Global Health Security in the DNA Age

Ryan Morhard

Council on Foreign Relations Global Health Program

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Introduction

The advent of the current biotechnology revolution has significant implications for global health security governance. At the heart of this revolution are advancements in the ability to read, write, and edit DNA. Facilitated by progress in biological science and coupled with accelerating developments in computing, automation, and artificial intelligence, this revolution can be summarized by an apparent contradiction: biological science has the potential to render epidemics no longer a threat to humanity, while at the same time presenting new biological risk to global health security governance.

The current moment can be best understood as a dawning "DNA age," where these accelerating technologies are helping to drive down relevant costs at a rate faster than Moore's Law [PDF], the phenomenon describing the increase in computer chip performance and a corresponding decrease in cost over time. As a result, it is now possible to program cells in a manner comparable to computers. The ability to "read, write, and edit genetic code, which has rendered biology programmable" has led the U.S. government to believe that biotechnology will play an "outsized importance over the coming decade," particularly in the context of geopolitical competition.

Biotech on the Global Agenda Beyond COVID-19

As an illustration of the anticipated "outsized importance," the Joe Biden administration has recently announced an ambitious strategy to apply the latest in biotechnology to unlock innovations across a fairly comprehensive list of priorities, including "health, climate change, energy, food security, agriculture, supply chain resilience, and national and economic security." Alongside the new strategy, the White House convened senior security, economic, and science and technology officials for a biotechnology summit that recognized new abilities to program microbes and featured commitments to grow the domestic bioeconomy and strengthen the biotech-related defense industrial base. Biotech was also featured in the recent CHIPS and Science Act, and, later, the Biden administration added a leading Chinese genomics company to its periodically updated list of Chinese military-affiliated companies. A new National Security Commission on Emerging Biotechnology also will begin meeting.

China is also investing in biotech as the next big industrial revolution and is pursuing wide-ranging applications of biotechnology for increased sustainability and economic resilience. In the DNA age, policymakers are applying the expertise in biology and biotechnology that they have built up during the COVID-19 response to other items on the top of their agendas. Biotech is featuring more prominently on global agendas because the bio-based economy stands to be massive and transformative. Ultimately, the DNA age has the potential to be more impactful than the electronics age that has characterized the revolution in digital technology since the 1940s and has played a pivotal role in global economy and security.

This anticipated economic restructuring is because programming biology can be incredibly powerful. Biology makes things—almost everything. Driven by DNA code, living things make our air, produce our food, and clean our water. Biology is the original, and most powerful, manufacturing technology.

Accordingly, advancements in cell programming stand to influence all industries that produce physical goods. In fact, driven by governments and businesses looking to meet emissions reductions targets, maintain resilient supply chains, ensure food security, and further reduce reliance on fossil fuels, experts anticipate that by the end of the decade biotechnology could be used extensively in manufacturing industries that account for more than a third of global output—a shade under $30 trillion in value.

Nearly all economic sectors stand to be affected by this manufacturing revolution, with the greatest potential in areas far beyond health care and pharmaceuticals. In fact, applications of biotechnology in domains such as agriculture and food, consumer products and services, and materials and energy production could soon overtake economic impacts resulting from applications for human health. In the DNA age, industries that previously never used biotechnology are starting to, potentially at an incredible scale. This innovation has significant implications for global health security.

Imagine if SARS-CoV-2 were a computer virus instead of a biological virus. In that scenario, the full might and muscle of industry (including massive information technology firms) would have been brought to bear for an overwhelming response. A world where more companies are biotechnology companies could produce a similarly resounding response, far beyond what has been possible through traditional investments in public health.

"COVID-29": Envisioning a Pandemic Response That Isn't Dictated by Scarcity

A large and vibrant bio-based economy has already proven to deliver dramatically improved pandemic preparedness. Indeed, response to the COVID-19 pandemic has shown that, when combined with public sector leadership and support, the bioeconomy offers ready capacity to support bio-surveillance, environmental monitoring, and continuous development and large-scale production of diagnostics, therapeutics, and vaccines.

Consider the 2009 H1N1 influenza pandemic. By the end of the H1N1 pandemic, countries used existing and substantial influenza vaccine manufacturing capacity to administer more than 350 million doses of vaccine. For comparison, to respond to the present pandemic, nations have administered more than 12.8 billion doses of COVID-19 vaccines. Similarly, during the H1N1 pandemic, the United States sequenced [PDF] fewer than ten thousand influenza samples. Today, more than thirteen million SARS-

CoV-2 sequences have been shared with the Global Initiative on Sharing Avian Influenza Data (GISAID). Or, consider testing in China, where cities with populations greater than ten million people are regularly testing.

It is not entirely fair to directly compare the two pandemic responses. However, given that public health preparedness was largely neglected [PDF] during the decade between the two pandemics, the comparison does invite consideration of what is possible in a world where biotechnologies are increasingly applied across our economy.

President Biden's recently released National Biodefense Strategy recognizes the new opportunities associated with these capabilities. The new strategy calls for the United States to develop a test to detect a hypothetical pathogen within 12 hours and produce enough vaccines to protect the nation within 130 days. This would have been science fiction using state-of-the-art biotechnology just five or ten years ago.

