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The tyranny of choice: reproductive selection in the future

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ABSTRACT

This article explores the enormous challenges to reproductive decision making that could result from two emerging technologies: the potential capacity to create vast numbers of embryos for preimplantation genetic diagnosis and the ability to obtain ever more predictive information about the embryo. Together these technologies could change our reproductive experience, exacerbate existing inequities, and profoundly affect reproductive decision making. Simply comprehending the dizzying amounts of predictive information about the health and traits of future children will overwhelm future parents. But trying to choose embryos with the 'best' combination of genetic variants could be paralyzing. Nevertheless, numerous pressures will make this technology alluring, compelling providers to develop remedies to assist future parents with these difficult reproductive decisions. The remedies, however, will create their own challenges. Some might test the limits of reproductive autonomy and heighten social inequities. A particularly vexing remedy would be the development of algorithms for embryo selection, which could routinize reproductive decisions, reduce societal diversity, exacerbate 'choice overload' effects, challenge professional norms, and raise the specter of eugenics. Ultimately, this article is a cautionary tale urging circumspection as technological advancements seem to propel us inevitably toward a reproductive future that could create a tyranny of choice.

KEYWORDS: preimplantation genetic testing, in vitro gametogenesis, genome sequencing, informed consent, reproductive autonomy, medical decision making

This article is influenced in many ways by the late Professor John Robertson and his work. First, it deals with new reproductive technologies, a topic to which he devoted so much of his professional life. It is impossible to grapple with issues related to reproductive technologies without considering John's important and highly influential views about reproductive autonomy and liberty. His work has been, and will continue to be, present in all discussions about the value and potential limits of new reproductive technologies.

Second, this piece follows from my first piece on in vitro gametogenesis (IVG),[1] which I presented at a Baby Markets Roundtable, where John was a commentator on an early draft. At that workshop, he also presented an early draft of a piece exploring another new reproductive technology—uterus transplants—which was ultimately published in this journal.[2] John was always intrigued by the ways in which technologies might advance reproductive options and his insights and responses to my first piece on IVG helped improve the piece immeasurably.

Finally, John was a commentator on an early draft of this piece, also presented at a Baby Markets Roundtable, which he co-hosted with Professor Michele Goodwin at the University of Texas Law School. As always, John's comments were exceptionally helpful. In addition, he was a gracious host, displaying his characteristic charm, wit, generosity, and sharp intellect. I am so grateful that I was able to attend one of the last professional meetings at which he was present. His passing is such a profound loss to all scholars interested in reproductive rights and emerging reproductive technologies not only because we will miss his voice, wisdom, and insight, but also because we have lost a dear friend and colleague.

INTRODUCTION

Important developments in genomic research and reproductive technologies are emerging in ways that could significantly change the reproductive landscape and vastly refine our capacity to select future children. Next-generation sequencing, which allows us to generate ever more meaningful information from biological specimens, will expand the range and nature of information that can be used for reproductive decision making. Improvements in our capacity to understand the clinical and phenotypic significance of genetic variants that correspond not only to diseases, but also to many non-disease traits, will also inevitably influence reproductive choices.

Other technological developments in the future may alter the way we obtain information for reproductive decision making. We are already experiencing some changes with the emergence of non-invasive prenatal testing ('NIPT'), which allows for analysis of fetal cells without the invasive procedures of amniocentesis and chorionic villus

1 Sonia M. Suter, *In Vitro Gametogenesis: Just Another Way to Have a Baby?*, 3 J. L. & Biosci. 87 (2016) [hereinafter Suter, *IVG*].

2 John A. Robertson, *Other Women's Wombs: Uterus Transplants and Gestational Surrogacy*, 3 J. L. & Biosci. 68 (2016).

sampling.[3] While still not a diagnostic test, NIPT is a highly sensitive screening test that has expanded the number of people seeking prenatal information.[4]

Preimplantation genetic diagnosis ('PGD') offers another mechanism to learn about the future child by conducting genetic analysis of embryos created through in vitro fertilization ('IVF').[5] With expanded genomic analysis, PGD could provide a wealth of information for reproductive decision making. Because PGD is expensive and requires the physically burdensome process of egg retrieval necessary for IVF, it is not a widely adopted technique for reproductive decision making.[6] However, emerging technologies, such as the creation of gametes in vitro, could change this. When combined with genome sequencing, it could have a profound effect on reproductive testing, leading to efforts to "'perfect" reproduction'[7] through a process that has been called 'Easy PGD'.[8]

Why, one might wonder, would parents choose this method of reproduction over sex? Because it could expand reproductive choice in ways we have never seen. Easy PGD ('EPGD') would allow parents to select embryos for implantation based on disease risks, less significant ailments, and even certain non-medical traits on a scale far beyond what PGD currently allows. While the number of embryos available for PGD today is limited by the number of eggs that can be retrieved from a woman, IVG would make it possible to generate hundreds or thousands of ova. As a result, it would be possible to create just as many embryos, which would maximize parents' ability to identify an embryo with the 'healthiest' or 'optimal' genetic profile.[9]

The prospect of EPGD raises a host of serious and legitimate concerns. As I have described in earlier work[10] and will only briefly revisit here, it could change our reproductive experience, alter our understanding of reproduction, and exacerbate existing inequities. In addition, if EPGD becomes a reality,[11] its capacity to offer virtually

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3 Jaime King, *Not this Child: Constitutional Questions in Regulating Non-Invasive Prenatal Genetic Diagnosis and Selective Abortion*, 60 UCLA L. Rev. 2, 6 (2012).

4 'NIPT is an accurate screening test for Down's, Edwards' and Patau's syndromes [chromosomal anomalies].' It can also be used to diagnose 'other genetic conditions and impairments in fetuses'. Nuffield Council on Bioethics, Noninvasive Prenatal Testing: Ethical Issues 2 (2017); Gary J.W. Liao et al., *Non-Invasive Prenatal Testing Using Cell-Free Fetal DNA in Maternal Circulation*, 428 Clin. Chim. Acta 44 (2014).

5 Originally, PGD involved genetic or chromosomal analysis of a single totipotent cell extracted from a 3-day-old, 8-cell embryo. Judith Daar, *A Clash at the Petri Dish: Transferring Embryos with Known Genetic Anomalies*, J. L. & Biosci. 00 (forthcoming 2018) [hereinafter Daar, *Clash*]. To improve its reliability, embryologists began to let the embryo develop to the blastocyst stage, 5 days after fertilization, when there are 100–200 cells for analysis. *Id.* at 00. Now, instead of 'taking a single blastomere from the embryo itself' for analysis, 'the standard of care is moving to removing multiple cells from the outer or placental portion of the embryo (the trophectoderm)'. *Id.*

6 The IVF procedure itself typically costs between $10,000 and $14,000 (which doesn't include the genetic diagnosis). Judith F. Daar, Reproductive Technologies and the Law 174 (2d ed. 2013). In addition, it requires egg retrieval, which can be physically taxing. See *infra* text accompanying note 15.

7 Suter, *IVG*, *supra* note 1, at 118.

8 In his new book, *The End of Sex*, he predicts that this technology will become widely adopted in the not-too-distant future. Henry T. Greely, The End of Sex 3 (2016). As is likely obvious, the title evokes his prediction that the technique will be so widely used that it will replace sex, for many, as the preferred mode of reproduction. *Id.* at 1–2.

9 Greely, *supra* note 8, at 191–96; Suter, *IVG*, *supra* note 1, at 94–95.

10 *Id.*

11 There are some reasons to be skeptical about whether this technology will emerge or more specifically how quickly it will emerge. *See infra* text accompanying notes 30–37.

unlimited reproductive options could lead to enormous decision-making challenges for those who choose this method of reproduction.

Part I describes the technologies that could lead to EPGD, including in vitro gametogenesis ('IVG') and next-generation sequencing ('NGS'). Part II reviews some of the general social and ethical concerns regarding EPGD, while Part III focuses on the decision-making challenges that EPGD would present, which would be unlike any we have seen with current reproductive testing. Next-generation sequencing and increased understanding of the links between genotype and phenotype (the observable characteristics that result from the interaction of genotype with the environment) will provide parents with dizzying amounts of probabilistic information about an enormous range of health risks and traits for each embryo. Making sense of that for one embryo is challenging enough; trying to make sense of it for tens or hundreds of embryos would be even more daunting.[12]

But the most overwhelming choices parents will confront will be deciding which embryos to implant based on the genomic profiles generated by EPGD. Genomic analysis will reveal heightened risks for some serious diseases and decreased risks for others as well as predictive information about the probabilities of non-medical traits. Trying to decide which genomic profiles possess the combination of propensities for health and non-medical traits that offer the best quality of life for the future child would be challenging if only a handful of embryos were involved. But trying to evaluate the relative tradeoffs among different sets of health risks and traits among tens or hundreds of embryos will be staggeringly difficult. How will parents even begin the process of making such choices, let alone choose? And what will this mean for decision making? While the goal of EPGD would be to maximize parental choice, the vast number of options may in fact lead to paralysing choices and 'choice overload'.[13]

Although some parents might choose to sort through the enormous amount of information to select embryos for implantation, the sheer quantity of information will undoubtedly lead many to seek some sort of guidance or shortcut to navigate this process. Part IV explores the potential remedies that professional societies, providers, or commercial entities could implement to address some of these decision-making challenges associated with information overload, including limiting the disclosure of certain kinds of information. While such remedies raise issues related to reproductive autonomy, Part V explores an even more vexing remedy: the development of algorithms to assist with the complex task of embryo selection. It argues that this remedy may be worse than the problem it tries to solve by routinizing reproductive decisions based on hidden biases, reducing societal diversity, exacerbating 'choice overload effects', challenging professional norms, and raising the specter of eugenics.

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[12] New technologies like CRISPR, which allows for precise genome editing, *see* The National Academy of Sciences, Engineering, Medicine, Human Genome Editing: Science, Ethics, and Governance (2017), compound some of these issues. My focus, however, is on the decision-making issues that arise when choosing among embryos as opposed to decisions concerning the genetic alteration of embryos through CRISPR, which are conceptually distinct and raise a different set of issues. It is certainly possible that CRISPR could be used in conjunction with EPGD, but I reserve analysis of the added complications that would pose with respect to reproductive decision making for another day.

[13] I began to think about these problems in writing a book review of The End of Sex. Sonia M. Suter, *Book Review: The End of Sex and the Future of Human Reproduction*, 3 J. L. & Biosci. 436 (2017).

In exploring these issues, the larger goal of this piece is twofold: first, to imagine what reproductive decision making might look like in a world of EPGD and second, to offer some (additional) reasons we should be skeptical about putting resources into the development of EPGD. Rather than expand reproductive choice, EPGD has the potential to create a tyranny of choice.

I. The Technology Behind Easy PGD

To make sense of the concerns regarding Easy PGD ('EPGD'), it is important to understand the technologies that would make it possible. EPGD would involve the use of four different technologies: *in vitro* gametogenesis ('IVG'), in vitro fertilization ('IVF'), preimplantation genetic diagnosis ('PGD'), and broad-scale genomic analysis, such as next-generation sequencing ('NGS'). Two of these technologies, IVF and PGD, already exist. Genome sequencing is also currently possible, but the technology and our ability to interpret this information leave much room for improvement. Finally, IVG is a promising—but not yet viable—technology for reproduction in humans. The four technologies would be used for EPGD in a multistep process. First, IVG would be used to create a large number of ova. Using IVF, the ova would be fertilized in a petri dish with naturally derived or IVG-generated sperm.[14] Finally, using NGS, PGD would identify genetic variants to create a genomic profile for each of the resulting embryos.

Assuming its safety and efficacy, the initial step of IVG would allow us to generate gametes (particularly ova) in vitro as opposed to physically retrieving them from women, which would offer a few advantages. First, it would avoid the physically burdensome and potentially risky process of obtaining eggs, which requires the woman to receive hormone injections so she can produce multiple eggs and to undergo surgery with general anesthesia to retrieve the eggs.[15] Second, IVG would allow us to obtain vastly more eggs than we can with current techniques. While hormone treatment can enhance egg production, there are still limits as to how many eggs can be obtained from a woman at any one time.[16]

In theory, IVG would present no such limits. Increasing the quantity of eggs would make it possible to create many more embryos,[17] which could enhance reproductive options. The more embryos available for genomic analysis, the more 'nuanced and comprehensive' the embryo selection process could be.[18] As one study noted, to have a 99.99% chance of selecting a particular genotype at 15 loci, one would need to create 10,000 embryos from which to choose.[19] Being able to create a large number of embryos would therefore allow for very robust embryo selection.

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14 DAAR, *supra* note 6, at 36 (describing the IVF process).

15 *Id.*; Society for Assisted Reproductive Technology, *In Vitro Fertilization (IVF): What are the Risks?* https://www.sart.org/globalassets/rf/news-and-publications/bookletsfact-sheets/english-fact-sheets-and-info-booklets/in_vitro_fertilization_ivf_what_are_the_risks_factsheet.pdf (accessed Jun. 5, 2018) (describing such risks as 'mild to moderate pelvic and abdominal pain, . . . injury to organs near the ovaries, . . . [and] pelvic infection').

16 See Hannah Bourne et al., *Procreative Beneficence and In Vitro Gametogenesis*, 30 MONASH BIOETHICS REV. 29, 33 (2012).

17 There are far fewer limits in the natural derivation of sperm. In addition, IVG could potentially be used to generate sperm, if there were any physical limits in obtaining sperm.

18 Suter, *IVG*, *supra* note 1, at 116.

19 Bourne et al, *supra* note 16, at 34, 36.

While IVG is not currently a viable technology for human reproduction, current efforts are underway to make that possible. Given that I and others have provided a more detailed description of the state of the technology elsewhere,[20] I offer only a brief account of what IVG involves. At this point, most of the research on IVG has focused on mice, with some impressive results. Researchers have been able to develop viable eggs from somatic skin cells of adult mice, which, when fertilized with naturally derived sperm, have resulted in embryos, and ultimately, the birth of healthy, fertile offspring.[21] Numerous other IVF projects are currently underway including those involving primates.[22]

To date, research on IVG in humans and nonhuman primates has not had the same level of success. Just as with earlier work in mice, the first attempts at IVG in humans involved efforts to derive gametes from embryonic stem cells.[23] With advances in stem cell research, scientists have been able to induce and isolate human primordial germ-like cells from human pluripotent stem cells.[24] While scientists have yet to produce demonstrably functional human ova, a recent article predicts 'that experimental refinements likely will permit derivation of functional eggs and sperm from human [induced pluripotent stem cells] in the not too distant future.'[25]

Assuming that IVG could lead to the creation of multiple embryos via IVF, the next step would be analysing the embryos with PGD and NGS. How effectively or easily this could be achieved is uncertain and would depend on the state of both technologies. Researchers would first need to overcome several substantial technical challenges so that genome sequencing for EPGD would be accurate, fast, and cheap. This process would require sequencing the 6.4 billion base pairs of the cells removed from the dividing embryo with 'high accuracy' and in a time frame that would both optimize the power of NGS and allow for the successful transfer of an embryo for implantation.[26] In addition, the sequencing technology would need to be affordable. Researchers are currently exploring various methods of NGS, although we should expect the nature of large-scale sequencing in the future to be different (potentially much different) from what is

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20 See Greeley, *supra* note 8, at 121–36; Suter, *IVG*, *supra* 1, at 89–91; I.G. Cohen et al., *Disruptive Reproductive Technologies*, 9 Sci. Transl. Med. 1, 1 Jan. 11, 2017, http://stm.sciencemag.org/content/scitransmed/9/372/eaag2959.full.pdf (accessed Jun. 5, 2018).

21 Quan Zhou et al., *Complete Meiosis from Embryonic Stem Cell-Derived Germ Cells in Vitro*, 18 Cell Stem Cell 330 (2016) (noting that researchers in China used embryonic stem cells to develop sperm-like cells that fertilized naturally derived eggs, eventually producing fertile mouse offspring).

