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EXTINCTION BY DESIGN

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Thank you, Vicki, thank you all for coming, and thank you to the law school faculty and staff who've been extremely gracious. It has been a real pleasure to be here. I'm going to talk to you all about genetic engineering and the future of human evolution. *Extinction by Design*¹ was the original title for my book, but the marketing people at the Johns Hopkins University Press said, "No, the word 'dystopia' has to be in your title." So *Extinction by Design* wasn't the title of the book, but it is the title of tonight's talk.

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1. MAXWELL J. MEHLMAN, *TRANSHUMANIST DREAMS AND DYSTOPIAN NIGHTMARES: THE PROMISE AND PERIL OF GENETIC ENGINEERING* (2012).

On the one hand, you have transhumanists,² who are very excited about genetic-engineering prospects. For them, it's the way we are going to begin to control, and eventually completely control, our evolutionary future. Oxford professor Nick Bostrom said that "current human nature is improvable through the use of applied science and other rational methods, which may make it possible to increase human health-span, extend our intellectual and physical capacities, and give us increased control over our own mental states and moods."³ To transhumanists, evolutionary engineering, or what some call "directed evolution," is really the apotheosis of our species.⁴ UCLA's Gregory Stock announced that "humanity is leaving its childhood and moving into its adolescence as its powers infuse into realms hitherto beyond our reach."⁵ Transhumanism bears a striking resemblance to religion; it seeks to provide a measure of control over the savage aspects of nature, and it also wants to provide us hope in the face of death. "The holy grail of enhancement," explained transhumanist John Harris, "is immortality."⁶ Others see human evolutionary engineering as a way to turn the tables on what Richard Dawkins calls the "selfish gene."⁷ "We are built as gene machines," Dawkins claimed, "but we have the power to turn against our creators."⁸ Julian Savulescu, Oxford transhumanist, stated that "[h]umanity until this point has been a story of evolution for the survival genes Now we are entering a new phase of human evolution—evolution under reason—where human beings are masters of their destiny. Power has been transferred from nature to science."⁹

How close are we to being able to engineer human evolution? We've come quite far in terms of plants. The United States Grocery Manufacturers Association estimates that 70% of all food sold in the

2. *Id.* at 6 (defining "transhumanist," a term coined by Julian Huxley, as people who "look forward to the prospect of germline genetic engineering as an opportunity to reengineer the human species").

3. Nick Bostrom, *In Defense of Posthuman Dignity*, 19 *BIOETHICS* 202, 202–03 (2005) (footnotes omitted).

4. MEHLMAN, *supra* note 1, at 6.

5. Gregory Stock, *Germinal Choice Technology and the Human Future*, 10 *REPRODUCTIVE BIOMEDICINE ONLINE* 27, 34 (2005).

6. JOHN HARRIS, *ENHANCING EVOLUTION: THE ETHICAL CASE FOR MAKING BETTER PEOPLE* 59 (5th ed. 2010).

7. RICHARD DAWKINS, *THE SELFISH GENE* (3d ed. 2006).

8. *Id.* at 201.

9. Julian Savulescu, *Human–Animal Transgenesis and Chimeras Might Be an Expression of Our Humanity*, 3 *AM. J. BIOETHICS* 22, 24 (2003).

United States contains ingredients from genetically modified crops.¹⁰ You may be aware of the current controversy to try to get the Food and Drug Administration (FDA) to put labeling on genetically modified foods.¹¹ However, we have long genetically engineered animals; it's called breeding. One result is the Belgian Blue beef cow, which has been bred over a number of years to look the way it does. It's apparently very good eating, but that's old-fashioned genetic engineering. What we now have is more active genetic manipulation, like the Enviropig. The Enviropig was a product of the United States Department of Agriculture's effort to make pork "The Other White Meat" a few years ago. The Enviropig digests 90–100% of the phosphorus in its diet, compared to only 50% for normal pigs, and this has a lot of environmental advantages.¹² Now, these animal manipulations, as seen in the Enviropig, are germline genetic engineering. Germline genetic engineering means that these changes, the genetic changes made in these animals, are passed on to future generations. So, the Belgian Blue beef cow's calves will also have the genetic changes produced by hybridization and animal husbandry. The "Enviropiglets" will also have the genetic modifications of the parents.

