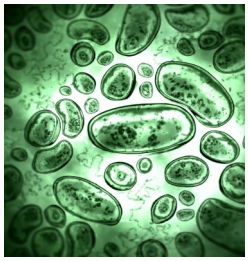
Synthetic Biology 101

Friends of the Earth

In May 2010 J. Craig Venter's company Synthetic Genomics announced that it had made the world's first organism with a completely synthetic genome. According to Venter, this organism was the first self-replicating species on the planet whose entire biological makeup was created by a computer.[1] While the field of synthetic biology has been growing at a tremendous rate, few in the public or policy spheres had ever heard of synthetic biology or considered the field's risks and benefits.

What is Synthetic Biology?



Synthetic biology is "the design and construction of new biological parts, devices and systems that do not exist in the natural world and also the redesigning of existing biological systems to perform specific tasks."[2] Instead of inserting genes from one species into another, what is considered more "traditional" genetic engineering, synthetic biology aims to create life from scratch with computer-synthesized DNA or without the use of DNA entirely.

Proponents hope this emerging technology will be used to produce the next-generation of fuels, medicines, and industrial chemicals. The U.S. government and the oil industry are the major funders of synthetic biology research so far – supporting start-up synthetic biology companies with hundreds of millions of dollars.

Applications of Synthetic Biology

The first major commercial applications for synthetic biology will be to produce biofuels and medicines. Eventually, synthetic biologists hope to create any type of valuable industrial chemicals that would otherwise be produced by petrochemicals.

Biofuels:

Synthetic biology is being used in two different processes for biofuels production - first is using synthetic enzymes to break down biomass into sugars for fuel, and second is creating microbes that produce fuel directly. Enzymes, which are proteins that catalyze reactions, are being engineered with synthetic DNA into microbes and tailored to break down certain types of biomass, such as woodchips or corn stalks. This would increase the rate at which biomass is broken down into sugars that can then be fermented into ethanol or other types of fuels. Synthetic biologists hope to change the organisms so that the oil they produce is chemically similar or identical to the oils that are currently used in today's transportation and energy infrastructure. These microbes would become "living chemical factories" that could be engineered to pump out almost any type of fuel or industrial chemical.

Medicines:

The other major application of synthetic biology that will likely see commercialization soon is the production of medicine. Already in production is arteminisic acid – a precursor to the important anti-malarial medicine arteminisin – which is being produced by *E. coli* with synthetic DNA. Proponents of synthetic biology claim that vaccines for influenza produced by synthetic organisms are close to commercialization.

Different Approaches to Synthetic Biology

DNA Synthesis:
At the most basic level, synthetic biology involves the use synthetic DNA that was uploaded or written on a computer and "printed" out onto a sheet of glass from bottles of nucleic acids (adenine, thymine, cytosine, and guanine—represented by the letters A, T, C, and G). These DNA strands are then inserted into organisms through a variety of genetic engineering techniques.

Biobricks:
Biobricks are standard DNA sequences that code for certain functions. DNA sequences can be created to make an organism glow, for example, and engineering that biobrick into an organism should make it glow. These open-source "bricks" can be used by researchers across the world to construct new genes and DNA sequences.

Minimal Genome:
Researchers, most notably Craig Venter, are working to produce an organism with the minimum number of genes needed to survive. One could then add any DNA sequence to this "minimal genome" and produce fuel, medicine, or any other synthetic product.

Xenobiology:
The four nucleic acids (A, T, C, and G) are linked together in nature by the backbone of DNA – a sugar group (2-deoxyribose) and phosphate. Xenobiologists hope to combine the nucleotide bases to different sugars in DNA, to create things such as threose nucleic acid (TNA), hexose nucleic acid (HNA), and glycol nucleic acid (GNA) – all of which never existed in nature before.

Protocells :
Researchers are testing combinations of inanimate chemicals to create protocells, or synthetic life without DNA. These protocells would be like truly creating life from scratch.

Dangers of Synthetic Biology

Environmental Harms:

Synthetic biology threatens the world's biodiversity through the contamination of genomes that have evolved over billions of years with synthetic DNA. Once it has contaminated a species, this synthetic DNA cannot be recalled and will pass on indefinitely through generations. Some applications involve growing synthetic organisms in open ponds or intentionally releasing them into the environment. While other types of pollution can be cleaned up and do not breed, synthetic biological creations are designed to self-replicate and once released into the environment they would be impossible to stop.

The ways in which these organisms will interact with the natural environment is unpredictable, potentially devastating, and permanent. A synthetic organism designed for a specific task, such as eating up oil from oil spills in the ocean, could interact with naturally occurring organisms and adversely harm the environment. The synthetic organism could displace existing organisms or interfere with the existing ecosystem. Once it found an ecological niche in which to survive, it would be difficult if not impossible to eradicate.[3]

Socioeconomic Harms:

Synthetic biology is creating a new "bioeconomy" in which any and all types of biomass can become a feedstock to produce industrial products such as fuel, chemicals, medicines, and plastics. Theoretically any product made from petrochemicals can one day be made by synthetic microbes in a vat eating plant sugars. But who will decide what plant matter is turned into an industrial feed stock, who decides what land is used to grow food or biomass, and whose land will be used to grow these feedstocks for synthetic organisms? [4]

Synthetic biology enthusiasts falsely assume there will be an endless supply of biomass and "marginal" land to fuel their biological revolution. These "marginal" lands are often the source of livelihood for small-scale farmers, pastoralists, women, and indigenous peoples. These "marginal" lands should be used to grow food for local communities, not fuel or industrial chemicals for wealthy nations. Synthetic organisms require an incredible amount of land, water, and fertilizer – all of which are already in short supply for food production. Increasing pressure on already strained land will only worsen issues of land grabbing, land ownership, biodiversity, and the health of the land and surrounding communities.

Biosecurity Threats:

The poliovirus and the 1918 Spanish Influenza have already been recreated using mail-order DNA from a DNA synthesis company and were proven to be deadly in lab rats. A growing "Do-it-Yourself biology" movement that encourages the use of synthetic biology tools in people's garages increases the risk that dangerous pathogens may be intentionally or unintentionally created and released.

Regulation of Synthetic Biology

The risks synthetic biology pose to human health and the environment are serious since synthetic biology has the ability to create organisms that have never existed before and their complexity will only increase over time. We must establish a regulatory framework before this technology evolves too far and it is too late.

Friends of the Earth US is calling for a **moratorium on the release and commercial use of synthetic organisms** until there is adequate scientific analysis to justify such activities and until the impacts on the environment, biodiversity, human health, and all associated socio-economic repercussions, are examined. After then, appropriate regulations at the local, national, and international level must be established to ensure human health and the environment are not threatened before the moratorium should be lifted.

Citations

1 - Wade, Nicholas. "Researchers Say They Created a 'Synthetic Cell.'" *The New York Times*. 20 May 2010. www.nytimes.com/2010/05/21/science/21cell.html

2 - *Extreme Genetic Engineering: An Introduction to Synthetic Biology*. ETC Group, 2007.

3 - Rodemeyer, Michael. *New Life, Old Bottles: Regulating the First-Generation Products of Synthetic Biology.* Woodrow Wilson International Center for Scholars, Synthetic Biology Project, 2009.

4- *Extreme Genetic Engineering: An Introduction to Synthetic Biology*.