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Responses to "Questions for the Record" Submitted by Chairwoman Haley Stevens.

Questions:

"Biotechnology is democratizing, enabling the spread of the "garage biology" you discussed in your testimony. While this promotes innovation, it also increases the risks. You were very clear that we should err on the side of openness. However, we still must have systems and processes to manage the risks. What is the role of the US government in managing the risks of synthetic biology? How can we better incentivize venture capitalists who fund synthetic biology entrepreneurs, citizen scientists, universities, and private industry to address risks in this sector? How does your own venture capital firm take into account security risks when making your investment decisions?"

Responses:

Madame Chairwoman,

Thank you for the opportunity to comment on the critical intersection of innovation, economics, and security in regards to the future of biotechnology. Below I address each of your questions in detail. Given the critical role of biotechnology in our physical and economic security, that is, in US national security, my responses are extensive.

To begin, I would like to reiterate that synthetic biology is an approach to engineering biological systems, and that it comprises not just an expanding body of knowledge but also a growing set of tools. I suggest that in public policy conversations we should clearly differentiate between the tools themselves and the use of those tools by particular people for particular ends.

We must be concerned about security, and about risk, because those various ends might be beneficial or they might be nefarious. But a conversation putatively about risk from technologies is instead really about risk from human behavior, and about the choices humans make in using technologies. Consequently, the use of biotechnological tools by humans to cause harm is no more relevant to a specific harm than is the use of screwdrivers by humans to cause a specific harm. The comparison of biotechnology and screwdrivers is here not incidental, and I will employ it throughout my responses.

Notably, so far as I am aware, the use of screwdrivers to cause harm, either directly through use as a sharp object or indirectly through the construction of devices that kill or maim, vastly exceeds any harm caused by the human use of biotechnology. And deaths attributed to the use of screwdrivers are very clearly caused by humans who chose to behave in way that caused those deaths.

We do not typically fear new screwdrivers, nor do we speak of a proliferation of new screwdrivers as increasing any particular risk, whether they are employed in garages or elsewhere. Instead our culture usually sees new tools as providing new opportunities. It is generally assumed that one learns how to use a screwdriver at a young age, and also learns to use it responsibly. The same should be true of biotechnology. And yet public conversations about synthetic biology consistently elevate fear above opportunity. This may be because, unlike screwdrivers, we do not yet gain experience with the capabilities and limitations of biotechnology at a young age. But that time will come, and with it we should ensure that knowledge of responsible use becomes ingrained along with skill in using the tool itself.

Q: What is the role of the US government in managing the risks of synthetic biology?

The short answer to this question is that, at a minimum, the US government should continue its policy of encouraging all those who wish to learn to use biotechnology to also become familiar with safe and secure use of that technology, i.e., the government should encourage training in the responsible use of biotechnology. It is probably infeasible to *require* training in responsible use, in part because biotechnological skills can be acquired in venues beyond any plausible jurisdiction of the US government. In other words, the US government should continue the policy of engagement and normative education now implemented by the FBI and other agencies. The long answer is that, both in principle and in practice, the US government may be able to do no more than the short answer.

There are (at least) two foundational questions here in regards to biosecurity: 1) What does the Constitution allow the US government to do in principle with legislation or with rules? 2) What policies will in practice increase security?

Without delving overly into detail, the notional basis of the US government to take legislative action to control the use of biotechnology is likely to be found in its obligations as a State Party to the Biological Weapons Convention (BWC). The BWC is a non-self-executing treaty, and the US has obligations under Article IV to, "in accordance with its constitutional processes, take any necessary measures to prohibit and prevent the development, production, stockpiling, acquisition or retention of the agents, toxins, weapons, equipment and means of delivery specified in Article I of the Convention, within the territory of such State, under its jurisdiction or under its control anywhere."[1]

The BWC is similar in structure to the International Chemical Weapons Treaty, and specific legislative action to enforce the BWC may need to follow along similar lines as the International Chemical Weapons Treaty Implementation Act ("the Act"). However, there is some question about whether the Act is constitutional. Briefly, it is disputed by many that enacting legislation at the federal level to implement treaty obligations is among the powers enumerated by the Constitution, and, to the contrary, it is further asserted that the federal government cannot use international treaties to introduce, via legislation, restrictions on the actions of states or individuals[2]. According to these arguments, neither the Commerce Clause nor the Necessary and Proper Clause can be used to justify federal legislation that domestically enforces treaties. This might begin to sound like a rehash of a 10th grade civics lesson, except that these matters have recently come before the Supreme Court, and have yet to be settled. In the recent *Bond v US* decision, which in principle hinged on the constitutionality of the Act, the Court explicitly opted not to settle the constitutional matter and ruled instead on a narrower basis[3].

