wary of machines "that had too many glitches to be trustworthy". The speed and accuracy of later models threatened to make the mathematicians' roles redundant, but the women staved off obsolescence for some time by redefining their official jobs as programmers. Holt misses an opportunity here to make the connection between the experiences of JPL's human computers in relation to the rise of automation, and today's widespread anxieties over the 'age of artificial intelligence'.

Personal anecdotes include details of the family arrangements that the women had to make in an era when marriage and children meant leaving the workforce. These will fascinate general readers and provide valuable primary source materials for future academics. Yet Holt does not contextualize the JPL crunchers' experience in the broader history of women in science and technology. She does observe that the proportion of JPL technical jobs held by women — 15% in the 1990s — was partly due to women organizing the hiring process. Yet although the figure was higher than elsewhere in NASA, it was still remarkably low. And in the same way that NASA failed to celebrate these women's contributions, it also overlooked the evidence in favour of including women in the astronaut corps. As space curator Margaret Weitekamp has detailed in *Right Stuff, Wrong Sex* (Johns Hopkins University Press, 2004), the benefits of sending women to space included their small size compared to men, which meant that they would need less food and water.

Engagement with such studies would have helped Holt to analyse how typical the JPL programmers' experience was for women in technical fields, and to explicate her original findings more clearly. Many scholarly studies describe the exodus of women at other institutions from programming by the 1950s. By contrast, Holt notes, some of the early female crunchers stayed at JPL well into the twenty-first century, some in managerial roles. That raises questions about what made JPL different and, crucially, about retaining women in technical fields today. That story remains to be written. ■

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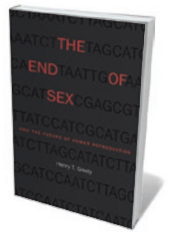
GENETICS

Coitus defunctus

Lori Andrews assesses Henry Greely's treatise on how technology will oust reproductive intimacy.



The End of Sex and the Future of Human Reproduction
HENRY T. GREELY
Harvard University Press: 2016.

For millennia, people have been trying everything from magic to medicine to influence the traits of their children. Recommendations from relatives and advice columns have, across time, included: put a knife under your bed if you want a boy; eat sweets while pregnant if you want a girl; place headphones on your pregnant belly and play Jacopo Peri's *Euridice* to ensure that your future child will appreciate opera.

Current genetic technologies offer parents more-precise means of predicting and perhaps shaping the traits of their children. Embryos created through *in vitro* fertilization (IVF) can be analysed using pre-implantation genetic diagnosis (PGD); their entire genomes can even be sequenced. And the gene-editing technique CRISPR–Cas9 is expected to one day offer couples a chance to repair and enhance the genes of their embryos.

In *The End of Sex and the Future of Human Reproduction*, lawyer and bioethicist Henry Greely does an enviable job of explaining the scientific underpinnings and legal regulation of current reproductive and genetic technologies. The central focus of his book is his prediction that a new technology will develop — one that he dubs "Easy PGD". Greely envisions a situation in which a woman will not have to undergo treatment with hormones and have her eggs removed to produce an embryo for testing — as is done in the course of IVF. Instead, some of her skin cells will be removed and coaxed by stem-cell technologies to turn into eggs. The eggs will then be fertilized by sperm from her partner to create as many as 100 embryos. In this scenario, parents will be able to choose which embryos to have implanted in the woman's uterus on the basis of hundreds of traits (or more) revealed by whole-genome sequencing.

Greely makes three claims about this putative Easy PGD. First, it will replace sex as a way to create babies. Second, it will be more socially acceptable than current PGD and prenatal genetic-testing technologies. And third, it will be free to the user.

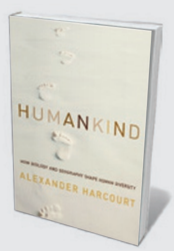
THE PROCESS OF DECISION-MAKING WOULD BE DAUNTING.

All three claims are problematic.

Greely assumes that people will elect to create children with Easy PGD rather than through sex because of the desire to control the traits of their children. But if people were so keen to choose embryos on the basis of their genotypes, all couples who use IVF would submit their embryos to genetic testing (given that this would involve no extra risk to the woman). In the United States, only 5% of such couples do so.

