

BEYOND NATURE? GENOMIC MODIFICATION AND THE FUTURE OF HUMANITY

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*“Consider the work of God: For who can make straight that which He hath
made crooked?”
–Ecclesiastes 7:13*

I

INTRODUCTION

Just as humans dreamed of flying¹ long before the Wright Brothers’ maiden flight near Kitty Hawk in 1903,² visions of altering humanity predate recent leaps in human genome editing technologies. These methods—most notably “CRISPR”³—may make possible things that were once the sole province of fiction.⁴ But in contrast to the early twentieth century rush to exploit breakthroughs in human powered and controlled aviation, the modern-day reaction to heritable human genome editing is one of hesitation and fear. A robust consensus prevails among expert scientists, physicians, legal experts and ethicists that we should go forward slowly—if at all—with modifying the human genome in ways that promise to extend to future generations.⁵ Leading press

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1. See, e.g., LEONARDO DA VINCI, NOTEBOOKS 98–101 (Thereza Wells ed., 2008) (depicting flying machines modeled on the physiologies of bats and birds).

2. DAVID MCCULLOUGH, THE WRIGHT BROTHERS 85–108 (2015).

3. “CRISPR” stands for “Clustered Regularly Interspaced Short Palindromic Repeats.” A game changing development, CRISPR has been called the “Model T of genetics.” Michael Specter, *The Gene Hackers*, NEW YORKER (Nov. 16, 2016), <https://www.newyorker.com/magazine/2015/11/16/the-gene-hackers> [<https://perma.cc/S7C7-HHQ8>] (quoting Stanford University professor Henry T. Greely). See *infra* Part II.

4. See Brendan P. Foht, *Gene Editing: New Technology, Old Moral Questions*, NEW ATLANTIS, Winter 2016, at 3, 3 (“The fears and the hopes of genetically engineering the human race have been haunting the modern mind for the better part of a century, although only in the last decade have techniques been developed that might give us the power to modify the genomes of human beings at the embryonic stage.”).

5. See, e.g., NAT’L ACADS. SCIS., ENG’G & MED., HUMAN GENOME EDITING: SCIENCE, ETHICS, AND GOVERNANCE 134 (2017) (“More research is needed before any germline intervention could meet the risk/benefit standard for authorizing [human] clinical trials”); *Ethical Embryo Editing*, 549 NATURE 307, 307 (2017) (noting that “[c]onsensus guidelines” promulgated by prominent advisory groups hold

outlets concur.⁶

The need for extreme caution on human germline modification⁷ is defended on a number of grounds: the interests of future generations, safety considerations, equality concerns, the evils of eugenics, and the importance of public trust in science.⁸ But none of these justifications bears up under scrutiny. Indeed, what is most striking about the case made for proceeding at a crawl—with selected research permitted but clinical applications on hold—is how the considerations cited in its favor militate instead for advancing with all deliberate speed.

There is another problem with the “go very slow” approach—namely, that events are overtaking it. The simplicity and low cost of some gene editing techniques may enable scientists and others to evade legal limits and ethical guidelines,⁹ in effect engaging in what this article terms “genomic

“that editing the human germ line can be justified for the scientific purpose of research into fundamental biology” but not yet for “clinical applications”); David Baltimore et al., *A Prudent Path Forward for Genomic Engineering and Germline Gene Modification*, 348 *SCIENCE* 36, 37 (2015) (cautioning against “attempts at germline genomic modifications for clinical applications in humans”); Edward Lanphier et al., *Don’t Edit the Human Germ Line*, 519 *NATURE* 410, 410 (2015) (“At this early stage, scientists should agree not to modify the DNA of human reproductive cells.”). See also Kelly E. Ormond, et al., *Human Germline Genome Editing: American Society of Human Genetics Position Statement*, 101 *AM. J. HUM. GENETICS* 167, 172–73 (2017) (concluding “at this time, given the nature and number of unanswered scientific, ethical, and policy questions, it is inappropriate to perform germline gene editing that culminates in human pregnancy” and that “[f]uture clinical application of human germline genome editing should not proceed unless, at a minimum, there is (a) a compelling medical rationale, (b) an evidence base that supports its clinical use, (c) an ethical justification, and (d) a transparent public process to solicit and incorporate stakeholder input”); UNESCO INT’L BIOETHICS COMMITTEE, *UPDATING ITS REFLECTION ON THE HUMAN GENOME AND HUMAN RIGHTS* (Oct. 2, 2015), <http://unesdoc.unesco.org/images/0023/002332/233258E.pdf> [<https://perma.cc/DTA5-6Y7X>] (endorsing a moratorium on human germline editing).

6. E.g., *The Age of the Red Pen*, *THE ECONOMIST* (Aug. 22, 2015), <https://www.economist.com/news/briefing/21661799-it-now-easy-edit-genomes-plants-animals-and-humans-age-red-pen> [<https://perma.cc/8LWU-HUFM>] (stating that “germline editing is widely seen as a bourn no ethical traveler should cross”); *A Pause to Weigh Risks of Gene Editing*, *N.Y. TIMES* (Dec. 18, 2015), <https://www.nytimes.com/2015/12/18/opinion/a-pause-to-weigh-risks-of-gene-editing.html> [<https://perma.cc/RE92-NM5V>] (opining that the “technology for altering defects in the human genome has progressed so rapidly in the last three years that it has outstripped the ability of scientists and ethicists to understand and cope with the consequences” and endorsing a “pause in using the technique to produce genetic changes that could be inherited by future generations” until a large number of conditions are met).

7. This article uses the terms “heritable human genome editing,” “human germline editing,” and “human germline modification” to denote clinical applications of methods designed to alter human germline (that is, reproductive) cells, including ova, sperm, the cells that give rise to ova and sperm, and very early-stage human embryos. Changes to germline cells have the potential to affect descendants of treated individuals. *NAT’L ACADS. SCIS., ENG’G & MED.*, *supra* note 5, at 3. In this key respect, heritable genome editing differs from somatic—or non-inheritable—genome editing, which alters the somatic cells that contribute to the various tissues of the body (for example, skin, liver, lungs, heart) but not to the germline. The effects of modifications to somatic cells are limited to the individual treated and will “not be inherited by future generations.” *Id.* at 83. Somatic genome editing generally enjoys acceptance for interventions aimed at curing or preventing disease or disability. *Id.* at 103–10. See also *infra* Part II.

8. See *infra* Part III.

9. See Niklaus H. Evitt, Shamik Mascharak & Russ B. Altman, *Human Germline CRISPR-CAS Modification: Toward a Regulatory Framework*, 15 *AM. J. BIOETHICS* 25, 26 (2015) (“A complete ban or temporary moratorium will be nearly impossible to enforce due to the low cost of CRISPR and

moonshining.”¹⁰ As a result, efforts to constrain the spread of human germline modification may not only fail to achieve their core aim but drive cutting edge work into the shadows—out of sight of government regulators, trusted medical and scientific organizations, and the general public. The end consequence could be a world in which important biomedical innovation takes place without the benefits of inclusive public deliberation.¹¹

This article is organized as follows. Part II describes the promise of heritable genome editing methods and the recent scientific advances that lend urgency to questions regarding when, where, how, by whom, and for what purposes these new technologies will be deployed. Part III examines the dominant views that the best course of action is to “exercise great caution”¹² or even “hit the pause button”¹³ when it comes to clinical uses of heritable genome editing technologies. In this Part we argue that such recommendations are rooted in flawed assumptions, including ones about how the current generation can best safeguard and promote the interests of future ones. Although human germline editing entails risks, later generations will likely be better served if present day decision makers embrace the Enlightenment principles of daring to know¹⁴ and harnessing knowledge to improve human lives.¹⁵ Part IV turns to regulatory and governance issues. It explains how all three sectors of the economy—government, nonprofit organizations, and profit-seeking firms—play important roles in biomedicine,

heterogeneity of regional ethical codes.”); Debra J. H. Mathews, Robin Lovell-Badge et al., *A Path Through the Thicket*, 527 NATURE 159, 160 (2015) (warning that “the ease of use and accessibility” of CRISPR and related technologies “make it ripe for exploitation by rogue or charlatan organizations”); Rowan Jacobsen, *A Future of Genetically Engineered Children is Closer Than You’d Think*, MOTHER JONES (September/October 2017), <http://www.motherjones.com/politics/2017/08/a-future-of-genetically-engineered-children-is-closer-than-you-d-think/> [https://perma.cc/BM6U-TYHF] (reporting that, even though federal law prohibits the Food and Drug Administration (FDA) from “reviewing applications for germline editing of human embryos, meaning no clinical trials can move forward,” research in this area “continues around the world” and “anyone who wants to escape the rules can do so”). See also *infra* Part II.