In the face of this uncertainty, there are two obvious alternatives to pursue. First, each of the fifty states could enact legislation aimed at implementing the BWC. Second, as was the case with Prohibition, the Constitution itself might be amended to specifically proscribe certain substances or technology and to enable federal legislation to enforce that proscription.

1 The Biological Weapons Convention: An Introduction, The United Nations, June 2017. https://www.unog.ch/80256EDD006B8954/(httpAssets)/6D16C7B1933F0937C125815D00349763/$file/BWS%20brochure.pdf
2 See, for example, Cruz, Ted, "Limits on the Treaty Power", *Harvard Law Review*, 2014. https://harvardlawreview.org/2014/01/limits-on-the-treaty-power/
3 https://www.law.cornell.edu/supct/html/09-1227.ZO.html

It is not my intention here to take a position on these matters. Rather, I merely wish to observe that what might appear as an obvious course to enacting domestic policy may, in practice, run aground on questions that have occupied us since the founding of the country. It may be that other national governments have an easier time managing such questions, in that their authority is clearer or more absolute. But then the Founders were well aware that they were not choosing the easy path.

It is worth considering the text of the BWC in a bit more depth. Article I makes explicit that the Convention is targeted at intent, specifically using language that States Parties pledge never to acquire or retain materials “of types and in quantities that have no justification for prophylactic, protective or other peaceful purposes.” All of biology is dual use, and it is only through the intent of the wielder that a molecule or an organism can be unambiguously identified as a weapon.

The architects of the BWC were both wise and clever. They recognized that biological technologies would be a force for good in the world, and also recognized that they could not predict how biological technologies would develop. The document that they created was intended to facilitate the ability of States Parties to put their feet down and stamp out biological weapons while encouraging innovation and peaceful use.

Articles I and IV are together very clear: States Parties must renounce the use of biological weapons and must also work to eradicate them as allowed and enabled by their constitutions.

In my travels through domestic and international biosecurity over the last two decades, I have found that most discussions of biological weapons end at the content of Article IV, and are primarily focussed on implementing laws and regulations to contain and control the use of biological technologies. However, the Convention itself does not end at Article IV. Rarely do biosecurity conversations encompass Article X, which 'requires States Parties to “facilitate, and have the right to participate in, the fullest possible exchange of equipment, materials and scientific and technological information” for the use of biological agents and toxins for peaceful purposes'.[4]

Article X continues:

> *Parties to the Convention in a position to do so shall also cooperate in contributing individually or together with other States or international organisations to the further development and application of scientific discoveries in the field of biology for the prevention of disease, or for other peaceful purposes.*
>
> *This Convention shall be implemented in a manner designed to avoid hampering the economic or technological development of States Parties to the Convention or international cooperation in the field of peaceful biological activities, including the international exchange of biological agents and toxins and equipment for the processing, use or production of biological agents and toxins for peaceful purposes in accordance with the provisions of the Convention.*

Article X is crafted specifically with the goal that States Parties “shall” not only endeavor to avoid hampering peaceful biological research and development, but also “shall" cooperate to further peaceful development of biological technologies. Consequently, national policies that embrace Article I at the expense, or even the exclusion, of Article X, might be viewed as counterproductive to the larger aims of

4 The United Nations, 2017.

the Convention. Neither does simple proscription in any context appear to be consistent with the aims of Article X. The tricky part of implementing obligations under the BWC is, therefore, managing the balance between nefarious and beneficial use of tools, which brings us back to the challenge of judging intent. This will always be a messy, labor intensive problem, as judging intent is always contextual, and also contingent upon inferring a state of mind. In the US, these matters are argued before, and settled by, juries who have the task of weighing all the evidence put before them. I do not presume to have suggestions for improving our system of judging intent.

Despite the uncertainty cataloged above, I do have concrete recommendations regarding security policy. And so I return to the second question I asked above: What policies will in practice increase security? To which I now add: what policies will in practice decrease security?

As I stated in my prior testimony, there is already massive economic demand for the fruits of biotechnology, and the technology itself is broadly democratized. The US government has experience with trying to control technologies in similar situations with the aim of improving security, and the results are not encouraging. The following paragraphs are adapted from a forthcoming article of mine on this subject, to appear in *Nature Biotechnology* later this year[5].