22 Joseph Bennington-Castro, *You Wouldn't Believe What Baby-Making Science Could Soon Deliver*, NBC News, Feb. 1, 2017, http://www.nbcnews.com/mach/science/you-won-t-believe-what-baby-making-science-could-soon-n714411?cid=eml_mach_20170202 (accessed Jan. 1, 2018) (noting the projects of Kyle Orwig, reproductive scientist at the University of Pittsburgh, including one involving primates). So far researchers have not been able to create healthy, fertile pups using only IVG-derived gametes as opposed to a combination of an IVG-derived gamete and a naturally derived gamete. Suter, *IVG*, *supra* note 1, at 90.

23 Bourne et al, *supra* note 16, at 31.

24 Naoko Irie & M. Azim Surani, *Efficient Induction and Isolation of Human Primordial Germ Cell-Like Cells from Competent Human Pluripotent Stem Cells*. 1363 Methods Mol. Biol. 217 (2017); Kehkooi Kee et al., *Human Dazl, Daz and Boule Genes Modulate Primordial Germ-Cell and Haploid Gamete Formation*, 462 Nature 222 (2009); Charles A. Easley IV et al., *Direct Differentiation of Human Pluripotent Stem Cell into Haploid Spermatogenic Cells*, 2 Cell Rep. 440 (2012); Bourne et al., *supra* note 16, at 32.

25 Cohen et al., *supra* note 20, at 1.

26 Greely, *supra* note 8, at 107 (noting that EPGD would have to be done by the sixth day so that the embryo could be frozen or transferred).

possible right now.[27] Developing the sequencing technology will be easy, however, in comparison to the challenge of improving our ability to interpret the vast amount of data that NGS could generate. How well we will be able to do that in the future is not clear.

Given that genomic information varies in its significance in determining phenotype, we will need to be able to interpret the genome comprehensively so that we can establish which genetic variants are particularly meaningful and informative. Highly penetrant genetic variants (where the probability is high that the variant will lead to the associated phenotype)[28] will be far more informative than low penetrant genetic variants.[29] Even with lower penetrant variants, however, NGS may still be able to offer predictions about the likelihood of the phenotype's developing.

In theory, large-scale sequencing would ultimately provide comprehensive genomic information about a range of phenotypes—physical health risks, intellectual or cognitive disorders, and non-medical traits. The first two categories could be broken down based on degree of severity and age of onset (eg do they occur in childhood or adulthood?). Non-medical traits would include things like sex, physical characteristics (height, build, hair color, eye color, etc.), temperaments (tendencies toward extroversion, introversion, anxiety, etc.), and capacities in areas such as athletics, scholastics, music, etc. Crucial information would be the probability that the genotype would actually result in the specific phenotype, whether medical or non-medical. A few genotypes would be strongly determinative of phenotype; others would only increase the odds of the phenotypes, sometimes only by insignificant amounts. The degree to which our capacity to interpret the genome improves in the coming years will strongly influence how much we will be able to predict about the health and non-medical traits of future children through EPGD.

As this brief discussion suggests, the ultimate viability and timing of EPGD are to some extent speculative, dependent as they are on the development of many different technologies and the ability to combine them safely, effectively, and affordably. As the late Professor John Robertson observed in commenting on a draft of this piece, EPGD involves a number of technological steps, each of which could be a significant limiting factor: the IVG process, the mechanized fertilization leading to the creation of embryos, and the extensive throughput from NGS and PGD. It would be no small task to make each of these steps safe, effective, and affordable. Difficulties with any one step could slow, or even halt, the emergence of EPGD.[30]

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27 *Id.*

28 Joel Zlotogora, *Penetrance and Expressivity in the Molecular Age*, 5 GENET. MED. 347 (2003); David N. Cooper, *When Genotype is Not Predictive of Phenotype: Towards an Understanding of the Molecular Basis Reduced Penetrance in Human Inherited Disease*, 132 HUM. GENET. 1077 (2013); Sonia M. Suter, *Genomic Medicine: New Norms Regarding Genetic Information*, 15 HOUSTON J. HEALTH L. & POL'Y 83 (2015) [hereinafter Suter, *Genomic Medicine*].

29 The predictive value of genetic variants depends less on whether the phenotype relates to disease or traits. Some non-medical traits (such as 'skin, hair, and eye color, as well as hair type, nose shape, male pattern baldness, early gray or white hair') and some diseases are very strongly influenced by genes, which means that genomic analysis could provide useful information about these traits. Other, less penetrant, traits, such as intelligence and diabetes, may be far more difficult to predict with genomic analysis. GREELEY, *supra* note 8, at 116–18.

30 Personal commentary from Professor John Robertson, May 8, 2017.

There are other reasons to be circumspect about whether and how quickly EPGD could become a reality or whether it would become widespread. First, we might be skeptical about how much meaningful information large-scale sequencing will actually provide. But even if it is not fully comprehensive, our capacity to identify and successfully interpret a significant amount of genomic information will surely improve in the coming decades,[31] even if much of the information is probabilistic as opposed to fully determinative. Perhaps more uncertain is whether we will be able to create viable eggs and sperm for purposes of reproduction. Epigenetic challenges alone—specifically, altering the imprinting patterns of the genes in the somatic cells that would be used to generate the gametes through IVG to make them consistent with the imprinting patterns of gametes—will be difficult to achieve and will require a great deal of research.[32]

In addition, even if it becomes technologically possible to generate hundreds or even thousands of embryos, fertility clinics would confront vexing storage and funding challenges. Biobanks currently struggle to find funding to exist in perpetuity.[33] And fertility clinics already face storage issues concerning 'abandoned' embryos when gamete progenitors do not pay storage fees or cannot make decisions about disposition of extra embryos.[34] One might imagine, therefore, that fertility clinics would institute specific destruction policies for individuals who wanted to create hundreds or thousands of embryos for EPGD.

Another limiting factor might be the fact that some individuals are uncomfortable destroying embryos, even with current IVF. The potential creation and destruction of 'not just a handful of embryos, but literally thousands', would be even more troubling for such people.[35] If clinics imposed mandatory destruction requirements, this might further limit the scope of those who use EPGD.

Finally, EPGD would necessarily be limited to planned pregnancies. Given that roughly 45% of pregnancies are unintended,[36] many individuals would utilize EPGD technology only with some pregnancies, or not at all. The fact that unintended pregnancy rates are highest among poor and low-income women, young women,

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31 Professor Greely argues that these improvements 'will not happen in order to allow Easy PGD but in order to interpret the genetic risks of living people. Once it is available for that purpose, however, its application to Easy PGD is simple'. GREELY, *supra* note 8, at 119.

32 Suter, *IVG*, *supra* note 1, at 91. Some have argued that because of the genetic differences between mice and humans, this will be much more difficult to overcome in humans than in mice. See Clara Y. Cheong, *Germline and Somatic Imprinting in the Nonhuman Primate Highlights Species Differences in Oocyte Methylation*, 25 GENOME RES. 611 (2015) (detailing certain fundamental differences in imprinting control mechanisms between mice and primates).

33 See Don Chalmers et al., *Has the Biobank Bubble Burst? Withstanding the Challenges for Sustainable Biobanking in the Digital Era*, 17 BMC MED. ETHICS 39 (2016).

34 See Sharon Kirkey, *Put Limit on How Long Canadian Fertility Clinics Can Store Frozen Embryos, Academics Argue*, NATIONAL POST, June 22, 2016, http://nationalpost.com/news/canada/put-limit-on-how-long-canadian-fertility-clinics-can-store-frozen-embryos-academics-argue (accessed Jun. 1, 2018) (noting that these issues leave clinics 'in the legally tenuous position of either destroying the embryos without clear authority to do so, or storing them indefinitely').

35 *See* Suter, IVG, *supra* note 1, at 116-17.

36 Lawrence B. Finer & Mia R. Zolna, *Declines in Unintended Pregnancy in the United States, 2008-2011*, 374 NEW ENG. J. MED. 843 (2016) (noting that the unintended pregnancy rate in the USA dropped from 51% to 45% from 2008 to 2011); Jonathan Bearak et al., *Global, Regional, and Subregional Trends in Unintended Pregnancy and Its Outcomes from 1990 to 2014: Estimates from a Bayesian Hierarchical Model*, 6 LANCET e380 (2018) (finding a worldwide rate of unintended pregnancies of 44% in 2010-2014).

cohabiting women, and minority women[37] means that those most likely to use EPGD would be higher income, white women, raising serious equity concerns.

In spite of these uncertainties, research is clearly underway to develop and improve technologies that hold real promise and that would be essential to the ultimate feasibility of EPGD. While scientists may not actively try to bring about EPGD, there is good reason to believe it will emerge 'as a "secondary" use, or effect, of many other developments',[38] such as advancements in IVG and improvements in DNA sequencing and DNA analysis.[39] In addition, even if not everyone would choose EPGD (because of concerns about embryo destruction or because of unintended pregnancies), it is still highly plausible that many people (especially those with the greatest resources and education levels) would take advantage of this technology. As a result, this article operates under the assumption that EPGD could well become a significant, if not widespread, part of our reproductive landscape in the not-too-distant future. With that assumption in mind, I turn, in Part II, to the general issues with respect to EPGD and, in Part III, to the specific decision-making challenges that its emergence could present.

II. Changing Reproduction in Kind or Degree?

In many ways, as I have argued elsewhere, EPGD raises the same kinds of issues as other technological advances in reproduction. Like those technologies, EPGD is not 'per se problematic'; instead much depends on the motivations underlying its use, such as whether they are 'rooted in concern about the best interests of the child and family' or 'based on prejudice or conceptions of the future child only in terms of the presence or absence of disease or traits'.[40] Nevertheless, EPGD has the potential to 'subtly shift attitudes about prenatal selection and intensify some of the … concerns surrounding prenatal selection', such as the exacerbation of inequalities; the reinforcement of prejudice against those with disabilities or undesirable traits; and the commodification of reproduction by viewing children as products to design, rather than gifts to accept.[41]

Indeed, EPGD's ease and highly refined selection could increase the troubling aspects of reproductive selection to such an extent that it would change the reproductive experience in kind, not just degree. For example, the ability to select among so many embryos based on non-medical traits and less serious diseases could gradually, but profoundly, alter attitudes about what is in the future child's best interest. More important,

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37 Finer & Zolna, *supra* note 36, at 843, 845.

38 Greely, *supra* note 8, at 105. One question is how likely these advances and commercialization would occur in the United States as opposed to in other countries. See June Carbone, *Peer Commentary:* In Vitro *Gametogenesis: Just Another Way to Have a Baby*, 3 J. L. & Biosci. 673, 674 (2016) (suggesting that the 'initial development of IVG [one of the necessary steps for EPGD] is unlikely to take place in the United States').

39 The history of science is replete with instances in which research in one area results in secondary applications. See eg Joe Palca, *New Study Highlights Strong Link Between Basic Research and Inventions*, All Things Considered, Aug. 14, 2017, https://www.npr.org/2017/08/14/543477432/new-study-highlights-strong-link-between-basic-research-and-inventions (accessed May 28, 2018).

40 Suter, *IVG*, *supra* note 1, at 115.

41 *Id.*; Michael J. Sandel, *The Case Against Perfection*, Atlantic Monthly, Apr. 2004, at 55. This notion of accepting one's child as a gift is particularly applicable when parents select embryos based on non-medical traits or less serious medical conditions. If their selection is intended to avoid the trauma of a serious and painful illness in the future child, the gift concept may seem to minimize the serious trauma that seriously ill children and their families face.

it could shift the goal of selection from preventing harm to 'perfecting' reproduction[42] far more than occurs today with prenatal testing. These cultural shifts would routinize selection against not just disabilities, but also disfavored non-medical traits, ultimately leading to a vicious cycle: reproductive choices would reinforce prejudice by reducing the number of children born with the disfavored disabilities or traits, which would increase selection against those traits, thereby further reinforcing prejudice, etc.[43] While such a vicious cycle already exists with current reproductive technologies, the degree would be significantly different with EPGD, potentially changing the experience in kind.

In addition, being able to select embryos on the basis of a wide spectrum of medical and non-medical traits enhances the commodification concerns profoundly. Parents might fixate on the full spectrum of medical and non-medical traits they tried to avoid or cultivate through EPGD, leading to parents to see their children in terms of their potential traits. Heightened expectations might substantially raise the possibility for disappointment if children don't measure up to those expectations.

EPGD also magnifies concerns about depriving the child of an open future because it would allow parents to learn about diseases that may develop later in life. Such a result would challenge the long-held view that children should generally not be tested for late-onset conditions, but should instead be allowed to decide as adults whether they want to learn such information.[44]

Finally, EPGD could 'impoverish the informed consent process as providers and patients view [embryo selection] as routine, rather than a deeply personal choice that is not necessarily for everyone'.[45] To be sure, informed consent is already routinized to some extent with prenatal testing,[46] but this will occur to a much greater degree with EPGD, particularly if the various pressures discussed in Part III motivate enough people to use it for its refined means of selection. In addition, as Part III argues, EPGD will raise additional challenges to informed consent, leading to paralysing choices and choice overload. Unfortunately, the potential remedies to these informed-consent challenges, as Part V argues, have the potential to further routinize the decision-making process in ways we have not seen, potentially changing the experience of reproduction. Before addressing that issue, however, we turn to the paralysing choices of EPGD.

III. Paralysing Choices and Choice Overload

The rationale for combining IVG, IVF, PGD, and NGS to develop EPGD would be to offer parents a range of reproductive choices: specifically, to be able to select against

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42 Suter, *IVG, supra* note 1, at 118.

43 *Id.*

44 See eg Greer Donley et al., *Prenatal Whole Genome Sequencing: Just Because We Can Should We?*, Hastings Ctr. Rep., July–Aug. 2012, at 28, 34–35 (providing chart of guidelines from professional organizations about genetic testing in children and fetuses).

45 Suter, *IVG, supra* note 1, at 118.

46 Sonia M. Suter, *The Routinization of Prenatal Testing*, 28 Am. J. L. & Med. 233 (2002) [hereinafter Suter, *Routinization*].

certain medical conditions and/or to select for or against certain non-disease traits.[47] In spite of that goal, there are reasons to think that this expansion of choice could potentially be overwhelming for many. As Section III.A suggests, just trying to process and make sense of the vast amount and different kinds of information that EPGD could generate to decide what information would be valuable for selecting embryos could be overwhelming. On top of that, as Section III.B describes, would be the challenge of deciding what information would be valuable for selecting embryos. Finally, Section III.C explores the most difficult decision of all: evaluating the relative tradeoffs of the genomic profiles of so many embryos and choosing which embryo(s) to implant.

A. Information Overload and Comprehension Challenges

To take advantage of EPGD, future parents would first have to understand the range and type of information that EPGD could generate. This could prove complex and logistically difficult because it would provide information about hundreds or thousands of variants. The sheer quantity of information will present informational challenges. In addition, the phenotypic implications of genetic variants associated with medical conditions can differ widely in terms of the nature of the condition, the age of onset, severity, whether treatment or prophylactic measures are available, expressivity (how variable the phenotypic expression of the disease is[48]), and penetrance (the probability that the variant will lead to the associated condition[49]). Further complicating matters, the significance of some variants will be unknown.[50]

To decide what kind of information to obtain, one would need to understand the nature of information available through EPGD as well as its implications. Educating patients about all of the potential genetic variants that could be identified and their different phenotypic implications would take an enormous amount of time and personnel. Some have estimated that it would take two to six hours of in-person genetic counseling over several sessions.[51] That estimate does not include discussions about non-medical trait information. Even with an adequate number of genetic counselors and sufficient time, most individuals would have difficulty absorbing so much complex, largely probabilistic, and varied information. EPGD could, therefore, present significant problems of information overload and comprehension challenges even before people faced their first decision: determining what kind of information would be relevant for their reproductive choices with EPGD.[52]

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47 EPGD would also allow parents to select *for* medical conditions, such as deafness and dwarfism, as some parents have done. See Darshak M. Sanghavi, *Wanting Babies Like Themselves, Some Parents Choose Genetic Defects*, New York Times, Dec. 5, 2006, at D5.