10. Not prone to adhere to laws, regulations, or professional norms, the manufacturers of the extralegal alcoholic product “moonshine” were particularly active in the United States during the 1920 to 1933 Prohibition Era. See generally Joseph C. Douglas, *Miners and Moonshiners: Historic Industrial Uses of Tennessee Caves*, 26 MIDCONTINENTAL J. ARCHEOLOGY 251 (2001); Phil Roberts, *Regulating Liquor: Prohibition Enforcement, Official Corruption, and State Efforts to Control Alcohol after Prohibition Repeal*, 12 WYO. L. REV. 389 (2012) (describing the response to prohibition laws).

11. Cf. J. BENJAMIN HURLBUT, EXPERIMENTS IN DEMOCRACY: HUMAN EMBRYO RESEARCH AND THE POLITICS OF BIOETHICS 2 (2017) (“How should a democratic polity reason together about morally and technically complex problems that touch upon the most fundamental dimensions of human life—through what institutional mechanisms, guided by what forms of authority, and subject to what political norms and limitations?”).

12. Eric S. Lander, *Brave New Genome*, 373 NEW ENGLAND J. MED. 5, 7 (July 2, 2015).

13. JENNIFER A. DOUDNA & SAMUEL H. STERNBERG, A CRACK IN CREATION: GENE EDITING AND THE UNTHINKABLE POWER TO CONTROL EVOLUTION 209 (2017).

14. See Immanuel Kant, *What is Enlightenment?* (1784), <http://www.columbia.edu/acis/ets/CCREAD/etscc/kant.html> [https://perma.cc/E7W8-YHK6] (“*Dare to know!* (*Sapere aude.*) ‘Have the courage to use your own understanding,’ is therefore the motto of the enlightenment.”).

15. See JONATHAN ISRAEL, A REVOLUTION OF THE MIND: RADICAL ENLIGHTENMENT AND THE INTELLECTUAL ORIGINS OF MODERN DEMOCRACY 1–20 (2012) (describing the centrality of ameliorating the human condition in Enlightenment thought).

and offers suggestions for adapting biomedical oversight to present day realities. Part IV also details the value of functioning markets for democratic deliberation about biomedical innovation. In conclusion, Part V offers some thoughts about why human germline modification should attract support from across the political spectrum.

II

NEW TECHNOLOGIES AND THE HUMAN GENOME

A. Genome Editing: The Next Weapon in The War on Disease

Modern medicine has wrought miracles by delivering effective therapies for a slew of once untreatable maladies.¹⁶ But it still offers far too little to those who suffer from—or are carriers of—serious genetic abnormalities. These intractable conditions include autosomal recessive disorders such as Tay Sachs disease, a neurodegenerative disorder that kills most of its victims in early childhood, and sickle cell disease, which causes lifelong problems due to red blood cell abnormalities. There are also autosomal dominant conditions, including the late onset and always fatal Huntington’s disease. All exact an enormous and ghastly toll in terms of physical suffering, emotional distress, and economic loss.¹⁷

To be sure, science and medicine have not ignored the plight of sufferers of genetic disorders. For decades, vast quantities of money and expertise have poured into gene therapy research and clinical applications.¹⁸ Yet while these gene therapy initiatives—which entail making changes to somatic, or non-reproductive cells—have achieved some notable successes,¹⁹ progress has proved slower and harder than many anticipated.²⁰

16. See generally ROY PORTER, *THE GREATEST BENEFIT TO MANKIND: A MEDICAL HISTORY OF HUMANITY* (1997).

17. Sheila Jasanoff, J. Benjamin Hurlbut & Krishanu Saha, *CRISPR Democracy: Gene Editing and the Need for Inclusive Deliberation*, 32 *ISSUES SCI. & TECH.* (Fall 2015), <http://issues.org/32-1/crispr-democracy-gene-editing-and-the-need-for-inclusive-deliberation/> [<https://perma.cc/EV8N-6W6J>] (reporting that “[u]p to 10% of the U.S. population is estimated to carry traits for one or another rare genetic disease” and acknowledging that “[o]ur moral intuition rebels against pointless suffering” engendered by such conditions).

18. Luigi Naldini, *Gene Therapy Returns to Centre Stage*, 526 *NATURE* 351 (2015); James M. Wilson, *The History and Promise of Gene Therapy*, 31 *GENETIC ENG’G & BIOTECH. NEWS* 62 (2011).

19. E.g., David Benjamin Turitz Cox, Randall Jeffrey Platt & Feng Zhang, *Therapeutic Genome Editing: Prospects and Challenges*, 21 *NATURE MED.* 121 (Feb. 2015) (describing applications which help correct genetic mutations and treat diseases); John Carroll, *FDA Experts Offer a Unanimous Endorsement for Pioneering Gene Therapy for Blindness*, *SCIENCE* (Oct. 13, 2017), <http://www.sciencemag.org/news/2017/10/fda-experts-offer-unanimous-endorsement-pioneering-gene-therapy-blindness> [<https://perma.cc/Q3Q5-HYHM>].

20. See DOUDNA & STERNBERG, *supra* note 13, at 158 (cautioning that “[t]he decades-long struggle to make good on the promise of gene therapy should serve as a reminder that medical advances are almost always more complicated than they might seem”); Maxwell J. Mehlman, *Genomics and the Law*, in *THE OXFORD HANDBOOK OF U.S. HEALTH LAW* 1113, 1125–26 (I. Glenn Cohen, Allison K. Hoffman & William M. Sage eds., 2017) (discussing the history of gene therapy).

Somatic genome editing is the obvious next step in this well-established approach to developing treatments for genetic conditions²¹ and as such meets with widespread acceptance. But no matter how successful somatic genome editing methods turn out to be, the most they can hope to achieve is the cure of particular individuals. While that is a great accomplishment, it is not wholly satisfactory, for in fighting disease humans seek to do more than prevail in individual cases. The history of medicine and public health is one of efforts to win wars, not just skirmishes. Victory has meant eradicating scourges such as smallpox and polio to save future as well as extant humans from premature death and lives marred by disfigurement or paralysis.²²

To end genetic disease is not a matter of vanquishing harmful microorganisms. Rather, success will require winning an internal battle of sorts—one against aspects of humanity itself. To think along these lines is to ponder a host of profound questions that have inspired a rich, voluminous literature in science, medicine, philosophy, ethics, and law.²³ Until very recently, these questions—though fascinating—were of more academic than practical interest given that the capacity to alter the human germline appeared to be a long way off, if attainable at all. While work was ongoing on several promising technologies with potential applications for human genome editing,²⁴ no clinical use was on the near or even medium-term time horizon.

This status quo changed in the early years of this decade. Announcement followed announcement of startling new developments involving the path breaking CRISPR technology, culminating in the harnessing of CRISPR for genome editing.²⁵ CRISPR offers nothing less than a “simple, inexpensive, and

21. See NAT'L ACADS. SCIS., ENG'G & MED., *supra* note 5, at 103–09 (noting that in “most respects, somatic cell genome editing will be developed with the benefit of gene therapy’s robust base of technical knowledge, and within the existing system of regulatory oversight and ethical norms that have facilitated the current research and clinical development of somatic cell and gene therapy around the world”). The term gene editing denotes “repairs [of] mutated genes directly in the genome, while gene therapy splices new, healthy genes into the genome.” DOUDNA & STERNBERG, *supra* note 13, at 163.

