitrin Professor of Bioethics, Director of the Center for Bioethics, and Affiliated Professor of Philosophy at New York University. He is the author of *The Right to Be Loved* (Oxford University Press, 2015); *Philosophical Foundations of Human Rights* (Oxford University Press, 2015); and *Moral Brains: The Neuroscience of Morality* (Oxford University Press, 2016). He has given TED talks in New York and Geneva, and he has been featured in *The New York Times*, *The Atlantic*, *The Guardian*, *Harper's Magazine*, *Sydney Morning Herald*, *Scientific American*, *Newsweek*, and other media outlets.

MORE ABOUT THE AUTHOR [+]

Human-induced climate change is one of the biggest problems that we face today. Unfortunately, existing solutions such as behavioral and market solutions appear to be insufficient to mitigate the effects of climate change while geoengineering could have catastrophic consequences for us and the planet. In this paper, I propose that we explore a new kind of solution to climate change, namely, human engineering, which involves biomedical modifications of humans so that they can mitigate or adapt to climate change. I shall argue that human engineering is potentially less risky than geoengineering and that it could make behavioral and market solutions more likely to succeed.

INTRODUCTION

Human-induced climate change is one of the biggest problems that we face today. Millions could suffer hunger, water shortages, diseases, and costal flooding as a result of climate change.[1] The latest science suggests that we may be near or even beyond the point of no return.[2] The risks of the worst impacts of climate change can be lowered if the greenhouse gas levels in the atmosphere can be reduced and stabilized. To reduce greenhouse gas emissions, various solutions have been proffered, ranging from low-tech behavioral solutions such as encouraging people to drive less and recycle more; to market solutions such as carbon taxation, emissions trading, and other ways of incentivizing industries to adopt cleaner power, heat, and transport technologies; to geoengineering, that is, large-scale manipulations of the environment including reforestation, spraying sulfate aerosols into the stratosphere to alter the reflectivity of the planet, and fertilizing the ocean with iron to spur algae blooms so that they can help remove carbon out of the atmosphere.[3]

Each of these solutions has its merits and demerits. For instance, behavioral solutions are ones that most of us could easily physically perform. On the other hand, many people lack the motivation to alter their behavior in the required ways. Importantly, even if behavioral solutions were widely adopted, such behavioral changes may not be enough to mitigate the effects of climate change. Similarly, market solutions could, on the one hand, reduce the conflict that currently exists for companies between making profit and minimizing undesirable environmental impact. But, on the other hand, effective market solutions such as international emissions trading require workable international agreements, which have thus far seemed difficult to orchestrate. For example, current data suggests that the Kyoto

Protocol has not really been successful in producing demonstrable reductions in emissions in the world,[4] and there is already some evidence that the US, for example, is unlikely to meet the targets set by the Paris Agreement.[5] Moreover, it has been estimated that to restore our climate to a hospitable state requires us to cut our carbon emissions globally by at least seventy percent.[6] Given the inelastic and rising demands for petrol and electricity, there are serious issues about whether market solutions such as carbon taxation can by themselves deliver reductions of this magnitude.

As a result, some scientists and policy makers are proposing that we take very seriously the idea of geoengineering, since, at least in theory, the impact of geoengineering could be significant enough to mitigate climate change.[7] However, a major problem with geoengineering is that, in many cases, we appear to lack the necessary scientific knowledge to devise and implement geoengineering without significant risk to ourselves and to future generations. Indeed, spraying sulfate aerosols could destroy the ozone layer and iron fertilization could promote toxic planktons and destroy some or all forms of marine life.

In this context, I propose that we explore another kind of solution to the problem of climate change, one that has not been considered before and one that is potentially less risky than geoengineering, something that my colleagues and I have elsewhere called "human engineering."[8]

Human engineering involves the biomedical modification of humans to make us better at mitigating, and adapting to the effects of, climate change. I shall argue that human engineering potentially offers an effective means of tackling climate change, especially if implemented alongside the sorts of solution that we have already described.

Before I explain the proposal, let me make clear that human engineering is intended to be a voluntary activity—possibly supported by incentives such as tax breaks or sponsored health care—rather than a coerced, mandatory activity. I am positively against any form of coercion of the sort that the Nazis perpetrated in the past (segregation, sterilization, and genocide). Also, this proposal is intended for those who believe that climate change is a real problem, and who, as a result, are willing to take seriously potentially catastrophic measures such as geoengineering. Someone who does not believe that climate change is a real problem is likely to think that even asking people to recycle more is an overreaction to

climate change. Finally, the main claim here is a modest one, namely, human engineering should be considered alongside other solutions such as geoengineering. The claim is not that human engineering ought to be adopted as a matter of public policy. This is an attempt to encourage "outside the box" thinking vis-à-vis a seemingly intractable problem.