Presumably, we can agree on the simple idea that improving safety and security should be our primary goal. With that established, we can then explore how we might pursue that goal. We can start with the following testable hypothesis: Does restricting access to democratized technologies improve safety and security? There is copious data available to test this hypothesis, and the hypothesis does not fare well. Its failure, and in particular the manner in which it fails, suggests that restricting access to raw materials and markets in attempts to reduce the production, distribution, and consumption of illegal substances often creates insecurity and is thereby counterproductive.

In the case of alcohol, Prohibition in the U.S. was repealed not only because it did not prevent access to alcohol – Anheuser-Busch did a brisk business at the time selling copper kettles, yeast, and other ingredients for beer – but it also incentivized the creation of illicit production and distribution networks that were extremely violent and costly to society[6]. Quantitative data on behavior during the period is hard to come by, but anecdotally it is clear that “the law that was meant to stop Americans from drinking was instead turning many of them into experts on how to make it, and in many parts of the United States more people were drinking, and people were drinking more.”[7]

In the case of methamphetamines, the U.S. Drug Enforcement Administration’s own reporting reveals that the suppression of “mom-and-pop” production beginning in 2001 resulted in the creation of foreign manufacturing that within two years surpassed the domestic production it replaced[8],[9]. Moreover, these professionalized, international drug trafficking organizations, formed to satisfy U.S. domestic demand, are also harder to surveil and disrupt than their predecessors; increased proscription thereby created bigger, blacker markets than existed previously.

5 Robert Carlson, *Nature Biotechnology*, In preparation, 2019.
6 Knoedelseder, William. *Bitter Brew : The Rise and Fall of Anheuser-Busch and America’s Kings of Beer*. 1st ed. New York: New York : HarperBusiness, 2012.
7 Lerner, Michael, in the online material for *Prohibition*, Ken Burns and Lynn Novick, Dirs., Florentine Films, 2011. http://www.pbs.org/kenburns/prohibition/unintended-consequences/.
8 Carlson, R., *Biology is Technology: The Promise, Peril, and New Business of Engineering Life*, Harvard University Press, Cambridge, MA, 2010.
9 Carlson, R., “The Pace and Proliferation of Biological Technologies”, *Biosecurity and Bioterrorism*, 2003, 1(3).

The resulting concentration of economic resources enables investment in innovation that is specifically aimed at circumventing proscriptions, as demonstrated by experience with cocaine trafficking. Restricting access to U.S. markets has led drug cartels to build semi- and fully-submersible vessels that can carry illicit cargo worth hundreds of times the cost of the vessel itself[10],[11]. The relative value of vessel and cargo means that these smugglerines constitute disposable infrastructure, which utility is itself another techno-economic innovation incentivized by proscription, and which has security implications far beyond drug trafficking[12]. The cartels have recently demonstrated further innovation by deploying advanced surface vessel hull designs that were previously only available to race competitors and special forces[13]. All three types of vessels have proven very difficult to locate at sea, and it is unclear what fraction are ever intercepted[14]. Unfortunately, many decades of significant spending on hard security measures in the U.S. – e.g., prohibitions on the sale or possession of precursor chemicals, and crackdowns on domestic production laboratories – have not had a lasting impact on illicit drug markets. The primary effect of implementing these measures is apparently to shift use between illicit drugs over time, without significantly affecting aggregate demand[15],[16]. (Note that this is a distinctly different problem than the misuse of legal pharmacologicals, which is argued to be the cause of widespread harm from opioid use.)

More directly relevant to the use of biotechnology in garages is the outcome of attempts to restrict the use of synthetic chemistry to produce so called “legal highs”. Also referred to as “bath salts” and “synthetic cannabinoids”, among other street names, these chemicals can be produced just about anywhere, using modest technology, and are often drawn from academic literature describing the synthesis of psychoactive compounds[17]. These compounds are explicitly legal in many countries until their specific chemical structure is outlawed. A 2010 news report described “a wave of laboratory-adept European entrepreneurs who see gold in the gray zone between legal and illegal drugs”[18]. The article focussed on the story of an out-of-work carpenter who turned to synthesizing these drugs to make ends meet, a sure sign that a technology has been thoroughly democratized. This laboratory-adept entrepreneur averred that he was always ready to move onto the next compound when authorities banned whatever he was selling, staying just ahead of the law, thereby illustrating an international phenomenon. In the U.S., the Synthetic Drug Abuse Prevention Act of 2012, which added fifteen specific chemical structures to schedule 1 of the Controlled Substances Act, was reportedly circumvented within days by entrepreneurial chemists who were ready to commercialize compounds with structures different to those proscribed by the Act[19]. Here, again, regulation created perverse incentives to innovate in the very market that regulation was supposed to eliminate.

