



Online Ethics Center
FOR ENGINEERING AND SCIENCE

Background

Description

Part of unit 2 of the [Course on Genomics, Ethics, and Society](#), this section gives a background on the ethics of genomics, synthetic biology, microorganisms and biofuels.

Body

Synthetic Biology: Key Technologies

A significant and increasing amount of research now carried out at the level of micro-organisms falls into the category of "synthetic biology" (though not all genetic modification at the level of micro-organisms falls into this category). While the term "synthetic biology" seems to have been first used in 1974 by Waclaw Szybalski, the field now known as "synthetic biology" only really emerged in the early 2000s as the cost of gene sequencing plummeted. We are particularly interested in synthetic biology here as it's often claimed that it raises social and ethical questions particularly acutely.

There's much debate about how to define "synthetic biology". Fundamentally, synthetic biology concerns deliberate human engineering of biological processes, in particular the creation of novel DNA sequences. The UK Royal Society defines synthetic biology as "an emerging area of research that can broadly be described as the design and construction of novel artificial biological pathways, organisms or devices, or the redesign of existing natural biological systems." (see <https://royalsociety.org/policy/projects/synthetic-biology/>) A number of different

technologies may be involved:

- **Protocells:** Cells made “from the bottom up,” or created out of basic biomolecules, often including those not found in any other living cells. Protocells are artificial, designed to be self-replicating and to metabolize materials from their surrounding environment in order to grow.
- **Biobricks:** Standardized strands of DNA that code for specific functions. These can be inserted into organisms, sometimes in combination with other “bricks,” in order to play specified roles in those organisms. “Bricks” can be shared between researchers in order to construct new DNA sequences.
- **Minimal Genome:** Researchers have attempted to create organisms that possess the minimum genetic material needed in order to survive. Further sequences can be added to this “minimal genome” or “chassis” in order to serve other functions, like producing fuel or medicine.

Synthetic biology is, firstly, important in developing basic understanding of the genome; but it also allows for engineering microorganisms to perform new functions, and altering genome sequences to change proteins. The capacity to do this has a whole range of potential uses: The Royal Society, for instance, suggests these technologies may be used for developing cheap anti-malarial drugs, for producing “green hydrogen” for fuel, and programmable cells to treat cancer; other potential uses include vaccines, carbon sequestration, bioremediation, food additives (for instance, to create particular aromas) cosmetics and perfumes. There is enormous potential, in particular, for producing biofuels that can provide important sources of energy not derived from fossil fuels, as some organisms (like algae) naturally produce materials that (assisted by engineering techniques) can be converted into biofuel, while other organisms (like *E. coli*) can be genetically modified to create fuel precursors.

Research into synthetic biology has been supported both by public and private funding. A 2010 research brief published by the Woodrow Wilson International Center noted that between 2005 and 2010, the US government had allocated approximately \$430M for research into synthetic biology, the majority of which came from the Department of Energy. High levels of private funding have been made available too: for instance the Gates Foundation donated \$42.6M for research into producing the anti-malarial drug artemisinin. (Balmer & Martin, 2008). Research into synthetic biology is carried out both within universities, and private research organizations, most prominently the Craig Venter Institute, which has received both

private and public funding.

Synthetic Biology: Concerns, Values, and Consequences

As was noted in Unit 1, social and ethical concerns about genomic technologies fall into two broad categories: *intrinsic* concerns, about the nature of the technology in itself, and *extrinsic* concerns about the consequences of research into or use of the technology: the risks the technology poses, and its social and environmental impacts. Synthetic biology raises both types of concern particularly acutely. The creation of artificial life, for instance, is sometimes regarded as being intrinsically problematic (though there's a debate here about what "life" actually means). Bryan Norton, for instance, a well known environmental ethicist, argues that synthetic biology introduces life forms that are new "in an important sense" (see his short paper at <http://bioethics.gov/sites/default/files/Synthetic-Biology.pdf>) Others, who don't object to the technology in principle, are concerned by the social and environmental risks they believe it to pose. Intrinsic concerns about synthetic biology fall into two related categories: concerns about "naturalness" and concerns about "playing God". The primary worries about risks and consequences concern the unforeseen consequences of deliberate uncontained uses of synthetic genetic material, accidental escapes of such material, or the uses of synthetic genetic material as weapons or in other forms of bioterrorism.

