CRISPR People: *He Jiankui v. Science*

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INTRODUCTION

In 2018, Dr. He Jiankui of the People's Republic of China announced at the Second International Summit on Human Genome Editing that he had engineered the birth of the first babies with edited genomes. At the time of this announcement, twin girls had already been born to one mother, and another woman was pregnant.[1] Dr. He had edited the *CCR5* gene with the goal of disabling it and helping the babies avoid infection with human immunodeficiency virus (HIV).[2] He claimed his goal was altruistic: to spare them from the illness and stigma their HIV-positive fathers endured.[3] To his surprise, the international scientific community condemned him for his irresponsible and unethical foray into human germline genome editing (HGGE).[4]

In 2021, Professor Hank Greely of Stanford Law School published his account of Dr. He and his experiment, entitled *CRISPR People: The Science and Ethics of Editing Humans*.[5] The author states that his book "lies uneasily somewhere between history and journalism."[6] *CRISPR People* does rely on contemporaneous media accounts, and historians will benefit from its rich detail, but as Professor Greely admits, when it comes to what Dr. He actually

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[1] NAT'L ACAD. SCI., ENG'G, & MED., SECOND INTERNATIONAL SUMMIT ON HUMAN GENOME EDITING: CONTINUING THE GLOBAL DISCUSSION: PROCEEDINGS OF A WORKSHOP IN BRIEF 2 (2019) [hereinafter SECOND INTERNATIONAL SUMMIT].

[2] *Id.* Based on data that Dr. He provided, observers believe that the twins did not receive *CCR5Δ32*, the variant known to confer resistance to HIV-1. One girl has novel mutations in both alleles of *CCR5*. The other has a novel mutation in one allele, but the other is unmodified. Whether either girl is truly immune to HIV is unknown. Sean P. Ryder, *#CRISPRbabies: Notes on a Scandal*, 6 CRISPR J. 355, 355-56 (2018).

[3] Jon Cohen, *What Now for Human Genome Editing?*, 362 SCIENCE 1090 (2018).

[4] *Id.* at 1091; SECOND INTERNATIONAL SUMMIT, *supra* note 1, at 8.

[5] HENRY T. GREELY, CRISPR PEOPLE: THE SCIENCE AND ETHICS OF EDITING HUMANS (2021).

[6] *Id.* at 297.

did, "[w]e don't really know."[7] Dr. He, his colleagues, and the Chinese government are unreliable narrators.[8] Key details, such as the specific edits made to the babies' genomes, have not been independently verified or, in the case of the third baby, revealed.[9] As time goes by, additional or contradictory information may emerge and further complicate the story Professor Greely tells.

Nevertheless, *CRISPR People* is worth reading, for it offers more than history and journalism. Scientists, bioethicists, academics, policymakers, and legislators will value *CRISPR People* for its policy discussion. All readers will appreciate Professor Greely's storytelling abilities as he describes his flawed protagonist, those who enabled him, and those who opposed him—both before and after the experiment that would ultimately land him in prison. As it turns out, the title of *CRISPR People* has a clever double meaning: it refers not only to babies with altered genomes, but also to the scientists, bioethicists, and lawyers who people its pages.

CRISPR PEOPLE

Like a good lawyer, Professor Greely lays a solid foundation for his policy prescriptions. Thus, Part I of his book is descriptive: it provides the reader with background information about He Jiankui, his experiment, HGGE, CRISPR, and the ethics and law of HGGE before Dr. He's experiment. Part II describes the announcement at the Second International Summit and recounts reactions from around the world, including China, which convicted He Jiankui and sent him to prison. Part II also names scientists and others who knew in advance what He Jiankui planned to do but failed to dissuade him from moving forward with his experiment. Part III shifts from description to prescription. After providing an in-depth critique of He's experiment, it outlines what "Science" (meaning the scientific community[10]) must do to prevent future unethical uses of HGGE. Lastly, Part IV blends policy analysis with pragmatic solutions. It discusses the pros and cons and potential uses of HGGE, and discusses regulatory options.

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[7] *Id.* at 3.
[8] *Id.* at 3-4.
[9] *Id.* at 17-18, 153.
[10] *Id.* at xii.