22. PORTER, *supra* note 16, at 485–87. See also ROBERT WILLIAM FOGEL, *THE ESCAPE FROM HUNGER AND PREMATURE DEATH, 1700–2100: EUROPE, AMERICA, AND THE THIRD WORLD* (2004) (describing efforts to increase human longevity).

23. See, e.g., *ENGINEERING THE HUMAN GERMLINE: AN EXPLORATION OF THE SCIENCE AND ETHICS OF ALTERING THE GENES WE PASS TO OUR CHILDREN* (Gregory Stock and John Campbell eds., 2000) (describing different perspectives on genomic modification); ALLEN BUCHANAN, DAN W. BROCK, NORMAN DANIELS & DANIEL WIKLER, *FROM CHANGE TO CHOICE: GENETICS AND JUSTICE* (2000) (examining ethical issues in genetics within a historical context); JOHN HARRIS, *CLONES, GENES, AND IMMORTALITY: ETHICS AND THE GENETIC REVOLUTION* (1998) (analyzing the moral considerations that guide human biotechnology); FRANCES KAMM, *MORALITY, MORTALITY: DEATH AND WHOM TO SAVE FROM IT* (1993) (discussing ethical theories of transplantation and other life-and-death decisions); PHILIP KITCHER, *THE LIVES TO COME: THE GENETIC REVOLUTION AND HUMAN POSSIBILITIES* (1996) (discussing ethical implications of novel therapies).

24. See, e.g., Thomas Gaj, Charles A. Gersbach, & Carlos F. Barbas, *ZFN, TALEN and CRISPR/Cas-based Methods for Genome Engineering*, 31 *TRENDS BIOTECH.* 397, 397 (July 2013) (describing the Zinc-finger nucleases and transcription activator-like effector nucleases as a “powerful class of tools that are redefining the boundaries of biological research”).

25. Patrick D. Hsu, Eric S. Lander & Feng Zhang, *Development and Applications of CRISPR-Cas9 for Genome Engineering*, 157 *CELL* 1262 (2014); *CRISPR Timeline*, BROAD INSTITUTE,

remarkably effective genome engineering method” that enables users to “make specific and efficient modifications to a genome.”²⁶ This is important. Although advances in DNA sequencing capabilities and the careful study of the genome have yielded a plethora of information concerning “the genetic changes that influence the development of disease,” the precision tools needed to act on this information were lacking.²⁷ CRISPR fills this gap. It was not the first genome editing method, any more than the Model T was the first car. But the developers of CRISPR—like those of the Model T—succeeded in making “a difficult process cheap and reliable.”²⁸

B. The Pursuit of Knowledge: When Should We Stop?

The breathtaking speed of advances in CRISPR technology—along with the potential dangers of a user-friendly, inexpensive, and portable genome editing method—unsettled many, including some of the scientists most closely associated with CRISPR research.²⁹ There followed a series of conferences and other deliberations on the ramifications of genome editing technologies for science and society. One of the highest profile efforts was a January 2015 meeting at the Carneros Inn in Napa Valley, inspired in part by the example of the famous 1975 Asilomar conference on recombinant DNA that led to a research moratorium and has become a cynosure of scientific self-regulation.³⁰ Attended by prominent scientists, bioethicists, and others, the 2015 Napa Valley event generated a position statement which was published in the top academic journal *Science*.³¹ It also helped fuel a 300 plus page report from the National Academies of Sciences, Engineering, and Medicine³² as well as statements from UNESCO,³³ the American Society of Gene and Cell Therapy, the Center for Genetics and Society,³⁴ the European Group on Ethics in Science and New Technologies,³⁵ the

<https://www.broadinstitute.org/what-broad/areas-focus/project-spotlight/crispr-timeline> [<https://perma.cc/9LBJ-JPLG>] (last visited Feb. 18, 2018).

26. Baltimore et al., *supra* note 5, at 6.

27. *Id.*

28. Specter, *supra* note 3.

29. See, e.g., DOUDNA & STERNBERG, *supra* note 13, at xi–xii, 198–99 (describing how anxieties about the misuse and detrimental consequences of her scientific work sparked nightmares for the author).

30. See Paul Berg & Janet E. Mertz, *Personal Reflections on the Origins and Emergence of Recombinant DNA Technology*, 184 GENETICS 9, 15–16 (2010) (recounting—with approval—the moratorium on some recombinant DNA experiments imposed as the result of the 1975 conference at Asilomar); Henry T. Greely, *Of Science, CRISPR-Cas9, and Asilomar*, STAN. L. SCH. L. & BIOSCI. BLOG (Apr. 4, 2015), <https://law.stanford.edu/2015/04/04/of-science-crispr-cas9-and-asilomar/> [<https://perma.cc/67DY-RG24>].

31. Baltimore et al., *supra* note 5.

32. NAT’L ACADS. SCIS., ENG’G & MED., *supra* note 5.

33. UNESCO INT’L BIOETHICS COMMITTEE, *supra* note 5.

34. *Open Letter Calls for Prohibition on Reproductive Human Germline Modification*, CTR. GENETICS & SOC’Y (Nov. 11, 2015), <https://www.geneticsandsociety.org/internal-content/open-letter-calls-prohibition-reproductive-human-germline-modification?id=8999> [<https://perma.cc/56Q9-MSSL>].

35. EUR. GROUP ON ETHICS & SCI. & NEW TECHS. (EGE), STATEMENT ON GENE EDITING 1 (2016), https://ec.europa.eu/research/ege/pdf/gene_editing_ege_statement.pdf#view=fit&pagemode=

Hinxton Group (an international consortium of ethicists, scientists and policy experts),³⁶ and many others. While there are important variations in the positions articulated—and even a few outliers who push for upping the pace of innovation³⁷—the emergent consensus was and remains one of substantial caution with respect to human germline editing. Research should continue, albeit with careful attention to the fraught ethical issues involved, while clinical applications must remain out of bounds so as to provide ample time for constructive dialogues among experts and the public about the appropriate uses of these new technologies.³⁸

Implicit in these recommendations is a lack of a sense of urgency.³⁹ The unarticulated assumption is that the governments of rich, scientifically advanced nations can—and should—act together with leading professional organizations to control who will edit the human germline and for what ends. That means they have the power to create temporal space for the high quality, unhurried deliberations they believe are essential before giving serious consideration to allowing medical consumers access to human germline modification. Yet recent history and current events both undercut this conception of how things do and should work. Every month brings news of more breakthroughs. In July 2017, news broke of the “first known attempt at creating genetically modified human embryos in the United States.”⁴⁰ In September 2017, *Science* reported that

none [<https://perma.cc/D9LF-BVEF>] (“As to human germline editing, the EGE is of the view that there should be a moratorium on gene editing of human embryos or gametes which would result in the modification of the human genome.”).

36. Sarah Chan et al., *Genome Editing Technologies and Human Germline Genetic Modification: The Hinxton Group Consensus Statement*, 15 AM. J. BIOETHICS 42 (2015).

37. E.g., John Harris, *Germline Manipulation and our Future Worlds*, 15 AM. J. BIOETHICS 30 (2015) (“We will at some point have to escape beyond both our fragile planet and our fragile nature. One way to enhance our capacity to do both these things is by improving on human nature”); Henry I. Miller, *Letter: Germline Gene Therapy: We’re Ready*, 348 SCIENCE 1325, 1325 (Jennifer Sills ed., 2015); Julian Savulescu, Jonathan Pugh, Thomas Douglas & Christopher Gyngell, *The Moral Imperative to Continue Gene Editing Research on Human Embryos*, 6 PROTEIN & CELL 476 (2015); Kevin R. Smith, Sarah Chan & John Harris, *Human Germline Genetic Modification: Scientific and Bioethical Perspectives*, 43 ARCHIVES MED. RES. 491 (2012); Henry I. Miller, *Gene Editing is Here, and Desperate Patients Want It*, WALL ST. J. (Oct. 13, 2017), <https://www.wsj.com/articles/gene-editing-is-here-and-desperate-patients-want-it-1507847260>; Steven Pinker, *The Moral Imperative for Bioethics*, BOS. GLOBE (Aug. 1, 2015), <https://www.bostonglobe.com/opinion/2015/07/31/the-moral-imperative-for-bioethics/JmEkoyzITAu9oQV76JrK9N/story.html> [<https://perma.cc/CQA2-68XK>].

