Fall 2021

How Analogizing Socio-Legal Responses to Organ Transplantation Can Further the Legalization of Reproductive Genetic Innovation

Myrisha S. Lewis

How Analogizing Socio-Legal Responses to Organ Transplantation Can Further the Legalization of Reproductive Genetic Innovation

*Myrisha S. Lewis**

ABSTRACT

The Nobel Foundation emphasized the significance of genetic innovation to society, science, and medicine by awarding the 2020 Nobel Prize in Chemistry to "the CRISPR/Cas9 genetic scissors." This Article focuses on "reproductive genetic innovation," a term that includes cytoplasmic transfer, mitochondrial transfer, and germline or heritable gene editing techniques that are all categorized as "experimental" in the United States. These techniques all use in vitro fertilization, a legal and widely available practice. Yet reproductive genetic innovation has resulted in controversy and numerous barriers including a recurring federal budget rider, threats of federal enforcement action, and the unavailability of federal funding.

At its inception, organ transplantation faced similar controversy and barriers, including prosecutorial scrutiny of surgeons and lawsuits against surgeons for the wrongful death of patients. Now, insurance coverage of organ transplantation and the opt-in system for organ donation commonly available through Departments of Motor Vehicles indicate that organ transplantation is societally accepted and routine. At first blush, organ donation and reproductive genetic innovation have little in common due to factors such as disparate senses of urgency, matters of reproductive choice, and heritable changes. Yet despite these differences, the techniques have important and underappreciated similarities such as the use of foreign biological material, genetic transfer, concerns about allocation, and extensive controversy at inception.

---

* Associate Professor, William & Mary Law School; J.D., Columbia Law School; A.B., Harvard College. For helpful comments and suggestions, I thank Aaron Bruhl, Greer Donley, Doron Dorfman, Tara Grove, Laura Heymann, Julia Mahoney, Nate Oman, Govind Persad, Jessica Roberts, Ana Santos Rutschman, Shaakirrah Sanders, Jake Sherkow, and workshop participants at William & Mary Law School, the 2020 Lutie A. Lytle Black Women Law Faculty Workshop, the Virtual Health Law Workshop, the 2020 Wiet Life Sciences Law Scholars Workshop, the 2020 Chicagoland Junior Scholars Conference, the University of Maine, and the Family Law Scholars and Teachers Conference, where I presented earlier versions of this Article. Cori Cichowicz, Karsyn Keener, Majesta-Doré Legnini, Kevin Ross, and Xijia Yuan provided excellent research and citation assistance.

After highlighting these underappreciated scientific and historical similarities, the Article argues that because organ transplantation and reproductive genetic innovation share critical similarities, society should use the lens of organ transplantation when considering the legalization of reproductive genetic innovation. Using this lens will help the discourse and analysis overcome the "Yuck Factor" or moral panic that currently accompanies reproductive genetic innovation.

TABLE OF CONTENTS

I. INTRODUCTION

MORAL panic often accompanies innovation, especially in medicine. Generally, "[a] moral panic [results when] a specific group [is] viewed as threatening those around them; without action, they risk destroying society as a whole."[1] It may be hard to believe today, but zippers, for example, were once criticized for facilitating sex.[2] Moral panic has described society's reactions to other commonplace goods and services such as life insurance, which was once "berated as a 'speculation repugnant to the law of God and man.'"[3]

Moral panic is often accompanied or signaled by the invocation of science fiction. After the first heart transplant, a 1968 *Saturday Evening Post* editorial entitled *Frankenstein in South Africa* observed that "the idea of a dead man's heart continuing to beat inside someone else is only one degree short of that ultimate goal of the hero of Gothic science fiction, the transplanting of the brain."[4] Today, this possibility is largely disregarded (and not even considered by most Americans) because organ transplantation is widespread and perceived as a social good.[5] Beyond surgical procedures, moral panic or the "Yuck Factor," is also associated with "techno-anxiety," which describes science-related fears including fears related to organ and tissue transplantation and in vitro fertilization (IVF).[6] A recent article in *The New York Times* observed:

> Louise [Brown, the first baby born using in vitro fertilization,] was widely, glibly and incorrectly called a "test-tube baby." The label was

1. Bela August Walker, *Deciphering Risk: Sex Offender Statutes and Moral Panic in a Risk Society*, 40 U. BALT. L. REV. 183, 196–97 (2010). Moral panic defines the responses of society to a "condition, episode, person, or group of persons [that] emerges to be defined as a threat to societal values and interests." STANLEY COHEN, FOLK DEVILS AND MORAL PANICS: THE CREATION OF THE MODS AND ROCKERS 1 (Routledge 3d ed. 2002) (1972).

2. *See* Ian Johnson, *Zipper Anniversary: 10 Bits of Trivia to Impress the Pants off You,* CBC NEWS (Apr. 29, 2013, 5:25 AM), https://www.cbc.ca/news/technology/zipper-anniversary-10-bits-of-trivia-to-impress-the-pants-off-you-1.1305202 [https://perma.cc/H7X4-WNBX].

3. Roy Kreitner, *Speculations of Contract, or How Contract Law Stopped Worrying and Learned to Love Risk*, 100 COLUM. L. REV. 1096, 1100 (2000).

4. Editorial Board, *Frankenstein in South Africa*, SATURDAY EVENING POST, Feb. 10, 1968, at 72.

5. *See Theological Perspective on Organ and Tissue Donation*, UNITED NETWORK FOR ORGAN SHARING, https://unos.org/transplant/facts/theological-perspective-on-organ-and-tissue-donation [https://perma.cc/W8UT-NV9D].

6. COHEN, *supra* note 1, at xxx; Julia D. Mahoney & Gil Siegal, *Beyond Nature? Genomic Modification and the Future of Humanity*, 81 LAW & CONTEMP. PROBS. 195, 195 (2018) ("[T]he modern-day reaction to heritable human genome editing is one of hesitation and fear."); *see also* Charles W. Schmidt, *The Yuck Factor: When Disgust Meets Discovery*, 116 ENV'T HEALTH PERSPS. 524, 525 (2008) ("'[Y]uck factor' has become a catchall phrase to describe technophobic sentiments that vary by what triggers them."); Katherine Purvis, *'Yuck Factor' Puts Off Eye Donors, Leaving Vital Transplants at Risk*, THE GUARDIAN (May 7, 2019, 9:00 A.M.), https://www.theguardian.com/society/2019/may/07/eye-donors-transplant-risk-corneas [https://perma.cc/CG7J-P4HX]; Clyde Haberman, *Scientists Can Design 'Better' Babies. Should They?*, N.Y. TIMES (June 10, 2018), https://www.nytimes.com/2018/06/10/us/11retro-baby-genetics.html [https://perma.cc/M2V3-8KF7].

> enough to throw millions of people into a moral panic, for it filled them with visions of Dr. Frankenstein playing God and throwing the natural order of the universe out of kilter.[7]

Moral panic has accompanied several issues related to reproduction including surrogacy,[8] Safe Haven Laws,[9] responses to the maternal consumption of certain substances during pregnancy,[10] and IVF.[11]

A present-day moral panic surrounds techniques involving genetic innovation in reproduction.[12] In this article, the term "reproductive genetic innovation" includes mitochondrial transfer, cytoplasmic transfer, and heritable gene editing, which are reproductive techniques that combine IVF with genetic modifications or substitutions.[13] Mitochondrial transfer, a technique that changes approximately 0.1% of DNA, could prevent the transmission of harmful genetic disease.[14] But this promising technique has been sensationalized as "three-parent" IVF, a characterization that scientists oppose because the third party would be a donor who would contribute only a trivial amount of genetic material.[15] Media coverage of cytoplasmic transfer, a technique similar to mitochondrial transfer, has been accompanied by headlines such as "[t]he girl with three biological parents."[16] Similarly, dystopian references to movies like *Gattaca* and novels like Aldous Huxley's *Brave New World* commonly arise as observ-

---

7. Haberman, *supra* note 6.

8. Kimberly D. Krawiec, *Show Me the Money: Making Markets in Forbidden Exchange*, 72 LAW & CONTEMP. PROBS. i, xi (2009).

9. Carol Sanger, *Infant Safe Haven Laws: Legislating in the Culture of Life*, 106 COLUM. L. REV. 753, 781–88 (2006).

10. Michele Goodwin, *Fetal Protection Laws: Moral Panic and the New Constitutional Battlefront*, 102 CALIF. L. REV. 781, 793–94, 805 (2014); Justin D. Levinson, Robert J. Smith & Koichi Hioki, *Race and Retribution: An Empirical Study of Implicit Bias and Punishment in America*, 53 U.C. DAVIS L. REV. 839, 862–63 (2019).

11. June Carbone & Naomi Cahn, *Embryo Fundamentalism*, 18 WM. & MARY BILL RTS. J. 1015, 1037–38 (2010); Haberman, *supra* note 6.

12. *See, e.g.*, Michael J. Reiss, *What Sort of People Do We Want? The Ethics of Changing People Through Genetic Engineering*, 13 NOTRE DAME J.L., ETHICS & PUB. POL'Y 63, 78–85 (1999); Sarah Ruth Bates, *Rewriting Our Genes Is Easier Than Ever. That Doesn't Mean We Should Do It*, WBUR (Jan. 3, 2020), https://www.wbur.org/cognoscenti/2020/01/03/germline-prime-gene-editing-sarah-ruth-bates [https://perma.cc/EN4T-BWJV]; Chloe Nevitt, *From the BrainSTEM: The Mammoth Cometh*, MCGILL TRIB. (Mar. 24, 2015), https://www.mcgilltribune.com/sci-tech/from-the-brainstem-the-mammoth-cometh [https://perma.cc/UND4-PXNT]; *Statement on NIH Funding of Research Using Gene-Editing Technologies 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/4WZV-ZRYJ].

13. *See infra* Section II.B.

14. NUFFIELD COUNCIL ON BIOETHICS, NOVEL TECHNIQUES FOR THE PREVENTION OF MITOCHONDRIAL DNA DISORDERS: AN ETHICAL REVIEW vii, 18–19, 25 (2012).

15. *See, e.g.*, Rebecca Jacobson, *Why the Term 'Three-Person Baby' Makes Doctors Wince*, PBS NEWS HOUR, (Feb. 10, 2015, 2:31 PM), https://www.pbs.org/newshour/science/term-three-person-baby-makes-doctors-wince [https://perma.cc/3Y4M-HPKF]; Rob Stein, *Clinic Claims Success in Making Babies with 3 Parents' DNA*, NPR (June 6, 2018, 5:11 AM), https://www.npr.org/sections/health-shots/2018/06/06/615909572/inside-the-ukrainian-clinic-making-3-parent-babies-for-women-who-are-infertile [https://perma.cc/7SY6-WGT2].

16. Charlotte Pritchard, *The Girl with Three Biological Parents*, BBC NEWS (Sept. 1, 2014), https://www.bbc.com/news/magazine-28986843 [https://perma.cc/J62P-B8WL].

ers expect that reproductive genetic innovation will lead to a "brave new world" full of children created with pre-ordained roles in furtherance of social stability.[17]

Although few people realize it, and no one invokes Huxley over it, individuals' DNA can change naturally or because of routine medical procedures:

1. A woman's blood donation revealed that she had two blood types because she had "acquired" the DNA of her twin in the womb;[18]
2. A man experienced several DNA changes years after receiving a bone marrow donation as part of his leukemia treatment. The DNA in his blood is solely the donor's DNA, the DNA in his saliva and cheeks is both his original DNA and the donor's DNA, and his semen contains only the donor's DNA;[19]
3. Medical testing for a woman in need of a kidney transplant revealed that the children she conceived and gave birth to were not her genetic children;[20]
4. Women have acquired the genomes of their children after pregnancy;[21] and
5. Studies have revealed that blood transfusions sometimes transfer DNA from donor to recipient.[22]

These genetic changes occur after commonly accepted medical experiences and are accompanied by sensational news coverage, yet there are no cries for the end of pregnancy, bone marrow transplantation, or organ

17. ALDOUS HUXLEY, A BRAVE NEW WORLD 8–10 (ALFRED A. KNOPF 2013) (1932); Michael J. Sandel, *The Case Against Perfection*, THE ATLANTIC (Apr. 2004) (citing GATTACA (Columbia Pictures 1997)), https://www.theatlantic.com/magazine/archive/2004/04/the-case-against-perfection/302927 [https://perma.cc/J3XY-M748].

18. I. Dunsford, C.C. Bowley, Ann M. Hutchison, Joan S. Thompson, Ruth Sanger & R.R. Race, *A Human Blood-Group Chimera*, 2 BR. MED. J. 81, 81 (1953); Carl Zimmer, *DNA Double Take*, N.Y. TIMES (Sept. 16, 2013), https://www.nytimes.com/2013/09/17/science/dna-double-take.html [https://perma.cc/2U3B-85GP].

19. Chris Long & Brittney Chilton, Washoe County Sheriff's Office Forensic Science Division, Chimeric Fluidity: A Case Study of a Male Stem Cell/Bone Marrow Transplant Patient (citing Evan M. Bloch, Rachel P. Jackman, Tzong-Hae Lee & Michael P. Busch, *Transfusion-Associated Microchimerism: The Hybrid Within*, 27 TRANSFUSION MED. REVS. 10, 10–20 (2013)), https://vb6ykw2twb15uf9341ls5n11-wpengine.netdna-ssl.com/wp-content/uploads/2019/07/6.-ChimericFluidityWCSOFSD.pdf [https://perma.cc/P6ZN-XQPR]; Heather Murphy, *When a DNA Test Says You're a Younger Man, Who Lives 5,000 Miles Away*, N.Y. TIMES (Dec. 12, 2019), https://www.nytimes.com/2019/12/07/us/dna-bone-marrow-transplant-crime-lab.html [https://perma.cc/YG3W-8E4E].

20. Zimmer, *supra* note 18; *see also* Neng Yu, Margot S. Kruskall, Juan J. Yunis, Joan H.M. Knoll, Lynne Uhl, Sharon Alosco, Marina Ohashi, Olga Clavijo, Zaheed Husain, Emilio J. Yunis, Jorge J. Yunis & Edmond J. Yunis, *Disputed Maternity Leading to Identification of Tetragametic Chimerism*, 346 NEW ENG. J. MED. 1545, 1545 (2006).

21. Kristen Chen, Ramen H. Chmait, Douglas Vanderbilt, Samuel Wu & Linda Randolph, *Chimerism in Monochorionic Dizygotic Twins: Case Study and Review*, 161 AM. J. MED. GENETICS 1817, 1822–23 (2013); Bloch et al., *supra* note 19, at 10–11; Zimmer, *supra* note 18.

22. Bloch et al., *supra* note 19, at 11; Michelle N. Gong, *What Happens to the Donor's DNA in a Blood Transfusion?*, SCI. AM. (Jan. 23, 2009), https://www.scientificamerican.com/article/donor-blood-transfustion [https://perma.cc/3E8G-DYXP].

transplantation.[23] Instead, these occurrences and procedures are commonly accepted by society (although still newsworthy) as indicated by insurance coverage and the lack of any significant social outcry.[24]

It may come as a surprise given its widespread acceptance today, but organ transplantation sparked controversy at its inception.[25] Controversy surrounding organ transplantation culminated in discussions of the definition of death, prosecutorial scrutiny of surgeons, wrongful death suits by "donors" against the surgeons who transplanted loved ones' organs into recipients, and the eventual passage of brain death statutes.[26] These brain death statutes, the passage of the Uniform Anatomical Gift Act in all fifty states, and other federal legislation facilitated the acceptance of organ transplantation and increased availability of organs.[27] Thus, much of the controversy related to the legality of organ transplantation and the proper role of physicians and surgeons in "experimental" techniques has dissipated, and today organ transplantation enjoys societal acceptance.[28] Organ transplantation is still accompanied by bioethical concerns and controversy, including those related to racial disparities, black-market organ sales, supply and demand limitations, and resource allocation issues, but it enjoys a societal acceptance that has led to a "hands-off" approach in which the technique is permissible, and individuals can decide whether to (try to) avail themselves of the technique as donors, recipients, or nonparticipants.[29]

---

23. Bloch et al., *supra* note 19, at 11 (noting that microchimerism can occur after organ transplantation).

24. *See, e.g.*, Melissa Wong, *Coverage for Kidneys: The Intersection of Insurance and Organ Transplantation*, 16 CONN. INS. L.J. 535, 543 (2010).

25. THOMAS STARZL, THE PUZZLE PEOPLE: MEMOIRS OF A TRANSPLANT SURGEON 148 (1992) (discussing how Norman Shumway, a surgeon known for his work in heart transplantation, was the subject of prosecutorial investigation although he ultimately escaped prosecution); Kieran Healey, *Sacred Markets and Secular Ritual in the Organ Transplant Industry*, *in* THE SOCIOLOGY OF THE ECONOMY 310 (ed. Frank Dobbin 2004) ("Since the 1970s, organ transplantation has been transformed from an experimental therapy of last resort into a common medical procedure.").

26. *See supra* note 25 and accompanying text; *infra* Parts II and III.

27. *See* Jay A. Friedman, *Taking the Camel by the Nose: The Anencephalic as a Source for Pediatric Organ Transplants*, 90 COLUM. L. REV. 917, 966 (1990); Samantha Weyrauch, *Acceptance of Whole-Brain Death Criteria for Determination of Death: A Comparative Analysis of the United States and Japan*, 17 UCLA PAC. BASIN L.J. 91, 96–99 (1999); BARRY FURROW, THOMAS L. GREANEY, SANDRA H. JOHNSON, TIMOTHY STOLTZFUS JOST, ROBERT L. SCHWARTZ, HEALTH L.: CASES, MATERIALS & PROBS. 1290 (8th ed. 2018); *id.* at 1304–05; Linda C. Fentiman, *Organ Donation as National Service: A Proposed Federal Organ Donation Law*, 27 SUFFOLK U. L. REV. 1593, 1596 (1993).

28. *See infra* Part II.

29. *See infra* Part II; Michele Goodwin, *Altruism's Limits: Law, Capacity, and Organ Commodification*, 56 RUTGERS L. REV. 305, 328 (2004); Julia D. Mahoney, *Altruism, Markets, and Organ Procurement*, 72 LAW & CONTEMP. PROBS. 17, 20 (2009); Arthur L. Caplan, *The Ethics of the Unmentionable*, 46 J. MED. ETHICS 687, 687 (2020); Nathan B. Oman, *Beyond Gift and Bargain: Some Suggestions for Increasing Kidney Exchanges*, 81 LAW & CONTEMP. PROB. 37, 37–65 (2018); Michele Goodwin & Nevin Gewertz, *Rethinking Colorblind State Action: A Thought Experiment on Racial Preferences*, 72 LAW & CONTEMP. PROBS. 251, 252–54 (2009); Jamila Jefferson-Jones, *The Exchange of Inmate Organs for Liberty: Diminishing the "Yuck" Factor Repugnance Debate*, 16 J. GENDER, RACE & JUST. 105, 107–08 (2013); Philip J. Cook & Kimberly D. Krawiec, *If We Pay Football Play-*

This Article advocates for viewing reproductive genetic innovation through the lens of organ transplantation instead of the lens of sensationalism. The use of the lens of organ transplantation would apply a medicalized view to these techniques by focusing on their therapeutic uses as opposed to a science-fiction view that focuses on matters such as eugenics-related concerns and sensationalism.[30] In prior works, I have emphasized, as a matter of regulation, the similarities between techniques involving reproductive genetic innovation and assisted reproductive technology (ART), namely IVF and FDA-approved gene therapy products. Framing reproductive genetic innovation in terms of organ transplantation, a societally accepted (and encouraged) practice, could minimize the Yuck Factor's prevalence in discussions of reproductive genetic innovation. Further, as the first expected uses of reproductive genetic innovation are medical uses as opposed to enhancement-based uses, this Article focuses on these therapeutic uses in its analysis.[31]

Despite the promise of reproductive genetic innovation, its use in the United States is severely curtailed by the federal regulatory system that has rendered the techniques unavailable.[32] Moral panic lies at the heart of the overregulation of reproductive genetic innovation.[33] The proscription of these techniques stems from an underlying political and ethical opposition to embryo destruction, broader concern for future generations, and concern about altering the genomes of the future.[34] Reproductive genetic innovation is viewed by many as controversial, based not only on safety and efficacy concerns but also, for many, based on ethical and moral views that are ultimately incorporated into political decisions.[35]

---

ers, Why Not Kidney Donors?, 41 REGUL. 12, 12–13 (2018); Steven P. Calandrillo, *Cash for Kidneys? Utilizing Incentives to End America's Organ Shortage*, 13 GEO. MASON L. REV. 69, 69, 132 (2004).

30. For more on medicalization, see Dayna Bowen Matthew, *Health and Housing: Altruistic Medicalization of America's Affordability Crisis*, 81 LAW & CONTEMP. PROBS. 161, 161–70 (2018); William Sage & Jennifer Laurin, *If You Would Not Criminalize Poverty, Do Not Medicalize It*, 46 J.L., MED. & ETHICS 573, 573–80 (2018); Erik Parens, *On Good and Bad Forms of Medicalization*, 27 BIOETHICS 28, 28–30 (2013); Peter Conrad, *The Shifting Engines of Medicalization*, 46 J. HEALTH & SOC. BEHAV. 3, 10 (2005).

31. *See infra* Section II.B.1.a–b (discussing prior medical uses of mitochondrial and cytoplasmic transfer).

32. *See infra* Section II.B.2 (discussing how the FDA, and later Congress, have enacted barriers to the use of reproductive genetic innovation in the United States).

33. *See, e.g.*, *supra* notes 1–11 and accompanying text.

34. Mahoney & Siegal, *supra* note 6, at 203–06; Jacob S. Sherkow & Christopher Thomas Scott, *The Pick-and-Shovel Play: Bioethics for Gene-Editing Vector Patents*, 97 N.C. L. REV. 1497, 1519 (2019). *But see infra* Section IV.A (discussing the legalization of mitochondrial transfer in the United Kingdom).

35. *See, e.g.*, Sherkow & Scott, *supra* note 34, at 1497–99 ("[R]ecent developments in genome editing technologies such as CRISPR . . . depending upon one's perspective promise both the salvation and destruction of humankind."); Interview by Christine Lingham of Peter Marks at Molecular Med. Tri-Conference, (Mar. 4, 2020) ("[Heritable genetic modifications] is a tremendously controversial area."), https://www.triconference.com/transcripts/peter-marks-transcript [https://perma.cc/A4QF-3J78]; *see also infra* Parts II and III (discussing the commingling of social and political considerations with regulatory decision-making related to techniques involving genetic modification in reproduction). *See generally* Myrisha S. Lewis, *How Subterranean Regulation Hinders Innovation in Assisted Reproduc-*

The Article recommends that federal legislators cease renewing the budget rider that prohibits the U.S. Food and Drug Administration (FDA) from considering techniques involving heritable genetic modification.[36] With the continuation of the budget rider, substantive discussion is curtailed, and unlike with organ transplantation, innovation is stymied, and researchers cannot have productive conversations with federal agency members, as evidenced by the FDA's denial of a researcher's request for pre-application meetings because of the rider.[37] Alternatively, the FDA could interpret the budget rider less broadly to encompass fewer techniques used in reproductive genetic innovation, especially since many scientists and physicians disagree with the FDA's current overexpansive interpretation.[38] More broadly, the Article also argues for the removal of federal regulation from reproductive genetic innovation and an emphasis on the role of states in the regulation of reproduction and medicine.

One might question the analogy to organ transplantation as this Article compares techniques that have been classified as products (biologics, drugs, or both) by the FDA and as body parts by the National Organ Transplant Act.[39] While reproductive genetic innovation is often examined singularly through the lenses of bioethics or ART, this Article will show how discussions surrounding organ and tissue donation could be both a useful lens and a helpful analogy to use while examining reproductive genetic innovation.[40] There are many underappreciated similarities between reproductive genetic innovation and organ transplantation, such as the use of foreign biological material, genetic transfer, concerns about allocation, and extensive controversy at inception, along with some dissimilarities and competing analogies.[41] There is robust scholarship on issues involving genetic innovation and genetic modification in reproduc-

---

tive Technology, 39 CARDOZO L. REV. 1239 (2018) [hereinafter Lewis, *Subterranean Regulation*] (discussing how political, ethical, and social views can affect regulatory decision-making in the realm of techniques involving genetic modification); Myrisha S. Lewis, *Is Germline Gene Editing Exceptional?*, 51 SETON HALL L. REV. 735, 763–94 (2021) [hereinafter Lewis, *Germline Gene Editing*] (discussing the social, political, and ethical objections to techniques involving genetic modification and their similarities to other forms of assisted reproductive technology).

36. *See infra* notes 142–143 and accompanying text (discussing the budget rider added in 2015—and renewed every year since—that prohibits the FDA from considering applications involving heritable genetic modification).

37. *See infra* note 143 and accompanying text.

38. *See* Radhika Viswanathan, *3 Biological Parents, 1 Child, and an International Controversy*, VOX (July 28, 2018, 10:00 AM) ("'[Mitochondrial replacement therapy] can technically be construed as germline modification, so mitochondrial replacement got swept up into that [budget] rider,' said Brown University's [Eli] Adashi. 'It was caught up in the gene editing concerns, and I think it's sort of an unfortunate linkage.'"), https://www.vox.com/2018/7/24/17596354/mitochondrial-replacement-therapy-three-parent-baby-controversy [https://perma.cc/NX7M-T8K7]; Eli Y. Adashi & I. Glenn Cohen, *Going Germline: Mitochondrial Replacement as a Guide to Genome Editing*, 164 CELL 832, 833 (2016).

