

Synthetic biology 101

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.ⁱ While the field of synthetic biology has been growing at a rapid rate, public policies and regulations to ensure the field does not threaten the environment, biodiversity, or human health have yet to be developed.

What is Synthetic Biology?

Synthetic biology broadly refers to the use of computer-assisted, biological engineering to design and construct new synthetic biological parts, devices and systems that do not exist in nature and the redesign of existing biological organisms.ⁱⁱ While synthetic biology incorporates the techniques of molecular biology, it differs from recombinant DNA technology in that synthetic biology introduces synthetically constructed parts and is



not limited to the modification of natural organisms, but also extends to the construction of new life forms with no natural counterpart. Additionally, synthetic biology is working at an increased level of complexity not seen in “traditional” genetic engineering.

Differing 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 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: Xenobiologists are attempting to create alternative genetic systems such as novel nucleic acids, “suicide genes,” or mirror biology. For example, one research team has replaced thymine with 5-chlorouracil in the genome of E. coli where others are attempting to create “mirror” cells that cannot reproduce with their wild relatives. Xenobiology as a form of biocontainment is theoretical at this point.

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.



Applications of Synthetic Biology

Proponents hope synthetic biology will produce the next-generation of fuels, industrial chemicals, natural product substitutes, and biomedical applications. Eventually, synthetic biologists believe they could replace our oil-based economy with a new “bioeconomy” in which synthetic organisms can break down biomass to produce any type of fuel, industrial chemical, natural products, or medicines and vaccines.

Biofuels: Biofuels production through synthetic biology is being conducted in two main ways. First, organisms synthetically engineered to break down biomass into sugars for fuel. Enzymes, which are proteins that catalyze reactions, are being engineered by synthetic microbes that are tailored

to break down certain types of biomass, such as sugarcane, woodchips or corn stalks for example. These microbes would become “living chemical factories” that could be engineered to pump out almost any type of fuel or industrial chemical. Second, organisms are being designed to produce fuel directly. Algae naturally produces oils, but through synthetic biology tools algae can be reengineered algae to produce oils that are chemically similar or identical to the oils that are currently used in today’s transportation and energy infrastructure.

Industrial Chemicals: A wide range of industrial chemicals are being produced through synthetic biology. Amyris Biotechnologies, for example, is producing farnesene – an essential building block for a wide range of chemical products (detergents, cosmetics, perfumes and industrial lubricants and transportation fuels) – through its synthetically engineered yeast. DuPont is working with Tate and Lyle to use their synthetically engineered yeast to ferment corn sugars into a bio-plastic, marketed as Sorona.



acid – a precursor to the important anti-malarial medicine artemisinin – which is being produced by *E. coli* with synthetic DNA. Other researchers and companies are working on ways to produce vaccines through synthetic microbes.



Natural Product Substitutes: Synthetic biologists are working to replace natural products with synthetically produced equivalents. Much attention is being given to the synthetic production of rubber through isoprene – a crucial building block for making artificial rubber. The gene encoding isoprene (previously found in rubber trees) has been synthetically engineered by DuPont subsidiary, Genencor, into *E. coli* to produce isoprene. Other products currently being produced through synthetic biology include vanilla, stevia, and palm oil among others.

Biomedical Applications: The other major application of synthetic biology that will likely see commercialization soon is the production of medicine. Already in production is artemisinin

Potential Impacts on the Conservation and Sustainable Use of Biodiversity

The release of synthetic microbes

Synthetic organisms threaten biological diversity if they escape into the environment – either intentionally or unintentionally from a lab. Organisms are being synthetically engineered to survive, function, and propagate in the natural environment. If they found an ecological niche, they could displace wild populations and disrupt entire ecosystems.ⁱⁱⁱ Synthetic organisms could also escape unintentionally from laboratories, biorefineries, and production vats through faulty containment systems or human error. Once in the environment, it will be impossible to recall or clean up the organisms and they could become a new class of invasive species or pollutant and disrupt ecosystems.

The increased demand on land, biomass, water and other natural resources

Synthetic biology may facilitate the creation of a new “bioeconomy” in which plant matter is processed into commercial products through synthetic organisms. This increased demand for biomass could have serious impacts on biodiversity and the livelihood and food security of smallholder farmers, forest-dwellers, livestock-keepers and fishing communities who depend on biodiversity, especially in the developing world. First generation biofuels have already led to massive changes in land use, impacting the food and water supply. So-called “next generation” fuels will only exacerbate this problem by



transforming previously “low-value” forest and agricultural “wastes” such as straw, leaves and branches into valuable feedstocks and by growing biomass on “marginal” lands for chemical and energy companies. This is in itself a problem since these resources are not “wastes” but important components of soil’s recycling of nutrients and its capacity to sustain soil health, promote biodiversity, and sequester CO₂. Additionally, “marginal” lands are often the source of livelihood for small-scale farmers, pastoralists, women, and indigenous peoples. Increased demand for biomass to produce biofuels through synthetic organisms will add even more pressure on soils, water resources and ecosystem integrity that are already stretched beyond breaking point. This demand will also compete with food security, livelihood needs, biodiversity

and conservation goals since there is simply not enough land or plant matter for all the uses that are being contemplated. With an estimated 86% of global biomass stored in the tropics or subtropics, developing countries are already being tapped as the major source of biomass to supply industrial-scale feedstock for fermentation tanks and biorefineries.^{iv}

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 proper regulations and safeguards 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:

- Governmental bodies, with full participation of the public, have conducted proper risk assessments.
- The health, environmental and socio-economic risks of synthetic biology are fully known and strategies for mitigating those risks are in place.
- National and international oversight and security mechanisms equipped to keep pace with the risks are in place.

Until that time, synthetic biology should remain in the lab and synthetic organisms must not be allowed to escape into our environment or be used at a commercial scale.

Endnotes

i 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

ii Synthetic Biology: Applying Engineering to Biology Report of a NEST High-Level Expert Group. Published by the European Commission 2005. [ftp://ftp.cordis.lu/pub/nest/docs/syntheticbiology_b5_eur21796_en.pdf](http://ftp.cordis.lu/pub/nest/docs/syntheticbiology_b5_eur21796_en.pdf)

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

iv ETC Group. 2010. *The New Biomasters: Synthetic Biology and The Next Assault on Biodiversity and Livelihoods*. www.etcgroup.org