So what are some examples of human engineering? Here are four examples that a) seem realistic and feasible to implement in the near future; and b) seem potentially desirable even for people who may not care about climate change. I am not wedded to these examples and readers are welcome to come up with better examples to illustrate the point that human engineering should be taken seriously.

PHARMACOLOGICAL MEAT INTOLERANCE

A widely cited report by the UN Food and Agriculture Organization estimates that 18% of the world's greenhouse emissions (in CO_2 equivalents) come from livestock farming, a higher share than from transport. Others have suggested that livestock farming accounts for at least 51% of the world's greenhouse emissions.[9] Still others have estimated that nitrous oxide and methane from livestock may double by 2070.[10] This alone would make meeting climate targets essentially impossible. However, even by the more conservative estimate, close to 9% of human CO_2 emissions are due to deforestation for expansion of pastures, 65% of anthropogenic nitrous oxide is due to manure, and 37% of anthropogenic methane comes directly or indirectly from livestock. Some experts estimate that each of the world's 1.5 billion cows alone emit 100–500 liters (about 26–132 gallons) of methane a day.[11] Since a large proportion of these cows and other grazing animals are meant for consumption, reducing the consumption of these kinds of red meat could have significant effects on the environment.[12] Indeed, even a minor (21–24%) reduction of red meat consumption would achieve the same reduction in emissions as the total localization of food production, that is, having zero "food-miles."[13]

Now some people will not give up eating red meat no matter what. However, there are others who would be willing to give up eating red meat, but they lack the motivation or will power to do so. After all, many people find the taste of red meat irresistible. This may explain why many vegetarian restaurants serve vegetarian dishes with plant-based ingredients that taste like meat.

Human engineering could help here. Just as some people have natural intolerance to, for example, milk or crayfish, we could artificially induce mild intolerance to red meat. While meat intolerance is normally uncommon, in principle, it could be induced by stimulating the immune system against common bovine proteins.[14] The immune system would then become primed to react to them, and henceforth eating "eco-unfriendly" food would

Rotating milking parlor at a dairy farm in California, USA.

induce unpleasant experiences. Even if the effects do not last a lifetime, the learning effect is likely to persist for a long time.

In fact, there is evidence that meat intolerance can be triggered naturally. Bites from Lone Star ticks can make people allergic to red meat.[15] Lone Star ticks carry a sugar called alpha-gal, which is also found in red meat, but not in people. Normally, alpha-gal in meat poses no problems for people. But when a Lone Star tick bites a person, it transfers alpha-gal into the blood stream. As a result, the person's body produces antibodies to fight the sugar. The next time a person eats red meat, the person has an allergic reaction, which could be mild or severe.

A potentially safe and practical way of inducing such intolerance may be to produce "meat" patches—akin to nicotine patches. People can wear these patches in order to curb their enthusiasm for red meat. To ensure that these patches have the broadest appeal, we can produce patches that just target animals that contribute the most to greenhouse gas emissions, so that people need not become full vegetarians if they do not want to.

MAKING HUMANS SMALLER

Human ecological footprints are partly correlated with our size. We require a certain amount of food and nutrients to maintain each kilogram of body mass. Other things being equal, the larger one is, the more food and energy one requires. Indeed, basal metabolic rate (which determines the amount of energy needed per day) scales linearly with body mass and length.[16] In addition to needing to eat more, larger people also consume more energy in less obvious ways. For example, a car uses more fuel per mile to carry a heavier person than a lighter person; more fabric is needed to clothe larger than smaller people; heavier people wear out shoes, carpets, and furniture more quickly than lighter people, and so on.

A way to reduce this ecological footprint would be to reduce size. Since weight increases with the cube of length, even a small reduction in, for example, height might produce a significant effect in size. (To reduce size, we could also reduce average weight. But to keep the discussion simple, I shall just use the example of height). Reducing the average US height by just 15 centimeters (5.9 inches) would mean a mass reduction of 23% for men and 25% for women, with a corresponding reduction of metabolic rate (15%/18%).