39. *See infra* Part II.

40. *See infra* Parts II and III.

41. *See infra* Parts II and III.

tion, including articles by a number of scholars (including myself) that focus on scientific acceptance, regulatory choices, and ethical considerations.[42] While the discourse related to reproductive genetic innovation focuses on controversy and "lines that should not be crossed," organ transplantation is largely neglected in the American and global discourses surrounding techniques involving reproductive genetic modification.[43] This Article fills that gap.

Part II of the Article provides a scientific and regulatory overview of (1) organ and tissue transplantation and (2) reproductive genetic innovation. Part III identifies four important commonalities between organ transplantation and reproductive genetic innovation that make the former a valid frame for considering the latter: (1) the use of foreign biological material, (2) genetic transfer, (3) concerns about allocation, and (4) extensive controversy at inception. Part III also identifies and analyzes the dissimilarities between organ and tissue transplantation and reproductive genetic innovation, which include potential heritable changes, eugenics-related concerns, disparate senses of urgency, and matters of reproductive choice. Despite these dissimilarities, Part IV shows the advantages of applying the organ transplantation lens that emphasizes medical therapy instead of prospective (and often implausible) enhancement to the analysis of reproductive genetic innovation.

II. SCIENTIFIC AND LEGAL BACKGROUND

This Part provides a medico-legal overview of organ and tissue transplantation (the replacement of unhealthy organs and tissues) and reproductive genetic innovation (the field of reproductive techniques that improves fertility outcomes and prevents the transmission of genetic diseases and traits that may reduce quality and length of life). This medico-legal overview includes scientific background and regulatory reactions for

42. Often these two literatures overlap. *See, e.g.*, June Carbone & Jody Lyneé Medeira, *Buyers in the Baby Market: Toward a Transparent Consumerism*, 91 WASH. L. REV. 71, 72–74 (2016); Glenn Cohen, *Circumvention Medical Tourism and Cutting Edge Medicine: The Case of Mitochondrial Replacement Therapy*, 25 IND. J. GLOB. LEGAL STUD. 439, 439–42 (2018); Henry T. Greely, *CRISPR'd Babies: Human Germline Genome Editing in the 'He Jiankui Affair*,' 6 J.L. & BIOSCIENCES 111, 115 (2019). *See generally* Lewis, *Subterranean Regulation*, *supra* note 35; Myrisha S. Lewis, *The American Democratic Deficit in Assisted Reproductive Technology Innovation*, 45 AM. J.L. & MED. 130 (2019) [hereinafter Lewis, *The American Democratic Deficit*]; Seema Mohapatra, *Politically Correct Eugenics*, 12 FIU L. REV. 51 (2016); Sonia M. Suter, *The 'Repugnance' Lens of* Gonzales v. Carhart *and Other Theories of Reproductive Rights: Evaluating Advanced Reproductive Technologies*, 76 GEO. WASH. L. REV. 1514 (2008); *infra* notes 149–150 and accompanying text (providing an overview of the legal scholarship that applies to techniques involving genetic innovation).

43. *See, e.g.*, Nancy M.P. King, Pat C. Lord & Douglas E. Lemley, *Editing the Genome: Prospects, Progress, Implications, and Cautions*, 5 CURRENT GENETIC MED. RESP. 35, 36 (2017). Professor Marsha Garrison has proffered that the system of organ allocation in the United States through the United Network for Organ Sharing (UNOS) might be useful in the regulation of assisted reproductive technology. *See* Marsha Garrison, *Regulating Reproduction*, 76 GEO. WASH. L. REV. 1623, 1648–49 (2008).

organ and tissue transplantation in Section A and reproductive genetic innovation in Section B.

A. Organ and Tissue Transplantation

The American Red Cross routinely runs blood drives, drivers opt into organ donation regimes, families are asked whether the organs of their deceased loved ones at hospitals should be donated, and prospective bone marrow donors sign up for registries that match donors to potential recipients.[44] The 1990 Nobel Prize in Physiology or Medicine was awarded to two physicians, Joseph E. Murray and E. Donnall Thomas, "for their discoveries concerning organ and cell transplantation in the treatment of human disease"—namely, kidney and bone marrow transplantation.[45]

1. Scientific Background on Organ and Tissue Transplantation

Organ transplantation is used when a person's organs no longer function due to disease or injury.[46] In 1954, Dr. Joseph E. Murray transplanted the first kidney in Boston, Massachusetts.[47] Dr. Thomas Starzl performed the first successful liver transplant in 1967.[48] The next year, Dr. Normal Shumway performed America's first successful heart transplant at Stanford University Hospital.[49] Also, Dr. E. Donnall Thomas performed the first successful allogeneic hematopoietic cell transplant using stem cells from siblings in 1969 and the first bone marrow transplant

44. Blood Services, Am. Red Cross, https://www.redcrossblood.org/give.html/find-drive [https://perma.cc/YW9M-X3UK]; *Donate Bone Marrow*, Health Res. & Servs. Admin., https://bloodstemcell.hrsa.gov/donor-information/donate-bone-marrow [https://perma.cc/9HAR-38K6]; *see also* A. Ralph, J.R. Chapman, J. Gillis, J.C. Craig, P. Butow, K. Howard, M. Irving, B. Sutano & A. Tong, *Family Perspectives on Deceased Organ Donation: Thematic Synthesis of Qualitative Studies*, 14 Am. J. Transplant. 923, 925, 930 (2014); 42 U.S.C. § 274k (mandating a bone-marrow transplantation program); Jessie Halladay, *Organ Donor Icon Now on Licenses in 47 States*, USA Today, (Jan. 22, 2013, 4:03 PM), https://www.usatoday.com/story/news/nation/2013/01/22/organ-donation-drivers-licenses/1855871 [https://perma.cc/AS7T-HCNK].

45. *See* Karl G. Blume & Irving L. Weissman, *E. Donnall Thomas (1920-2012)*, 109 Proc. Nat'l Acad. Scis. 20777, 20777–78 (2012); *E. Donnall Thomas: Facts*, Nobel Prize, https://www.nobelprize.org/prizes/medicine/1990/thomas/facts [https://perma.cc/45W7-M8R7]; *Joseph E. Murray: Biographical*, Nobel Prize, https://www.nobelprize.org/prizes/medicine/1990/murray/biographical [https://perma.cc/NQ6Y-2VRU]; *The Nobel Prize in Physiology or Medicine 1990*, Nobel Prize, https://www.nobelprize.org/prizes/medicine/1990/summary [https://perma.cc/NJ7Y-28S5].

46. *See, e.g.*, *Lung Transplant Performed on Covid 19 Patient at Northwestern Medicine*, Nw. Med. (June 11, 2020), https://www.nm.org/about-us/northwestern-medicine-newsroom/press-releases/2020/lung-transplant-performed-on-covid-19-patient-at-northwestern-medicine [https://perma.cc/2XSY-GTZC].

47. *History*, Organ Procurement & Transplantation Network, https://optn.transplant.hrsa.gov/learn/about-transplantation/history [https://perma.cc/32DZ-BBLC]; Gina Kolata, *2 American Transplant Pioneers Win Nobel Prize in Medicine*, N.Y. Times (Oct. 9, 1990), https://www.nytimes.com/1990/10/09/science/2-american-transplant-pioneers-win-nobel-prize-in-medicine.html [https://perma.cc/QQ2Y-3KNM].

48. *History*, *supra* note 47; Starzl, *supra* note 25 at 166, 169.

49. *History*, *supra* note 47.

in the United States in 1972.[50] In 1989, the first transplant of a liver from a living donor to a living recipient in the United States was performed; donations of livers from living donors to living recipients are now common.[51] However, success at this early point in time only referred to medical success in terms of the procedure and not their acceptance by the public.[52]

Bone marrow transplantation merits a special mention in this Article because it is a commonly accepted treatment that has resulted in the genetic modification of at least one individual (the recipient).[53] As of 2007, "hematopoietic-cell transplantation," a term that includes bone marrow and stem cell transplantation, is "now available at 500 or more centers in more than 50 countries."[54] Individuals, like those mentioned in Part I's vignettes, who contain multiple sets of DNA are referred to as "chimeras."[55] Just as organs are transplanted to treat disease, bone marrow is also transplanted to treat leukemia and other bone and blood diseases.[56] Chimerism can result from bone marrow transplants, natural changes, and other causes.[57] Because recipients of bone marrow and stem cells have multiple, genetically different sets of DNA in their bodies, popular DNA testing services like 23andMe and Ancestry.com caution that bone marrow transplant recipients should not use their services, because their chimerism will cause "analysis failure."[58] Currently, blood transfusion re-

50. Blume & Weissman, *supra* note 45, at 20777.

51. *History*, *supra* note 47; *Living Donor Liver Transplant*, JOHNS HOPKINS MED.: COMPREHENSIVE TRANSPLANT CTR., https://www.hopkinsmedicine.org/transplant/programs/liver/living-donor-liver-transplant [https://perma.cc/PTT2-HEDW].

52. *See* R.M. Langer & Barry D. Kahan, *100 Years Ago: Ullmann's Pioneering Operation—Autotransplantation of the Kidney*, 34 TRANSPLANTATION PROC. 429, 432 (2002); *infra* Part III.D.2 (discussing the term "successful" and its different meanings in medicine according to scientists and legislators).

53. *See* Zimmer, *supra* note 18. Experts expect that bone marrow transplantation should not result in heritable genetic changes, although they have not been able to test this expectation. *See id.* This possibility interests forensic scientists in light of criminal law's focus on DNA. *Id.*

54. *See* Frederick R. Appelbaum, *Hematopoietic-Cell Transplantation at 50*, 357 NEW ENG. J. MED. 1472, 1474 (2007); *see also Hematopoietic Stem Cell*, NAT'L CANCER INST., https://www.cancer.gov/publications/dictionaries/cancer-terms/def/hematopoietic-stem-cell [https://perma.cc/LJ9G-ASFH].

55. *See supra* notes 18–22 and accompanying text; Maria Themeli, Miguel Waterhouse, Juergen Finke & Alexandros Spyridonidis, *DNA Chimerism and Its Consequences After Allogeneic Hematopoietic Cell Transplantation*, 2 CHIMERISM 25, 25 (2011); Yu et al., *supra* note 20, at 1545.

56. *Bone Marrow Transplant Solutions*, MAYO CLINIC, https://www.mayoclinic.org/departments-centers/bone-marrow-transplant/home/orc-20212005 [https://perma.cc/R4TP-WG2H].

57. Alan W. Flake & Esmail D. Zanjani, *In Utero Transplantation*, *in* THOMAS' HEMATOPOIETIC CELL TRANSPLANTATION: STEM CELL TRANSPLANTATION 577 (Frederick R. Appelbaum et al. eds., 4th ed. 2004); Nancy M.P. King, *Accident & Desire: Inadvertent Germline Effects in Clinical Research*, 33 HASTINGS CTR. REP. 23, 28 (2003); Rachael Rettner, *3 Human Chimeras That Already Exist*, SCI. AM. (Aug. 8, 2016), https://www.scientificamerican.com/article/3-human-chimeras-that-already-exist [https://perma.cc/VLY4-LSC6].

58. *I Received a Bone Marrow Transplant, Can I Use the 23andMe Personal Genetic Service?*, 23ANDME, https://customercare.23andme.com/hc/en-us/articles/202907990-I-received-a-bone-marrow-transplant-can-I-use-the-23andMe-Personal-Genetic-Service

sults in the transmission of DNA from donor to recipient, albeit temporarily.[59]

2. Regulatory Reactions to Organ and Tissue Transplantation

Reproductive genetic innovation and organ transplantation face widely divergent regulatory treatment as legal access to reproductive genetic innovation is severely curtailed in the United States, unlike the extensive legal access to organ transplantation. While early pioneers in organ transplantation faced prosecution and wrongful death lawsuits[60] that were resolved in their favor, organ transplantation enjoys unquestioned legality today in the United States.[61]

Federal law provides certain limitations on the procurement of organs through the National Organ Transplant Act, which includes prohibitions on the sale of certain organs.[62] The term "human organ" in the National Organ Transplant Act includes:

> human (including fetal) kidney, liver, heart, lung, pancreas, bone marrow, cornea, eye, bone, and skin or any subpart thereof and any other human organ (or any subpart thereof, including that derived from a fetus) specified by the Secretary of Health and Human Services by regulation.[63]

Notably, the definition of "organ" excludes sperm, eggs, and blood.[64]

[https://perma.cc/325Y-XZ4Q]; *If I Received a Bone Marrow or Stem Cell Transplant, Should I Use AncestryDNA?*, ANCESTRYDNA LEARNING HUB, https://www.ancestry.com/lp/bone-marrow-stem-cell-transplant-dna-test [https://perma.cc/8DSB-4YJF]; Sarah Zhang, *A Woman's AncestryDNA Test Revealed a Medical Secret*, THE ATLANTIC (Sept. 13, 2019), https://www.theatlantic.com/science/archive/2019/09/woman-cord-blood-donor-dna-test/597928 [https://perma.cc/66D8-G6YM].

59. Gong, *supra* note 22; Michelle Ng Gong, Yang Sai, Wei Zhou, B. Taylor Thompson, Li-Lian Xu & David C. Christiani, *Genotyping Patients with Recent Blood Transfusions*, 14 EPIDEMIOLOGY 744, 744 (2003); Bloch et al., *supra* note 19, at 11.

60. *See* Lawrence K. Altman, *Norman E. Shumway, 83, Who Made Heart the Transplant a Standard, Dies*, N.Y. TIMES (Feb. 11, 2006), https://www.nytimes.com/2006/02/11/health/norman-e-shumway-83-who-made-the-heart-transplant-a-standard.html [https://perma.cc/XQ8S-HC42]. Although charges were considered, prosecutors ultimately did not bring charges against Norman Shumway, and state legislatures instead adopted the brain death definition of death. *See id.* The disputes over brain death versus cardiac death remained an issue for physicians other than Dr. Shumway who continued performing heart transplants in the early years. *See Heart Operation Key Issue in Trial*, N.Y. TIMES (Oct. 29, 1973), https://www.nytimes.com/1973/10/29/archives/heart-operation-key-issue-in-trial-medical-definition-of-death.html [https://perma.cc/5VU4-BQ27]. *See generally* Tucker v. Lower, 1 Va. Cir. 124 (1972); Ronald Converse, *But When Did He Die?:* Tucker v. Lower *and the Brain-Death Concept*, 12 SAN DIEGO L. REV. 424 (1975).

61. *See, e.g.*, 42 U.S.C. § 274 (2013); *Organ Procurement and Transplantation Network*, U.S. DEP'T HEALTH & HUM. SERVS., https://optn.transplant.hrsa.gov [https://perma.cc/VRX4-KZTZ]. While organ transplantation techniques were not illegal, there were many aspects of organ transplantation that could be illegal, such as organ sales. *See infra* note 67 (citing state statutes prohibiting organ sales).

62. *See, e.g.*, § 274e.

63. *Id.* § 274e; *see infra* note 184 (discussing controversy related to fetal tissue that is outside of the scope of this Article).

64. John A. Robertson, *Paid Organ Donations and the Constitutionality of the National Organ Transplant Act*, 40 HASTINGS CONST. L.Q. 221, 223, 229 (2013); Flynn v. Holder, 684 F.3d 852, 858–59 (9th Cir. 2012).

Similarly, human tissues are obtainable through "eye banks" and "tissue banks" that sell certain human tissues such as corneas.[65] America's public–private partnership for organ procurement is between the Health Resources and Services Administration, a part of the U.S. Department of Health and Human Services, and the United Network for Organ Sharing (UNOS), which facilitates organ transplantation and procurement in the United States.[66]

States also supplement these federal laws by prohibiting the sale of organs.[67] Surgical techniques, as part of the state-regulated practice of medicine, are not subject to approval by the FDA and receive little oversight at the state level.[68] For example, in the context of organ transplantation, surgeons developed the organ transplantation techniques, and the FDA only became involved through the use of anti-rejection drugs.[69] Thus, organ transplantation procedures developed in an unregulated manner, and federal involvement stemmed from the use of a drug to strengthen outcomes, addition of the technique to the Medicare list of covered procedures, and decades later, the operation of a "quasi-public" system that surrounds procuring and allocating organs.[70] Further, as a general matter within medical practice, there is significant space for decision-making within the doctor–patient relationship.[71]

---

65. Julia D. Mahoney, *The Market for Human Tissue*, 86 VA. L. REV. 163, 183–86 (2000) (explaining how tissue banks can sell certain human tissues in spite of the National Organ Transplant Act); Michele Goodwin, *Formalism and the Legal Status of Body Parts*, 2006 U. CHI. LEGAL F. 317, 330–32 (2006) (discussing the tissue banking industry).

66. *About the OPTN*, ORGAN PROCUREMENT & TRANSPLANTATION NETWORK, https://optn.transplant.hrsa.gov/governance/about-the-optn [https://perma.cc/43Z9-7KEM]; *About UNOS*, UNITED NETWORK FOR ORGAN SHARING, https://unos.org/about [https://perma.cc/BLF7-T2NS].

67. Robertson, *supra* note 64, at 223, 250; Robert Steinbuch, *Kidneys, Cash, and Kashrut: A Legal, Economic, and Religious Analysis of Selling Kidneys*, 45 HOUS. L. REV. 1529, 1552–53 (2009). Similar to federal law, state statutes generally prohibit giving, receiving, or facilitating the transfer of organs in exchange for "valuable consideration." *See, e.g.*, CAL. PENAL CODE § 367f (West 2011); FLA. STAT. § 873.01 (1999); LA. STAT. ANN. § 14:101.1 (1986); N.Y. PUB. HEALTH LAW § 4307 (McKinney 2019); TEX. PENAL CODE ANN. § 48.02 (West 2017); WIS. STAT. § 146.345 (2001).

68. *See infra* Section IV.B (discussing how innovation unfolds in surgery through reduced oversight); Lars Noah, *Assisted Reproductive Technologies and the Pitfalls of Unregulated Biomedical Innovation*, 55 FLA. L. REV. 603, 617–18 (2003) (discussing the lack of governmental oversight of "new medical procedures").

69. STARZL, *supra* note 25, at 211, 240, 295; Lawrence K. Altman, *Government Approves New Drug to Assist in Liver Transplants*, N.Y. TIMES (Apr. 13, 1994), https://www.nytimes.com/1994/04/13/us/government-approves-new-drug-to-assist-in-liver-transplants.html [https://perma.cc/FQ45-F6EC].

70. STARZL, *supra* note 25, at 211, 240, 295 (describing the role of the FDA in anti-rejection drug trials); Altman, *supra* note 69; Garrison, *supra* note 43, at 1648–49 (2008).

71. Garrison, *supra* note 43, at 1633–36 ("In keeping with the principle of patient autonomy, most medical decisions—in gastroenterology, gynecology, ART, and across the full spectrum of medical practice—are not subject to any governmental regulation whatsoever.").

B. Reproductive Genetic Innovation

This Article will focus nearly exclusively on medical techniques involving genetic innovation before a child is born, as these techniques tend to elicit controversy and overregulation.[72] As noted in Part I, this Article classifies three specific reproductive techniques involving genetic alterations as reproductive genetic innovation: cytoplasmic transfer, mitochondrial transfer, and germline genome editing, using techniques such as CRISPR-Cas9.[73]

There is another type of genetic modification commonly referred to as "gene therapy."[74] CRISPR-Cas9 "genetic scissors" can also be used in gene therapy, which does not elicit the same controversy as heritable gene editing because "gene therapy" typically refers to somatic or non-reproductive gene therapy that does not result in heritable genetic changes.[75] While many of the risks of non-heritable gene editing have been accepted by society in a way that does not hinder the legality of the techniques, thus leading to the FDA's approval of assorted gene therapies, the same has not occurred for germline gene editing.[76] Germline or heritable genetic modification, a focus of this Article, affects "germ" or reproductive cells, leading to assorted objections related to heritability that do not accompany somatic cell genetic modification (gene therapy).[77]

---

72. For more on the ethical controversy that accompanies germline gene editing, see Lewis, *Germline Gene Editing*, *supra* note 35, at 763–94.

73. *See, e.g.*, John M. Conley, *A Lawyer's Guide to CRISPR*, 97 N.C. L. Rev. 1041, 1042–47 (2019) (providing a scientific overview of CRISPR technology); Motoko Araki & Tetsuya Ishii, *Providing Appropriate Risk Information on Genome Editing for Patients*, 34 Trends Biotech. 86, 86 (2016) (noting that CRISPR-Cas9 can be used for somatic and germline genetic modification).

74. For more on the scientific and regulatory differences between somatic (non-reproductive) and non-somatic (reproductive) gene therapy, see Nat'l Acad. of Scis., Eng'g & Med., Human Genome Editing: Science, Ethics, and Governance 5 (2017); Gail H. Javitt & Kathy Hudson, *Regulating (for the Benefit of) Future Persons: A Different Perspective on the FDA's Jurisdiction to Regulate Human Reproductive Cloning*, 2003 Utah L. Rev. 1201, 1213–14.

75. Javitt & Hudson, *supra* note 74, at 1213–15. While an early gene therapy trial was controversial, its controversy stemmed largely from medical risk and not moral controversy. *See, e.g.*, Sheryl Gay Stolberg, *F.D.A. Officials Fault Penn Team in Gene Therapy Death*, N.Y. Times (Dec. 9, 1999), https://archive.nytimes.com/www.nytimes.com/library/national/science/health/120999hth-gene-therapy.html [https://perma.cc/55K3-9ERZ]; Rick Weiss & Deborah Nelson, *Teen Dies Undergoing Experimental Gene Therapy*, Wash. Post (Sept. 29, 1999), https://www.washingtonpost.com/wp-srv/WPcap/1999-09/29/060r-092999-idx.html [https://perma.cc/S9S9-45AV]. *But see What are the Ethical Concerns of Genome Editing?*, Nat'l Hum. Genome Rsch. Inst. (Aug. 3, 2017), https://www.genome.gov/about-genomics/policy-issues/Genome-Editing/ethical-concerns#6 [https://perma.cc/23R8-3WVD] ("Some researchers and bioethicists are concerned that any genome editing, even for therapeutic uses, will start us on a slippery slope toward using it for non-therapeutic and enhancement purposes, which many view as controversial.").

76. *See Approved Cellular and Gene Therapy Products*, U.S. Food & Drug Admin. (July 24, 2020), https://www.fda.gov/vaccines-blood-biologics/cellular-gene-therapy-products/approved-cellular-and-gene-therapy-products [https://perma.cc/KN2P-DGV4].

77. *See Germ Cell*, Nat'l Cancer Inst., https://www.cancer.gov/publications/dictionaries/cancer-terms/def/germ-cell [https://perma.cc/6XPZ-UNVR]; Javitt & Hudson, *supra* note 74, at 1214–15; Nancy M.P. King, *Human Gene-Editing Research: Is the Future Here*

In prior works, I have referred to cytoplasmic transfer and mitochondrial transfer collectively as "advanced assisted reproductive technologies" (AARTs).[78] AARTs are similar as they use a donor's non-nuclear genetic material to replace the intended parent's non-nuclear genetic material, which is not associated with physical traits like hair and eye color.[79] Whether AARTs constitute heritable genetic modification is the subject of significant debate in the United States and across the world.[80] In this Article, I refer to cytoplasmic and mitochondrial transfer techniques using the term "substitution" instead of modification because many scientists and observers view AARTs as akin to organ or tissue transplantation as opposed to modification, which will be explained further in both this Part and Part III. This Section will provide scientific background on AARTs and germline gene editing.

1. Scientific Background on Reproductive Genetic Innovation

Reproductive genetic innovation involves ART, namely IVF. In the United Kingdom in 1978, as a result of the research of Robert Edwards and Patrick Steptoe, Louise Brown became the first baby to be born through IVF.[81] In 2010, Robert Edwards was awarded the Nobel Prize in

---

Yet?, 97 N.C. L. REV. 1051, 1051 (2019) ("Genetic treatments for already-born persons are not controversial . . . ."); *see also* discussion *infra* Section III.B (regarding the dispute over whether mitochondrial transfer and cytoplasmic transfer constitute "germline" modification).

78. *See* Lewis, *Subterranean Regulation*, *supra* note 35, at 1239.

79. *See, e.g.*, Shoukhrat Mitalipov & Don P. Wolf, *Clinical and Ethical Implications of Mitochondrial Gene Transfer*, 25 TRENDS ENDOCRINOLOGY & METABOLISM 5, 7 (2014); Rob Stein, *Her Son Is One of the Few Children to Have 3 Parents' DNA*, NPR (June 6, 2018, 5:47 PM), https://www.npr.org/sections/healthshots/2018/06/06/616334508/her-son-is-one-of-the-few-children-to-have-3-parents [https://perma.cc/9M7W-MWZF].