10 “To Smuggle More Drugs, Traffickers Go Under the Sea”, Micheal Schmidt and Thom Shanker, *The New York Times*, 9 September, 2012.
11 “Watch the US Coast Guard seize a narco sub laden with more than 5,600 pounds of cocaine”, Christopher Woody, *Business Insider*, 31 October, 2016.
12 Lichtenwald, Terrance G., Mara H. Steinhour, and Frank S. Perri, “A Maritime Threat Assessment of Sea Based Criminal Organizations and Terrorist Operations.” *Homeland Security Affairs,* 8, Article 13, August, 2012.
13 “Colombian Drug Smugglers Built This Stealthy, Special Forces-Inspired Boat”, Kyle Mizokami, *Popular Mechanics*, 13 June, 2017.
14 ibid.
15 “Meth, the Forgotten Killer, Is Back. And It’s Everywhere”, Frances Robles, *The New York Times*, 13 February, 2018.
16 *2018 National Drug Threat Assessment*, Drug Enforcement Administration, U.S. Department of Justice, 2018.
17 David Nichols. “Legal Highs: The Dark Side of Medicinal Chemistry.” *Nature* 469, no. 7328 (2011): 7.
18 “In Quest for 'Legal High,' Chemists Outfox Law”, Jeanne Whalen, *The Wall Street Journal*, 30 October, 2010.
19 “New Federal Ban On Synthetic Drugs Already Obsolete”, Brandon Keim, *Wired*, 12 July, 2012.

Based on the above data, it appears that the hypothesis that restricting access to democratized technologies always improves public safety and security is false. Instead, even in the face of significant sanctions for the production, distribution, and use of illicit drugs, regulation can be ineffective or deleterious. The points of failure of drug proscription are relatively easy to diagnose: broad demand supports the use of tools and skills that cannot be readily constrained. It seems plausible that the history of responses to drug prohibitions by manufacturers, traffickers, and customers represents a general phenomenon. In the absence of practical means to physically prevent access to democratized technologies, increased regulation creates perverse incentivizes for innovation while evidently having minimal impact on demand. This experience suggests that any security strategy based on proscription of democratized technologies is doomed not merely to failure, but is doomed to exacerbate insecurity by incentivizing individuals to hide their activities.

The consistent outcomes of drug and alcohol proscription point to a consistently misformulated strategy to control tools and skills in a market in which 1) those tools and skills are already widely available, 2) those tools and skills are required broadly across the economy, and 3) consumers are willing to pay prices that support the illicit use of those tools and skills.

Similarly, biotechnological skills are already broadly available. Biotechnological skills already support a significant fraction of the economy in many developed countries, demonstrating the existence of significant demand. Indeed, public and private investment around the world is directed at increasing the prevalence and utility of those skills in order to generate skilled jobs and economic growth. Taken together, these characteristics suggest that attempts to control the use of biotechnological skills will fare no better than prior attempts to control synthetic chemistry.

Indeed, FBI officials explicitly acknowledge the implausibility of top down efforts to physically prevent access to widely accessible tools and ideas, particularly in the context of large and rapidly growing international demand[20]. Yet that does not mean no action can be taken. The US government does have in place “systems and processes to manage the risks” of synthetic biology and garage biology, and they comprise the engagement activities described in my prior testimony. I reiterate my earlier recommendation, which is that the US government “should devote resources to continuing engagement activities that are, in my experience, the best single step that the U.S. government has taken to improve security.” The US government arrived at this policy after discovering that attempting to constrain the use of biological technologies in the name of improved security was not merely ineffective, but counterproductive.

In the years after 2001, the U.S. government investigated, arrested, and sought to prosecute several scientists and biohackers under terrorism charges without sufficient legal basis or evidence. In at least one case, public accusations were revealed to be errant even before charges were brought, resulting in financial penalties for the U.S. government[21]. In another case, an indictment was eventually dismissed by a federal judge as “insufficient on its face”[22]. One defendant pled guilty to a reduced charge to end his legal ordeal due to health concerns, a charge that arguably would have been dismissed along with the rest had that case gone to trial. This underreported and poorly understood historical episode had a chilling

20 “A Way to Brew Morphine Raises Concerns Over Regulation”, Donald G. McNeil Jr., *The New York Times*, 18 May, 2015.
21 “The Wrong Man”, David Freed, *The Atlantic*, May, 2010.
22 “Charge Dropped Against Artist in Terror Case”, The Associated Press, 22 April, 2008.

impact on the willingness of garage biohackers to disclose or discuss their activities. Here I write from personal experience.