How could height reduction be achieved? Height is determined partly by genetic factors and partly through diet and stressors. One possibility is to use preimplantation

genetic diagnosis (PGD). PGD is currently employed in fertility clinics as a relatively safe means of screening out embryos with certain inherited genetic diseases. One might also be able to use PGD to select shorter children. This would not involve modifying or altering the genetic material of embryos in any way. It would simply involve rethinking the criteria for selecting which embryos to implant.

Also, one might consider hormone treatment either to affect somatotropin levels or to trigger the closing of the epiphyseal plate earlier than normal. Hormone treatments are currently already used for growth reduction in excessively tall children.[17]

Finally, there is a strong correlation between birth size and adult height.[18] Gene imprinting, where only one parent's copy of the genes is turned on and the other parent's copy is turned off, has been found to affect birth size, as a result of evolutionary competition between paternally and maternally imprinted genes.[19] So drugs or nutrients that either reduce the expression of paternally imprinted genes or increase the expression of maternally imprinted genes could potentially regulate birth size.

LOWERING BIRTHRATES THROUGH COGNITIVE ENHANCEMENT

In 2008, John Guillebaud, an emeritus professor of family planning and reproductive health at University College London, and Dr Pip Hayes, a general practitioner from Exeter, pointed out that "each UK birth will be responsible for 160 times more greenhouse gas emissions … than a new birth in Ethiopia."[20] Given this, they argue that, as a way to mitigate climate change, Britons should consider having no more than two children.

There are of course already many available methods of curbing birthrates such as the use of contraception. But given the problems of climate change, it seems that we need to accelerate this process. There is strong evidence that birthrates decline as more women receive adequate access to education.[21] While the primary reason for promoting education is to improve human rights and well-being, fertility reduction may be a positive side effect from the point of view of tackling climate change. In general, there seems to be a link between cognition and lower birthrates. In the US, for example, women with low cognitive ability are more likely to have children before age eighteen.[22] Hence, another

possible human engineering solution is to use cognition enhancements such as Ritalin and Modafinil to achieve lower birthrates. As with education, there are many other, more compelling reasons to improve cognition, but the fertility effect may be desirable as a means of tackling climate change. Even if the direct cognitive effect on fertility is minor, cognition enhancements may help increase the ability of people to educate themselves, which would then affect fertility, and indirectly climate change.

PHARMACOLOGICAL INDUCTION OF ALTRUISM AND EMPATHY

Many environmental problems are the result of collective action problems, in which individuals do not cooperate for the common good. But if people were generally more willing to act as a group, and could be confident that others would do the same, we may be able to enjoy the sort of benefits that arise only when large numbers of people act together. Pharmacological induction of altruism and empathy may help increase the chances of this occurring.[23]

There is evidence that altruism and empathy have biological underpinnings and can be affected pharmacologically. For example, test subjects given the prosocial hormone oxytocin, which is available as a prescription drug, were more willing to share money with strangers and to behave in a more trustworthy way.[24] Also, a noradrenaline reuptake inhibitor increased social engagement and cooperation with a reduction in self-focus during an experiment.[25] Furthermore, oxytocin appears to improve the capacity to read other people's emotional state, which is a key capacity for empathy.[26] This suggests that interventions affecting the sensitivity in these neural systems could also increase the willingness to cooperate with social rules or goals.

These examples are intended to illustrate some possible human engineering solutions. Others like them might include increasing our resistance to heat and tropical diseases, reducing our need for food and water, and, more speculatively, giving humans cat eyes so that they can see better at night and thereby reduce global energy usage considerably.[27]

A CASE FOR HUMAN ENGINEERING

Why should we take human engineering solutions seriously? There are at least two reasons: human engineering is potentially less risky than geoengineering; and human engineering could make behavioral and market solutions more likely to succeed.

In comparison to geoengineering, the human engineering solutions canvassed here rely on tried-and-tested technology, whose risks, at least at the individual level, are comparatively low and well known. For example, PGD—the process that would enable us to select smaller children—is an accepted practice in many fertility clinics. And, oxytocin, which could be used to increase empathy, is already used as a prescription drug. Also, given that human engineering applies at the level of individual humans, it seems that we should be better at managing its risks in comparison to the risks imposed by something like geoengineering which takes place on a much larger, global, scale.

“If we disappear then nature will continue, but if nature disappears then none of us will survive.”

SEBASTIÃO SALGADO (1944–)
Brazilian photographer.