80. This debate includes arguments that focus on the definition of the germline, the significance of mitochondrial DNA as compared to nuclear DNA, the extent of manipulation involved, and the meaning of genetic modification or alteration. *See, e.g.*, NAT'L ACAD. OF SCIS., ENG'G & MED., MITOCHONDRIAL REPLACEMENT TECHNIQUES: ETHICAL, SOCIAL, AND POLICY CONSIDERATIONS 88 (2016) ("This committee . . . views 'genetic modification' and 'germline modification' as two separate concepts, the first being 'changes to the genetic material within a cell' and the latter 'human inheritable genetic modification.'"); Lucía Gómez-Tatay, José M. Hernández-Andreu & Justo Aznar, *Mitochondrial Modification Techniques and Ethical Issues*, 6 J. CLIN. MED. 25, 31 (2017); Mitalipov & Wolf, *supra* note 79, at 1, 3 ("[T]he techniques . . . described herein induce permanent changes to [mitochondrial DNA] that would be transmitted through generations, thus qualifying as germline gene therapy."); Viswanathan, *supra* note 38; NUFFIELD COUNCIL ON BIOETHICS, *supra* note 14, at 57–58; Patrick Skerrett, *Experts Debate: Are We Playing with Fire when We Edit Human Genes?*, STAT NEWS (Nov. 17, 2015) (quoting Steven Pinker), https://www.statnews.com/2015/11/17/gene-editing-embryo-crispr [https://perma.cc/4GB9-9Q5L]; Ainsley J. Newson & Anthony Wrigley, *Is Mitochondrial Donation Germ-Line Gene Therapy? Classifications and Ethical Implications*, 31 BIOETHICS 55, 57–58 (2017); Rosamund Scott & Stephen Wilkinson, *Germline Genetic Modification and Identity: The Mitochondrial and Nuclear Genomes*, 37 OXFORD J. LEGAL STUD. 886, 903 (2017); *Cultivating the Best Science Is Our Best Hope*, UNITED MITOCHONDRIAL DISEASE FOUND., https://www.umdf.org/mitochondrial-replacement-therapy [https://perma.cc/7MRS-SXS8].

81. *World's First "Test Tube" Baby Born*, HISTORY (March 12, 2010), https://www.history.com/this-day-in-history/worlds-first-test-tube-baby-born [https://perma.cc/JG9A-9JTD].

Physiology or Medicine for his work on IVF.[82] In October 2020, Jennifer Doudna and Emanuelle Charpentier were awarded the Nobel Prize in Chemistry for the development of the CRISPR-Cas9 method of genome editing.[83] ART techniques that do not involve genetic modification enjoy a societal acceptance that reproductive genetic innovation does not.[84]

a. Cytoplasmic Transfer

In 1997, the first baby in the world was born as a result of cytoplasmic transfer.[85] Physicians at domestic and foreign fertility clinics used cytoplasmic transfer in the 1990s to improve fertility outcomes for women who faced difficulty in conceiving.[86] Cytoplasm envelopes the nucleus, which contains 99.9% of human DNA.[87] The cytoplasm of the cell also contains mitochondria, organelles that are the cell's source of energy.[88] Using IVF, cytoplasmic transfer involves removing the cytoplasm from a donor egg and adding it to the egg of an intended mother.[89] The transfer of cytoplasm from one egg cell to another also includes the transfer of mitochondria.[90] At least twenty-three children in the United States were born through the use of cytoplasmic transfer in the 1990s.[91] In 2016, a follow-up study of children conceived using cytoplasmic transfer in the 1990s was conducted at the St. Barnabas Medical Center in New Jersey.[92]

---

82. Martin H. Johnson, *Robert Edwards: The Path to IVF*, 23 REPROD. BIOMED. ONLINE 245, 245 (May 16, 2011) (citing Press Release, The Nobel Prize, The Nobel Prize in Physiology or Medicine 2010 (Oct. 4, 2010), https://www.nobelprize.org/prizes/medicine/2010/press-release [https://perma.cc/JD3K-EPNY]), https://www.rbmojournal.com/article/S1472-6483(11)00237-9/fulltext [https://perma.cc/Z58K-VKFG].

83. Press Release, The Nobel Prize, Press Release: The Nobel Prize in Chemistry 2020 (Oct. 7, 2020), https://www.nobelprize.org/prizes/chemistry/2020/press-release [https://perma.cc/7FD9-CA4G].

84. Leon R. Kass, *The Wisdom of Repugnance*, THE NEW REPUBLIC, June 2, 1997, at 17.

85. Steve Connor, *Three-Parent Babies: 'As Long as She's Healthy, I Don't Care', Says Mother of IVF Child*, INDEP. (Aug. 26, 2014, 11:34 PM), https://www.independent.co.uk/news/science/three-child-babies-the-mothers-view-as-long-as-she-s-healthy-i-don-t-care-9690059.html [https://perma.cc/VY9F-EAUB].

86. NUFFIELD COUNCIL ON BIOETHICS, *supra* note 14, at 36–37. For background on how the procedure developed, see generally Jason A. Barritt, Steen Willadsen, Carol Brenner & Jacques Cohen, *Epigenetic and Experimental Modifications in Early Mammalian Development: Part II Cytoplasmic Transfer in Assisted Reproduction*, 7 HUM. REPROD. UPDATE 428 (2001); Gómez-Tatay et al., *supra* note 80.

87. *See, e.g.*, NUFFIELD COUNCIL ON BIOETHICS, *supra* note 14, at 18.

88. *Id.*

89. *See, e.g.*, *id.* at 25, 36–38.

90. Barritt et al., *supra* note 86, at 428.

91. *See, e.g.*, Lewis, *Subterranean Regulation*, *supra* note 35, at 1250–51 (citing FOOD & DRUG ADMIN. CTR. FOR BIOLOGICS EVAL. & RSCH., BIOLOGICAL RESPONSE MODIFIERS ADVISORY COMMITTEE OPEN SESSION MEETING #32, 46 (2002) [hereinafter MEETING #32 TRANSCRIPT], https://www.fda.gov/OHRMS/DOCKETS/ac/02/transcripts/3855t1-01.pdf [https://perma.cc/89CC-PYUT]).

92. Serena H. Chen, Claudia Pascale, Maria Jackson, Mary Ann Szvetecz & Jacques Cohen, *A Limited Survey-Based Uncontrolled Follow-Up Study of Children Born After Ooplasmic Transplantation in a Single Centre*, 33 REPROD. BIOMEDICINE ONLINE 737, 737 (2016), https://www.sciencedirect.com/science/article/pii/S1472648316305569 [https://perma.cc/5YGR-Q7SG].

That follow-up study ultimately failed to find any negative effects of the technique on the health of the children conceived.[93]

b. Mitochondrial Transfer

Mitochondrial transfer is "related to" or similar to cytoplasmic transfer.[94] Mitochondria are organelles contained within the cytoplasm of the cell.[95] Mitochondria have their own DNA that is different from nuclear DNA.[96] Mitochondrial DNA is also maternally inherited, unlike nuclear DNA that is inherited from both the mother and the father.[97] Mitochondrial transfer uses the genetic material of a donor but otherwise keeps the DNA of the intended "genetic parents" who provide nuclear DNA.[98] Ultimately, mitochondrial transfer affects approximately 0.1% of DNA.[99]

Generally, mitochondrial DNA only comes from the intended mother.[100] Thus, using mitochondrial transfer to prevent the passage of defective mitochondria from mother to child is classified by some as "heritable," because the healthy mitochondrial DNA would be passed on to subsequent generations.[101] Reportedly, the first child in the world born as a result of mitochondrial transfer was born in 2016 in Mexico through the work of a U.S.-based physician, Dr. John Zhang.[102] Mutated mitochondria can lead to genetic diseases of various severity, and mitochondrial transfer can prevent the inheritance of those mutated mitochondria.[103] It is also possible that mitochondrial transfer, like cytoplasmic transfer, could improve fertility outcomes.[104] Because mitochondria are the source

93. *Id.* The study acknowledged that it suffered from low participation rates. *Id.* at 743.

94. *See* NUFFIELD COUNCIL ON BIOETHICS, *supra* note 14, at 25, 36–37.

95. NAT'L ACAD. OF SCIS., ENG'G & MED., *supra* note 80, at 18.

96. *Mitochondrial DNA*, NAT'L HUM. GENOME RSCH. INST., https://www.genome.gov/genetics-glossary/Mitochondrial-DNA [https://perma.cc/C94K-7J7E].

97. *Id. But see* Shiyu Luo, C. Alexander Valencia, Jinglan Zhang, Ni-Chung Lee, Jesse Slone, Baohend Gui, Xinjian Wang, Zhuo Li, Sarah Dell, Jenice Brown, Stella Maris Chen, Yin-Hsiu Chien, Wuh-Liang Hwu, Pi-Chuan Fan, Lee-Jun Wong, Paldeep S. Atwal & Taosheng Huang, *Biparental Inheritance of Mitochondrial DNA in Humans*, 115 PROC. NAT'L ACAD. SCIS. 13039, 13039 (2018) (noting "exceptional cases where paternal [mitochondrial DNA] could be passed to the offspring").

98. NUFFIELD COUNCIL ON BIOETHICS, *supra* note 14, at 32, 32 n.54, 34; Cohen, *supra* note 42, at 440–41. Additionally, while scientists may intend to alter less than 0.1% of the DNA of children conceived using AARTs, their efforts may result in different outcomes. *See, e.g.*, Sara Reardon, *Genetic Details of Controversial "Three-Parent Baby" Revealed*, NATURE (Apr. 3, 2017), https://www.nature.com/news/genetic-details-of-controversial-three-parent-babyrevealed-1.21761 [https://perma.cc/76U6-ST5T].

99. NUFFIELD COUNCIL ON BIOETHICS, *supra* note 14, at 18–19, 32, 34.

100. NAT'L ACAD. OF SCIS., ENG'G & MED., *supra* note 80, at 4 n.2, 5, 34. *But see* Luo et al., *supra* note 97, at 13039.

101. NAT'L ACAD. OF SCIS., ENG'G & MED., *supra* note 80, at 4–5, 119–20 (recommending only male embryos be selected if mitochondrial transfer is used in the United States due to the maternal transmission of mitochondrial DNA).

102. Michelle Roberts, *First 'Three Person Baby' Born Using New Method*, BBC NEWS (Sept. 27, 2016), https://www.bbc.com/news/health-37485263 [https://perma.cc/7URJ-AG2B].

103. NUFFIELD COUNCIL ON BIOETHICS, *supra* note 14, at 12, 84; *see, e.g.*, Reardon, *supra* note 98.

104. *See* NAT'L ACAD. OF SCIS., ENG'G & MED., *supra* note 80, at vii; Alice Park, *A Baby Was Born with DNA from 3 People. Here's How That's Possible*, TIME, (Apr. 11,

of the cell's energy, mitochondrial disease tends to affect organs that require significant amounts of energy, such as the brain, heart, and kidneys, and manifest in diseases such as Leigh syndrome.[105]

Because individuals can be carriers of defective mitochondria and have either no or limited symptoms, it is often difficult to identify those carriers and accurately calculate the prevalence of mitochondrial mutations.[106] For example, one source states that "[o]ne in 200 are born with the relevant mutation but roughly one in 5,000 are affected by mitochondrial disease."[107] One study found that "the average number of births per year among women at risk for transmitting [mitochondrial DNA] disease is 152 . . . in the United Kingdom and 778 . . . in the United States."[108]

Pre-implantation genetic diagnosis (PGD) is a technique that can be combined with IVF to select embryos with specific characteristics like sex or the improbability of certain genetic disorders.[109] The first birth of a child as a result of the combination of PGD and IVF occurred in 1990 in the United Kingdom.[110] While PGD can be combined with IVF to select embryos by sex or to prohibit certain genetic disorders, PGD is often unable to identify embryos with "normal" mitochondria due to the complexities of mitochondrial inheritance.[111]

c. Germline Gene Editing

Gene, or genome, editing is a promising technique that permits scientists to cut, add, or change specific DNA.[112] CRISPR-Cas9 is one method of gene editing that is often the subject of scientific and media coverage, with recent coverage focusing on Nobel Prize-winning scientists Jennifer Doudna and Emmanuelle Charpentier.[113] Genome editing has been char-

---

2019, 5:02 PM), https://time.com/5569057/three-parent-baby-dna [https://perma.cc/WQ5Z-RVFR]; Stein, *supra* note 15.

105. NUFFIELD COUNCIL ON BIOETHICS, *supra* note 14, at 21, 27; *see supra* Part I.

106. Patrick F. Chinnery, *Primary Mitochondrial Disorders Overview*, *in* GENE REVS. 1, 3, 5–6, 8 (2000) (ebook); *see, e.g.*, Robin Banerji, *The Woman Who Lost All Seven Children*, BBC NEWS (Sept. 20, 2012), https://www.bbc.com/news/magazine-19648992 [https://perma.cc/3JQE-3PFN].

107. Cohen, *supra* note 42, at 440.

108. Gráinne S. Gorman, John P. Grady & Doug M. Turnbull, *Mitochondrial Donation—How Many Women Could Benefit?*, 372 NEW ENG. J. MED. 885, 886 (2015).

109. Alan Handyside, *Celebrating 20 Years of Preimplantation Genetic Diagnosis*, BIONEWS (July 23, 2010), https://www.bionews.org.uk/page_92472 [https://perma.cc/2QH5-GXKS].

110. *Id.*

111. *See* NAT'L ACAD. OF SCIS., ENG'G & MED., *supra* note 80, at 44–46, 46 n.19.

112. *What Are Genome Editing and CRISPR-Cas9?*, MEDLINEPLUS (July 28, 2020), https://ghr.nlm.nih.gov/primer/genomicresearch/genomeediting [https://perma.cc/V2ZZ-J2CE]; *see also* Greely, *supra* note 42, at 115 ("I speak of 'genome' editing and not 'gene' editing because such modifications may often change more than one gene, or even change DNA that is not in what is usually considered a 'gene'.").

113. *See, e.g.*, Eric S. Lander, *Brave New Genome*, 373 NEW ENG. J. MED. 5, 5–6 (2015). For more on different forms of germline editing, see NAT'L ACAD. OF SCIS., ENG'G & MED., *supra* note 74, at 1–2; Heidi Ledford & Ewen Callaway, *Pioneers of Revolutionary CRISPR Gene Editing Win Chemistry Nobel*, NATURE (Oct. 7, 2020), https://www.nature.com/articles/d41586-020-02765-9 [https://perma.cc/52F5-RFHH].

acterized as, "depending upon one's perspective, promis[ing] both the salvation and destruction of humankind."[114] This Article will focus on germline gene editing, which results in heritable changes which are passed on to subsequent generations, as opposed to somatic cell genome editing, which does not.[115] Current expectations are that germline gene editing could not only result in the birth of children who do not have or carry the genetic mutations that their parents have, but also create future generations without harmful genetic traits.[116] PGD, which is often suggested as a substitute to reproductive genetic innovation, is not suitable for all ART patients because, even with ART, some individuals fail to produce embryos that are suitable for implantation (rendering the targeting of disease-causing traits premature).[117] Nevertheless, a recent study revealed that germline gene editing could be used to edit mitochondria and eventually cure mitochondrial disease, potentially rendering mitochondrial transfer obsolete.[118]

Germline genome editing, while currently not being used clinically in the United States, could eventually treat, reduce the incidence of, or at least increase our understanding of a number of diseases including "diabetes, heart disease, schizophrenia, and autism."[119] Beyond that, many expect that both somatic and germline genome editing could also treat (or prevent), "cystic fibrosis, hemophilia, . . . sickle cell disease . . . cancer, heart disease, mental illness, and human immunodeficiency virus (HIV) infection," and assorted clinical trials are underway to target diseases like these through somatic cell gene therapy.[120]

Germline gene editing is accompanied by a number of safety and efficacy concerns that are sometimes referred to as "research ethics concerns about . . . safety."[121] Safety concerns that accompany human germline gene editing include "incomplete editing, inaccurate editing, off-target mutations, on-target mutations with unintended consequences [like the damage of the genome,] and mosaicism."[122] Mosaicism, for example,

114. Sherkow & Scott, *supra* note 34, at 1498–99.

115. *See supra* notes 73–75 and accompanying text (discussing the differences in somatic cell and germline gene editing).

116. Christopher Gyngell, Thomas Douglas & Julian Savulescu, *The Ethics of Germline Gene Editing*, 34 J. APP. PHIL. 498, 499–501 (2017).

117. *Id.*; *see* George Q. Daley, Robin Lovell-Badge & Julie Steffann, *After the Storm—A Responsible Path for Genome Editing*, 380 NEW ENG. J. MED. 897, 898–99 (2019).

118. *See* Beverly Y. Mok, Marcos H. de Moraes, Jun Zeng, Dustin E. Bosch, Anna V. Kotrys, Aditya Raguram, FoSheng Hsu, Matthew C. Radey, S. Brook Peterson, Vamsi K. Mootha, Joseph D. Mougous & David R. Liu, *A Bacterial Cytidine Deaminase Toxin Enables CRISPR-Free Mitochondrial Base Editing*, 583 NATURE 631, 631 (2020).

119. Patrick D. Hsu, Eric S. Lander & Feng Zhang, *Development and Applications of CRISPR-Cas9 for Genome Engineering*, 157 CELL 1262, 1271 (2014); Julian Savulescu, Jonathan Pugh, Thomas Douglas & Christopher Gyngell, *The Moral Imperative to Continue Gene Editing Research on Human Embryos*, 6 PROTEIN & CELL 476, 476 (2015).

120. *What Are Genome Editing and CRISPR-Cas9?*, *supra* note 112.

121. Françoise Baylis, *Human Germline Genome Editing and Broad Societal Consensus*, 1 NATURE HUM. BEHAV., 1, 1 (May 8, 2017), https://www.nature.com/articles/s41562-017-0103 [https://perma.cc/E9VZ-MNTX].

122. *Id.*; *see also* Sherkow & Scott, *supra* note 34, at 1509; Michael Kosicki, Kärt Tomberg & Allan Bradley, *Repair of Double-Strand Breaks Induced by CRISPR-Cas9*

would result when the editing target contained both edited and unedited cells.[123] Off-target effects occur when the intentional targeting of a site leads to the unintended editing of another site in the genome.[124] To date, scientists have made significant strides in addressing these issues, and germline gene editing is expected to be "ready" for human clinical use in the next five to ten years.[125] Yet some physician–researchers, namely Dr. He Jiankui in China, moved ahead of this timeline and used germline gene editing in human embryos that led to the birth of several children and widespread condemnation.[126] Part of this condemnation stemmed from a number of safety concerns such as the mosaicism of one of the embryos and possible unintended (or disregarded) consequences.[127] Fur-

Leads to Large Deletions and Complex Rearrangements, 36 NAT. BIOTECH. 765, 765 (2018); Haoyi Wang & Hui Yang, *Gene Edited Babies: What Went Wrong and What Could Go Wrong*, 17 PLOS BIOL. 1, 3 (2019), https://journals.plos.org/plosbiology/article?id=10.1371/journal.pbio.3000224 [https://perma.cc/CZ5J-J32R]; Salima Hacein-Bey-Abina, Christof von Kalle, Manfred Schmidt & Françoise Le Deist, *A Serious Adverse Event After Successful Gene Therapy for X-Linked Severe Combined Immunodeficiency*, 348 NEW ENG. J. MED. 255, 255 (2003); Michael V. Zuccaro, Jia Xu, Carl Mitchell, Rogerio Lobo, Nathan Treff & Dieter Egli, *Allele-Specific Chromosome Removal after Cas9 Cleavage in Human Embryos*, 183 CELL 1650, 1650 (2020).

123. Sherkow & Scott, *supra* note 34, at 1509.

124. Dana Carroll, *Collateral Damage: Benchmarking Off-Target Effects in Genome Editing*, 20 GENOME BIO.: EDITORIAL 114, 114 (2019), https://genomebiology.biomedcentral.com/articles/10.1186/s13059-019-1725-0#citeas [https://perma.cc/28FG-EHAA]; Sherkow & Scott, *supra* note 34, at 1509; *id.* at 1517–19 (discussing assorted safety-based concerns for genome editing, including mosaicism, editing efficiency constraints, and the need for detecting off-target effects). *See generally* Andrew V. Anzalone, Luke W. Koblan & David R. Liu, *Genome Editing with CRISPR–Cas Nucleases, Base Editors, Transposases and Prime Editors*, 38 NATURE BIOTECH. 824, 826, 828–29, 831–38 (2020).

125. *We're on the Cusp of a Gene Editing Revolution, Are We Ready?*, NEW SCIENTIST (July 27, 2016), https://www.newscientist.com/article/mg23130842-900-were-on-the-cusp-of-a-gene-editing-revolution-are-we-ready [https://perma.cc/MWZ3-P8ML]; *see* NUFFIELD COUNCIL ON BIOETHICS, GENOME EDITING AND HUMAN REPRODUCTION: SOCIAL AND ETHICAL ISSUES 1, 44 (2018). *But see* Henry T. Greely, *Human Germline Genome Editing: An Assessment*, 2 CRISPR J. 253, 254 (2019) ("I do not think human [germline genome editing] alone has much new potential—for evil, for good, or in any other ways, in the next 30 years or so.").

126. For reactions to the announcement of Dr. He's work using CRISPR to edit human embryos that were implanted and resulted in the birth of gene-edited children, see Editorial Board, Opinion, *We Have the Technology to Customize Our Babies. It Needs Regulation*, WASH. POST (May 21, 2019), https://www.washingtonpost.com/opinions/global-opinions/we-have-the-technology-to-customize-our-babies-it-needs-regulation/2019/05/21/ce6c554c-50b0-11e9-88a1-ed346f0ec94f_story.html [https://perma.cc/U5AB-EZR4]; Francis S. Collins, *NIH Supports International Moratorium on Clinical Application of Germline Editing*, NAT'L INSTS. OF HEALTH (Mar. 13, 2019), https://www.nih.gov/about-nih/who-we-are/nih-director/statements/nih-supports-international-moratorium-clinical-application-germline-editing [https://perma.cc/7JE9-MN7U]; Sui-Lee Wee, *Chinese Scientist Who Genetically Edited Babies Gets 3 Years in Prison*, N.Y. TIMES (Dec. 30, 2019), https://www.nytimes.com/2019/12/30/business/china-scientist-genetic-baby-prison.html [https://perma.cc/UP5S-WC5M]; Gina Kolata, Sui-Lee Wee & Pam Belluck, *Chinese Scientist Claims to Use Crispr to Make First Genetically Edited Babies*, N.Y. TIMES (Nov. 26, 2018), https://www.nytimes.com/2018/11/26/health/gene-editing-babies-china.html [https://perma.cc/L8YL-VN53]; Baylis, *supra* note 121, at 1.

127. *See, e.g.*, Eric Lander, Françoise Baylis, Feng Zhang, Emmanuelle Charpentier & Paul Berg, Comment, *Adopt a Moratorium on Heritable Genome Editing*, 567 NATURE 165, 166 (2019) ("He attempted to inactivate the gene CCR5, which encodes a receptor

ther, as detailed in other sections, the fact that germline gene editing would lead to heritable genetic changes has engendered opposition to the technique, although this same possibility also exists with somatic cell gene therapy, a far less controversial technique used in FDA-approved products.[128]

2. Regulatory Reactions to Reproductive Genetic Innovation

The federal regulatory system has been especially hostile to reproductive genetic innovation. After reports of births resultant from cytoplasmic transfer, the technique (and its providers) were targeted by the FDA for atypical regulatory treatment as compared to traditional ARTs like IVF or insemination.[129] While the FDA does not regulate ART techniques like IVF or artificial insemination, the FDA sent letters to providers of cytoplasmic transfer stating that they would need to submit an investigational new drug (IND) application to the FDA to continue providing their techniques.[130] IND applications are submitted by companies in order to market pharmaceuticals in the United States.[131] After receiving these letters, physicians stopped providing these techniques to patients in the United States.[132] This regulatory treatment is peculiar in light of the usual practice–products divide in U.S. medical regulation. The practice–products distinction between the practice of medicine, which is regu-

---

that HIV uses to enter cells. However, this change is not benign: it has been reported to substantially increase the risk of complications, and death, from certain other viral infections, including West Nile virus and influenza.").

128. King et al., *supra* note 43, at 39; Oleg E. Tolmachov, *Split Vector Systems for Ultra-Targeted Gene Delivery: A Contrivance to Achieve Ethical Assurance of Somatic Gene Therapy* In Vivo, 83 MED. HYPOTHESES 211, 212 (2014). For more on the concern that somatic cell gene therapy could lead to unintended germline modification, see, for example, NAT'L ACAD. OF SCIS., ENG'G & MED., *supra* note 74, at 97–99, 105–06; King et al., *supra* note 43, at 38; Kevin R. Smith, *Gene Therapy: Theoretical and Bioethical Concepts*, 34 ARCHIVES MED. RES. 247, 256–57 (2003) (noting that the possibility of germline transmission with gene therapy is "very low").

129. Lewis, *Subterranean Regulation*, *supra* note 35, at 1243. For some, including the CDC, artificial insemination is not ART. *See What is Assisted Reproductive Technology?*, CTRS. DISEASES CONTROL & PREVENTION (Oct. 8, 2019), https://www.cdc.gov/art/whatis.html [https://perma.cc/4TFK-7F28].

