2ND ANNUAL

Global Forum on Scientific Advances Important to the Biological Weapons Convention

JOHNS HOPKINS CENTER FOR HEALTH SECURITY

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Executive Summary

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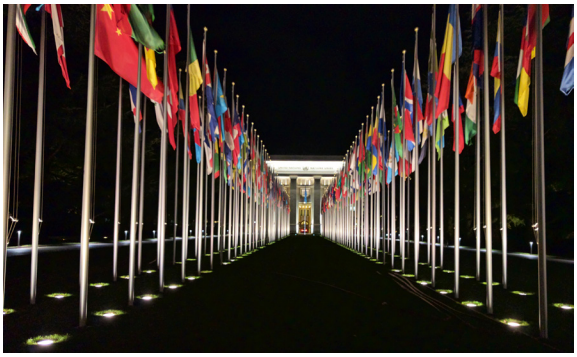

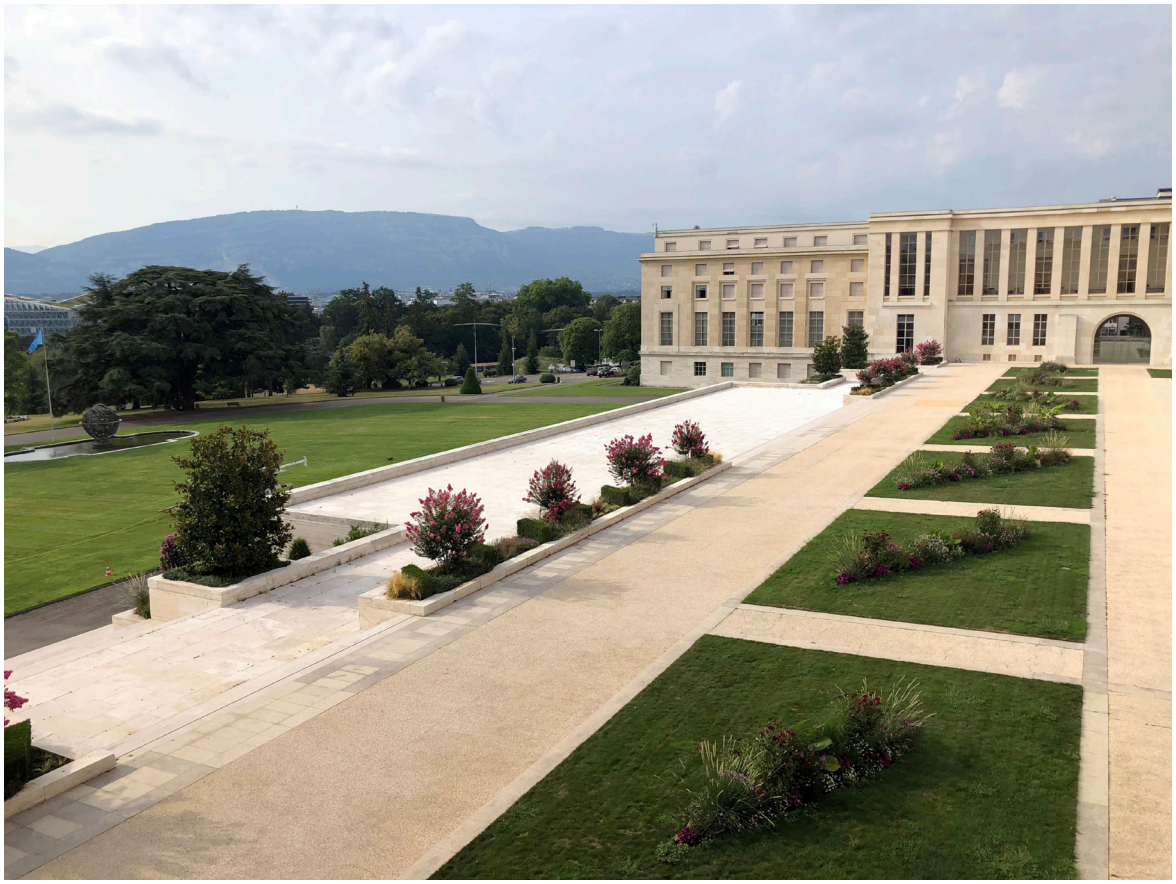

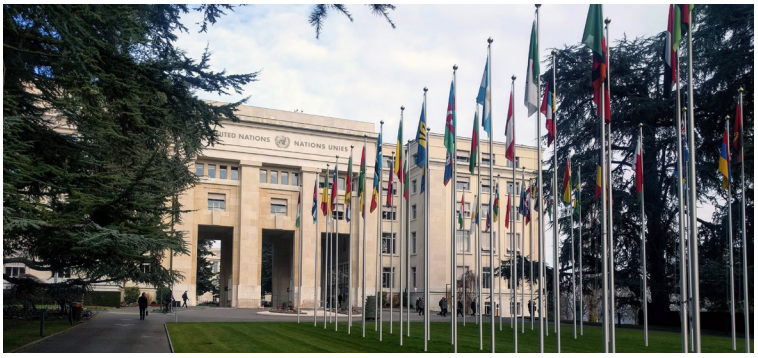
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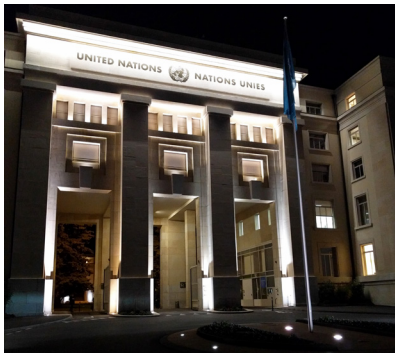
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Introduction

The **Global Forum on Scientific Advances Important to the Biological Weapons Convention** facilitates engagement between scientists performing cutting-edge research and States Parties delegations to the Biological Weapons Convention (BWC). The forum helps the delegates become familiar with some of the rapid advances in the biological and related sciences that affect the treaty and also demonstrates to scientists how the treaty should shape the governance of these technologies. Our efforts to inform BWC delegations on emerging and future biology and biotechnology capabilities supplements an existing portfolio of programs. These programs—including the BWC Meetings of Experts and regional science and technology workshops hosted by the InterAcademy Partnership—work collectively to help States Parties identify and evaluate potential biological threats and develop mechanisms to allow the BWC to remain adaptive to these new capabilities. Additionally, the Global Forum supports efforts, such as model codes of conduct, to foster a culture of responsibility among the scientific community that enables researchers to pursue advanced and revolutionary capabilities while simultaneously encouraging them to account for potential risks and mitigate those effects.

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Since the BWC's inception, States Parties have engaged in a variety of efforts to learn from emerging science and technology advances, particularly in the fields of biology and biotechnology. The BWC does not have a dedicated formal process or body to identify emerging and future science and technology capabilities and evaluate their associated potential benefits and risks to biological weapons nonproliferation. The Global Forum was designed to provide an analogue for this function by leveraging the insight and expertise of the broader scientific community to inform and support States Parties' efforts to ensure the BWC remains able to address future threats. Additionally, many frontline scientists are not fully aware of the BWC and do not necessarily consider the role of the BWC in their work or their own role in supporting associated norms. The Global Forum also aims to inform frontline scientists of BWC principles and priorities and increase global awareness of and support for biological weapons nonproliferation.

