Meeting of the States Parties to the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction

20 August 2021

English only

2020 Meeting
Geneva, 22-25 November 2021

Meeting of Experts on Review of developments in the field of science and technology related to the Convention
Geneva, 1-2 September 2021
Item 4 of the provisional agenda
Review of science and technology developments relevant to the Convention, including for the enhanced implementation of all articles of the Convention as well as the identification of potential benefits and risks of new science and technology developments relevant to the Convention, with a particular attention to positive implications

Benefits of science and technology developments for the global COVID-19 response

Submitted by the United States

Summary

The COVID-19 pandemic continues to have devastating impacts for all States Parties and is a stark illustration of the threats posed by novel pathogens with pandemic potential. Recent advances in biotechnology have proven invaluable in supplementing traditional public health response measures to COVID-19. Notably, advances in vaccine technology in the past two decades led to record-breaking vaccine development timelines, and whole genome sequencing enabled identification and tracking of new COVID-19 variants. International collaboration has played a critical role in these developments. While Biological and Toxin Weapons Convention (BWC) States Parties necessarily consider the potential misapplication of science and technology (S&T) advances for weapons purposes, it is also important to consider how advances can yield large benefits for medicine, health, agriculture, and other aspects of well-being and public good. This paper highlights S&T advances that enhanced the international community's capacity to respond to disease outbreaks and other biological threats.

I. Introduction

1. Biotechnology advances enhance our collective capacity to respond to disease outbreaks and other biological threats. A wide range of scientific and technical advances continue to support the world's public health response to the COVID-19 pandemic. This paper focuses on two specific examples of the invaluable contribution of emerging S&T

advances to public health and global health security – vaccine development and genomic sequencing. These examples highlight the importance of maximizing the benefits of current and future science and technology innovation, especially to enhance our collective ability to prepare for, detect, and respond to biological threats.

2. While BWC States Parties have long considered potential risks posed by new developments in science and technology for bioweapons misuse, it is also important to recognize the benefits from new advances in preventing, detecting, and responding to biological catastrophes. Another United States Working Paper[1] summarizes recent discussions by States Parties within MX2 about identifying, assessing, and managing the risks and benefits of S&T advances, and those principles apply equally to the advances described here. States Parties' MX2 discussions are also currently focused on developing a structured and systematic process for S&T advice relevant to the BWC that might consider both risks and benefits. The technological advances leveraged during the COVID-19 pandemic highlights their critical role in biothreat detection, prevention, and response and, more broadly, the benefits of S&T advances in the life sciences.

II. Advances in vaccine development

3. Vaccines protect against the spread of disease by providing immunity to individuals. While vaccines have traditionally taken 10-20 years to develop, vaccines against COVID-19 were researched, developed, and taken to market in under one year, thanks to an established knowledgebase, advances in DNA synthesis technology and bioinformatics, longstanding biodefense research and development investments, and international collaboration. The World Health Organization (WHO) stated in February 2020 that it did not expect a vaccine to become available in less than 18 months. The genomic sequence of SARS-CoV-2 was published by Chinese scientists in January 2020[2], prompting immediate global research and development activity to produce a safe and effective vaccine. Development moved forward at record pace without compromising on safety by running multiple steps in parallel, leveraging platform technologies, and building from work on other coronaviruses. In the United States, the first large scale clinical trials began in July 2020 and the first emergency use authorization for COVID-19 vaccines was in December 2020.[3,4] The unprecedented level of collaboration in the multinational pharmaceutical industry, among governments, and among scientists led to multiple vaccines authorized for use by numerous countries by the end of 2020, less than a year after detection of the novel virus. Importantly, the extraordinarily rapid development of life-saving vaccines was facilitated and sped up by rapid and public sharing of viral genomic sequence data and other outbreak related data, among other critical components such as platform technologies, sample sharing, and long-standing investments in research and development.