How about humans? We haven't come this far, but we're making progress. As we discover new genes, we will develop genetic tests for them; as we have discovered important genetic factors, DNA factors, we have developed genetic tests for them.¹³ A direct-to-consumer genetic testing company called 23andMe allows you to mail a saliva sample to them and then go online a couple of weeks later to discover your results.¹⁴ 23andMe will do the testing for 180 genetic characteristics and disorders, including a number of medical conditions, such as Tay-Sachs disease, as well as non-medical traits like memory, intelligence, and

10. See Gregory N. Mandel, *Gaps, Inexperience, Inconsistencies, and Overlaps: Crisis in the Regulation of Genetically Modified Plants and Animals*, 45 WM. & MARY L. REV. 2167, 2177 (2004).

11. COUNCIL ON SCI. AND PUB. HEALTH, AM. MED. ASS'N, LABELING OF BIOENGINEERED FOODS 6 (2012), www.ama-assn.org/resources/doc/csaph/a12-csaph2-bioengineeredfoods.pdf.

12. Doug Farquhar & Liz Meyer, *State Authority to Regulate Biotechnology Under the Federal Coordinated Framework*, 12 DRAKE J. AGRIC. L. 439, 448–49 (2007).

13. See Teri A. Manolio, *Genomic Medicine: Genomewide Association Studies and Assessment of the Risk of Disease*, 363 NEW ENG. J. MED. 166, 176 (2010) (explaining various studies advancing the understanding of single-nucleotide polymorphisms and some of their findings).

14. 23ANDME, <http://www.23andme.com> (last visited Sept. 17, 2013).

longevity.¹⁵ They'll sell you the tests for these characteristics, but it is another question whether or not the tests actually and accurately can tell us much. Computerized dating services are beginning to match people based on their genetic compatibility. This is one of my favorites. There is an online service where you can send in a saliva sample and you will be matched to a person of the opposite gender based on the differences in your immune systems.¹⁶ Apparently, there was a study that showed women preferred the smell of men who had immune systems that were, genetically, the most different from their own; and that's the basis for this company.¹⁷

If we add genetic testing to in vitro fertilization we get what is called pre-implantation diagnosis. This is when you take an egg and fertilize it with a sperm in a petri dish in a laboratory.¹⁸ During this in vitro fertilization process, you don't just fertilize and create one embryo, you create probably a dozen or so. Then you can wait until the embryo divides into about an eight-cell stage, snip off one of the cells—apparently that doesn't harm the rest of the embryo—and then you can subject the DNA in that cell nucleus to genetic testing. You can do this for each of the dozen or so embryos conceived in the laboratory. Then, you pick a couple of the embryos that have the best genetic makeup to implant in the womb and bring to term as a child.¹⁹ As we develop our ability to test for different genetic characteristics, people can begin to shape the genes of their offspring. The genes of the discarded embryos will not be passed on and will no longer play a role in human evolution. The ones that are passed on will persist as long as their line does.

Interestingly, the United Kingdom is so concerned about the in vitro fertilization process of pre-implantation genetic diagnosis that they've already made it illegal to select embryos based on anything except genes with disease characteristics.²⁰ In other words, in the United Kingdom, neither an in vitro fertilization clinic nor a fertility center may test an embryo for a non-disease characteristic because it is against United

15. *23andMe Democratizes Personal Genetics*, 23ANDME (Sept. 9, 2008), <http://mediacenter.23andme.com/press-releases/23andme-democratizes-personal-genetics/>.

16. MEHLMAN, *supra* note 1, at 2.

17. Natasha Singer, *Better Loving Through Chemistry*, N.Y. TIMES, Feb. 7, 2010, at BU3, available at <http://www.nytimes.com/2010/02/07/business/07stream.html>.

18. MEHLMAN, *supra* note 1, at 3.

19. *Id.*

20. HUMAN FERTILISATION AND EMBRYOLOGY ACT AMENDMENTS, 2008, c. 22, § 11, sch. 2 (UK), available at <http://www.legislation.gov.uk/ukpga/2008/22/contents>.

Kingdom law. In vitro fertilization, as a technology, is still in its infancy in the United States (as it is in the United Kingdom) but the United States is already taking steps to regulate the practice.