This book review tracks the book's organization. It first summarizes the content of each Part. Then it comments on interesting points and critiques Professor Greely's proposals.

A. Part I: Background

Part I includes five chapters. Chapter One describes He Jiankui's background and education, earlier research, growing interest in *CCR5* and HIV, and ultimate experiment.[11] The chapter further details the birth of the twins, the announcement of their birth, the edits made to their genomes, and He Jiankui's trial, conviction, and three-year prison sentence and fine for violating Chinese law.[12] Chapter Two describes HGGE and its potential to alter genes that can be passed down to future generations,[13] in contrast with somatic cell genome editing, in which scientists alter genes in specific tissues or organs of existing persons.[14] Although HGGE could be accomplished by editing sperm or eggs, rather than embryos, Professor Greely explicitly excludes discussion of that possibility from his book, perhaps to limit the scope of discussion to what Dr. He did.[15] Chapter Three explains the origin, development, and utility of CRISPR, the molecular editing tool that makes it easy for scientists to alter the DNA of living creatures.[16] Chapter Four presents relevant ethics discussions prior to He's experiment, from the 1975 Asilomar conference on recombinant DNA to conversations and reports about HGGE.[17] Lastly, Chapter Five presents the law of HGGE before He's experiment, beginning with international norms on human subject research and proceeding through federal regulation in the United States, bans in Europe, and fertility clinic guidance in China that Dr. He violated.[18]

For readers who are new to HGGE and He's experiment, Part I provides a valuable orientation and entree into the book. This review finds two takeaways. The first has to do with He Jiankui and his qualifications, or lack thereof, to perform HGGE. He attended the University of Science and Technology of China and graduated with a physics degree.[19] He moved on to the United States.

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[11] *Id.* at 5-15.
[12] *Id.* at 16-20.
[13] *Id.* at 24-31.
[14] *Id.* at 28.
[15] *Id.* at 30.
[16] *Id.* at 33-42.
[17] *Id.* at 49-73.
[18] *Id.* at 76-88.
[19] *Id.* at 5.

There, he earned a doctorate in biophysics at Rice University under advisor Michael Deem and spent a postdoc year studying microfluidics in Stephen Quake's laboratory at Stanford University.[20] Upon his return to China, he joined the faculty of the Southern University of Science and Technology, where he specialized in gene sequencing.[21]

As Professor Greely emphasizes, He Jiankui was not qualified to practice HGGE.[22] Dr. He had no expertise in the relevant fields: human reproduction, genetics, or genome editing. Yet, beginning in 2016, he practiced on animal and human embryos, informed Professor Deem that he aspired to be the first to generate edited babies, recruited couples for his experiment, edited embryos, and transferred them to women—all in the space of two years.[23] Professor Greely surmises that Dr. He derived inspiration from another experiment, published in 2015, in which Chinese scientists announced that they had become the first to edit human embryos in the laboratory.[24] The more interesting point is that Dr. He was able to bring about the birth of these children despite his lack of relevant expertise. He did have help from Zhang Renli, who microinjected the embryos, and Quin Jinzhou, an embryologist, who both received prison sentences and fines for their roles in the experiment.[25] However, as Part I.C of this review explains below, Dr. He and his colleagues created random mutations and not the naturally-occurring genetic variant that confers some protection against infection with HIV. As it turns out, creating babies with altered genomes is disturbingly easy, but providing them with desired traits or phenotypes is difficult.

The second takeaway deals with the scientific community and self-regulation. Professor Greely recounts his experiences at a 2014 workshop in Napa, California, where eminent scientists and bioethicists gathered to discuss issues related to genome editing in general and HGGE in particular.[26] Jennifer Doudna, who received a Nobel Prize in Chemistry in 2020 along with Emmanuelle Charpentier for developing a CRISPR-based system for cutting

[20] *Id.* at 5-7.
[21] *Id.* at 7-9.
[22] *Id.* at 8.
[23] *Id.* at 10-15.
[24] *Id.* at 9.
[25] David Cyranoski, *What CRISPR-Baby Prison Sentences Mean for Research*, NATURE NEWS (Jan. 3, 2020), https://perma.cc/KCA5-UEN9.
[26] GREELY, *supra* note 5, at 60-63.