130. Lewis, *Subterranean Regulation*, *supra* note 35, at 1241–43, 1259. There are federal regulations that apply to labs that perform ART. *See, e.g.*, 21 C.F.R. § 1271.3(b), (d) (2016); U.S. FOOD & DRUG ADMIN., ELIGIBILITY DETERMINATION FOR DONORS OF HUMAN CELLS, TISSUES, AND CELLULAR AND TISSUE-BASED PRODUCTS (2007); Eligibility Determination for Donors of Human Cells, Tissues, and Cellular and Tissue-Based Products, 69 Fed. Reg. 29,786, 29,787 (May 25, 2004) (to be codified at 21 C.F.R. pts. 210, 211, 820, 1271); Human Cells, Tissues, and Cellular and Tissue-Based Products; Establishment Registration and Listing, 66 Fed. Reg. 5447, 5447 (Jan. 19, 2001) (to be codified at 21 C.F.R. pts. 207, 807, 1271).

131. *See* Lewis, *Germline Gene Editing*, *supra* note 35, at 795–804 (discussing the parallels between the uncertainties associated with genetic modification and the adverse effects of approved biologics and drugs, including gene therapy products). For more on investigational new drug applications and their role in the pharmaceutical approval process, see *Investigational New Drug (IND) Application*, U.S. FOOD & DRUG ADMIN. (Feb. 24, 2021), https://www.fda.gov/drugs/types-applications/investigational-new-drug-ind-application [https://perma.cc/EBD9-5NEM].

132. Lewis, *Subterranean Regulation*, *supra* note 35, at 1244.

lated by states, and the products regulated by the federal government is a nuanced distinction that has been the subject of scholarly debate.[133] Admittedly, there are difficulties in defining the scope of the practice of medicine and in defining the federal products regulated by the FDA.[134] These difficulties will be further analyzed in Part IV, where the Article argues in favor of a resolution in favor of increased state regulation instead of federal regulation.[135]

While scientific advances in mitochondrial transfer have been made in the United States, these advances have been subjected to the same regulatory treatment as cytoplasmic transfer; thus, the technique is, as a practical matter, unavailable in the United States.[136] For example, the FDA sent an Untitled Letter to Ovascience, an American company providing a technique involving mitochondrial transfer, that noted that the company's techniques would require an IND and led to Ovascience stopping its mitochondrial transfer techniques in the United States.[137] The FDA has posted an advisory online listing all of the techniques classified as reproductive genetic innovation in this Article as requiring an (expensive) IND application even though these techniques involve the practice of medicine.[138]

This regulatory treatment has not prevented some U.S.-based physi-

133. *See* Patricia J. Zettler, *Toward Coherent Federal Oversight of Medicine*, 52 SAN DIEGO L. REV. 427, 434–54, 460–64 (2015) (discussing the practice-products divide); Patricia J. Zettler, *Pharmaceutical Federalism*, 92 IND. L.J. 845, 851–52, 892 (2017); Lars Noah, *Ambivalent Commitments to Federalism in Controlling the Practice of Medicine*, 53 U. KAN. L. REV. 149, 158–65, 172–74 (2004).

134. Noah, *supra* note 133, at 164 ("[C]ourts also have struggled with questions about how to characterize the practice of medicine.").

135. *See infra* Part IV.

136. *See FDA Regulation of Human Cells, Tissues, and Cellular and Tissue-Based Products (HCT/P's) Product List*, U.S. FOOD & DRUG ADMIN., (Feb. 1, 2018), https://www.fda.gov/vaccines-blood-biologics/tissue-tissue-products/fda-regulation-human-cells-tissues-and-cellular-and-tissue-based-products-hctps-product-list [https://perma.cc/B3HK-BBW3]; Brittany Shoot, *3-Parent IVF: Why Isn't It Available in the United States?*, THE GUARDIAN (Feb. 27, 2015, 8:22 PM), https://www.theguardian.com/sustainable-business/2015/feb/27/3-parent-ivf-us-mitochondria-dna-babies [https://perma.cc/H5U9-Y9PA]; *Ooplasmic/Cytoplasmic Transfer*, CTR. FOR GENETICS & SOC'Y, https://www.geneticsandsociety.org/internal-content/ooplasmiccytoplasmic-transfer [https://perma.cc/8MBH-9Y32].

137. *See* Lewis, *Subterranean Regulation*, *supra* note 35, at 1281–82. The company, Ovascience, no longer exists because of a merger with Millendo Therapeutics, Inc., a company that focuses on treating "orphan endocrine diseases." *See* Press Release, Millendo Therapeutics, Millendo Therapeutics Announces Successful Merger Completion (Dec. 7, 2018), https://investors.millendo.com/news-releases/news-release-details/millendo-therapeutics-announces-successful-merger-completion [https://perma.cc/Z24G-67KL]; Ovascience, Inc., Registration Statement (Form S-4) (Nov. 1, 2018), https://www.sec.gov/Archives/edgar/data/1544227/000104746918006980/a2236886zs-4a.htm [https://perma.cc/QKP3-P8EU].

138. *FDA Regulation of Human Cells, Tissues, and Cellular and Tissue-Based Products (HCT/P's) Product List*, *supra* note 136. For more on the costs of drug approval, see Jason Millman, *Does it Really Cost $2.6 Billion to Develop a New Drug?*, WASH. POST: ECON. POL'Y (Nov. 18, 2014), https://www.washingtonpost.com/news/wonk/wp/2014/11/18/does-it-really-cost-2-6-billion-to-develop-a-new-drug [https://perma.cc/Y9KY-DT2C]; Joseph A. DiMasi, Henry G. Grabowski & Ronald W. Hansen, *Innovation in the Pharmaceutical Industry: New Estimates of R&D Costs*, 47 J. HEALTH ECON. 20, 24–25 (2016).

cians from traveling abroad to provide the technique to patients.[139] For example, U.S.-based physician John Zhang traveled to Mexico to provide the technique to a couple who wanted to avoid transmitting Leigh syndrome, a mitochondrial disease that impacts the central nervous system, to their child.[140] Providing the technique in Mexico allowed them to avoid the limitations of the U.S. regulatory system.[141] While earlier legal scholarship has focused on the FDA and its interpretations and applications of the Federal Food Drug & Cosmetic Act and the Public Health Service Act, Congress recently added another obstacle to the use of reproductive genetic innovation in the United States: a budget rider that has been renewed each year since 2015.[142] Thus, when Dr. John Zhang requested a pre-IND meeting with the FDA regarding mitochondrial transfer techniques, that request was denied in a letter noting that the budget rider prevented the FDA from even considering the application.[143]

C. Foundation for Commonalities Comparison: Grouping Reproductive Genetic Innovation

The ART techniques involving genetic modification studied in this Article include techniques that are heritable, like germline gene editing, and (arguably) non-heritable, like cytoplasmic and mitochondrial transfer.[144]

---

139. *See, e.g.*, Roberts, *supra* note 102; Emily Mullin, *Pregnancy Reported in the First Known Trial of "Three-Person IVF" for Infertility*, STAT News (Jan. 24, 2019), https://www.statnews.com/2019/01/24/first-trial-of-three-person-ivf-for-infertility [https://perma.cc/BM8A-HH9T].]

140. *See, e.g.*, Ariana Eunjung Cha, *This Fertility Doctor Is Pushing the Boundaries of Human Reproduction, with Little Regulation*, Wash. Post: Health & Sci. (May 11, 2018), https://www.washingtonpost.com/national/health-science/this-fertility-doctor-is-pushing-the-boundaries-of-human-reproduction-with-little-regulation/2018/05/11/ea9105dc-1831-11e8-8b08-027a6ccb38eb_story.html [https://perma.cc/LA2X-VUYM]; Jill Neimark, *A Baby with 3 Genetic Parents Seems Healthy, but Questions Remain*, NPR (Apr. 8, 2017, 5:00 AM), https://www.npr.org/sections/health-shots/2017/04/08/523020895/a-baby-with-3-genetic-parents-seems-healthy-but-questions-remain [https://perma.cc/8DNX-HW8A]; Roberts, *supra* note 102; *Leigh syndrome*, Nat'l Ctr. for Advancing Translational Sci., https://rarediseases.info.nih.gov/diseases/6877/leigh-syndrome [https://perma.cc/9P6B-CZ3G].

141. *See, e.g.*, Neimark, *supra* note 140; John Zhang, Hui Liu, Shiyu Luo, Zhuo Lu, Alejandro Chávez-Badiola, Zitao Liu, Mingxue Yang, Zaher Merhi, Sherman J. Silber, Santiago Munné, Michalis Konstantinidis, Dagan Wells, Jian J. Tang & Taosheng Huang, *Live Birth Derived from Oocyte Spindle Transfer to Prevent Mitochondrial Disease*, 34 Reproductive Biomed. Online 361, 363–64 (2017).

142. Russell A. Spivak, I. Glenn Cohen & Eli Y. Adashi, *Germ-line Gene Editing and Congressional Reaction in Context: Learning from Almost 50 Years of Congressional Reactions to Biomedical Breakthroughs*, 30 J.L. & Health 20, 21–22 (2017); Consolidated Appropriations Act of 2016, Pub. L. No. 114-113, § 749, 129 Stat. 2283, 2283 (2015) (prohibiting the FDA from consider applications involving heritable genetic modification).

143. *See* Letter from Mary A. Malarkey, Dir., Off. of Compliance & Biologics Quality, Trustee for Biologics Evaluation & Rsch., to John Zhang, Chief Exec. Officer, Darwin Life, Inc. & New Hope Fertility Ctr. (Aug. 4, 2017) [hereinafter Letter from Mar A. Malarkey], https://www.fda.gov/media/106739/download [https://perma.cc/5PEC-8RZP]; Spivak et al., *supra* note 142, at 21–22.

144. *See supra* note 80 (discussing the debate over the meaning of "germline," "heritability," and "alteration").

Although some would not include germline gene editing in a comparison with cytoplasmic and mitochondrial transfer, there are at least five reasons for collectively comparing classifying techniques involving genetic modifications or substitutions (cytoplasmic transfer, mitochondrial transfer, and germline gene editing) to organ transplantation. First, while mitochondrial transfer targets less genetic material than cytoplasmic transfer, mitochondrial transfer and cytoplasmic transfer are "related," because cytoplasmic transfer also involves the transfer of mitochondria that are located in the cytoplasm.[145] Second, all three of the techniques encompassed within reproductive genetic innovation share common ethical objections that increase as the amount of genetic modification increases.[146] Third, while cytoplasmic transfer is an older technique than mitochondrial transfer and germline gene editing, its regulatory treatment through Untitled Letters informs how the FDA has treated subsequent technologies involving genetic modification of embryos.[147] Thus, the regulatory treatment of cytoplasmic transfer is a useful historic tool. Fourth, AART techniques and heritable genome editing have been added to the same FDA-provided list of techniques requiring an IND application in the United States.[148]

Not only are AART techniques and heritable genome editing subject to the FDA's restrictions requiring the submission of an IND application, but they are also subject to a federal budget rider preventing the consideration of techniques involving inheritable genetic modification.[149] As a result, if scientists want to pursue the significant research trials that are generally required for pharmaceuticals in the United States, they would

145. *See* Adashi & Cohen, *supra* note 38, at 833. For technical background on the techniques used in mitochondrial and cytoplasmic transfer, see NUFFIELD COUNCIL ON BIOETHICS, *supra* note 14, at 32–39; Henry E. Malter & Jacques Cohen, *Ooplasmic Transfer: Animal Models Assist Human Studies*, 5 REPROD. BIOMED. ONLINE 26, 28 (2002), https://www.rbmojournal.com/article/S1472-6483(10)61593-3/pdf [https://perma.cc/R8UH-MH7Y].

146. *See supra* Section II.B.

147. For a comprehensive accounting of the FDA's targeting of cytoplasmic transfer and similar forms of assisted reproductive technology involving genetic modification, see Lewis, *Subterranean Regulation*, *supra* note 35, at 1241–47, 1251–62. For the FDA's perspective on the distinctions between Untitled and Warning Letters, see U.S. FOOD & DRUG ADMIN., REGULATORY PROCEDURES MANUAL, CHAPTER 4: ADVISORY ACTIONS 3–8, 62, https://www.fda.gov/media/71878/download [https://perma.cc/5QLT-2AKR].

148. *See FDA Regulation of Human Cells, Tissues, and Cellular and Tissue-Based Products (HCT/P's) Product List*, *supra* note 136.

149. *See* Consolidated Appropriations Act of 2016, Pub. L. No. 114-113, § 749, 129 Stat. 2283, 2283 (2015). The budget rider has been added to the FDA's appropriations each year since 2016. *See, e.g.*, Spivak et al., *supra* note 142, at 21–22; *see also* PETER MARKS, U.S. FOOD & DRUG ADMIN., UPDATE FROM THE CENTER FOR BIOLOGICS EVALUATION AND RESEARCH (CBER): PROGRESS ADVANCING THE DEVELOPMENT OF COMPLEX BIOLOGIC PRODUCTS 18 (2018) ("Somatic cell versus germline editing relevant. By law FDA cannot currently accept an investigational or marketing application for a product that involves heritable genetic modification."), https://www.fdli.org/wp-content/uploads/2018/05/Center-for-Biologics-Evaluation-and-Research.pdf [https://perma.cc/Y86N-GQZD]; JAMES KOZUBEK, MODERN PROMETHEUS: EDITING THE HUMAN GENOME WITH CRISPR-CAS9 349 (2016); *FDA Regulation of Human Cells, Tissues, and Cellular and Tissue-Based Products (HCT/P's) Product List*, *supra* note 136.

face regulatory hurdles as evidenced by the FDA's response to Dr. John Zhang.[150] Fifth, heritable genome editing is often the subject of commentary by federal government officials and federal legislators, unlike other federally regulated products.[151]

Ultimately, germline gene editing is accompanied by the same ethical controversy surrounding cytoplasmic and mitochondrial transfer as well as intensified versions of related controversy focusing on issues of identity, hubris, embryo destruction, and consent for future generations.[152] Thus, germline genome editing's controversy is a magnified version of the controversy accompanying various AARTs. Not only does germline genome editing face regulatory hurdles, but at this time, many scientists, including pioneers of the technique, are opposed to using it in embryos for various reasons—including the aforementioned safety and efficacy concerns and ethical motivations—and many are calling for more public discourse and a global regulatory regime.[153]

---

150. *See* Rebecca S. Eisenberg, *The Role of the FDA in Innovation Policy*, 13 MICH. TELECOMM. & TECH. L. REV. 345, 370–71 (2007) (discussing the role of clinical trials in the FDA's approval process). *But see* Greely, *supra* note 42, at 128 ("There is no reason to think that FDA, based on the current (grossly lacking) information on safety and efficacy of CRISPR in human embryos, would allow an IND to go into effect, let alone approve an NDA or BLA. This is true on strict scientific grounds, as a gateway matter, without even considering the possible influence of political opposition to such efforts, opposition that could affect decisions by FDA or by the Secretary of Health and Human Services, to which FDA reports.").

151. *See infra* note 309 (providing the statements of Peter Marks, the director of the Center for Biologics Evaluation and Research (CBER) at the Food and Drug Administration); *see also infra* note 220 (providing the commentary of various Congressional members on the subjects of somatic and germline gene editing); Carrie D. Wolinetz & Francis S. Collins, Nat'l Insts. Health, Correspondence, *NIH Supports Call for Moratorium on Clinical Uses of Germline Gene Editing*, 567 NATURE 175, 175 (2019), https://www.nature.com/articles/d41586-019-00814-6 [https://perma.cc/JY4E-2PNX]. While there is commentary related to the pricing of pharmaceuticals, the commentary often does not focus on the actual target of the products, unlike the products involve issues related to reproduction.

152. *See infra* Part III. For more on the scholarly debate related to traditional assisted reproductive technology and its impact on identity, see, for example, DEREK PARFIT, REASONS AND PERSONS 351–79 (1986); I. Glenn Cohen, *Intentional Diminishment, the Non-Identity Problem, and Legal Liability*, 60 HASTINGS L.J. 347, 352–59 (2008); I. Glenn Cohen, *Of Modest Proposals and Non-Identity: A Comment on the Right to Know Your Genetic Parents*, 13 AM. J. BIOETHICS 45, 46–47 (2013); I. Glenn Cohen, *Regulating Reproduction: The Problem with Best Interests*, 96 MINN. L. REV. 423, 437 n.32 (2011).

153. *See, e.g.*, *ARM Gene Editing Task Force Therapeutic Developers' Statement of Principles*, ALL. REGENERATIVE MED. (Aug. 27, 2019) (disavowing germline gene editing through a statement of principles "signed by 15 of the preeminent companies active in developing therapeutic human genome editing technologies . . . intended to set forth a bioethical framework for the use of these technologies."), https://alliancerm.org/statement-of-principles [https://perma.cc/39MM-R9C5]; *UNESCO Panel of Experts Calls for Ban on "Editing" of Human DNA to Avoid Unethical Tampering with Hereditary Traits*, UNESCO (citing U.N. Educ., Sci. and Cultural Org.: Int'l Bioethics Comm., Report of the IBC on Updating Its Reflection on the Human Genome and Human Rights, ¶ 118, U.N. Doc. SHS/YES/IBC-22/15/2/ REV.2 (2015), https://unesdoc.unesco.org/ark:/48223/pf0000233258 [https://perma.cc/FT5B-7636]), https://en.unesco.org/news/unesco-panel-experts-calls-ban-editing-human-dna-avoid-unethical-tampering-hereditary-traits [https://perma.cc/JU2Y-Y9H2]. *But see* Lander et al., *supra* note 127, at 165 ("By 'global moratorium,' we do not mean a permanent ban. Rather, we call for the establishment of an international framework in which nations, while retaining the right to make their own decisions, voluntarily

III. COMMONALITIES BETWEEN ORGAN TRANSPLANTATION AND REPRODUCTIVE GENETIC INNOVATION

This Part is both descriptive and normative. This Part revisits the forgotten history and controversy of organ transplantation and compares that controversy (and early lack of success) to the controversy and current state of innovation accompanying heritable genetic modification. Applying the organ transplantation lens to reproductive genetic innovation is underexplored in the legal literature.[154] There is, of course, literature that discusses issues such as how to best facilitate organ donation, questions as to whether individuals should be compensated for organ donation, and concerns about disparities in the allocation of organs; yet the atomization and granularity of both the ART and organ transplant literature largely neglects parallels between reproductive genetic innovation and organ transplant.[155]

This Part identifies four important commonalities between organ transplantation and reproductive genetic innovation that favor shifting the lens applied to those techniques from one of sensationalism or social opposition to one that focuses on the practice of medicine. Those four commonalities between organ transplantation and reproductive genetic innovation that are underexplored in the literature and media accounts are: (1) the use of foreign biological material, (2) genetic transfer, (3) concerns about allocation, and (4) controversy at its inception. In this Part, the Article will address each of these commonalities in turn before discussing the dissimilarities between techniques involving organ transplantation and reproductive genetic innovation. Ultimately, both drawing on the history of organ transplantation and recognizing the similarities between techniques involving reproductive genetic innovation and organ

---

commit to not approve any use of clinical germline editing unless certain conditions are met."). *See generally* Lander et al., *supra* note 127.

154. For a comparison between organ transplantation and mitochondrial transfer, see Kenan Malik, *The Three-Parent Baby's First Step*, N.Y. TIMES (Feb. 22, 2015), https://www.nytimes.com/2015/02/23/opinion/the-three-parent-babys-first-step.html [https://perma.cc/KFF9-2CEJ]; Julian Savulescu, *Mitochondrial Disease Kills 150 Children a Year. A Micro-Transplant Can Cure It*, THE GUARDIAN (Feb. 2, 2015, 6:49 AM), https://www.theguardian.com/science/2015/feb/02/mitochondrial-transfer-micro-transplant-parliamentary-debate [https://perma.cc/CLT3-UNWF]; Garrison, *supra* note 43, at 1648–53 (arguing that "[a] quasi-public entity like UNOS" could be created to regulate ART).

155. For more on traditional issues covered in the literature related to organ transplantation, see *supra* note 42. For more on traditional issues covered in the literature related to ART, which crosses constitutional law, family law, health law, and reproductive rights, see, for example, Carbone & Medeira, *supra* note 42, at 72–73; June Carbone, *Who Decides What Number of Children Is 'Right'?*, 104 NW. U. L. REV. COLLOQUY 109, 114–15 (2009) (citing Jaime King, *Predicting Probability: Regulating the Future of Preimplantation Genetic Screening*, 8 YALE J. HEALTH POL'Y & ETHICS 283, 322 (2008)); June Carbone & Paige Gottheim, *Markets, Subsidies, Regulation, and Trust: Building Ethical Understandings into the Market for Fertility Services*, 9 J. RACE, GENDER & JUST. 510, 511–13 (2006); Andreas S. Voss, *The Right to Privacy & Assisted Reproductive Technologies: A Comparative Study of the Law of Germany and the U.S.*, 21 N.Y. L. SCH. J. INT'L & COMP. L. 229, 230–32 (2002); Lewis, *Subterranean Regulation*, *supra* note 35, at 1241 n.1.

transplantation should foster the viewing of techniques involving reproductive genetic innovation through a less sensational lens.

A. The Use of Foreign Biological Material

Both organ transplantation and reproductive genetic innovation require the use of external material—whether that is the use of donor DNA, organs or tissues, or vectors to deliver gene-changing material (and in some cases, genetic material to be inserted, as well).[156] While there are currently efforts underway to create or "grow" organs in laboratories, animals, or in space, organ transplantation today focuses on the use of donor material.[157] Organ transplantation and reproductive genetic innovation share several similarities. First, both reproductive genetic innovation and organ transplantation involve substitutions or corrections.[158] Organ transplantation involves replacing defective organs with healthy ones.[159] Similarly, cytoplasmic and mitochondrial transfer replace defective cell parts with the cell parts of healthy donors.[160] Germline gene editing, while requiring more change than cytoplasmic and mitochondrial transfer, also involves the removal, addition, or replacement of defective genes and the use of a vector-based delivery system.[161]

Organ transplantation, as supported by extensive donor registries and family donors, requires the tissue or organs of other humans.[162] Techniques involving reproductive genetic innovation involve permanently replacing defective cell or tissue parts, whereas organ or bone marrow transplantation involves replacing defective organs or tissues.[163]

B. Genetic Transfer

As noted in the Article's introductory vignettes, many commonly ac-

156. *See, e.g.*, Anna Nowogrodzki, *The Challenge of Using CRISPR to Knock in Genes*, The Scientist (Mar. 1, 2019), https://www.the-scientist.com/lab-tools/jacking-up-gene-knock-ins-65504 [https://perma.cc/EB59-EKE8]; Inder M. Verma & Nikunj Somia, *Gene Therapy–Promises, Problems and Prospects*, 389 Nature 239, 239 (1997).

157. *See* Hiroshi Nagashima & Hitomi Matsunari, *Growing Human Organs in Pigs–A Dream or Reality?*, 86 Theriogenology 422, 422, 426 (2016); Sheyna Gifford & Joao Paulo Zambon, *Recycling Organs–Growing Tailor-Made Replacement Kidneys*, 10 Regen. Med. 913, 913–14 (2015); Emma Woollacott, *Why Your New Heart Could Be Made in Space One Day*, BBC News (Jan. 22, 2019), https://www.bbc.com/news/business-46944972 [https://perma.cc/5YFG-W4TG].

158. Nat'l Acad. of Scis., Eng'g & Med., *supra* note 74, at 147 ("Before the modern tools needed to modify DNA were developed, government-supported research was focused on developing solid-organ transplantation to replace damaged or diseased organs and on bone marrow transplantation and reconstitution to cure leukemia and other life-threatening disorders, even though these treatments required substituting donor DNA for the patient's DNA in the solid-organ or blood-forming cells. Those cases fell clearly under what is typically considered medical care.").

159. *The Organ Transplant Process*, Health Res. & Servs. Admin., https://www.organdonor.gov/about/process/transplant-process.html [https://perma.cc/E7SC-694Y].

160. *See supra* Sections II.B.1.a–b.

161. *See supra* Section II.B.1.c.

162. *See supra* Section II.A.

163. *See supra* Section II.C.

cepted medical techniques involve DNA transfer.[164] DNA transfer from donor to recipient, of varying time lengths, accompanies organ transplantation.[165] Using the donor's tissue or organs also results in the transferring of the donor's DNA.[166] In certain forms of organ or tissue transplant, such as organ transplantation, blood transfusion, or tissue donation techniques, DNA transfer is temporary, but in others, such as bone marrow transplantation, it can be permanent.[167]

DNA transfer also accompanies cytoplasmic and mitochondrial transfer as donor cytoplasm and donor mitochondria replace the intended parents' non-nuclear DNA in amounts that vary based on the procedure.[168] Professor Alison Murdoch, a fertility specialist in the United Kingdom, has compared a child who has received a bone marrow transplant to a child who would be conceived using mitochondrial transfer on the basis that they would both contain DNA from three people.[169] Thus, just as children naturally contain the DNA of their parents, children who receive a bone marrow transplant or are conceived using mitochondrial transfer would have a third person's DNA, although not in large amounts.[170] Professor Murdoch notes that "[t]his may be argued to be an issue of scale, not one of fundamental moral concern."[171] Similarly, organ transplantation is generally not seen as an issue of fundamental moral or religious concern, even though it involves removing part of a person's body and replacing it with another person's body part.[172] Germline gene editing, depending on its target and the type of vector used, also tends to involve the transfer of genetic material (sometimes permanently).[173] As will be emphasized in Part IV, the genetic changes and transfers of organ transplantation have not affected its societal acceptance and also should not

164. *See supra* Part I.