Delivering on President Biden's ambitious strategy is not only possible, but practical given newly developed biodefense capabilities. In the next ten to twenty years, experts expect the biotechnology to be powering applications across the economy with potentially $4 trillion in direct economic impact a year. The response to COVID-19 illustrates that a booming bioeconomy could dramatically improve availability of and access to medical countermeasures. Critically, COVID-19 has also demonstrated that far more is required for an effective pandemic response than tests and vaccines, although these are necessary elements.

Advancements in biotechnology ensure that, more than ever, global access to the tests and vaccines required to save lives and prevent a pandemic will be primarily a political decision. If world leaders prioritize pandemic preparedness, the gains of the next ten years will far exceed the gains since 2009's H1N1, and it is foreseeable that humanity could be capable of responding to a global pandemic with such unprecedented speed and scale that future responses are no longer dictated by scarcity of medical countermeasures.

Biosecurity is Like Cybersecurity

There seems to be consensus that prevailing mechanisms for global health security governance are inadequate. Indeed, a historic process is now underway to seek agreement on a new global treaty on pandemic prevention, preparedness, and response.

Many pressing areas for potential reform exist. Negotiations should recognize the opportunities presented by the "bio-revolution." The expansion of industrial applications of biotechnology, and increasing adoption of bio-manufacturing, provide dramatically improved and neglect-resistant health security capabilities. Failure to account for these new opportunities could render painfully negotiated decisions obsolete from the start. However, the bio-revolution presents more than just opportunities for health security; it also introduces new risks to be accounted for.

Notably, while there are new risks associated with emerging biotechnologies, governance around intentional misuse of biotechnology has long been insufficient, in part due to the dual-use nature of biotechnology. Because so much of advanced biotechnology is dual-use, and driving benefits across society, it is impractical to have the same kinds of verification approaches in biology as we see for nuclear or chemical activities. Instead, the Biological Weapons Convention (BWC), the main treaty prohibiting the weaponization of biology, relies on confidence-building measures (CBM) to assess compliance. In 2021, most countries that are party to the BWC did not submit CBM reports.

Further, the BWC is famously underfunded, particularly given the challenges that its members and its secretariat are meant to address. It has only a few staff members and a budget smaller than that of the average McDonald's franchise. These institutional hurdles predate some of the newer, arguably more pressing, challenges that are presented by the bio-revolution.

For example, gain-of-function studies that tweak pathogens in ways that could make them spread faster or become more dangerous to people are of prime concern. Similarly, as the ability to synthesize new DNA code has increased, so has urgency regarding governance mechanisms to reduce the likelihood of accidental or deliberate misuse of DNA synthesis that could result in the spread of dangerous agents. Concerns have also been expressed relating to the proliferation of labs authorized to carry out work with the most dangerous pathogens, with increasing calls for transparency surrounding research in these, particularly to ensure activities are being undertaken safely and for peaceful purposes.

Each of these areas are critical for consideration, and are included, among other issues, as within the mandate of a newly announced organization, the International Biosecurity and Biosafety Initiative for Science. This organization aims to strengthen biosecurity norms and develop innovative tools to uphold them, and represents an important step forward in health security governance.

Perhaps most importantly, advancements in biotechnologies also invite fundamental changes in how we think about biosecurity. Before the bio-revolution, managing biological risk was largely synonymous with public health preparedness. In the context of a growing bioeconomy, and when biotechnologies are increasingly important economically and geopolitically, biosecurity can be thought of in the same way cybersecurity is today. Much like the emergence of cybersecurity alongside the digital revolution, similar capabilities are likely to emerge alongside the bio-revolution.

For example, in October, leadership from the Intelligence Advanced Research Projects Activity announced new tools to help protect the U.S. bioeconomy by making it easier to detect theft of engineered organisms. These tools are the first of their kind, and, beyond their important applications in industrial biotechnology, could also be used to provide an early warning of bioweapons, such as a new deadly bacteria or a modified virus that thwarts existing vaccines. Detecting manipulated or malicious code is a feature of cybersecurity that is now part of the biosecurity tool kit.

Biosecurity infrastructure that mirrors our approach to cybersecurity would also entail significant improvements in bio-surveillance. There are vast systems to monitor, contain, and mitigate the spread of computer viruses; comparable networks for the microbial world would deliver exponential improvements in the early warning and monitoring approaches and technologies we use to prevent the spread of infectious diseases.

Finally, platforms also stand to play an important role in biosecurity, just as they have for cybersecurity. Big platforms such as Amazon Web Services or Google are relied upon to provide cybersecurity alongside computing services. In the bio-revolution, biology will likewise take place in the cloud, providing an important opportunity for similar, platform-derived biosecurity.

These developments are essential. In the same way that it would be dangerous (and impractical) to depend on computers and software without cybersecurity, it would be even more unwise to grow the bioeconomy without a foundation of biosecurity. Efforts in this regard represent new and important opportunities for governments to leverage growing capacities, and also signify a fresh chapter in global efforts to mitigate the risk and harm of biological threats.

Looking Forward

The DNA age represents a new phase for global health security. Change will not be immediate, but it will be dramatic. These changes will accelerate as biotechnologies transform manufacturing and are applied to economic and security challenges such as climate change, food security, and supply chain resilience.

As demonstrated by COVID-19, the growing bioeconomy will generate upgraded tools for fighting pandemics. However, new biotechnologies and applications will also generate new risks. These risks reveal gaps in global health security governance. At the same time, if the development of cybersecurity alongside the digital revolution is any indication, the expanding bioeconomy will also give rise to new means, new investments, and new, very committed stakeholders, who will fully modernize the way we manage biological risk.