# THE GROWTH OF AMATEUR BIOLOGY: A DUAL USE GOVERNANCE CHALLENGE?

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## EXECUTIVE SUMMARY

Concerns that legitimate life science research might be misapplied to develop biological weapons have led to a convergence of science and security policy, with increasing focus on dual use governance measures and policies aimed at educating and engaging scientists in relation to biosecurity threats (McLeish & Nightingale, 2007). Many of these dual use governance approaches are aimed at traditional institutions of science, such as university education, training, funding, publishing and peer review (Revill & Jefferson, 2013). However, in light of developments in 'synthetic biology', an emerging area of biological research that combines science and engineering, concerns have been expressed over the potential 'de-skilling' of biology and the growth of an amateur biology community (Edwards & Kelle, 2012; Schmidt, 2008; Tucker, 2011). How, then, might dual use governance measures be extended to amateur biologists who typically operate outside of traditional institutional structures? Drawing on the dual use governance framework, this paper examines the growth of the amateur biology community and its relationship to wider biosecurity policy concerns. The paper suggests that perceptions of the biosecurity threat presented by amateur biology overlook the extent to which a culture of responsibility has been fostered within the community and suggests that, far from being outsiders, many amateur biology groups are becoming increasingly professionalised. Moreover, drawing on scholarship on the role of tacit knowledge in scientific research and the experiences of DIYbio groups in the UK, this paper argues that threat perceptions overstate the link between synthetic biology and amateur biology and the extent to which biology has become de-skilled and more widely accessible to amateurs.

The paper also makes a series of recommendations in relation to this issue area:

**1. Academics and other interested stakeholders should support the self-regulatory efforts of the amateur biology community by partnering with local community laboratories and sharing resources on biosafety, biosecurity and laboratory best practice.**

**2. Outreach to the amateur biology community should be promoted at an international level, led by the ISU, interested State Parties to the BWC or another international forum, in order to facilitate engagement between the amateur biology community and relevant national regulatory and enforcement authorities.**

**3. Further studies should be conducted to examine the activities and types of experiments being performed by members of the amateur biology community, and to explore the relationship between amateur biology and synthetic biology.**

**4. In the context of BWC science and technology reviews, deeper analysis should be encouraged, through initiatives led by academics and NGOs, of supposed trends towards increased access, which take into account the role of tacit knowledge. Assessment of the amateur biology community could provide an illuminating case study in this regard.**

# 1. INTRODUCTION

Concerns that legitimate life science research might be misapplied to develop biological weapons have led to a convergence of science and security policy, with increasing focus on dual use governance measures and policies aimed at educating and engaging scientists (McLeish & Nightingale, 2007). The dual use threat is acknowledged in the 1972 Biological Weapons Convention (BWC), an international arms control treaty that prohibits the development and use of biological weapons. Until recently, States Parties to the BWC undertook a review of '*new scientific and technological developments relevant to the Convention*' (BWC Article XII) as part of the five-yearly review of the treaty, but following repeated calls for a more robust process, developments in science and technology are now discussed annually at the Meeting of Experts and Meeting of State Parties (RC7 Final Document, 2011). A common theme to emerge from these reviews is that research and innovation capabilities are proliferating. This proliferation is dependent on the development and commercialisation of foundational technologies such as high-throughput gene synthesisers and sequencers, the emergence of innovative approaches to conceptualising and engineering biological systems and processes, as well as developments in the way information is shared and exchanged through digital tools and online communities (see for example, ISU, 2011).

These trends potentially facilitate de-skilling dynamics within biotechnology innovation, and increase the range of contexts in which research and innovation could take place. Such developments potentially undermine the comprehensiveness of existent and proposed models of dual use governance which are aimed at traditional scientific institutions. This includes, for example, dual use education for life scientists, ethics review as part of funding requirements, as well as dual use review as part of the peer review process within life science journals.

Emerging communities of amateur biologists, who conduct biological experimentation as a hobby rather than a profession, have become a focal point for these concerns (Edwards & Kelle, 2012; NSABB, 2011; Schmidt, 2008; Tucker, 2011). Such concerns have tended to be framed in terms of the extent to which the existence of dual use governance mechanisms might be extended to these communities, who are typically understood to operate outside of traditional structures.

