Synthetic biology and biosecurity: an agenda for social science research

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The dominant narrative permeating scientific and policy discussions on the security threat posed by synthetic biology can be summarized as follows:

- Synthetic biology is making it easier for non-experts to manipulate dangerous pathogens and, therefore, making it easier for terrorists to concoct bioweapons.
- Synthetic biology has led to the growth of a do-it-yourself biology community that could offer dual-use knowledge and equipment to bioterrorists seeking to do harm.
- DNA synthesis has become cheaper and can be out-sourced, making it easier for terrorists to obtain the basic materials to create biological threat agents.
- Non-experts could use synthetic biology to design radically new pathogens.
- Terrorists want to pursue biological weapons for high-consequence, mass-casualty attacks.

This narrative rests on misleading and stubbornly enduring assumptions about both synthetic biology and bioterrorism; yet these five 'myths' are challenged by social science research into the realities of scientific research currently being conducted in both professional and do-it-yourself laboratories, and by an analysis of historical cases of bioterrorism (see Jefferson et al 2014; Marris et al 2014). Here, we focus on the first three 'myths' and suggest that social science research has significant contributions to make in countering these simplistic assumptions.

1. Synthetic biology is not easy. The assumption that synthetic biology makes it easy for *anybody* to "engineer biology" is not true. The underlying vision holds that well-characterized biological parts can be easily obtained from open-source online registries and then assembled, by people with no specialist training working outside professional scientific institutions, into genetic circuits, devices and systems that will reliably perform desired functions in live organisms. This vision, however, does not even reflect current realities in academic or commercial science laboratories, let alone the situation facing people with no specialist training who work outside professional scientific institutions. Academic and commercial researchers are still struggling with every stage of the standardization and mechanization process. Moreover, even if the engineering approaches proposed by synthetic biology are successful in making processes more systematic and more reproducible, skills will not become irrelevant, and not all aspects of the work become easier. Certainly, advances in synthetic biology do not make it easier for *anybody* to engineer living organisms, including dangerous ones.

2. Do-it-yourself biology is not particularly sophisticated. Developments in synthetic biology are seen to be closely associated with the growth of the do-it-yourself bio-community, and some observers have expressed concerns that do-it-yourself biologists could offer knowledge, tools, and equipment to bioterrorists seeking to do harm. But the link between synthetic biology and DIYbio, and the level of sophistication of the experiments typically being performed, is grossly overstated. Do-it-yourself biologists typically comprise a wide range of participants of varying levels of expertise, ranging from complete novices with no prior background in biology to trained scientists who conduct experiments in their own time. Studies of scientific practice in community labs demonstrate the challenges that amateur biologists face while trying to successfully conduct even rudimentary biological experiments. In particular, these amateurs lack access to the shared knowledge available to institutional researchers, highlighting the importance of local, specialized knowledge and enculturation in laboratory practices (see Revill & Jefferson, 2014).

3. Building a dangerous virus from scratch is difficult. DNA synthesis is one of the key enabling technologies of synthetic biology. There are now a number of commercial companies that provide DNA synthesis services, so the process can be out-sourced. The price charged by these companies has greatly reduced over the last 20 years and is now around 3 cents a base pair, which puts the cost within reach of a broad range of actors. This has led to routine statements suggesting that it is now cheap and easy to obtain a synthesized version of any desired DNA sequence. However, even specialized DNA synthesis companies cannot easily synthesize, *de novo*, any desired DNA sequence. Several commercial companies provide routine gene synthesis services for sequences of less than 3,000 base pairs, but length is a crucial factor, the process is error prone, and some sequences are resistant to chemical synthesis. A number of synthesized DNA fragments would have to be assembled to produce a full genome, which means that, even if doing so were not already regulated by voluntary guidelines, simply ordering the full-length genome sequence of a small virus online is not possible. Ordering short DNA sequences and assembling them into a genome requires specialist expertise, experience, and equipment available in professional laboratories but not easily accessible to amateurs. For longer sequences, assembly of DNA fragments becomes the crucial step. This was the major technological feat in the work conducted at the J. Craig Venter Institute that produced a "synthetic" bacterial genome, and the Gibson assembly method developed for that project is now widely used. Gibson et al's own account of that work, however, demonstrates how the assembly of smaller fragments into larger ones and eventually into a functioning genome requires substantial levels of expertise and resources, including those needed to conduct trouble-shooting experiments to identify and correct errors when assembled DNA constructs do not perform as expected. Indeed, constructing a genome-size DNA fragment is not the same as creating a functional genome, and ensuring the desired expression of viral proteins is a well-documented, complex challenge.

An Agenda for Social Science Research. There is an important role for social science research in countering oversimplified understandings of synthetic biology practices and providing more balanced assessments of the security implications. In particular, through in-depth ethnographic work, social science research can play a crucial role in highlighting the importance of the social context of science and technology and characterising the significance of intangible dimensions of research, such as tacit knowledge and community practices. Our analysis of current debates on the potential for the so-called "dual-use" of synthetic biology demonstrates that is crucial for social scientists to question the sociotechnical promises constructed by synthetic biologists. Taking them for granted leads to unhelpful "speculative ethics", which is evident in much of the current discussions about the "societal issues" related to synthetic biology.

References

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