Clouds of smoke fill the atmosphere as areas of tropical forest are destroyed to plant oil palms in Tripa, Aceh Province, Indonesia. Palm oil is used as a vegetable fat in products ranging from chocolate and breakfast cereals to shampoo. It is also classified as a biofuel.

Human engineering could also make behavioral and market solutions more likely to succeed in the following way. Pharmacologically induced altruism and empathy could increase the likelihood that we adopt the necessary behavioral and market solutions for curbing climate change. Pharmacological meat intolerance could make the behavioral solution of giving up red meat much easier for those who want to do so but who find it too difficult.

Moreover, human engineering could be more liberty enhancing than certain behavioral and market solutions. As we have seen, given the seriousness of climate change, some people have proposed that we ought to restrict human reproduction and adopt something akin to China's one-child policy.[28] However, suppose that the relevant issue is some kind of fixed allocation of greenhouse gas emissions per family. If so, given certain fixed allocations of greenhouse gas emissions, human engineering could give families the choice between having one large child, two medium-sized children, or three small-sized children. In this context, human engineering seems more liberty enhancing than a policy that says that one can only have one or two children.

Furthermore, some human engineering solutions might be "win-win" solutions in the sense that desirable effects are very likely to result from implementing them regardless of their effectiveness at tackling climate change. For instance, cognitive enhancement, if effective at reducing birthrates, could enable China to limit or dispense with its controversial, coercive one-child policy. At the same time, improved cognition is itself of great value. Similarly, if pharmacological meat intolerance is effective at reducing greenhouse gases that result from the farming of certain kinds of animals for consumption, it could reduce the need to tax undesirable behavior. In addition, the health benefits of eating less red meat and the reduction in suffering of animals farmed for consumption are themselves positive goods.

More generally, as well as helping to mitigate climate change, human engineering could also help solve some other serious problems of the modern world: smaller people, more considerate people, and lower meat consumption, can help address the problems associated with unsustainable energy demands and water shortage.

At this point, it is worth reiterating that human engineering is intended to be a voluntary activity. I am positively against others coercing someone to take up these pharmacological measures. The idea here is there are people who would like to do the right thing, but owing to a weakness of will, they cannot get themselves to do the right thing. Having the option to use human engineering, such as pharmacological altruism, may help these people overcome their weakness of will voluntarily and enable them to do the right thing.

SOME POSSIBLE CONCERNS REGARDING HUMAN ENGINEERING

As with all biomedical treatments—including those routinely prescribed by medical professionals—human engineering carries risks. The possibility of these risks means that if people are to be persuaded to undergo human engineering, the risks associated with it must be minimized.

This said, these risks should also be balanced against the risks associated with taking inadequate action to combat climate change. If behavioral and market solutions alone are not sufficient to mitigate the effects of climate change—then even if human engineering were riskier than these other solutions, we might still need to consider it. Also, it is important not to exaggerate the risks involved in human engineering. This is a very real possibility, since people are generally less tolerant of risks arising from novel, unfamiliar technologies than they are of risks arising from familiar sources.[29] To counter this effect, it is worth remembering both that much of the technology involved in human engineering—such as PGD and oxytocin—is already safely available for other uses, and that in non-climate change contexts our society has been willing to make biomedical interventions on a population-wide scale. For example, fluoride is deliberately added to water with the aim of fortifying us against tooth decay, even though doing so is not without risks. Similarly, people are routinely vaccinated to prevent themselves and those around them from acquiring infectious diseases, even though vaccinations sometimes have side effects, and can even lead to death. Hence, with respect to safety, it seems that we should judge human engineering solutions on a case-by-case basis, and not rule them out *tout court*.

Others may be concerned that human engineering involves interfering with nature. In the biomedical enhancement debate, Michael Sandel argues that a problem with human enhancement is that it represents "a Promethean aspiration to remake nature, including human nature, to serve our purposes and satisfy our desires."[30] Given that human engineering is using biomedical means for the sake of climate change, some might worry that this problem would similarly be present in human engineering. Indeed, a number of environmentalists believe that it is precisely our interference with nature that has given rise to climate change. These environmentalists might therefore object to human engineering on the ground that it, too, is interfering with nature.

While there is something to this concern, the view that "it is morally impermissible to interfere with human nature, because this is interfering with nature, and it is morally impermissible to interfere with nature" seems too strong. Vaccination and giving women access to epidural during labor both interfere with nature, but we would not therefore conclude that their usage is morally impermissible. Also, not every human engineering

Ron Mueck
Couple Under An Umbrella (2013).
Various materials,
300 × 400 × 350 cm.

solution involves interfering with human nature, if by interference one means making modifications to human beings. The selection of a smaller child through PGD, for example, involves no more interference with nature than the standard IVF process, which is not generally viewed as morally suspect.