In addition to the BWC, several other prominent international fora have recently noted the importance of evaluating advances in science and technology, particularly

their impacts on disarmament and international security. In October 2019, Dr. Robert Mardini, the head of the delegation for the International Committee of the Red Cross (ICRC), stated that, while scientific progress may be inevitable, its weaponization is not.[1] This sentiment underscores the delicate balance that the BWC aims to strike with respect to science and technology. It is critical that the BWC continue to identify, understand, and evaluate emerging capabilities and their potential impact on biological weapons nonproliferation in order to mitigate the risk of their use for nefarious purposes, while promoting access to and use of these capabilities for legitimate purposes.

In July 2019, UN Secretary-General António Guterres highlighted transdisciplinary approaches to identifying emerging capabilities as mechanisms for supporting nonproliferation treaties. In particular, his report to the UN General Assembly emphasized the importance of transdisciplinary efforts "that seek to identify enabling capabilities for strengthening treaty implementation, including . . . to recognize unusual biochemical phenomena in order to trigger mitigation and response [activities]."[2] He also identified the value of developing a culture of responsibility in the scientific community—potentially through scientific codes of conduct, a high-profile topic of discussion at BWC meetings over the past several years—to mitigate nonproliferation risks associated with advanced science and technology capabilities. Given the dual-use nature of the biological sciences—that is, that research intended for beneficent purposes may be misused for harm—advances in biology and biotechnology have implications for biological weapons nonproliferation norms. By gathering scientists at BWC meetings and promoting dialogue with the broader BWC community, including States Parties delegations, we aim to raise awareness of the BWC and its underlying principles among the scientific community, and we hope that these scientists will return to their home institutions, establish support for the BWC among their colleagues, and consider the implications of their work, positive and negative, on global efforts to prevent the use of biological weapons.

Opening and Introduction

The 2019 Global Forum opened with remarks by Dr. Gigi Gronvall, Senior Scholar at the Johns Hopkins Center for Health Security and Principal Investigator for the Global Forum, followed by His Excellency Ambassador Yann Hwang, Permanent Representative of France to the Conference on Disarmament in Geneva and Chair of the 2019 BWC Meeting of States Parties, and Ms. Anja Kaspersen, Director of the Geneva Branch of the United Nations Office for Disarmament Affairs. Ambassador Hwang emphasized the importance of addressing emerging science and technology, not only with respect to the BWC, but also in the broader context of international peace and security. He also drew attention to the need to leverage the benefits associated with these emerging capabilities rather than bind future progress in the name of security. Ms. Kaspersen highlighted ongoing efforts around the world to engage young scientists in nonproliferation issues and build an international community of support for the BWC among those on the front lines of advanced research. She also took the opportunity to point out 3 specific aspects of science and technology that will be critical for supporting the BWC: (1) establishing and bolstering preparedness capabilities and capacity for health emergencies, (2) safeguarding the use of science for peaceful purposes, and (3) evaluating the potential benefits and risks associated with emerging capabilities. The 2019 Global Forum agenda was developed to discuss and debate these topics and others through diverse, international expert presentations and dialogue.

Full transcripts of the remarks provided by Dr. Gronvall, Ambassador Hwang, and Ms. Kaspersen follow, and the presentation slides for each speaker have been posted to the 2019 Global Forum event website.

Welcome Remarks from Dr. Gigi Gronvall

Senior Scholar, Johns Hopkins Center for Health Security

Good morning, and welcome, everyone, to the Second Annual Global Forum on Scientific Advances Important to the Biological and Toxin Weapons Convention (BWC). While it may seem like just yesterday that we gathered at the Palais des Nations last year for the inaugural Global Forum, much has happened over the past year, and science and technology continue to forge ahead, yielding new discoveries and capabilities that have potential impact on the BWC and nonproliferation norms and policies.

We have gathered a tremendous group of science and policy experts from around the world, including all 3 BWC Regional Groups, and we are excited for the opportunity to discuss a broad scope of complex technical and policy challenges facing the BWC. Building on the tremendous success of last year's Global Forum, our aims remain twofold, both founded in the importance of facilitating engagement between scientists and policymakers.

First, we envisioned this workshop as a mechanism to inform BWC delegations on emerging and future capabilities across the broad spectrum of biology and biotechnology. By providing a platform for cutting-edge scientists to describe their work and state of capabilities in their field, we can provide critical information for BWC delegations as they work collectively to strengthen the BWC and identify policies and mechanisms to improve the treaty's ability to adapt to emerging capabilities and threats.

Second, the Global Forum provides an opportunity for scientists to learn more about the BWC and associated nonproliferation norms. We hope that an improved understanding of BWC, including the challenges that rapidly advancing biology and biotechnology can pose, will help these experts share these lessons with their colleagues and improve awareness of and support for the BWC and associated nonproliferation norms among the global scientific community. There has been considerable effort in the BWC over the past several years to find common ground on mechanisms that will allow the BWC to evolve and adapt to advancements in biology and biotechnology, including scientific advisory boards or officers and scientific codes of conduct, but much work remains on these issues. Independent of these efforts, substantive engagement between scientists and policymakers will remain critical to identifying and evaluating future capabilities and threats in order to develop and implement policies and mechanisms to strengthen the BWC.

As we get ready to kick off the 2019 Global Forum, I am reminded of the statement by Mr. Robert Mardini, the Head of Delegation for the International Committee of the Red Cross, to the United Nations First Committee in October. In his address, he noted that while advancements in science and technology, including biology, may be inevitable, their weaponization is not. This sentiment gets to the core of the importance of science

and technology to the BWC and the critical role of continuing to identify, understand, and evaluate emerging science and technology capabilities and their potential impact on the BWC. Rapidly emerging capabilities across biology and biotechnology have long posed challenges for the BWC, particularly with respect to understanding biological weapons risk, addressing threats from nonstate actors, and developing and implementing mechanisms to strengthen the treaty, but we hope that events like the Global Forum can help shed light on these emerging capabilities and identify policies and mechanisms to not only mitigate the associated risks, but also to leverage these capabilities to strengthen the BWC.

I am joined this morning by Ms. Anja Kaspersen, Director of the Geneva Branch of the United Nations Office for Disarmament Affairs, and His Excellency Ambassador Yann Hwang, Permanent Representative of France to the Conference on Disarmament and Chair of the 2019 BWC Meeting of States Parties. I would like to thank both of them for taking time out of their busy schedules this week to provide some brief remarks on the critical importance of advancements in science and technology for the BWC and the role of scientific engagement in developing effective nonproliferation policies. I would also like to thank UNODA for supporting our efforts directly this year, as we are cosponsoring this year's Global Forum. Judging by the attendance in the room first thing this morning, this is already proving to be a fruitful partnership, and we are excited to move forward in collaboration with UNODA to expand the reach and impact of the Global Forum in the coming years.

Without further ado, I would like to hand the floor over to Ms. Kaspersen and Ambassador Hwang. Thank you.