We've also begun to actively manipulate genes for therapeutic purposes in this country. Ashanti DeSilva, generally said to be the first patient successfully treated with human gene therapy, was born with a malfunctioning immune system.²¹ A more severe type of this disease is popularly known as the "Bubble Boy" disease, and the more severely affected children have to be completely sealed off from germs in the world. DeSilva's condition wasn't quite as severe, so she could be in the world, but she was terribly susceptible to infection and had to be continuously given various drugs to try to create an immune system for her. She was at Rainbow Babies and Children's Hospital (which was across the street from our law school) when she had blood removed so it could be taken to the National Institute of Health in Bethesda.²² The DNA was taken out of her blood sample, manipulated, and then that blood was re-infused—put back into her cells—at Bethesda. As a result, she developed a partially functional immune system, and the amount of drugs and other treatments she has had to take since then have been greatly reduced compared to before the gene therapy.²³

We haven't done any intentional human germline genetic engineering, which means we haven't intentionally tried to do something that would be passed on to the DNA of offspring, but we've done it inadvertently. An example of this is ooplasmic transfer,²⁴ which is a technique that is used to respond to a certain infertility problem where, for various reasons, the embryo does not implant properly into the wall of the womb. As it turns out, the reason is a problem in the egg's cytoplasm (the material around the nucleus) that makes up that embryo. The technique to respond to such a problem is to take the cytoplasm from a donor egg and place it in the mother's egg. What you end up with is the nucleus from the mother, but the cytoplasm surrounding it comes from a donor egg of another person. Well, so far so good except that the cytoplasm also contains DNA, which means not all of the DNA is found

21. MEHLMAN, *supra* note 1, at 4.

22. See RAMEN NAAM, MORE THAN HUMAN: EMBRACING THE PROMISE OF BIOLOGICAL ENHANCEMENT 15 (2005).

23. *Id.* at 15–16.

24. MEHLMAN, *supra* note 1, at 58 (defining "ooplasmic transfer" as a technique "where cytoplasm from a donor egg is added to the cytoplasm of another egg to increase its chances of developing").

in the nucleus, some is found in little structures called mitochondria which are found in the cytoplasm. So, when you do this ooplasmic transfer fertility treatment, you end up with a child who has DNA, not from two people, but from three, because they have the DNA from the father, the mother (in the nucleus of the egg that becomes the child), and the donor (in the mitochondria).²⁵ All of that will be passed on to the offspring, and that is germline genetic manipulation. In fact, the FDA has sent warning letters to fertility clinics expressing an interest in regulating this practice because it is a form of germline genetic engineering.²⁶

Researchers have produced the first successful, intentional germline genetic engineering in primates. Marmosets have been given a jellyfish gene that makes them glow under black light. This gene was passed on to the offspring of the first generation of genetically engineered marmosets.²⁷ It turns out that it is a very big deal in this field to take this step from lower animals to primates, a major step toward, for example, intentional human germline genetic engineering. So, we're getting there.

You might think that, with this growing progress, this growing mastery, we really have nothing to fear from trying to direct our evolutionary future; we're learning how to do it, we'll eventually get it right, and then we'll be okay. The problem is that these efforts have not worked smoothly. All of these efforts have been accompanied by, really, some terrible results. For example, you may remember cloning Dolly the Sheep. It took 277 attempts to produce Dolly the Sheep;²⁸ that means that 276 were failed and discarded sheep embryos.²⁹ Had we been making these attempts on humans, there would have been 276 human embryos created that didn't work, and that would have raised some serious problems for us. We've tried to clone monkeys, but none of them survived past 25 days.³⁰ Going back to genetically modified foods, 30 years ago it took about 80 days for a broiler chicken to reach its full

25. *Id.* at 60.

26. See Shannon Brownlee, *Designer Babies: Human Cloning Is a Long Way Off, but Bioengineered Kids Are Already Here*, WASH. MONTHLY, Mar. 2002, at 25.

27. Jason Palmer, *Glowing Monkeys 'to Aid Research'*, BBC NEWS (May 27, 2009, 18:20 GMT), <http://news.bbc.co.uk/2/hi/8070252.stm>.

28. *Dolly the Sheep*, NAT'L MUSEUMS SCOT., http://www.nms.ac.uk/our_collections/highlights/dolly_the_sheep.aspx (last visited Sept. 7, 2013).