Moreover, if human engineering could mitigate the effects of climate change, arguably this would bring about a net reduction in human interference with nature at large. Lastly, Sandel is objecting to human enhancement partly because many people want to use it "to serve our purposes and satisfy our desires." But human engineering, as I envisage it, is an ethical endeavor in that mitigating climate change can promote the well-being of many people and animals which are vulnerable to the effects of climate change. Given this, it seems that even those who share Sandel's disapproval can share in the aims of human engineering.

A further concern with human engineering is that some of the solutions may affect children, sometimes irreversibly. To be sure, not all human engineering solutions that would involve children are necessarily controversial. For instance, would we as parents really object to the use of cognitive enhancement on our children as a means of lowering birthrates? There is evidence that many parents are happy to give their children cognitive enhancements such as Ritalin. Still, there are other human engineering solutions that would involve children and that may be controversial, such as giving hormone treatments to their children. In such a case, issues about a child's present and future autonomy and the limits of parental authority would certainly arise.[31] Even in this case though, it is helpful to point out that parents are currently permitted to give hormone treatments to their children, who are otherwise perfectly healthy, so that, for example, a daughter who is predicted to be 1.98 meters (6 feet 5 inches) tall could instead be 1.83 meters (6 feet) tall. On what grounds then should we forbid other parents who want to give hormone treatments to their children so that their children could be 1.52 meters (5 feet) tall instead of 1.62 meters (5 feet 5 inches) tall? It might be thought that in case of the former, the daughters would later appreciate and consent to the parents' decision. But if climate change would seriously affect the well-being of millions of people including one's children, then these children may also later appreciate and consent to the parents' decision.

As a general remark, it is worth asking ourselves why more controversial kinds of human engineering would be contemplated. They might be contemplated because there is evidence that existing solutions for mitigating climate change are likely to fall short of their intended goals, and because millions could suffer hunger, water shortages, diseases, and costal flooding if climate change were not mitigated. In the biomedical enhancement literature, some people believe that, however controversial a technology may be, parents have the right socially and biologically to modify their children as long

as doing so would on the whole promote their children's well-being, and as long as there exists no better means of achieving such an end. Given the seriousness of climate change, and given the possible lack of alternative solutions, we might conclude that if a particular human engineering solution would on the whole promote a child's well-being, then parents should also have a right to implement such a solution even if the solution is a controversial one.

Let me address one last concern, namely, human engineering is likely to have limited appeal. For example, who in their right mind would choose to make their children smaller?

In response, it is helpful to note first that while it is tempting to focus on the most provocative examples of human engineering solutions discussed here, it is not the case that human engineering is synonymous with lack of appeal. After all, cognitive enhancements and pharmacological means of resisting meat are likely to appeal to many people, since improved cognition and the health benefits of reduced consumption of red meat are good in themselves.

Secondly, it is understandable why some people would react negatively toward the idea of having smaller children, since, in our society, being tall is often seen as being advantageous. Indeed, studies have shown that women find taller men more attractive than shorter men and that taller people enjoy greater career success.[32] However, the fact that a particular human engineering solution may not appeal to some people is not a reason to avoid making such a solution available. For one thing, what may be unappealing today may not be so tomorrow. Indeed, people's attitudes toward vegetarianism have drastically changed as a result of vegetarianism's ethical status. Also, it is worth remembering how fluid human traits like height are. A hundred years ago people were much shorter on average, and there was nothing wrong with them medically. We should be wary of the idea that there is an optimal height, namely, the average height in our society today, since this may simply reflect a status-quo bias. Lastly, it is helpful to point out that being small could be advantageous in a number of circumstances. Certainly, there is an advantage to being small given the rapidly shrinking airline seats. In addition, how many centenarians, that is, people who are over a hundred years old, are over 1.83 meters (6 feet) tall? There is evidence that taller people are at higher risk for cancer and tend to suffer more respiratory and cardiovascular illnesses.[33] Moreover, as we prepare for the human exploration of Mars[34] and other planets, it seems likely that height restriction on astronauts will be considered, given not only the cost of fuel but also the resources needed to sustain these individuals.

