



# Reprogramming Biology

Tinkering with our genetic programs will extend longevity By RAY KURZWEIL

**Biology is now in the early stages** of a historic transition to an information science, while also gaining the tools to reprogram the ancient information systems of life. Our electronic devices typically update their software every few months, yet the 23,000 software programs called genes inside our cells have not changed appreciably in thousands of years. As we begin to understand biology in terms of its information processes, however, we are developing realistic models and simulations of how disease and aging progress and ways to reprogram them.

RNA interference (RNAi), which science learned about only in the past several years, can turn specific genes off. Because many types of illness depend on gene expression at some point, RNAi heralds a breakthrough technology. One example of a gene that we would like to turn off is an insulin receptor gene that tells fat cells to hold on to every calorie. When that gene was blocked in the fat cells of mice during a study at the Joslin Diabetes Center, those mice ate a lot but remained thin and healthy. They lived almost 20 percent longer.

Innovative means of adding beneficial genes to patients' bodies are starting to overcome the hurdles for gene therapy. United Therapeutics, a company I advise, has licensed and adapted a technique that modifies cells in vitro, verifies that the new genetic information has been properly inserted, replicates the modified cell millions of times and then injects those cells back into the bloodstream, where they embed themselves into the right tissues. This method has cured fatal pulmonary hypertension in animals and is entering human trials.

Another important line of attack is to regrow our own cells, tissues and even whole organs. A major benefit of this "therapeutic cloning" technique will be the ability to create tissues from versions of our cells that have been made "younger" by correcting DNA errors and senescence-related changes. For example, we will be able to create heart cells from your skin-derived stem cells and introduce them into your system through the bloodstream. Over time, the new cells will replace your old ones, resulting in a rejuvenated heart.

**Versions of our cells will be made "younger" by correcting DNA errors.**

Nanotechnology can go beyond the limitations of biology. Harvard University and Massachusetts Institute of Technology researchers have designed nanoparticles that latch onto cancer cells, burrow inside and release toxins to destroy them. Another scientist cured type 1 diabetes in rats with a nanoengineered device that uses seven-nanometer pores to controllably release insulin while blocking antibodies.

Our ability to understand and even reprogram the brain is also accelerating. The latest in vivo scanners can image individual interneuronal connections firing in real time. IBM has begun an ambitious effort to simulate a substantial portion of the cerebral cortex at a detailed level. Rising numbers of artificial neural implants can replace diseased tissue, such as an FDA-approved one for Parkinson's patients that allows software updates to be downloaded from outside the body.

As an information technology, biology is subject to what I call the "law of accelerating returns." Such technologies double their price performance and capacity in less than a year. Sequencing DNA has come down in price by half annually, from \$10 per base pair in 1990 to under a penny today. The amount of genetic data we have sequenced has more than doubled every year. At this rate, we will increase the capability of these technologies by a factor of 1,000 in less than a decade and by a billion in 25 years.

Human life expectancy was only 37 years in 1800. Our ability to reprogram biology will dramatically increase it again, but this progression will be much faster. I expect that within 15 years, we will be adding more than a year annually to remaining life expectancy. So my advice is: take care of yourself the old-fashioned way for a while longer, and you may get to experience the remarkable century ahead in full. ■

*An expanded version of this essay is available online at [www.sciam.com/ontheweb](http://www.sciam.com/ontheweb)*

*Ray Kurzweil is a pioneering inventor, recipient of the National Medal of Technology and author. His most recent book is *The Singularity Is Near: When Humans Transcend Biology*.*