38. E.g., Baltimore et al., *supra* note 5; EUR. GROUP ON ETHICS & SCI. & NEW TECHS. (EGE), *supra* note 35 (“The EGE considers that deliberation regarding the acceptability and desirability of gene editing will require inclusive debate which extends to civil society where diverse perspectives and those with different expertise and values can be heard.”).

39. See, e.g., NAT’L ACADS. SCIS., ENG’G & MED., *supra* note 5, at 189 (“Heritable germline genome-editing trails must be approached with caution, but that does not mean they must be prohibited. . . . [C]linical trials could be initiated, limited to only the most compelling circumstances and subject to a comprehensive oversight framework that would protect the research subjects and their descendants; and have sufficient safeguards in place to protect against inappropriate expansion to uses that are less compelling or less well understood.”).

40. Steve Connor, *First Human Embryos Edited in U.S.*, MIT TECH. REV. (July 26, 2017), <https://www.technologyreview.com/s/608350/first-human-embryos-edited-in-us/> [<https://perma.cc/2C82-TX7X>] (characterizing the experiment as breaking new ground by demonstrating that it is “possible to

scientists in China made effective use of “base editing” (also known as “chemical surgery”), a novel and promising embryo editing technique.⁴¹ And toward the end of 2017, researchers at the Salk Institute announced the development of a technique to alter the activity, as distinct from the underlying sequence, of genes associated with disease.⁴²

Perhaps most important, some of the reported breakthroughs involve entities not beholden to the policies and value judgments of the establishment organs that produce ethical and legal guidelines. The “base editing” breakthrough mentioned above was not the first major achievement by this Chinese research team. In fact, the *New York Times* characterized an earlier embryo experiment of theirs as “dreaded, yet widely anticipated.”⁴³ This helped fuel the drive—which was already well underway—to slow the train of scientific experimentation.⁴⁴

The results of the so-called dreaded 2015 experiment were not published in a prestigious outlet like *Science* or *Nature*, but instead in *Protein & Cell*—described by *Science* as “an obscure Chinese journal published by an affiliate of China’s Ministry of Education.”⁴⁵ But whether the scientific mainstream likes it or not, *Protein & Cell’s* publication of groundbreaking research findings means it is no longer obscure, but internationally known. In sum, the traditional gatekeepers of scientific publication have lost a chunk of their power.

This may not be a bad thing. Many outside of this mainstream world likely have their own thoughts on scientific and medical progress and how it should or should not go forward.⁴⁶ It is understandable if they chafe under laws and

safely and efficiently correct defective genes that cause inherited diseases” and noting that while “none of the embryos were allowed to develop for more than a few days—and there was never any intention of implanting them in a womb—the experiments are a milestone in what may prove to be an inevitable journey toward the birth of the first genetically modified humans”). See also Hong Ma et al., *Correction of a Pathogenic Gene Mutation in Human Embryos*, 548 NATURE 413 (2017); Miller, *Gene Editing is Here*, *supra* note 37 (terming the experiment a “major advance” because, among other reasons, “all of the cells in the successfully modified embryos contained the normal DNA” and “if one of the study’s corrected embryos had been implanted” there is “a reasonable chance it would have become a healthy baby”).

41. Puping Liang et al., *Correction of -thalassemia Mutant by Base Editor in Human Embryos*, 8 PROTEIN & CELL 811 (2017); Jon Cohen, *Is a New Embryo-Editing Technique Better than CRISPR?*, SCIENCE (Sept. 28, 2017), <http://www.sciencemag.org/news/2017/09/new-embryo-editing-technique-better-crispr> [<https://perma.cc/48C7-AT3F>].

42. Hsin-Kai Liao et al., *In Vivo Target Gene Activation via CRISPR/Cas9-Mediated Transposigenetic Modulation*, 171 CELL 1495 (2017).

43. Gina Kolata, *Chinese Scientists Edit Genes of Human Embryos*, N.Y. TIMES (Apr. 24, 2015), <https://www.nytimes.com/2015/04/24/health/chinese-scientists-edit-genes-of-human-embryos-raising-concerns.html> [<https://perma.cc/S9DU-FQG4>] (reporting that this experiment had as its objective the creation of a non-viable human embryo with “a precisely altered gene in every cell but no other inadvertent DNA damage”).

44. See DOUDNA & STERNBERG, *supra* note 13, at 213–16.

45. Jocelyn Kaiser & Dennis Normille, *Chinese Paper on Embryo Engineering Splits Scientific Community*, SCIENCE (Apr. 24, 2015), <http://www.sciencemag.org/news/2015/04/chinese-paper-embryo-engineering-splits-scientific-community> [<https://perma.cc/XD7T-MAV9>]. There are reports that *Nature* and *Science* rejected the manuscript “partly because they had ethical objections to the experiments it described.” DOUDNA & STERNBERG, *supra* note 13, at 216.

46. See, e.g., Kaiser & Normille, *supra* note 45 (describing divergent reactions to reports of embryo

guidelines that do not further—and may even be inimical to—their values.

In a brave new world of inexpensive, easy-to-use technologies,⁴⁷ this pluralism has major ramifications for the design, crafting, and enforcement of legal and ethical standards.⁴⁸ What makes moonshine hazardous, after all, is not that it is an alcoholic beverage. It is that making alcohol on the sly often entails methods and materials that pose grave risks—both short and long term—to end users. In the context of human genome editing, a similar insight holds. The “genomic moonshining” that can flow from an insistence on keeping the current bright line boundary between somatic and heritable genome editing might have dire side effects—ones likely to be most keenly felt by consumers. Before devoting more resources to delineating and policing this somatic/heritable boundary, it makes sense to take a hard look at it.

III

TRANSFORMING HUMANITY: WHY NOT GO FORWARD?

Deliberations about human genome editing are not taking place against a blank backdrop. Article 1 of UNESCO’s 1997 Universal Declaration on the Human Genome and Human Rights reads: “The human genome underlies the fundamental unity of all members of the human family, as well as the recognition of their inherent dignity and diversity. In a symbolic sense, it is the heritage of humanity.”⁴⁹

From one perspective, statements like this are mere symbolism and provide no clear guidance for setting law or policy.⁵⁰ Formulated at a time when altering the human germline was the stuff of fantasy, language about “the heritage of humanity” may be better understood as an acknowledgment of the human genome’s value as a unique public good than as a move to forestall permanently the possibility of *any* heritable genome modification. But that is not the modal interpretation. The principle that the human genome is the “heritage of humanity” has for the most part been construed as placing human germline modification out of bounds.

engineering breakthroughs).

47. See Connor, *supra* note 40 (describing regulatory barriers to the “creation” of “gene-edited” individuals in the United States and noting that such creation “could be attempted at any moment” in facilities that operate in countries with “no such legal restrictions”).

48. See *infra* Part IV.

49. UNESCO, UNIVERSAL DECLARATION ON THE HUMAN GENOME AND HUMAN RIGHTS (1997), <http://www.unesco.org/new/en/social-and-human-sciences/themes/bioethics/human-genome-and-human-rights/> [<https://perma.cc/3MN5-UL6G>]. Other prominent institutions have expressed similar views. *E.g.*, HUGO ETHICS COMMITTEE, STATEMENT ON BENEFIT-SHARING (Apr. 9, 2000), http://www.hugo-international.org/Resources/Documents/CELS_Statement-BenefitSharing_2000.pdf [<https://perma.cc/G97K-BZTD>].

50. Cf. Pilar N. Ossorio, *The Human Genome as Common Heritage: Common Sense or Legal Nonsense?*, 35 J. L., MED. & ETHICS 425, 425 (2007) (“In the opening years of the 21st century, it became fashionable to describe the human genome as belonging to the common heritage of humanity.”).