Introductory Remarks from Ms. Anja Kaspersen

Director, United Nations Office for Disarmament Affairs, Geneva Branch

Excellencies, distinguished delegates, ladies, and gentlemen,

Thank you, Gigi. I would first like to thank you and your team at the Johns Hopkins Center for Health Security for organizing this second annual event and for agreeing to have our Office as a co-organizer. I'm sure that the discussions today are going to make a significant contribution to the deliberations at the Meeting of States Parties this week.

As many of you know, my Office here in Geneva hosts the Implementation Support Unit of the Biological Weapons Convention. We are therefore very involved in supporting the implementation of the Convention and the conduct of its meetings here in Geneva.

As you will hear later from Daniel Feakes, the head of the Implementation Support Unit, we have been conducting a range of activities in recent years focusing on the implications of advances in science and technology for the Convention.

One set of activities will be described in more detail at a side event from 09:00 this Thursday, which I encourage you all to attend. This activity consisted of a series of 5 regional S&T [science and technology] workshops, and experts involved in hosting each of the workshops will describe the outcomes of the workshops at the side event.

Another initiative has been aimed at fostering biosecurity networks of young scientists in the Global South. We had a first workshop under this project here in August, and we will organize a second such workshop next year. This year, 20 young scientists from developing countries came here to Geneva to attend the Meeting of Experts on science and technology and then spent 2 days discussing S&T issues. They have since established a vibrant and active online community from which I am hopeful other initiatives will develop.

Both of the activities I mentioned here were funded by the European Union and were supported by experts from the Johns Hopkins Center for Health Security. This demonstrates the vital role of partnerships between the United Nations and scientific communities when discussing issues at the intersection of science and policymaking and diplomacy.

It is for this reason that we were very keen to be involved in the organization of this event. The Secretary-General of the United Nations, himself an engineer by training, has frequently stressed the importance of dialogue between science and diplomacy, particularly with regard to emerging technologies. His Disarmament Agenda, which he launched here in Geneva last year, and which our Office is actively implementing,

contains specific action items on promoting dialogue on these issues and bringing scientific expertise more actively into disarmament discussions. Our involvement in this event today should therefore be seen in the context of the Secretary-General's overall agenda to incorporate scientific expertise into international policymaking.

As we look at the programme for today's discussions, and the agenda for the Meeting of States Parties itself, I would like to refer to 3 areas in which I think that science and technology can make a vital contribution to the BWC; these are preparedness, safeguarding the peaceful uses of biology, and building capacities to review and assess relevant scientific advances.

We will hear more about these 3 topics during this week, and I am glad to see all 3 of them reflected in the programme for today's discussions. They are of importance to the current geostrategic landscape and will only grow in importance as we look forward.

Next year marks the 45th anniversary of the BWC, and the following year will see the Convention's Ninth Review Conference. Next year also marks the 75th anniversary of the founding of the United Nations. These events will hopefully encourage us all to frame our discussions not only in a historical context but also in one firmly looking to the future.

I wish you all the best for the discussions today and would like to once again thank Gigi and the Johns Hopkins team for bringing this fabulous event to UN Geneva.

Thank you.

Introductory Remarks from Ambassador Yann Hwang

Chair, 2019 BWC Meeting of States Parties

Thank you for the invitation to attend this second annual Global Forum on Scientific Advances Important to the Biological Weapons Convention. I applaud the Johns Hopkins Center for Health Security and the United Nations Office for Disarmament Affairs for organizing this meeting.

The Center for Health Security is a world leader in examining how scientific and technological innovations can strengthen health security. The Center operates an amazing range of activities from meetings such as this, to the Emerging Leaders in Biosecurity Initiative, to exercises such as the recent Event 201 high-level pandemic policy exercise and multilateral dialogues with countries from different regions around the world.

The Office for Disarmament Affairs is a vital part of the international disarmament machinery. Its Geneva Branch hosts the Implementation Support Unit of the Biological Weapons Convention, which plays a crucial role in supporting States Parties in their implementation of the Convention, and I would like to thank Ms. Kaspersen for her Office's vital support to the Convention.

Today you will consider issues which are vital, not just for the BWC itself, but also for international peace and security, and perhaps even for our future survival.

We have heard in this year's report from the Global Preparedness Monitoring Board how there is a very real threat of a rapidly moving, highly lethal pandemic killing 50 to 80 million people and wiping out nearly 5% of the world's economy. A global pandemic on that scale would be catastrophic, creating widespread havoc, instability, and insecurity.

This threat is taken seriously by those of us here in Geneva who work on the Biological Weapons Convention, as is the urgent need for global action to mitigate the consequences. In its report, the Board concluded that the world is not currently prepared for such an eventuality. It is therefore highly appropriate that you are meeting here in Geneva on the eve of the 2019 Meeting of States Parties to the BWC.

As most of you know, the BWC was the world's first multilateral treaty to ban an entire category of weapons of mass destruction. While subsequent treaties covering other WMD have incorporated robust verification systems, the BWC remains a bulwark against the hostile use of biology. No country today even publicly admits to possessing biological weapons, let alone actually uses them.

Turning to the subject of this global forum, we also need to maintain our vigilance with respect to advances in science and technology that are relevant to the BWC. During this meeting, you will hear from a world-class and regionally diverse group of experts about the cutting edge of biology and current approaches to addressing the risks and benefits posed by scientific advances.

I am pleased to see that this global forum will also discuss the "positive role" of advanced biology. Scientific advance is not something that we should fear; instead, we should celebrate it. Without scientific advances, our world would be a very different place. We should not see science and technology as an existential threat.

We cannot un-invent these advances, nor should we. We cannot simply ban new technologies or keep them limited to a small number of countries. We need to all work together—across our traditional boundaries and silos—to come to consensus agreements on how to manage such advances, while taking account of ethical, environmental, legal, economic, societal, and, of course, security implications.

I have to leave now to attend to preparations for tomorrow's Meeting of States Parties, but I would like to thank once again the Johns Hopkins Center for Health Security for organizing this meeting, and I wish you all stimulating discussions today and look forward to hearing about the outcomes of your deliberations.

Summary of Forum Sessions

Session 1: Gene Drives and Engineered Ecology

What can we expect from these advancing capabilities, and what are their implications for the BWC?

Moderator:

Michael Montague, PhD, Senior Scholar, Johns Hopkins Center for Health Security, United States of America

Panelists:

1. Philipp Messer, PhD, Assistant Professor, Cornell University, United States of America
2. Chloe Hawkings, PhD, Assistant Professor, Rutgers University, United States of America
3. Michael Santos, PhD, Associate Vice President of Science, Foundation for the National Institutes of Health, United States of America
4. Alexander Kagansky, PhD, Head, Center for Genomic and Regenerative Medicine of the School of Biomedicine, Far Eastern Federal University, Russia

The first panel focused on gene drives, an emerging biotechnology capability that has received widespread attention as both a revolutionary tool to combat infectious diseases and a potential major threat to the environment and ecosystems around the world. Dr. Michael Montague opened with a brief overview of the relevant technical aspects of gene drives and some of their potential benefits and limitations. Dr. Montague noted that the primary application of gene drives is to manipulate wild species, rather than farmed species, due to a variety of factors. In addition to the technical aspects of gene drives, he also highlighted a variety of ethical concerns about their future use.

