HEADLINE: READ THIS BEFORE YOU FREAK OUT OVER GENE-EDITED SUPERBABIES

Sit down America, and let's talk about making babies. Specifically, designer babies. Because ever since in vitro fertilization made it possible for parents to select embryos with the best genetics, precisely-engineered progeny have been a big fear. And now that a powerful gene-editing technique has been used on human embryos, it's fine to get a little freaked out. So let's talk about 21st century trust fund babies with privilege notarized onto their DNA, medical mutants with genetic mistakes that will be passed on for generations, and armies of super soldiers with genetically engineered immunity to arsenals of chemical and biological weapons. But—here's the important bit—let's not leave out the hope of eradicating thousands of diseases, and the potential to make many pharmacological treatments obsolete.

Before we fear and hope too far into the future, let's go back to April 18, when a group of Chinese scientists announced they'd edited the DNA of some 80 fertilized (but nonviable) eggs. They were trying to eliminate a recessive sequence of code that causes ß-thalassemia, a type of anemia that requires sufferers to get lifelong blood transfusions. The news caught the public by surprise, but biologists had been bracing for it. In the months prior, several groups had published letters urging

genetic researchers to exercise caution, and even suggesting an outright moratorium on embryonic gene editing. But the most concrete action came after, on April 29, when the director of the National Institutes of Health assured us that none of his agency's federally allocated money would pay for scientists meddling with DNA in a human zygote.

> **Zygote**: A fertilized human egg. Changes made to a zygote's DNA would be passed along to other cells as the egg multiplies and becomes an embryo, a fetus, a baby, a child, and a grown up of reproductive age.

The scientists are right to call for caution, but all those feet pumping on the brakes kind of makes it look like genetic research is skidding out of control. But very few of the scientists want a firm embargo on editing human embryos. In reality, the signatories of those commentaries in *Science* and *Nature* have a broad spectrum of opinions on the risks of this new technology. Some think gene editing for therapeutic purposes will inevitably lead to the creation of genetic classism. Others believe this could be the most important medical breakthrough of the century. But most fall somewhere between the two extremes.

Collectively, scientists threw up a flag because they wanted a time out. According to most, the public needs to get educated on all the potential consequences of gene editing, as well as all the safety and efficacy benchmarks researchers need to meet before they're anywhere near comfortable enough to start diving into human embryo editing. "This is still an incredibly young area of science," says Debra Mathews, a geneticist and bioethicist at the Johns Hopkins Berman Institute of Bioethics. Long before we get to 'Ought we,' she says, we need to know the answers to 'What can we do?' and 'Is it safe?'

This technology could change the future of the human race. ß-thalassemia is only one of many inherited conditions that gene editing could target. And though some of these conditions—like ß-thalassemia—trace back to mutations in a single gene, any edits could have unforeseen consequences. And even though scientists are the most well-informed on a technical level, many agree that society should be telling them how far it's comfortable with them taking that technical expertise. The biggest fear of these scientists is that average citizens—and the governments that serve them—will make their rules about gene editing without thinking things through.

> **Gene-editing**: There are several techniques, but the most noted is called CRISPR/Cas9. In nature, microbes use it to immunize their DNA against viruses, by snipping out distinctive sections of viral DNA and pasting them into their own genome. In 2012, biologists figured out they could use the system to edit the genes of any organism. It's precise enough to target a single gene, and easy enough that anyone with a degree in biology, a computer tutorial, and a couple thousand dollars in lab equipment can do it.

Poorly-conceived policy has led science astray before. In the 1990s, embryonic stem cell research got caught up in the great abortion debates. Ideologues on both sides lobbed incendiary factoids at each other, until the territory between them was too wasted for reasonable discussion. The result was the Dickey-Wicker amendment, which makes embryonic stem cell work off limits for federal research dollars.

It also put the legality question in the states' hands, which led to stem cell laws that are patchy. "There are some states where it is OK to do embryonic stem cell research; there are others that make it a felony," says Mathews.

The NIH announcement raises the same fears of short-sighted and fragmented legislation. Instead of preserving the sanctity of human heritage, the country could prevent itself from eradicating the most inhumane heritable diseases. And legislation could potentially affect other types of gene editing that have nothing to do with unborn babies.

> **Gene therapy**: Technologies like CRISPR/Cas9 can also target DNA in non-embryonic cells. For example, scientists in a current clinical trial are using gene editing to teach T-cells how to recognize and eliminate cancer cells. Another group is modifying the T-cell so its genes are inaccessible to HIV. Both trials involved drawing a patients' blood, modifying its DNA, and reintroducing it.

The point being, science needs room to figure out exactly what this technology is capable of doing. Right now, researchers have a ton of potential on their hands, but not a lot of agreement about how far that potential reaches.

Figuring out the efficacy and safety of embryonic gene editing means years *and years* of research. Boring research. Lab-coated shoulders hunched over petri dishes full of zebrafish DNA. Graduate students staring at chromatographs until their eyes ache. Western blot. Occasionally a paper will come along with some exciting news, with caveats that the results are too species-restricted and laboratory-dependent to mean much more than, "Hey guys, still working on it, and making progress!"

Only then (if we agree we're cool with it) come clinical trials on human zygotes. "This medical tech should be treated equally to all other medical tech," says George Church, a geneticist from Harvard. "It's guilty until treated innocent: You don't move on to the general public until you go through clinical trials."

So what's there to be afraid of? Plenty. Even after years of perfecting techniques on bacteria, bird, mouse, and other model organism DNA, side effects are always possible. "Even if everything went entirely perfectly, an edit might change something else—like expression of some nearby gene—or

change epigenetic states," says Paul Knoepfler, a stem cell biologist at UC Davis.

Knoepfler also worries that the gene-editing technology will create a slippery slope: that gene editing will—at least at first—only be accessible by the privileged, even if the law deems that we only use gene editing to cull harmful DNA. The elite might not get enhanced with more smarts, better looks, or bigger muscles, but they would be generally healthier.

But it's important to temper those fears with other considerations. For instance, by the time embryonic gene editing makes its way through clinical trials, some scientists think it could be affordable for anyone. And side effects might not be a factor. "If I change a single cystic fibrosis allele back to normal form, it's extraordinarily unlikely that would have a debilitating side effect," says Church. "If I change your brown eyes to blue, it's unlikely that you'll fall down from a stroke."

And don't forget the hope. That gene editing might be the most important medical discovery of the century. That it could genetically vaccinate our species against thousands of harmful diseases—everything from Alzheimer's to cystic fibrosis. That it could usher in a new epoch of health care.

So be afraid, be hopeful, and above all be educated. Let's not fall back into cable news parapets, and let's not let this conversation get chewed up by the 140 character outrage industrial complex. But mostly, let's not have gene editing fall prey to science-deaf legislation. At least, let's not pass those laws without taking a good hard look at the real risks—and real possibilities—of human gene editing.

[1] Correction 11:44 ET 5/4/2015 Zebrafish, not zebra finch. (back)

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