This paper examines the amateur biology community and its relationship to wider biosecurity policy concerns. It is argued within this paper that, despite the '*amateur*' label, this community is becoming increasingly professionalised and is receptive to the type of soft law intervention points which characterises precautionary self-governance. Moreover, drawing on scholarship on the role of tacit knowledge in scientific research, this paper argues that certain framings of the threat posed by these communities overstate the link between synthetic biology and amateur biology as well as the extent to which biology has become easier, de-skilled and more widely accessible. It is argued within this paper that further analysis is required to assess the extent to which life science research is becoming easier and more accessible to amateurs, and suggests that outreach and engagement with the community plays an important role in encouraging dual use awareness and promoting responsibility.

# 2. WHAT IS AMATEUR BIOLOGY?

Amateur biologists are often discussed as if they were a homogeneous group, but in fact comprise of 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 do-it-yourself experiments in their own time. The key and unifying interest is in experimentation, which is in contrast to the long tradition of observational amateurism associated with natural history (such as bird watching). Amateur biologists typically assemble into community groups, both physically and electronically, to share their interest in biology. The largest such group is DIYbio, '*an organization dedicated to making biology an accessible pursuit for citizen scientists, amateur biologists and biological engineers who value openness and safety*' (DIYbio.org).

DIYbio has over 2000 members globally, although the actual number of members regularly conducting biological experimentation is much smaller. Some amateur biologists work in home laboratories assembled from everyday household tools and second-hand laboratory equipment purchased on the internet. However, the majority of amateur biologists conduct their experiments in community labs or hackerspaces (Grushkin, 2013). The origins of the amateur biology community can be located in the San Francisco programmer and maker communities (Tocchetti, 2012) and the Bay Area remains a vibrant hub for community lab activity. There are currently around 40 local DIYbio groups, with the majority in the USA and Europe, who organise meetings and community activities.

The amateur biology community is typically financed through membership fees for community labs and the hosting of workshops to the general public; however, grant funding, '*crowdfunding*' (Box.1) and commercialisation of products also offer possible finance routes. For example, the DIYbio Manchester group based at the Manchester Digital Laboratory (MadLab) collaborated with researchers from Manchester Metropolitan University (MMU) in a bid to fund a citizen science project. They were successful in obtaining a £29,705 grant from the Wellcome Trust Engaging Science Scheme for a twelve-month project aimed at building an innovative citizen science community and enabling wider participation in biological research.

**Box. 1 Crowdfunding**

Crowdfunding or crowd-sourced fundraising is an initiative, usually orchestrated via the internet, in which a network of individuals collectively pool their money to support a specific project or activity initiated by other people or organisations. Crowdfunding can be sought to support a wide range of initiatives, from disaster relief and political campaigns to software development and scientific research.

Members of BioCurious, a community lab in Silicon Valley, sought crowd-sourced funding through Kickstarter, an online fundraising platform for creative projects, to engineer a bioluminescent plant. By the time the Kickstarter effort ended, the project team had successfully received a pledge of nearly $500,000 US from over 8,000 backers. Given its success on Kickstarter, the glowing plants project raises questions about non-traditional funding structures that may not be subject to the same types of oversight and review as traditional forms of science funding.

## 3. THE DE-SKILLING DYNAMIC

The amateur biology community has raised a number of biosecurity concerns, predicated on the assumption that potentially dual use biological research is becoming increasingly accessible to non-experts. For example, advances in synthetic biology, particularly in the goal of developing standardised genetic parts, are seen to be making biology easier to access for the non-specialist. Indeed, a number of leading synthetic biologists have pursued a deliberate de-skilling agenda through, for example, the formation of the annual International Genetically Engineered Machine (iGEM) competition aimed at undergraduate students, and through the dissemination of synthetic biology kits and how-to protocols (Kelle, 2012). This raises concerns that potentially dual use biological research is becoming increasingly accessible and could be performed outside of traditional research environments by non-professionals. For example, discussing the creation of novel strains of H5N1 influenza virus, a member of the US National Science Advisory Board for Biosecurity (NSABB) was recently quoted as saying:

> "*I worry about the garage scientist, about the do-your-own scientist, about the person who just wants to try and see if they can do it.*" (Zimmer, 2012)

However, the experiences of the amateur biology community suggests that the types of projects being conducted tend to be far less sophisticated than experiments involving genetic design and, rather, demonstrate the considerable challenges involved in successfully performing even basic biological experimentation. For example, the types of community projects that have been conducted at the London BioHackspace, a DIYbio group on London, have included the optimisation of techniques for DNA extraction and polymerase chain reaction (PCR) process, sex typing with *amelogenin* and plant species testing. Moreover, the development of techniques necessary to perform even basic biological experimentation often requires guided instruction and practice, something that is built up over the course of a biologist's academic career and not always readily accessible to an amateur. For example, even something as routine as using a pipette can present challenges for a non-specialist. Discussing the '*art*' of pipetting, one amateur biologist at MadLab states:

> "*The hardest part of the process was getting our samples into the gel using a micropipette. It turns out there is a bit of an art to pipetting... The more experienced pipettors claimed that it took them weeks to get the proper technique*" (http://madlab.org.uk).

Similarly, members of London BioHackspace have noted the challenge of overcoming pipetting errors when trying to optimise techniques for DNA extraction and PCR process (http://wiki.london.hackspace.org.uk). Even the use of equipment for PCR requires a certain level of learning-by-doing, and reading a manual alone is not always sufficient:

> "*After spending some time with the manual I think I have it figured out,* ***but it's definitely something that's going to need training and/or practice to learn to use.****.. The interface [of the thermal cycler] is quite logical and comprehensible when you're used to it, but it's bafflingly opaque to first-time users*" (http://wiki.london.hackspace.org.uk) [emphasis added].

The importance of gradually developing these fundamental skills over the course of a biologist's academic career was noted by the 2012 University College London iGEM team who collaborated

with members of London BioHackspace to develop a public biobrick (a standardised, interchangeable biological device):

> "*Academics build their knowledge step by step, but a biohacker may not have that structure of knowledge – they have gaps here and there, so their knowledge isn't so well organised.... I think the Biohackers gained a lot of experience* [from the collaboration] *in terms of structure because within science, the steps to achieving a specific goal can sometimes be very hazy.*" (http://2012.igem.org/Team:University_College_London)

This highlights the importance of tacit knowledge in scientific practice. Broadly, tacit knowledge refers to knowledge that cannot be fully codified and easily transferred, but rather is acquired through learning by doing or learning by example (Polanyi, 1974). Indeed, public accounts of science tend to differ considerably from informal accounts of how science actually takes place, and often conceal the importance of social elements such as tacit knowledge (Vogel, 2012). The role of this form of tacit knowledge has typically been undervalued in assessments of the biosecurity threat posed by advances in science and technology that purport to de-skill (Vogel, 2012; Revill & Jefferson, forthcoming), but as the experiences of the amateur biology community suggest, the role of tacit knowledge warrants further attention.

This is not to say that developments in science and technology do not pose any dual use threat, but rather that social elements should also be taken into account in order to avoid distorted threat perceptions. Furthermore, this is not to suggest that amateur biologists lack capacities and capabilities for more sophisticated experimentation. Some DIYbio groups are beginning to conduct significantly more sophisticated experimentation that draws on advances in synthetic biology, such as the members of BioCurious involved in engineering a bioluminescent plant (Box 1). However, in examples such as the Glowing Plant project, the DIY biologists involved are professionally trained scientists working on their own enterprise; the extent to which true novices are or could be involved is therefore questionable.[1] Rather, the experiences of many amateur biologists serve to illustrate the considerable obstacles involved in mastering the necessary techniques and skills to perform basic biological experiments.

## 4. CHALLENGES FOR DUAL USE GOVERNANCE?

Another concern associated with the amateur biology community is that by operating outside of traditional scientific structures, this community will not be exposed to existing dual use governance mechanisms. First, measures designed to raise awareness of dual use issues among scientists (see, for example, Dando, 2011) will not reach those amateurs who lack a formal biology education. Moreover, without formal training, amateurs will not receive indoctrination in biosafety and good laboratory practice. Indeed, this concern was expressed by a member of the London BioHackspace, who noted that, "*one concern is that people with "techy" backgrounds might forget they are dealing with biology,*" (interview with member of London BioHackspace, 2012).