isolated DNA in the lab,[27] was one of the hosts.[28] R. Alta Charo, a prominent law professor and bioethicist, was present.[29] Paul Berg, a biochemist who invented recombinant DNA and received a Nobel Prize for Chemistry in 1980, was there.[30] David Baltimore, who received a Nobel Prize in Medicine or Physiology for discovering the enzyme reverse transcriptase, was also in attendance.[31] These thought leaders discussed their concerns and published four recommendations: discourage clinical trials of HGGE for the time being; establish fora in which experts can discuss scientific, ethical, social, and legal implications of the technology; encourage research to determine the efficacy and specificity of molecular editing tools; and gather scientists, geneticists, bioethicists, lawyers, and others from around the world to consider issues and develop policies.[32]

This workshop is powerful evidence that Science does regulate itself. Indeed, it has for a long time.[33] However, Professor Greely's presence there also indicates that he is more than a historian or journalist—he is an insider and participant. Moreover, his book includes profiles of Doudna, Charo, Berg, and Baltimore, all of whom he knows personally.[34] While his personal insights add interest and charm, they are a further indication that his perspectives and recommendations may have been shaped by the scientific/bioethical establishment to which he belongs.[35] In making this observation, this review does not mean to single out Professor Greely; doubtless other journalists, historians, and lawyers with the expertise and contacts to mediate between Science and the public are subject to the same influences. However, although self-regulation can be beneficial, insiders may have the same blind spots as the scientists they seek to regulate, leading Science to receive stunted feedback. If outsiders and nonconformists were admitted to public policy discussions, their

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[27] Heidi Ledford & Ewen Callaway, *Pioneers of Revolutionary CRISPR Gene Editing Win Chemistry Nobel*, NATURE NEWS (Oct. 7, 2020), https://perma.cc/9XU6-5KDG.
[28] GREELY, *supra* note 5, at 60-61.
[29] *Id.* at 60-61.
[30] *Id.* at 50-52, 61-62.
[31] *Id.* at 56-57, 60-61.
[32] David Baltimore et al., *A Prudent Path Forward for Genomic Engineering and Germline Gene Modification*, 348 SCIENCE 36, 37-38 (2015).
[33] As Professor Greely notes, Berg and Baltimore were two of five members of the organizing committee for the Asilomar conference of 1975. GREELY, *supra* note 5, at 60-61.
[34] *Id.* at 50-51, 56-57, 63-64, 69. Later in the book, Professor Greely also profiles George Church, Steve Quake, and William and Ben Hurlbut. *Id.* at 111-12 (Church), 125-26 (Quake), 130-31 (Hurlbuts).
[35] For a description of Professor Greely's positions at Stanford University and service to prestigious entities such as the National Academies and National Institute of Health, see *Henry T. Greely*, STAN. L. SCH., https://perma.cc/5WHW-HWM6.

contributions might lead to unexpected insights or even provide early warning signs of problematic research that they or others have planned.

For example, consider Dr. He. In 2014, when the Napa workshop occurred, he was not pursuing HGGE, so it wouldn't have made sense to invite him—yet. Later, when he first began editing animal and human embryos, he attended scientific conferences with Jennifer Doudna and other prominent researchers. They dismissed him and his work as unimportant,[36] and perhaps it was at that point in time. Yet what his work presaged was very important. Dr. He was the very epitome of an outsider lurking on the fringes of the field. Yet it was this outsider who should have been noticed and heard. By the time Science realized his intentions, it was too late: the babies had already been altered and born.[37] This review returns to this point in Part I.C.1 below.

B. Part II: Revelations and Reproaches

Part II has three chapters. Chapter Six describes the news leaks about He's experiment, his meetings with other scientists immediately prior to the Second International Summit, and his presentation at the Summit.[38] Chapter Seven reports reactions worldwide to He's experiment.[39] For example, in China, 122 scientists and ethicists promptly issued a statement condemning the experiment as dangerous, unethical, and a blow to the reputation of Chinese biomedical research.[40] Dr. He was tried, convicted of unauthorized practice of medicine, and sentenced to three years in prison and a fine of 3 million yuan, or around $430,000.[41] China released Dr. He from prison in 2022.[42] It will be interesting to see whether he retreats into a safe silence or provides further information about his experiment and experiences with the Chinese justice system.

