Slowly boiling the frog? Reasons for disquiet over synthetic biology

Helena Paul and Ricarda Steinbrecher warn that the rapidly developing field of synthetic biology – which proposes releasing artificial living organisms into the environment – is running ahead of the necessary precautionary controls.[1]

Synthetic biology is presented as a potential means of addressing challenges and bringing economic benefits for society.[2] Underlying this is the unstated proposition that perhaps science can help politicians sidestep political and economic problems through new technologies. There is no agreed definition of what exactly synthetic biology is, and how it differs from genetic engineering used to produce GM organisms so far. However, the definition provided by the UK Royal Society is one place to start: "the design and construction of novel artificial biological pathways, organisms or devices, or the redesign of existing natural biological systems."[3] The language of 'synbio' is that of computing and the images are concepts from engineering, with talk of building new assemblies of DNA on the hollowed out chassis of a cell, while the practice is still largely cut, copy, mix and paste.[4]

Although the presentation of synthetic biology is becoming more nuanced, the image of biological components as pieces in a game is developing through iGEM, a series of international student competitions focused on the issue.[5] Some are tempted to believe that we will use synbio to 'improve nature', for example, through the creation of organisms that are more 'efficient', with functions that do not serve a human purpose being deleted and those that do being enhanced.

Uncertain science

However, first attempts have revealed that we do not understand enough about gene functions and interactions to build new organisms from scratch, or even decide which genes to leave out of a 'minimal' genome. It is largely a hit and miss process, useful for learning but not ripe for release. Few genes and/or their products are involved in only a single function or activity. Most have several functions and interact with each other in complex and subtle ways in response to circumstances. This demonstrates that genomes are dynamic systems.

To some extent, synthetic biology is an extension of genetic engineering and it can be difficult to differentiate between the two especially where they overlap. Synbio ranges from synthesising known genes from sequence data to designing completely new genes, working with entire genetic systems instead of single genes and proceeding at a much faster pace and broader scale.

Can policy and regulation keep up?

We therefore need to ask whether current analysis, regulation, and risk assessment models are equipped to deal with new and emerging challenges posed by both genetic engineering and synbio, especially as the technologies move further away from genetic engineering, as we assume they will. How can we update regulation, oversight and mindsets to deal with this?

Beyond oversight and regulation, there are wider considerations. The development of new and the refinement of existing technologies raise new scientific, ethical and socioeconomic questions, but these are rarely addressed under current forms of risk assessment and decision-making. The public almost never has the opportunity to debate these issues, or whether certain technologies should continue to develop, and if so how. There is currently no mechanism to halt a technology the public does not want and views as dangerous. The problem is compounded by the fact that equipment is increasingly cheap and almost anyone can access and use DNA sequences, unsupervised, for any purpose, with potential for deadly mistakes and aggressive applications.

There are thus major tensions between promoting synthetic biology to address political and economic problems and the need for extreme caution when considering the potential environmental impacts of releasing novel organisms. One proposed technical solution is to develop strategies to prevent the survival or reproduction of these organisms. For example, with bacteria, certain fungi (including yeast and moulds) and small algae, strategies considered include changing their genes to prevent them from producing or metabolising vital nutrients, so theoretically they could not survive in the 'wild'. However, horizontal gene transfer, a survival and evolutionary tool highly developed and utilised amongst micro-organisms, enables them to share information and quickly replace missing or faulty genes. Biological containment – including Genetic Use Restriction Technologies (GURTs), also called 'Terminator Technologies' – intended for plants and animals, is a flawed strategy and an unreliable practice. Every organism has a clear interest in reproduction and survival and will tend to adapt. The UN Convention on Biological Diversity has established a moratorium on Terminator Technologies and is considering a similar moratorium on the environmental release and commercial use of organisms produced through synthetic biology. These provide a vital opportunity to pause and consider the implications before releasing the products of such technologies into complex and still little understood environments.

And this is the most important point of all. While genetic engineering is useful for research, our understanding of the ecosystems into which genetically engineered organisms and the products of synthetic biology could be released, either deliberately or accidentally, is still in its infancy. Ecosystems are highly complex, dynamic webs of interrelationships that we are barely beginning to understand and we urgently need more research. We should observe and try to understand better the systems we depend on before we risk releasing synbio products into them. We cannot allow political expediency, facilitated by technology, to take precedence. We must beware of becoming like the proverbial frog in the slowly heating water – it does not perceive the gradual change in temperature, fails to jump out while it still can, and is finally boiled.

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References

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