Secondly, in traditional structures of science, team leaders are legally responsible for ensuring compliance of those they supervise. However, while amateur biologists are subject to the same risk regulations as professional scientists, amateur biology projects are not necessarily held to account

[1] While community projects at BioCurious are open to anyone, participation in projects that involve considerably more wetlab work is only open to members who have taken the lab's biosafety training.

by a defined hierarchy of project leadership, which removes an important layer of oversight and makes compliance difficult to monitor.

Finally, as noted above, the emergence of non-traditional funding mechanisms such as Kickstarter and other crowd-sourced funding also raises questions about oversight and review. Currently, three major funding agencies for bioscience research in the UK require applicants to consider the risks of misuse associated with their proposal (BBSRC, MRC & Wellcome Trust, 2005). Alternative funding routes may not be subject to the same standards of ethical, safety and dual use review.

However, many of these concerns overlook the extent to which members of the amateur biology community are aware of and willing to engage on safety and security issues. As noted above, participants in amateur biology are subject to the same risk regulatory frameworks as professional scientists and, while compliance may be more difficult to monitor, most members of community labs are keen to ensure that they are operating within their legal requirements. For example, the London BioHackspace is aware of UK and EU regulations on the contained use of genetically modified organisms and has pledged not to perform such work unless their facility obtains regulatory approval to do so. Similarly the group at MadLab are seeking a license for a new biosafety level one lab space in which to conduct transgenic work. Indeed, far from being outsiders, the trend towards a licensed community lab model suggests that the amateur biology movement is becoming increasingly professionalised. This is particularly notable in community biolabs in the USA. For example, Genspace, a community biolab in New York City, meets the National Institutes of Health Biosafety Level One requirements, has its own external Safety Advisory Board and provides safety and equipment training for all its members.

Furthermore, significant efforts have been made to foster a culture of responsibility within the community. DIYbio, in partnership with the Synthetic Biology Project at the Woodrow Wilson Center, has developed a Draft Code of Ethics for amateur biologists. Regional groups from Europe, including participants from England, France, Germany, Denmark and Ireland, convened in May 2011 at the London School of Economics BIOS Centre to draft a Code of Ethics. In July 2011, a second meeting was held in San Francisco, with participants from regional DIYbio groups across North America. Despite the diversity of participants, both groups developed a similar set of themes, with a focus on transparency, safety and peaceful purposes.

As well as being an important step towards promoting best practice among community members, part of the motivation for the code also appears to have been a concerted attempt to demonstrate the community's willingness to engage on safety and security issues, particularly following alarmist newspaper headlines such as "*Amateurs are new fear in creating mutant virus*" (Zimmer, 2012). As one amateur biologist noted: "*The code, to many biohackers, was more of a defensive thing, in response to a perceived view that biohacking was dangerous.*" (Interview with member of London Biohacking group, 2012).

In January 2013, DIYbio also launched an '*Ask a Biosafety Officer*' web portal in which anyone with a question can submit their query to a panel of volunteer biosafety experts. The recently formed DIYBio Europe has also established a set of Community Biolab Guidelines, with an emphasis on communication, openness, lab organisation and user and environmental safety. These initiatives are important in promoting safety and responsibility and perhaps demonstrate a greater willingness among the amateur biology community to engage on these issues than has typically been found in the professional science community (Revill & Jefferson, 2013).