29. MEHLMAN, *supra* note 1, at 61.

30. Christina Ramires Ferreira et al., *Pronounced Segregation of Donor Mitochondria Introduced by Bovine Ooplasmic Transfer to the Female Germ-Line*, 82 BIOLOGY OF REPRODUCTION 563, 596 (2010) available at <http://www.bioreprod.org/content/82/3/563.full.pdf+html>.

weight. Through careful breeding (or the old-fashioned form of genetic engineering), it now takes half that time, or about 40 days. The problem is that the growth rate of their bones and cardiovascular system is slower than the growth rate of their muscles (the meat), so they have leg and heart problems, their immune systems are compromised, and they get diseases more easily.³¹ These adverse effects are inadvertent, but they are there.

We've also had some notable failures in human gene therapy. Probably the most well-known is 18-year-old Jesse Gelsinger who died in 1999 while undergoing a gene-therapy-manipulation experiment.³² His death led to an FDA investigation of the University of Pennsylvania where the experiment had been done. The investigation turned up conflicts of interest and led to regulatory sanctions on the University's gene therapy programs.³³ In 2000, French researchers announced that they had successfully used gene therapy to create functioning immune systems in ten newborns. These newborns had a form of the immunodeficiency disorder that Ashanti DeSilva had had (a form of Bubble Boy disease), and the French researchers announced that they produced a complete cure in these kids by genetically manipulating their DNA.³⁴ The newborns now had fully functional immune systems. Three years later, nine of them developed T-cell leukemia because, unbeknownst to the researchers, the genetically modified DNA took up residence too close to a cancer gene, an oncogene, triggered it, and they got the leukemia form of cancer.³⁵ So, a lot of technical concerns and a lot of technical difficulties yet to overcome.

Some commentators object to evolutionary engineering even if it were technically flawless and produced exactly the result that we wanted it to produce. However, I don't think some of their objections are very compelling. For example, one objection is that evolutionary engineering is playing God. We can't do this, we shouldn't do this because it is hubris; this is treading on what God should be doing for us. The problem with this argument is that we have been playing God, in an evolutionary sense, ever since we began developing modern medicine, or even not-so-modern medicine. We play God whenever we provide medical assistance

31. MEHLMAN, *supra* note 1, at 62.

32. *Id.* at 63.

33. *Id.* at 64.

34. *Id.* at 64–65.

35. *Id.* at 65.

to those who would have otherwise succumbed to illness, which allows them to have children later, thereby directly affecting human evolution; a tiny effect, but a direct effect. So, the question is, how is that different from what some transhumanists think we ought to be doing?

Another standard objection to evolutionary engineering is that we would be predetermining the futures of our children to too great an extent; we would be locking them into some parental notion of what they should be and how they should live their lives. The thing is, we have been trying to shape our children's futures for a while, right? It's not clear why parents would use genetic engineering to narrow or restrict their children's future potential rather than expand it. I mean, why wouldn't you give your child advantages and abilities in various areas if you could, and then let them pick the profession and hobbies most congenial to them. So, I don't place a great deal of importance in that objection.

Now, another objection is that we shouldn't interfere with natural evolution because it will do a much better job than we possibly could; it will produce more evolutionary progress than anything we could achieve with our own science. After all, look at where natural evolution has already taken us. We started out as single-cell organisms and now we are *Homo sapiens*. Recall the Time-Life book with the famous illustration, *The March of Progress*,³⁶ and think about how much progress we've made. The problem with this objection is that it is incorrect from an evolutionary biology standpoint. Ernst Mayr, professor and biologist, pointed out that if natural selection works so well, how come 99.9% or more of all evolutionary lines have become extinct?³⁷ In fact, he pointed out, "the earliest . . . organisms, the bacteria, are just about the most successful of all with a total biomass that may well exceed that of all other organisms combined."³⁸ There's no progress in natural evolution, explains Mayr, because "there is no known genetic mechanism that could produce goal-directed evolutionary processes."³⁹ Stephen J. Gould may have put it best when he said that "[h]umans are here by the luck of the draw, not the inevitability of life's direction or evolution's mechanism."⁴⁰

36. *Id.* at 137.

37. ERNST MAYR, WHAT EVOLUTION IS 155 (2001).

38. *Id.* at 278.

39. *Id.* at 134.