Lastly, in Chapter Eight, Professor Greely names those who knew Dr. He planned to conduct the experiment, or even that he had achieved pregnancies,

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[36] GREELY, *supra* note 5, at 10-11.
[37] *See infra* Part B (discussing Dr. He's dinner with Jennifer Doudna on the eve of the Second International Summit).
[38] GREELY, *supra* note 5, at 91-108.
[39] *Id.* at 109-13.
[40] *Id.* at 113-14.
[41] *Id.* at 116-18.
[42] Antonio Regalado, *The Creator of the CRISPR Babies Has Been Released from a Chinese Prison*, MIT TECH. REV. (Apr. 4, 2022), https://perma.cc/AU5N-TBB2.

but failed to stop or report him. His rogues' gallery includes Mark DeWitt, Craig Mello, Stephen Quake, Matthew Porteus, William Hurlbut, and Michael Deem.[43] The doxing of these individuals, some of whom were only peripherally involved with the experiment, may seem harsh, but Professor Greely has a compelling objective in doing so: to lay the foundation for Chapter Ten of the book, discussed below.

Within Part II, one event stands out: Dr. He's dinner with Summit organizers, including Jennifer Doudna, on November 26, 2018. According to Professor Greely, she found Dr. He to be defiant, upset, and surprised that people reacted negatively to his experiment.[44] But *CRISPR People* omits a detail available from other sources: according to Alta Charo, who was also present at the dinner,[45] Dr. He believed that he was following in the footsteps of Robert Edwards, who he viewed as "a hero, a paradigm breaker, a disrupter."[46] Edwards is the British physiologist who, along with gynecologist Patrick Steptoe, developed in vitro fertilization (IVF) and brought about the birth of Louise Brown in 1978.[47] He received the Nobel Prize in Physiology or Medicine in 2010 for his work in developing IVF.[48] Edwards was a far more careful man than He Jiankui: he began studying the basic biology of fertilization in the 1950s and learned to fertilize human eggs in the lab before proceeding to human trials.[49] Nevertheless, as this review explains below, the history of IVF is relevant to Professor Greely's policy prescriptions.

C. Part III: Crafting A Response

Part III crafts a response to He's experiment. In Chapter Nine, Professor Greely sets the stage by explaining why He's experiment was unethical. It involved "a terrible risk/benefit ratio; very questionable consent; inappropriate approval processes; complete opacity; and, finally, the violation of what came as close as possible in the world of science to an international consensus against germline genome editing (at least, yet)."[50] Professor Greely then examines

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[43] GREELY, *supra* note 5, at 121-41.
[44] *Id.* at 103-04.
[45] *Id.*
[46] Cohen, *supra* note 3, at 1090.
[47] For an account of their work, see ROBERT EDWARDS & PATRICK STEPTOE, A MATTER OF LIFE (1980).
[48] Press Release, The Nobel Assembly at Karolinska Institutet, The Nobel Assembly at Karolinska Institutet Has Today Decided to Award The Nobel Prize in Physiology or Medicine 2010 to Robert G. Edwards for the Development of In Vitro Fertilization (Oct. 4, 2010) (available at https://perma.cc/T6QU-4AUG).
[49] *Id.*
[50] GREELY, *supra* note 5, at 147.

these failures in detail.[51] He explains that the ends did not justify the unethical means. The babies born from the experiment did not receive the naturally-occurring *CCR5Δ32* variant that is known to confer some resistance to HIV infection.[52] Instead, Dr. He created random edits that "seem very likely to make those [*CCR5*] genes nonfunctional, but do those particular mutations have the same safety profile as *CCR5Δ32*? We have no idea."[53] It would be hard to imagine a more damning bioethical analysis.