To drive home the point that having smaller children need not be unappealing, imagine that our preindustrial ancestors are given a choice between a) a world populated by nine billion people who have intervened in their own biology such that most of them are smaller than they would otherwise have been, and who as a result live in a sustainable world; b) a

world populated by nine billion people who have not intervened to affect their own height and who as a result live in a non-sustainable world; and c) a world populated by six billion people who have not intervened to affect their own height and who live in a sustainable world. It is not obvious that, to our preindustrial ancestors, a) would stand out as the least appealing option. In fact, it seems plausible that they might prefer a) to b) or c), given that a) allows more people to live in a sustainable world. If so, in dismissing certain human engineering solutions as unappealing, we should ensure that we are not thereby implicitly endorsing a more familiar, but certainly no more appealing, set of circumstances.

CONCLUSION

I hope to have sketched some plausible scenarios of what human engineering solutions to climate change might involve. I argued that human engineering is potentially less risky than geoengineering and that it could make behavioral and market solutions more likely to succeed. I also considered possible concerns regarding human engineering and I suggested some responses to these concerns.

It may turn out that human engineering is not the best way of tackling climate change. But to concede this now would be to ignore the widely acknowledged fact that we do not currently know which solutions to climate change will be the most effective.

To combat climate change, we can either change the environment or change ourselves. Given the enormous risks associated with changing the environment, we should take seriously the idea that we may need to change ourselves.

NOTES

1. IPCC, "Ipcc Fourth Assessment Report 2007, Working Group II Report 'Impacts, adaptation and vulnerability,'" (2007).
2. See http://www.climatecentral.org/news/world-passes-400-ppm-threshold-permanently-20738 (accessed on Oct 1, 2016).
3. D. W. Keith, "Geoengineering the climate: History and prospect," *Annual Review of Energy and the Environment* 25 (2000).
4. Igor Shishlov, Romain Morel, and Valentin Bellassen, "Compliance of the parties to the Kyoto Protocol in the first commitment period," *Climate Policy* 16(6) (2016).
5. Jeffery B. Greenblatt and Max Wei, "Assessment of the climate commitments and additional mitigation policies of the United States," *Nature Climate Change*, advance online publication (2016).
6. Warren M. Washington et al., "How much climate change can be avoided by mitigation?," *Geophys. Res. Lett.* 36(8) (2009).
7. House of Commons Science and Technology Committee, "The regulation of geoengineering," (Fifth Report of Session 2009-10).
8. S. Matthew Liao, Anders Sandberg, and Rebecca Roache, "Human engineering and climate change," *Ethics, Policy & Environment* 15(2) (2012).
9. R. Goodland and J. Anhang, "Livestock and climate change: What if the key actors in climate change are… cows, pigs, and chickens?," *World Watch*, November/December (2009).
10. Fredrik Hedenus, Stefan Wirsenius, and Daniel J. A. Johansson, "The importance of reduced meat and dairy consumption for meeting stringent climate change targets," *Climatic Change* 124(1) (2014).
11. K. A. Johnson and D. E. Johnson, "Methane emissions from cattle," *Journal of Animal Science* 73(8) (1995).
12. G. Eshel and P. A. Martin, "Diet, energy, and global warming," *Earth Interactions* 10 (2006).
13. C. L. Weber and H. S. Matthews, "Food-miles and the relative climate impacts of food choices in the United States," *Environmental Science & Technology* 42(10) (2008).
14. V. F. Aparicio et al., "Allergy to mammal's meat in adult life: Immunologic and follow-up study," *Journal of Investigational Allergology and Clinical Immunology* 15(3) (2005).
15. See https://www.dtnpf.com/agriculture/web/ag/news/livestock/article/2016/04/25/lone-star-tick-bite-can-create-beef (accessed on Oct 1, 2016).
16. M. D. Mifflin et al., "A new predictive equation for resting energy expenditure in healthy individuals," *American Journal of Clinical Nutrition* 51(2) (1990).
17. A. Grüters et al., "Effect of different oestrogen doses on final height reduction in girls with constitutional tall stature," *European Journal of Pediatrics* 149(1) (1989).
18. H. T. Sorensen et al., "Birth weight and length as predictors for adult height," *American Journal of Epidemiology* 149(8) (1999).
19. Austin Burt and Robert Trivers, *Genes in Conflict* (Cambridge, MA: Belknap Press, 2006).
20. John Guillebaud and Pip Hayes, "Population growth and climate change," *British Medical Journal* 337 (2008): 576.
21. United Nations, *Women's Education and Fertility Behaviour: Recent Evidence from the Demographic and Health Surveys* (New York: United Nations, 1995).
22. D. L. Shearer et al., "Association of early childbearing and low cognitive ability," *Perspectives on Sexual and Reproductive Health* 34(5) (2002).
23. T. Dietz, E. Ostrom, and P. C. Stern, "The struggle to govern the Commons," Science 302(5652) (2003).
24. Paul J. Zak, Angela A. Stanton, and Sheila Ahmadi, "Oxytocin increases generosity in humans," *PLoS ONE* 2(11) (2007).
25. W. S. Tse and A. J. Bond, "Difference in serotonergic and noradrenergic regulation of human social behaviours," *Psychopharmacology* 159(2) (2002).
26. A. J. Guastella, P. B. Mitchell, and M. R. Dadds, "Oxytocin increases gaze to the eye region of human faces," *Biological Psychiatry* 63(1) (2008).
27. See http://www.theadaptors.org/episodes/2015/2/11/cat-eyes-for-climate-change (accessed on Oct 1, 2016).
28. Sarah Conly, *One Child: Do We Have a Right to More?* (New York: Oxford University Press, 2016); Travis N. Rieder, *Toward a Small Family Ethic: How Overpopulation and Climate Change Are Affecting the Morality of Procreation* (New York: Springer, 2016).
29. P. Slovic, "Perception of risk," *Science* 236(4799) (1987).
30. M. Sandel, *The Case Against Perfection: Ethics in the Age of Genetic Engineering* (Harvard: Harvard University Press, 2007).
31. S. Matthew Liao, "The ethics of using genetic engineering for sex selection," *Journal of Medical Ethics* 31 (2005).
32. R. Kurzban and J. Weeden, "Hurrydate: Mate preferences in action," *Evolution and Human Behavior* 26(3) (2005); T. A. Judge and D. M. Cable, "The effect of physical height on workplace success and income: Preliminary test of a theoretical model," *Journal of Applied Psychology* 89(3) (2004).
33. Geoffrey C. Kabat et al., "Adult stature and risk of cancer at different anatomic sites in a cohort of postmenopausal women," *Cancer Epidemiology Biomarkers & Prevention* (2013).
34. See http://www.nasa.gov/content/nasas-journey-to-mars (accessed on Oct 1, 2016).