40. STEPHEN JAY GOULD, THE RICHNESS OF LIFE: THE ESSENTIAL STEPHEN JAY GOULD 285 (2006).

Now, it's tempting to argue that evolutionary engineering couldn't make things any worse, so we don't have to worry about it. I mean, natural evolution doesn't produce progressive momentum, so we don't have to worry about interfering with it. There are two problems with this argument. One is that, given our technological abilities, human misbehavior can be very destructive. If we get things wrong, our actions can have very serious consequences. Think, for example, of global warming. Second, we have no idea how much worse directed evolutionary engineering could have been compared to natural evolution because we understand very little about natural evolution. Now, this may come as a surprise because we've all gone to the museums and seen the dioramas and they look absolutely straightforward. But beyond biologists agreeing that evolution is a fact, we enter a realm of enormous disagreement and uncertainty about many key aspects of human evolution. Why are we bipedal? Why did we leave the forest for the savanna? How did we get out of Africa? Why do we have such large brains? The list of questions goes on and on. There is no accepted agreement among the biologists and evolutionists about how any of this has happened; we're still debating all of these questions, and every time somebody comes up with a promising theory somebody else shoots it down when they find a new fossil. A few years ago, a group of fossil hunters found the bones of Ardi and declared that she was the first and oldest human ancestor. This discovery was soon refuted. The headline was: "Ardi: the human ancestor who wasn't."⁴¹

This is just the fight between the paleontologists. There are also the molecular biologists who say the entire field of paleontology is misled because the fossils are not a valid source of evolutionary data. Then there are biological anthropologists, paleoclimatologists, developmental psychologists, and on and on, all of whom are fighting for scarce research dollars, tenure slots, and other scarce opportunities; it's a very, very bitter argument. Needless to say, all of these disagreements give the creationists a field day. Knowing as little as we do about natural evolution makes it hard to determine what a difference evolutionary engineering could make, and this causes tension. On the one hand, it makes it hard to argue against evolutionary engineering on the grounds

41. Eben Harrell, *Ardi: The Human Ancestor Who Wasn't?*, TIME, May 27, 2010, available at <http://www.time.com/time/health/article/0,8599,1992115,00.html>; see also MEHLMAN, *supra* note 1, at 141 (discussing how Ardi was not the ancestor originally claimed).

that natural evolution is clearly better when there is so little known about natural evolution; but, on the other hand, we need to be very cautious when we alter processes that we understand so poorly—the stakes are very high.

Now, some say that there's no need for concern, and I've heard that response to my book, articles, and other things I have said before. People say that our technology will never get that good, we'll never be able to truly engineer human evolution, and we will never have any major impact on the human evolutionary future. For example, people have said that we'll never have enough *in vitro* fertilization and genetic engineering because, if it's going to be a germline result, it has to take place fairly early on in embryonic development. Not enough people can access that technology to make any significant difference to humanity's collective gene pool. Well, that's the way it looks now, but who can say that in 50 or 75 years this technology will not become so widespread that enough people on the planet will use it and it could have an effect on humanity's collective gene pool. Furthermore, many of the skeptics—the critics—are researchers in genetics, and they're afraid that, if people get concerned about this, the legislature may decide to regulate their research, limit their work, and cut back on their funds. So, they have a conflict of interest, and we have to think about that when considering their criticisms. Plus, I think that it's at least important to begin thinking about the issues and concerns they raise. So, allow me to think about them with you.

How could evolutionary engineering cause harm? In the first place, if it isn't done right, it could cause enormous physical harm to the engineered children. Considering the complexity of genetic engineering, we could make dreadful mistakes and produce horrifying results. Even if our techniques were technically successful, so that we produced the changes we wanted, the affected children could be socially stigmatized. They could either act or appear different, or their peers may find out and say, "hey, little Jimmy was genetically engineered," and they could be hazed and stigmatized; there could be all kinds of social impacts.⁴² Some people fear that the biological harm we could cause children could be so great that those who were genetically engineered could be unable to reproduce or, for some other reason, could cause the end of Homo

42. MEHLMAN, *supra* note 1, at 86 (pointing out that not everyone agrees with the choice to genetically alter a child and therefore "evolutionary engineered children may strike others as abhorrent" because of the way in which they were produced).

sapiens and the destruction of the human species. In evolution, the destruction of a species, or the end of the species, isn't necessarily a bad thing. Evolution is all about species coming and going. However, there does seem to be something unsettling about the extinction of the entire human race, or in biological terms, our human lineage. We had a discussion just before the talk about Ray Kurzweil's *Singularity*;⁴³ it could be that all we have to do is create computers that could carry all of our knowledge and culture through a machine. This frightens me. I don't find this to be a satisfactory sort of evolutionary future for humanity, but we can talk about it perhaps, if you'd like.