This school of thought has been enshrined in a great deal of law, medicine, and scientific practice⁵¹—perhaps without careful reflection, but enshrined nonetheless. Consequently, as genome editing technologies have emerged, a demarcation has been drawn between the probably permissible (somatic genome editing, at least for therapeutic goals) and the ethically problematic (heritable genome editing).⁵²

As human germline modification moves from ideation to reality, the question of whether to continue to respect this line becomes more pressing. There is no convincing argument for doing so, and cordoning off the human germline from human interference is a goal that is neither defensible nor likely achievable. In what follows, we explain why we reject the rationales for a moratorium on human germline modification and instead endorse moving ahead with dispatch.

A. The Interests of Future Generations

The most salient distinction between somatic and heritable genome editing is that the first affects only the individual treated while the second may affect future generations. Opponents of human germline modification argue against moving forward on the grounds that later generations may be affected and today's experimenters do not know with certainty what those effects will be.⁵³

Given the myriad ways the present generation shapes the genetic makeup of future generations without a full grasp of the consequences of its actions, this line of argument is puzzling. From time immemorial, humans have engaged in mate selection with an eye toward the characteristics of their descendants. Increased understanding of the human genome has led to the creation of tools for better mate choice—in the sense of avoiding grave genetic diseases⁵⁴—and there is no resistance to making thoughtful use of such tools. In addition, antibiotics and many other modern medical treatments have the “inadvertent but accepted

51. See Elisabeth Hildt, *Human Germ Line Interventions—Think First*, 7 FRONTIERS GENETICS 81, 81 (2016) (“Up to now, at least in Western countries, there has been a broad consensus to ban interventions that aim to modify the human germline.”); Lander, *supra* note 12, at 7 (“At least among Western governments, there has been a longstanding consensus that manipulating the human germline is a line that should not be crossed.”); Francis Collins, *Statement on Nat'l Inst. of Health Funding of Research Using Gene-Editing Tech's in Human Embryos*, NAT'L INST. HEALTH (Apr. 28, 2015), <https://www.nih.gov/about-nih/who-we-are/nih-director/statements/statement-nih-funding-research-using-gene-editing-technologies-human-embryos> [<https://perma.cc/F6FE-6NWB>] (“The concept of altering the human germline in embryos for clinical purposes has been debated over many years from many different perspectives, and has been viewed almost universally as a line that should not be crossed.”).

52. Foht, *supra* note 4, at 5 (“The conventional wisdom that has taken shape around genetic technologies holds that we should sharply distinguish between ‘somatic’ gene therapies (which we are supposed to consider largely acceptable) and ‘germline’ gene therapies (which we should oppose).”).

53. E.g., Lanphier et al., *supra* note 5, at 410 (maintaining that “genome editing in human embryos using current technologies could have unpredictable effects on future generations. This makes it dangerous and ethically unacceptable”).

54. See Barbara Prainsack & Gil Siegal, *The Rise of Genetic Couplehood? A Comparative View of Premarital Clinical Testing*, 1 BIOSOCIETIES 17 (2006) (describing “Dor Yeshorim,” a genetic testing program designed to assess the “genetic compatibility of prospective couples in Orthodox Jewish communities in Europe, the U.S. and Israel”); Gil Siegal, *Looking for Ms. or Mr. Gene Right: Premarital Genetic Screening*, ACTION BIOSCIENCE (June 2007), <http://www.actionbioscience.org/genomics/siegal.html> [<https://perma.cc/65K6-YUGQ>].

effects” of “alter[ing] the allele frequency of certain disease-causing mutations in the human gene pool”⁵⁵ by saving patients who would otherwise perish.

Turning to more controversial practices, reproductive medicine in the United States and other countries often entails procedures designed to reduce the number of individuals with particular genetic traits. Most prominently, both pre-implantation genetic diagnosis (PGD)⁵⁶ and pregnancy termination are widely employed to prevent live births of children with genetic problems.⁵⁷ There is no dispute that the present generation’s use of PGD and selective termination affects the genetic profiles of future generations. This point bears emphasis, for one argument against human germline editing is that it may lead to the modification of genes that confer benefits as well as cause harm.⁵⁸ While this is a risk that deserves attention, it is one we are already running.

The conviction that the welfare of future generations is best served by eschewing heritable genome editing may stem from a view that there is “option value” in holding back.⁵⁹ Under that line of thought, editing the human germline will lead to irreversible consequences while refraining from doing so now preserves an option to do so later.⁶⁰ But this is not a satisfactory argument. First, as noted earlier, human behavior already has a significant impact on the genotypes of members of future generations. There is no basis to a claim that practitioners are delaying a decision in this area or that their acts remain “reversible.” Second, the assumption that scientific progress can be tolled ignores what we know about the nature of innovation. Leaps of human understanding of the magnitude seen in the past decade are the exception in human history, not the rule. And they have often stemmed from active, complex social networks comprising universities, conduits of knowledge and highly motivated, talented individuals⁶¹—exactly the sort of environment that recent accounts of CRISPR’s development describe as key to CRISPR’s stunning successes.⁶² All of this means

55. Donald B. Kohn, Matthew H. Porteus & Andrew M. Scharenberg, *Ethical and Regulatory Aspects of Genome Editing*, 127 BLOOD 2553, 2554 (2016).

56. See HENRY T. GREELY, THE END OF SEX AND THE FUTURE OF HUMAN REPRODUCTION 2 (2016) (predicting that in the next twenty to forty years most well off would-be parents will reproduce by having embryos created in a lab and then using PGD to assess the embryos for transfer, with some selected for implant but many rejected as suboptimal).

57. The potential of human germline editing to reduce the number of discarded embryos and fetuses is one reason the authors believe human germline editing should appeal to many who identify as pro-life. See *infra* Part V.

58. One commonly cited example is the gene for sickle-cell disease, which also confers some protection from malaria. See Catherine de Lange, *How Sickle Cell Carriers Fend Off Malaria*, NEW SCIENTIST, (May 11, 2011), <https://www.newscientist.com/article/dn20450-how-sickle-cell-carriers-fend-off-malaria/> [<https://perma.cc/UB6C-AZT9>] (summarizing research on the “elusive mechanism” of this phenomenon).

59. Cf. Julia D. Mahoney, *The Illusion of Perpetuity and the Preservation of Privately Owned Lands*, 44 NAT. RES. J. 573 (2004) (examining the “option value” of decisions not to develop land).

60. Cf. AVINASH K. DIXIT & ROBERT S. PINDYCK, INVESTMENT UNDER UNCERTAINTY (2014).

61. See generally JOEL MOKYR, THE GIFTS OF ATHENA: HISTORICAL ORIGINS OF THE KNOWLEDGE ECONOMY (2002) (tracing the development of human knowledge).

62. E.g., Eric S. Lander, *The Heroes of CRISPR*, 164 CELL 18, 18 (2016) (observing that “an

hitting the pause button on human germline editing may not be as viable an option as its proponents assume. There is no way to put individuals and institutions in suspended animation such that, when the resume button is pushed, things are bound to pick up where they left off. Broken momentum means lost opportunities.

How the present generation should take account of the needs and preferences of future generations raises hard questions with no simple answers.⁶³ “It has been,” writes philosopher Annette Baier, “a normal human wish that future generations will not curse their predecessors, but rise up and call them blessed.”⁶⁴ With that in mind, it is worth pondering the emotions that a decision to call “time out” on human germline modification will inspire in the later born. While gratitude is a possibility, it is also easy to imagine bewilderment or irritation at those who failed to do what they could to combat devastating genetic diseases. On the other hand, if history is any guide, a choice to go ahead may well elicit admiration and even wonder.⁶⁵

B. Safety

All new medical technologies entail risks. For a sobering reminder of how quickly and unexpectedly things can go wrong, one need only look at the history of efforts to develop gene therapy treatments.⁶⁶ In determining whether to move ahead with heritable human germline editing, the question at hand is not whether it is perfectly safe. It is not.⁶⁷ But to demand perfect safety would be absurd. When

inspiring ensemble of a dozen or so scientists . . . with their collaborators and other contributors . . . discovered the CRISPR system, unraveled its molecular mechanisms, and repurposed it as a powerful tool for biological research and biomedicine”).