By 2004, I was regularly briefing security and law enforcement organizations in Washington DC on global trends in biotechnology while maintaining a lab in my own garage, the existence of which did not enter into my briefings precisely because I was concerned about overenthusiastic law enforcement. Only much later did I speak freely about my garage lab, which I built to support a start-up company, and only then because US security policy was restructured according to the 2009 National Strategy for Countering Biological Threats[23]. To this day, I am aware of individuals who have chosen to keep their garage labs secret precisely because they fear that a future political reversal of the two most recent National Strategies, presumably accompanied by new legislation and law enforcement priorities, could land those maintaining garage labs in legal peril. The FBI's public statements about its shift in strategy and its embrace of engagement and transparency, now acknowledging that “We’ve learned that the top-down approach doesn’t work,” have not been sufficient to overcome distrust[24]. Consequently, it is not now possible to assess how many garage labs are in operation in the U.S. precisely because of the fear of sanction instilled by prior government actions. The ongoing lack of even rudimentary information about how many garage labs are in operation, let alone what practitioners are up to in those labs, counts as a safety and security own-goal that could have been avoided, and that must not be repeated.

This paucity of data is a global problem and is a characteristic of the challenges inherent in economic and security assessments of democratized technologies. In the absence of voluntary information sharing, not only do we not know how many garage labs are active in the US, but we *cannot know* without some combination of pervasive surveillance and invasive physical searches, a strategy that is logistically implausible and also generally incompatible with the laws and values of this country.

How can we construct a biosecurity and biosafety policy conversation that 1) respects demonstrated public interest in participating in the biotechnology revolution, while at the same time 2) also respects the need to monitor potential threats, but 3) simultaneously avoids casual calls for restricting access to biotechnology as a magical route to improved safety and security? Given the difficulty of physically controlling access to biotechnology, maximizing transparency and information is the only plausible course available to improve security. This statement should be treated as a policy hypothesis as well, though one consistent with recent experience across multiple law enforcement and security jurisdictions. This hypothesis is also consistent with the 2009 U.S. National Strategy for Countering Biological Threats, which does not advocate for controlling access to biological technologies, nor for surveilling those who use biotechnology, and – to the contrary – explicitly states the security benefits of transparency and broad, open access[25].

Finally, this transparency and open access must be accompanied by personal responsibility. That sense responsibility can be fostered through education and engagement. As I stated in my prior testimony:

> *The U.S. government would do well to develop a network of community laboratories that would provide access to infrastructure, increase communication between innovators, and facilitate*

23 Ledford, H., “Garage biotech: Life hackers”, 6 October 2010, Nature 467, 650-652.
24 McNeil, 2015.
25 “National Strategy for Countering Biological Threats”, National Security Council, 2009. https://obamawhitehouse.archives.gov/sites/default/files/National_Strategy_for_Countering_BioThreats.pdf

engagement with the U.S. government in regards to national security and national technology development goals[26]. In addition to providing venues for education and public conversations, this strategy would facilitate economic development via start up formation, thereby accelerate job creation, and would dovetail nicely with the aforementioned existing FBI outreach activities.

Q: How can we better incentivize venture capitalists who fund synthetic biology entrepreneurs, citizen scientists, universities, and private industry to address risks in this sector?

There are two broad areas of risk to consider here. The first, which I have extensively discussed above, is a physical risk from human behavior that can only be addressed through encouraging safe and beneficial use of biotechnology. I firmly believe that more education, and more exposure to positive norms, is the best route to ameliorating this risk. The US government can incentivize participation in open networks and normative conversations by providing venues for education and engagement, as described at the end of the previous answer.

The second broad area of risk boils down to international competition. This is a different definition of risk than used above, and has more to do with physical and economic security. I will here refer back to my prior testimony, although I would be happy to take this up again if desired by the Committee.

Q: How does your own venture capital firm take into account security risks when making your investment decisions?

We carefully evaluate the combination of team and technology to ensure that our investments are aligned with both public and private interests. To that end, we vet not only the entrepreneurs who might receive an investment but also other participating investors, along with customers and suppliers. In this we take an expansive view of “security” and “risk” that includes both the potential end use of a technology and the potential end user. Ultimately, these are matters of judgement that reduce to intent, both ours and the entrepreneurs.

26 Carlson, R. “Building a 21st Century Bioeconomy: Fostering Economic and Physical Security Through Public-Private Partnerships and a National Network of Community Labs”, Biodesic, 2011.