It might be argued that we do not need to worry about saving the human genetic lineage because everyone will realize that it is too dangerous to try to manipulate our children's genes, but some parents already go to extremes in terms of giving their kids an advantage. Think of what some parents do. An extreme case is a beauty pageant with toddlers; you can watch them on television. It's not far-fetched to imagine that some of these really aggressive parents might be willing to try some really risky experiments on their children, or their future children, in an effort to try to give them some kind of social advantage.

Another danger, I think, is from cults. The Raelians were named after their founder, a former French racecar driver named Claude Vorilhon, who changed his name to Rael.⁴⁴ At one point, they claimed to have 70,000 followers, and they believed that life on earth started from DNA brought here by aliens called the Elohim; in 2003 they claimed to have successfully cloned a human being.⁴⁵ You can imagine a group like this encouraging one another and parents, or prospective parents, to try genetic engineering to fulfill this kind of cult's mission and vision.⁴⁶ And what they're doing could be defended by the free exercise of religion. So, we also have that problem.

The governments in some countries might require parents to make certain genetic changes, but why would they do that? Well, they might want to create better soldiers or more productive workers. China is already doing some of this—much more than anybody else—although on

43. RAY KURZWEIL, *THE SINGULARITY IS NEAR: WHEN HUMANS TRANSCEND BIOLOGY* (2005).

44. Anne Berryman, *Who Are the Raelians*, TIME, Jan. 4, 2003, available at <http://www.time.com/time/nation/article/0,8599,404175,00.html>.

45. DeNeen L. Brown, *The Leader of UFO Land; His Holiness Rael Explains the Origins of Life on Earth. Except for That Clone*, WASH. POST, Jan. 17, 2003, at C01.

46. MEHLMAN, *supra* note 1, at 187.

a technically cruder scale. Anybody know who Yao Ming is? How was he produced? Well, the Chinese government got his mother, who was a successful basketball player, to mate with another extremely tall, athletic person.⁴⁷ When Yao Ming was about six years old, he was plucked from those parents, sent to a basketball school, and the rest is history.⁴⁸ Genetic engineering by the government. Advances in genetic engineering could dwarf this relatively crude or primitive effort, and you can imagine an international arms race for planetary domination involving more sophisticated forms of genetic engineering. If they do it, might not we feel that we have to as well?

So, it seems to me that we need to think about protecting those who are at risk: our children, their children, our future descendants, and the human lineage. To do this, we need two things: we need tools, and we need rules. We need rules for what is and is not allowed and tools to enforce those rules. With children and engineering children, we have the principle of parental reproductive and child-rearing freedom. Parents have a great deal of freedom to do what they want with their children reproductively, and they can choose how to raise and teach them, and this is enshrined in our constitutional law. But this parental freedom is not unlimited because we also have abuse-and-neglect laws.⁴⁹ If what the parents do to their children is sufficiently dangerous or harmful, the law or the government will step in and prevent them, or punish them, for doing so.

So, in terms of a rule, when would genetic engineering be deemed, or should it be deemed, abuse and neglect? What should the rule be? Well, one possibility is allowing parents to genetically engineer children without interference. The only exceptions to this would be when they do so in such a way that no reasonable parent would choose, or in such a way that tends to expose the child to a substantial risk of either serious bodily or serious mental harm, or if they cause an impairment that is not outweighed by the potential benefit to the child. There are weasel words here, but lawyers will recognize the most important one, which is "reasonable." Nevertheless, we have to work on something like this so that we are able to deal with future technologies.

Now, abuse-and-neglect laws alone won't work because they would

47. Brook Larmer, *The Creation of Yao Ming*, SPORTS ILLUSTRATED, Sept. 26, 2005, available at <http://sportsillustrated.cnn.com/vault/article/magazine/MAG1116102>.