Dr. Philipp Messer provided a detailed look at potential uses of gene drives and ongoing efforts to model their effects in the environment, including 2 particular foci of current gene drive research: (1) propagating a desired characteristic throughout a target population, and (2) driving a target population to zero. The first use has been studied for malaria control by promoting the spread of antimalarial genes in mosquito populations. The second has been proposed to reduce targeted mosquito populations and invasive species by forcing sterility or altering sex ratios. Both desired outcomes of gene drives have the potential to cause deliberate or accidental deleterious effects on ecosystems

around the world, so it is crucial that researchers better understand and characterize the potential effects of their release, both intended and unintended. Dr. Messer discussed efforts to model gene drives in target populations, including the effects of resistance to the gene drives and fitness cost to the modified organisms that could negatively affect the ability to propagate the desired characteristics through the target population. He used several animations to illustrate these effects and discussed the need for further research to understand the limitations and capabilities of gene drives.

Dr. Chloe Hawkings described how certain characteristics of insects make them ideal targets for gene drives, and she delved into some of the ethical issues associated with utilizing gene drives in wild populations. Insects exist in large populations and exhibit short generation times with large numbers of offspring; thus, gene drive traits can be rapidly spread through a given population. Insects also have fairly well-characterized genomes, which further increases our ability to identify target genes. In addition to the technical challenges, the use of gene drives faces a number of ethical considerations, including the cascading ecological ramifications of driving a species to extinction, the spread of modified organisms beyond the target population or geographical area, and the risk of transferring modified genes to nontarget organisms. In particular, Dr. Hawkings noted that gene drives have demonstrated the potential to be one of the most powerful tools for combating disease spread, and any misuse, deliberate or accidental, could severely erode public confidence and willingness to use gene drives in the future. In order to mitigate these risks, further investigation is needed to identify appropriate ways to utilize gene drives in advance of their use, including identifying the most appropriate target genes and organisms, identifying and implementing effective regulatory mechanisms, and developing technical means of limiting, controlling, or countering gene drives after they have been released.

Dr. Michael Santos built on the theme of gene drives as a powerful tool for vector-borne diseases. He noted the considerable global burden from vector-borne diseases, including more than 700,000 deaths each year worldwide. Each year, more than 400,000 people die globally from malaria alone (with more than 90% of cases in Africa), and malaria control efforts cost more than US$3 billion annually. In addition to the benefits discussed previously on this panel, gene drives offer other potential advantages over traditional interventions, such as the use of insecticides. Only about 5 species of mosquito out of more than 3,500 are responsible for malaria transmission. Using insecticides would indiscriminately kill all species of mosquito in the target area, as well as other types of insects; however, gene drives could target specific species (or even subspecies) without killing others. This level of precision could reduce the direct impact on the ecosystem by limiting the scope of affected species. Despite the potential for success, many barriers remain. As noted previously, no gene drives have been deployed in the wild, and additional research is needed to determine how laboratory studies will translate to larger-scale application in complex and uncontrolled environments. One of the biggest challenges facing gene drives, beyond the technical aspects, is establishing effective and appropriate governance or regulatory mechanisms for their use. At this

point, most of the regulatory policies and frameworks that address gene drives were established for genetically modified organisms (GMOs). While gene drive mosquitoes do fall under the umbrella of GMOs, this term is typically used to describe plants and crops that have been genetically modified but do not spread their modified genes through wild populations. Thus, existing regulatory policies, legislation, and programs may not adequately address the unique characteristics of gene drives, including those discussed previously. Risk assessments are ongoing in a variety of settings, including in research facilities and in government programs and regulatory agencies, to provide input for decision makers and support the development of appropriate oversight mechanisms.

Dr. Sasha Kagansky provided the perspective of advanced biology and biotechnology work going on outside of academic and government laboratories, with a particular focus on the do-it-yourself biology (DIY Bio) community. He discussed an ongoing effort to better understand and characterize the types of researchers, settings, work, regulatory mechanisms, and perceptions in place in the DIY Bio community around the world. Because the DIY Bio community exists largely outside of formal research facilities and programs—and associated oversight and regulatory systems—there is considerable uncertainty regarding how these researchers operate, including questions regarding ethical and safety training and practices. Dr. Kagansky presented findings from a survey of DIY Bio participants around the world, an early step in a larger effort to inform effective policy decision making and implementation to address DIY Bio research and practice. Respondents were asked to consider the risk (low, medium, high) of various types of DIY Bio research and techniques, including "bioart," gene drives, gene therapy, CRISPR, and bioprospecting. The majority of respondents assessed each of the 5 categories to be medium or high risk, with gene therapy and bioart receiving the highest proportion of "high risk" responses. Additionally, the survey asked about research settings and organisms used in DIY Bio work. Overall, 79% of respondents indicated that they worked in collaboration with other researchers, compared to only 21% who worked alone. The participants indicated the use of a broad scope of organisms in their work—including viruses, fish, birds, and mammals (including humans)—but the most common organisms were bacteria (~30%), plants (~20%), and fungi (>15%). Notably, between 5% and 10% of respondents reported using mammals, including humans. This effort will continue with targeted interviews and focus groups, which will aim to further characterize the DIY Bio community, identify appropriate mechanisms to ensure that their work can continue safely, and communicate these needs to appropriate policymakers.

Session 1: Q&A

Following the expert panel presentations, Global Forum attendees were given an opportunity to make comments and ask questions of the panelists. Most of the comments and questions in Session 1 addressed concerns about potential negative effects of gene drives and mechanisms in place to mitigate those risks. One attendee called attention to the risk that gene drives could be used for nefarious purposes and

suggested that a moratorium on gene drive research could be an appropriate mechanism to mitigate this risk. The panelists first highlighted that the characteristics of gene drives, including a limited ability to control which populations are targeted after release, would likely make gene drives undesirable as a weapon, although gene drives could, from a technical perspective, impart negative characteristics with the same efficiency as those desired for positive purposes. This argument is often cited for biological weapons more broadly, particularly those capable of transmitting beyond the primary victims, but this may not necessarily be a deterrent for all actors. Second, gene drives are covered under the BWC, like any other potential biological weapon, which further acts as a deterrent to the development and use of these capabilities for nefarious purposes. Additionally, the panelists noted that a number of programs researching gene drives are investigating tools to counter or remediate the effects of gene drives, which essentially involve the use of gene drives themselves. A moratorium on gene drive research would also apply to the research necessary to counter their effects.

Other questions focused on more technical issues, including the biosafety precautions necessary to work on gene drives, the prevention of transboundary (ie, cross-border) spread of gene drives, and international agreements that address gene drives. The panelists stated that most gene drive research occurs in BSL-2 containment, typically in BSL-3 facilities. Because the gene drives themselves are not infectious in humans, the larger concern is preventing the release or escape of the vectors—typically insects—from containment. The issue of transboundary spread remains a challenge, but some frameworks do exist to mitigate this risk. Existing customs and border control programs—particularly those that govern the importation of animals, meat, and produce—can provide surveillance, deterrence, and protection against importing potentially dangerous materials. Additionally, the Convention on Biological Diversity explicitly regulates modified living organisms, including transboundary issues. Finally, collaborative national and regional efforts to address vector control and risk assessment can provide more consistent approaches across multiple countries to mitigate transboundary threats.