165. *See supra* Section II.A.1.

166. *See supra* Section II.A.1.

167. *See* Zimmer, *supra* note 18; *see also supra* Section II.A (discussing the permanent DNA changes resultant from being a bone marrow transplant recipient).

168. *See supra* Section II.B; NAT'L ACAD. OF SCIS., ENG'G & MED., *supra* note 80, at 45, 101.

169. *See* Alison Murdoch, *IVF and The Prevention of Mitochondrial DNA Disease: The Moral Issues*, BIONEWS (May 3, 2011), https://www.bionews.org.uk/page_92949 [https://perma.cc/4EGA-EFBL].

170. *See id*.

171. *Id.*

172. *See, e.g.*, *Religion & Organ Donation*, JACKSONVILLE TRANSPLANT ALL. ("The gift of organ donation enjoys broad support among many religions in the U.S., although there may be differences of opinion even within a particular religious group."), https://jaxtransplant.org/religion-and-donation [https://perma.cc/U8H7-EB84]; *Theological Perspectives on Organ and Tissue Donation*, UNITED NETWORK FOR ORGAN SHARING (separating views on organ donation by theological group/denomination), https://unos.org/transplant/facts/theological-perspective-on-organ-and-tissue-donation [https://perma.cc/6ATK-GWZU]. *But see* Healey, *supra* note 25, at 317–18.

173. *See, e.g.*, Liz Ahlberg Touchstone, *For CRISPR, Tweaking DNA Fragments Before Inserting Yields Highest Efficiency Rates Yet*, UNIV. ILL.: NEWS BUREAU (Dec 23, 2019, 10:00 AM), https://news.illinois.edu/view/6367/805239 [https://perma.cc/7SFN-UP66]; NAT'L ACAD. OF SCIS., ENG'G & MED, *supra* note 80, at 6–7.

impact the societal (and regulatory acceptance) of germline genetic modification.

C. Concerns About Allocation and Accessibility

Issues of equality and access accompany both organ transplantation and reproductive genetic innovation.[174] In the context of organ transplantation, controversy related to resource allocation tends to focus on disparities in organ allocation and, to a less controversial extent, solutions for incentivizing organ donation to fill the gap between supply and demand, as many people die on the UNOS transplant list while waiting for organs.[175] Some controversy has been resolved by legal mechanisms such as the Uniform Anatomical Gift Act, which facilitated the use of organ "donor cards" and the process of ascertaining whether a deceased donor would have wanted to donate their organs and tissues upon death.[176] Nevertheless, even though organ transplantation enjoys significant societal acceptance in the United States, concerns related to fairness and access to organs, a scarce resource, remain.[177] Scandals have accompanied organ transplantation including the harvesting of dead bodies for organs and the proposed but thwarted efforts by Dr. Barry Jacobs to sell organs from deceased Caribbean donors to Americans in need of organs, which eventually led to the passage of the National Organ Transplant Act.[178]

Similarly, reproductive genetic innovation, like ART, is accompanied by concerns such as access for people without financial means, which could further exacerbate economic and racial disparities.[179] Moreover, there is a concern among many scholars, patients, and patient advocates that these techniques at the very least raise eugenics concerns, namely, that the majority may allocate these techniques in a way to marginalize individuals with conditions that society deems disabilities.[180] This marginalization could take place through the creation of a society in

174. *See supra* notes 29 and accompanying text.

175. Fentiman, *supra* note 27, 1594–96; *Organ Donation Statistics*, Health Res. & Servs. Admin. (May 2021) (providing data on organ transplant, including shortages and the number of listed, and on prospective recipients who die while awaiting an organ), https://www.organdonor.gov/statistics-stories/statistics.html [https://perma.cc/ZT8P-JV8A]; *see also Facts About Organ Donation*, United Network for Organ Sharing (2020) ("The waitlist is better described as a giant pool of patients.", https://unos.org/transplant/facts [https://perma.cc/G7DG-YCGQ]).

176. Fentiman, *supra* note 27, at 1596. For more on the history of the Uniform Anatomical Gift Act (including its amendments), see Michele Goodwin, *The Body Market: Race Politics & Private Ordering*, 49 Ariz. L. Rev. 599, 617–25 (2007). For an analysis of the doctrine of presumed consent (and its controversial nature) in connection with the Uniform Anatomical Gift Act, see David Orentlicher, *Presumed Consent to Organ Donation: Its Rise and Fall in the United States*, 61 Rutgers L. Rev. 295, 300–08 (2009).

177. *See infra* Section III.C.

178. Michele Goodwin, *Empires of the Flesh: Tissue and Organ Taboos*, 60 Ala. L. Rev. 1219, 1220, 1247 (2009); Michele Goodwin, *The Veneer of Altruism*, 14 Am. Med. Ass'n J. Ethics 256, 256–57 (2012).

179. Kimberly M. Mutcherson, *Procreative Pluralism*, 30 Berkeley J. Gender L. & Just. 22, 41–43 (2015).

180. Mohapatra, *supra* note 42, at 69–70; Kass, *supra* note 84, at 24.

which parents feel obligated to use reproductive genetic innovation in a way that could eradicate certain traits.[181]

D. Controversy at Inception

Organ transplantation and reproductive genetic innovation have both been accompanied by controversy, albeit for different reasons. While organ transplantation is relatively commonplace today, as evidenced by its coverage by insurance and normalization, at its inception, organ transplantation faced controversy related to the appropriateness of such a technique, moral panic, and other concerns that accompany innovation and controversy related to organ procurement and allocation, as discussed in Section III.C above.[182] The controversy related to the appropriateness of organ transplantation focuses on a number of issues including the commodification and commercialization of organs that occur even in the context of organ donation being construed as the "gift of life."[183] Tissue transplantation has similarly been accompanied by commodification-related controversy surrounding commercial tissue banks, scandals related to the black market acquisition of tissue, and the impact of presumed consent statutes especially in the realm of cornea removal.[184]

Even dialysis treatment was viewed as "unnatural" early in its use.[185] Some surgeons were even targeted for possible criminal prosecution, and substantial efforts contributed to eventual insurance coverage of the tech-

181. Mohapatra, *supra* note 42, at 69–70; Eric Rakowski, *Who Should Pay for Bad Genes?*, 90 Calif. L. Rev. 1345, 1345, 1353, 1392, 1398 (2002).

182. *See, e.g.*, William Heisel, *UCI Settles Cadaver Program Lawsuit*, Orange Cnty. Reg. (Dec. 5, 2005, 3:00 AM), https://www.ocregister.com/2005/12/05/uci-settles-cadaver-program-lawsuit [https://perma.cc/9GZK-5RJF]; Ari Bloomekatz & Harold Lee, *Willed Body Program Faces Uncertain Future at UCLA*, Daily Bruin (Mar. 11, 2004, 9:00 PM), https://dailybruin.com/2004/03/11/willed-body-program-faces-unce [https://perma.cc/L7MR-6FVP]; Claudia Buck, *More Californians Are Becoming Body Donors for Medical Research*, Sacramento Bee (Nov. 16, 2016 5:12 PM), https://www.sacbee.com/news/local/health-and-medicine/article113820838.html [https://perma.cc/C8NW-LU6F]; Goodwin, *supra* note 65, at 340–41.

183. Goodwin, *supra* note 29, at 311, 317, 327 (citing Julia D. Mahoney, *The Market for Human Tissue*, 86 Va. L. Rev. 163, 165 (2000)); Margaret Jane Radin & Daniel I. Steinberg, *Contested Commodities: The Trouble with Trade in Children, Body Parts, and Other Things*, 6 B.U. Pub. Int. L.J. 821, 822 (1997); Margaret Jane Radin, *Market-Inalienability*, 100 Harv. L. Rev. 1849, 1854–55 (1987).

184. Goodwin, *supra* note 65, at 329–40, 352, 356. For more on commercial tissue banks, see *id.* at 364–65, 379–80. While outside of the scope of this Article, fetal tissue transfer has also been an area of controversy. *See, e.g.*, Shaakirrah R. Sanders, *The Corporate Privacy Proxy*, 105 Cornell L. Rev. 1171, 1181–82 (2020); I. Glenn Cohen, *Planned Parenthood and Fetal Tissue Sale: Manufactured Controversy and The Real Ethical Debate*, Health Affs. Blog (Mar. 9, 2016), https://www.healthaffairs.org/do/10.1377/hblog20160309.053793/full [https://perma.cc/XX3Y-2Y58]; Khiara M. Bridges, *On the Commodification of the Black Female Body: The Critical Implications of the Alienability of Fetal Tissue*, 102 Colum. L. Rev. 123, 138–66 (2002); Robertson, *supra* note 64, at 260 (discussing Levi Itzhak Rosenbaum, the first person to be criminally charged with a violation of the National Organ Transplant Act).

185. David Hamilton, A History of Organ Transplantation: Ancient Legends to Modern Practice 296 (2012).

nique.[186] Further, early human organ transplant recipients did not live for long.[187] Ultimately, pharmaceuticals, namely anti-rejection drugs, increased the success of organ transplantation.[188] Hematopoietic cell transplantation, including bone marrow donation, is still accompanied by controversy; however, that controversy tends to focus on matters related to the appropriateness of children donating bone marrow to their siblings, the storage of cord blood, and efficacy-related issues regarding the appropriateness of bone marrow transplantation for certain ailments and the complications associated with transplantation.[189] Similarly today, IVF, a component of all of the reproductive genetic innovations analyzed in this Article, is relatively commonplace; it is widely available but only covered by insurance in some states.[190]

Although the term experimental is often used in a pejorative way that corresponds with the dismissal of a technique or innovation, the term was accurate when describing early organ transplantation work.[191] The first chapter of *Thomas' Hematopoietic Cell Transplantation: Stem Cell Transplantation*, a textbook that was renamed to honor the physician who pioneered stem cell transplantation, provides a historical overview of progress in bone marrow and stem cell transplantation.[192] The text char-

186. *See supra* Part I (discussing prosecutorial investigations and wrongful death lawsuits involving surgeons).

187. *See* Clyde F. Barker & James F. Markmann, *Historical Overview of Transplantation*, 3 COLD SPRING HARBOR PERSPS. MED. 1, 3 (2013); Harry Schwartz, *Heart Transplants*, N.Y. TIMES (Aug. 26, 1973), https://www.nytimes.com/1973/08/26/archives/a-long-shot-and-still-running-heart-transplants.html?searchResultPosition=10 [https://perma.cc/V6UX-SHJR].

188. Thomas E. Starzl, *History of Clinical Transplantation*, 24 WORLD J. SURG. 759, 762–64 (2000); Gina Kolata, *Scientists Are Teaching the Body to Accept New Organs*, N.Y. TIMES (Jan. 22, 2019), https://www.nytimes.com/2019/01/22/health/organ-transplants-immune-system.html [https://perma.cc/MW2U-9DC2].

189. For an overview of controversy related to hematopoietic stem cell transplantation, see, for example, Görgün Akpek, *Current Controversies in Bone Marrow Transplantation*, 92 J. NAT'L CANCER INST. 1358, 1358–59 (2000). *See also* Katrina Ann Williamson & Christian J. Vercler, *Should Children Be Asked to Be Bone Marrow Donors for Siblings?*, 18 AM. MED. ASSOC. J. ETHICS 18, 18 (2016); Terri Coles, *Controversy Brews Over Storing of Cord Blood*, REUTERS (May 8, 2008), https://www.reuters.com/article/columns-columncoles-cordblood-dc/controversy-brews-over-storing-of-cord-blood-idUSTON90061520080509 [https://perma.cc/3KE2-HPPG].

190. *See* Kass, *supra* note 84, at 17 ("We have become accustomed to new practices in human reproduction: not just in vitro fertilization, but also embryo manipulation, embryo donation, and surrogate pregnancy."); NAT'L ACAD. OF SCIS., ENG'G & MED., *supra* note 74, at 107–09 (discussing the possibility of fetal genome editing, a topic that is outside of the scope of this Article); Benjamin J. Peipert, Shelun Tsai, Melissa N. Montoya, Ryan C. Ferrante & Tarun Jain, *Analysis of State Mandated Insurance Coverage for Infertility Treatment and Fertility Preservation in the United States*, 114 FERTILITY & STERILITY e4, e4–e5 (2020).

191. *See, e.g.*, Karp v. Cooley, 493 F.2d 408, 423 (1974) ("[There are] few reported cases where experimentation has been recognized as a separate basis of liability [in medical malpractice actions]"). In *Karp*, a widow sued her deceased husband's treating physician for wrongful death after her husband died after the first use of an artificial heart in a human. *Id.* at 411–15.

192. Karl G. Blume & E. Donnall Thomas, *A History of Allogeneic and Autologous Hematopoietic Cell Transplantation*, *in* THOMAS' HEMATOPOIETIC CELL TRANSPLANTATION: STEM CELL TRANSPLANTATION 1–5 (4th ed. 2004).

acterizes the 1950s and 1960s, the time period preceding success in clinical bone marrow transplantation, as marked by general pessimism about the field.[193] The remaining subsections explore both the underlying bases for the controversy, pessimism, and opposition that historically accompanied organ transplantation and the controversy and opposition that accompanies techniques involving genetic innovation in reproduction.

1. Uncertainty/Technical Limitations/Experimentation

Uncertainty accompanies innovation. For example, an attempt at a mother–daughter "living" lung transplant was characterized as experimental in 1990 due to the unknown effects on the donor (the child's mother) and the unknown expected success of the transplant, because the only previous transplants had used cadaver donors and "fewer than 20 . . . ha[d] been performed in children worldwide . . . ."[194] A liver transplant pioneer, Dr. Thomas Starzl, stated in a speech in which he addressed organ transplantation's connection to the "ancient creed of medicine" that one needed to consider this issue:

> [F]irst, because of the widespread lay publicity that has accompanied such efforts and, second, because the harsh term "*purely experimental*" has consistently been applied to these procedures by virtually all workers in the field as well as by interested observers.
>
> The designation of "*experimental*" is perfectly correct. . . . Nevertheless, the primary purpose in these human cases was therapeutic, and it is important to realize that this objective has been met to a degree that may not be generally appreciated.[195]

Further, organ transplantation's acceptance can be separated by the type of organ, because kidney transplants were the first to become commonly accepted before health care institutions and society viewed other organ transplantations as commonplace.[196] In 2013, the Health Resources and Services Administration noted that "[u]ntil only recently, the kidney was considered life enhancing, not lifesaving."[197] Similar concerns faced other early transplants. Dr. Starzl, who carried out the first successful liver transplant, wrote an account of liver transplantation and other forms of

---

193. *Id.* at 2.

194. Robert Steinbrook, *Lung Transplant—Taking Risks to Save a Life: Medicine: The Mother-Daughter Surgery Illustrates the Chances That Doctors and Family Members Are Willing to Take with Experimental Operations. The Ultimate Success Will Not Be Known for Years*, L.A. TIMES (Oct. 29, 1990, 12:00 AM), https://www.latimes.com/archives/la-xpm-1990-10-29-mn-2687-story.html [https://perma.cc/WN88-CJ6L].

195. STARZL, *supra* note 25, at 163–64 (emphasis added).

196. *Id.* at 155 ("The concept of transplanting any organ beyond the kidney was contrary to institutional interests and purposes in most places. This would be a pervasive attitude until the 1980s."); Kieran Healy, *Sacred Markets and Secular Ritual in the Organ Transplant Industry*, *in* THE SOCIOLOGY OF THE ECONOMY 312 (Frank Dobbin ed., 2003) ("Even when generally accepted, organ procurement can spark moral controversy . . . .").

197. Organ Procurement and Transplantation Network, 78 Fed. Reg. 40,033, 40,038 (July 3, 2013) (to be codified at 42 C.F.R. pt. 121); *see also* Orentlicher, *supra* note 176, at 297 n.4.

transplantation before his death.[198] He frequently described the early transplant operations as controversial.[199] In the 1970s, bone "marrow transplants were often applied as desperate measures for desperate situations."[200] Nevertheless, physicians like Dr. E. Donnall Thomas continued the research that they had begun in the 1950s.[201] Eventually, Joseph E. Murray and E. Donnall Thomas received the 1990 Nobel Prize in Physiology or Medicine "for their discoveries concerning organ and cell transplantation in the treatment of human disease."[202]

The societal acceptance of bone marrow transplantation has been at least partially attributed to "a better understanding of factors leading to improved transplantation outcomes, especially selection of appropriate patients for transplantation at a point in their disease course when transplantation is most likely to be of benefit."[203] Since early transplant efforts, outcomes have improved, and the technique is now used on older patients.[204] In the 1980s, autologous stem cell transplantation was described as "the treatment of choice."[205] With the passage of time, survival outcomes associated with hematopoietic cell transplantation have increased.[206] Similarly, partial donations of livers from living donors to living recipients are also routine and are even covered by insurance today, which was not always the case.[207]

Dangers accompany all medical innovations and many medical procedures, including procedures and testing conducted on pregnant women and their fetuses.[208] Similar dangers exist with organ transplantation,

198. STARZL, *supra* note 25, at ix.

199. *Id.* at 172.

200. Mary M. Horowitz, *Uses and Growth of Hematopoietic Cell Transplantation*, *in* THOMAS' HEMATOPOIETIC CELL TRANSPLANTATION, *supra* note 192, at 9.

201. *See, e.g.*, E. Donnall Thomas, Harry L. Lochte, Wan Ching Lu & Joseph W. Ferrebee, *Intravenous Infusion of Bone Marrow in Patients Receiving Radiation and Chemotherapy*, 257 NEW ENG. J. MED. 491, 496 (1957); *Father of Bone Marrow Transplantation Dr. E. Donnall Thomas Dies*, FRED HUTCH (Oct. 20, 2012), https://www.fredhutch.org/en/news/releases/2012/10/e-donnall-thomas-dies.html [https://perma.cc/F9SU-XEM4].

202. *See* Part I *supra*; *E. Donnall Thomas: Facts*, *supra* note 45.

203. Horowitz, *supra* note 200, at 10.

204. *Id.*

205. *Id.* at 11.

206. *Id.* at 14.

207. Wong, *supra* note 24, at 542–55; JoNel Aleccia, *No Cash, No Heart. Transplant Centers Require Proof of Payment*, KAISER HEALTH NEWS (Dec. 5, 2018), https://khn.org/news/no-cash-no-heart-transplant-centers-require-proof-of-payment [https://perma.cc/NZ2W-96V4]; Natalie Halley, *What to Know About Living Liver Donation*, UNIV. CHI. MED. (Aug. 8, 2019), https://www.uchicagomedicine.org/forefront/transplant-articles/what-to-know-about-living-liver-donation [https://perma.cc/Y4RP-QM6R]; *History*, *supra* note 47.

208. *See, e.g.*, Garrison, *supra* note 43, at 1636–37 (citation omitted) (discussing the risks of standard obstetrical practices); Kendra L. Hogan, Katie J. Schenning & Kirk J. Hogan, *Trouble in Mind: Healthcare Informed Consent, Surgery, Anesthesia, and the Aging Brain*, 38 J. LEGAL MED. 221, 247–54 (2018); M.-K. Wu, P.M.H. Dummer & P.R. Wesselink, *Consequences of and Strategies to Deal with Residual Post-Treatment Root Canal Infection*, 39 INT'L ENDODONTIC J. 343, 349 (2006); Nerissa Hannink, *What Are the Long-Term Health Risks of Having Your Tonsils Out*, UNIV. MELBOURNE: PURSUIT (June 8, 2018), https://pursuit.unimelb.edu.au/articles/what-are-the-long-term-health-risks-of-having-your-tonsils-out [https://perma.cc/2YS9-PA6Z]; *Liposuction: Lipoplasty*, AM. SOC'Y

which involves medical and surgical techniques for both the living donors and the recipients.[209] In the realm of germline genome editing, "edited" individuals could face the dangers that accompany FDA-approved gene therapy, in addition to dangers specific to heritable genetic modification and some AARTs.[210] Even within the category of transplants, some transplants are more effective than others. For example, adult lung transplants are less common and less successful than heart, kidney, and liver transplants.[211] Further, early transplant recipients suffered from a number of adverse events, and risks continue to accompany organ donation and receipt through transplantation.[212]

The word "experimentation" can be another way to indicate controversy. Recently, in an article addressing mitochondrial transfer in the United Kingdom, Jeffrey Kahn, the Chair of the committee that produced the National Academy of Science (NAS) report on mitochondrial transfer in the United States responded: "We just don't know if it's safe. . . . This is an uncontrolled experiment in which women are being offered a new technology that's never been tried before. That's why it's a concern."[213] This quote, featured in an NPR article, did note that the technique was considered "ethical" by the NAS panel.[214]

Techniques involving reproductive genetic innovation continue to be characterized as experimental.[215] The term experimental often accompa-

---

PLASTIC SURGEONS, https://www.plasticsurgery.org/cosmetic-procedures/liposuction/safety [https://perma.cc/WL47-628E]; Jacque Wilson, *When Routine Surgeries Go Wrong*, CNN HEALTH (Dec. 19, 2013, 7:14 AM), https://www.cnn.com/2013/12/19/health/routine-surgery-complications/index.html [https://perma.cc/UR7S-8FBM]; *Wisdom Tooth Extraction*, MICH. MED.: UNIV. MICH. HEALTH (July 28, 2019), https://www.uofmhealth.org/health-library/tm6328 [https://perma.cc/7YLK-5K4U].

209. *See, e.g.*, Steinbrook, *supra* note 194.

210. *Id.* For more on the risk of assisted reproductive technology and AARTs, see *supra* Part II.

211. Steinbrook, *supra* note 194.

212. For more on the risks of organ transplantation, see Barker, *supra* note 187, at 4–5, 8–11; Anthony Ripley, *Transplants Pose Mental Problem*, N.Y. TIMES, Jan. 3, 1972, at 9; Michael Green, *Introduction: Infections in Solid Organ Transplantation*, 13 AM. J. TRANSPLANTATION 3, 3–4 (2013); M.G. Ison & M.A. Nalesnik, *An Update on Donor-Derived Disease Transmission in Organ Transplantation*, 11 AM. J. TRANSPLANTATION 1123, 1123, 1125–26 (2011); *Organ Transplants and Cancer Risk*, NAT'L INSTS. HEALTH (Nov. 21, 2011) (citing Eric A. Engels et al., *Spectrum of Cancer Risk Among US Solid Organ Transplant Recipients*, 306 J. AM. MED. ASS'N 1891 (2011)), https://www.nih.gov/news-events/nih-research-matters/organ-transplants-cancer-risk [https://perma.cc/P53G-HTRA]. For more on the risks of early organ transplantation, see, for example, Joseph E. Murray, *The Fight for Life*, HARV. MED. MAG., https://hms.harvard.edu/magazine/science-emotion/fight-life [https://perma.cc/MP8X-6BQ8]; David K.C. Cooper, *Christiaan Barnard—The Surgeon who Dared: The Story of the First Human-to-Human Heart Transplant*, 11 GLOB. CARDIOLOGY SCI. & PRAC. no. 2, 2018; Thomas E. Starzl, Lawrence J. Koep, Charles G. Halgrimson, J. Hood, Gerhard P.J. Schroter, K.A. Porter & Richard Weil III, *Fifteen Years of Clinical Liver Transplantation*, 77 GASTROENTEROLOGY 375, 376 (1979); Gül Dabak & Ömer Senbaklavaci, *History of Lung Transplantation*, 17 TURK THORACIC J. 71, 72 (2016).

213. Stein, *supra* note 79.

214. *Id.*

215. The FDA, medical establishment, and much of the public view these techniques as experimental despite being currently utilized in humans. *See* discussion *supra* Sections II.B-C; *see also* MEETING #32 TRANSCRIPT, *supra* note 91; Barritt et al., *supra* note 86; *Ooplasmic/Cytoplasmic Transfer*, *supra* note 136; Alice Park, *Experts Are Calling for a Ban*

nies techniques involving the handling of embryos by physicians or researchers, such as innovation in ART, including IVF and techniques involving reproductive genetic innovation.[216] For example, in support of the Dickey–Wicker Amendment that bans federal funding of research involving the destruction of human embryos, then-Representative Dickey (Republican, Arkansas) stated that "we cannot allow Federal funds to be used to terminate lives, for the creation or the experimentation which is a lethal experimentation because it is eliminating lives [and] is not acceptable."[217] While some of these concerns are based on a risk-based analysis, some of these concerns also stem from objections (including religious objections) to techniques that can result in embryo destruction as often occurs in ART and research related to ART.[218] In the United States, techniques involving genetic modification in ART are effectively banned by the FDA as a matter of administrative law and by the U.S. Congress through a budget rider.[219] This budget rider also obtained support from legislators who were concerned about the destruction of embryos.[220]

2. Practical Outcomes and "Success"

The definition of "successful" in the words of scientists and historians may not be the same as that of the general public, which might focus on subsequent lifespan or enhanced quality of life as opposed to scientists'

---

on Gene Editing of Human Embryos. Here's Why They're Worried, TIME (Mar. 13, 2019, 2:22 PM), https://time.com/5550654/crispr-gene-editing-human-embryos-ban [https://perma.cc/FJ6C-PB7C]; Sherkow & Scott, *supra* note 34, at 1548 (describing the vectors used in genome editing technologies as "highly experimental").

