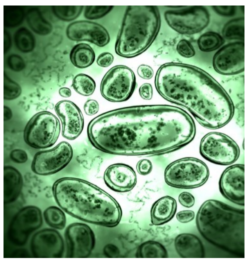
Synthetic Biology 101:

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.[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*.

Synthetic Biology:
A Threat to Biological Diversity

Friends of the Earth

Synthetic biology's Impact on Biological Diversity:

The release of synthetic microbes:
Synthetic organisms will threaten biological diversity if they escape into the environment. Intentional release is being proposed for bioremediation, such as cleaning up oil spills, and soil enhancement. These organisms are being specifically 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. Synthetic organisms could also escape unintentionally from laboratories, biorefineries, and production vats through faulty containment systems or human error. Many of these microbes are engineered to break down biomass or produce lipids for fuel and their escape could be disastrous. Escaped organisms tailored to break down cellulose or produce oils directly could lead to the destruction of all plant matter or the introduction of toxic compounds into the environment. Novel synthetic microbes could also have unexpected pathogenic qualities with negative consequences for both ecosystems and human health.

The increased demand on land, biomass, water and other natural resources:
Most commercial interest in synthetic biology is focused on developing microbes, such as yeast and *E. coli*, which can break down cellulose or other plant sugars into fuels, chemicals and plastics. First generation agrofuels have already led to massive changes in land use, impacting food and water supplies. 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 energy and chemical 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 biodiversity and crops, absorbing CO^2 and water. 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, the livelihood of communities, biodiversity, and conservation goals since there is simply not enough land or plant matter for all the uses that are being contemplated.

Synthetic biology - Opening the Door for "Digital Biopiracy."

While the CBD has been discussing a Protocol on Access and Benefit Sharing for many years, developments in synthetic biology allow would-be biopirates to steal genetic resources more efficiently. While "traditional" biopiracy involves the physical removal of material from a community to private hands, synthetic biology enables "digital biopiracy" where the DNA of an organism is sequenced in situ, uploaded to the internet as information, and then transferred digitally to a DNA synthesizer to be copied and rebuilt elsewhere. This digital transfer of DNA sequences does not even require a Material Transfer Agreement (MTA) since no physical material is transferred. Yet, the technology allows corporations, governments and individuals to freely take genetic material for private use in new synthetic organisms, which can then be patented as inventions. While synthetic biologists like to talk of writing new genetic code from scratch, in reality most synthetic DNA sequences developed for synthetic biology are near-copies of natural genetic code that has 'evolved' through computer models. The implications of this digital biopiracy are far reaching. For example, companies and researchers are already developing organisms that will produce natural compounds such as rubber and artemisinin in closed vats. These production facilities could undercut the livelihoods and rights of some of the poorest farmers and plantation workers in the world, by moving raw material production from the field to the fermentation vat, while gains will also move from communities to big commercial interests.

Decisions on Synthetic Biology at COP 10 in Nagoya

The Parties to the Convention of Biological Diversity have a number of opportunities to address the governance gaps on genetic resources, biosafety and biodiversity impacts that have emerged with the rapid development of synthetic biology.

Access and Benefit Sharing:

Following a request from the Working Group on ABS, the CBD Secretariat commissioned a review paper on the definition of 'genetic resources' in the context of advances in modern biotechnology including Synthetic Biology. That paper (UNEP/CBD/WG-ABS/9/INF/1) notes "the ABS system may not be able to capture the future potential value of genetic material, not least when it is used in or as a basis for synthetic biology" further noting that if the concept of genetic resources is not expanded to include "informational and digital dimensions" valuable uses of genetic resources will fall outside the ABS framework.

Friends of the Earth US Recommendations:

- Parties should close this potentially significant loophole by explicitly extending the definition of genetic resources to include genetic information stored or transmitted in a digital form.
- The construction of genetic parts, biobricks, metabolic pathways and synthetic chromosomes for use in synthetic biology should be included under an international ABS regime whether or not those parts are derived from naturally occurring analogues.

Other instances for decisions on Synthetic Biology at COP 10:

At SBSTTA 14, synthetic biology was discussed under two agenda items, namely, "Biofuels and Biodiversity" and "New and Emerging Issues".

The draft Decision on Biofuels to be considered at COP 10 is contained in document UNEP/CBD/COP/10/3:

[14. Decides to convene an ad-hoc technical expert group on synthetic biotechnologies and other new technologies that are used or projected to be used in the next generation of biofuels to assess their impact on biodiversity and related livelihoods.]

[16. Urges Parties and other governments, in accordance with the precautionary approach, to ensure that living organisms produced by synthetic biology are not released into the environment until there is an adequate scientific basis on which to justify such activities and due consideration of the associated risks for the environment and biodiversity, and the associated socio-economic risks, are considered]

Furthermore, synthetic biology is also tackled in the draft Decision on "New and Emerging Issues" (UNEP/CBD/COP/10/3) :
Invites parties, other governments and relevant organizations to submit information on synthetic biotechnology and geoengineering in accordance with the procedure of decision 9-29, for consideration of SBSTTA, while applying the precautionary approach on the field release of synthetic life, cells or genomes into the environment.

Friends of the Earth US Recommendations:

Appropriate oversight and international governance rules need to be put in place to ensure that synthetic biology does not further threaten biodiversity and livelihoods while pilfering genetic resources. The CBD is the authoritative body on this matter. While Friends of the Earth US is broadly supportive of the three decisions communicated by SBSTTA 14 on Synthetic Biology we would further recommend that:

- Decisions taken regarding synthetic biology and the development, handling and use of synthetic organisms or synthetic genetic parts should be subject to the strict application of the precautionary principle.
- That there should be no environmental release of synthetic living organisms whatsoever.
- That commercial use of synthetic organisms should not proceed until the direct and indirect impacts on conservation and sustainable use of biodiversity are better understood and assessed, including the cultural and socioeconomic impacts and the impacts of traditional knowledge as well as the rights of Indigenous Peoples, farmers, fisherfolk, and pastoralists. This includes the impacts of procuring feedstocks for biorefineries.
- That the Working Group on Article 8(j) should be asked to consider the impact of developments in Synthetic Biology on Traditional Knowledge, Innovations and practices

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