Session 2: Advancing Agriculture and Animal Science

What is the current state of capabilities, and what are the impacts on the BWC?

Moderator:

Gigi Gronvall, PhD, Senior Scholar, Johns Hopkins Center for Health Security, United States of America

Panelists:

1. Christine Uhlenhaut, PhD, Chargée de Mission for Biological Threat Reduction, World Organisation for Animal Health (OIE), France
2. Luis Alberto Ochoa Carrera, MSc, Head, Epidemiological Surveillance & Research Laboratory Network, Mexican Institute for Social Security, Mexico
3. George Obiero, PhD, Director, Centre for Biotechnology and Bioinformatics, University of Nairobi, Kenya
4. Faisal Khan, DPhil, Director and Assistant Professor, Institute of Integrative Biosciences, CECOS University, Pakistan

The second panel of the day emphasized the importance of advances in science and technology on plant and animal health, particularly in the context of agriculture and deliberate biological threats. Animal and plant health are growing areas of interest in the BWC, and this session addressed challenges at the nexus of advanced biology and biotechnology, plant and animal health, and deliberate biological threats. Historically, discussions and policies aimed at mitigating the risk of deliberate biological threats have focused on direct threats to human health, much like public health and health care more broadly. But as attention to the complex and interconnected nature of human, animal, plant, and environmental health has grown, so has attention on the potential for deliberate biological threats on animals and plants and the potential downstream effects on human health and social, economic, and political stability. Many countries around the world depend heavily on agriculture for economic and food stability, and attacks on agricultural plants and animals could have devastating effects on human populations. The ongoing epidemic of African swine fever in Asia illustrates the potential impact that an animal disease can have on national and regional economics, food security, and human health.

The second session opened with a presentation by Dr. Christine Uhlenhaut, who discussed the importance of laboratory networks and capabilities, including the shift from highly capable but centralized laboratories toward distributed field-based capabilities. She noted that there are still large geographic regions that do not have animal-specific reference laboratories, including Central America, Africa, and Central, South, and Southeast Asia, all areas that rely heavily on agricultural economies and

face a myriad of animal and zoonotic disease threats. Advances in biotechnology have supported the emergence of new diagnostic and screening capabilities, including robust handheld and field-deployable assays that can provide rapid and accurate results in low-resource settings. Dr. Uhlenhaut also noted the potential for gene drives and other synthetic biology capabilities to improve disease control for animals and increase the efficiency of agricultural practices, including meat and milk production and developing resistance to various pathogens. Additionally, international programs and consortia, such as the Coalition for Epidemic Preparedness Innovations (CEPI), support the development of novel medical countermeasures (MCMs), including via emerging biotechnology capabilities, that could provide critical protection for ongoing, emerging, and future health emergencies. While CEPI focuses on human diseases, these same techniques and technology could also be leveraged for animal and plant diseases, which would be particularly helpful in situations such as the current African swine fever outbreak. In addition to synthetic biology and biotechnology, other emerging fields of technology have tremendous potential to support animal and plant health, especially for agriculture. Drones, particularly the airborne variety, are capable of supporting a wide variety of processes, ranging from seed planting and crop spraying to mapping and surveillance (including for diseases). Drones could be useful in implementing advanced capabilities and making more efficient use of available resources compared to current practices. But these advances do not come without risks. As illustrated by the de novo synthesis of horsepox in 2016, scientists now possess the ability to construct viable pathogens without access to specimen samples. This experiment raised concerns that scientists could use this capability to resurrect eradicated pathogens. Only 2 pathogens have been successfully eradicated: smallpox, a human-specific virus, and rinderpest, a highly lethal virus in cattle and other similar animals. The return of rinderpest via de novo synthesis, particularly in an unvaccinated and wholly susceptible cattle population, could be devastating to agricultural economies, food security, and human health around the world.[3]

Mr. Luis Ochoa Carrera, Head of the Epidemiological Surveillance & Research Laboratory Network at the Mexican Institute for Social Security, continued the second session with a more explicit focus on agroterrorism. Mr. Ochoa began with a discussion of the factors that place agriculture at risk for deliberate biological events. Agricultural activity often spans large geographic areas that encompass the fields and pastures required to cultivate plants and raise animals; these large areas are difficult to secure against criminal or terrorist activity. Additionally, some livestock are confined to specific areas, such as chicken egg-laying facilities, which can facilitate the rapid spread of disease. Animals and plants are also vulnerable to more pathogens than humans, many of which are hardy and persistent in the environment or easily accessible in endemic areas, which can allow nefarious actors to bypass government programs designed to limit access to dangerous pathogens. Additionally, since livestock and agricultural crops are not regularly exposed to foreign pathogens, they often have little or no immunity to new pathogens, making them particularly vulnerable. Even the rumor, suspicion, or threat of an outbreak could have a significant impact on agricultural operations or

negative economic or food security consequences, including through the culling of entire populations of animals or the destruction of entire plant crops. The impact of such an event could have far-reaching economic implications for individuals, farms and farmers, local or national governments, relevant businesses or industries, and related larger national, regional, or global economic systems. A number of barriers remain to addressing agroterrorism threats. Like many biosafety and biosecurity issues, limited financial resources, awareness, interest, and political will hinder progress in efforts to establish and implement appropriate training and ethics programs and national-level policies to address agroterrorism threats. Mr. Ochoa noted that many of the terms and concepts associated with agroterrorism overlap with existing programs that address other topics or threats—including the term "biosecurity." These overlaps potentially result in duplication of efforts—further stressing limited resources—and limit the ability to combat agroterrorism directly. A multisectoral and multilateral approach is necessary to identify appropriate levels of oversight and regulation for potential agroterrorism threats, which could vary by country or sector.

Dr. George Obiero discussed plant and animal biotechnology research at his center—the Centre for Biotechnology and Bioinformatics (CEBIB) in Kenya—and its role in plant and animal health in Africa. As a whole, Africa faces a diverse and complex set of biosecurity challenges and threats, ranging from agricultural and food security challenges to emerging and high-consequence infectious diseases. Advances in biology and biotechnology offer the promise of novel solutions to these problems, many of which have affected African countries for decades or longer. CEBIB is housed at the University of Nairobi in Kenya, but it comprises research and postgraduate training programs across the continent that support collaborative efforts to address a myriad of human health, agricultural, industrial, and environmental issues. Recent and ongoing research facilitated by CEBIB includes bioprospecting to identify catalysts to optimize industrial fermentation processes, screening and monitoring for contamination in food sources and antimicrobial resistance in cattle, implementing surveillance and diagnostics for emerging infectious diseases such as foot and mouth disease and rabies, and improving crop resistance to diseases and drought to increase crop yields. Collaborative efforts like those at CEBIB are critical to identifying local and national needs and identifying sustainable solutions, but it is critical to implement effective biosafety, biosecurity, and ethics oversight. CEBIB implements both top-down and bottom-up approaches to promote and ensure the responsible conduct of research. CEBIB collaborates with national governments and other institutions to ensure appropriate policies and programs are in place, including institutional biosafety committees, and implements biosafety/biosecurity and ethics training for students, starting at orientation. Additionally, CEBIB leads formal and informal efforts to inform and educate the public and raise awareness about their research efforts.