216. Garrison, *supra* note 43, at 1634 ("ART practitioners may offer experimental treatments before clinical trials have been completed without any effort to enroll patients in those trials, and some of these experimental treatments may pose risks to adult patients or their children.").

217. Eli Y. Adashi & I. Glenn Cohen, *Selective Regrets: The "Dickey Amendments" 20 Years Later*, JAMA NETWORK (Nov. 5, 2015), https://jamanetwork.com/channels/health-forum/fullarticle/2760581 [https://perma.cc/4CXQ-VCNT]. The Dickey–Wicker Amendment was named after its coauthors, Jay Dickey and Roger Wicker. *See*, Kyla Dunn, *The Politics of Stem Cells*, NOVA (Apr. 1, 2005), https://www.pbs.org/wgbh/nova/article/stem-cells-politics [https://perma.cc/3AZZ-FRS9].

218. *See, e.g.*, Anne Drapkin Lyerly, Karen Steinhauser, Corrine Voils, Emily Namey, Carolyn Alexander, Brandon Bankowski, Robert Cook-Deegan, William C. Dodson, Elena Gates, Emily S. Jungheim, Peter G. McGovern, Evan R. Myers, Barbara Osborn, William Schlaff, Jeremy Sugarman, James A. Tulsky, David Walmer, Ruth R. Faden & Edward Wallach, *Fertility Patients' Views About Frozen Embryo Disposition: Results of a Multi-Institutional U.S. Survey*, 93 FERTILITY & STERILITY 499, 499–502, 506–07 (2010); Juli Fraga, *After IVF, Some Struggle With What To Do With Leftover Embryos*, NPR (Aug. 20, 2016, 7:00 AM), https://www.npr.org/sections/health-shots/2016/08/20/489232868/after-ivf-some-struggle-with-what-to-do-with-leftover-embryos [https://perma.cc/9JNE-NDSM].

219. *See* I. Glenn Cohen & Eli Y. Adashi, *Preventing Mitochondrial DNA Diseases: One Step Forward, Two Steps Back*, 316 J. AM. MED. ASS'N 273, 273–74 (2016).

220. 163 CONG. REC. H3071, H3294 (daily ed. May 3, 2017) ("The bill also includes a prohibition on gene editing of human embryos. This is a tremendous victory for those who are concerned about life."). For more on religious views related to embryo use in ART and embryo destruction, see Ian H. Kerridge, Christopher F. C. Jordens, Rod Benson, Ross Clifford & Rachel A. Ankeny, *Religious Perspectives on Embryo Donation and Research*, 5 CLINICAL ETHICS 35, 43 (2010); Atsushi Tanaka & Seiji Watanabe, *Can Cytoplasmic Donation Rescue Aged Oocytes?*, 18 REPROD. MED. & BIOLOGY 128, 132, 136 (2019).

focus on technique. The idea of "success" pervades discussions of organ transplantation.[221] Further, the idea of controversy was common in early discussions and analysis of organ transplantation techniques.[222] After the first human-to-human heart transplant, the recipient had "an initial excellent recovery" but "died on the 18th postoperative day."[223] Similarly, while discussing advances in the transplantation of other organs after the "growing success with kidneys," observers noted that while many achievements in organ transplants "are now considered the 'firsts' for each organ and were generally well conducted and based on experimental experience, they were controversial at the time because the grafts all failed, promptly and unpleasantly in most cases."[224] In 1978, reporting related to liver transplants noted that 90% of Dr. Thomas Starzl's liver transplants were "successful" "meaning patients live for a year or more."[225] Later, after more long-term reliability had been achieved, a committee report accompanying the law that expanded Medicare coverage following liver transplantation from 12 months to 36 months noted that "a great many transplants have not stabilized or cannot be deemed successful after 12 months."[226] Further, transplants are viewed as successful today because anti-rejection drugs are used to help the grafts last much longer.[227]

Disputes about success and controversy also accompany both traditional ART and reproductive genetic innovation. As a matter of controversy, early in the use of artificial insemination, the procedure was deemed "adultery" or "adultery by doctor" by some judges and observers.[228] In the realm of AARTs like cytoplasmic transfer, the definition of success varies. A success for parents is the birth of a healthy child while success for some scientists and parents may be the creation of embryos

221. *See* discussion in Section III.D.2.

222. STARZL, *supra* note 25, at 172 ("Was it worth this much trouble to save so few people? This is what I was asked more and more. In England, the same question was being asked of Roy Calne, who started a liver transplant program in May 1967, the only other one in the world. Like ours, it was controversial. Of his first five patients, only one left the hospital alive.").

223. Noedir A.G. Stolf, *History of Heart Transplantation: A Hard and Glorious Journey*, 32 BRAZILIAN J. CARDIOVASCULAR SURGERY 423, 425 (2017).

224. HAMILTON, *supra* note 185, at 287.

225. Frank W. Martin, *Dr. Tom Starzl, A Surgical Pioneer, Gambles with Long, Long Odds in Human Organ Transplants*, PEOPLE (Nov. 20, 1978, 12:00 PM), https://people.com/archive/dr-tom-starzl-a-surgical-pioneer-gambles-with-long-long-odds-in-human-organ-transplants-vol-10-no-21 [https://perma.cc/3BPQ-C6S4].

226. H.R. REP. No. 95-549, at 10 (1977), https://congressional-proquest-com.proxy.wm.edu/congressional/docview/t49.d48.13172-9_h.rp.549?accountid=15053 [https://perma.cc/4JYN-SM8A].

227. Stolf, *supra* note 223, at 427 ("In 1978, cyclosporine was introduced in kidney transplantation and, in 1980, in cardiac transplantation at Stanford.").

228. *See* Naomi Cahn, *The New Kinship*, 100 GEO. L.J. 367, 389 n.112 (2012); Gaia Bernstein, *The Socio-Legal Acceptance of New Technologies: A Close Look at Artificial Insemination*, 77 WASH. L. REV. 1035, 1073 (2002); Courtney Megan Cahill, *Reproduction Reconceived*, 101 MINN. L. REV. 617, 622 (2016) (citing Kara W. Swanson, *Adultery by Doctor: Artificial Insemination, 1890-1945*, 87 CHI.-KENT L. REV. 591, 593 (2012)).

that do not manifest chromosomal or other abnormalities.[229]

Additional legislation on the definition of death facilitated the levels of organ transplantation seen today.[230] Before that legislation, transplantation pioneers like Dr. Norman Shumway faced prosecution for their work in human transplantation due to the controversy over donor death.[231] Improvements in anti-rejection drugs also aided in the success of organ transplantation as medical progress happens over time, and techniques often are not perfect when they are first used.[232] Interestingly, a "public trial," referred to as "Consensus Development Review," was commenced before Medicare added liver transplantation to its list of approved treatments, thus rendering it no longer experimental.[233] Eventually, Congress held hearings and discussed many issues including who would pay for organ transplantation and how to procure donors.[234]

3. Long-term Effects

Long-term effects are often cited as an objection to ART techniques involving heritable genetic modification,[235] but those same concerns existed with organ transplantation. For example, after the first living lung transplant from a mother to her daughter, media coverage noted that it would take approximately three to four years to assess the success of the transplant.[236] Beyond graft-versus-host disease, "[t]ransplant recipients remain at risk for late complications long after [hematopoietic cell transplantation] . . . . These include late infections, cataracts, abnormalities of growth and development, thyroid disorders, chronic lung disease, and avascular necrosis."[237] Yet, there is already a method of addressing long-term effects, which is already in place for approved methods of gene therapy: long-term follow-up studies.[238] As a result, the fact that the long-term effects of heritable genetic modification are unknown should not hinder the use of these techniques (or at least early experimental efforts) in humans.

A concern about the long-term effects of reproductive genetic innovation also persists. Scientists have called for a public consultation or dis-

229. *ART Success Rates*, CTRS. FOR DISEASE CONTROL & PREVENTION (Apr. 20, 2021) (defining success as live born infants or frozen eggs or embryos for future use) https://www.cdc.gov/art/artdata/index.html [https://perma.cc/2GLB-Z83W].

230. STARZL, *supra* note 25, at 112–13, 147; *see also* Lesley A. Sharp, *Organ Transplantation as a Transformative Experience: Anthropological Insights into the Restructuring of the Self*, 9 MED. ANTHROPOLOGY Q. 357, 361–62 (1995).

231. STARZL, *supra* note 25, at 148–50.

232. *Id.* at 162.

233. *Id.* at 252–54, 269.

234. *Id.* at 270–80.

235. Bryan Cwik, *Intergenerational Monitoring in Clinical Trials of Germline Gene Editing*, 46 J. MED. ETHICS 183, 183, 185 (2020); Gyngell et al., *supra* note 116, at 504, 506–08; Skerrett, *supra* note 80.

236. Steinbrook, *supra* note 194.

237. Horowitz, *supra* note 200, at 14.

238. For more on the role of long-term follow-up studies in approved somatic-cell gene therapies, see Lewis, *Subterranean Regulation*, *supra* note 35 at 797, 810–11.

course on the issue.[239] While there are many stakeholders, especially the parents of children (or future children) who would like to facilitate the clinical use of reproductive genetic innovation, there are other stakeholders who also want to influence regulation in a way that would hinder the clinical use of reproductive genetic innovation.[240]

4. Consent

Concerns about consent surround both organ transplantation and reproductive genetic innovation.[241] Consent-based concerns in organ transplantation tend to surround the supply (and suppliers) of organs. These concerns surround the procurement process, including concerns about illegal organ harvesting, fears of inadequate medical care for potential donors to hasten their deaths (and the providing of organs), and concerns about child donors.[242] At the time of the first living donor transplant from mother to child, some observers noted that the child could not meaningfully consent to the operation.[243] In spite of these concerns, adults routinely consent to medical treatments for children to give children the required treatment.[244] Thus, while it is true that existing children cannot consent to medical treatments and that future children cannot consent to their parents' use of IVF, pre-birth diagnostic procedures such as amniocentesis, AARTs, or their parents' diets and environmental exposures, the lack of consent should not prohibit the use of these techniques.[245] Further, some bioethicists have noted that "[t]he view that emphasizes the need to ask the consent of future generations . . . fails to state how such consent could be obtained."[246] In the realm of AARTs and germline gene editing, there is a concern about future persons and their ability to consent. More specifically, there is a concern about whether children can adequately comprehend and consent to donating bone marrow to their siblings; this concern also accompanies pediatric

239. NAT'L ACAD. OF SCIS., ENG'G & MED., *supra* note 74, at 163; Baylis, *supra* note 127, at 1–3.

240. Andrew B. Coan, *Is There a Constitutional Right to Select the Genes of One's Offspring?*, 63 HASTINGS L.J. 233, 266 (2011) ("[I]mportant stakeholders [are those] with the potential to influence regulation of genetic-selection decisions . . . .").

241. While much of the concern about consent relates to the consent of parents over children who would be modified due to germline gene editing or AARTs, there is also a concern about intergenerational consent and the effect on future unborn generations. For more on intergenerational ethics, see, for example, Lawrence B. Solum, *To Our Children's Children: The Problems of Intergenerational Ethics*, 35 LOY. L.A. L. REV. 163, 166–72 (2001).

242. *See supra* note 29.

243. Steinbrook, *supra* note 194.

244. Ann MacLean Massie, *Withdrawal of Treatment for Minors in a Persistent Vegetative State: Parents Should Decide*, 35 ARIZ. L. REV. 173, 180 (1993).

245. *See* Skerrett, *supra* note 80; Garrison, *supra* note 43, at 1634–36; Gyngell et al., *supra* note 116, at 507, 510.

246. Giulia Cavaliere, *Genome Editing and Assisted Reproduction: Curing Embryos, Society or Prospective Parents?*, 21 MED., HEALTH CARE & PHIL. 215, 218 (2018); Gyngell et al., *supra* note 116, at 510 (noting the impossibility of obtaining the consent of future generations).

organ donation where parents make decisions for children.[247]

5. Identity and "Three Parents"

Both organ and tissue transplantation and reproductive genetic innovation have been accompanied by identity-related concerns, although the nuance varies by technique. In anthropology and psychology, articles have focused on providing the perspective of individuals, especially recipients of organs, who have noted the potentially transformative impact of their new organs—which, according to some recipients, have come with various qualities "ranging from criminality to artistic talent"—on their identity and everyday lives.[248]

Just as bioethicists have questioned (and minimized) the roles of organ and tissue donors in the identity of recipients, bioethicists have also questioned (and minimized) the role of donors of genetic material in the lives of the children conceived as a result of AARTs.[249] While laws in some states are changing to recognize three or more parents, reproductive genetic innovation is not the same as a three- or more-parent family because the small genetic contribution of the donor is more akin to organ donation than "three parent in vitro fertilization."[250]

6. The "Yuck Factor"

Organ transplantation and reproductive genetic innovation have all been accompanied by the Yuck Factor which accompanies innovations that result in concerns that something is "wrong because it's just not right, because it's not natural."[251] The Yuck Factor does not accompany organ transplantation very much today; however, the term Yuck Factor originated in a discussion of reactions to organ transplantation involving anencephalic infants.[252]

While the Yuck Factor is referred to as a singular response to medical innovation, Professor Hank Greely has noted that the intellectual versions of the Yuck Factor come in two categories: (1) "the religious perspective: that this is not how God meant us to be" and (2) "the secular . . .

247. For an overview of controversy and ethical guidelines related to pediatric organ donation, see Williamson & Vercler, *supra* note 189; Catherine Kim, *Children as Live Kidney Donors for Siblings*, 5 VIRTUAL MENTOR 240, 240–41 (2003).

248. *See, e.g.*, Lesley A. Sharp, *Organ Transplantation as a Transformative Experience: Anthropological Insights into the Restructuring of the Self*, 9 MED. ANTHROPOLOGY Q. 357, 365, 371–73 (1995) (citing Deborah C. Beidel, *Psychological Factors in Organ Transplantation*, 7 CLINICAL PSYCH. REV. 677, 686 (1987)); *id.* at 369 (describing the "utter shock" of recipients of organ donation when the family of the organ donor came to the hospital "to find their new 'family'").

249. *See infra* note 299 and accompanying text (dismissing the ideas that mitochondrial transfer and organ transplantation affect identity).

250. *See, e.g.*, June Carbone & Naomi Cahn, *Parents, Babies, and More* Parents, 92 CHI.-KENT L. REV. 9, 9–10, 16 (2017); *see also infra* discussion in Part IV.

251. Henry T. Greely, *Remarks on Human Biological Enhancement*, 56 U. KAN. L. REV. 1139, 1153 (2008).

252. Matthew C. Nisbet, *The Competition for Worldviews: Values, Information, and Public Support for Stem Cell Research*, 17 INT'L J. PUB. OP. RSCH. 90, 93 n.3 (2005).

[or] maybe the pantheistic version . . . is that this is not the way evolution intended us to be."[253] The Yuck Factor can also be "a more visceral reaction" that "reflects disgust."[254] As a result, concerns that physicians or scientists are "playing God" could be categorized as reactions based on the Yuck Factor or moral panic.

In the realm of organ transplantation, procurement workers still "often struggle to convince [people who would be] organ sources and their next of kin to overcome what is for many a strong, instinctive aversion to organ harvest."[255] Reproductive genetic innovation encounters the same opposition that confronted techniques involving ART such as opposition to embryo destruction or the idea that scientists or physicians are playing God.[256] Other concerns include that such techniques encourage the "commodification" of reproduction by "making[ ] procreation into manufacture (literally something 'handmade')."[257] Furthermore, the use of these reproductive genetic innovations leads to a concern that "changing the shared human germline" is occurring, which is problematic because (1) no non-human tissues are used and (2) the existence of the "shared human identity" has done very little to aid the day-to-day treatment of humans in general, let alone the progress of medicine.[258] In the United States, for example, religious opposition plays a role in the regulatory treatment of these techniques; although, significantly, opposition to germline modification exists among members of both the Democratic and Republican parties, in spite of statements from the NAS's Institute of Medicine noting limited conditions under which clinical investigations should go forward.[259] Viewing techniques involving reproductive genetic

253. Greely, *supra* note 251, at 1153–54.

254. Henry T. Greely, *Regulating Human Biological Enhancements: Questionable Justifications and International Complications*, 4 SANTA CLARA J. INT'L L. 87, 93 (2006); Schmidt, *supra* note 6, at 526.

255. Julia D. Mahoney, *Altruism, Markets, and Organ Procurement*, 72 LAW & CONTEMP. PROBS. 17, 20 (2009).

256. *See, e.g.*, Larry G. Locke, *The Promise of CRISPR for Human Germline Editing and the Perils of "Playing God,"* 3 CRISPR J. 27, 27–31 (2020); Sonia M. Suter, *A Brave New World of Designer Babies?*, 22 BERKELEY TECH. L. J. 897, 960 (2007) ("[M]edical treatments generally interfere with the 'natural' process of evolution, and yet, for the most part, we welcome medical advancements.").

257. *See* Kass, *supra* note 84, at 23.

258. *See* Beth Baker, *The Ethics of Changing the Human Genome*, 66 BIOSCIENCE 267, 269 (2016) (quoting U.S. Representative Bill Foster who described CRISPR as "in some ways, an attack from the future on our shared humanity"); Barry R. Furrow, *The CRISPR-Cas9 Tool of Gene Editing: Cheaper, Faster, Riskier?*, 26 ANNALS HEALTH L. 33, 41 (2017); Pilar N. Ossorio, *The Human Genome as Common Heritage: Common Sense or Legal Nonsense?*, 35 J.L. MED. & ETHICS 425, 425–26 (2007); Nadia Primc, *Do We Have a Right to an Unmanipulated Genome? The Human Genome as the Common Heritage of Mankind*, 34 BIOETHICS 41, 41–42 (2020); Vera Lúcia Raposo, *Gene Editing, the Mystic Threat to Human Dignity*, 16 J. BIOETHICAL INQUIRY 249, 255 (2019).

259. *See* NAT'L ACAD. OF SCIS., ENG'G & MED., *supra* note 74, at 181–94; Baker, *supra* note 258, at 269 (quoting U.S. Representative Bill Foster who noted, of fellow lawmakers' reactions to CRISPR: "I found to my pleasant surprise that a lot of partisanship melts away . . . sometimes, I think of this as like an attack on Earth from an alien civilization, which of course would cause all Democrats and Republicans to come together. This is, in some ways, an attack from the future on our shared humanity."); Andrew Joseph, *Congress*

innovation through the lens of organ transplantation offers a supplemental lens for viewing or analogizing the techniques to existing procedures that are commonly accepted in medical treatment in the United States.

E. Dissimilarities and Competing Analogies

Naturally, there are some differences between reproductive genetic innovation and organ transplantation. As noted above, reproductive genetic innovation and organ transplantation have been controversial for different reasons. Some would note the disparate senses of urgency. Under this theory, one would compare the urgency of organ transplantation, which saves someone from death or a debilitating condition, to techniques involving reproductive genetic innovation, which aim to improve life for a child who does not exist yet.[260] In general, there are perspectives that often stem from religious views about the appropriateness of the use of ARTs and arguments against the use of ARTs under the theory that using ART "does violence to human dignity and to the marriage act."[261] Further, a recurring argument in assisted reproduction, in general, is the idea that individuals who require ART to become genetic parents do not have to reproduce using ART but could adopt instead.[262] This Article sets aside that argument and accepts that for many parents, adoption is not a substitute for ART, which allows parents to conceive children to whom they are genetically related and, for some parents, to conceive genetically related children who would lack the genetic conditions that the parents would otherwise pass on to their children.[263] Moreover, other options, such as pregnancy followed by prenatal testing and the abortion of fetuses that would be affected by heritable disease, are unappealing to

---

Revives Ban on Altering the DNA of Human Embryos Used for Pregnancies, Sci. Am. (June 5, 2019) ("Democrat Nita Lowey of New York, said she 'reluctantly supported' returning the ban to the bill. She acknowledged that editing embryonic DNA had some potential risks, but added that it could cure and prevent genetic disease."), https://www.scientificamerican.com/article/congress-revives-ban-on-altering-the-dna-of-human-embryos-used-for-pregnancies [https://perma.cc/3MLN-CYAA]; Rob Stein, *House Committee Votes to Continue Ban on Genetically Modified Babies*, NPR (June 4, 2019, 4:38 PM) (quoting U.S. Representative Robert Aderhold: "There are just too many unknowns . . . . Many of us believe it's just a step too far too soon."), https://www.npr.org/sections/health-shots/2019/06/04/729606539/house-committee-votes-to-continue-research-ban-on-genetically-modified-babies [https://perma.cc/C4W4-ENGM]; *see also* Cary Funk, Brian Kennedy & Elizabeth Sciupac, Pew Rsch. Ctr., U.S. Public Wary of Biomedical Technologies to 'Enhance' Human Abilities 5 (2016), https://www.pewresearch.org/internet/wp-content/uploads/sites/9/2016/07/PS_2016.07.26_Human-Enhancement-Survey_FINAL.pdf [https://perma.cc/4AYG-FGZH] ("In general, the most religious [Americans] are the most wary about potential [human] enhancements").

260. Goodwin, *supra* note 178, at 1223.

261. John M. Haas, *Begotten Not Made: A Catholic View of Reproductive Technology*, U.S. Council of Catholic Bishops (1998), http://www.usccb.org/issues-and-action/human-life-and-dignity/reproductive-technology/begotten-not-made-a-catholic-view-of-reproductive-technology.cfm [https://perma.cc/49AF-UB22].

262. *See, e.g.*, I. Glenn Cohen & Daniel L. Chen, *Trading-Off Reproductive Technology and Adoption: Does Subsidizing IVF Decrease Adoption Rates and Should it Matter?*, 95 Minn. L. Rev. 485, 486–88, 509–26 (2010).

263. *See, e.g.*, Nuffield Council on Bioethics, *supra* note 125, at 23.

some couples.[264]

The specter of abortion and its legal treatment, while not the focus of this Article, is also relevant in terms of the regulation of AARTs and organ transplantation. Techniques involving organ donation tend to avoid issues of reproductive choice.[265] Beneath the controversy that accompanies all the techniques involving ART is the specter of abortion that does not accompany organ transplantation. For many, abortion encounters a moral opposition in the United States similar to techniques involving ART and reproductive genetic innovation.[266] There is a significant debate, not only in American politics but also in American legal scholarship, about the legality of abortion and its accompanying controversy. The issues of embryo destruction and the selective destruction of fetuses that arise in the context of ART generally, as well as in reproductive genetic innovation and prenatal testing, all connect back to issues related to the origins of life and, by connection, abortion.[267]

Many Americans support the legality of abortion, although they would not necessarily obtain one themselves.[268] Similarly, organ transplantation is societally accepted, although many individuals would not donate their organs as either living or deceased donors, as illustrated by the gap between the number of organs needed and the number of organs available. In a similar vein, ART is societally accepted and available throughout the United States, although many individuals do not avail themselves of ART techniques or, for that matter, prenatal testing. One could argue that, for some opponents, opposition to reproductive genetic innovation is a proxy for opposition to abortion.

Further, there are differences between the types of techniques that fall within the umbrella term of reproductive genetic innovation, as highlighted in the beginning of Part I. Genetic modification, whether heritable or not, should not involve the same resource constraints as organ

264. FRANÇOISE BAYLIS, ALTERED INHERITANCE: CRISPR AND THE ETHICS OF HUMAN GENOME EDITING 30 (2019).

265. While penis transplants have been pioneered recently, currently, efforts at penis and urogenital transplants specifically do not involve the transplantation of the testes, so as to avoid these reproductive issues. *See, e.g.*, Denise Grady, *Penis Transplants Being Planned to Help Wounded Troops*, N.Y. TIMES (Dec. 6, 2015), https://www.nytimes.com/2015/12/07/health/penis-transplants-being-planned-to-heal-troops-hidden-wounds.html [https://perma.cc/XDG7-Q5BR].

266. *See supra* note 261. Religious opposition to abortion also connects to religious views related to paternalism, which can lead to laws that minimize or aim to minimize women's control over their own bodies. A future piece will explore these issues.

267. Matthew C. Nisbet, *The Competition for Worldviews: Values, Information, and Public Support for Stem Cell Research*, 17 INT'L J. PUB. OP. RSCH. 90, 91–92 (2005).