48 Zlotogora, *supra* note 28, at 347 (describing expressivity as 'the differences observed in the clinical phenotype between two individuals with the same genotype').

49 *Id.*; Cooper, *supra* note 28, at 1077; Suter, *Genomic Medicine*, *supra* note 28, at 83.

50 See Mark A. Rothstein, *The Case Against Precipitous, Population-Wide Genome Sequencing*, 40 J. L. Med. & Ethics 682, 683–84 (2012); Brent L. Fogel, *Interpretation of Genetic Testing: Variants of Unknown Significance*, 17 PMC 347 (2013) (highlighting the difficulty of dealing with variants of unknown significance and how to communicate such results to patient families).

51 Jonathan S. Berg et al., *Deploying Whole Genome Sequencing in Clinical Practice and Public Health: Meeting the Challenge One Bin at a Time*, 13 Genet. Med. 499 (2011).

52 This problem is not unique to EPGD. Scholars are already addressing the decision-making challenges of moving from targeted genetic testing to genome sequencing in the general population, see eg Sarah Bowdin et al., *The Genomic Clinic: A Multidisciplinary Approach to Assessing the Opportunities and Challenges of In-*

B. Paralysing Choices and Choice Overload

Even if we could establish mechanisms to ensure adequate comprehension of the vast and varied amount of information genomic analysis could provide with EPGD, people would still face numerous challenges in deciding what information to obtain and what to do with it.

1. Deciding What to Learn. Deciding what kind of genomic information one wants to receive is not unique to the reproductive context. For example, while most individuals would want information about medically actionable health risks in the adult genetic testing context,[53] they may be uncertain about the value of learning information related to health risks for which there are limited or no interventions. People are often not good predictors, *ex ante*, about the kind of information they will want when they actually confront the option to obtain such information.[54] It is, after all, sometimes very hard to know what our future desires will be.

These challenges are potentially even greater in the reproductive context where the interest in and desire for genetic information is not simply a medical decision, but a choice based on personal values and circumstances. Certainly such factors come into play with many medical decisions to varying degrees. But personal values and circumstances are particularly central to decisions concerning prenatal testing—by which I mean amniocentesis, chorionic villus sampling, or NIPT, as opposed to (ordinary or Easy) PGD[55]—because, currently, prenatal testing is not offered with the goal of providing treatment for serious medical conditions.[56] Instead, its goal is to give parents the opportunity to prepare for the birth of a child with an identified medical condition or to consider pregnancy termination or placing the child for adoption. Because there is usually no medically 'optimal' choice, decision making in this context is especially influenced by one's beliefs and personal situation. It is a complicated process inextricably

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tegrating Genomic Analysis into Clinical Care, 35 Hum. Mutat. (2014); Henry T. Greely, *Get Ready for a Flood of Genetic Testing*, 469 Nature 289 (2011); Rothstein, *supra* note 50, at 683–84, and in the context of prenatal testing, see Dina F. Maron, *What Fetal Genome Screening Could Mean for Babies and Parents*, Scientific American, Jan. 15, 2014, https://www.scientificamerican.com/article/what-fetal-genome/; Susan Y. Rojahn, *A Brave New World of Prenatal DNA Sequencing*, MIT Technology Review, https://www.technologyreview.com/s/510181/a-brave-new-world-of-prenatal-dna-sequencing/ (describing the growing market for prenatal genome sequencing and the techniques involved) (accessed Jan. 1, 2018).

53 See *ACMG Recommendations for Reporting Incidental Findings in Clinical Exome and Genome Sequencing*, 13 Am. C. Med. Genet. & Genomics 565, 567–68 (2013).

54 When genetic testing for Huntington's disease first became available, the number of people with a family history of the disease who had indicated that they would seek genetic testing for the gene was much greater than the number who actually sought genetic testing. Susan Creighton et al., *Predictive, Prenatal and Diagnostic Genetic Testing for Huntington's Disease: The Experience in Canada from 1987 to 2000*, 63 Clini. Genet. 462 (2003).

55 Technically, PGD is also prenatal testing, but the latter term generally refers to testing associated with a pregnancy, whereas PGD is a form of preimplantation testing.

56 Of course, given that I am speculating about a future technology, CRISPR could well be a viable means to correct certain genetic variants that threaten the health of the fetus. Whether the desire to avoid disease will lead to a greater uptake of CRISPR over EPGD is a question beyond the scope of the article. The two technologies, however, would offer different purposes. It is unclear whether more people would prefer to select the 'optimal' embryo or edit the genome of a fetus. In any event, it is likely that the two techniques would coexist.

intertwined with issues of reproductive autonomy[57] and also linked to desires for reassurance and efforts to do what is best as a parent.[58]

Prenatal information can be a double-edged sword, both relevant to reproductive decisions and potentially anxiety provoking.[59] It may be difficult for individuals to know, in advance, what the information would mean to them, how it might affect their reproductive decisions and planning, or whether it would contribute to anxiety in the pregnancy. As a result, decision making is complex even in the current environment where prenatal testing focuses on a single or limited number of conditions. If NGS becomes part of prenatal testing, deciding what information would be relevant for reproductive choice will become even more complicated.

Some of the same considerations would influence decisions about what information to obtain when using NGS in the context of ordinary or Easy PGD.[60] But the relevance of genomic information will often differ depending on whether it is obtained through prenatal testing or PGD. Rather than influencing decisions about termination or adoption, as it would with prenatal testing, genomic information from (E)PGD would influence the selection of embryos for implantation.[61] Because PGD does not involve considerations of whether to continue a presumably wanted pregnancy, parents would probably find a broader swath of genomic information relevant to (E)PGD as compared to prenatal testing. In other words, information that might not influence decisions about whether to continue a pregnancy, such as lesser medical risks, could potentially influence decisions about which embryos to implant.

As researchers discover more meaningful associations between genetic variants and non-medical traits, comprehensive genomic analysis will force us to consider the relevance of information about non-medical traits in this context. Certain non-medical traits, such as sex, influence decisions to terminate pregnancies in some countries.[62] In the United States, however, few find this information relevant for pregnancy termination, although parents often want to learn the sex of the fetus for planning

57 See eg John Robertson, Children of Choice: Freedom and the New Reproductive Technologies (1996) (describing reproductive autonomy as a constitutionally protected liberty interest).

58 See Stephanie Morain et al., *A New Era in Noninvasive Prenatal Testing*, 369 New Eng. J. Med. 499 (2013); Suter, *Routinization*, *supra* note 46, at 247.

59 See Benjamin E. Berkman & Michelle Bayefsky, *Prenatal Whole Genome Sequencing: An Argument for Professional Self-Regulation*, 17 Am. J. Bioethics 26, 26 (2017); Patricia Volk, *The T.M.I. Pregnancy*, New York Times, June 4, 2014, https://opinionator.blogs.nytimes.com/2014/06/04/the-t-m-i-pregnancy/ (accessed May 15, 2018); Kat McGowan, *Prenatal Testing Is About to Make Being Pregnant a Lot More Stressful*, Quartz, Mar. 25, 2016, https://qz.com/646436/prenatal-testing-is-about-to-make-being-pregnant-a-lot-more-stressful/ (accessed May 31, 2018).

60 *Cf.* Karen Hurley et al., *Incorporating Information about Pre-Implantation Genetic Diagnosis into Discussions about Testing and Risk-Management for BRCA1/2 Mutations: A Qualitative Study of Patient Preferences*, 18 PMC 6270, 6270 (2016) ('[T]he highly technical nature of PGD makes it difficult to integrate PGD information into genetic counseling sessions that already cover probabilistic, emotionally-charged risk information.').

61 Certain genomic information might be valuable to plan for the care of the child. Parents might, for example, decide that they would like to know about inborn errors of metabolism to make dietary adjustments immediately in the newborn period. Kathryn M. Camp et al., *Nutritional Treatment for Inborn Errors of Metabolism: Indications, Regulations, and Availability of Medical Foods and Dietary Supplements Using Phenylketonuria as an Example*, 107 Mol. Genet. & Metab. 3 (2012) (describing nutritional treatment for phenylketonuria). While some parents might implant an embryo that would develop an inborn error of metabolism and plan to treat with diet, many or most would likely chose a different embryo that did not have such a risk.

62 See President's Council on Bioethics, Beyond Therapy: Biotechnology and the Pursuit of Happiness 61 (Oct. 2003) (noting that the sex ratio of boys to girls in certain countries shows a preference for boys over

purposes or merely to satisfy curiosity.[63] One would therefore expect non-medical trait information generally to be less relevant to decisions about whether to continue a pregnancy than information about serious medical risks.[64]

Indeed, as more non-medical trait information becomes available through prenatal testing, parents might be even less likely to terminate based on this information because it would include a mixed bag of more and less 'desirable' traits. For example, genomic analysis could reveal an increased propensity for certain characteristics the parents might not prefer (eg shorter stature[65]) in combination with an increased propensity for traits the parents particularly value (eg musicality[66]). The more comprehensive and complex the genomic profile of the fetus, the better the odds it would only satisfy curiosity and not assist with decisions about whether to continue a pregnancy.

In the context of ordinary or Easy PGD, however, genomic information about non-medical traits would probably be far more material for embryo selection. The question would not be 'Should I continue this pregnancy with a child that has some traits I wish were different?' Instead, the question would be, 'Should I implant an embryo with this particular combination of traits instead of the other embryos with different combinations of traits?' Even here, not all non-medical trait information would be important for embryo selection. And even if it were important, most parents would probably not consider such information as consequential as information about health risks. Nevertheless, many parents would probably want to consider whether and to what extent trait information would help them select embryos.[67]

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girls by exceeding the natural ratio of 102–106 to 100 with ratios of from 107.5 to 100 in Venezuela and as high as 120 to 100 in Azerbaijan and noting that '[a]lthough data is lacking regarding the techniques people in these countries use to produce these large shifts in the sex ratio we suspect that sonography-plus-abortion is by far the most common'); Mary Carmichael, *No Girls, Please*, Newsweek Magazine, Jan. 26, 2004, at 50.

63 One of the reasons people have shown such a strong interest in NIPT is the ability to obtain gender information for gender reveal parties or to plan the child's room, choose names, etc. Personal communication with Dr. Marsha Michie, Assistant Professor, University of California, Mayo Clinic (Feb. 8, 2017). '[I]n the United States, there is limited and inconclusive evidence that immigrants from [East and South Asia]—or anywhere else—are obtaining sex-selective abortions in this country.' Guttmacher Institute, *Abortion Bans in Cases of Sex or Race Selection or Genetic Anomaly*, https://www.guttmacher.org/state-policy/explore/abortion-bans-cases-sex-or-race-selection-or-genetic-anomaly (accessed Jan. 1, 2018). The interest in sex selection in this country tends to focus on preconception selection, and the preferences tend to be balancing gender in a family or controlling birth order. See Jamie S. King, *Stanford Law and Biosciences Blog* (Oct. 9, 2011), https://law.stanford.edu/2011/10/09/americas-role-in-sex-selection/ (accessed Jan. 1, 2018) ('One consistent theme is the idea that parents in today's society have smaller families and want the ability to parent children of both sexes.').

64 Even so, there would be some exceptions as noted earlier. Some individuals want to select *for* genetic conditions, such as deaf parents who wish to have deaf children. See *supra* note 47.

65 See Joel Hirschhorn et al., *Rare and Low-Frequency Coding Variants Alter Human Adult Height*, 186 Nature 186 (2017).

66 See Yi Ting Tan et al., *The Genetic Basis of Music Ability*, 5 Front. Psychol. 658 (2014).

67 See Gautam Naik, *A Baby, Please. Blond, Freckles – Hold the Colic*, Wall Street Journal, Feb. 12, 2009, https://www.wsj.com/articles/SB123439771603075099 (accessed Jul. 11, 2018) (reporting that when a Los Angeles fertility clinic, Fertility Institutes, advertised PGD for 'physical traits', it received 'half a dozen' requests for the service); Jay Bennett, *Genetic Engineering Now Allows Parents to Select the Gender and Eye Color of Their Children*, Popular Mechanics, Feb. 5, 2016 (noting that Fertility Institutes offers screening for eye and skin color). When I inquired at Fertility Institutes as to whether they were currently offering such screening, however, they informed me that, although it is technologically possible to do so, they aren't offering it

Those choosing to procreate via EPGD, therefore, would probably find a wide range of information (regarding both medical risks and non-disease traits) relevant to embryo selection. After all, the point of pursuing this mode of reproduction would be to maximize the chance of finding an embryo with the 'best' possible genomic profile (however 'best' would be understood). Because not all of the potential information would be equally important to this decision and because the disclosure of too much information could complicate the process of selecting embryos, parents would probably prefer to receive only the information they would find useful for embryo selection. This would require deciding in advance what information would be valuable, a very challenging process indeed.

2. Choosing Embryos—A Paralysing Choice? Deciding what information to obtain for reproductive decisions is quite different from actually deciding what to do once one has the information. Before exploring these challenges with respect to EPGD, I begin with the prenatal testing context.[68] The difference between decisions in these two contexts helps highlight how paralysingly difficult decisions in the latter context might be.

As noted earlier, prenatal testing differs from (E)PGD in that the decision is limited to questions about a single pregnancy.[69] With targeted genetic testing, parents often consider in advance whether information about a clinically relevant variant would be useful to prepare for the birth of a child with the condition or to decide whether to continue the pregnancy or place the child for adoption. Even if many cannot know for sure how they will respond before getting results, most give serious thought to the options. With genomic analysis, however, parents cannot possibly fully contemplate their potential responses to the enormously broad range of information they could receive.

In addition, genomic analysis could reveal information about risks for conditions that vary in likelihood and severity. Parents could learn, for instance, that the fetus faced a higher than average risk of a few adult-onset conditions, such as pancreatic cancer, type 1 diabetes, and coronary heart disease; a higher than average risk of bipolar disorder; a lower than average risk of autism and asthma; a higher than average chance of exceptional athletic abilities; and a lower than average chance of musical ability. Reproductive decisions based on this complicated and unpredictable constellation of risks would be much more complex than decisions based on a high risk of a medical condition, which the parents would have thought about at some length.

When we consider genomic analysis in the context of (E)PGD, the decision making would be even more complex. Not only would more genomic information be relevant to decisions about embryo selection,[70] but individuals would have to consider the genomic profiles of not just one embryo, but multiple embryos with ordinary PGD, or tens, hundreds, or possibly even thousands[71] of embryos with EPGD, an enormous task in itself.

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at the moment because 'funding for equipment and the actual testing . . . is . . . extremely super expensive to run').

68 Again, I emphasize that I am distinguishing prenatal testing, through amniocentesis, chorionic villus sampling, or NIPT, from (ordinary or easy) PGD. See *supra* text accompany note 55.

69 See *supra* text accompanying note 61.

70 See *supra* text accompanying notes 62–67.

71 As noted earlier, some factors, such as issues of storage capacity, might limit how many embryos would ultimately be produced. See *supra* text accompanying notes 33–34.

Even more difficult would be comparing the relative tradeoffs of the various genomic profiles to decide which embryos to implant because each genomic profile would present a different set of risks. Trying to assess the relative costs and benefits of the different variants identified in each of the embryos would be further complicated by the fact that the disease risks could vary in several respects: probability of manifestation, degree and range of severity, age of onset, treatment options, etc. How would one choose, for example, between an embryo with a genomic profile indicating an increased risk of coronary artery disease, colon cancer, and type 1 diabetes and a decreased risk of schizophrenia, breast and ovarian cancer, and asthma, and another embryo with an increased risk of bipolar disorder, cataracts, autism, and breast cancer and a decreased risk of leukemia, Parkinson's disease, and lung cancer.[72] Now imagine trying to make such comparisons for not just two or ten embryos (with ordinary PGD), but for tens, hundreds, or thousands of embryos, as one might with EPGD. The vastly increased magnitude of options would materially change the experience, making it exceptionally difficult, if not virtually impossible or paralysing.