4. Although traditional vaccine technologies, such as inactivated virus vaccines, are contributing significantly to the COVID-19 response, this paper focuses on newer vaccine technologies – mRNA and viral vectors – to illustrate the benefits of new scientific advances during the pandemic. One key benefit of these next generation vaccine technologies is that obtaining the genetic sequence of the virus is enough to begin vaccine development (rather

[1] BWC/MSP/2020/MX.2/WP.1

[2] https://virological.org/t/novel-2019-coronavirus-genome/319

[3] Simon, M. and Fox, M. Pfizer and BioNTech begin large-scale trial of coronavirus vaccine in the United States. CNN, 28 July 2020. https://edition.cnn.com/2020/07/28/health/pfizer-coronavirus-vaccine-trial-begins-biontech/index.html

[4] U.S. Food & Drug Administration. Moderna COVID-19 Vaccine. https://www.fda.gov/emergency-preparedness-and-response/coronavirus-disease-2019-covid-19/moderna-covid-19-vaccine

than receiving and growing virus samples).[5] This advance accelerates development as several steps in traditional inactivated virus vaccine development are bypassed, such as optimization of growth and purification conditions for a novel virus. Additionally, there are biosafety and biosecurity benefits in avoiding the risks associated with handling live pathogens. Finally, these new vaccine technologies have the potential to be "plug and play platforms" that are flexible and can pivot to produce modified vaccines that target new variants of COVID-19 as they emerge or vaccines for entirely different pathogens more rapidly and efficiently than previous technologies.

5. Messenger RNA, or mRNA, is a molecule naturally present in all cells that carries the instructions for making proteins. An mRNA vaccine takes advantage of that natural role by delivering these instructions directly into the cell via a nanoparticle. Upon receiving the COVID-19 mRNA vaccine, human cells will produce a non-harmful part of the virus (the "spike" protein on the surface of SARS-CoV-2), which the immune system recognizes and builds a defense against. This vaccine technology decreases the laborious process of other vaccine technologies by bypassing the need to produce large quantities of protein in a laboratory for delivery to patients or large quantities of inactivated virus as a delivery vehicle. Prior to COVID-19, no vaccines had been authorized using mRNA technology, even though research has been ongoing for decades and some vaccines have been tested in human clinical trials for several years. The Moderna and Pfizer/BioNTech mRNA vaccines became the first vaccines authorized for use based on mRNA technology.

6. Viral vector vaccines are a second type of newer technology that proved critical in COVID-19 vaccine development. Differences between viral vector vaccines and mRNA vaccines include the type of genetic material (DNA or RNA vs. mRNA) and the delivery method (viral vector vs. nanoparticle). Through these vaccines, a different, harmless virus delivers genetic material (DNA or RNA) that, similar to mRNA vaccines, provides human cells the instructions to make a viral protein (such as the SARS-CoV-2 spike protein). As with mRNA vaccines but in contrast to some classical vaccine technologies, the original SARS-CoV-2 virus is not needed to initiative development of the vaccine. While scientists have studied viral vector vaccines for decades and there are over a dozen approved veterinary vaccines using this platform, the first such vaccine was approved for use in humans only two years ago, against Ebola.[6] In response to COVID-19, researchers and biotechnology companies in the United States (Johnson & Johnson), China (CanSino Biologics), the United Kingdom (Oxford-AstraZeneca), and Russia (Gameleya Research Institute) all developed viral vector vaccines that are in use today around the world.

III. Advances in genomic sequencing applied to public health and outbreak surveillance

7. Whole genome sequencing – the ability to read an organism's genetic instructions – is useful throughout the public health response to a disease outbreak. When genomic sequence data is made publicly accessible, it can be used to detect novel pathogens, support efforts to develop vaccines and diagnostics, and carry out ongoing surveillance to identify new variants. While many other life sciences techniques are needed to fully characterize a novel pathogen or a newly identified variant, sequencing is a critical and, often, first step. To begin, a sample is taken from a patient (such as a nasal swab), then processed and fed to an

[5] van Riel, D. and de Wit, E. Next-generation vaccine platforms for COVID-19, Nature Materials. 19, 810-812, 23 July 2020. https://www.nature.com/articles/s41563-020-0746-0

[6] Dumiak, M. Proven against Ebola, a vector shows its broader potential. Int'l AIDS Vaccine Initiative, 2019. https://www.iavi.org/iavi-report/vol-23-no-2-2019/proven-against-ebola-a-vector-shows-its-broader-potential

instrument that reads the genetic code of the virus (or other organism). Reading the code of a virus is like getting a fingerprint and an instruction manual at the same time – it can give insight into how the virus works, what species it may infect, which drugs might be used to stop it, and how virus samples are similar or different to previously sequenced organisms.