1. Naturalness, Artificiality, and Intrinsic Value

A common objection to synthetic biology is that the creation of artificial cells and organisms is *unnatural*. But this worry can take different forms, so we need to consider it more carefully; we also need to think about why "naturalness" might be thought of as being morally relevant.

Naturalness, in this context, can be understood in two ways: in terms of materials (composition); and in terms of origins (history, that is, where something has come from). The *materials* used to create artificial cells and organisms can also typically be found in other living cells and organisms (e.g., the nucleotide adenosine). If we

understand “natural” to mean “found in nature,” then most research in synthetic biology is in this sense natural or using natural components (though there are some exceptions, like the protocells discussed above). More commonly, “natural” and “unnatural” refer to the *origins* of artificial cells and organisms. The products of synthetic biology are “unnatural” because they are intentional human creations. If we accept this use of “unnatural”, that the products of synthetic biology are unnatural seems unproblematic. But why is this of moral, or value, significance? After all, we are surrounded by things that are human creations: clothes, cars, furniture and so on; their “unnaturalness” doesn't seem to generate moral concern. So, what's special about synthetic biology?

One focus here is on the *novelty of synthetic life*. Though human beings create other human lives (through reproduction), and regularly modify the genomes of animals (e.g., through selective breeding), creating life out of basic organic and inorganic material is not something that has been possible until very recently. So we might think there's a step change here in terms of what humans are able to do. However, it's not clear why novelty alone should be seen as problematic, unless it is combined with some other consideration (e.g. the riskiness of synthetic organisms, as discussed below).

A second reason for thinking naturalness is morally relevant concerns the intrinsic value of life. Suppose one thinks that just being a living organism is sufficient to give a being value, independent of its usefulness to people. It might be argued that part of what makes life intrinsically valuable is its origins. Every non-synthetic organism is a result of a long evolutionary process, without which that organism would not exist; perhaps this is part of its value? In contrast, most synthetic life has no evolutionary history, and exists only because of intentional human creation.

But most of those who argue that life has intrinsic value don't rest such value on the origins of life. A group of philosophers in modern environmental ethics, for instance, called “biocentric ethicists” argue that individual living things have value. However, they base this value on claims that living beings have *interests* (they can be harmed or benefited) or that they are in some sense *goal-oriented*. On this conception of what makes life valuable, all synthetic life is intrinsically valuable as well as “natural” life, despite its artificial or unnatural origins.

The third reason for thinking that naturalness is morally relevant, is the claim that life is not for human beings to manipulate however they wish; it's just not the kind of

thing that should be broken down and re-engineered into new forms. On this view, artificially creating or modifying life both simultaneously demeans life and falsely elevates human beings. It is, as philosophers say, a “category mistake” for humans to engage in creating life. This objection is often termed “playing God,” and will be discussed in more detail below.

2. Synthetic Biology and “playing God”

To say that the development or use of a technology is “playing God” is usually intended negatively; there’s something wrong with human beings “playing God”. But what actually is the objection here?

In order to understand what the objection might be, we need to think about what “playing God” might mean, since it can be interpreted in different ways. In a religious sense, it can mean that humans are understood to be literally crossing a boundary set by God, by acting in ways that only God should act – in the case of synthetic biology, creating life by synthesizing new genes. On this view, what's wrong with "playing God" is, essentially, breaking God's rules or going against God's design and intention for human beings.