Including trait information in the analysis would further complicate the decision. Even if one focused on disease risks and used trait information as a tie breaker for embryos with similar disease risks (however determined), difficult tradeoffs would be inevitable. Several embryos might have numerous traits that are both desirable and undesirable to the parents. Imagine, for example, the genomic analysis of one embryo: female, who would experience early graying and be moderately tall with a heavy build; 65% chance of scoring in the top half of the SAT tests; good chance of above-average athletic ability; and likely to be introverted. Now imagine the genomic profile of another embryo: male, who would have male-pattern baldness, medium height, and medium build; 40% chance of scoring in the top half of the SAT tests; likely to have above-average musical ability; and likely to be anxious.[73] How would one compare the complex mix of non-medical traits of just two embryos, let alone tens or hundreds of embryos?

The problem, quite simply, is one of 'choice overload'.[74] Studies in various contexts have shown that a proliferation of choice can lead to decision-making difficulties.[75] What's worse, not only can choice overload affect decision making, it has also

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72 GREELY, *supra* note 8, at 194–95.

73 These scenarios combine examples from *Id*.

74 See Jonathan D. D'Angelo & Catalina L. Toma, *There Are Plenty of Fish in the Sea: The Effects of Choice Overload and Reversibility on Online Daters' Satisfaction with Selected Partners*, 20 MEDIA PSYCHOL. 1, 3-6 (2016); Alina Tugend, *Too Many Choices: A Problem that Can Paralyze*, NEW YORK TIMES, Feb. 26, 2010, https://www.nytimes.com/2010/02/27/your-money/27shortcuts.html (accessed Jul. 11, 2018) (citing research scientist, Benjamin Scheibehenne); Bobby Miller, *More is Less? How Choice Overload Affects People, Businesses and Society,* NVATE, Jan. 9, 2014, http://nvate.com/16452/choice-overload/ (accessed Dec. 30, 2017). Some parents might focus on just a few genetic variants of particular importance to them. See Bourne et al, *supra* note 16, at 959–60 (noting that to produce an embryo with the desired genotype at 15 loci, one would need to create 10,000 embryos), which would narrow down the number of embryos from which to select. But even then, a handful of embryos might have the desirable combination of genotypes. How would parents choose among them? Moreover, because EPGD would be marketed as maximizing reproductive options, many parents would prefer to select embryos based on a broad range of genomic information rather than a limited set of loci.

75 Eli Finkel et al., *A Critical Analysis from the Perspective of Psychological Science*, 13 PSYCHCOL. SCI. PUB. INTEREST 3, 32 (2012) (citing numerous studies that have shown that 'a large degree of choice can overwhelm people,

been shown to lead to reduced satisfaction with the choice that one ultimately makes.[76] If similar dissatisfaction arose with EPGD, this could intensify the concerns about commodification of children and the threat of disappointment if heightened expectations were dashed.[77]

As we have seen, EPGD will present a number of decision-making challenges: comprehending the enormous range of information it could provide; deciding what information to obtain; and finally, using the information to select among tens, hundreds, or possibly thousands of embryos. While, in theory, the potentially endless array of options would maximize choice, EPGD could, in practice, present paralysing choices for many.

C. The Pressures in Favor of EPGD

Before turning to the approaches that might be used to remedy these decision-making challenges, I want to take a moment to respond to the objection that, even if EPGD were to become technologically feasible, the demand for it would be rather low because of the concerns described above. I am skeptical about that prediction given the many countervailing pressures in favor of EPGD, such as a thirst for information, strong marketing efforts, incentives created by insurance companies and wellness programs, competitive pressures among future parents, and clinics' attempts to avoid liability. For example, history suggests that the drive for information will be too great for parents and commercial ventures to ignore. As Barry Schwartz argues in *The Paradox of Choice: Why More is Less*, technology and cultural norms have led to a 'vastly expanding … range of choices' in virtually all areas of our life, including what items to buy, what health insurance and retirement plans to purchase, what medical care to accept, how to work, how to pray, how to love, and even who to be.[78] Yet, even though this proliferation of 'choice no longer liberates, … [and] might even be said to tyrannize', societal pressures push toward more, not less, choice. Our society is 'enamored of freedom, self-determination, and variety, and we are reluctant to give up any of our options'.[79] In addition, a deep cultural belief that knowledge provides power and control would feed a desire for as much reproductive information as possible, helping to fuel consumer demand and bring EPGD to fruition.

Marketing efforts are also likely to strengthen these cultural norms. One can imagine advertising that would promote the value of maximizing reproductive options through EPGD. We have already witnessed such efforts with respect to NIPT, which is touted as providing information that offers control and reassurance.[80] EPGD marketing could

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undermining their ability to make good decisions and sometimes producing a state of choice overload, in which people simply avoid making any decision rather than exerting the mental effort required to compare and contrast so many options').

76 Barry Schwartz, The Paradox of Choice: Why More is Less (2004); D'Angelo & Toma, supra note 74, at 34.

77 See *supra* Part II.

78 Schwartz, *supra* note 76, at 9–42.

79 *Id.* at 2–3.

80 Personal communication with Dr. Marsha Michie, Assistant Professor, University of California, San Francisco, and Dr. Megan Allyse, Assistant Professor of Biomedical Ethics, Mayo Clinic (Feb. 8, 2017). See also Antonio Regalado, *Prenatal DNA Sequencing*, MIT Tech. Rev., https://www.technologyreview.com/s/513691/prenatal-dna-sequencing/ (accessed Dec. 30, 2017); Beth Daley, *Oversold and Misunderstood: Prenatal Screening Tests Prompt Abortions*, New Eng. Ctr. Investigative Reporting, Dec.

similarly prey on notions of responsible parenthood,[81] urging people to use EPGD to ensure their future children are as healthy, talented, and successful as possible.

Insurers might also influence consumer demand.[82] Today most insurers do not cover PGD,[83] which is more expensive than a natural pregnancy with prenatal testing and an abortion. When assessing cost-effectiveness, insurers do not tend to consider a reproductive test's ability to reduce the lifetime costs of caring for children with serious illnesses because people do not tend to stay with a particular insurer for a long time.[84] Thus, even if (E)PGD could prevent the birth of (and associated costs of caring for) a child with a significant health risk, insurers would likely only cover EPGD if its cost was sufficiently low and the information it generated could avoid the need for prenatal testing and pregnancy termination to avoid many diseases. Also relevant to insurance coverage of EPGD would be the recommendations of professional organizations. To determine whether reproductive tests are medically necessary for coverage decisions, 'virtually all' insurance plans rely on the American College of Obstetricians and Gynecologists' assessments of the value of the test.[85] Over time, we have seen a shift in cost justifications and professional acceptance of a wider scope of NIPT for a broader range of consumers. One could imagine a similar evolution with EPGD.

Employee wellness programs, which aim to reduce health care costs by encouraging employees to engage in healthy behavior, might also create incentives to use EPGD.[86] Most such programs focus on carrots or sticks to influence behavior that affects *employee* health. But one could envision some employers offering discounted insurance premiums or co-pays for employees who used EPGD to reduce the health care costs of their *dependents*. While there is no evidence that wellness programs include PGD today,

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13, 2014), https://eye.necir.org/2014/12/13/prenatal-testing/ (accessed Dec. 15, 2017) (noting that '[a]dvertisements for these new prenatal screens are filled with bright skies, serene, full-bellied women, and, most of all, assurances that the tests can be trusted' in the context of a race 'to corner what one market research firm predicts will be a $3.6 billion global industry by 2019'); McGowan, *supra* note 59 (observing that 'the extensive marketing and commercial success of NIPT has experts worried').

81 See Suter, *Routinization*, *supra* note 46, at 248; *cf.* Janet Malek & Judith Daar, *The Case for a Parental Duty to Use Preimplantation Genetic Diagnosis for Medical Benefit*, 12 Am. J. Bioethics 3 (2012) (focusing on the duty to select against serious diseases through PGD).

82 'The overall finances required for PGD can present an economic barrier for prospective parents . . . . Additionally, many genetic high risk individuals are not diagnosed with infertility, which is often a prerequisite for health insurance plans in the United States that do cover costly IVF treatments.' Kathryn T. Drazba et al., *A Qualitative Inquiry of the Financial Concerns of Couples Opting to Use Preimplantation Genetic Diagnosis to Prevent the Transmission of Known Genetic Disorders*, 23 J. Genet. Couns. 202, 203 (2013).

83 *Id.* Patricia E. Hershberger et al., *Unraveling Preimplantation Genetic Diagnosis for High-Risk Couples: Implications for Nurses at the Front Line of Care*, 15 Nurs. Womens Health 36, 41 Box 4 (2012). That limitation, however, may be changing for some insurers. Priority Health, for example, deems PGD necessary. Therefore, it will cover PGD with prior authorization in limited circumstances: when the likelihood of detecting the genetic condition is 25% or greater because both partners are carriers of a single autosomal recessive gene, or one partner is a carrier of a single gene autosomal dominant disorder or a single X-linked disorder. Priority Health, Medical Policy No. 91540-R12, Genetics: Counseling, Testing, Screening, Effective Date: Mar. 1, 2017.

84 Personal communications with Whitney Williams, CEO, JW Market Access Consults, Aug. 16, 2017.

85 *Id.*

86 'Nearly 90% of employers offer wellness incentives, or financial rewards or prizes to employees who work toward getting healthier.' Jen Wieczner, *Your Company Wants to Make You Healthy*, Wall Street Journal, Apr. 8, 2013, https://www.wsj.com/articles/SB10001424127887323393304578360252284151378 (accessed Dec. 15, 2017).

this might change if the cost of EPGD were substantially cheaper than the current cost of PGD. Creating incentives for employees to use EPGD as part of wellness programs could certainly increase the demand for this technology.[87]

In addition, given competitive pressures to achieve high success rates, fertility clinics might encourage fertility patients to use EPGD. By producing so many embryos, EPGD could substantially increase the odds of producing viable embryos. In addition, genetic analysis might become valuable in assessing embryo viability.[88] While full genome analysis might not be necessary for that purpose, once the costs and throughput of the technology became manageable, clinics might offer large-scale sequencing as an add-on feature for fertility patients.

The biggest motivator for clinics to encourage patients to use EPGD, however, would be to reduce the threat of liability. Clinics might worry that fertility patients who

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87 Although the Genetic Information Nondiscrimination Act ('GINA') prohibits employers from asking employees for genetic information, genetic information can be collected as part of a wellness program, as long as the employee provides 'prior knowing, voluntary, and written authorization; only the employee and a licensed health care professional or board-certified genetic counselor . . . receive individually identifiable information concerning the results of such services; and any individually identifiable genetic information provided in connection with the health or genetic services provided under this exception is only available for the purposes of such services and shall not be disclosed to the employer except in aggregate terms that do not disclose the identity of specific employees'. Amanda K Sarata, et al., Cong. Research., R41314, The Genetic Nondiscrimination Act of 2008 and the Patient Protection and Affordable Care Act of 2010: Overview and Legal Analysis of Potential Interactions 8 (2011) (citing Pub. L. 110–233 § 202(b); 42 U.S.C. §2000ff-1(b)).

Were employers to require disclosure of EPGD as part of wellness plans, as the EEOC recently allowed with respect to spousal medical information (which is part of the definition of an employee's genetic information), Regulations Under the Genetic information Nondiscrimination Act, 81 Fed. Reg. 31,143 (May 17, 2016), there might be questions about the legality of the incentives, see AARP v. US EEOC, 267 F. Supp. 3d 14 (D.C. 2017) (holding that EEOC regulations allowing incentives of up to 30% of the cost of coverage in exchange for participation in health-contingent wellness programs for employer-sponsored wellness programs were arbitrary and capricious), *modified* 292 F. Supp. 3d 238 (2017) (affirming summary judgement for the AARP, but modifying the ruling to remand to the EEOC without vacatur and imposing vacatur of the EEOC regulations).

Last year, efforts were made to remove the protections of GINA with respect to wellness plans when Representative Foxx introduced House Bill 1313 to reduce the burdens on employers in implementing wellness programs. H.R. 1313, 115th Cong. (2017). The bill would have allowed 'employers broader authority to collect identifiable personal and familial medical history and genetic tests through voluntary wellness programs' and to incentivize participation in these programs by offering discounts on health plan premiums for those who participate. Duke SciPol, *Preserving Employee Wellness Programs Act (HR 1313, 115th Congress)*, Mar 30, 2017, http://scipol.duke.edu/content/preserving-employee-wellness-programs-act-hr-1313-115th-congress (accessed May 25, 2018); H.R. 1313, 115th Cong. § 3b (2017) ('Notwithstanding any other provision of law, the collection of information about the manifested disease or disorder of a family member shall not be considered an unlawful acquisition of genetic information with respect to another family member as part of a workplace wellness program'). Using the same definition of 'family member' that GINA uses, this bill would have allowed employers to obtain genetic information not only of children, but also fetuses or an embryo or a family member. 29 C.F.R. § 1635.3(c)(v) (defining 'genetic information' in part as 'the genetic information of any embryo legally held by the individual or family member using an assisted reproductive technology'). Ultimately, the bill, which would have undone privacy protections under GINA and the American with Disabilities Act, was not enacted.

88 Jacinta Bowler, *A Swedish Scientist is Using CRISPR to Genetically Modify Health Human Embryos*, Scientific Alert, Sept. 29, 2016, http://www.sciencealert.com/a-swedish-scientist-is-using-crispr-to-genetically-modify-healthy-human-embryos (accessed Dec. 22, 2017) (describing a scientist's efforts to edit the genome of early embryos to discover which genes are associated with normal embryonic development and fertility).

don't use EPGD would sue for wrongful birth claims [89] if the resulting child had a condition that could have been detected through genome sequencing of the embryo that was implanted and which could have been prevented had another embryo without the relevant genetic mutations been implanted.[90]

Currently, wrongful birth claims arise when specific risk factors—eg when both parents are carriers of a gene for a recessive condition—warrant targeted genetic or other diagnostic testing. With large-scale sequencing, however, many genetic mutations associated with disease could be identified without a prior known risk. If EPGD becomes viable, fertility clinics might try to protect themselves against wrongful birth liability by asking patients who don't undergo EPGD to sign waivers or exculpatory clauses agreeing not to sue the clinic for wrongful birth. Whether courts would uphold such claims would depend on their views as to the importance or necessity of the service and the relative bargaining power of the patient and the clinic.[91] If enforceable, these provisions would create yet another incentive for fertility patients to choose EPGD.

Finally, if individuals with fertility issues began to use EPGD in increasing numbers, it might not be long before EPGD moved out of the realm of infertility treatment to become mainstream. Those who could reproduce the 'old-fashioned' way might not want to lose out on the competitive advantages EPGD could potentially provide. We already witness significant parental efforts, in certain segments of society, to maximize children's competitive advantages through private coaching, music lessons, tutoring, college preparatory programs, enrollment in elite schools (from preschool to college), etc. Selecting embryos with the greatest probability of possessing physically and culturally advantageous traits through EPGD would be just one more way to increase the competitive advantages for one's future child.

For all of these reasons, it seems highly plausible that, in spite of the concerns regarding EPGD, the demand and market for this technology would not be insignificant. Providers of EPGD would therefore have strong incentives to address its decision-making challenges so they could more fully promote the technology. I turn now to the remedies that these different entities might develop to achieve that goal, beginning with those that address comprehension issues and decisions about what information to

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89 The majority of jurisdictions recognize such claims in the context of prenatal testing. See Keel v. Banach, 624 So. 2d 1022, 1030 (Ala. 1993) (allowing parents to recover the damages associated with 'the extraordinary expenses they incur because of the child's unhealthy condition').

