Brief for GSDR 2015

The promise of synthetic biology for sustainable development

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Introduction

The field of synthetic biology opens up the possibility of finding solutions to pressing sustainable development challenges – water, energy, food, health – but at the same time raises novel questions about appropriate regulation of new technologies.

Synthetic biology builds on the achievements and uses the techniques of genetic engineering, which involves the alteration of an organism's genetic material using biotechnology. Synthetic biology has been defined as "the design and construction of new biological parts, devices, and systems, and the re-design of existing, natural biological systems for useful purposes" (Nature). It has also been described as "the construction of customized biological systems to perform new and improved functions, through the application of principles from engineering and chemical synthesis" (ter Meulen, 2014). Synthetic biology represents the convergence of technologies from the life sciences, such as DNA recombination, with other fields like engineering, computational technology and nanotechnology (OECD, 2014).

In the near- to medium-term, synthetic biology has the potential to alter production processes of a range of products, such as consumer goods, medicines, plastics and related chemicals. Already a laundry detergent produced by a firm marketing "green" household products contains oil produced by modified algae, replacing palm oil that is widely associated with deforestation (NYT, 2014). With respect to biofuels, non-edible plant species are being adapted to increase biomass yield and to grow on marginal lands. Other applications include amplifying or re-engineering metabolic pathways of yeast and other organisms to boost fuel production. Most plastics - ubiquitous in our lives, think of everything from paints to clothes - are derived from fossil fuel sources. Bio-engineered alternatives are beginning to be introduced. Looking further into the future, the possibility of completely new, synthetic organisms may herald an era of bio-production with vast potential, but one that is difficult to assess from the vantage point of the present.

Issues for scientific debate

Artemisinin is a key ingredient in the leading drug combination used to treat the most lethal form of malaria, a disease that afflicts more than 200 million people annually. Until the semi-synthetic version was engineered, the sole source of the active ingredient came from the sweet wormwood plant. The natural cultivation cycle caused lags in supply and price volatility, so the Bill & Melinda Gates Foundation funded an initiative to apply synthetic biology to produce the active ingredient. Scientists genetically engineered metabolic pathways in yeast cells to produce artemisinic acid, a precursor to artemisinin (Ro et al, 2006). The process was further refined by a biotechnology company, so as to facilitate large-scale production. The technology was then licensed royalty-free to a pharmaceutical company, which in August 2014 shipped the first batches of drugs made with the semi-synthetic artemisinin.

Concerns have been raised about the impact of semi-synthetic artemisinin, as well as other bio-engineered products, on the livelihoods of the thousands of producers in developing countries cultivating the natural crop (ETC, 2007; Peplow, 2013). Some have warned of a wide-spread disruption for farmers' livelihoods, highlighting the unintended social impacts of this new technology (Thomas, 2011).

While ultimately successful, the artemisinin example also demonstrates the high cost and long development time before the bio-engineered product could be brought to market. The process was a far cry from predictably harnessing biological parts for efficient production, as an engineer might design an industrial process. One key reason is

that the sheer complexity of biological systems makes engineering approaches difficult; with the current state of knowledge biological systems are not easily reduced to modules that function in predictable ways.

Several approaches are being used to advance synthetic biology as a predictable, reliable technology, derived from the diverse scientific communities working in this field. Hailing predominantly from an engineering and software background, researchers are seeking to modify and build organisms using a library of standard biotechnology "components", roughly akin to constructing with Lego blocks (Silva & Way, 2014). Making this approach – known as rational design – work depends on more effectively bringing together detailed knowledge from silo-like specialist domains, e.g. gene expression, enzymes, protein structure and more. Other researchers, generally rooted in the life sciences, emphasise that evolution is a powerful tool that can be put to work in the lab to come up with new organisms that possess the desired functions. So-called directed evolution works by introducing random genetic variations in large numbers of organisms, which are then rapidly screened for the desired characteristic (Arnold & Meyerowitz, 2014). Overall, the complementarity of the two approaches is recognized – evolution may be capable of solutions not possible through rational design, and harnessing both approaches dramatically broadens the possibilities for new bio-processes (Ferry et al, 2012).