63. See Julia D. Mahoney, *Perpetual Restrictions on Land and the Problem of the Future*, 88 VA. L. REV. 739 (2002) (examining intergenerational obligations in the context of restrictions on land development); Martin L. Weitzman, *A Review of The Stern Review on the Economics of Climate Change*, 45 J. ECON. LIT. 686, 690 (2007) (discussing the complexities of taking the welfare of future generations into account when crafting climate change policy).

64. Annette Baier, *For the Sake of Future Generations*, in *EARTHBOUND: NEW INTRODUCTORY ESSAYS IN ENVIRONMENTAL ETHICS* 214, 215 (Tom Regan ed., 1984).

65. Cf. MCCULLOUGH, *supra* note 2, at 227–29 (describing the celebration of the Wright brothers’ flight); MOKYR, *supra* note 61, at 297 (“Given that increasing this knowledge was costly and often socially disruptive, the political will by agents who controlled resources to actually do so . . . was not invariably there. . . [but] useful knowledge mattered. It is neither Whiggish nor naïve to suggest that its accelerating growth since 1750 has affected the world more than all other social and political changes taken together.”).

66. See Mehlman, *supra* note 20, at 1125–26 (recounting the death of a nineteen-year old in the course of an “experiment to develop a gene transfer treatment for a genetic liver disease with severe and often fatal effects on newborns”).

67. See Collins, *supra* note 51 (citing “serious and unquantifiable safety issues” as a reason why the National Institutes of Health “will not fund any use of gene-editing technologies in embryos”); Jennifer A. Doudna, *Embryo Editing Needs Scrutiny*, 528 NATURE S6 (Dec. 2015) (urging scientists to develop standards); Stefan Hohmann, *Editor’s Comment on “CRIPR/Cas9-mediated Gene Editing in Human Zygotes Using Cas9 Protein,”* 292 MOD. GENETICS GENOMICS 535, 535 (2017) (expressing the view that present and previous work indicate that the safety hurdles in early stage embryo editing can probably be overcome while cautioning there is a “long way until gene editing in human embryos becomes feasible with high fidelity and safety”).

analyzing risks, recall that society does not expect certainty in removing all possible harms. Such a demand would make any progress impossible in medicine and all other fields.

Rather, one must ask whether the “heritable” component of genome editing is such a reliable proxy for danger that it makes sense to continue to put a heavy thumb on the scale for developing somatic genome editing applications while stalling heritable ones. Here it is hard to make out a convincing case for “yes.” Editing somatic cells to treat genetic disease is “much more complex” as a practical matter than editing germ cells⁶⁸ and carries significant risks of its own.⁶⁹ Whether any particular application of genome editing technologies is appropriate for use will hinge on the precise facts of particular circumstances. Insisting on a bright line between somatic and heritable genome editing, in short, is not a reliable means of ensuring safety. This is particularly true given the prospect of “genomic moonshining.” Restrictions on heritable genome editing could drive consumers who are denied treatment at reputable medical centers to seek help from dodgier entities,⁷⁰ exposing desperate families to serious harms.

C. Equality

Some express fears that the use of heritable genome editing will worsen societal inequalities and lead to a world of genetic haves and have-nots.⁷¹ Upon examination, this concern is not persuasive. By far the strongest demand for human germline editing will probably be for modifications aimed at eliminating devastating heritable conditions. Those efforts will result in greater, not lesser, equality as more individuals enjoy lives free from the burdens of serious genetic ailments like Tay Sachs disease, Sickle Cell anemia, and Huntington’s disease. In short, heritable genome editing has enormous potential to be an equalizing technology.⁷²

68. DOUDNA & STERNBERG, *supra* note 13, at 160 (“Reversing a disease-causing mutation in a single human germ cell is much simpler than trying to do the same thing inside some of the fifty trillion somatic cells that make up a human body. To pull that off, scientists have to solve a host of new problems.”).

69. See NAT’L ACADS. SCIS., ENG’G & MED., *supra* note 5, at 88–89.

70. Cf. GLENN COHEN, PATIENTS WITH PASSPORTS: MEDICAL TOURISM, LAW AND ETHICS (2014) (detailing the risks associated with medical tourism); R. Alta Charo, *On the Road (to a Cure?)—Stem-Cell Tourism and Lessons for Gene Editing*, 374 N. ENG. J. MED. 901, 901 (2016) (“Given the stories about amazing potential and early breakthroughs in laboratory and animal models, gene editing may trigger another wave of medical tourism.”).

71. E.g., *About Human Germline Editing*, CTR. GENETICS & SOC’Y (July 9, 2015), <https://www.geneticsandsociety.org/internal-content/about-human-germline-gene-editing> [<https://perma.cc/4SVV-Q3J4>]; Marcy Darnovksy, *Human Gene Editing is a Social and Political Matter, Not Just a Scientific One*, THE GUARDIAN (Dec. 4, 2015), <https://www.theguardian.com/science/2015/dec/04/human-gene-editing-is-a-social-and-political-matter-not-just-a-scientific-one> [<https://perma.cc/X6QQ-KRFQ>].

72. See PHILIP KITCHER, THE LIVES TO COME: THE GENETIC REVOLUTION AND HUMAN POSSIBILITIES 326 (1996) (arguing that the “most exhilarating prospect” of new genetic technologies is the ability “to repair misfortunes that ground tragic inequalities in the quality of lives”).

Of course, it is possible that there will also be demand for so-called enhancements—a difficult to define term that generally “refer[s] to changes that alter what is ‘normal,’ whether for humans as a whole or for a particular individual prior to enhancement.”⁷³ If that is true, then the gulf between the richer and the poorer could grow as some spend money on genetic improvements while others go without. There are two points to make about enhancements. First, the traits most often mentioned as probable objectives of enhancement efforts—intelligence, athletic prowess, and the like—are very complex ones not susceptible to being “predicted using DNA tests.”⁷⁴ As a result, the issue of enhancements may never pose much of a quandary. To shrink from helping individuals (or families of potential individuals) with serious genetic diseases due to speculation that the “one percent” may eventually use human germline editing to enhance themselves seems hard to defend. Second, somatic genome editing is also a potential vehicle for achieving enhancements.⁷⁵ That means that opposition to enhancements is not a good reason to support a bright line between somatic and heritable genome editing.

D. “Eugenics”

The most emotionally charged criticism of heritable genome editing is that it threatens to usher in a new era of “eugenics.”⁷⁶ Popular during the first third of the twentieth century, the so-called science of eugenics held that excessive breeding by the unfit was degrading the quality of the human “stock.” These fears led to a surge of involuntary sterilizations around the world, including an estimated 60,000 in the United States alone.⁷⁷ In 1927, the U.S. Supreme Court sustained Virginia’s eugenics law against constitutional challenge in *Buck v. Bell*⁷⁸—a decision now so notorious it is considered part of U.S. constitutional law’s “anti-canon.”⁷⁹

73. NAT’L ACADS. SCIS., ENG’G & MED., *supra* note 5, at 138.

74. Cecile J.W. Janssens, *Forget About Designer Babies: Gene Editing Won’t Work on Complex Traits Like Intelligence*, CONVERSATION (Dec. 3, 2015), <https://theconversation.com/forget-about-designer-babies-gene-editing-wont-work-on-complex-traits-like-intelligence-51557> [<https://perma.cc/RQ5K-8JJU>]. See also JIM KOZUBEK, MODERN PROMETHEUS: EDITING THE HUMAN GENOME WITH CRISPR-CAS9, at 345–55 (2016).

75. See NAT’L ACADS. SCIS., ENG’G & MED., *supra* note 5, at 147–48.

76. E.g., Robert Pollack, *Letter: Eugenics Lurk in the Shadow of CRISPR*, 348 SCIENCE 871, 871 (2016) (asserting that a complete and total ban on human germline modification is warranted to prevent the “opening of a return” to practices of eugenics, which entail the “weeding out of the ‘bad’ versions” of the human genome “not just for the health of an individual, but for the future of the species”).