Yet, despite considerable efforts at promoting responsibility, questions remain over the sufficiency of self-governance. The Glowing Plant project (Box 1) has sparked particular controversy since backers pledging more than $40 US through Kickstarter have been promised their own pack of glowing plant seeds, which would effectively entail the deliberate release of a genetically modified organism (*Arabidopsis*). As well as prompting a backlash from environmental campaign groups, some members of the DIYbio community also feel that this project is bringing unwanted attention and could jeopardise the legitimacy of the community's self-governance approach (Ghorayshi, 2013). In response to public concerns, Kickstarter has already introduced a new rule within its guidelines banning initiatives that provide genetically modified organisms as prizes to its investors, suggesting that the risk of public and regulatory 'backlash' is taken seriously.[2]

## 5. PROMOTING OUTREACH

If self-governance is not adequate, restricting DIYbio activity is not necessarily an appropriate response. It has been suggested that attempts to limit the freedom of amateur biologists could drive what is currently an open and engaged community into an "*underground activity*" (UNICRI, 2011). Rather, an outreach approach should be encouraged to maintain engagement with biosafety and biosecurity issues and to provide an informal means of oversight.

The US Federal Bureau of Investigation (FBI) weapons of mass destruction outreach program have launched a series of efforts to promote outreach and oversight of the amateur biology community. The first outreach effort was initiated in August 2009 during an FBI sponsored conference on synthetic biology. Jason Bobe, co-founder of DIYbio, was invited to give a presentation at the conference and leaders in the field of DIYbio were invited to participate alongside FBI officials, academics and industry representatives. The FBI's interest in DIYbio initially raised suspicions for amateur biologists, particularly given the arrest of bioartist Steve Kurtz in May 2004.[3] However, the event was successful in building dialogue and formed the foundation for future outreach activity.

In July 2010, the first FBI-DIYbio workshop was hosted in Washington, DC. The dialogue focused on safety and security issues and the importance of instilling a form of self-policing in the amateur biology community. In June 2012 the FBI-DIYbio workshop was held in San Francisco and invitation was extended to amateur biology groups outside the US. Participants from around twenty groups internationally were invited to attend the event, which was fully sponsored by the FBI. The three-day event covered a range of issues in safety and security and participants were given a take-home pack containing resources on biosafety and biosecurity.

Outreach plays an important role in helping to empower the amateur biology community to develop and maintain community-based best practice in biosafety and biosecurity, and also to encourage vigilance and raise awareness of what they should do if they suspect inappropriate activity. Yet, notwithstanding the efforts of the FBI, and the active participation of the BWC's Implementation Support Unit (ISU) in these activities, there is currently no international process or forum to support

[2] Kickstarter added a clause in their guidelines that, 'projects cannot offer genetically modified organisms as a reward', (revised 31 July 2013), http://www.kickstarter.com/help/guidelines, accessed 10 Sep. 2013.

[3] Kurtz had been working on an art installation about genetically modified agriculture and his home contained a range of laboratory equipment, including Petri dishes and non-pathogenic bacteria. In May 2011, Kurtz's wife collapsed from heart failure. Paramedics and the police responded to his 911 call and were alarmed by the material they found at his home and contacted the FBI. The FBI detained Kurtz for 22 hours on suspicion of bioterrorism, although no charges for bioterrorism were ultimately brought against him.

outreach to the amateur biology community, nor a mechanism to ensure dialogue with relevant national authorities.

## 6. AMATEUR BIOLOGY AND THE BWC

In order to address this gap, the ISU has submitted a proposal to the G8 Global Partnership Biosecurity Sub-Working Group to support, among other initiatives, an annual international meeting of amateur science groups active in biology. The project aims to encourage transparency in order to provide confidence that they are not undertaking security-relevant activities, and to ensure that amateur biology groups are able to communicate with the relevant national regulatory and enforcement authorities if they do have concerns.[4] Activities such as this are crucial in facilitating outreach and building responsibility in the amateur biology community.

Furthermore, engagement with the community also provides an opportunity to assess the types of projects being conducted and examine the extent to which biology really is becoming de-skilled. Indeed, analysis of the role of tacit knowledge is frequently absent in assessments of science and technology advances in the context of the BWC, particularly in claims made about trends towards increasing ease and access. For example, the Chinese National Science and Technology Review Paper submitted to the Seventh Review Conference of the Biological Weapons Convention stated:

> "*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.*" (China, 2011).