268. Jamie Ballard, *Most Americans Think Abortion Should Be Legal to Some Extent* (July 11, 2020, 9:00 AM) (summarizing a recent The Economist/YouGov Poll on American attitudes related to abortion and other political issues where 7% identified as "neither" and 8% were "not sure"), https://today.yougov.com/topics/legal/articles-reports/2020/07/11/america-abortion-poll [https://perma.cc/7NEH-H9CZ]; Carrie Blazina, Michael Lipka & John Gramlich, *Key Facts About the Abortion Debate in America*, PEW RSCH. CTR. (June 17, 2021), https://www.pewresearch.org/fact-tank/2019/08/30/facts-about-abortion-debate-in-america [https://perma.cc/QJ3P-GVWA].

transplantation. Organ transplantation is limited, at least currently, by a scarcity of organ donors; there are too few organ donors, and many of those awaiting organ donation die due to the lack of available organs.[269] Techniques involving reproductive genetic innovation will, however, still be accompanied by concerns about racial and socioeconomic disparities that also accompany the organ transplantation system in the United States.[270]

Some would compare reproductive genetic innovation to eugenics instead of organ transplantation. Concerns about eugenics accompany reproductive genetic innovation and ART in general, as ART techniques can facilitate parents' efforts to select children who have certain traits, whether for medical purposes like selecting embryos that do not contain genetic abnormalities or for non-medical purposes such as sex selection.[271] Some might be concerned that reproductive genetic innovation will lead to the eradication of certain traits in the human population, similar to the eugenics movement that aimed to prevent certain individuals from reproducing. Moreover, individuals raise concerns about "designer babies" and the (currently) fictionalized abilities of parents to create a new race of children. These concerns are exacerbated for some when potentially enhancement-based uses of reproductive genetic innovation are raised as opposed to its therapeutic uses.[272] This Article disagrees with that perspective for several reasons. First, reproductive genetic innovation does not aim to prevent certain individuals from reproducing all together. Second, the expectation is that reproductive genetic innovation will (at least initially) be used for therapeutic purposes, such as returning individuals to a baseline medical function (in a lifesaving manner in many instances), as opposed to enhancement-based purposes. Further, even if enhancement-based uses are possible, this should not prohibit the use of reproductive genetic innovation because many medical techniques and products can be used for therapy or enhancement, which do not prohibit

269. *See Organ Donation Statistics*, HEALTH RES. & SERVS. ADMIN. (Sept. 2020), https://www.organdonor.gov/statistics-stories/statistics.html [https://perma.cc/XW2X-6QDZ]; S. Ali Husain, Kristen L. King, Stephen Pastan, Rachel E. Patzer, David J. Cohen, Jai Radhakrishnan & Sumit Mohan, *Association Between Declined Offers of Deceased Donor Kidney Allograft and Outcomes in Kidney Transplant Candidates*, JAMA NETWORK OPEN (Aug. 30, 2019), https://jamanetwork.com/journals/jamanetworkopen/fullarticle/2749266 [https://perma.cc/BBJ2-M5X6].

270. For concerns related to racial and wealth disparities in organ transplantation, see Goodwin & Gewertz, *supra* note 29, at 253; *Wealthy More Likely to Get Organ Transplants: Study*, NAT'L POST (Nov. 9, 2015), https://nationalpost.com/health/wealthy-more-likely-to-get-organ-transplants-study [https://perma.cc/7FS9-T2N5]. For concerns related to race and wealth disparities related to germline genetic modification and assisted reproductive technology in general, see NUFFIELD COUNCIL ON BIOETHICS, *supra* note 125, at 87; Clara C. Hildebrandt & Jonathan M. Marron, *Justice in CRISPR/Cas9 Research and Clinical Applications*, 20 AMA J. ETHICS 826, 827–28 (2018); Mohapatra, *supra* note 42, at 72, 75.

271. King, *supra* note 155, at 312; Suter, *supra* note 256, at 899–902, 906–16; Judith F. Daar, *ART and the Search for Perfectionism: On Selecting Gender, Genes, and Gametes*, 9 J. GENDER RACE & JUST. 241, 247–48 (2005).

272. Kass, *supra* note 84, at 25.

their legality.[273] Third, historically, eugenics practices were conducted by the state, whereas individuals, not states, opt for reproductive genetic innovation.[274] At the same time, this emphasis on private actors does not allay many individuals' concerns, because the wealthy may be more able to access these techniques, even if insurance coverage of ART occurred.[275] Yet issues of accessibility continue to accompany medical techniques and products in the United States and the world, and the fact that some may be better able to access the technique than others should not prohibit the potential legalization of the techniques in the United States.[276] Furthermore, improving access to reproductive genetic innovation in the United States could minimize disparities because access to these techniques would not be limited to wealthy individuals with the means to access innovative physicians and researchers in foreign countries, which is what is currently facilitated by the current system.

Organ transplantation is a procedure that does not result in heritable change. Thus, even though bone marrow transplantation, such as in the transplantation story mentioned in Part I's vignettes, might change the DNA in the recipient's semen, physicians do not expect that it will cause changes to the sperm and thus become heritable, although scientists could not test that expectation as the recipient had a vasectomy.[277] Heritability, which occurs with germline changes, is the source of much of the ethical opposition to reproductive genetic innovation.[278]

Heritability affects the analysis of the potential long-term effects of reproductive genetic innovation as compared to the long-term effects of organ donation. Organ and tissue donation, for example, can lead to genetic change, yet they do not lead to genetic change at the germline level; thus, these changes are not heritable. Therefore, analyses of the long-term effects of organ transplantation focus on the long-term effects for the donor and the recipient, whereas germline genetic modification is accompanied by a concern for the long-term effects of germline gene editing on the individual recipient of germline gene editing and the recipient's progeny.[279] For many observers, the idea that a change is heritable is the basis

273. *See, e.g.*, Bryan Cwik, *Revising, Correcting, and Transferring Genes*, 20 AM. J. BIOETHICS 7, 7 (2020) ("The distinction between *germline* and *somatic* gene editing (like the distinction between therapy and enhancement) is fundamental to the ethics of human gene editing.").

274. *See* Suter, *supra* note 256, at 898; Nicholas Agar, *Liberal Eugenics*, 12 PUB. AFFS. Q. 137, 137 (1998).

275. Alison K. Hoffman, *Selective Breeding in an Era of Reproductive Technologies. By Judith Daar*, 4 J. L. & BIOSCIENCES 671, 677 (2017) (book review).

276. For more on access-related concerns in ART, see Mary Crossley, *Dimensions of Equality in Regulating Assisted Reproductive Technologies*, 9 J. GENDER RACE & JUST. 273, 274–81 (2005).

277. Zimmer, *supra* note 18; Murphy, *supra* note 19 ("[A] donor's blood cells should not be able to create new sperm cells . . . .").

278. *See supra* Part II.

279. *See supra* Section III.D.3; NUFFIELD COUNCIL ON BIOETHICS, *supra* note 125, at 88; Geng Zhang, Weijun Qin, Jianlin Yuan, Changsheng Ming, Shuqiang Yue, Zhengcai Liu, Lei Yu, Ming Yu, Xiaokang Gao, Yu Zhou, Longxin Wang, Xiaojian Yang, Kefeng Dou & He Wang, *A 14-Year Follow-Up of a Combined Liver-Pancreas-Kidney Transplan-*

for the cessation of regulatory debate and scientific progress. I do not share this view. As will be explained in Part IV, these differences do not mandate a dissimilar regulatory treatment of organ transplantation and techniques that modify genetic material. This normative position, which I have also taken in previous Articles,[280] stems from the fact that heritable changes can result from environmental influences, natural occurrences, and in another sense, parents' choices about with whom to reproduce and, with the use of technologies such as PGD, whether to use certain embryos at all.[281] Similarly, research shows that certain drugs used in cancer treatment can possibly lead to germline genetic changes.[282]

Moreover, the concern about heritability naturally connects to previously mentioned arguments about humans playing God.[283] In contrast, organ transplantation enjoys significant religious acceptance (although some religions still prohibit it) with some religions encouraging transplantation, and still others taking a hands-off approach.[284] This charitable or altruistic construction of organ or tissue donation starts to wane, however, the closer one moves to donations or techniques involving reproduction. For example, egg and sperm donation are often implicated in the use of in vitro reproduction and other forms of ART that are often condemned by religious sects.[285] Even acknowledging variance within religious sects, if one extended the religious condemnation of ART to AARTs and germline genetic modification, viewing these techniques through the lens of particularly conservative faiths would likely extend that condem-

---

tation: Case Report and Literature Review, 7 FRONTIERS MED. 1, 4–5 (2020); Geir Mjøen, Stein Hallan, Anders Hartmann, Aksel Foss, Karsten Midtvedt, Ole Øyen, Anna Reisæter, Per Pfeffer, Trond Jenssen, Torbjørn Leivestad, Pål-Dag Line, Magnus Øvrehus, Dag Olav Dale, Hege Pihlstrøm, Ingar Holme, Friedo W. Dekker & Hallvard Holdaas, *Long-Term Risk for Kidney Donors*, 86 KIDNEY INT'L 162, 162 (2014).

280. *See, e.g.*, Lewis, *Subterranean Regulation*, *supra* note 35.

281. *See, e.g.*, *supra* notes 18–22 and accompanying text (discussing causes of chimerism); Lewis, *Germline Gene Editing*, *supra* note 35, at 809 (discussing the field of epigenetics and also the impacts of environmental influences such as radiation); Suter, *supra* note 256, at 962 (discussing the complex relationship between genes and the environment).

282. Gyngell et al., *supra* note 116, at 506 (citing C.D. Glen & Y.E. Dubrova, *Exposure to Anticancer Drugs Can Result in Transgenerational Genomic Instability in Mice*, 109 PROC. NAT'L ACAD. SCIS. 2984, 2984–87 (2012)).

283. *See supra* Section III.D.6.

284. *See, e.g.*, *Religion and Organ Donation*, HEALTH RES. & SERVS. ADMIN. (Apr. 2021), https://www.organdonor.gov/learn/who-can-donate/religion [https://perma.cc/87BV-KXEM]; *see also* Orentlicher, *supra* note 176, at 319 (citing ELLIOTT N. DORFF, MATTERS OF LIFE AND DEATH: A JEWISH APPROACH TO MODERN MEDICAL ETHICS 15 (1998)).

285. *See, e.g.*, *Instruction Dignitas Personae on Certain Bioethical Questions*, HOLY SEE (Dec. 2008), http://www.vatican.va/roman_curia/congregations/cfaith/documents/rc_con_cfaith_doc_20081208_dignitas-personae_en.html [https://perma.cc/63RE-T5LR]; John M. Haas, *Begotten Not Made: A Catholic View of Reproductive Technology*, U.S. COUNCIL OF CATH. BISHOPS (1998), http://www.usccb.org/issues-and-action/human-life-and-dignity/reproductive-technology/begotten-not-made-a-catholic-view-of-reproductive-technology.cfm [https://perma.cc/FYJ5-N4NL]; Ariana Eunjung Cha, *How Religion Is Coming to Terms with Modern Fertility Methods*, WASH. POST (Apr. 27, 2018), https://www.washingtonpost.com/graphics/2018/national/how-religion-is-coming-to-terms-with-modern-fertility-methods [https://perma.cc/6S29-DPAH].

nation to AARTs and to germline genetic modification.[286] These aforementioned religious concerns are often encompassed in discussions of ethical or moral views which have the tendency to affect regulatory and legislative decisions, especially regulatory and legislative decisions that impact reproductive rights.

IV. STRATEGIC BENEFITS OF VIEWING REPRODUCTIVE GENETIC INNOVATION THROUGH THE LENS OF ORGAN TRANSPLANTATION

While allocation concerns and resource-related controversy continue to accompany organ transplantation at the micro-level, the technique is societally accepted at the macro level. This Part identifies the benefits of applying the organ transplantation lens delineated in Part II to reproductive techniques involving genetic innovation. Section A builds on the commonalities outlined in Part II. Section B notes that viewing reproductive genetic innovation through the lens of organ transplantation instead of through the lens of moral panic could facilitate the use of life-saving techniques involving reproductive genetic innovation by reducing the Yuck Factor or moral panic that accompanies these techniques.

A. Analogizing Organ Transplantation and Reproductive Genetic Innovation

Analogies to transplantation surround descriptions of techniques involving reproductive genetic innovation. Mitochondria have been described as the "batteries in a cell" or the "powerhouse[ ] of a cell" due to their role in providing energy to the cell.[287] In the United Kingdom, media coverage of forms of mitochondrial transfer has included analogies like "changing the batteries in a laptop" or "changing the bacteria in our intestines."[288] Some scientists have used similar analogies such as "molecular scissors" or "nanoscissors" that "make cuts near genes . . . you want to alter" when referring to germline gene editing technologies.[289] Similarly, word processing metaphors that focus on the "cut and paste" func-

286. *See* Andrew Joseph, *God and the Genome: A Geneticist Seeks Allies Among the Faithful*, STAT News (Oct. 13, 2016), https://www.statnews.com/2016/10/13/genome-religion-ethics-ting-wu [https://perma.cc/DR3Q-PV7T].

287. Nuffield Council on Bioethics, *supra* note 14, at 18; Helen R. Brooks, *Mitochondria: Finding the Power to Change*, 175 Cell 891, 891 (2018).

288. Nuffield Council on Bioethics, *supra* note 14, at 78 (citing Sarah Boseley, *Scientists Seek to Implant Embryos with Genetic Material from Three Parents*, The Guardian (Apr. 19, 2011, 11:09 AM), http://www.guardian.co.uk/science/2011/apr/19/scientists-embryos-three-parents [https://perma.cc/7DFC-VVL4]). *But see* Emily Mullin, *Despite Calls for a Moratorium, More 'Three-Parent' Babies Expected Soon*, Medium: OneZero (Sept. 16, 2019) ("'Swapping mitochondria might not be as straightforward as just changing the batteries in a device,' says Patrick Chinnery, a professor at the University of Cambridge who investigates mitochondria and human diseases . . . ."), https://onezero.medium.com/despite-calls-for-a-moratorium-more-three-parent-babies-expected-soon-8a2464165423 [https://perma.cc/KM2Z-EY3Q].

289. Skerrett, *supra* note 80 (noting the possibility of off-target effects where using the "nanoscissors" can cut genes other than the ones scientists want to alter).

tions of genome editing have also been used to explain the technique.[290] Similar metaphors have also been used to explain the shortcomings of the technique. For example, Professor Françoise Baylis has used the following metaphor to explain off-target effects:

> [O]ff-target effects would be like what would happen if a copyeditor used the "find and replace" function for the word *hello*, and the program also found and replaced similar words like *hell* or *jello*. These errors (edits in the wrong places) would scramble the meaning of the text. With genome editing, equivalent errors in the human genome could seriously harm patients.[291]

The mechanics of the techniques used in reproductive genetic innovation and their associated descriptions lend themselves toward an organ transplantation analogy.

The language of transplantation has also accompanied innovation in ART. This Article uses the term transfer when referring to AARTs like mitochondrial transfer and cytoplasmic transfer.[292] Yet the scientific literature also refers to the AARTs as transplants. For example, cytoplasmic transfer is referred to as both cytoplasmic transfer and cytoplasmic or "ooplasmic transplantation" by those who work at the New Jersey clinic where it was developed in the United States.[293]

The United Kingdom has taken a markedly different approach to the approval of mitochondrial transfer. After an extensive public consultation in the United Kingdom in 2012, the country approved the technique for clinical trials.[294] During that extensive public consultation, some members of the public noted that the characterization of mitochondrial transfer as a "substitution" as opposed to a "modification" rendered it different from germline modification "in the sense that it is commonly understood."[295]

Mitochondria are generally not seen as significant to identity which, at least in bioethics discourse, tends to focus on nuclear DNA.[296] Scientists and scientific groups have addressed what they perceive to be the insignificance of mitochondrial DNA to identity by stating that "since [mitochondrial DNA] does not carry any genetic data associated with the normally accepted characteristics of identity[,] [a]n analogy could be drawn with replacing the battery in a camera—the brand of the battery

---

290. Sherkow & Scott, *supra* note 34, at 1511 ("In describing CRISPR, for example, the moniker 'gene editing' has accordingly conjured up metaphors of word processing, with Cas9 . . . being likened to cut-and-paste. To further the analogy, new enzymes, to date, can find-and-replace, randomly delete, and highlight text." (citations omitted)).

291. BAYLIS, *supra* note 264, at 22.

292. *See supra* Sections II.B.1.a.–b.

293. Malter & Cohen, *supra* note 145, at 26.

294. James Gallagher, *UK Approves Three-Person Babies*, BBC NEWS (Feb. 24, 2015), https://www.bbc.com/news/health-31594856 [https://perma.cc/HM9C-CWL7].

295. HUM. FERTILISATION & EMBRYOLOGY AUTH., MITOCHONDRIA REPLACEMENT CONSULTATION: ADVICE TO GOVERNMENT 9–10 (2013).

296. *See supra* Section II.B.1.b.

does not affect the functioning of the camera."[297] In the United States, some have described the technique as "swapping" out defective mitochondria.[298] Views of mitochondria as part of a process are similar to views of many organ donation recipients who see the organ as part of a "machine" as opposed to an identity-affecting entity.[299] As Professor Julian Savulescu wrote in support of the legalization of mitochondrial transfer in the United Kingdom:

> It would be absurd to say a child who receives a liver or kidney now has 'three parents.' It is equally absurd to say a child who has been cured of mitochondrial disease has three parents.[300]

In the United Kingdom, for example, during a public discourse related to mitochondrial transfer, parallels between organ and tissue donation arose.[301] There, some of the respondents surveyed in the United Kingdom's public consultation related to mitochondrial transfer posited that because mitochondrial transfer involved a "substitution" of donated DNA as opposed to a "modification," the technique differed from genetic alteration and was thus less objectionable.[302] In other words, mitochondrial transfer might be properly considered an organ transplant instead of a prospective eugenics practice.[303] Applying the same framing that was used in the United Kingdom to U.S. discourse and decision-making related to reproductive genetic innovation could yield a similar result.

Admittedly, there are many cultural and legal differences between the United Kingdom and the United States. For example, the U.K.'s Human Fertilisation & Embryology Authority has noted that "people should feel the same about [egg and sperm donation] as they do about altruistic, or living, organ donation."[304] Similarly, the Chair of the Human Fertilisation and Embryology Authority "said she wanted egg donation to become 'as obvious as blood donation.'"[305] While it is unlikely that Americans will take such a view of egg and sperm donation for several reasons—including that egg and sperm "donation" is accompanied by compensation and not subject to the "valuable consideration" limitations of the National Organ Transplant Act—the organ transplantation lens could affect socie-

297. NUFFIELD COUNCIL ON BIOETHICS, *supra* note 14, at 53.

298. Skerrett, *supra* note 80.

299. *See, e.g.*, NAT'L ACAD. OF SCIS., ENG'G & MED., *supra* note 74, at 101.

300. Savulescu, *supra* note 154.

301. For more on the techniques used in mitochondrial transfer, see Gómez-Tatay, et al., *supra* note 80, at 28–31.

302. HUM. FERTILISATION & EMBRYOLOGY AUTH., *supra* note 295, at 16.

303. For more on the history of eugenics, see *supra* Section II.E.

304. Jane Hughes, *Egg and Sperm Donors: HFEA in Drive to Increase Numbers*, BBC NEWS (Apr. 5, 2012), https://www.bbc.com/news/health-17613561 [https://perma.cc/5MY6-UE2L].

305. Nick Collins, *Donating Sperm and Eggs 'Should Be as Common as Giving Blood,'* DAILY TELEGRAPH (Apr. 5, 2012, 6:07 PM), https://www.telegraph.co.uk/news/health/news/9185916/Sperm-and-egg-donation-should-be-like-giving-blood.html [https://perma.cc/2AH4-AMAM].

tal and regulatory acceptance of reproductive genetic innovation.[306]

B. Medicine and Innovation

There are different models of accepting innovation.[307] One model is to attempt a new innovation, introduce it into clinical practice, and see what happens afterwards; this is often used in fertility treatment.[308] Another model of innovation is to conduct extensive studies and release that technique to the public after those studies favor widespread clinical use; pharmaceutical regulation is one variant of this model.[309] Medicine implements both methods. Pharmaceuticals are known for the many "phases" required before a product obtains marketing approval by the FDA.[310] Surgery is known for its hands-off innovation from the perspective of governmental regulators, as is ART that does not involve any genetic modification.[311] Neither model is perfect. Even with the many

306. Hughes, *supra* note 304. In the United States, the term donor accompanies egg and sperm donation, even though there is a robust market in which donors are essentially compensated. *See, e.g.*, Bridget J. Crawford, *Tax Talk and Reproductive Technology*, 99 Bos. U. L. Rev. 1757, 1757–65 (2019); Kimberly D. Krawiec, *Altruism and Intermediation in the Market for Babies*, 66 Wash. & Lee L. Rev. 203, 218, 220–23 (2009).

307. *See* King et al., *supra* note 43, at 36; Nancy M.P. King & Gail Henderson, *Treatments of Last Resort: Informed Consent and the Diffusion of New Technology*, 42 Mercer L. Rev. 1007, 1012–13 (1991); Patrick L. Taylor, *Overseeing Innovative Therapy Without Mistaking It for Research: A Function-Based Model Based on Old Truths, New Capacities, and Lessons from Stem Cells*, 38 J.L. Med. & Ethics 286, 287 (2010).

308. Jane Johnson & Katrina Hutchison, *They Know How to Work It, That's Their Focus in Life: The Complex Role of Industry Representatives in Surgical Innovation*, 13 J. Empirical Rsch. on Hum. Rsch. Ethics 461, 462 (2018) ("Sometimes innovations devised on the spot to solve a crisis can be so successful that they can find their way into routine practice."); Taylor, *supra* note 307, at 287; King & Henderson, *supra* note 307, at 1012; Jack Wilkinson, Phillipa Malpas, Karin Hammarberg, Pamela Mahoney Tsigdinos, Sarah Lensen, Emily Jackson, Hoyce Harper & Ben W. Mol, *Do à la Carte Menus Serve Infertility Patients? The Ethics and Regulation of In Vitro Fertility Add-Ons*, 112 Fertility & Sterility 973, 973–75 (2019); Joyce Harper, Emily Jackson, Karen Sermon, Robert John Aitken, Stephen Harbottle, Edgar Mocanu, Thorir Hardarson, Raj Mathur, Stephane Viville, Andy Vail & Kersti Lundin, *Adjuncts in the IVF Laboratory: Where Is the Evidence for 'Add-On' Interventions?*, 32 Hum. Reprod. 485, 486 (2017); Pamela Mahoney Tsigdinos, *The Big IVF Add-On Racket*, N.Y. Times (Dec. 12, 2019), https://www.nytimes.com/2019/12/12/opinion/ivf-add-ons.html [https://perma.cc/4RE2-7E96]; Carbone, *supra* note 155, at 114.

309. *See* Nathan Cortez, *FDA and the Marketplace of Ideas for Medical Products*, 45 J.L. Med. & Ethics 39, 39 (2017) (discussing FDA's need to review scientific basis and clinical evidence before endorsing a product's safety and effectiveness); Taylor, *supra* note 307, at 287; King & Henderson, *supra* note 307, at 1012; Interview by Christine Lingham of Peter Marks at Molecular Med. Tri-Conference, *supra* note 35; Raymond V. Damadian, *The Story of MRI*, 266 Saturday Evening Post 53, 55–92 (1994).

310. *See* Cortez, *supra* note 309; Dov Fox, *Safety, Efficacy, and Authenticity: The Gap Between Ethics and Law in FDA Decision-Making*, 2005 Mich. St. L. Rev. 1135, 1161–64 (2005) (summarizing the process of FDA approval); Aaron S. Kesselheim, Michael S. Sinha, Jerry Avorn & Ameet Sarpatwari, *Pharmaceutical Policy in the United States in 2019: An Overview of the Landscape and Avenues for Improvement*, 30 Stan. L. & Pol'y Rev. 421, 432, 448 (2019).

311. *See* Carbone & Medeira, *supra* note 42, at 72–73; Dov Fox, *Reproductive Negligence*, 117 Colum. L. Rev. 149, 161–62 (2017); Saksham Gupta, Ivo S. Muskens, Luis Bradley Fandino, Alexander F.C. Hulsbergen & Marike L.D. Broekman, *Oversight in Surgical Innovation: A Response to Ethical Challenges*, 42 World J. Surgery 2773, 2773 (2018) ("[S]urgical innovation currently falls outside the realm of oversight since it is often

phases of innovation required before obtaining FDA marketing approval, many pharmaceuticals still harm people, whether those harms are known before approval (and thus disclosed in product labeling) or discovered afterwards through mechanisms such as physician reporting or medical malpractice litigation.[312] Some devices, surgical procedures, and assorted add-ons in ART are particularly ineffective, yet they continue to be commonly marketed and provided to patients.[313] Further, if randomized controlled trials are used in relation to these ineffective techniques, it is often *after* the techniques are commonly used.[314]

Currently, reproductive genetic innovation cannot benefit from either model. The FDA has declared jurisdiction over those techniques, and Congress has prohibited the FDA from considering the applications of those gene modifying techniques where the FDA has asserted jurisdic-

---

intended to benefit an individual patient rather than systematically investigate a procedure."); King, *supra* note 155, at 322 (discussing the "theory-driven" nature of ART innovation); David Magnus, *Translating Stem Cell Research: Challenges at the Research Frontier*, 38 J.L. MED. & ETHICS 267, 267–68 (2010); Anna C. Mastroianni, *Liability, Regulation and Policy in Surgical Innovation: The Cutting Edge of Research and Therapy*, 16 HEALTH MATRIX 351, 366–69 (2006); Noah, *supra* note 68, at 618 ("The government plays essentially no role in reviewing new medical procedures . . . in advance of their use in patients, leaving the task of scrutinizing the safety and effectiveness of innovative techniques for biomedical researchers and professional self-regulation . . . ."); Sharon Begley, *From Assisted Hatching to Embryo Glue, Most IVF 'Add-Ons' Rest on Shaky Science, Studies Find*, STAT NEWS (Nov. 5, 2019), https://www.statnews.com/2019/11/05/ivf-add-ons-shaky-science-studies [https://perma.cc/T8U2-ULH6].