1. Shunning He Jiankui

Professor Greely shifts in Chapter Ten to prescribing measures Science can take to prevent a reoccurrence of He's malfeasances. First, he urges that other scientists shun Dr. He, journals refuse his papers, and funders reject his projects.[54] Cancelling Dr. He may deter others from following in his footsteps, although one suspects that his trial, conviction, and imprisonment offer more powerful inducements to mind regulatory authorities. Indeed, as Greely recognizes later in the same chapter, another scientist seems to have learned that very lesson. In 2019, Denis Rebrikov, a Russian geneticist, announced that he planned to use HGGE to help genetically deaf couples have children with normal hearing. However, Rebrikov said he would proceed only if the Russian ministry of Health approved. When the Ministry opposed him instead, Rebrikov faded from the scene.[55]

However, this review believes Dr. He should be heard—not as a scientist, but as a pariah. Three years in prison may have humbled him. If Dr. He is willing to acknowledge his mistakes, he may also be willing to talk about why he made them, and how Science might discourage others from making similar mistakes in the future. But if he remains defiant, he may yet provide valuable information. It would be interesting to hear why he continues to believe that he did the right thing, and whether his outsider status is part of the reason for his defiance. If so, taking steps to incorporate outsiders into the scientific establishment may help to deter misbehavior.

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[51] *Id.* at 147-71.
[52] *Id.* at 152-57.
[53] *Id.* at 152-53.
[54] *Id.* at 174-75.
[55] *Id.* at 190-93.

2. Scientific Snitching Bodies

Professor Greely then floats his most striking proposal: the creation of "scientific snitching bodies" to which scientists must report research that is dangerous, unethical, or illegal.[56] These bodies could reside in several places: universities, funding entities, national governments, or international organizations.[57] Professor Greely cites precedents, such as academic honor codes and mandatory reporting of impaired physicians, and recommends further study and thought to hammer out details.[58]

This review has two concerns about this proposal. First, scientific snitching bodies seem unlikely to deter renegade scientists who see themselves as paradigm breakers or disruptors. Rather, the bodies may drive renegades underground. If they do, responsible scientists will lose the opportunity to engage with the renegades in private and dissuade them from conducting unethical experiments. This lost opportunity may not seem to matter; after all, Dr. He's contacts did not dissuade him. However, the fallout from Dr. He's experiment may have strengthened peer pressure. Responsible scientists who become aware of unethical experiments will now be motivated to intervene lest they become infamous by association. And renegades may now heed private warnings from peers because they do not wish to become outcasts in their own profession. It is one thing to be an outsider, like Dr. He before his experiment, and another thing to be an outcast, like Dr. He after his experiment.

Second, scientific snitching bodies pose a more fundamental problem: they could impair the free flow of information on which scientific inquiry depends. Responsible scientists familiar with Dr. He's experiment may already have intuited that it is better not to know too much about renegades and their plans. This instinct to avoid trouble will strengthen if and when Science imposes a duty to snitch. No one likes snitching, and no one wants to be punished for failing to snitch. Thus, responsible scientists may decide that it's safer not to learn too much about experiments that might be controversial. Indeed, they may decide that entire fields are best left alone. Why devote one's career to a touchy subject like HGGE, when so many other fields raise fewer ethical concerns and pose less risk of having to snitch? Any proposal that could have a chilling effect on scientific exchange deserves close scrutiny, and that includes scientific snitching bodies.

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[56] *Id.* at 178-79.
[57] *Id.* at 179.
[58] *Id.*

3. Humility

Lastly, Professor Greely argues that He's experiment has reinforced the image of the mad scientist who does what he wants, society be damned.[59] To recover Science's reputation and restore public trust, Greely argues it must declare that only the public can decide if HGGE can be used.[60] Professor Greely prescribes this message: "Science is part of society. The decision to use this technology belongs in part to scientists, but ultimately to societies." [61]

Professor Greely objects to the hubris of scientists and organizations who focus on technological details rather than the need for public acceptance.[62] As an example of such hubris, he cites the closing statement from the Second International Summit, which requested a translational pathway toward clinical trials in a manner that implied scientists were in charge.[63] Interestingly, in 2020, the International Commission on the Clinical Use of Human Germline Genome Editing—a collaboration between the U.S. National Academies of Science and Medicine and Royal Society of the United Kingdom—established such a pathway for rare couples who carried serious monogenic diseases and generated no unaffected embryos, or so few that IVF with preimplantation genetic diagnosis did not lead to pregnancy.[64] This 2020 Report described the basic research, preclinical evidence in support of a specific use, and approvals required before conducting clinical trials,[65] and detailed the elements of a clinical trial.[66] It also conceded the need for public engagement on the decision to use HGGE [67] and set forth societal considerations to explore.[68] Professor Greely was unable to comment—the 2020 Report had not yet been released when he wrote his book—but in a later article, he criticized the report for not