Dr. Faisal Khan closed out the second expert panel with a discussion of the current state of the synthetic biology community in Pakistan. Pakistan is largely an agricultural country, so plant, animal, and environmental health are primary concerns, including

water quality, improving plant growth and crop yields, and environmental and biological/disease surveillance. The growth of the synthetic biology community in Pakistan has largely been driven through grassroots support by early adopters, such as teams competing in the International Genetically Engineered Machines (iGEM) program. The community has now established a number of foci, including community-based laboratories, industry and private sector start-up companies, academic institutions, and the health sector. Community seminars and training are even available in some locations to raise awareness and interest in synthetic biology, particularly for younger students. A reinvigorated National Institute of Health and an active Pakistan Biological Safety Association (PBSA) have begun to address synthetic biology and advanced biotechnology issues directly and holistically at the national level, but many barriers remain to fully leveraging these capabilities and ensuring their appropriate and responsible use in Pakistan. As in many countries, the pace of advances in biology and biotechnology capabilities has outpaced regulation and oversight efforts. Dr. Khan described how some cultural norms and legacy systems hinder interdisciplinary and multisectoral collaboration, including at academic institutions. Additionally, the responsible conduct of research is currently not part of most formal education curricula, so it may be necessary to identify other mechanisms to promote these principles and ethics. Potential options include top-down approaches, such as through the PBSA, or bottom-up approaches, including through support from members of the growing synthetic biology community themselves, including iGEM teams and alumni. The current economic climate in Pakistan has made it difficult for the national government to prioritize advanced biology and biotechnology for investment. Still, Pakistan has a relatively young population, and dedicated resources could help to develop a cadre and network of rising students and professionals to drive the field of synthetic biology in Pakistan.

Session 2: Q&A

The question-and-answer portion of Session 2 largely focused on the responsible conduct of research in the context of plant and animal health. One attendee asked about the risk that synthetic biology and the deliberate misuse of biological agents poses to agriculture. The panelists noted that while agriculture faces a broad scope of threats—including natural and accidental risks posed by climate change, industrial chemicals and radiological material, and pests—there has not yet been a documented example of a deliberate biological event associated with agriculture. The degree of impact of such an event would likely vary by country and crop, and national and regional risk assessment efforts would be the best source of information on the potential impact.

Other questions focused on applying principles of "the responsible conduct of research" consistently at the international level and what kind of mechanisms would be necessary to reinforce these principles. One challenge is the absence of a consensus definition of "responsible research." While there may be similarities across different applications of this concept, the exact conditions and considerations may inherently vary by

country, field, purpose, and other factors. Different research settings may use different definitions of "acceptable risk," which will factor into how they determine what research is acceptable and responsible to conduct. Despite variations in how these concepts are defined and applied, there are multiple sources of guidance on these topics at the international level. In order to more consistently apply these principles across countries, a holistic approach is needed. International perspectives, including from developing nations, are needed to better understand their needs and concerns in order to more effectively evaluate the risk-benefit balance for proposed research. Agricultural risks are often viewed as secondary to human and animal health threats, but biological attacks on agricultural targets could result in significant human and animal health as well as economic consequences, particularly for monoculture economies. Increased attention to agricultural threats can provide necessary and critical input to evaluations of proposed research, which can improve the utility of these assessments.

Session 3: Barriers and Opportunities for Addressing Science and Technology in the BWC

What policies for cutting-edge biology could strengthen the BWC?

Moderator:

Nancy Connell, PhD, Senior Scholar, Johns Hopkins Center for Health Security, United States of America

Panelists:

1. Daniel Feakes, MA, Chief, BWC Implementation Support Unit, Switzerland
2. Jonathan Forman, PhD, Science Policy Advisor, Organisation for the Prohibition of Chemical Weapons, The Netherlands
3. Gigi Gronvall, PhD, Senior Scholar, Johns Hopkins Center for Health Security, United States of America
4. Katherine Littler, Co-Lead, Global Health Ethics, World Health Organization, Switzerland
5. J. Milkah Muthoni Mwangi, MSc, Senior Research Scientist, Kenya Medical Research Institute (KEMRI), Kenya

The final session of the 2019 Global Forum focused squarely on the perspective of policies and programs that could be implemented at the global, national, or facility level to balance the potential benefits and risks associated with emerging biology and biotechnology capabilities. Oversight and regulation of emerging capabilities is necessary to mitigate risks, but associated limitations can potentially stifle progress or hinder countries' ability to leverage these capabilities for peaceful purposes.

The panel opened with Mr. Daniel Feakes, who addressed how the BWC has historically approached emerging science and technology. He noted that BWC States Parties explicitly identified the challenges posed by emerging capabilities at least as far back as the Second BWC Review Conference in 1986. He also commented that the traditional approach in the disarmament and nonproliferation communities focuses largely on the risks associated with these advances, but there are many benefits as well. For many years, the BWC has attempted to incorporate technical expertise into discussions on how to best address science and technology, including through the BWC Meetings of Experts, but there is likely an opportunity to update this model to better leverage the scientific community in these discussions.

Dr. Jonathan Forman provided insight into how the Chemical Weapons Convention (CWC) approaches the process of evaluating and adapting to emerging capabilities.

While both the BWC and CWC include specific language requiring States Parties to evaluate emerging science and technology, neither treaty delineates how this should be accomplished. And interestingly, neither treaty explicitly includes challenges or benefits associated with these advances. The biggest difference between the BWC and the CWC lies in their respective approaches to operation and implementation. While the BWC has the Implementation Support Unit, a dedicated 4-person team responsible for coordinating all BWC meetings and related activities, the CWC has the Organisation for the Prohibition of Chemical Weapons (OPCW), which involves hundreds of administrative and technical experts tasked with addressing all aspects of CWC implementation, including the assessment of emerging science and technology issues. Much like the BWC, rapid scientific progress is posing significant challenges for the CWC, especially through the use of artificial intelligence and computing, which can even further increase the pace of progress. Beyond simply evaluating the capabilities of emerging techniques and processes, the biggest barrier to addressing emerging science and technology is uncertainty. As noted previously, science and scientific advances are not inherently bad, so preventing deliberate misuse must rely on identifying unusual or risky behavior or signals of potential nefarious activity, which is a major challenge. Finally, Dr. Forman addressed the potential limitations of implementing these policies around the world. National-level policies are necessary to ensure appropriate oversight and governance of scientific research and material, but countries will inevitably take different approaches to doing so. These differences will introduce variation in the efficacy of these policies, which could potentially result in associated vulnerabilities and gaps that can be exploited. International coordination is critical to promote consistent application of these policies, which can mitigate risks and enable all countries to benefit.