77. THOMAS C. LEONARD, ILLIBERAL REFORMERS: RACE, EUGENICS & AMERICAN ECONOMICS IN THE PROGRESSIVE ERA (2017); Philip R. Reilly, *Eugenics and Involuntary Sterilization: 1907–2015*, 16 ANN. REV. GENOMICS & HUM. GENETICS 351 (2015).

78. 274 U.S. 200 (1927).

79. RANDY E. BARNETT & JOSH BLACKMAN, CONSTITUTIONAL LAW: CASES IN CONTEXT 949 (2017). See also ADAM COHEN: IMBECILES: THE SUPREME COURT, AMERICAN EUGENICS, AND THE STERILIZATION OF CARRIE BUCK (2016); PAUL A. LOMBARDO, THREE GENERATIONS, NO IMBECILES: EUGENICS, THE SUPREME COURT, AND *BUCK V. BELL* (2010).

What those who invoke the specter of eugenics fail to recognize is that human germline modification is its opposite, not its heir. At the core of support for eugenics was the conviction that—for the benefit of society—certain individuals should *not* reproduce. The alleged good of the collective trumped the rights of individuals, and government force took center stage in determining the genetic profile of the generations to come.⁸⁰ By contrast, a chief goal of heritable genome editing would be to expand the options available to individuals while leaving sensitive decisions about family life up to them. If this technology fulfills its promise, then many with well-founded anxieties about the genetic makeup of their descendants who in the past would have hesitated to have children will have access to viable treatments.

E. Public Trust in Science

Highly sensitive to worries that biomedical technologies might unleash terrible ills,⁸¹ some scientists and policy experts defend a moratorium on human germline editing on the grounds that failure to do so could erode public support of CRISPR and other gene editing technologies. They fear that such a loss could delay clinical uses of somatic genome editing⁸² and reduce scientists' public standing.⁸³

The problem with these arguments is that they amount to little more than overwrought speculation. While the evidence on public attitudes toward human germline editing is sparse, the results of a just-published survey are instructive. Respondents expressed approval of both somatic and germline therapies, with roughly two-thirds deeming each “acceptable.”⁸⁴ These findings may reflect a shift in public attitudes.⁸⁵ But it bears emphasis that even earlier surveys that found less support for human germline modification did not report any findings indicating that the public is up in arms over it. A 2016 Pew Research Center report on public attitudes toward biomedical technologies stressed that “large shares” of Americans surveyed “say they think of science and technology, writ large, as mostly beneficial forces in American society”⁸⁶ and found that when

80. Daniel Frost, *Protection Against Eugenics: A Comparison of Two Jurisprudences*, 42 J. SUP. CT. HIST. 275, 276–78 (2017).

81. See Specter, *supra* note 3.

82. See DOUDA & STERNBERG, *supra* note 13, at 211; Lanphier et al., *supra* note 5, at 411.

83. E.g., Niklaus H. Evitt, Shamik Mascharak & Russ B. Altman, *Human Germline CRISPR-CAS Modification: Toward a Regulatory Framework*, 15 AM. J. BIOETHICS 25, 26 (2015) (expressing concern that “rapid proliferation” of germline editing therapies could lead to “public mistrust” of the scientists developing these new technologies).

84. Dietram A. Scheufele et al., *U.S. Attitudes on Genome Editing*, 357 SCIENCE 553, 553 (2017).

85. See Jon Cohen, *Americans are Becoming More Open to Human Genome Editing, Survey Finds, but Concerns Remain*, SCIENCE (Aug. 10, 2017), <http://www.sciencemag.org/news/2017/08/americans-are-becoming-more-open-human-genome-editing-survey-finds-concerns-remain> [<https://perma.cc/6T9C-X3NU>].

86. Cary Funk, Brian Kennedy & Elizabeth Sciupac, *U.S. Public Wary of Biomedical Technologies to “Enhance” Human Abilities*, PEW RES. CTR. 97 (2016), http://assets.pewresearch.org/wp-content/uploads/sites/14/2016/07/02120148/PS_2016.07.26_Human-Enhancement-Survey_FINAL.pdf

asked about heritable “changes to a baby’s genetic makeup,” roughly half reported feeling “very” or “somewhat” enthusiastic about the technology.⁸⁷

Given these findings, one can argue that skittish scientists and others should focus on how refusing to proceed with promising avenues of inquiry could undermine public confidence in science and technology. In catering to fears not firmly grounded in reality, they risk looking more like purveyors of moral panics or politicians manqué than dispassionate, trustworthy seekers of truth.

F. Conclusion

The arguments mustered against proceeding with heritable genome modification are not persuasive. While opponents raise serious concerns, all point against calling time out on the development of clinical applications of human germline editing. Admittedly, predictions are hard, especially about the future,⁸⁸ and this is an area of unusual dynamism. Nevertheless, it is not just possible but essential to reach a preliminary conclusion about whether to go forward or sit tight.

Throughout history, biomedical advances have tended to improve rather than degrade human well-being. These measures have (often inadvertently) altered the genetic makeup of future generations. While both somatic and heritable genome editing pose dangers that should command attention, there is no justification for labeling somatic interventions necessarily safer than germline ones. In addition, on balance human germline editing appears more likely to reduce—rather than fuel—health inequalities as it will likely lead to the births of fewer humans with serious genetic diseases. As for the alleged hazard of eugenics, the rise of human germline editing promises to undermine, not increase, government power over what genes will and will not be passed down to later generations. Finally, it is hard to think of a faster way to erode public trust in science and scientists than to invoke unsound reasons to put a stop to efforts to prevent, treat, and cure serious diseases.

IV

THE REGULATION OF GENOME EDITING TECHNOLOGIES:

THE STATE, NONPROFIT ORGANIZATIONS AND THE MARKET

A decade ago, human germline modification lay far in the future, and some

[<https://perma.cc/DW6K-X49K>].

87. *Id.* at 122–23. Those surveyed were provided with this vignette: New developments in genetics and gene-editing techniques are making it possible to treat some diseases and conditions by modifying a person’s genes. In the future, gene-editing techniques could be used for any newborn, by changing the DNA of the embryo before it is born, and giving that baby a much reduced risk of serious diseases and conditions over his or her lifetime. Any changes to a baby’s genetic make-up could be passed on to future generations if they later have children, and over the long term this could change the genetic characteristics of the population.

88. This statement is often attributed to Niels Bohr. See Alan G. Mencher, *On the Social Deployment of Science*, 27 BULL. ATOMIC SCIENTISTS 37 (1971). Yogi Berra, Sam Goldwyn and others are also credited with variations of it.

doubted it would come at all. Even with the advent of CRISPR, there seemed to be ample time to ponder at leisure the consequences of a technology that although having the “potential to free humanity from painful diseases” might, or so many fear, take society to “creepy places.”⁸⁹ But events are moving faster than expected. As cutting-edge research in this area attracts interest around the world, it appears increasingly likely that the United States and other powerful governments will not be able to halt human germline modification—even if they want to do so.⁹⁰ That makes the need to consider how best to proceed with “editing humanity” ever more pressing.⁹¹

Not surprisingly, legal issues relating to human germline modification are receiving worldwide attention.⁹² As of 2018, however, there is no discernible uniformity in legislative and regulatory regimes. Instead, there is a mosaic of rules ranging from blunt prohibition to more lax and permissible approaches.⁹³ Many nations flatly forbid any interference with the human germline and even provide for criminal sanctions in selected cases.⁹⁴ Others, including the United States, have restrictions in place that have the intended effect of making it hard to pursue legally clinical applications of human germline modification technologies.⁹⁵ That said, it is vital to recognize that the American approach to the regulation of germline modification is very much a work in progress involving a set of complex institutions. In addition to the federal government and the individual state governments, the United States has a powerful and influential nonprofit sector

89. Rowan Jacobsen, *A Future of Genetically Engineered Children is Closer Than You'd Think*, MOTHER JONES (Sept./Oct. 2017), <http://www.motherjones.com/politics/2017/08/a-future-of-genetically-engineered-children-is-closer-than-you-d-think/> [https://perma.cc/7CH5-VHQT].