312. *See* Nicholas S. Downing, Nilay D. Shah, Jenerius A. Aminawung, Alison M. Pease, Jean-David Zeitoun, Harlan M. Krumholz & Joseph S. Ross, *Postmarket Safety Events Among Novel Therapeutics Approved by the US Food and Drug Administration Between 2001 and 2010*, 317 J. AM. MED. ASS'N 1854, 1861; George Horvath, *Trading Safety for Innovation and Access: An Empirical Evaluation of the FDA's Premarket Approval Process*, 2017 BYU L. REV. 991, 997; Justin M. Mann, *FDA Adverse Event Reporting System: Recruiting Doctors to Make Surveillance a Little Less Passive*, 70 FOOD & DRUG L.J. 371, 375–78 (2015); J. David Prince, *The Puzzle of Parallel Claims, Preemption, and Pleading the Particulars*, 39 WM. MITCHELL L. REV. 1034, 1044–45 (2013) (discussing the facts that led to the holding in *Riegel v. Medtronic, Inc.*, 552 U.S. 312 (2008), in which a patient suffered severe injuries and permanent disabilities from the use of an FDA-approved medical device); *Finding and Learning About Side Effects (Adverse Reactions)*, U.S. FOOD & DRUG ADMIN. (July 19, 2018), https://www.fda.gov/drugs/drug-information-consumers/finding-and-learning-about-side-effects-adverse-reactions [https://perma.cc/5KAP-7WX7].

313. *See* Harper et al., *supra* note 308, at 486; Wilkinson et al., *supra* note 308, at 973–75; Aaron E. Carroll, *Heart Stents Are Useless for Most Stable Patients. They're Still Widely Used*, N.Y. TIMES (Feb. 12, 2018), https://www.nytimes.com/2018/02/12/upshot/heart-stents-are-useless-for-most-stable-patients-theyre-still-widely-used.html [https://perma.cc/6Q7W-JM53]; Tracie White, *Stents, Bypass Surgery Show No Benefit in Heart Disease Mortality Rates Among Stable Patients*, STAN. MED. NEWS CTR. (Nov. 16, 2019), https://med.stanford.edu/news/all-news/2019/11/invasive-heart-treatments-not-always-needed.html [https://perma.cc/W3J5-6X22]; Tsigdinos, *supra* note 308.

314. *See* Sarah Armstrong, Monique Atkinson, Jeanette MacKenzie, Allan Pacey & Cynthia Farquhar, *Add-Ons in the Laboratory: Hopeful, but Not Always Helpful*, 112 FERTILITY & STERILITY 994, 994–95 (2019); Garrison, *supra* note 43, at 1634–36; Sarah Lensen, Jack Wilkinson & Lynn Sadler, *A Randomized Trial of Endometrial Scratching Before In Vitro Fertilization*, 380 NEW ENG. J. MED. 1777, 1777–78 (2019); Sarah Lensen, Norman Shreeve, Kurt T. Barnhart, Ahmed Gibreel, Ernest Hung Yu Ng & Ashley Moffett, *In Vitro Fertilization Add-Ons for the Endometrium: It Doesn't Add-Up*, 112 FERTILITY & STERILITY 987, 987, 990 (2019); Begley, *supra* note 311.

tion.[315] The effect is to prohibit some strides in this area generally and to drive some physicians, researchers, and patients abroad.

Within the realm of federally regulated medical products, ascertaining which products are drugs and which products are biologics is difficult—this problem has resulted in the creation of a new statutory category, "combination products."[316] The creation of this category forms part of a regulatory and statutory reaction to the evolution of medical therapies that do not always fit neatly within one category. This Article highlights the statutory categories of drugs and biologics because the FDA has previously asserted that AARTs and germline genetic modification will be regulated similarly to drugs, biologics, or both.[317] In previous works, I have argued that subjecting techniques involving genetic modification to federal law, which occurred before Congress added the recurring budget rider that currently prevents the FDA from considering these techniques, stemmed from the commingling of social and political considerations with regulatory decision-making related to techniques involving genetic modification in reproduction.[318] I have also argued that these techniques fall outside of the jurisdiction of the FDA because they are part of the state-regulated practice of medicine.[319] Under the FDA's jurisdictional assertion, these reproductive techniques would be classified as products (namely drugs, biologics, or both) instead of similar techniques like IVF or surgical techniques.[320] Applying such federal regulatory requirements to the practice of medicine has had chilling effects in the field of U.S. ART-involving genetic innovation, which caused physicians who had been providing those techniques to stop providing them domestically or to travel abroad to provide the techniques to interested parties.[321] I continue that argument in this Article.

The regulatory treatment of organ transplantation also provides a state-centric regulatory pathway that should also be followed in reproductive genetic innovation. Traditional ART has also benefitted from a state-centric manner of regulation in which the federal government is

315. *See FDA Regulation of Human Cells, Tissues, and Cellular and Tissue-Based Products (HCT/P's) Product List*, *supra* note 136.

316. 21 U.S.C. § 353(g)(1)(A); *see also* FDA Regulation of Combination Products; Public Hearing, 67 Fed. Reg. 65,801, 65,801–04 (Oct. 28, 2002), http://www.govinfo.gov/content/pkg/FR-2002-10-28/pdf/02-27267.pdf [https://perma.cc/KKB3-MY6L]; *Frequently Asked Questions About Combination Products*, U.S. FOOD & DRUG ADMIN., http://www.fda.gov/combination-products/about-combination-products/frequently-asked-questions-about-combination-products [https://perma.cc/Z8P3-L6QG]. Biological products are defined in 42 U.S.C. § 262(i); drugs are defined in 21 U.S.C. § 321(g)(1).

317. *See FDA Regulation of Human Cells, Tissues, and Cellular and Tissue-Based Products (HCT/P's) Product List*, *supra* note 136; *see also* 42 U.S.C. § 262(j).

318. *See generally* Lewis, *Subterranean Regulation*, *supra* note 35; Lewis, *The American Democratic Deficit*, *supra* note 42.

319. *See* Lewis, *Subterranean Regulation*, *supra* note 35, at 1281–89; Myrisha S. Lewis, *Halted Innovation: The Expansion of Federal Jurisdiction over Medicine and the Human Body,* 2018 UTAH L. REV. 1073, 1086–109.

320. *See FDA Regulation of Human Cells, Tissues, and Cellular and Tissue-Based Products (HCT/P's) Product List, supra* note 136; *see also* 42 U.S.C. § 262(j).

321. Lewis, *Subterranean Regulation*, *supra* note 35, at 1260–62.

marginally involved in regulation, namely by the provision of laboratory safety standards that aim to prohibit cross-contamination and impose testing requirements under limited circumstances.[322] While many scholars have called for increased regulation of ART, I do not join that call.

At its inception, the government treated organ transplantation as surgical innovation, which was minimally regulated as part of the state-based practice of medicine, allowing organ transplantation research to develop further.[323] Yet organ transplantation's growth under a state-centric regime did not prevent legal scrutiny. Some pioneering surgeons like Dr. Norman Shumway faced prosecutorial scrutiny, although he was ultimately not criminally charged.[324] States also passed statutes to clarify the definition of death, which ultimately minimized the specter of prosecution, the threat of criminal prosecutions to assisting healthcare workers, and the likelihood of wrongful death lawsuits post operation.[325]

States have a history of legislating in the realm of reproduction that could be useful in terms of limiting reproductive genetic innovation. For example, a state-centric approach would not mean that all forms of reproductive genetic innovation would be permitted. States have specifically enacted statutes banning human reproductive cloning for example.[326] States also prohibit the sale of human organs through statutes supplementing the National Organ Transplant Act.[327]

Reproductive genetic innovation would benefit from a state-centric form of regulation for several reasons. First, looking at the example of organ transplantation, where research was permitted to flourish without federal barriers, reproductive genetic innovation would benefit from a permissible regime in which research can continue instead of the current regime where wealthier individuals can travel abroad to obtain techniques that are not permitted in the United States. Second, a permissive regime would allow the United States to benefit from state "laboratories of experimentation."[328]

Further, there is a robust regime of scientific and medical regulation in the United States. State laws do apply to medicine and research, and many institutions follow federal regulations for all research, even if the specific research being conducted is not federally funded.[329] There is also

---

322. *See supra* note 130 (citing federal regulations relevant to ART laboratory safety).
323. NAT'L ACAD. OF SCIS., ENG'G & MED., *supra* note 74, at 147.
324. STARZL, *supra* note 25, at 148.
325. *See supra* note 67 and accompanying text (discussing state statutes on the definition of death and organ donation).
326. Judith F. Daar, *The Prospect of Human Cloning: Improving Nature or Dooming the Species?*, 33 SETON HALL L. REV. 511, 518 (2003); Adrienne N. Cash, *Attack of the Clones: Legislative Approaches to Human Cloning in the United States*, 26 DUKE L. & TECH. REV. 1, 4 (2005).
327. *See supra* note 67 and accompanying text (discussing state statutes on the definition of death and organ donation).
328. *See, e.g.*, New State Ice Co. v. Liebmann, 285 U.S. 262, 311 (1932) (Brandeis, J., dissenting).
329. *See, e.g.*, MD. CODE ANN., HEALTH–GEN. § 13-2002 (West 2019); CAL. HEALTH & SAFETY CODE § 111525 (West 2019) (requiring and defining the role of consent "[p]rior to

an aspect of self-regulation, as evidenced by the many practitioners of reproductive genetic innovation who expressed their outrage at Dr. He's use of germline gene editing which they deemed premature.[330] Moreover, if techniques move from experimental to established, insurance coverage could play a limiting role.[331] To revisit enhancement or eugenics concerns, it is unlikely that insurance companies would pay for enhancement-based uses of reproductive genetic innovation because insurance companies focus on covering medical necessity.[332] While neither insurance limitations nor state law prohibit normatively undesirable uses of reproductive genetic innovation, rogue actors will likely flourish regardless of regulatory restrictions.[333]

Alternatively, limitation of the scope of the recurring budget rider might engender positive growth. Currently, the interpretation of the budget rider includes techniques that involve genetic substitutions instead of modifications like cytoplasmic and mitochondrial transfer.[334] Thus, Congress should consider re-writing the budget rider to clarify that techniques such as mitochondrial and cytoplasmic transfer, which involve far less genetic change than germline gene editing, do not constitute "heritable genetic modification." Alternatively, the FDA could change its interpretation of the budget rider to exclude techniques like cytoplasmic and mitochondrial transfer. A narrower interpretation could facilitate a piecemeal approach to innovation in which AARTs, which involve less modification than germline gene editing, could also serve as a potential model for future uses of germline gene editing and other forms of reproductive genetic innovation.[335]

C. Reducing Sensationalism

While there are certainly reasoned concerns that accompany reproductive genetic innovation, such as those related to efficacy, equality, and eugenics, these issues should be approached through a lens of medical analysis as opposed to sensationalism. Besides supporting a reasoned inquiry, the organ transplant analogy also cabins out uses of reproductive genetic innovation that would not occur for therapeutic reasons. These concerns for enhancement are often the basis for the slippery slope argu-

---

prescribing or administering an experimental drug"); Barbara A. Noah, *Bioethical Malpractice: Risk and Responsibility in Human Research*, 7 J. Health Care L. & Pol'y 175, 214 n.168 (2004).

330. R. Alta Charo, *Rogues and Regulation of Germline Editing*, 380 New Eng. J. Med. 976, 977 (2019).

331. *Id.* at 979 (discussing insurance coverage of medically necessary treatments and products).

332. *Id.*

333. *Id.* at 976.

334. *See 3 Biological Parents, 1 Child, and an International Controversy*, *supra* note 38 (quoting Eli Adashi, M.D.); Letter from Mary A. Malarkey, *supra* note 143.

335. While this Article focuses on three techniques, there is an expectation that scientists will continue to innovate in this area. *See, e.g.*, June Carbone, *Peer Commentary: In Vitro Gametogenesis: Just Another Way to Have a Baby.*, 3 J.L. & Biosciences. 673, 674–76 (2016).

ments that lead opponents of reproductive genetic innovation to assume that the potential perils of reproductive genetic innovation should outweigh imminent disease-curing uses.[336] Even though organ transplants are substitutions that are commonly accepted, not all organ or genetic substitutions would automatically be societally acceptable. For example, organ transplants are used to replace diseased or defective organs, not healthy ones. This Article focuses on the medical or therapeutic use of gene editing, which is the first expected use, just as organ transplants are used for life-saving purposes, although a larger discussion may ultimately need to emphasize possible enhancements related to organ transplantation, such as face transplants, which have been recently carried out.[337]

There are many techniques and practices that enjoyed former societal acceptance but are now (generally) rejected such as conversion therapy for children and ovariotomies and lobotomies to treat mental illness symptoms.[338] Yet the current structure is one in which the regulatory system seems to be at an impasse. Instead of facilitating research that would explore these concerns, progress is halted in the United States, driven abroad, or driven underground.[339] The current regime of FDA assertions of jurisdiction and the recent appropriations rider prevent techniques involving reproductive genetic innovation from moving from "experimental to established."[340] These federal actions serve to stymie research and innovation.

---

336. The term enhancement is difficult to define. For an example of its typical use, see Javitt & Hudson, *supra* note 74, at 1217 ("For example, in 1997 the RAC sponsored the first Gene Therapy Policy Conference to discuss the use of gene therapy for 'enhancement,' meaning for use in non-life-threatening conditions such as baldness." (citation omitted)); NAT'L ACAD. OF SCIS., ENG'G & MED., *supra* note 74, at 9; King, *supra* note 77, at 1077 ("Discussion of the similarities and differences among prevention, treatment, and enhancement is a debate that is older and broader than genetics . . . Consider just two examples: vaccines *enhance* immune system function in order to *prevent* infection; erythropoetin is a *treatment* used to restore red blood cell production after cancer chemotherapy causes anemia, but it is also used to increase the blood's oxygen-carrying capacity in order to *prevent* altitude sickness or enhance aerobic efficiency in healthy individuals.").

337. The topic of therapy versus enhancement is a part of a robust medico-legal literature. A companion article focused on the normalization of reproductive genetic innovation will address this topic.

338. *See, e.g.*, Thomas Schlich, *Cutting the Body to Cure the Mind*, 2 LANCET PSYCHIATRY 390, 391–92 (2015); Rebecca Klein, *Millions of Taxpayer Dollars Are Going to Schools That Push Conversion Therapy*, HUFFINGTON POST (June 10, 2020, 5:45 AM), https://www.huffpost.com/entry/voucher-programs-conversion-therapy_n_5ed07722c5b6c9605a95e4a2 [https://perma.cc/S2LM-6DRP]; *Policy and Position Statements on Conversion Therapy*, HUM. RTS. CAMPAIGN (providing the position statements of various medical and professional organizations on conversion therapy), https://www.hrc.org/resources/policy-and-position-statements-on-conversion-therapy [https://perma.cc/24N6-EKPG]; *The Lies and Dangers of Efforts to Change Sexual Orientation or Gender Identity*, HUM. RTS. CAMPAIGN, https://www.hrc.org/resources/the-lies-and-dangers-of-reparative-therapy [https://perma.cc/7QC4-M8VB].

339. *See* Lewis, *Subterranean Regulation*, *supra* note 35, at 1259–62.

340. Richard A. Rettig, *Origins of the Medicare Kidney Disease Entitlement: The Social Security Amendments of 1972*, *in* INST. OF MED., BIOMEDICAL POLITICS 176, 179 (Kathi E. Hanna ed., 1991); *id.* at 181 ("The Gottschalk Committee report, in 1967, sanctioned dialysis and transplantation as established therapies, thus resolving the conflict between clinicians who wished to treat patients and researchers who thought dialysis experimental.").

Medical innovations are experimental before they become commonplace. Even today, adverse effects are continually discovered of approved pharmaceuticals and approved procedures.[341] Patients who see medical practitioners for routine surgeries like wisdom teeth extraction, root canals, tonsillectomies, obstetrical procedures, and liposuction are presented with the many ways that those surgeries and procedures could go wrong or be potentially fatal or harmful to the unborn.[342] The same dangers exist with organ transplantation for both the living donors and the recipients in addition to dangers that are specific to heritable genetic modification (and FDA-approved non-heritable genetic modification).[343]

Applying the lens of organ transplantation to reproductive genetic innovation reveals that, while there is significant opposition to gene modifying techniques, it is possible that the reaction to treatment through gene modifying techniques resembles the reaction to organ transplantation in the 1970s. As a result, with expected increases in safety and efficacy over time, the acceptance of reproductive genetic innovation could increase. Moreover, the body-modifying aspects of reproductive genetic innovation may be disregarded, like the body-modifying effects of organ transplantation are minimized. As noted above, organ transplantation involves the modification of the human body to the extent that recipients of organs must take anti-rejection drugs for years, obtain new organs or tissue, and in the case of bone marrow donation, the DNA of the donor becomes a part of the recipient's blood.[344] Further, the acceptance of organ transplantation that stemmed from advances in efficacy through anti-rejection drugs, Congressional hearings on insurance coverage of the technique, and societal discourse through litigation, reveals a path forward for the acceptance of gene modifying techniques.[345]

Many of the same risks of organ transplantation exist with techniques

341. *See, e.g.*, Downing et al., *supra* note 312, at 1854 (explaining that of 222 novel therapeutics approved between 2001 and 2010, 32% had a post-market safety event); *Finding and Learning About Side Effects (Adverse Reactions)*, *supra* note 312. For information on week-to-week recalls and market withdrawals, see *Recalls, Market Withdrawals, & Safety Alerts*, U.S. FOOD & DRUG ADMIN., https://www.fda.gov/safety/recalls-market-withdrawals-safety-alerts [https://perma.cc/NV4Y-SVA5].

342. Garrison, *supra* note 43, at 1633, 1636–37; Hogan et al., *supra* note 208, at 247–54; George P. Smith, *The Vagaries of Informed Consent*, 1 IND. HEALTH L. REV. 109, 112–23 (2004); Wu et al., *supra* note 208, at 349; Hannink, *supra* note 208; *Liposuction: Lipoplasty*, *supra* note 208; Wilson, *supra* note 208; *Wisdom Tooth Extraction*, *supra* note 208.

343. *See, e.g.*, Steinbrook, *supra* note 194; *supra* Section III.D.1 (discussing the comparative efficacy of various organ transplants and the adverse events suffered by historical and contemporary transplant recipients and donors).

344. *See, e.g.*, Kolata, *supra* note 188; Murphy, *supra* note 19; *Post-Transplant Medications*, UNITED NETWORK FOR ORGAN SHARING, https://transplantliving.org/after-the-transplant/preventing-rejection/post-transplant-medications [https://perma.cc/43QH-5B92].

345. A future Article will adapt some of the events in the acceptance of organ transplantation (beyond abolishing the current budget rider and convening Congressional hearings), to show how events should unfold in a manner that fosters societal education and potentially societal acceptance.

involving reproductive genetic innovation.[346] Admittedly, the analogy between organ transplantation and germline gene editing is not perfect. But few analogies are. Some parts of the analogy to organ transplantation work better for certain techniques. For example, the analogy between mitochondrial transfer and organ transplantation is likely easier to draw because mitochondrial transfer involves substitution but usually not modification as the terms are generally understood.[347] Some areas of particular differences include the general lack of heritable genetic changes, at least under our current understanding of the science.[348] There are certainly differences in kind and degree between the uncertainty of organ transplantation; however, these differences should not result in the prohibition of techniques involving reproductive genetic innovation.

There are still a number of unknowns in the realm of reproductive genetic innovation. In 2002, an article co-authored by one of the providers of cytoplasmic transfer in the U.S., before it was effectively banned by the FDA, noted "the true extent, nature, and variability of mitochondrial transfer and maintenance during development following cytoplasmic transfer are not yet understood."[349] Similarly, many note that there is no way to know what the long-term effects of germline gene editing are.[350] Others object to germline gene editing because it also produces unpredictable effects, namely "off target effects," which is also a concern with forms of gene editing that do not result in heritable changes.[351] Some object based solely on the heritability of genetic modification, and others object based on a combination of the aforementioned reasons. Yet there is no way to know what long-term effects of many procedures and products may arise.

It may turn out that the safety- or bioethically-based concerns that accompany germline gene editing and AARTs are revealed to have a proven basis in fact. This may severely limit the use of these techniques or weigh against incorporating techniques involving genetic modification.[352]

---

346. *See, e.g.*, Horowitz, *supra* note 200, at 14; *supra* note 127–128 and accompanying text (discussing the risks of genetic modification); *supra* note 344 and accompanying text (discussing the risks of organ transplantation).

347. *See supra* Section II.B.1.b (discussing mitochondrial transfer and society's view that it is substitution, not modification).

348. *See supra* note 19 (discussing an individual whose semen contains the DNA of his bone marrow donor).

349. *See* Malter & Cohen, *supra* note 145, at 31.

350. DOV FOX, BIRTH RIGHTS AND WRONGS: HOW MEDICINE AND TECHNOLOGY ARE REMAKING REPRODUCTION AND THE LAW 26 (2019).

351. Interview by Christine Lingham of Peter Marks at Molecular Med. Tri-Conference, *supra* note 35.

352. For concerns about harming children, see George J. Annas, Lori B. Andrews & Rosario M. Isasi, *Protecting the Endangered Human: Toward an International Treaty Prohibiting Cloning and Inheritable Alterations*, 28 AM. J.L. & MED. 151, 158 (2002) ("[M]any believe that . . . inheritable genetic alternations at the embryo level will never be safe because they will always be inherently unpredictable in their effects on the children and their offspring."); Katherine Drabiak, *Untangling the Promises of Human Genome Editing*, 46 J.L. MED. & ETHICS 991, 997 (2018) (discussing safety risks with germline modification and its potential harm on children).

Often, genetic changes are associated with negative health outcomes as a result of disease-causing mutations. These disease-causing mutations can result from inheritance, environmental conditions, and other causes.[353] Currently, techniques involving reproductive genetic innovation involve changing genetic material for medical treatment, which is a positive accomplishment, although they could ultimately be used for enhancement purposes.[354]

For at least some legislative and regulatory actors, the recurring appropriations rider and the FDA's jurisdictional assertions are motivated by social or political views that have the potential to impact regulatory decision-making.[355] By changing the discourse related to techniques involving reproductive genetic innovation, it is possible to influence the views of Congressional and administrative agency actors. Ultimately, to the extent that this discourse can resolve issues related to moral or political views, it could reduce reproductive or medical tourism. As indicated by the above example of physicians and patients traveling to jurisdictions with lax regulations, patients, including American patients, are willing to travel to these jurisdictions to obtain reproductive techniques.[356] This is less than ideal and possibly harmful. As society waits for improvements in germline genetic modification that could render it suitable for more widespread clinical trials and forward movement in the research and use of mitochondrial and cytoplasmic transfer, viewing techniques involving reproductive genetic innovation through the lens of organ transplantation could minimize sensational views of the technique and facilitate discourse, objective analysis, funding, and research.

V. CONCLUSION

Scientists and physicians routinely engage in procedures that result in the genetic modification of a patient that, while once viewed as controversial for safety reasons (or not at all in the realm of natural occurrences), similarly elicited moral panic, albeit to a lesser extent than the amount of moral panic that is accompanying heritable gene editing today. Drawing upon the histories of commonly accepted procedures, including organ transplantation and the United Kingdom's experience in approving

353. *See* COMM. ON ASSESSING INTERACTIONS AMONG SOC., BEHAV., AND GENETIC FACTORS IN HEALTH, GENES, BEHAVIOR, AND THE SOCIAL ENVIRONMENT: MOVING BEYOND THE NATURE/NURTURE DEBATE 50–53 (Lyla M. Hernandez and Dan G. Blazer eds., 2006) (discussing "gene-environment interactions"), https://www.ncbi.nlm.nih.gov/books/NBK19929/pdf/Bookshelf_NBK19929.pdf [https://perma.cc/P4K3-QPWL]; *see also* discussion of mitochondrial inheritance *supra* Section II.B.1.b.

354. Often, genetic mutations cause disease. *See, e.g.*, NAT'L ACAD. OF SCIS., ENG'G & MED., *supra* note 74, at 111; Murdoch, *supra* note 169 ("Like PGD, preventing mitochondrial DNA disease falls within the good medical practice of preventing serious illness, not eugenics.").

355. Cohen, *supra* note 42, at 453–54 (noting the scant legislative history accompanying the budget rider which prohibits FDA consideration of techniques involving heritable genetic modification); Stein, *supra* note 259.

356. *See supra* Section II.B.2.

clinical trials related to mitochondrial transfer, this Article situates innovative heritable gene editing techniques within the realm of medical procedures.[357] The modifications of genetic composition resulting from these reproductive genetic techniques, by themselves, should be insufficient to hinder their use.

357. *See* Gretchen Vogel, *United Kingdom Gives Green Light for Mitochondrial Replacement Technique*, SCI. (Dec. 15, 2016, 11:30 AM), https://www.sciencemag.org/news/2016/12/united-kingdom-gives-green-light-mitochondrial-replacement-technique [https://perma.cc/S8HN-7SYY].