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## GENEWATCH

### DESIGNER EGGS AND STEM CELL SAUSAGE

By Henry T. Greely

*GeneWatch* has asked me, and others, to predict the future of genetics 20 years out; but, questioning authority, I am going to disobey and instead predict it 60 years out. This is, of course, madness. The longer the reach, the greater the hubris, both because of the greater chance of truly unexpected "black swan" events-having a 1 in 10,000 event happen in 60 years is three times as likely as having one happen in 20 years-as well as the greater effect of a small deviation at the beginning over three times as many years. On the other hand, the great advantage of a 60-year prediction is that there is no chance I'll be around to be embarrassed in 60 years, while my survival for 20 more years is (I hope) plausible.

So, what will genetics, or more broadly, the biosciences, look like in the year 2072? Let's leave some of the possibilities to one side-a small remnant of humanity struggles to survive in the aftermath of the nuclear holocaust of 2027 or a non-computerized humanity abandons serious science after the Butlerian Jihad, also known as the Fifth Great Awakening. Assume general continuity with today's world (an assumption that seems unlikely but at least gives us a framework for discussion). In that case, I predict three major consequences of the biosciences revolution, driven by, but extending beyond, genetics.



First, human reproduction will be much more selective. Most children, except for the poorest inhabitants of the poorest nations, will be conceived through in vitro fertilization so that preimplantation genetic diagnosis can be used to select the genetic traits of the next generation. The key development here will be making human eggs from induced pluripotent stem cells, freeing IVF from the unpleasant, expensive, and risky process of egg retrieval.

Second, human medicine will be greatly improved, largely by our greater ability to intervene in both pathogens and human cells at the molecular level. Infectious diseases will be nearly conquered either by direct attack on their molecular weaknesses or by improving the ways our immune systems respond to them. Major non-infectious diseases, including cancer and heart disease, will also be greatly reduced by more effective prevention and more effective treatments, for cancer probably through precise targeting of tumor cells. Stem cell transplants, as dissociated cells, as tissues, and as whole solid organs, will play an important role in treating some conditions; so (finally) will gene therapy. People will still die, but rarely of illness; they will often live until their 90s or 100s, at which point their bodies, and perhaps especially their brains, will just wear out.

Third, the non-human biological world will have been engineered, the better to serve, and amuse, humanity. Most people will eat lots of nutritious and (fairly) tasty meat derived from stem cells, which will be cheaper, much greener, and more humane. (The rich will still eat dead steers, at a high price and with a frisson of sinfulness akin to what may lead some to smoke cigars.) Crop shortages will disappear as genetically modified crops make their own fertilizers, increase yields, and adjust to the environment of a climate-changed world. The carbon dioxide levels of the atmosphere will begin, slowly, to come down through a combination of genetically engineered, carbon-neutral biofuels and specially engineered "remediation" organisms that suck CO<sub>2</sub> and other greenhouse gases out of the air. The passenger pigeon, the dodo, the mammoth, and the saber-toothed cat will roam again in animal parks; a few spots will feature vaguely disappointing "best guesses" at recreated dinosaurs.

Does this sound disappointingly positive, even Pollyannaish? It shouldn't. The technologies can be used in good ways or in ways dystopian enough for the most dedicated bioluddite. Many of us would view control over human reproduction as a good thing if it allowed parents to prevent the births of children with serious genetic diseases, but few of us would be happy with governments forcing parents to have children with, or without, particular genetic traits. No doubt, some people will try to create genetic super-beings, with risks to the rest of society and, even more likely, unforeseen physical or mental problems for the new "super" men and women. Deeply genetic medicine could end up creating a geriatric overclass, as parents, grandparents, and great grandparents stick around and increasingly monopolize wealth (thanks to early investments) and power (thanks to both high wealth and strong voter participation). In a worst case, medical advances may keep (rich) old bodies alive, at high cost, while not being able to prevent those old brains from deteriorating. For every algal source of green biofuel there is likely to be a novel kudzu, wreaking unforeseen havoc; for every healthy mammoth in a theme park in Alaska there will be

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terrorists, and bored teenaged hackers will have used biological weapons- and might use them again.

I strongly suspect that the one part of the biosphere that will not change much is the human mind, individual and collective. We will still rise to breathtaking moral heights and sink to appalling depths. We will still make brilliant leaps and behave with stunning ineptitude. When people are concerned, all solutions are just introductions to new problems. My own guess is that we will use these vast new tools of control over biology both wisely and foolishly and that, on balance, we will muddle through. But it will not be dull.

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