Dr. Gigi Gronvall focused on the governance of gene synthesis. A number of existing regulatory structures and frameworks exist to mitigate the risk of the deliberate misuse of dangerous pathogens, including Select Agent programs; however, these programs typically rely on preventing access to these pathogens. The ability to synthesize the genome of dangerous pathogens de novo enables individuals or groups to circumvent existing restrictions by creating dangerous pathogens from scratch. The International Gene Synthesis Consortium, an industry-led group of gene synthesis companies, aims to address this threat by screening gene synthesis orders to identify potentially risky sequences before orders are filled.[4] These companies represent approximately 80% of the volume of gene synthesis orders worldwide, but this is far from an ideal solution. As was demonstrated in 2016 with the de novo synthesis of the horsepox virus, it is possible to obtain the genetic material necessary to assemble a functional virus genome, even for large and complex viruses.[5] Additionally, recent advances in synthetic biology techniques enable researchers to build genomes from increasingly smaller fragments of DNA or RNA, which significantly decreases the effectiveness of screening algorithms. Furthermore, “benchtop synthesizers” offer distributed synthesis capabilities that may be able to operate outside of existing screening networks and enable users to create any desired genetic sequence at the individual lab level. Dr. Gronvall discussed a number of screening options to help mitigate these risks. One option is to classify benchtop

synthesis units and genetic "modification" or "assembly" companies as "providers" of genetic material, which would bring benchtop synthesis technologies into existing governance structures and allow for the development of future targeted legislation or governance. She also recommended mandating the use of screening algorithms, requiring government-funded research to use companies that participate in screening networks, and supporting the development of improved screening processes and international collaboration to ensure global coverage.

Dr. Katherine Littler addressed a myriad of challenges in regulating emerging technologies and capabilities. She emphasized that emerging technologies do not exist in a vacuum and that they will inevitably merge with existing and future capabilities. This eventuality necessitates the development of regulatory frameworks that are capable of implementing appropriate limits on emerging and future technologies without adversely affecting other technologies or combinations of technologies. Dr. Littler noted that existing governance frameworks provide patchwork and inconsistent coverage for advancing technologies. Opacity and poor clarity in the purpose, scope, approach, and authority of these programs; overlapping, but not necessarily complementary, frameworks; and a myriad of enforcement and implementation challenges have resulted in critical gaps and variation in how countries, organizations, and industries address emerging biology and biotechnology capabilities. Regulatory systems often move slowly, either by design or necessity, and the rapid pace of advancement, democratization, international collaboration, and transfer of these capabilities far outpaces these systems' ability to adapt to new capabilities. Rather than addressing individual technologies or capabilities, a holistic approach is needed to maintain the flexibility and responsiveness necessary to establish and maintain the oversight for these technologies. Critically, regulatory mechanisms need to incorporate the expertise and perspectives of scientists to develop and employ advancing technologies, as they are the most familiar with the associated capabilities and risks. Additionally, regulatory programs should contribute to and encourage the implementation of efforts to promote effective regulatory mechanisms among the scientific community, including efforts to promote the responsible use of science. Dr. Littler also introduced the work of the WHO Expert Advisory Committee on Human Genome Editing, which is addressing many of these issues in response to the so-called CRISPR babies born in China in 2018. The committee consists of 4 working groups dedicated to tackling issues associated with identifying and registering relevant research, cultivating a commitment to the responsible stewardship of science, providing appropriate oversight for the research, and facilitating education and engagement with the scientific community and the public. The ongoing work of this committee is dedicated to identifying the scope of appropriate governance frameworks, the mechanisms to implement effective oversight and regulation, and the stakeholders—including government agencies, funders, research institutions, researchers, and patients—that should have input into regulatory decision making.

Closing out the final session, Ms. J. Milkah Mwangi discussed challenges and opportunities in the context of emerging biotechnology and efforts in Kenya to establish Africa as a leader in effectively leveraging these capabilities. Many countries in Africa, like most developing nations, face a myriad of barriers to gaining access to and using emerging biotechnology processes, equipment, and expertise. Ms. Mwangi approaches these challenges as opportunities, such as the opportunity for Kenya and other African countries to be proactive in establishing themselves as global leaders on these issues. For example, there is still considerable uncertainty regarding off-target effects or incomplete targeting mutations associated with CRISPR and other techniques; however, this is also an opportunity to establish longer-term studies that can provide valuable data. Additionally, aging experts may risk the loss of expertise in their field, but this provides opportunities for mentorship to support the establishment of future cadres of global experts and leaders. The absence of existing mechanisms to provide oversight of scientific research can be an opportunity to implement programs based on best practices identified by experts around the world and to address the complexities of updating existing but ineffective mechanisms. Africa faces a myriad of health and biosecurity risks for which advances in biology and biotechnology could hold the solutions, so there is considerable incentive for these countries to take the lead on biotechnology governance to ensure that they are in the best position to take advantage of new capabilities. In that vein, Kenya has implemented measures to improve its ability to address emerging risks and technologies, including a national bio-risk curriculum to instill these principles in rising students and professionals; national regulatory bodies, including the National Biosafety Authority and Institutional Review Board; and new and updated national legislation to govern the import and export of dual-use technologies. Ms. Mwangi also introduced the African Women for Biosciences program, which was established to facilitate increased engagement of African women in biology and biosecurity policy discussions. The program supports the development of a diverse and representative professional network in Africa and provides additional perspectives on critical policy challenges and decisions.

Session 3: Q&A

In the final discussion period, the participants addressed a range of issues regarding how to improve the BWC's ability to identify, evaluate, and leverage advances in science and technology. One attendee asked about mechanisms to increase the number of scientists involved in diplomacy, and the panelists addressed a broad scope of potential benefits and challenges associated with this proposition. First, scientists are well positioned to provide technical input for policy discussions and provide context for broad scientific concepts and capabilities, which could improve scientific literacy among diplomats and support effective and evidence-based policy decisions. That being said, there are potentially barriers to translating technical expertise to diplomatic discussions. One panelist commented that communicating technical information is different than some of the "political theatrics" that are inherently a part of diplomacy, and the communication skills required for each may not necessarily translate to the other. Additionally, diplomatic solutions may necessarily require concessions to political

necessity, which may run counter to scientific evidence. Attendees also asked about mechanisms under the auspices of the BWC itself to identify and evaluate emerging scientific advancements. The BWC does not currently have a dedicated body to monitor advances in science and technology, but several proposals have been mooted, including various forms of a scientific advisory board and expanded involvement of technical experts in BWC meetings, such as the Meetings of Experts. Outside the BWC, other international bodies, including the WHO, have various mechanisms in place to proactively evaluate particular areas of scientific advancement. The biggest challenges facing these efforts are adequately evaluating potential risks and benefits of emerging and future capabilities under considerable uncertainty and implementing effective regulation and oversight that can mitigate risks without unnecessarily stifling progress. In order to address these challenges, efforts to identify and assess emerging capabilities must draw lessons from similar capabilities that emerged in other fields and other advances as well as assessment techniques and mechanisms used in other fields and fora, particularly at the international level.