90 See Christina L. Goebelsmann, *Note, Putting Ethics and Traditional Legal Principles Back into California Tort Law: Barring Wrongful-Birth Liability in Preimplantation Genetic Testing Cases*, 43 Loy. L.A. L. Rev. 667, 667 (2010) (noting that preimplantation genetic testing 'has the potential to place doctors at risk for liability under the tort of wrongful birth'); MacKenna Roberts, *Australian Parents Launch 'Wrongful Birth' Claim for Negligent Genetic Testing*, BioNews, Jan. 28, 2008, https://www.bionews.org.uk/page_90589 (accessed May 15, 2018). But see Doolan v. IVF America (MA) Inc., 2000 WL 33170944 at *4 (Mass. Super. 2000) (failing to allow a wrongful birth claim to go forward after PGD on the grounds that the claim that another embryo would not have the illness at issue has to be discounted by the 'possibility that he might have been afflicted with another type of birth defect or long term illness').

91 See Tunkl v. Regents of the Univ. of CA, 383 P.2d 441, 444–l45 (Cal. 1963) (describing six factors relevant to determining the enforceability of exculpatory clauses). Courts vary in the tests they use for deciding whether to uphold such clauses. See Hanks v. Powder Ridge Restaurant Corp., 885 A.2d 734, 742–43 (Conn. 2005). While courts void exculpatory clauses as a violation of public policy when patients are asked to sign them as a condition of becoming a hospital patient, see *Tunkl*, 383 P.2d, at 441, fertility treatment is not likely to be viewed as a necessity or as important as hospital care.

obtain in Part IV. Part V then turns to the most vexing remedy for the decision-making challenges of EPGD—the creation of algorithms to help parents select embryos.

IV. Remedies to Address Paralysing Choices

Two types of providers of EPGD would have incentives to minimize the decision-making challenges of EPGD. Professionals involved in the delivery of this technology might feel professionally and morally obligated to address these problems so that patients are not overwhelmed (assuming their guidelines condoned the use of EPGD). Commercial providers would also be quite eager to prevent these difficulties so they could better market the technology as offering a sense of empowerment.[92] I should note at the outset that my efforts to distinguish between these two groups may be more conceptual than actual. In theory, they represent two different kinds of actors, but the line between the two is becoming increasingly blurry. Section IV.A discusses potential efforts to maximize comprehension. Section IV.B explores potential efforts to help patients decide what information to obtain, suggesting that some of the remedies may challenge reproductive autonomy and raise equity concerns.

A. Understanding the Range of Possible Information

I only briefly address remedies for the comprehension issues related to EPGD because these are the least problematic. Given the impossibility of outlining the significance of all of the genetic variants that could be identified from genome sequencing, as well as the difficulties people might experience trying to comprehend such information,[93] scholars have recommended categorizing genomic information based on various features. In the context of NGS in the population at large, one suggestion has been to divide the information into 'bins' based on characteristics associated with medical conditions, such as age of onset, medical actionability, severity, and likelihood of the condition's developing.[94] With respect to genome sequencing in prenatal testing, one group recommended presenting information to parents on the basis of three dimensions: (1) the type of information that genomic analysis could provide—'physical; intellectual and cognitive; psychiatric; life-shortening/lethal conditions; and nonmedical', (2) the clinical severity of the conditions, and (3) the 'probabilistic level of association between genotype and phenotype'.[95] Such an approach could become a practical necessity for

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92 In theory, the State might also be motivated to address these decision-making challenges. There is reason, however, to think that such State action is not likely. First, to the extent that the State would have any concerns about EPGD, it is more likely to be troubled by the generation of multiple embryos with the purpose of selecting only a few for implantation than by the decision-making challenges. As a result, any state regulation would be more likely to ban or limit the creation of embryos for PGD. Given the striking lack of regulation of ART historically, however, it is far more likely that most states and the federal government simply wouldn't regulate this form of ART at all. As a result, I leave for another paper a discussion of what State involvement in regulating EPGD might look like and what the constitutional implications would be.

93 See *supra* text accompanying notes 48–52.

94 Berg et al., *supra* note 51, at 501–3; Eline M. Bunnik, *A Tiered-Layered-Staged Model for Informed Consent in Personal Genome Testing*, 21 Eur. J. Hum. Genet. 596, 597–98 (2013).

95 Stephanie C. Chen & David T. Wasserman, *A Framework for Unrestricted Prenatal Whole-Genome Sequencing: Respecting and Enhancing the Autonomy of Prospective Parents*, 17 Am. J. Bioethics 3, 9-11(2017) (recommending the creation of the five categories 'based on evidence that women make pregnancy decisions differently with respect to similar categories') (citing Athena P. Souka et al., *Attitudes of Pregnant Women Regarding Termination of Pregnancy for Fetal Abnormality*, 30 Prenat. Diagn. 977 (2010)).

prenatal testing if it ultimately includes NGS, especially if parents have discretion to determine the scope of information they receive. Similar approaches would likely be used for EPGD.

Because the information would be expressed in probabilistic terms, however, the comprehension challenges would be still be daunting for many, especially considering how pervasive innumeracy is.[96] Nevertheless, while the bin approach has its limitations,[97] we simply do not have sufficient resources or time (from both practitioners' and patients' perspectives) for providers to offer a detailed account of all of the information generated by this kind of testing.[98] Decision aids, however, could be used to supplement the bin approach. They might provide general descriptions of the categories, giving individuals the option to explore more detailed descriptions with respect to each category in more depth and on their own time.[99] These solutions would not be perfect, but they might be the best we can do under the circumstances.

B. Deciding What Information to Obtain

Comprehending the vast amount of information that EPGD could provide is just the first step in the decision-making process. Deciding what information might be relevant in selecting embryos would be even more difficult. As we shall see, various actors might develop and/or offer strategies to combat these difficulties.

1. Professional Guidelines. Professional groups might try to ameliorate this problem by limiting how much genomic information is disclosed. In spite of the long-standing deference toward patient autonomy in genetics,[100] professionals have begun to consider some limits on patient choice. For example, the American College of Medical Genetics and Genomics Working Group initially recommended informing patients undergoing whole genome sequencing about genetic variants associated with certain inherited, monogenic conditions 'amenable to medical intervention', whether or not patients had consented to such disclosure. The justifications for departing from an autonomy-based model of disclosure were principles of beneficence and the obligation to avoid harm as well as concern about limited resources and capabilities of laboratories and

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96 See Michael Shermer, *Folk Numeracy and the Middle Land: Why Our Brains Do Not Intuitively Grasp Probabilities*, 299 Scientific American 40, Sept. 1, 2008, https://www.scientificamerican.com/article/why-our-brains-do-not-intuitively-grasp-probabilities/ (accessed Dec. 15, 2017) (describing why people have challenges grasping probabilities).

97 See Jonathan S. Berg et al., *An Informatics Approach to Analyzing the Incidentalome*, 15 Genet. Med. 36 (2013) (' [T]he disadvantage of introducing more and more categories is that the clinical decision making could devolve into a gene-by-gene menu, which would impose prohibitive demands on clinicians and laboratories with respect to informed consent and analysis.').

98 See *supra* text accompanying notes 51-52.

99 *Cf.* C. Nagle et al., *Use of a Decision Aid for Prenatal Testing of Fetal Abnormalities to Improve Women's Informed Decision Making: A Cluster Randomized Controlled Trial,* 115 Brit. J. Obstet. & Gynaecol. 339, 339 (2008) (finding that 'a tailored prenatal testing decision aid plays an important role in improving women's knowledge of first and second trimester screening tests'); Suter, *Genomic Medicine, supra* note 28, at 103.

100 See Jeffrey R. Botkin, *Prenatal Screening: Professional Standards and the Limits of Prenatal Choice*, 75 Obstet. & Gynecol. 875 (1990) ('There is no area of medicine with a stronger commitment to patient autonomy than reproductive genetics.').

medical professionals.[101] While updated recommendations allow patients to opt out of such disclosure, they do not call for personal tailoring of genome sequence results.[102]

Similar concerns about beneficence and limited resources have led to recommendations to *limit* disclosure of genomic information with uncertain or no clinical significance.[103] Such information could overwhelm patients by expanding the amount of information they receive and could cause confusion about its significance (or lack thereof). If misunderstood, it could lead to anxiety and/or inappropriate clinical action.[104]

As we consider introducing genome sequencing in prenatal testing, professional organizations and scholars are debating whether medical professionals should play a gatekeeping role with respect to information disclosure. In part, to remedy decision-making challenges of broad-scale testing, some scholars advocate professional self-regulation, whereby professional societies would offer 'high-value information … as a default part of the standard of care'.[105] How the lines would be drawn is not fully clear, but they could, for example, distinguish between serious medical conditions and minor medical conditions or non-medical traits. Others argue that, to protect reproductive autonomy, parents should be the ultimate arbiters.[106] Even these scholars, however, recognize the complexity of such decisions and therefore propose a default option whereby providers could decide the scope of information disclosure for patients who find such choices taxing.[107]

Similar debates have played out with respect to PGD as scholars and advisory committees consider whether parents should be able to receive non-medical trait information in addition to information about disease risks.[108] These debates have focused primarily on the societal and ethical concerns of selecting embryos based on traits, such as sex, rather than concerns about information overload. But if large-scale sequencing is used with PGD (whether ordinary or Easy), professionals might want to limit the scope of disclosure to minimize these problems.

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101 *ACMG Recommendations for Reporting Incidental Findings in Clinical Exome and Genome Sequencing*, 13 Genet. & Med. 565, 567–68 (2013).

102 ACMG Board of Directors, *ACMG Policy Statement: Updated Recommendations Regarding Analysis and Reporting of Secondary Findings in Clinical Genome-Scale Sequencing*, 17 Genet. Med. 68, 69 (2015).

103 *Cf.* Jae Y. Cheon et al., *Variants of Uncertain Significance in BRCA: A Harbinger of Ethical and Policy Issues to Come?*, 6 Genome Med. 1, 2–3 (2014) (noting the challenges of disclosing variants of uncertain significance at the BRCA loci).

104 *Id.* at 1, 5; Lauren Westerfield et al., *Counseling Challenges with Variants of Uncertain Significance and Incidental Findings in Prenatal Genetic Screening and Diagnosis*, 3 J. Clin. Med. 1018, 1025–26 (2014) ('[I]ncreased terminations for "insignificant" DNA changes may undermine the aim of prenatal screening "to help couples have healthy babies," thereby causing harm.').

105 See eg Berkman & Bayefsky, *supra* note 59, at 26 (suggesting that parents could 'seek additional information either after discussion with their prenatal care team or through commercial services'). Even if professionals agree in theory on the principles that would set the lines, it may be quite difficult in practice to sort out what is in and what is out, particularly at the margins.

106 See Chen & Wasserman, *supra* note 95.

107 *Id.* at 10.

108 ACOG Committee Opinion No. 360, *Sex Selection*, 109 Obstet. & Gynecol. 475 (2007) (opposing requests for preconception sex selection when based on concerns other than preventing sex-linked disorders); Ethics Committee of the American Society for Reproductive Medicine, *Preconception Gender Selection for Nonmedical Reasons*, 75 Fertil. & Steril. 861, 861 (2001) (concluding that the non-medical reasons should not be 'prohibited or condemned as unethical in all cases').

At the heart of these debates are questions of the clinical utility of genomic information in the reproductive context. There are no clear guidelines for assessing clinical utility,[109] which can be defined narrowly—in terms of only preventing or ameliorating health outcomes[110]—or broadly—in terms of the 'medical and social outcomes of testing' and potential interventions,[111] such as preparing for the care of an affected child or helping make decisions about termination or adoption. Genetic variants largely predictive of serious diseases clearly have clinical utility under either definition. Whether highly penetrant variants associated with non-medical traits also have clinical utility in the reproductive context is more complicated. Under the broader definition, some non-medical traits might have clinical utility because of their potential social impact on parents. Such information has not, however, been treated as having clinical utility thus far.[112]

One might argue that a wider range of genomic information is material for PGD as compared with prenatal testing decisions,[113] and therefore the broad definition of clinical utility would include non-medical information. Concerns about information overload, comprehension challenges, and limited resources (too few counselors and insufficient time), however, could lead professional societies to limit the scope of clinical utility. By limiting disclosure to information with clinical utility under the narrow definition, providers could better educate patients about, and patients could better comprehend, the limited information they receive. In addition, professional organizations might want to limit the use of medical resources for what could be viewed as 'trivial' reasons to select embryos.

Professional guidelines that limited the scope of genetic information disclosed through (E)PGD would, however, raise concerns about reproductive autonomy and medical paternalism given that the import of reproductive information has long been defined in terms of the patient's personal values, preferences, and circumstances. While professional considerations about the use of limited and scarce resources argue against unlimited patient autonomy, the possibility of obtaining broad amounts of non-medical information will force the medical profession and society to think hard about the appropriate scope of patient autonomy in this context. In short, this remedy pits professional autonomy and integrity against patient autonomy.[114]

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109 Personal communications with Whitney Williams, *supra* note 84.

110 Scott D. Grosse & Muin J. Khoury, *What is the Clinical Utility of Genetic Testing?*, 8 GENET. MED. 448, 448 (2006).

111 Wylie Burke, *Genetic Test: Clinical Validity and Clinical Utility*, 81 CURR. PROTOC. HUM. GENET. 1, 6 (2009). Clinical validity, i.e., 'the accuracy with which a . . . test identifies a particular clinical condition', *id.* at 6, is also necessary.

112 At this point, based largely on ACOG's recommendations, insurance only covers NIPT screening for chromosomal disorders, including Down Syndrome (trisomy 21), trisomy 13, trisomy 18, and X chromosome anomalies. ACOG Committee Opinion No. 640, *Cell-Free DNA Screening for Fetal Aneuploidy,* 126 OBSTET. & GYNECOL. e31, e31 (2015) (recommending that NIPT screening be limited to common trisomies and, 'if requested, sex chromosomes', but recommending against its inclusion of microdeletion syndromes). While the coverage of sex chromosomes analysis might seem to contradict that principle, the decision is based on the clinical utility of ruling out sex-linked conditions, not on a notion of clinical utility that considers satisfying parental curiosity. Personal communications with Whitney Williams, see *supra* note 84.

113 See *supra* text accompanying note 67.

114 *Cf. infra* text accompanying notes 129–34.

2. Commercial Entities. If professional guidelines limited disclosure only to genomic variants associated with serious conditions, some fertility clinics might fill the void by offering to provide information about variants associated with lesser health risks or non-medical traits. Although commercial labs would do the sequencing, the clinics might request more expansive analysis when sending samples to the labs. Commercial labs might also market their ability to provide more comprehensive genomic analysis, which could lead patients to demand more information from EPGD than the guidelines allow. One could imagine advocates of patient autonomy urging clinics to offer more expansive disclosure, much as they have pushed for broader access to genetic information through direct-to-consumer testing.[115] While some providers would adhere to professional guidelines, a good many might flout them for a competitive edge. Indeed, in the unregulated ART world, evidence suggests providers or clinics often ignore professional recommendations. For example, surveys of obstetricians and gynecologists show that 'a high proportion' offer expanded carrier screening 'upon patient request', in spite of the fact the American College of Obstetricians and Gynecologists and the American College of Medical Genetics and Genomics recommend more limited screening panels.[116]

On the other hand, fertility clinics would have incentives to prevent consumers from feeling overwhelmed by the sheer volume of information EPGD could generate. To allow for personal tailoring of information disclosure, they might offer different packages—eg a 'full-disclosure' package for consumers who want to know everything; a 'health' package, with disclosure of information limited to significant health risks; or a personalized disclosure package based on selected categories of information: health risks (segregated by age of onset, neurological, physical, etc.) and trait information (divided by appearance, intellectual abilities, temperament, aptitudes, etc.).[117] If the expense of licensing multiple packages is prohibitively expensive for some clinics, they might offer only one algorithm and differentiate themselves based on the kind of information their algorithm provided.