90. See Harald König, *The Illusion of Control in Germline-Engineering Policy*, 35 NATURE BIOTECH. 502, 504 (2017) (expressing skepticism that a “global ban” of human germline editing “across jurisdictions is feasible”).

91. Cf. Margaret Foster Riley, *Twenty-First Century Technologies with Twentieth Century Baggage: FDA in the Twenty-First Century: FDA Regulation of Regenerative Medicine*, in THE CHALLENGES OF REGULATING DRUGS AND NEW TECHNOLOGIES 455 (Holly Fernandez Lynch & I. Glenn Cohen eds., 2015) (exploring the challenges of regulating biomedical innovation given that the primary U.S. regulator, the FDA, “must regulate under statutes that are decidedly mid-twentieth century”); R. Isasi, E. Kleiderman & B.M. Knoppers, *Editing Policy to Fit the Genome? Framing Genome Editing Policy Requires Setting Thresholds of Acceptability*, 351 SCIENCE 337, 337 (2016) (“Balancing therapeutic prospects brought by scientific advances with regulation to address highly contested socioethical issues is the ultimate challenge in dealing with disruptive science.”).

92. E.g., Bertha Maria Knoppers et al., *Human Gene Editing: Revisiting Canadian Policy*, 2 NPJ REGENERATIVE MED. 3 (2017); NAT'L ACADS. SCIS., ENG'G & MED., COMM. ON SCI., TECH., & L. POL'Y & GLOBAL AFFS., INT'L SUMMIT ON HUMAN GENE EDITING: A GLOBAL DISCUSSION, MEETING IN BRIEF (Steven Olson ed., Dec. 2015), https://www.ncbi.nlm.nih.gov/books/NBK343652/pdf/Bookshelf_NBK343652.pdf [https://perma.cc/6C9P-ZENN] (summarizing discussions from an international summit).

93. See Isasi et al., *supra* note 91, at 337 (emphasizing that “defining the contours and diversity of national policy frameworks governing the human germline is difficult”). See also R. Alta Charo, *The Legal and Regulatory Context for Human Gene Editing*, 32 ISSUES SCI. & TECH., Spring 2016, at 39 (discussing regulatory options and enforcement mechanisms).

94. Isasi et al., *supra* note 91, at 337.

95. See I. Glenn Cohen & Eli Y. Adashi, *The FDA is Prohibited from Going Germline*, 353 SCIENCE 545 (2016); König, *supra* note 90, at 504.

that plays an important role in biomedical innovation. This nonprofit sector includes leading research universities as well as the nongovernmental organizations that helped to organize the Asilomar moratorium on recombinant DNA research in the 1970s⁹⁶ and those that more recently crafted guidelines for stem cell research on human embryos.⁹⁷ There are also a number of professional associations that take an active interest in human germline modification.⁹⁸ Interacting with governmental and nonprofit entities are profit-seeking firms, most prominently major pharmaceutical corporations.

The ramifications of CRISPR and other potential low cost and easy to use germline editing techniques are only starting to become evident. Even at this early date, however, there are two important observations to be made. The first concerns the role of markets in the development, dissemination and—perhaps ultimately—public acceptance of these path-breaking technologies. Calls for extensive public deliberation about the acceptability of human germline modification often assume that such deliberations must necessarily precede consumer access.⁹⁹ This needs to be rethought. It is not only through focus groups, voting, and political activism that individuals construct society. Decisions concerning whether and how to participate in markets have important moral components.¹⁰⁰ Such moral considerations are particularly salient in the context of medical decisions. The sorts of markets that emerge or fail to materialize in human germline modification services will provide crucial information about the moral judgments that actual individuals who face hard choices make in real life. Put simply, efforts to draw on “a diversity of perspectives to shape morally contested areas of emerging science and technology”¹⁰¹ should pay close attention to market behavior, for humans communicate through deeds as well as words.

This leads to the second point, which concerns regulation. This article argues that the case for drawing a bright line between somatic and heritable genome editing is not persuasive on either moral or practical grounds. The logical next step is for heritable genome editing to be added to the portfolio of the regulatory entities that now oversee gene therapy and are in the process of taking on somatic

96. See *supra* note 31 and accompanying text.

97. See Charo, *supra* note 93 (describing the development of these guidelines by the International Society for Stem Cell Research and the National Academies of Sciences, Engineering, and Medicine).

98. See, e.g., Kelly E. Ormond et al., *Human Germline Genome Editing: Am. Society of Human Genetics Position Statement*, 101 AM. J. HUM. GENETICS 167, 172–73 (2017) (“At this time, given the nature and number of unanswered scientific, ethical, and policy questions, it is inappropriate to perform germline gene editing that culminates in human pregnancy.”).

99. E.g., Baltimore et al., *supra* note 5, at 37.

100. See generally NATHAN B. OMAN, *THE DIGNITY OF COMMERCE: MARKETS AND THE MORAL FOUNDATIONS OF CONTRACT LAW* (2015); MICHAEL J. TREBILCOCK, *THE LIMITS OF FREEDOM OF CONTRACT* (1993) (discussing issues of commodification, externalities, coercion, information imperfections, paternalism, and discrimination).

101. Debra J.H. Mathews, Robin Lovell-Badge et al., *A Path Through the Thicket*, 527 NATURE 159, 161 (2015) (“For decades, people have been arguing about the pros and cons of human germline modification . . . [y]et good models for how to enable a diversity of perspectives to shape morally contested areas of emerging science and technology are hard to find.”).

genome editing.¹⁰² That framework could, of course, be further adjusted to take account of any special problems of heritable genome editing. In making these adjustments, it is critical for regulators and others to acknowledge that the old model of the government—often working in conjunction with prominent nonprofit groups—deciding which technologies will go forward is becoming obsolete as “genomic moonshining” and other evasions of their authority come to the fore. Regulators should consider shifting their approach from one of top down command and control regulation to one that places more emphasis on encouraging the disclosure of information about developments in heritable genome editing and other innovative technologies. Such an approach could help ensure that ground breaking research and clinical application will continue to be carried out in the United States, which would redound to the benefit not just of the U.S. but likely the entire world. Regulators should also take a careful look at the consequences of restricting public funding for controversial research. While such restrictions can serve to alleviate political discord, they also have the potentially deleterious side effect of decreasing public transparency and accountability by moving activity out of sight of democratically responsive entities.

V

CONCLUSION

Long a staple of dystopian fiction, human germline modification may well be on the cusp of becoming a reality. Although to date this news has elicited more apprehension than celebration, there are good reasons for this to change. History shows that biomedical technologies with the capacity to improve the lives of future generations tend to win public acceptance. In addition, human germline modification has the potential to appeal to Americans of all political persuasions. Pro-choice advocates may appreciate the expansion of reproductive options, while those who identify as pro-life may see human germline modification as a vast improvement over current practices such as preimplantation genetic diagnosis. That is because a chief goal of human germline modification is to fix embryos in order to enable them to develop into healthy individuals, not to identify and discard the less desirable ones. In a sense, then, heritable human genome editing can be thought of as the ultimate pro-life technology.

As with any technological advance, nightmare scenarios are easy to conjure up. No doubt human germline editing could prove highly destructive in the wrong hands. But the prospect of misuse is insufficient reason to draw back from knowledge that could greatly enhance the quality of human life by reducing or even eradicating diseases that have to date defeated medical science.

102. See NAT'L ACADS. SCIS., ENG'G & MED., *supra* note 5, at 34–57 (summarizing gene therapy regulation in the United States).

In thinking about how to go forward with modifications to the human germline, today's decision makers can take inspiration from the pioneers of aviation. Human flight was unprecedented and in some ways dangerous, yet humans had long envisioned doing it. And just as many works in our popular culture—Aldous Huxley's 1932 novel *Brave New World* and the 1997 film *Gattaca*, to name but two—warn of the dangers of genetic technologies, aviators had the ancient myth of Daedalus and Icarus, the father and son pair who ventured to fly with homemade wings made of wax and bird feathers. Icarus flew too close to the sun and plunged into the sea when the sun's heat melted the wax that held his wings together. Yet the lesson twentieth century innovators took from Icarus' fate was not to stay on the ground but to soar toward the future. We can do the same.