Keynote Address

The 2019 Global Forum's Keynote Address was delivered by Dr. Alessandro Marcello, Group Leader for the Molecular Virology Laboratory at the International Centre for Genetic Engineering and Biotechnology (ICGEB) in Trieste, Italy. Dr. Marcello introduced some of the broad scope of work conducted by ICGEB to support the development and adoption of advanced biotechnology and genetic engineering capabilities around the world. ICGEB's mandate includes not only assisting Member States in their efforts to strengthen the fields of genetic engineering and biotechnology, but crucially, also promoting international collaboration for the peaceful application of these capabilities. This mandate aligns well with Article X of the BWC, which obligates States Parties to contribute—individually, in collaboration with other States Parties, or with international organizations, such as ICGEB—to "further the development of scientific discoveries in the field of [biology] for the prevention of disease, or for other peaceful purposes."

In addition to conducting research directly at its own facilities, ICGEB's mission includes facilitating technology transfer to Member States, including for the research, development, and production of vaccines and other MCMs, which further supports the underlying aim of Article X of the BWC. Beyond technical research and development, ICGEB supports a variety of education and collaborative initiatives—including graduate education programs, fellowships, workshops, and other training—designed to facilitate engagement with the global scientific community on a variety of priority and emerging issues. As noted throughout the 2019 Global Forum, as well as the inaugural Global Forum in 2018, engaging scientists is critical to building awareness of the importance of identifying and understanding the potential risks associated with emerging and future advances in biology and biotechnology. Additionally, these efforts provide fora in which to cultivate sustainable programs dedicated to implementing effective risk assessment and mitigation policies, which will further support the nonproliferation norms associated with the BWC. These programs also include research grants to support training early career scientists and establishing research facilities in Member States, and many of these grants have been awarded to institutions in developing countries, illustrating the value of ICGEB to supporting the efforts outlined in Article X of the BWC.

Finally, ICGEB provides technical assistance and capacity building to Member States, with a focus on supporting the development and implementation of appropriate regulatory and oversight mechanisms for biotechnology and associated capabilities and products at the national level. For example, ICGEB collaborated with countries across sub-Saharan Africa—with support from the Bill and Melinda Gates Foundation—to enhance regulatory capacity and incorporate sustainable technical expertise in regulatory agencies in order to improve countries' ability to regulate emerging biotechnology, with a focus on those used for agricultural purposes. ICGEB also collaborated with the Gates Foundation to support the development of an e-learning

platform aimed at scientists that includes modules on biosafety and biosecurity that support risk assessment and mitigation at the operational level, including for dual-use research. This platform has already been adopted by 6 national-level regulatory agencies in Africa.

Dr. Marcello closed with a more direct look at the role of ICGEB in supporting the BWC and nonproliferation norms. ICGEB conducts and supports a broad scope of research and development for diagnostic tools and MCMs that could support surveillance and response to health emergencies, including deliberate biological events. By supporting research efforts in Member States and facilitating technology transfer, particularly to developing countries, ICGEB is playing a direct role in promoting geographic distribution and democratization of advanced biotechnology capabilities for peaceful purposes. These capabilities include the development of diagnostics, vaccines, and other MCMs and local MCM production capacity that could be critical to initiating rapid outbreak response operations. Additionally, the training and outreach programs supported by ICGEB align with a number of other programs, including the Global Forum, to build awareness of important principles, such as risk assessment and mitigation, related to biological weapons nonproliferation among the scientific community and future generations of scientists. Scientists working for ICGEB or in programs supported by ICGEB are on the front lines of advancements in biology and biotechnology, and these experts are critical to understanding the current and future capabilities associated with these technologies, including potential risks and opportunities to leverage these capabilities to support the prevention of and response to natural, accidental, and deliberate biological events. The BWC has long struggled to effectively identify and account for rapid advancements in biology and their potential impacts, positive and negative, on the treaty, and input from global experts working on the cutting edge of these advances is critical for the BWC and other international treaties to remain flexible and adaptable to future risks.

Keynote Address: Q&A

The attendees had a number of questions for Dr. Marcello regarding the development and deployment of field-based diagnostic tools, particularly in resource-limited settings. One attendee asked about the training requirements for responders, with a focus on biosafety and biosecurity considerations for using these tests in the field. Dr. Marcello highlighted the importance of adequate training for responders employing the diagnostics. Many of these tests are designed so that they can be used by nontechnical personnel and laypersons, but it is critical to ensure that all personnel receive proper training on both operations and safety for these tools. Another major concern was cybersecurity and protection of personal data, including for cell phones and other handheld or field-deployable devices. Dr. Marcello commented that advanced security algorithms and techniques, including emerging capabilities like blockchain, can provide high-level protection for handheld electronic devices and data transmissions. He also noted that distributed systems using handheld units in the field would necessitate the

use of centralized data storage and processing systems to validate and manage the field-collected data. The field-based tools are designed to provide rapid results and preliminary data, but verification is required. Security for these systems is paramount as well. Finally, Dr. Marcello responded to a question about the development of novel diagnostics and pharmaceuticals by emphasizing that the priority for ICGEB is focused on providing rapid access to diagnostics and pharmaceuticals in limited-resource settings as opposed to developing and producing tests and drugs for novel pathogens. Additionally, scaling up systems to achieve sustainable production and distribution capacity for these products would require significant investment.

Closing Thoughts and Future Directions

The 2019 Global Forum built on the success of the 2018 inaugural workshop. This year, more than 100 people attended the forum, representing more than 35 countries, including 6 continents and all 3 BWC Regional Groups. In addition to the BWC States Parties, the European Union and several international and nongovernmental organizations participated as well. The panelists represented diverse perspectives on a broad scope of challenges associated with emerging science and technology in the context of the BWC, and the discussion sessions provided an opportunity for in-depth debate on an array of technical and policy challenges, including between States Parties delegations and technical experts.

Looking ahead to the Third Annual Global Forum at the 2020 Meeting of States Parties, we are in the process of identifying prospective topics and participants. Our initial discussions have identified neurobiology, advanced computing and artificial intelligence, and inadvertent weaponization (ie, unintentionally developing capabilities and increasing risk for weaponization through research conducted for peaceful purposes).

The 2020 Meeting of States Parties represents one of the final opportunities for substantive discussion on challenges facing the BWC before States Parties convene for the Ninth BWC Review Conference in late 2021, when they are expected to decide on the content and format for the 2022-25 Intersessional Programme (ISP). The 2018-20 ISP provided a forum for technical discussion and debate on a broad scope of topics relevant to BWC implementation, including the assessment of advances in science and technology.

We would like to close by thanking all of the speakers, panelists, and attendees—particularly the BWC States Parties—who made the Second Annual Global Forum on Scientific Advances Important to the BWC such a tremendous success. We would also like to thank the United Nations Office for Disarmament Affairs and the BWC Implementation Support Unit for their support of the Global Forum. We are looking forward to an ongoing collaboration and partnership for future Global Forum meetings. Finally, we would like to thank the Open Philanthropy Project for providing funding support for the Global Forum project, which enabled us to invite panelists and speakers from around the world and promote the inclusion of diverse perspectives on these complex issues.

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