SELECT BIBLIOGRAPHY

—Aparicio, V. F., I. S. Marcen, A. P. Montero, M. L. Baeza, and M. D. Fernandez. 2005. "Allergy to mammal's meat in adult life: Immunologic and follow-up study." *Journal of Investigational Allergology and Clinical Immunology* 15(3): 228–231.

—Burt, Austin, and Robert Trivers. 2006. *Genes in Conflict*. Cambridge, MA: Belknap Press.

—Conly, Sarah. 2016. *One Child: Do We Have a Right to More?* New York: Oxford University Press.

—Dietz, T., E. Ostrom, and P. C. Stern. 2003. "The struggle to govern the commons." *Science* 302(5652): 1907–1912.

—Eshel, G., and P. A. Martin. 2006. "Diet, energy, and global warming." *Earth Interactions* 10: 1–17.

—Goodland, R., and J. Anhang. 2009. "Livestock and climate change: What if the key actors in climate change are… cows, pigs, and chickens?" *World Watch* (November/December): 10–19.

—Greenblatt, Jeffery B., and Max Wei. 2016. "Assessment of the climate commitments and additional mitigation policies of the United States." *Nature Climate Change* advance online publication.

—Grüters, A., P. Heidemann, H. Schlüter, P. Stubbe, B. Weber, and H. Helge. 1989. "Effect of different oestrogen doses on final height reduction in girls with constitutional tall stature." *European Journal of Pediatrics* 149(1): 11–13.

—Guastella, A. J., P. B. Mitchell, and M. R. Dadds. 2008. "Oxytocin increases gaze to the eye region of human faces." *Biological Psychiatry* 63(1): 3–5.

—Guillebaud, John, and Pip Hayes. 2008. "Population growth and climate change." *British Medical Journal* 337: 576.

—Hedenus, Fredrik, Stefan Wirsenius, and Daniel J. A. Johansson. 2014. "The importance of reduced meat and dairy consumption for meeting stringent climate change targets." *Climatic Change* 124(1): 79–91.

