We're doomed

Article (Published Version)

James Revill[1], a research fellow with the Harvard Sussex Programme, Science and Technology Policy Research Unit at the University of Sussex makes a big claim

"We're Doomed!"

Extensive reading around the advances in life sciences makes it easy to envision a gloomy future in which the hostile exploitation of cutting-edge biotechnology leads to the destruction of human kind. Yet there is a need for caution in reading too much into the hostile potential of clustered regularly interspaced short palindromic repeats (Crispr) and other shiny new technologies, not least because of the continued complexity and unpredictability of biological systems. Nonetheless, the rapid development of biotechnology warrants sustained attention from those looking to prohibit and prevent biological warfare and ensure that the development of technologies of relevance to biological weapons do not leave the biological disarmament regime obsolete.

Changing science and technology

It has frequently been argued that advances in science and technology will make significant acts of biological weaponeering ever easier and quicker to realise, with developments in fields such as bioinformatics, systems biology, neurobiology, nanotechnology and drug delivery, feeding into ever greater possibilities for the hostile exploitation of biology. Of particular note over the course of the last decade has been synthetic biology, a field which seeks to design and build new biological parts and systems or to modify existing ones to carry out novel tasks".[2] While lauded as a solution to many societal problems, one assessment of the risk of synthetic biology was outlined in 2011. A background paper on science and technology submitted to the Biological and Toxin Weapons Convention by China, noted:

"With the spread of synthetic biology, some small scale research groups and even some individuals are now able to make the deadly Ebola and smallpox viruses and even some viruses against which all drugs are ineffective, thus making it much harder to counter bioterrorism."[3]

If orange is indeed the new black, gene editing technology such as Crispr, is this season's synthetic biology, a source of both promise and peril that has become emblematic of the dangers of dual use biotechnology. In February

BRAINS! Thankfully the chances of CRISPR causing the zombie apocalypse are few and far between ©DoD

2016, James R Clapper, the director of national intelligence, identified gene editing technologies as being of particular concern, stating that:“Given the broad distribution, low cost, and accelerated pace of development of this dual-use technology, its deliberate or unintentional misuse might lead to far-reaching economic and national security implications.”[4] A blunter assessment of Crispr is evident in Gerstien’s provocatively titled paper, Can the Bioweapons Convention Survive Crispr?, which suggested that Crispr was widely available, allowing even largely untrained people to manipulate the very essence of life. Crispr-based kits go for less than $500 in some cases, with pathogen-specific kits, for instance West Nile virus…, offered up like so many choices at a grocery store.[5]

There are reasonable grounds for concern over Crispr. The technology offers a relatively flexible, simple, effective tool to enable the introduction of changes to DNA within cells[6] and empowers scientists with the capacity not only to read through gene sequencing and write through gene synthesis, but now theoretically ‘edit the text’ inside cells.[7]

To date Crispr Cas9 appears to have generated the most attention; however, other types and variants of Crispr, such as Cpf1 and C2c2, are being explored and these may offer distinct advantages in the future as research shifts from understanding to application in a potentially wide range of peaceful fields.[8] Although, thus far Crispr only appears to have been applied for peaceful purposes, the attention gene editing technology has received suggests it would be remarkable if the technology were not explored further in the advent of sophisticated future biological weapons programmes seeking to exploit the latest scientific advances for hostile purposes.

Don’t panic

Despite the potential of Crispr for peaceful, as well as harmful, purposes, the notion of gene editing is a rather misleading metaphor conveying as it does unrealistic expectations of human control.[9] Such technological breakthroughs are frequently accompanied by a series of promises that are amplified through media attention in the early stages of what Gartner labelled the hype cycle.

Beginning with a technology trigger following early proof-of-concept stories and media interest, over time technology follows through the hype cycle reach to what Gartner label a peak of inflated expectations before sliding down into a trough of disillusionment in which interest wanes as experiments and implementations fail to deliver[10]. Although technologies frequently recover to ascend the slope of enlightenment, generating societal value in the process, interest and investment is often more cautious.