However "playing God" can be also used in a looser, more secular sense to refer to the idea that technologies such as synthetic biology are *hubristic*: they invoke powers that fail to recognise humans’ proper status in the world. Hubris can be understood either to be objectionable in itself (the display of hubris is taken to be a kind of vice, following a virtue ethics tradition – see unit 1); or, alternatively, as problematic because it risks bad consequences. On the consequence-oriented view, since human beings are not omniscient or omnipotent, they can’t necessarily predict or control the consequences of their actions. So they should be very cautious about developments such as creating artificial life. Not to be cautious, on this view—which might require refraining from developing technology such as synthetic life at all—would be "playing God." What you think about the religious version of this view, of course, depends on whether you are a theist, and if so, what boundaries on human actions you believe God has set. For more secular interpretations, though, “playing God” may capture an attitude of unease, either with certain "hubristic" manifestations of human nature, or with the potential consequences of human actions. But the term used this way isn’t very precise, and for many policy questions it is often more useful to focus on the consequences of synthetic biology.

A useful discussion of "playing God" by Alexandre Erler (2010) can be found online at the Oxford University Practical Ethics blog, see:

<http://blog.practicaethics.ox.ac.uk/2010/05/is-playing-god-just-a-meaningless-phrase/>

3. Extrinsic Concerns: Risks and Consequences of Synthetic Biology

Why synthetic biology is risky: Many synthetic organisms are designed to self-replicate and adapt independently of human control. This is one aspect of what makes synthetic organisms interesting and potentially useful, but it is also what makes them unpredictable and inherently risky. Organisms that can self-replicate and evolve on their own could possibly change in ways that researchers had not anticipated, since like any living organism, they are subject to evolutionary forces. In addition to this inherent riskiness, as the cost of carrying out work in synthetic biology has reduced, it's become more feasible for many people to engage in it, including hobby 'garage biology' that people carry out at home. This opens up the possibility of pockets of relatively unregulated synthetic biology and raises the risk of accidental releases.

Kinds of risk: Two of the primary risks created by synthetic organisms, which are exacerbated by their unpredictability, are bioterrorism and damage to the environment. For instance, a terrorist group could release an infectious agent specifically intending for it to replicate on its own and spread among the general population. The polio virus, for instance, has been successfully synthesised from scratch (see <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1143801/>). Or suppose *E. coli* that has been modified to produce fuel precursors escaped from the lab; it's possible that it could impact other organisms, including *E. coli* found in other places in nature. These possibilities exist for many other organisms produced synthetically.

Ways of reducing risk: There are several possible ways of reducing the risk of negative consequences from synthetic biology. One avenue of risk reduction involves producing artificial organisms that are in various ways vulnerable: that can be made to self-destruct, or are created dependent on nutrients that they can only access inside a lab. A second way of reducing risk is to introduce regulatory frameworks governing both research into synthetic biology, and the release and use of synthetic genetic material. A number of non-governmental organizations (NGOs) have argued for the adoption of the precautionary principle (see unit 1) in the context of synthetic biology. One example of this can be found in the "Principles for

the Oversight of Synthetic Biology” available at

http://www.synbioproject.org/process/assets/files/6620/draft/principles_for_the_oversight_of

4. Justice and Democratic Deliberation

As well as risking bad consequences, synthetic biology may, as it develops, raise other concerns. For instance, if synthetic cells are used to produce large quantities of biofuels in the USA, this might displace biofuel markets from, say, the production of palm oil for biodiesel in Asia. This would have significant impacts on Asian economies, and in particular on farmers whose livelihood depends on palm oil plantations. These kinds of developments might raise international distributive justice issues, and would be very likely to exacerbate existing international inequalities. A number of potential developments in synthetic biology may raise concerns about justice and inequality (though equally, some developments might be justice-enhancing and reduce inequality).

As an emerging technology with wide-ranging social impacts, synthetic biology also raises questions about democratic deliberation and public education. In 2010, the President’s Commission for the Study of Bioethical Issues proposed five principles to guide future research in synthetic biology. These were (1) public beneficence, (2) responsible stewardship, (3) intellectual freedom and responsibility, (4) democratic deliberation, and (5) justice and fairness. An article summarizing these principles is included in the readings for this module and can also be found here:

<http://www.upenn.edu/president/images/president/pdfs/Gutmann-Hastings-Essay2011.pdf>

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