8. The use of genomic sequencing to advance public health has grown rapidly in the past five years, along with the transparent international and publicly accessible sharing of pathogen genomic sequence data. Virus sequencing and data sharing during the 2014 Ebola outbreak demonstrated the usefulness of sequencing for epidemiological tracing and diagnostic development, but sequencing was not widespread in public health laboratories. Advances in next generation sequencing technology are leading to a more rapid turnaround time and a much lower cost, increasing its usefulness as a public health tool. Sequencing instruments are becoming more common in research and diagnostics labs worldwide, as the cost has dropped significantly and genomic data analysis tools have improved. The expanded use of sequencing in the past few years as a medical and epidemiological tool laid the groundwork for the unprecedented scale of sequencing during the COVID-19 pandemic both for scientific research and public health screening.

9. *Identification of novel pathogens* – In many cases, genomic sequencing can be used in public health or diagnostic labs to determine what organism is making a patient sick. While visual inspection of organisms (through microscopy) and microbiology lab tests can also help determine the identity of a pathogen, genomic sequencing can be very effective at making a precise determination, without any prior knowledge of what type of pathogen might be present. Since genome sequencing works by reading the genetic material present in a sample, sequencing can be widely used to identify pathogens that were not detected by standard diagnostic methods. Genome sequencing was used to identify SARS-CoV-2 as the causative agent of a cluster of unknown pneumonia cases in Wuhan, China, alerting the international medical community to a novel pathogen. Next generation sequencing combined with epidemiological studies was used to recently determine that Ebola virus can persist in survivors and be transmitted months to years after the initial infection. Now public health groups sequence initial Ebola cases to determine if it is a new spillover event from an animal reservoir or if it was initiated by a persistent infection.

10. *Rapid medical countermeasure response* – With the genome sequence of a pathogen, scientists can rapidly begin to develop diagnostic tests, therapeutics, and vaccines. For example, a common diagnostic test used in labs and hospitals worldwide is polymerase chain reaction (PCR), which detects genetic material from a specific organism. This type of test can be rapidly developed and deployed for new pathogens using a published genome sequence. In the case of SARS-CoV-2, knowing the virus genome sequence spurred rapid diagnostic and vaccine development in countries worldwide. Accurate and rapid diagnostic tests have been critical worldwide by providing a method to screen for and potentially isolate cases and providing essential information about the parameters of the pandemic. Sequencing is also used widely among suspected tuberculosis cases to determine what, if any, antimicrobial resistant genes are present to identify an effective treatment.

11. *Identification of variants* – Ongoing genomic sequencing of patient samples during a disease outbreak can track new variants, aid in risk assessments, and monitor how they spread across the population. As organisms replicate, small changes can occur in the genetic code and are passed on to subsequent generations. Since the genome provides a fingerprint of an organism, genome sequencing of patient samples over time can track these genetic changes and monitor when new variants arise. During the COVID-19 pandemic, sequencing has identified new variants of concern globally, allowing countries to identify, assess, and track the spread of variants with different properties; implement changes in evidence-based public health measures; and modify existing diagnostic tests or vaccines if needed. For example, after noticing a large increase of cases in a specific region, the U.K. identified the Alpha

variant in November 2020 using genome sequencing and instituted tighter public health measures to prevent further spread.[7]