3. Insurers and Inequities. Finally, depending on their coverage decisions, insurers could potentially influence the scope of information disclosure and, ultimately, equality. If insurers covered EPGD, they would look to professional organizations'

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115 See Linda L. McCabe & Edward R.B. McCabe, *Direct-to-Consumer Genetic Testing: Access and Marketing*, 6 GENET. MED. 58, 58.

116 Peter Benn et al., *Obstetricians and Gynecologists' Practice and Opinions of Expanded Carrier Testing and Noninvasive Prenatal Testing*, 34 PRENAT. DIAGN. 145, 150 (2014). See also Valerie K. Blake et al., *Conflicts of Interest and Effective Oversight of Assisted Reproduction Using Donated Oocytes*, 43 J. L. MED. & ETHICS 410, 412 (2015) (describing evidence that 'fertility clinics . . . do not always comply with voluntary guidelines' and 'studies of clinic . . . websites [that]demonstrated non-compliance with the guidelines on donor compensation, donor age, and disclosure of risks'); Stephanie Nano, *Few Fertility Clinics Follow Embryo Guidelines*, S.F. CHRON. (Feb. 21, 2009), http://articles.sfgate.com/2009-02-21/news/17189772_1_two-embryos-fertility-clinics-success-rates (accessed May 16, 2018) ('Fewer than 20 percent of U.S. clinics follow professional guidelines on how many embryos should be implanted'); Judith Daar, *Federalizing Embryo Transfers: Taming the Wild West of Reproductive Medicine?*, COLUM. J. GENDER & L. 257, 276 (noting that although recent 'data suggests a trend toward adherence to embryo transfer guidelines', the 'overall transfer rate . . . exceeds industry-suggested limits').

117 It goes without saying that clinical validity would always be a requirement for disclosure of information related to these variants.

assessments of clinical utility to decide the scope of coverage. If such groups concluded that genomic information about non-medical traits or minor medical conditions had no clinical utility,[118] insurers would not cover disclosure of these variants. In practice, this would mean that labs would generate the genomic sequence, but insurance would only cover analysis of variants associated with highly penetrant *medical* conditions.[119] Such limitations on insurance coverage would not, however, prevent labs from offering broader analysis if there was sufficient market demand.[120]

The inevitable result would be two tiers of EPGD consumers: those whose analysis was limited to results for which there was insurance coverage and those with the means to obtain a broader range of genomic information, including information about non-medical traits. Being able to select on the basis of some non-medical information might merely fulfill parental preferences (eg green eyes over blue). But some selection might be for traits associated with societal advantages—such as height, intellectual ability, or impulse control. If access to this broader information was influenced by wealth, those with societal advantages (higher income, better education, access to health care, etc.) would be able to further enhance the opportunities for their future children by selecting for advantageous genetic variants.

If insurers did not cover EPGD, the scope of disclosure by commercial entities would be limited to information for which a sufficient portion of the market was willing to pay to make it cost effective, which would probably be broader than professional guidelines. In addition, only the wealthiest would be able to take advantage of this technology. The social inequities would be even starker here. Not only would the wealthier be able to select for advantageous traits, they would also be better able to use EPGD to avoid the burdens of caring for a child with serious illnesses, even though they would have the financial wherewithal to bear such burdens compared to those who could not afford EPGD.

As we have seen, attempts to ease the challenges of deciding what information to obtain through EPGD would not only test the limits of reproductive autonomy, especially for the most disadvantaged, but they could also heighten social inequities in a world of unequal access to health care and limited social support systems. These are not, however, the most troubling remedies for the decision-making challenges of EPGD, as Part V describes.

V. Algorithms—Is the Remedy Worse Than the Disease?

We turn now to the most vexing potential remedy for the paralysing choices of EPGD: algorithms. Section V.A. describes the two kinds of algorithms—individualized or generic—that could be used to help individuals with the difficult task of selecting among large quantities of embryos that present complicated tradeoffs of medical risks and traits. Section V.B describes the general issues algorithms present for reproductive decision making and the specific issues they raise, depending on who creates them.

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118 See *supra* note 112.

119 See *id.*

120 If insurers covered EPGD, presumably they would cover the cost of sequencing the entire genome since the cost differential between sequencing part or all of the genome would not be great. Indeed, it might be more costly to try to select out parts of the genome for sequencing than to sequence all of it. One could imagine, however, that coverage decisions might differentiate between what kind of genomic information was analysed and disclosed given that the *interpretation* of the sequence is the more costly part of genome sequencing.

A. Algorithms as a Remedy for Paralysing Choices

Professional groups, fertility clinics, and/or commercial labs might develop individualized or generic algorithms to help individuals process and sort through the results of EPGD.[121] Individualized algorithms would use parents' responses to questionnaires about their preferences to evaluate the embryos' genomic profiles and determine which embryo(s) had the highest overall score. Parents might identify the disease and/or non-disease traits they wanted to select against or for and the relative weights they would assign these categories, or they could just rank features most important to them and let the algorithm assign relative weights.

Even this task, however, could prove highly taxing. Some might find it too difficult or abstract to assign rankings or relative weights to different kinds of genomic information. As a result, providers of EPGD might develop generic algorithms. For example, they could create algorithms that award points for genotypes associated with diseases based on various categories: the potential severity, age of onset, degree of impairment or physical suffering, etc. Different weights would be assigned to different categories and the scores would be discounted by the probabilistic association between the variants and phenotype (penetrance).[122] These algorithms would be much like assessing quality-adjusted life years ('QALY')—if the goal were to select for embryos[123]—or disability-adjusted life years ('DALY')[124]—if the goal were to select against embryos. The resulting scores, based on the genomic profile of each embryo, would be used to select embryos for implantation. The outcome of these algorithms would depend as much on the weights assigned to the categories as to the determination of which categories to use. Two algorithms that used the same categories could lead to very different outcomes if different weights were assigned to each category. In other words, the formulas could have significant impact on the selection of embryos.

Individualized features could be used to modify generic algorithms based on key parental dislikes or predilections regarding medical and non-medical traits. Parents might indicate that a specific category of disease risk, such as a propensity for conditions that require specialized diets, like Celiac disease, would be a deal breaker. All embryos

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121 As noted above, cost may influence whether clinics are able to offer more than one algorithm package. See *supra* text accompanying note 118. To the extent that individuals have the wherewithal to choose among different clinics, the type of algorithm the clinic offered might influence their choice of clinics. Some people, however, may simply go to the clinic most accessible to them.

122 See *supra* text accompanying note 28. Algorithms might also factor in whether the variant is associated with great variability in expressivity.

123 Peter J. Neumann & Dan Greenberg, *Is the United States Ready for QALYs?*, 28 HEALTH AFF. 1366, 1367 (2009) ('QALYs represent health over time as a series of "preference-weighted" health states, where the quality weights reflect the desirability of living in the state, typically from "perfect" health (weighted 1.0) to death (weighted 0.0). Once the weights are obtained for each state, they are multiplied by the time spent in the state; these products are summed to obtain the QALYs.').

124 Franco Sassi, *Calculating QALYs and DALYs: Methods and Applications to Fatal and Non-Fatal Conditions, in* 1 HANDBOOK OF DISEASE BURDENS AND QUALIFY OF LIFE MEASURES 314 (Victor R. Preedy & Ronald R. Watson, eds., 2010) ('The DALY is primarily a measure of disease burden . . . . Although measured on similar scales, [QALYs] represent levels of quality of life enjoyed by individuals in particular health states, while [DALYs] represent levels of loss of functioning caused by diseases. The former are normally measured on a scale in which 1 represents full health and 0 represents death, therefore higher values correspond to more desirable states and states deemed worse than death can take negative values. The latter are measured on a scale in which 0 represents no disability, therefore lower scores correspond to more desirable states.'

with an increased propensity for such diseases would be excluded,[125] and the genomes of the remaining embryos would be ranked based on the generic algorithm. Conversely, only embryos with a significantly increased propensity for a particular trait, such as variants associated with intelligence (assuming a meaningful correlation between variant and trait)[126] would be selected for ranking according to the generic algorithm.[127]

Algorithms might also vary as to whether they factor in information about genetic variants associated with non-medical traits (which might depend on professional guidelines and who developed the algorithm). Individualized algorithms could offer parents the opportunity to decide what kinds of non-medical traits they wanted to include and the weight they would assign those traits. Alternatively, clinics might offer generic algorithms that include certain non-medical traits, perhaps relying on surveys of community preferences or based on the degree to which they were associated with 'success' or other measures of well-being, however defined or understood. As with variants associated with disease, values assigned to traits would have to be discounted based on the probabilities of expression.[128]

In designing algorithms, ART providers and clinics would have to decide to what extent they would allow patients to determine which traits to select for or against. For example, it is unlikely that providers would let future parents decide whether or not to select embryos based on lethal or debilitating childhood illnesses like Tay Sachs or Lesch Nyhan. Most clinics would likely use algorithms with a baseline selection against such devastating conditions. A more complicated issue is whether providers would be willing to honor other kinds of requests, particularly those that involve the selection *for* less serious disabilities. There are anecdotal cases of providers who have denied patients' requests to implant embryos identified through PGD as having genes associated with deafness or dwarfism. Some clinics, however, will implant such embryos,[129]

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125 Of course, one would have to decide what constituted a significantly increased propensity.

126 Genome-wide associate studies are identifying an increasing number of genes associated with intelligence. See Ian Sample, *Scientists Identify 40 Genes that Shed New Light on Biology of Intelligence*, GUARDIAN, May 22, 2017, https://www.theguardian.com/science/2017/may/22/scientists-uncover-40-genes-iq-einstein-genius (accessed Jun. 5, 2018) (noting that this research 'brings the number of genes known to have a bearing on IQ to 52'); W. David Hill, *A Combined Analysis of Genetically Correlated Traits Identifies 187 Loci and a Role for Neurogenesis and Myelination in Intelligence*, MOLECULAR PSYCHIATRY (Jan. 11, 2018) (finding '187 independent loci associated with intelligence, implicating 538 genes'). While genetic factors account for '50-80% of differences in intelligence, . . . [r]elatively few gene variants have reliably been associated with intelligence differences'. Hill, *supra*. Nevertheless, research 'may reach a point where the genomes of IVF embryos could be used to rank them according to their intellectual potential. . . .' *Id*.

127 Parental preferences could work the opposite way to narrow down embryos that were culled with a generic algorithm that, for example, ranked embryos based on disease risks or other QALY/DALY measures. The most highly ranked embryos would then be further narrowed down based on parental input about a few traits that they particularly valued or considered deal breakers.

128 Some genotypes will be more strongly associated with particular traits. See Zlotogora, *supra* note 28. Even with respect to a particular trait, like height, different genetic variants can have significantly different impacts. Richard Harris, *Which Genes Make You Taller? A Whole Bunch of Them, It Turns Out*, ALL THINGS CONSIDERED, Feb. 1, 2017, http://www.npr.org/sections/health-shots/2017/02/01/512859830/which-genes-make-you-taller-a-whole-lot-it-turns-out (accessed Dec. 15, 2017) (noting that about 700 genetic variants affect height, with some contributing as little as a millimeter of difference, others as much as an inch).

129 Daar, *Clash, supra* note 5, at 00.

suggesting there may be great variation as to how much algorithms would be personalized.[130]

Judith Daar has written thoughtfully about the challenges to physician autonomy that arise when patients want to use PGD to select for genetic anomalies. As she points out, 'providers are not obligated to meet every patient demand for treatment.'[131] She suggests that support for physician autonomy in this context may arise not only with respect to concerns about 'the medical appropriateness of the treatment', but also 'from a place deep within the doctor's personal identity'.[132] The Ethics Committee of the American Society for Reproductive Medicine recently grappled with these dilemmas in an opinion on the legitimacy of transferring genetically anomalous embryos. It found that 'valid and reasoned arguments exist to support provider decisions to assist in transferring genetically anomalous embryos, and in declining to assist such transfers'. In cases 'in which a child is highly likely to be born with a life-threatening condition that causes severe and early debility with no possibility of reasonable function',[133] however, the Committee found that '[p]hysician assistance in the transfer of [such] embryos is ethically problematic and highly discouraged.'[134] Should EPGD clinics follow these guidelines, one would expect great variety in the kinds of algorithms that clinics would use based on their willingness or reluctance to allow for selection based on certain genetic anomalies and possibly even some non-medical traits.

For all of these reasons, if EPGD were to become a reality, one could imagine fertility clinics offering a range of algorithms. Some might offer highly individualized algorithms for those who wanted full choice; others might offer more limited individualized algorithms. Still others might offer some kind of generic algorithm for those who wanted more assistance: generic algorithms that focus on health features, such as a reduced risk of serious childhood illnesses; generic algorithms that include non-medical traits, such as a propensity for athleticism or 'success'; etc.

Niche segments of the fertility market might emerge to cater to different kinds of decision-making preferences much as dating sites[135] and sperm banks have done to help individuals find the 'ideal' match or donor, respectively, from a potentially vast pool of candidates. Some dating services, for example, allow members to browse the profiles of all members with 'optional tests, quizzes, or guides' to help members find their love interests. The key, however, is that individuals have the freedom to 'choose

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130 We already see variation in the willingness of ART programs to offer fertility treatment. Surveys show that some ART providers are unwilling to provide fertility treatment to certain patients based on various factors. Although 'the key value' driving these decisions often tends to be 'ensuring a prospective child's safety and welfare and not risking the welfare of the prospective mother'—for example, when pregnancy would endanger the woman or there is a history of the man abusing existing children—clinics are just as likely to offer fertility treatment to couples who receive welfare, gay couples, or single men as they are to deny such treatment. Andrea D. Gurmankin et al., *Screening Practices and Beliefs of Assisted Reproductive Technology Programs*, 83 FERTIL. & STERIL. 61, 64–65 (2005).

131 Daar, *Clash, supra* note 5, at 00. She notes that discussions of physician autonomy tend to address conscientious objection to decisions such as abortion and/or refusal to offer futile care. *Id.* at 00–00.

132 *Id.* at 00.

133 Ethics Committee of the American Society for Reproductive Medicine, *Transferring Embryos with Genetic Anomalies Detected in Preimplantation Testing*, 107 FERTIL. & STERIL. 1130, 1134–35 (2017).

134 *Id.* at 1135.

135 I thank Professors Yaniv Heled and Radhika Rao for these observations.

the criteria for and expansiveness of their search'.[136] Similarly, many sperm banks allow you to peruse their websites broadly, although many offer the option to narrow the pool of donors based on basic attributes, such as hair and eye color, race, nationality, religion, education, height, weight, etc.[137] These general searches somewhat resemble parents wading through the genomic profiles created through EPGD and involve the greatest amount of time and energy on the part of the decision maker.

Certain dating sites and sperm banks, however, ease the selection process with something akin to the individualized algorithms I imagine for EPGD.[138] Some matchmaking sites, for example, use complex algorithms based on the member's 'in-depth personality profile' to find matches.[139] As OkCupid advertises, they use 'math in the name of love', working on 'algorithms, formulas, heuristics … to help people connect faster'.[140] eHarmony.com proclaims their matchmaking process 'cuts out the hours wasted … on other dating sites by showing only the matches that demonstrate compatibility with your profile.'[141] Some sites use algorithms based not only on responses to detailed questionnaires, but also on how an individual weights the questions.[142]

Similarly, some sperm banks offer refined search mechanisms. Fairfax Cryobank, for example, offers an advanced search that allows for greater specificity than its basic search with respect to ethnicity (fined tuned by country of origin), shades of skin tone (medium light, medium dark, light, dark, or medium), hair type (straight, curly, wavy), etc. It also offers a lifestyle search that selects donors based on astrology sign, favorite subject, religion, favorite pet, personal goals, and talents.[143] In addition, searches can be made based on physical resemblance to 'yourself, your partner or someone famous'[144] just by uploading a photo of the person to match. Using 'sophisticated mathematical formulas', Fairfax FaceMatch™ will compare the uploaded photo 'to every adult donor photo and provide results starting with the donor who most resembles the photo'.[145]

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136 http://www.onlinedatingmagazine.com/columns/industry/06-typesofonlinedatingservices.html (accessed Dec. 20, 2017).