48. *Id.*

49. MEHLMAN, *supra* note 1, at 168.

2013]

Extinction by Design

245

need to be tweaked. For example, they presently don't apply to injuries that occur prior to birth. So, if parents were to do something to a fetus or an embryo, or even an egg or a sperm, technically, that would not raise issues of abuse or neglect. It's only once children are born that parents could technically harm them, so we would need to redefine, or reimagine, our abuse-and-neglect laws. Also, what do we do when we enforce our abuse-and-neglect laws against the parents? We often will take the children away from the parents and place them with a foster family to prevent future harm. First of all, it's not clear that parents who tried something genetic that was dangerous and produced a bad result, and therefore ran afoul of the abuse-and-neglect laws, would be inclined to continue harming their children after that. So, the idea of preventing further abuse and neglect doesn't necessarily hold sway here. Additionally, taking children away from parents doesn't sound particularly helpful in this scenario. It may end up being a net loss to the children. What about fining the parents? Well, then they simply have less money with which to raise their children, so I think that, even though the abuse-and-neglect standard applies to the decisions parents make, the enforcement should be against the professionals who helped them to achieve the genetic engineering that they had selected. I think that the targets of enforcement have to be the fertility doctors, clinics, and geneticists that help parents accomplish genetic engineering until such time as this is something you can do in your garage or your backyard and you no longer need those professionals.

What about future descendants? Maybe these ideas can deal with the threats to the children who are the immediate, potential victims, but how about their kids and generations down the road? How safe does this technology have to be before we should allow it to become commonplace and sanctionless? For one thing, how many generations of testing do we have to do in a human-subject experiment to determine that there won't be unforeseen effects downstream? We face this problem now when we try to consider how many generations of animal testing we should do for a new drug. Typically, we don't do very many generations, but what about in human testing? Think about it. We're not going to let you do something until it has moved through multiple human generations. Think of what it would take to keep track of the offspring and to continue monitoring them for adverse effects. What if they chose not to participate any longer? So, a lot of problems with tracking the offspring. Ultimately, there may be no way to completely prevent

unforeseen downstream harm.

What about the human lineage? Well, what threatens lineages? What causes an entire lineage to become extinct? The following is the list that you get from evolutionary biology: loss of habitat, genetic drift (which is, in a way, random changes in genes), environmental catastrophes, inbreeding, extremely large body sizes, inability to reproduce, loss of genetic diversity, and the introduction and competition from a rival species.⁵⁰ Of these, only the last four through eight seem to be potentially subject to genetic engineering. Now, what about inbreeding? I think the dangers of inbreeding can be dealt with by our country's incest laws and cultural taboos. It's also hard to imagine that parents would voluntarily make their children so large as to threaten, you know, our collective survivability. After all, why would you make a 50-foot woman?

But it is possible to imagine a reduction in reproductive success; for example, radical gender imbalances caused by a parental preference for males over females. It's hard to imagine that being born a male could be considered a harm to the child, right? I mean, the male child in a society that prefers males is going to be arguably better off, so it would be hard to call that a form of parental harm to the child. Even if we were to tweak abuse-and-neglect laws to apply in these cases, they probably wouldn't do the trick. It also could be difficult to regard making everyone alike as harmful to a child, thus a threat to the lineage. So, if we were to find that parents had been choosing the same cluster of genetic characteristics—they all wanted blondes, they all wanted athletic kids, and so on—there would be a risk of reducing the genetic diversity of the species, of the lineage. We could find that, if there were not enough genetic variability, humans would not be able to withstand the sudden, unexpected environmental challenges we could encounter because you need to have enough genetic diversity to do that. For example, the problems we have had with genetically homogeneous crops sustaining sudden environmental changes.