[59] *Id.* at 180.
[60] *Id.* at 180-84.
[61] *Id.* at 183.
[62] *Id.* at 181-83.
[63] *Id.* at 182-83.
[64] INT'L COMM'N ON CLINICAL USE HUM. GERMLINE GENOME EDITING, HERITABLE HUMAN GENOME EDITING 101-04, 108-10, 121-43 (2020), https://perma.cc/VX6M-P5AA. [hereinafter 2020 REPORT].
[65] *Id.* at 124-35.
[66] *Id.* at 135-38.
[67] *Id.* at 146.
[68] *Id.* at 147-48.

saying more clearly and frequently that whether to permit HGGE was a social question.[69]

This review takes a different position. Science may be part of society, but society depends on the knowledge and benefits that Science provides. Thus, Science must speak and be heard on its own terms. In the opinion of this review, the 2020 Report acted properly by asserting scientific values and establishing a translational pathway for therapeutic applications of HGGE. Those who want a social and ethical debate can be counted upon to step forward and object, as critics of the 2020 Report did.[70] HGGE is not ready for safe human use,[71] so there is plenty of time for such a debate. The public can be trusted to sift through the competing views and decide through its political institutions whether HGGE should proceed. In the meantime, the information contained in the 2020 Report will help scientists understand the challenges involved and discourage them from conducting premature and unethical experiments.

But now, suppose Science also follows Professor Greely's advice, and loudly proclaims its willingness to defer to public opinion—even if that opinion is shaped by religious[72] and political[73] opposition to HGGE. By doing so, Science dilutes its message that HGGE may have beneficial therapeutic uses. Science also may discourage some reputable young scientists from pursuing HGGE. It would be rational to avoid a field that the scientific establishment has singled out as controversial—indeed, so controversial that one must bow to the opinions of religious and political opponents.

Consider the history of IVF, a related technology. When Robert Edwards and Patrick Steptoe began their research on human embryos, they encountered stiff opposition from theologians and even some scientists.[74] For example,

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[69] Misha Angrist et al., *Reactions to the National Academies/Royal Society Report on Heritable Human Genome Editing*, 3 CRISPR J. 332, 337-38 (2020).

[70] For example, Professors Arthur Caplan and Carolyn Riley Chapman said the 2020 Report "puts the technical cart ahead of the ethical horse," and Professor J. Benjamin Hurlbut complained that the 2020 Report designed regulation when society had not yet assessed the purpose, benefit, and good of HGGE. Angrist et al., *supra* note 69, at 340, 345.

[71] For the steps leading up to its possible use, see GREELY, *supra* note 5, at 247-67.

[72] The Roman Catholic Church teaches that IVF is morally wrong because it disassociates procreation from the conjugal act. VATICAN, CONGREGATION FOR THE DOCTRINE OF THE FAITH: INSTRUCTION DIGNITAS PERSONAE ON CERTAIN BIOETHICAL QUESTIONS ¶¶ 14–16 (2008), https://perma.cc/MLU7-9HS6. Thus, although the Church might accept interventions that alter gametes to be used during the conjugal act, it will not accept embryo editing. KERRY LYNN MACINTOSH, ENHANCED BEINGS: HUMAN GERMLINE MODIFICATION AND THE LAW 30-31 (2018).

[73] On the left, progressives warn of a slippery slope leading to genetic enhancements that amplify inequality. *See, e.g.*, Katie Hasson & Marcy Darnovsky, *Are We Mapping a Path to CRISPR Babies?*, The HILL (Sept. 13, 2020), https://perma.cc/S9PB-QXVT.

[74] EDWARDS & STEPTOE, *supra* note 47, at 98-118.

when Edwards attended a Washington, D.C., conference in October 1971, theologian Paul Ramsey blasted his work as unethical experimentation on future children who could not consent.[75] Leon Kass, a member of the National Academy of Sciences, speculated that IVF babies would be deformed.[76] James Watson, who had received the Nobel Prize for discovering the structure of DNA, warned darkly of "mistakes" that would necessitate infanticide.[77] Fortunately, Edwards and Steptoe were buoyed by support from other scientists who discussed their work and concluded it was safe and ethical.[78] They continued their research and eventually began to transfer embryos to women.[79] Public acceptance followed once Louise Brown was born.[80] Today, eight million children have been born through IVF.[81] However, this happy outcome was not inevitable. Edwards and Steptoe might not have persevered if the scientific establishment of their day had condemned their work or demanded that they defer to their religious and political opponents.