This statement illustrates a common framing of the dual use threat, in which assumptions are made about the speed of change and the ease of transfer and diffusion of science and technology. While amateur biology is not explicitly mentioned, the Swiss Opening Statement at the recent BWC Meeting of Experts also notes the link between revolutionary advances, ease of application and the potential for increased proliferation risks:

> "*We are witnessing rapid and revolutionary advances in the biological sciences and associated technologies... Many developments in the life sciences result, as a rule, in faster, cheaper, and easier applications of biological science and technology. More people in an ever larger number of locations take hold of these developments, which offer unprecedented opportunities, but may also increase proliferation risks and complicate biosafety and biosecurity efforts.*" (Switzerland, 2013).

The political significance of these opening statements should be emphasised, as Guthrie (2013) notes, "*making a statement in the name of a government requires that government to agree to a text – meaning that BWC issues get on the agenda of senior figures in that government as they approve the statement.*" Yet evident in these statements is a particular framing of science and technology that conflates advances in sophisticated techniques with increased access and ease of misuse, and overlooks the important social factors that contribute to success in scientific practice.

The role of tacit knowledge is an important factor to consider in claims about deskilling and requires further attention in BWC reviews of science and technology (Revill & Jefferson,

[4] To date, there has been little uptake of the document, despite efforts of the ISU to promote it.

forthcoming). The amateur biology community provides an insightful window into the challenges of translating supposedly revolutionary advances in science and technology into actual practice at the level of the non-expert.

## 7. RECOMMENDATIONS

**Recommendation 1: Academics and other interested stakeholders should support the self-regulatory efforts of the amateur biology community by partnering with local community laboratories and sharing resources on biosafety, biosecurity and laboratory best practice.**

Amateur biology represents a shift in which biological experimentation is taken outside of traditional institutions of science and into the hands of interested individuals, hobbyists and 'citizen scientists'. This has potential implications for dual use governance measures aimed at a conception of science as a professional vocation. Intervention points that are targeted at established structures and standards in science education, training, funding, publishing and peer review could therefore fail to reach these apparent outsiders. However, as this paper suggests, such an assessment overlooks the extent to which amateur biologists are becoming professionalised through the formation of community laboratories, codes of ethics and the promotion of a culture of responsibility. The self-regulatory approach and increasing professionalization of the amateur biology community should be encouraged.

**Recommendation 2: Outreach to the amateur biology community should be promoted at an international level, led by the ISU, interested State Parties to the BWC or another international forum, in order to facilitate engagement between the amateur biology community and relevant national regulatory and enforcement authorities.**

Outreach efforts sponsored by the FBI have indicated that the amateur biology community is willing to be transparent about its activities and to engage on safety and security issues. However, there is currently no international process to support outreach to amateur biologists, nor a mechanism to ensure dialogue with the relevant national regulatory and enforcement authorities if they do have concerns.

**Recommendation 3: Further studies should be conducted to examine the activities and types of experiments being performed by members of the amateur biology community, and to explore the relationship between amateur biology and synthetic biology.**

In addition to playing an important role in encouraging dual use awareness and promoting responsibility, outreach and engagement with the community could also provide an opportunity to assess just how far supposedly revolutionary advances in science and technology are being translated into actual practice at the level of the non-expert. As this paper has explored, biosecurity concerns relating to the amateur biology community frequently overstate the link between advances in fields of science that purport to de-skill, such as synthetic biology, and the level of sophistication of the actual experiments being conducted by amateur biologists.

**Recommendation 4: In the context of BWC science and technology reviews, deeper analysis should be encouraged, through initiatives led by academics and NGOs, of supposed trends towards increased access, which take into account the role of tacit knowledge. Assessment of the amateur biology community could provide an illuminating case study in this regard.**

Rather than being indicative of a de-skilling agenda, the experiences of the amateur biology community have tended to demonstrate the considerable challenges involved in successfully performing even basic biological experimentation. This illustrates the importance of social factors, such as learning by example, in translating codified, public accounts of science into actual practice. The role of this form of tacit knowledge is frequently absent in assessments of science and technology in the context of the BWC, particularly in claims made about trends towards increasing ease and access. Further in-depth analysis is required to assess the extent to which life science research is becoming easier and more accessible to amateurs. Since the role of tacit knowledge is not readily translated into interview or survey questions, ethnographic analysis of the amateur biology community, which would involve direct observation of the actual and ongoing experiences of community lab members, would be particularly useful.

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