A similar problem could arise if class-conscience parents engineered their children so that they could only mate with similarly modified children; and that's not so far-fetched. "I don't want you to marry or have a child with so-and-so because they're not sufficiently well-bred." If you have watched *Downton Abbey*, you have certainly seen that play

50. R. Bijlsma et al., *Genetic and Environmental Stress, and the Persistence of Populations*, in ENVIRONMENTAL STRESS, ADAPTATION AND EVOLUTION 193, 194 (R. Bijlsma & V. Loeschke eds., 1997).

out in that sitcom situation. So, as you can imagine, until genetic engineering becomes ubiquitous, parents who would genetically engineer their children to be “superior” would not want them to dilute their genetic advantages by having children with the genetically unprivileged. This could actually begin the formation of two separate breeding populations; that, as it turns out, is one of the conditions that leads to the development of multiple humanoid species because the inability to interbreed is one of the characteristics of the differences in species. It could be that everybody will get along and there won’t be a problem; but, at the same time, if we’re competing for scarce planetary resources, there could be some conflict between two different humanoid species. After all, this is what some evolutionary biologists believe happened to the Neanderthals; namely, we ate them.⁵¹ With modern weapons, it might not be a simple situation of one humanoid species destroying the other, but the result might be that we could end up destroying everybody through mutual destruction.

Interestingly, we already have a legal system capable of responding to these long-term, abstract threats to the lineage, and that’s the system of public health law. Here’s the key language from *Jacobson v. Massachusetts*,⁵² the most important United States Supreme Court opinion creating the constitutional premise behind the public health system:⁵³ “According to settled principles, the police power of a state must be held to embrace, at least, such reasonable regulations established directly by legislative enactment as will protect the public health and the public safety.”⁵⁴ Surely, preserving the human lineage would count as protecting public health and safety. So, our country has a legal system to

51. See Eduardo Moreno, *The Society of Our “Out of Africa” Ancestors: The Migrant Warriors that Colonized the World*, 4 COMMUNICATIVE & INTEGRATIVE BIOLOGY 163, 164–66, (2011), available at <http://www.landesbioscience.com/journals/cib/28MorenoCIB4-2.pdf> (hypothesizing how the aggressive tribes that left Africa to populate the rest of the world could have greatly influenced society’s antagonistic and warlike tendencies); see also Robin McKie, *How Neanderthals Met a Grisly Fate: Devoured by Humans*, GUARDIAN (May 17, 2009, 7:01 PM), <http://www.guardian.co.uk/science/2009/may/17/neanderthals-cannibalism-anthropological-sciences-journal> (discussing cannibalism as a reason behind the disappearance of Neanderthals).

52. *Jacobson v. Massachusetts*, 197 U.S. 11 (1905).

53. Frederick E. Soto, Jr., *Public Health Law*, in OPTOMETRIC CARE WITHIN THE PUBLIC HEALTH COMMUNITY 3 (Stanley Hatch et al. eds., 2010), available at <http://webpages.charter.net/oldpostpublishing/oldpostpublishing/Section%202,%20Principles%20of%20Public%20Health/Sect%202,%20Public%20Health%20Law%20by%20Soto.pdf>.

54. *Jacobson*, 197 U.S. at 25.

which we could turn. We could establish a unit within the public health service that identifies and monitors our reproductive behavior, assesses the risks from genetic engineering, and then intervenes to protect us if necessary. The problem is that the public health laws have not always been applied judiciously. We all remember the United States Public Health Service experiment at Tuskegee; men were left to suffer from syphilis long after there were treatments available because their physicians had been told not to treat them with penicillin when it became available.⁵⁵ We have also recently heard about experiments in Guatemala.⁵⁶ Those were public health experiments, not to mention the Eugenics movement during the early part of the 20th century, which, a lot of people don't realize, was promulgated by our public health system and officials. So, we would have to make sure we monitor the public health authorities and make sure that they act reasonably if we were to turn to the public health laws to protect us from these kinds of risks.

Finally, genetic researchers have to pave both the social and scientific path. They have to anticipate the public reaction to what they do because, otherwise, they will trigger a public backlash. Not only could that come back to bite them, but it could be something that would stifle scientific progress in general. Researchers must go slowly. They must be very careful to follow our ethical guidelines, our human subjects' protections, and they must be particularly careful when they embark on research in particularly troublesome areas like, for example, combining human and non-human DNA. Only in this way can human genetic engineering, which I submit is an inevitability, avoid the nightmare of the dystopians who envision that this is the path to extinction and ruin, and realize the dream of the transhumanists. Thank you very much.

55. MEHLMAN, *supra* note 1, at 117, 217.

56. U.S. Dep't of Health & Human Servs., *Fact Sheet on the 1946–1948 U.S. Public Health Service Sexually Transmitted Diseases (STD) Inoculation Study*, HHS.GOV, available at <http://www.hhs.gov/1946inoculationstudy/factsheet.html>.