In Brief

New Life Forms: New Threats, New Possibilities

For some years, scientists have felt that it should be possible to create new life forms "from scratch," perhaps by splicing together genes drawn from different sources to create a new functioning genome, perhaps by slowly combining genes synthetically into one or more functioning chromosomes, or perhaps by recombining many different genetic elements to see if a functional genome could be produced. Now, the quiet backwater of microbiology is about to move center stage in the genomics revolution.

Early work is already bearing fruit. A team at SUNY Stony Brook created an artificial polio type virus last year,[1] and this past fall Craig Venter announced that his Institute for Biological Energy Alternatives, with the generous support of the Department of Energy, had succeeded in the creation of a bacterial virus. What was interesting about Venter's announcement is that he and his team have developed a technique for the rapid recombination and transfer of many genes, thereby making the synthesis of new life forms less an experiment and more a form of manufacture.

Making an artificial virus from scratch is not only an impressive feat, it is also an important step in the radical transformation of genetic engineering. Today scientists can "synthesize" a small genome to create a virus. Soon they will move to larger genomes, and eventually to bacteria and possibly even to new genomes for larger animals and plants. It is conceivable that human beings will some day contain artificially synthesized chromosomes in their cells. Synthetic genomics may one day be one of the key spin-offs of the genomic revolution.

Right now, genetic engineering involves adding a small number of genes, often one at a time, to a plant or animal. The technique used by Venter's team makes it possible to design and create thousands of genes at once and transfer them. The difference in power between current genetic engineering and this emerging technology is the difference between monks painstakingly hand painting one book at a time and a printing press churning them out by the thousands.

The potential benefits of the technology are enormous. Synthetic genomics could provide us with microbes that have the ability to reduce carbon dioxide in the atmosphere. Genetically engineered bacteria could some day clean up pollutants within factories or eat radioactive waste. Gene therapy that uses "good" viruses to attack cancers and infections caused by "nasty" viruses and bacteria will likely take a giant leap forward when this technology is fully developed.

There are, however, some important questions to ask about synthetic genome technology. As with any product of genetic engineering in plants and animals, there is the potential for environmental harm if new synthetic organisms escape into the environment. It is already clear that the genetic engineering of seeds and plants has led to inadvertent and undesirable gene leakage that has proven costly to manage. It will be important that as synthetic microbial genomic technology develops, policies are established and enforced that can contain the spread of engineered organisms and their genes. The development of safety standards to confine synthetic organisms must proceed at a quicker pace.

A second major concern is that this technology can be used for bioterrorism. It will soon be possible to synthesize the genome for smallpox; preventing access to samples will then no longer be a protection because the information that makes it possible to construct it—the sequence for this genome—has already been published. It is easy to imagine this technology being abused—by terrorists from abroad or by disgruntled citizens. Who gets to learn how to use this technology, who gets to buy it, and how much is published about how to use it, all require careful thought. Developing these protections is a special challenge for research on a technology that is in its infancy. Most of the protections recently enacted do not apply to research that is this far "upstream"—yet by the time the research is fully developed, it may be too late to control.

A third issue is ownership and control. The battles over the ownership of individual genes and gene sequences should alert us to the fact that many parties will seek to own and control new life forms. But if these synthetic microbes are made at government expense, and if they are valuable in the battle against pollution or global warming, then what sort of access ought to be a part of granting patents or commercial control over them?

Ultimately, our best protection is likely to come from still more science: greater knowledge may provide us with vaccines and treatments that will protect us from the worse fears of the abuses of this technology. But it is imperative that we recognize the potential harms, learn from problems that have already arisen in other areas of genetic engineering and genomics, and address them rapidly.

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1. J. Cello, A.V. Paul, and E. Wimmer, "Chemical Synthesis of Polio Virus cDNA: Generation of Infectious Virus in the Absence of Natural Template," *Science* 297 (2002): 1016-1018.