D. Part IV: Next Steps for HGGE

Part IV rounds out *CRISPR People* with five more chapters. The first two evaluate policy arguments against HGGE. Chapter Eleven explains why there is no single, invariant, human genome that constitutes the unique heritage of humankind.[82] Rather, there are as many human genomes as there are humans, around 7.5 billion at present. Moreover, these genomes are not handed down intact from one generation to the next like heirlooms; they are the product of evolutionary forces and random combinations.[83] Chapter Twelve notes that critics view HGGE as unnatural, unsafe, coercive, inequitable, and a threat to

[75] *Id.* at 113.
[76] *Id.* at 112.
[77] *Id.* at 112-13.
[78] *Id.* at 115-16.
[79] *Id.* at 118-19.
[80] A Gallup poll taken in the United States after Louise Brown was born revealed that 60 percent of respondents favored IVF. Heather Mason Kiefer, *Gallup Brain: The Birth of In Vitro Fertilization*, GALLUP (Aug. 5, 2003), https://perma.cc/4LVZ-XUSS.
[81] Bart CJM Fauser, Editorial, *Towards the Global Coverage of a Unified Registry of IVF Outcomes*, 38 REPROD. BIOMEDICINE ONLINE 133 (2019).
[82] GREELY, *supra* note 5, at 209-15.
[83] *Id.* at 209-12.

diversity but finds that such concerns are unpersuasive, nonurgent, or manageable through regulation.[84]

To be sure, enhancement could raise greater concerns.[85] However, Chapter Thirteen explains why HGGE will not be used to enhance offspring anytime soon because "we know of almost no genetic variations that clearly are enhancing."[86] HGGE could correct genetic mutations that would otherwise cause a child to suffer a serious disease. However, most prospective parents will have alternatives. They can undergo IVF, screen for problematic genes, and transfer only unaffected embryos.[87] Alternatively, they might one day employ somatic genome editing to correct mutations in the tissues or organs of their children after birth, but in that case their grandchildren will also require somatic genome editing to correct any mutations they inherit.[88] Thus, while HGGE has great medical potential, it has few practical uses at present and few advantages over currently available strategies for avoiding transmission of genetic diseases.[89]

In the final two chapters, Professor Greely moves on to implementation. Chapter Fourteen presents a detailed process for proper HGGE use, from preclinical trials with ex vivo human embryos and nonhuman animals, to clinical trials in humans, and if all goes well, approval for general clinical use and monitoring of offspring.[90] Chapter Fifteen then discusses legal responses that could limit the use of CRISPR. Dr. He's experiment showed that it is relatively easy for renegades to create babies with altered genomes; nevertheless, Professor Greely rejects the premise that control over HGGE will be lost unless there is a ban.[91] He argues that "technological and social changes can be regulated in ways that avoid the worst results" and points to assisted reproduction as a case in point.[92] Professor Greely also suspects that few will argue for a constitutional right to use or prevent others from using HGGE.[93] He describes regulatory options, such as permitting HGGE only to prevent serious genetic diseases[94] or limiting its use to clinics or professionals with special

[84] *Id.* at 217-22.
[85] *Id.* at 223.
[86] *Id.* at 239-42.
[87] *Id.* at 226-32.
[88] *Id.* at 232-33.
[89] *Id.* at 245.
[90] *Id.* at 248-66.
[91] *Id.* at 269-73.
[92] *Id.* at 272-73.
[93] *Id.* at 289.
[94] *Id.* at 273-74.

qualifications.[95] He identifies the Food and Drug Administration (FDA) as the relevant regulator in the United States and addresses some challenges in applying its existing processes to this new technology.[96]