This notion of a hype cycle is an imperfect tool for predicting peaceful technology adoption, but nonetheless has a value in separating hype from the real drivers of a technology's commercial promise and informing investment decisions. It also encourages a reality check in relation to dual use technologies and a counter to some of the more doom-ladened prophecies about developments in biotechnology. Indeed, for all the progress in the life sciences, significant gaps remain in understanding and reliably predicting the effects of gene editing; let alone weaponising such genes, something which requires a series of additional steps – and additional skills and knowledge - to get close to a feasible weapon. As the SPIEZ Convergence report from 2016 stated regarding gene engineering ...is this easy to do? The answer is no. It requires more than understanding and using Crispr, and depends on a range of further knowledge, skills and capacities relating to the host and its biology.[11]

Changing the life science landscape

One of the counters to this argument is perceived changes in the landscape of life science research; specifically, the so called democratisation of biotechnology, a step which Gerstein suggests may already have brought biological attacks within the reach of terror groups like al Qaeda and ISIS…[12]

Again, there are reasonable grounds for concern about the changing human geography of the life sciences. Certainly, there has been an expansion of ‘DIY-bio’ groups from one in 2008, to around 40 local DIY-bio groups, with the majority in the US and Europe in 2013;[13] to 95 DIY-bio registered groups around the world in early 2017, the majority of which are located in North America and Europe[14]. The groups registered on DIYbio.org, vary considerably, from established physical laboratories, such as the London Biohackspace, to web pages for online groups, and have led to a rash of reports alluding to the possibility of basement bioterrorism.

Similarly, the International Genetically Engineered Machine (iGEM) Foundation’s competition has generated much attention, demonstrating as it does the extent to which undergraduate - and high school – students are able to manipulate biology. As with DIY-bio, the number of iGEM participants has grown considerably: from five teams and 31 participants in US universities in 2004; to 300 teams and 4,432 participants from across the globe in 2016[15]. Moreover, the achievements of iGEM teams are remarkable: from developing a framework for engineering co-cultures[16] to arming bacteria with targeted and specific toxin production against mites.[17]

Still, don’t panic!

What is often missing from accounts of the iGEM teams’ achievements are the difficulties and dogged determination of the students in repeating assembly procedures and experiments that failed and persisting with efforts to solve problems. Also understated is the extent to which topics such as biosafety, biosecurity and risk management are addressed in iGEM challenges, in part through the inclusion of iGEM biosafety committees.

DIY-bio groups are perhaps more of a concern, not least because of the possibility of co-locating life science expertise with other engineering skills outside the traditional laboratory setting. However, as a report on the seven myths

& realities about do-it-yourself biology has indicated, most DIY-ers are still learning basic biotechnology and most groups are limited to biosafety level 1 (BSL-1) organisms with few exceptions[18]. The authors interaction with one UK DIY-bio facility further suggest that, rather than an aversion to government oversight and safety/security procedures, some DIY bio groups at least have undertaken measures designed to ensure safety and security. These include the appointment of an experienced biosafety officer, laboratory rules, access controls, safety training, standard operating procedures, risk assessment processes and codes of conduct.

It is unlikely that all DIY-bio groups and amateur biologists are subjected to such rigour. Neither is it likely that biologists operating outside the traditional laboratory setting would easily be able to misuse Crispr-based kits purchased from grocery stores for the purpose of mass casualty terrorism. Biological WMD may be seductive to those seeking to cause harm, but in reality, achieving biological weapons with gigantic effect would present a considerable challenge for non-state actors. This, of course, does not prevent terrorists or criminals from pursuing 'scruffy' improvised biological weapons, but the costs of pursuing such weapons – including the opportunity costs of not pursuing other more credible routes – are likely to be significant in the calculus of whether such weapons should be pursued.

Biological disarmament

Developments in science and technology (S&T) nonetheless have major implications for how biological weapons are perceived. Over the course of the last century growing understanding of aerobiology and contagion engendered the theoretical possibility of strategic biological weapons, delivered not only through food and water contamination, but also through the air. As such, the fact a technology has been hyped doesn't mean it should be ignored by those endeavouring to prevent the re-emergence of biological warfare, including practitioners of biological disarmament diplomacy working on the Biological Weapons Convention (BWC).