137 See https://www.xytex.com/search-donors; https://fairfaxcryobank.com/search/ (accessed May 15, 2018).

138 http://datingtips.match.com/types-online-dating-7304700.html (accessed Dec. 20, 2017) (noting that 'matchmaking sites . . . alleviate the time spent searching through countless matches that are unrelated to [the individual's] interests by taking a detailed profile from [the individual] . . . and only providing matches . . . that directly meet the needs, wants and interests listed on [the individual's] profile').

139 *Id.*

140 https://www.okcupid.com/about (accessed Dec. 20, 2017).

141 https://www.datingsitesreviews.com/staticpages/index.php?page=2010000100-eharmony (accessed Dec. 20, 2017) (noting that their algorithm aims to cull the pool of members by eliminating 99.7% of those who are incompatible on 29 'Dimensions of Compatibility', gleaned from the members' completion of the 'comprehensive Relationship Questionnaire'). eharmony offers two other match options: Standard Matches and Flex Matches. "'Standard Matches" are based on Match Preferences (setting as the Age or Distance range you would like for your match) only.' *Id.* Flex Matches don't meet the match selection criteria the member indicates is most important, and occur when 'eHarmony is unable to find matches that meet your exact Match Selection criteria, but can sometimes uncover matches that are unexpectedly compatible.' *Id.*

142 Christopher McKinlay, Optimal Cupid: Mastering the Hidden Logic of OkCupid 11–12 (2014) (noting that responding to OkCupid's questionnaire requires making four decisions: '*Choosing whether to answer the question… Selecting your answer… Selecting acceptable match answers… Assigning the question a weight*').

143 https://fairfaxcryobank.com/search/ (accessed May 15, 2018).

144 *Id.*

145 The website warns that High (as opposed to Med or Low matches) 'occur infrequently'. https://fairfaxcryobank.com/fairfax-facematch#BestPhoto (accessed May 15, 2018). A test run using

GenePeeks launched an even more sophisticated sperm bank screening service in 2014, which resembles an EPGD algorithm in that it screens for donors least likely to result in the birth of a child with a recessive genetic disease. Working with two sperm banks, the company used a patented algorithm that 'creates thousands of hypothetical offspring' based on the genotypes of the mothers and potential donors. By scanning 'the resulting "digital children," the program can "flag pairings with an increased risk of inheriting genetic disorders.'[146] The analysis 'generates a personalized catalogue of risk-reduced donors for each prospective mother, filtering out donor matches with a high probability of passing on' the more than 500 inherited recessive diseases the company targets.[147] Noting, in 2014, that the analysis focused only on 'simple Mendelian disorders, with a one-to-one relation between genes and phenotype', the company was nevertheless optimistic about its potential to 'consider polygenic traits in the future'.[148]

Finally, another company, DonorMatchMe, offers both expanded choice—by aggregating 'available donor information from donor banks coast to coast so you do not have to'—and personalized choice—by providing 'all available filtering options … in addition to facial recognition technology that makes it more likely your child will look like you'.[149] The marketing utilizes precisely the kinds of strategies I imagine providers would use for their EPGD decision-making algorithms. It first offers the possibility of expansive choice: as the website queries, 'If you want a TRUE match, why limit your search to just part of the crowd?'[150] EPGD websites might similarly ask, 'If you want your IDEAL child, why limit your choices to nature?' Second, DonorMatchMe's website highlights the significance of the decision motivating the search: 'Choosing to have a child is one of the most important decisions anyone makes in their life.'[151] One imagines exactly the same language to promote EPGD. Finally, DonorMatchMe's website urges future parents to use its 'algorithms … to find your *perfect* Match', so as not 'to make searching for your *perfect* sperm or egg a frustrating chore'.[152] Such language promises perfection through the objective, scientific method of an algorithm. Undoubtedly, EPGD clinics would promote their algorithms with similar rhetoric.

In short, one can easily envision fertility clinics offering different selection methods for EPGD along the lines of these different types of dating or sperm bank

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a photo of George Clooney proved their point. Out of a pool of 410 donors, there were no High matches and only 12 and 8, Med and Low matches, respectively.

146 *Id.*

147 Bio-IT World Staff, *GenePeeks Launches Sperm Donor Matching Service*, Bio-IT World, May 22, 2014, http://www.bio-itworld.com/brief/2014/5/22/genepeeks-launches-sperm-donor-matching-service.html (accessed May 18, 2018).

148 *Id.* A recent visit to their website found a description of this preconception screening, called 'Matchright'. The website noted, however, that the company is 'currently not accepting orders for our Preconception Screen'. It referred visitors to an email address for 'any additional questions'. See http://www.genepeeks.com (last visited May 18, 2018). In response to my email asking whether they still offered Matchright screening for sperm donors or were simply overbooked, the company replied on May 21, 2018, 'We have suspended offering of our preconception screening service . . . while the company is being restructured, and we are not working with any clinical partners at this time.' Interestingly, a more recent attempt to visit their website on June 5, 2018 was met with the message 'This site cannot be reached'.

149 https://donormatchme.com/Home/BetterSearch (accessed May 18, 2018).

150 *Id.*

151 *Id.*

152 *Id.* (emphasis added).

websites. Instead of eHarmony, imagine EmbryoHarmony,[153] and instead of DonorMatchMe, imagine BabyMatch. If EPGD becomes an accepted form of ART, rather than leave parents to wade unassisted through the thicket of so much information, clinics would likely offer a range of algorithms to ease decision making. One can visualize the advertisements touting their potential to optimize the ability to find the 'ideal' parent–child match or to have children with a greater chance of health, 'success,' or well-being.

One might expect some backlash to such advertising given the reactions to 23andMe's patent for its Family Traits Inheritance Calculator, which was designed to predict 'six variable benign traits, including "eye color" and "muscle performance," based on how parental DNA would likely combine'.[154] When it filed for the patent in 2008, the company considered using enhanced gamete donor selection. Ultimately, however, it decided against doing so in response to concerns that this technology amounted to 'shopping for designer donors in an effort to produce designer babies'.[155] Whether such reactions would arise with respect to similar marketing for EPGD is uncertain. The reactions to 23andMe's patent reflect today's perspectives in light of current technologies. If as I predict, EPGD will develop gradually in response to technological advances and an ever-expanding scope of prenatal testing, it is not implausible (even if troubling) to believe society will gradually become more tolerant of the fine-tuned selection of EPGD and its associated algorithms.

B. The Problems with Algorithms

While algorithms could potentially be very helpful in assisting parents with the potentially paralysing choices of embryo selection through EPGD, they raise general and specific issues, depending on who develops them. Section V.B.1 describes the general impact of algorithms on reproductive decision making, while Sections V.B.2. and V.B.3 discuss the issues that might arise, respectively, if professionals and commercial entities developed algorithms for EPGD.

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153 I would love to take credit for this clever term, but Professor Radhika Rao deserves credit for coining it.

154 Eliot Marshall, *Company's 'Designer Baby' Patent Divides Bioethicists*, SCIENCE, Oct. 3, 2013, http://www.sciencemag.org/news/2013/10/companys-designer-baby-patent-divides-bioethicists (accessed May 15, 2018).

155 Lydia O'Connor, *23andMe Gets Patent for Baby Trait Predictions Calculator, But Says It Won't Be Used*, HUFFPOST, Oct. 5, 2013, https://www.huffingtonpost.com/2013/10/05/designer-babies_n_4046809.html (accessed May 15, 2018) (quoting Marcy Darnovsky, executive director of Center for Genetics and Society). See also Sigrid Sterckx et al., *'I Prefer a Child with . . .': Designer Babies, Another Controversial Patent in the Arena of Direct-to-Consumer Genomics*, 15 GENET. MED. 923, 924 (2013) (describing this 'computerized process for selecting gamete donors to achieve a baby with a "phenotype of interest" that the prospective parent "desires in his/her hypothetical offspring"' as seeming 'to have much broader implications' than using PGD to avoid serious genetic abnormalities since 'this process also entails the selection of traits that are not disease related'); *CGS Calls on 23andMe to Disavow 'Designer Babies': Controversial New Patent Raises Critical Questions*, Oct. 2, 2013, https://www.geneticsandsociety.org/press-statement/cgs-calls-23andme-disavow-designer-babies-controversial-new-patent-raises-critical?id=7193n (accessed May 15, 2018). (fearing 'this project . . . could encourage the dangerous idea that science should be used to breed "better" people, breathing new life into the specter of eugenics that has long hung over the field of genetics').

1. The Impact of Algorithms on Reproductive Decision Making. I begin by examining the general impact of using algorithms in this context.[156] Some might find it unsettling to use algorithms to select embryos because they rely on concrete expressions of preferences unlike selecting embryos in a more amorphous way. This concern, however, argues against EPGD itself or even ordinary PGD and prenatal testing. Inherent in the concept of EPGD is the idea that some embryos have genomic profiles that are more desirable (by whatever measure) than others. As long as parents use reproductive technologies to choose among embryos (or make decisions about pregnancies), certain preferences (whether expressed in mathematical formulas or not) inevitably shape those decisions. We cannot, therefore, fault algorithms on these grounds as long as we condone PGD and prenatal testing.

Others might argue, however, that algorithms for EPGD have the potential to enhance decision making by allowing individuals to manage complex amounts of information in systematic and consistent ways.[157] To the extent that individualized algorithms would accurately reflect individual preferences, they might seem like a more rational mechanism for decision making than the unsystematic way most of us make decisions involving complex costs and benefits. This argument presumes, however, that people have a clear understanding of and can articulate their values and preferences (generally and in this context). The more complex and elaborate the individualized algorithms, the more likely people would opt for generic algorithms, which would be problematic for several reasons.

First, we might worry that using generic algorithms would be an abdication of decision making with respect to a technology intended to enhance reproductive choice.[158] It might also challenge some presumptions underlying informed consent and genetic counseling norms: that individuals should be fully engaged in and willing to make their own reproductive decisions.[159] Of course, if the goal of EPGD is to expand choice, one could argue that the option to use generic algorithms is not an abdication of choice, but, instead, a decision about *how* to decide. Indeed, in a world where EPGD was widely accepted, one might argue that reproducing the 'old-fashioned' way would be the true abdication of procreative choice. Rather than let 'nature' randomly dictate the outcome,

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156 The Pew Research Center conducted 'a large-scale canvassing of technology experts, scholars, corporate practitioners and government leaders' about the 'potential impacts of algorithms [generally] in the next decade'. Lee Raine & Janna Anderson, Pew Research Center, *Code-Dependent: Pros and Cons of the Algorithm Age* 4 (Feb. 8, 2017), *available at* http://www.pewinternet.org/2017/02/08/code-dependent-pros-and-cons-of-the-algorithm-age/ (accessed Jul. 8, 2018). 'The non-scientific canvassing found that 38% of these particular respondents predicted that the positive impacts of algorithms will outweigh negatives for individuals and society in general, while 37% said negatives will outweigh positives; 25% said the overall impact of algorithms will be about 50-50, positive-negative.' *Id.*

157 This was one of the positive assessments of algorithms in the Pew study on algorithms. See *id.* at 7–9. As some scholars argued, algorithms can address 'difficult choices and problems, especially when intuitively we cannot readily see an answer or way to resolve the problem', can 'help make sense of massive amounts of data', can 'perform seemingly miraculous tasks humans cannot', and can 'ease the friction in decision making'. *Id.*

158 See *id.* at 10 (describing concerns that algorithms could 'present a caricature of our tastes and preferences' and fears that 'it will be simply too convenient for people to follow the advice of an algorithm (or, too difficult to go beyond such advice), turning these algorithms into self-fulfilling prophecies, and users into zombies who exclusively consume easy-to-consume items'); *id.* at 55 (describing worries that '[h]umans will lose their agency in the world').

159 See Barbara B. Biesecker, *Future Directions in Genetic Counseling: Practical and Ethical Considerations*, 8 KENNEDY INST. ETHICS J. 145 (1998).

using a generic algorithm with EPGD would be a choice to let some notion of 'better' or 'best' determine who will ultimately be born.

Moreover, people often turn to others—physicians, loved ones, or religious advisors—when making difficult medical or personal decisions.[160] These decision-making approaches, however, are quite different from allowing a generic algorithm, created by an impersonal entity—whether a provider or a company—to decide which embryos to implant. Typically, we relinquish decision-making authority for important decisions to those who have special knowledge of us and our individual circumstances. Generic algorithms, however, falsely suggest a uniformity of views[161] regarding genetic information and its relevance to reproductive decision making. By definition, they do not depend on, and therefore could easily lead to decisions inconsistent with, individual values or preferences.[162]

Another troubling feature of generic algorithms is the possibility that biases might shape reproductive outcomes.[163] Decisions about which criteria (serious disease risks, minor diseases, and/or non-medical traits) to consider and their weight in the algorithm would reflect value judgements about the relevance and appropriateness of using such information to select embryos.[164] What's worse, the embedded biases and values would be largely hidden.[165] As a result, the algorithmic selection could potentially be misperceived as scientific, objective, and even medically optimal, rather than

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[160] See France Légaré, *Decisions Faced by Patients: Primary Care, in* Encyclopedia of Medical Decision Making (Mark E. Cowan & Michael W. Kattan eds. 2009) (noting that 'individuals facing health-related decisions indicate that their preferred method for obtaining information remains the counseling offered by their physician'). Obviously, there are individual differences in the extent to which people rely on others and on whom they rely. One study shows that 'Americans overall are much less likely to rely a lot on advice from professional experts (25%) or religious leaders (15%) than they are on prayer or advice from family members. . . . However, there are differences among religious groups. For example, 40% of highly religious evangelical Protestants say they turn to religious leaders a lot for advice when making major life decisions.' Pew Research Center, *Religion in Everyday Life* 46 (Apr. 12, 2016), *available at* http://assets.pewresearch.org/wp-content/uploads/sites/11/2016/04/Religion-in-Everyday-Life-FINAL.pdf (accessed May 16, 2018).

[161] *Cf.* Raine & Anderson, *supra* note 156, at 12 (quoting a respondent who says that with algorithms '[w]e will all be mistreated as more homogenous than we are'). The degree of our discomfort here would be tied to whether the algorithm was entirely generic or whether it allowed for the incorporation of some individual preferences. The less individual preferences would be incorporated, the more problematic the algorithm would be, with a fully generic algorithm being the most problematic.

[162] *Cf. id.* at 9 (quoting respondents who worry that algorithms are 'creating a flawed, logic driven society and that as the process evolves . . . humans may get out of the loop, letting "the robots decide"').

[163] Algorithms (or models), 'despite their reputation for impartiality, reflect goals and ideologies' incorporating 'values and desires' in the data used and the questions asked. 'Models are opinions embedded in mathematics'. Cathy O'Neil, Weapons of Mass Destruction 29 (2016). 'Algorithm creators . . . , even if they strive for inclusiveness, objectivity, and neutrality, build into their creations their own perspectives and values.' Raine & Anderson, *supra* note 156, at 11. As one respondent noted in the Pew study on algorithms, 'algos are always rooted in the value systems of their creators'. *Id.* at 14. As another argued, 'algorithms will reflect the biased thinking of people . . . . Oversight will be very difficult or impossible.' *Id.* at 12.

[164] Biases can exist with QALYs as well. DA Pettitt et al., *The Limitation of QALY: A Literature Review*, 6 J. Stem Cell Research & Therapy 334 (2016), https://www.omicsonline.org/open-access/the-limitations-of-qaly-a-literature-review-2157-7633-1000334.pdf (accessed Dec. 15, 2017).