Finally, Professor Greely reaches the "metaquestion": what decision-making process should be employed to answer all the other questions he poses?[97] He reaches a middle-ground solution that is consistent with his remarks in Chapter Ten. Individuals, such as scientists, doctors, and patients should not decide.[98] Rather, the public must decide. However, given the difficulty of achieving consensus on a global scale, he is skeptical that a meaningful international treaty on HGGE will be adopted and enforced.[99] Instead, he suggests these decisions occur on a national scale. The public can express its views actively via referenda or new legislation or passively by acquiescing when the FDA or other entities regulate HGGE.[100] He rejects calls for consensus, which he correctly deems "a mushy concept at best."[101]

Professor Greely's refusal to endorse a ban will irritate those who believe the human genome should remain untouched, and his embrace of national regulation will offend others who prefer an international solution. On the other side of the debate, carriers of genetic diseases and their allies may be disappointed that he does not discuss their possible constitutional right to procreate via HGGE.[102] Thus, Professor Greely seems destined to displease critics on both sides. But that is the nature of reproductive issues: no matter what position one takes, one can never please everyone.

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[95] *Id.* at 278-79.
[96] *Id.* at 283-86.
[97] *Id.* at 286.
[98] *Id.* at 290.
[99] *Id.* at 287-88, 290.
[100] *Id.* at 288-89.
[101] *Id.* at 288.
[102] The U.S. Supreme Court has not addressed constitutional protection for assisted reproduction or genetic technologies. John A. Robertson, *Procreative Liberty in the Era of Genomics*, 29 AM. J.L. & MED. 439, 453-54 (2003). However, the Court has recognized a fundamental right to marry and raise a family, thereby implying a right to have children; thus, it could grant some degree of protection to assisted reproduction and genetic technologies. *Id.* at 454. Without reaching the constitutional question directly, the late John Robertson suggests that couples unable to produce healthy embryos have a plausible claim to procreate via HGGE. *Id.* at 476-77. Others have gone farther, arguing that couples unable to produce healthy embryos have a constitutional right to procreate via HGGE. *See*, *e.g.*, Paul Enriquez, *Editing Humanity: On the Precise Manipulation of DNA in Human Embryos*, 97 N.C.L. REV. 1147, 1220-26 (2019).

CONCLUSION

Professor Greely ends his book with acknowledgments. He questions whether he should acknowledge He Jiankui, who inspired him to write the book. Professor Greely concludes that no "thank you" is required, and that science and the world would have been better off without He Jiankui.[103]

This review agrees that Dr. He should never have conducted his premature and unethical experiment. However, it reaches a slightly different conclusion than Professor Greely. Perhaps science and the world *should* be grateful to He Jiankui—not for what he did, but for what he *didn't* do. Dr. He didn't try to make babies who would grow up to be taller or smarter or longer-lived. Such polygenic traits are difficult, if not impossible, to engineer.[104] If he had tried to edit multiple genes at once, the babies would likely have faced an even greater risk of serious physical harm than they already do from the bumbling, novel edits he made to the *CCR5* gene.

Moreover, the public would probably have reacted with greater fear and anger. Consider the results of a recent public opinion poll: 66 percent of United States respondents found it appropriate to alter a baby's genetic characteristics to treat a genetic disease or condition it would otherwise have when born, but 80 percent disapproved of changing the baby's genetic characteristics to make it smarter.[105] And had the public reacted with fear and anger, federal and state lawmakers might have banned HGGE altogether. Even somatic cell genome editing might have come under suspicion and prohibition, despite its promise in curing disease. So yes, we can thank Dr. He for not going far enough to frighten politicians into adopting radical solutions.

As for Professor Greely, we can thank him for writing this book. He has successfully documented He's experiment and situated it within the science, bioethics, and law of its time. Scientists, bioethicists, academics, policymakers, and legislators will find the book a useful resource in the ongoing debate on how to deal with HGGE. Future historians will value the book for the detail it provides, not only about the experiment and the babies, but also about the scientists and bioethicists—including Professor Greely—who are also CRISPR People.

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[103] GREELY, *supra* note 5, at 295.

[104] MACINTOSH, *supra* note 72, at 16-20.

[105] Cary Funk et al., *Biotechnology Research Viewed with Caution Globally, but Most Support Gene Editing for Babies to Treat Disease*, PEW RSCH. CTR. (Dec. 10, 2020), https://perma.cc/TS72-EX8G.