S&T is particularly important for this convention, with potential technological developments generating positive and negative implications for various aspects of this international agreement. Most obviously, changes in S&T can present challenges to the scope of the regime, potentially fragmenting international understandings as to what is prohibited and what is permitted. This is clearly important, but it is not the only area where S&T can have an impact.

The digitisation of biotechnology and growing challenge of intangible biological information presents a major challenge to export control measures; a changing landscape of life science research has implications for national measures designed to prohibit and prevent biological weapons. Advances in detecting, reporting and mitigating outbreaks of disease clearly have implications for the provision of assistance in the event of a violation of the convention; and changes in communications technology and collaborative practices have a bearing on international cooperation. For what it is worth, changes in S&T will also have had a profound effect on efforts to evaluate compliance with the convention, although this remains a fractious topic that is unlikely to be on the agenda in the near future.

Given the significance of S&T to this international agreement, it is unsurprising that there was widespread support around the principle of enhancing the process of reviewing science and technology under the BWC in the run-up to the review conference in late 2016. However, as Littlewood pointed out in the previous edition of *CBRNe World*, the conference resulted in a disappointing outcome, in which proposals for enhanced S&T reviews in future work between review conferences failed to come to fruition. Perhaps more than any other issue, this omission of S&T from the agenda of multilateral biological disarmament diplomacy raises the possibility of the Biological and Toxin Weapons Convention becoming detached from real world events[19]. The next meeting of states parties in December 2017 offers an opportunity to rectify this omission and restore S&T to the agenda. It is hoped states will seize this chance and should they do so, it will be important not to follow the hype and fixate on the negative potential of any one single technology to cause harm; but collectively remain alert to technical - and sociotechnical – changes of relevance to the convention, and respond accordingly.

1 The views expressed in this article are James Revill's own.
2 Secretary general of the OECD (2010). Synthesis report, Symposium on Opportunities and Challenges in the Emerging Field of Synthetic Biology, OECD & the Royal Society.
3 China. (2011) National science and technology paper submitted to the Biological and Toxin Weapons Convention, BWC/ CONF.VII/INF.3/Add.1. Geneva: UN.
4 Clapper, James. Worldwide threat assessment of the US intelligence community. 2016.
5 Gerstein, Daniel M. Can the Bioweapons Convention survive Crispr? Bulletin of the Atomic Scientists, no. July (2016).
6 Swiss Federal Office for Civil Protection. Spiez CONVERGENCE report on the second workshop, 2016. https://www.labor-spiez.ch/pdf/en/Report_on_the_second_workshop-5-9_September_2016.pdf.
7 Personal notes from SPIEZ convergence 2016.
8 Personal notes from SPIEZ convergence 2016.
9 Maben AJ. The Crispr fantasy: flaws in current metaphors of gene modifying technology (2016) 8 Inquiries Journal
10 http://www.gartner.com/technology/research/methodologies/hype-cycle.jsp#
11 Swiss Federal Office for Civil Protection. Spiez CONVERGENCE report on the second workshop, 2016. https://www.labor-spiez.ch/pdf/en/Report_on_the_second_workshop-5-9_September_2016.pdf.
12 Gerstein, Daniel M. Can the Bioweapons Convention survive Crispr? Bulletin of the Atomic Scientists, no. July (2016).
13 Jefferson. C. The growth Of amateur biology: a dual use governance challenge? Biochemical Security 2030 Project, Policy Paper 3, November 2013.
14 DIY Bio https://diybio.org/local/
15 See the iGEM Foundation website, http://igem.org/Main_Page
16 See for example http://2016.igem.org/Team:Imperial_College
17 iGEM 2016 Results http://2016.igem.org/Results
18 Grushkin D, Kuiken T and Millet P. Seven myths & realities about do-it-yourself biology (2013)
19 Littlewood. J (2016). Failing diplomacy on biological weapons, should we be worried?, *CBRNe World*.