[165] Just think of your news feed on Facebook, which is chosen by 'a mysterious algorithm that takes into account hundreds of factors', most of which are not immediately apparent. Vindu Goel, *Facebook Tinkers with Users' Emotions in News Feed Experiment, Stirring Outcry*, New York Times, June 29, 2014, https://www.nytimes.com/2014/06/30/technology/facebook-tinkers-with-users-emotions-in-news-feed-experiment-stirring-outcry.html (accessed Jul. 8, 2018). The possibility of hidden biases in algorithms was

a mathematical expression of values and preferences. Indeed, the appeal of these algorithms might be precisely their apparent objectivity.[166]

Finally, by eliminating the randomness of 'old-fashioned' reproduction, we might see less diversity in those born via EPGD, particularly if most, or a respectable minority, relied on generic algorithms. By standardizing reproductive choices based on the variants that were especially determinative in the program, algorithms would tend to favor certain kinds of traits (medical or non-medical) and disfavor others. This would be less likely with individualized algorithms, as long as individual preferences were sufficiently variable.[167]

From one perspective, the potential reduction in diversity might not be all bad if generic algorithms resulted in fewer children born with debilitating and serious diseases (most algorithms would be heavily weighted against such conditions) and more children born with higher 'quality adjusted life years'.[168] Such outcomes would be consistent with the values of most parents pursuing EPGD, who likely chose this method of reproduction, in part, to minimize suffering in their children. Otherwise, why go to the trouble of using EPGD; why not simply rely on 'old-fashioned' reproduction?[169]

On the other hand, the lack of variability that might occur if embryos were selected with generic algorithms would be troubling. We might worry about the long-term evolutionary implications, if they reduced genetic diversity. How much generic algorithms would reduce diversity (at least with respect to the loci that would be strong determinants of the algorithms' outcomes) would depend on how widely the public embraced EPGD and generic algorithms.

Even if generic algorithms didn't pose an evolutionary threat, the societal effects of insufficient diversity are troubling. If generic algorithms are used widely, they would lead to routinization of reproductive choices on a profoundly different scale than we currently see with reproductive testing[170] or might see with EPGD alone. The effects of the algorithms would dwarf cultural pressures that influence routinization. Rather than push people toward particular choices, as cultural pressures do today (and might do with EPGD), the algorithms would literally 'choose' embryos for implantation in a systematic and comprehensive way. Such choices could stigmatize the groups routinely

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a common concern among respondents in the Pew study on algorithms. See *supra* note 163. As one noted, '[t]he power to create and change reality will reside in technology that only a few truly understand.' Raine & Anderson, *supra* note 156, at 15. Respondents varied as to how hidden these biases are. Several offered despairing views: 'There is no transparency, and oversight is a farce. It's all hidden from view.' *Id.* at 42. 'Algorithms are too complicated to ever be transparent or to ever be completely safe.' *Id. at 85.* 'Only the programmers are in a position to know for sure what the algorithm does, and even they might not be clear about what's going on.' *Id.* at 19. Even a less pessimistic respondent queried, 'how do we educate ourselves about the way they work . . . what assumptions and biases are inherent in them, and how to keep them transparent?'). *Id.* at 5–6.

166 As I suggest below, this problem could be particularly true if professional societies created such algorithms. See *infra* Part V.B.2.

167 We might, however, be concerned about whether social norms and peer pressures could reduce variability of choices, even with individualized algorithms.

168 See eg Julian Savulescu, *Procreative Beneficence: Why We Should Select the Best Children*, 15 BIOETHICS 413 (2001); *supra* note 123.

169 Of course, this argument doesn't apply to those who use EPGD because of fertility issues because they don't have the option of reproducing the 'old fashioned' way. But it does apply to those who use EPGD to maximize the chance of having children with traits they desire. See *supra* text accompanying notes 91–92.

170 Suter, *Routinization, supra* note 46.

screened against,[171] ultimately leading to and/or reinforcing discrimination against those groups.[172] What's worse, these biases against or in favor of certain groups would be hidden in the mathematical equations, making the choices seem 'objective'.

Algorithms heighten concerns about EPGD in other ways. As noted earlier, EPGD's highly refined selection raises the possibility of heightened expectations about one's future child, which might be dashed if the child did not fulfill those parental expectations. Similarly the 'choice overload effect' of EPGD could potentially lead to dissatisfaction with the future child.[173] Algorithms, however, might make such dissatisfaction *especially* likely because, in being designed to help parents make the 'best' choices, they would further heighten parental expectations. Marketing would only exacerbate that effect. But individualized algorithms would be even worse because they would be promoted as finely tuning selection based on the particular preferences of the parents, leading to even stronger expectations of having their 'ideal' child.

To be sure, there have always been worries that prenatal selection encourages future parents to fixate on the future child in terms of the presence or absence of a particular trait (which to date has mostly been diseases). But if selection addresses a much broader spectrum of the future child's traits, and if algorithms promise to increase the odds of successfully selecting for children with those traits, then parents' fixation on whether the child develops the chosen or rejected traits, and the possibility of their disappointment if the child doesn't measure up to expectations, would increase exponentially.

Finally, the use of algorithms for EPGD decision making could further exacerbate the potential inequities discussed in Section IV.B.3. If insurers covered basic EPGD, but not the algorithmic analysis, this might indirectly limit access to either EPGD or refined use of the selection method. Further, if EPGD creates choice overload and leads some to opt out of choosing altogether, people who could not afford the additional costs of the algorithms would either avoid EPGD or end up choosing in a more limited way. Either way, they would not have the opportunity to make the more finely tuned selections that algorithms would allow. To the extent that algorithms allow for the ability to select on the basis of a combination of traits that offer societal advantages, we would once again see individuals of higher socioeconomic status multiplying the opportunities for their future children in stark contrast to those with fewer economic resources.

2. Professional Group's Algorithms. Quite apart from general concerns about algorithms, particularly generic algorithms, specific concerns might arise based on who develops the algorithms. In many ways, medical professionals or professional societies seem best suited for the task. They play a significant role in medical decision making. They have special insight and expertise as to what information is clinically relevant and the kinds of considerations that influence reproductive decisions. Genetics professionals, in particular, would have particular knowledge about different genetic variants—including the expressivity and penetrance of medical and non-medical traits—to create meaningful

171 *Cf.* Greely, *supra* note 8, at 244–49; Suter, *IVG, supra* note 1, at 118.

172 See Tom Shakespeare, *A Brave New World of Bespoke Babies?*, 17 Am. J. Bioethics 19 (2017); Greely, *supra* note 8, at 245–46; Suter, *IVG, supra* note 1, at 118.

173 See *supra* text accompanying notes 74–77. In the analogous online dating world, for example, this phenomenon has been shown to lead to dissatisfaction with one's selection of partners. D'Angelo & Toma, *supra* note 74, at 13–17. This study noted that this phenomenon may not become apparent immediately because of the complexity of the choices, the desire to publicly justify the choices, and the need for processing time. *Id.* at 5, 17–18.

categories for algorithms. Finally, health care providers have fiduciary duties to their patients.

Nevertheless, the development of generic algorithms by medical professionals might challenge their professional norms and identities in several ways. Such algorithms would deviate from the long-held perspective that the right reproductive choice for one person might not be the right choice for another. A generic algorithm by definition would imply that one size actually does fit all.

Developing generic algorithms would also depart from the neutral stance that such professionals, particularly genetic counselors, have long advocated. Even though patients would presumably have the option to reject the algorithms, assigning relative values to different genetic variants would overtly signal that the profession is not actually neutral about the reproductive choices. That the profession isn't neutral is not in and of itself a problem (or even a revelation[174]). But knowing that the profession is not neutral is altogether different from professionals expressing their biases in a program that could literally determine patients' decisions. Further, professionals might have unique biases that do not reflect those of the patient or broader population, which could distort decision making, particularly if their generic algorithms were widely adopted. It is hard to imagine precisely what those biases might be, should EPGD become a viable technology, but it is not unlikely that professionals may have strong views about the kinds of traits that parents should or should not select against, which may not always align with an individual's views, particularly regarding information about more minor medical risks or non-medical traits.[175]

Finally, influencing reproductive decision making in this manner would be reminiscent of the eugenics era when genetics professionals advocated for policies intended to shape reproductive decisions. Although the field of clinical genetics grew out of this movement,[176] clinical geneticists and genetic counselors have worked hard to distance themselves from eugenics.[177] Creating genetic algorithms would directly contravene such efforts.

Beyond concerns about professional identities and norms, we might further worry that the creation of generic algorithms by professionals would make these algorithms inordinately enticing. When faced with the overwhelming task of selecting from a multitude of embryos or providing input for individualized algorithms, people might find generic algorithms created by the very professionals to whom they turn for reproductive guidance a calming alternative in the chaos of choice.

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174 See Karen G. Gervais, *Objectivity, Value Neutrality, and Nondirectiveness in Genetic Counseling, in* Dianne M. Bartels et al., Prescribing Our Future: Ethical Challenges in Genetic Counseling 119 (1993).

175 *Cf.* Suter, *Routinzation, supra* note 46, at 245 and n.71 (describing biases among genetic counselors in favor of terminating pregnancies for abnormalities among genetic counselors and quoting a study that found that most counselors 'would have abortions for most abnormalities, half . . . would abort for *any* abnormality') (quoting Barbara K. Rothman, The Tentative Pregnancy: How Amniocentesis Changes the Experience of Motherhood 46 (1986)); *supra* text accompanying notes 129–30.

176 Ian H. Porter, *Evolution of Genetic Counseling in America, in* Genetic Counseling 17, 23 (Herbert A. Lubs & Feliz de la Cruz eds., 1977); Dorothy Nelkin & M. Susan Lindee, The DNA Mystique: The Gene as Cultural Icon 27 (1995) (noting that the American Eugenics Society sponsored nationwide 'mental and physical perfection contests'); Suter, *Routinization, supra* note 46, at 234–35.

177 *Cf.* Seymour Kessler, *The Psychological Paradigm Shift in Genetic Counseling*, 27 Soc. Biol. 167, 168, 182 (1980) (discussing the shift from the eugenics paradigm to the more contemporary paradigm of helping patients make their own decisions).

Adding to this concern is the risk that algorithms developed by medical professionals would enhance the sense that they offered medically 'objective' methods for selecting embryos.[178] Relying on them would not be like deferring to the expertise of professionals the way one might defer to a surgeon regarding the optimal surgical procedure. Neither is it like considering professional views when facing difficult decisions.[179] Instead, selecting embryos based on a generic algorithm would literally be handing over the decision to the algorithm, whose formula would have been shaped by the (largely hidden) values and biases of the professionals who created it. In many ways, this would amount to professionals giving advice about non-medical matters, which exceeds the scope of their expertise. In so doing, it would blur the lines between medical advice grounded in scientific knowledge and physicians' social or individual preferences.

There is reason to be troubled by this. Even today, reproductive decisions (such as choosing to undergo prenatal screening or testing) are often seen as medically responsible decisions, rather than personal decisions.[180] Professionally created generic algorithms might similarly be viewed as the medically responsible way to decide which embryo to select, particularly when alternative methods could be overwhelming. That perspective might further tempt patients to forego individualized decision making in favor of generic algorithms, enhancing concerns about the societal effects of algorithms dramatically routinizing reproductive choices.[181]

3. Commercial Algorithms. Finally, if algorithms were created by companies operating outside the clinical setting, where the fiduciary obligations of the doctor–patient relationship do not apply, we might worry about market forces influencing consumer demand. The market power to routinize this kind of decision making would potentially be much greater in this context for a few reasons. First, advertising would build on the notion that 'good' parents use not only EPGD but also algorithms because this is the optimal way to select embryos with the best prospects for health and longevity (much like NIPT marketing has done).[182] Second, because many algorithms would also incorporate information about genotypes associated with non-medical traits, such companies would promote their algorithms as offering the best method to choose an embryo with socially competitive advantages. Third, if such efforts were successful, market pressures would push toward expansive genetic analysis and potentially also toward *specific* outcomes based on whatever genetic variants the algorithms favored and disfavored. If widely used, these algorithms could narrow reproductive decisions in ways we have never seen. Moreover, because profit motives, rather than fiduciary obligations, would

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178 See *supra* text accompanying notes 166.

179 The genetic counseling community has generally resisted responding to queries about what the genetic counselor would do in the patient's shoes because they believe that what a genetic counselor would choose isn't necessarily what the client would want. Sonia M. Suter, *Sex Selection, Nondirectiveness, and Equality*, 3 Univ. Chicago L. Sch. Roundtable 473, 478–80 (1996). One could argue, however, that the patient is simply trying on different kinds of choices, not entirely putting her choice in the hands of the genetic counselor.

180 See Nancy A. Press & Carole H. Browner, *Collective Silences, Collective Fictions, in* Women and Prenatal Testing: Facing the Challenges of Genetic Technology 201 (Karen H. Rothenberg & Elizabeth J. Thomson eds., 1994).

181 One respondent in the Pew survey on attitudes toward algorithms described them as 'a way of routinizing certain choices and decisions . . . '. Raine & Anderson, *supra* note 156, at 16.

182 See *supra* text accompanying notes 80–81. Of course, fertility clinics could use such marketing techniques as well.

shape the algorithm design, the underlying biases would be much more problematic than in the clinical setting. The marketing and development of the programs would be based on what sells, not what is 'best' for patients, however that is understood by health care professionals in this context.[183]

For all of these reasons, there is reason to worry that algorithms, even if intended to address challenging decision making, will create their own sets of issues for patients, society, and even some health care providers. The remedy may truly be worse than the disease it seeks to cure.

CONCLUSION

Having described various concerns regarding EPGD and efforts to address the related decision-making challenges, I concede that this article explores a future that is speculative, even if highly plausible. We cannot know with certainty what technological advances will be possible and what the institutional and cultural reactions will be to those that unfold. But because new technologies often emerge before we have contemplated their implications, and because efforts are already under way to advance the very technologies that would make EPGD possible, this article is a call to pause and consider what EPGD would mean for parents, society, and the potential providers of EPGD.

If EPGD were to become a viable technology, it would raise and exacerbate many of the same issues we have faced with other reproductive technologies—their impact on the experience of reproduction, their influence on societal norms and behavior, and their implications for reproductive decision making. Contemplating a world where EPGD is the norm pushes us to consider the potential harms of unlimited, unrestricted reproductive choice and to recognize that the promise of expansive options may ultimately be illusory. In this article, I hope to demonstrate that the tyranny of choice could lead to the abdication of choice by some, which may lead to efforts by professional groups, fertility clinics, and commercial labs to intervene. It concludes that some of the potential efforts to ameliorate the tyranny of choice—such as restrictions of information or decision-making algorithms—may raise their own sets of issues for individuals, professionals, and society. For all of these reasons, my hope is that a careful examination of EPGD, before it becomes a viable option, will prevent us from adopting this new technology simply because technological advances seem to propel us inevitably toward it. Instead, we should think carefully about what kind of reproductive choice we want and whether it offers all that it promises.

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[183] See Raine & Anderson, *supra* note 156, at 17 (Among the concerns expressed about algorithms generally in the Pew Center survey were worries that '[a]lgorithms are defined by people who want to sell you something . . . and will twist the results to favor doing so'). Some scholars have expressed similar kinds of concerns about dating websites, arguing that commercial interests lead them to suggest their algorithms are scientifically based and reliable indicators of good matches, when in fact 'no compelling evidence supports matching sites' claims that mathematical algorithms work—that they foster romantic outcomes that are superior to those fostered by other means of pairing partners'. Finkel et al., *supra* note 75, at 3. See also Benjamin Winterhalter, *Don't Fall in Love on OkCupid*, JSTOR Daily (2016), https://daily.jstor.org/dont-fall-in-love-okcupid/ (accessed Jul. 10, 2018).