Synthetic biology researchers hailing from the engineering and software communities bring with them a tradition of sharing and open source standards, with a prominent example being the Registry of Standard Biological Parts, a collection of genetic parts that are used in the assembly of systems and devices in synthetic biology. On the other hand, the practice of IPR protection is more entrenched in the life sciences community, often being linked to the prevailing business model.

As yet another technology that is overwhelmingly being developed in US labs and a handful of other Western countries, there is a risk that developing nations will feel that they will be excluded from beneficial access to, and development of, this technology.

Synthetic biology, spanning a broad range of activities, brings with it great potential, but also risks such as the possibility of harm to biodiversity (ETC, 2014). Proponents have suggested a number of means to prevent gene contamination from the synthetic organism to wild or naturally occurring organisms, such as genetic "kill switches" and other means of preventing synthetic organisms from propagating outside the laboratory. The argument has also been made that existing regulatory frameworks are inadequate, especially in light of the fact that script for DNA sequences can be stored and transmitted digitally, that is without any living organisms changing hands.

There is a risk that control and regulation driven by exaggerated fears, as opposed to evidence, will stifle a technology with great potential to advance sustainable development. The Convention on Biodiversity has urged parties to adopt a precautionary approach, and there have also been calls for a moratorium (CBDa, 2012; CBDb, 2014). Going forward, there is a considerable risk that the public's inadequate understanding or mis-perceptions about the technology could hamper its contribution to sustainable development. Part of the responsibility will rest with scientists, who will need to couple technical skills with a willingness to openly address ethical and moral questions.

Issues for further consideration

The following are among the issues suggested for further consideration by policy-makers:

- Promote open public engagement and evidence-based communication of benefits and risk.
- Promote open source development models and platforms that direct research and resources to sustainable development challenges.
- Accelerate steps to move from discovery science towards more predictable, modular approaches.

- Address uncertainty about regulation of synthetic biology

References

Arnold, Frances H. and Meyerowitz, Joseph T. Evolving with Purpose. *Nature* 509, 166-167 (8 May 2014).

CBDa. Convention on Biodiversity. COP 11, Decision XI/11, New and emerging issues relating to the conservation and sustainable use of biodiversity. UNEP/CBD/COP/DEC/XI/115 December 2012

CBDb. Convention on Biodiversity. Subsidiary Body on Scientific, Technical and Technological Advice, Recommendation XVIII/7.New and emerging issues: synthetic biology. Eighteenth meeting, 23 - 28 June 2014.

ETC Group. Extreme Genetic Engineering: An Introduction to Synthetic Biology (2007).

ETC Group. Synthetic Biology: 10 key points for delegates (undated). http://www.etcgroup.org/sites/www.etcgroup.org/files/synbio_ETC4COP11_4web_0.pdf

Ferry, Michael S, et al. Synthetic biology approaches to biofuel production. *Biofuels* (2012) 3(1), 9–12.

OECD. Emerging Policy Issues in Synthetic Biology, OECD Publishing (2014).

Peplow, Mark. Malaria drug made in yeast causes market ferment Synthetic biology delivers combination therapies into an uncertain market. *Nature* 494, 160–161 (14 February 2013).

Ro, Dae-Kyun et al. Production of the antimalarial drug precursor artemisinic acid in engineered yeast *Nature* 440, 940-943 (13 April 2006).

Silver, Pamel A. and Way, Jeffrey C. Rationalizing nature. *Nature* 509, 166 (8 May 2014).

Strom, Stephanie. Changing the Science of Soap, *New York Times*, May 31, 2014, on page B1.

ter Meulen, Volker. Time to settle the synthetic controversy. *Nature* 509, 135 (08 May 2014).

Thomas, Jim. The Sins of Syn Bio: How synthetic biology will bring us cheaper plastics by ruining the poorest nations on Earth. *Slate*, 2 February 2011. http://www.slate.com/articles/technology/future_tense/2011/02/the_sins_of_syn_bio.html