—House of Commons Science and Technology Committee. "The regulation of geoengineering." 2010. http://www.publications.parliament.uk/pa/cm200910/cmselect/cmsctech/221/221.pdf. Fifth Report of Session 2009–10.

—IPCC. 2007. "Ipcc Fourth Assessment Report 2007, Working Group II Report 'Impacts, adaptation and vulnerability.'"

—Johnson, K. A., and D. E. Johnson. 1995. "Methane emissions from cattle." *Journal of Animal Science* 73(8): 2483–2492.

—Judge, T. A., and D. M. Cable. 2004. "The effect of physical height on workplace success and income: Preliminary test of a theoretical model." *Journal of Applied Psychology* 89(3): 428–441.

—Kabat, Geoffrey C., Matthew L. Anderson, Moonseong Heo, H. Dean Hosgood, Victor Kamensky, Jennifer W. Bea, Lifang Hou, Dorothy S. Lane, Jean Wactawski-Wende, JoAnn E. Manson, and Thomas E. Rohan. 2013."Adult stature and risk of cancer at different anatomic sites in a cohort of postmenopausal women." *Cancer Epidemiology Biomarkers & Prevention*.

—Keith, D. W. 2000. "Geoengineering the climate: History and prospect." *Annual Review of Energy and the Environment* 25: 245–284.

—Kurzban, R., and J. Weeden. 2005. "Hurrydate: Mate preferences in action." *Evolution and Human Behavior* 26(3): 227–244.

—Liao, S. Matthew. 2005. "The ethics of using genetic engineering for sex selection." *Journal of Medical Ethics* 31: 116–118.

—Liao, S. Matthew, Anders Sandberg, and Rebecca Roache. 2012. "Human engineering and climate change." *Ethics, Policy & Environment* 15(2): 206–221.

—Mifflin, M. D., S. T. Stjeor, L. A. Hill, B. J. Scott, S. A. Daugherty, and Y. O. Koh. 1990. "A new predictive equation for resting energy expenditure in healthy individuals." *American Journal of Clinical Nutrition* 51(2): 241–247.

—Rieder, Travis N. 2016. *Toward a Small Family Ethic: How Overpopulation and Climate Change Are Affecting the Morality of Procreation*. New York: Springer.

—Sandel, M. 2007. *The Case against Perfection: Ethics in the Age of Genetic Engineering*. Harvard: Harvard University Press.

—Shearer, D. L., B. A. Mulvihill, L. V. Klerman, J. L. Wallander, M. E. Hovinga, and D. T. Redden. 2002. "Association of early childbearing and low cognitive ability." *Perspectives on Sexual and Reproductive Health* 34(5): 236–243.

—Shishlov, Igor, Romain Morel, and Valentin Bellassen. 2016. "Compliance of the parties to the Kyoto protocol in the first commitment period." *Climate Policy* 16(6): 768–782.

—Slovic, P. 1987. "Perception of risk." *Science* 236(4799): 280–285.

—Sorensen, H. T., S. Sabroe, K. J. Rothman, M. Gillman, F. H. Steffensen, P. Fischer, and T. I. A. Sorensen. 1999. "Birth weight and length as predictors for adult height." *American Journal of Epidemiology* 149(8): 726–729.

—Tse, W. S., and A. J. Bond. 2002. "Difference in serotonergic and noradrenergic regulation of human social behaviours." *Psychopharmacology* 159(2): 216–221.

—United Nations. 1995. *Women's Education and Fertility Behaviour: Recent Evidence from the Demographic and Health Surveys*. New York: United Nations.

—Washington, Warren M., Reto Knutti, Gerald A. Meehl, Haiyan Teng, Claudia Tebaldi, David Lawrence, Lawrence Buja, and Warren G. Strand. 2009. "How much climate change can be avoided by mitigation?" *Geophys. Res. Lett.* 36(8): L08703.

—Weber, C. L., and H. S. Matthews. 2008. "Food-miles and the relative climate impacts of food choices in the United States." *Environmental Science & Technology* 42(10): 3508–3513.

—Zak, Paul J., Angela A. Stanton, and Sheila Ahmadi. 2007. "Oxytocin increases generosity in humans." *PLoS ONE* 2(11): 1–5.

OpenMind

OPENMIND CHANNEL

READ THE FULL BOOK

The Next Step: exponential life

[+]

RELATED ARTICLES

Man-Induced Climate Change

[+]

Technological Progress and Potential Future Risks

[+]

Innovation and Climate Change

[+]

OTHER BOOKS