Greely also speculates that couples will rush to use stem cells to create embryos because such an approach would be less ▸

Birth of a Theorem: A Mathematical Adventure
Cédric Villani (Vintage, 2016)
Tackling the 140-year-old Boltzmann equation (with Clément Mouhot) led mathematician Cédric Villani to win a share in the 2010 Fields Medal. Documenting this quest, Villani encapsulates the despair and elation that maths can incite (see Amir Alexander's review: *Nature* **519,** 31–32; 2015).



Humankind: How Biology and Geography Shape Human Diversity
Alexander Harcourt (Pegasus, 2016)
Biogeographer Alexander Harcourt ponders the myriad forces that led to the amazing diversity of *Homo sapiens* as we spread across the globe. He thinks that coastal migration once prevailed: harvesting seafood was easier than hunting.

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invasive than IVF. But there is no proof that the risks to women presented by IVF (such as ovarian hyperstimulation syndrome and pelvic infection) are a substantial deterrent when it comes to couples who use the procedure: globally, more than 400,000 children are born through IVF each year. Nor is there any evidence that couples would embrace an untested stem-cell procedure, with unknown risks to the resulting child.

Even if Easy PGD were risk-free, the process of decision-making would be daunting. Whole-genome sequencing would provide prospective parents with hundreds or thousands of bits of information about each embryo. The *BRCA1* tumour-suppressor gene alone consists of more than 81,000 base pairs. Of the hundreds of *BRCA1* mutations that have been reported, some are associated with an increased risk of developing breast cancer or ovarian cancer; others are not, and the significance of many is not yet known.

If the test reports a mutation of unknown significance in any of an embryo's 20,000 genes, parents might end up discarding a perfectly healthy embryo, or — if they have the embryo implanted anyway — worrying throughout the child's life about the potential manifestation of a horrible condition. Even the mutations that are associated with disease will be hard to make sense of. What does a person do with the knowledge that a certain embryo will develop into someone who has a breast-cancer risk 30% higher than that of the general population, double the baseline risk of developing Alzheimer's disease, and a 45% possibility of achieving a higher college admission score than another embryo with an equally complex data set?

Greely claims that Easy PGD will be more socially acceptable than current genetic testing of embryos and fetuses because, unlike existing approaches, it does not involve abortion. Yet whether the embryos are derived from skin cells or seeded with gametes, right-to-life advocates will oppose the termination of embryos that could be implanted to create children. Furthermore, many more embryos would be discarded using Greely's proposed Easy PGD than are now destroyed in the course of IVF and PGD.

Greely's final claim is that Easy PGD will be free. Using assumptions, including that it will cost US$1,000 to create 100 embryos from skin cells, $60 per embryo for genetic diagnosis, and $500 for genetic counselling, he estimates that it will cost about $11,000 for the entire procedure. According to Greely, at that cost, "the procedure should pay for itself for health reasons". But current genetic technologies also save future health costs, and these techniques are not always covered by health-care systems. In fact, it is extremely difficult for women below a certain income bracket to access them.

Greely imagines the slogans that clinics will use to tout Easy PGD: "You want the best for your child; why not have the best child you can?" But after exploring Greely's claims in detail, Easy PGD seems more likely to be an expensive technology of unknown risks that would present parents with hard-to-interpret information about as many as 100 embryos. The idea of Easy PGD should make us uneasy indeed. ■

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Pressed for Time: The Acceleration of Life in Digital Capitalism
Judy Wajcman (University of Chicago Press, 2016)
Sociologist Judy Wajcman sagely analyses the disparate experience of time as technology has evolved. Despite the common belief that smartphones heighten stress, she argues that we are not victims of machines, but masters of their role in our lives.

The Cosmic Cocktail: Three Parts Dark Matter
Katherine Freese (Princeton University Press, 2016)
What is the Universe made of? Physicist Katherine Freese chronicles the cracking of this beguiling enigma, from the eccentric, ski-jumping Fritz Zwicky (who coined the term dark matter) to particle-smashing physics (see Francis Halzen's review: *Nature* **509,** 560–561; 2014). **Emily Banham**

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