IV. International scientific collaboration and future advances

12. International collaboration is essential to share relevant information for development of vaccines, diagnostics, and other medical countermeasures. In the case of vaccine advances, international scientific collaboration was essential, from decades of research laying the groundwork to the first publication of the viral sequence and increased vaccine manufacturing. In April 2020, an international group of experts in coordination with the WHO pledged collaboration to speed development of vaccines against COVID-19.[8] This international group encouraged international cooperation among vaccine developers, regulatory agencies, funders, public health associations, and governments. The Coalition for Epidemic Preparedness Innovations (CEPI), among others, has worked to accelerate the development and manufacturing of vaccines through initiatives such as pooled financing, removing supply chain bottlenecks, and investing in manufacturing in advance of an approved vaccine.[9] This international effort was complemented by the efforts and investments of nations to accelerate research, development, and scaled manufacturing of vaccines. Moderna's SARS-CoV-2 mRNA vaccine was rapidly developed based on previous work on related viruses and leveraged a manufacturing process intentionally developed for rapid and versatile design against novel or changing viruses. With a successful and authorized mRNA vaccine, Moderna's technology is now being used for a variety of potential vaccines that are already in clinical trials, such as HIV, influenza, and Nipah virus. Beyond viruses, mRNA vaccine technology has the potential to vaccinate against proteins from bacterial and fungal pathogens too, thus creating a vast array of newly available vaccine targets.

13. International scientific collaboration and data sharing also play a critical role in the case of genomic sequencing. More than 120 countries have shared SARS-CoV-2 genomic data through GISAID and International Nucleotide Sequence Database Collaboration databases including GenBank, DNA DataBank of Japan (DDBJ), and the European Nucleotide Archive (ENA). In the last month alone, over 100,000 viral sequences were submitted to these databases, an unprecedented amount of international data sharing. This rapid and publicly accessible sharing of genomic data aids in the detection and assessment of new SARS-CoV-2 variants. The U.K. led the world early on in its sequencing efforts, developing the COVID-19 Genomics UK Consortium, which sequences over 10,000 viruses per week.[10] Other countries soon followed suit, promoting numerous national sequencing initiatives, such as the Africa CDC and WHO collaboration to launch a network of laboratories to sequence COVID-19 samples in Africa.[11] Sequencing technologies can be applied to any biological threat and, beyond aiding immediate outbreak response efforts, sequencing can help to identify genetic changes associated with specific pathogen properties.

---

[7] Cyranoski, D. *Alarming COVID variants show vital role of genomic surveillance*. Nature, 15 Jan 2021. https://www.nature.com/articles/d41586-021-00065-4

[8] *Public statement for collaboration on COVID-19 vaccine development.* World Health Organization, 13 April 2020. https://www.who.int/news/item/13-04-2020-public-statement-for-collaboration-on-covid-19-vaccine-development

[9] https://cepi.net/covax/

[10] Howes, L. *200,000 and counting: how the UK has sequenced so many cases of coronavirus.* C&EN, 3 Feb 2021. https://cen.acs.org/analytical-chemistry/sequencing/200000-counting-UK-sequenced-cases/99/web/2021/02

[11] *COVID-19 genome sequencing laboratory network launches in Africa*. World Health Organization, 10 Sept 2020. https://www.afro.who.int/news/covid-19-genome-sequencing-laboratory-network-launches-africa

For example, influenza and SARS-CoV-2 studies have identified point mutations associated with stability, host range, pathogenicity, and transmissibility, which are useful during surveillance efforts and when identifying viruses circulating in animals with pandemic potential.

V. Conclusion

14. Dealing responsibly with advances in science and technology requires BWC States Parties to not only consider the risks that may be posed by such advances, but also the potential benefits. The COVID-19 pandemic accelerated the research, development, and manufacturing capacity for newer vaccine technologies that can be rapidly applied to future biological threats. The pandemic also accelerated the use of genomic sequencing and data sharing for public health. The COVID-19 response demonstrates the need to invest in innovation and biodefense research and development and demonstrates the impactful benefits of international collaboration and scientific advances worldwide. While the pace of equitable vaccine distribution is still far below demand, the production of highly effective and safe vaccines against COVID-19 in less than one year and the scaling to more than 4.5 billion vaccine doses administered worldwide in just 20 months would not have been possible without decades of research and development, international scientific collaborations, funding and investment to support innovative technologies, and rapid international and publicly accessible sharing of genome sequence data during the pandemic. Investment in research and development related to vaccine technology continues to have a tremendous public health benefit, and now the groundwork is established for improved vaccine development for a variety of diseases. In particular, the combination of newer vaccine technologies that can rapidly pivot production with the power of sequencing technologies enables more efficient targeting of either new SARS-CoV-2 variants or entirely different pathogens and enhances our capacity to respond to future threats. Ongoing development of these technologies should continue to incorporate biorisk management to ensure safety and security while maximizing their benefit.