Final report to PASCC

# Improving Security through International Biosafety Norms

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UPMC Center for Health Security

## Acknowledgements

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## Executive Summary

This report is a compilation of the findings and recommendations discovered pursuing the Naval Postgraduate School Project on Advanced Systems and Concepts for Countering WMD (PASCC) Grant No. N00244-15-1-0028, for research entitled "Improving Security through International Biosafety Norms." The focus of this project was the potential for a biological research laboratory accident to spark an epidemic, and become an international public health problem. We examined what norms and expectations nations should have of each other to maintain a biosafety infrastructure capable of preventing and mitigating consequences a catastrophic biocontainment failure.

Most accidents in biocontainment laboratories are limited to the researchers involved and possibly their close contacts. While these accidents are unfortunate events that may have severe consequences for those directly affected, these incidents would not typically become matters of international concern. However, laboratory acquired infections (LAIs) with particularly transmissible pathogens, including non-circulating human influenza strains, Severe Acute Respiratory Syndrome (SARS), or engineered influenza strains could have consequences that go well beyond the laboratory, beyond borders, and could constitute a threat to national and global security. While there is a great deal of *technical* guidance for researchers and institutions to achieve high levels of safety, to train workers, and to foster a laboratory environment that holds safety as a priority, we found that there is a key piece is missing from the available guidance: national-level biosafety norms that could provide reassurance to other nations that consequential work is performed with appropriate and sufficient safety systems.

It would be helpful on an international level to know that potentially consequential research took place in an environment where there are high standards for the work, such as for equipment maintenance, worker safety training, health monitoring, surveillance, and other myriad activities to help keep the researchers and the larger public safe, and that the nation has an adequate surveillance system in place to identify and limit potential outbreaks that could result from such accidents. Without such national-level norms and expectations for biosafety and interest in making sure that research institutions that perform potentially high-consequence research adhere to those standards, there will remain insufficient incentives to commit the resources required to achieve high levels of biosafety in individual laboratories and institutions. Without these kinds of norms, nations will not have confidence that all necessary steps are being taken in other nations to prevent a high-consequence laboratory accident from occurring, or to limit its consequences.

Developing and agreeing to international biosafety norms is more important now than ever. Powerful tools to manipulate genomes, including CRISPR, are being used in laboratories around

the world, and even in the citizen-science community; these powerful technologies could be intentionally or inadvertently used to produce pathogens that would be difficult for public health measures to control. Additionally, there has been an increase in national laboratory capacities around the world, partly a result of the increased attention to the International Health Regulations and the Global Health Security Agenda; countries no longer are expected ship their samples to other nations with more advanced laboratory capacity, they are expected to develop that capacity within the nation to handle work with potentially pandemic causing pathogens.

Major findings of this year-long research project include the following:

1. **Through an empirical examination of all available international security and safety regulations and guidance related to biology, we found a gap related to the biosafety and governance of those pathogens that have increased potential to initiate an outbreak outside a laboratory with the potential to spread nationally or internationally, or even lead to a pandemic.** There is an extensive array of existing governmental mechanisms related to biology or infectious disease control, and we examined and summarized each, including the Global Health Security Agenda (2014), the International Health Regulations (2005), the Biological Weapons Convention, Cartagena Biosafety Protocol, and several dozen other agreements in our Synopsis of Biological Safety and Security Arrangements (published in July 2015). We found that there is a major gap in international biosafety agreements and arrangements related to high-consequence accidents that could arise with contagious pathogens (either natural pathogens or synthetic pathogens that are research constructs or artifacts).

2. **Worldwide, there is a wide divergence of the quality and quantity of biosafety regulations. Pathogens which could result in a consequential laboratory accident are not adequately addressed by publicly available regulations.** We performed case studies of the biosafety regulations of 10 nations: Brazil, China, India, Israel, Pakistan, Kenya, Russia, Singapore, the United Kingdom, and the United States. Online database searches for government documents, websites, media reports, and biosafety reviews were used to identify existing biosafety guidelines for each assessed nation and identify regulatory agencies, laboratory staff training programs, and incident response and reporting requirements. (It should be noted that this research did not address the success of implementing the relevant legislation and regulations.) Additionally, information was collected regarding current notable research priorities, research and development investments, and global biotechnology rankings to provide a synthetic overview of each nation's biological research capacity and interest and their existing investments in biosafety. Advanced or synthetic biology is not consistently addressed by national-level

biosafety policy, and funding information for biosafety was generally unavailable. This further demonstrates the need for a more uniformly agreed upon set of biosafety norms for especially consequential work.

3. **There is a stark need for more data to inform biosafety policy; very little research into biosafety research practices and equipment is being funded or performed.** The need for data that describes laboratory incident/accident rates is well understood, and efforts are underway in the US government to set up a system modeled on the system used in the aviation industry. However, more information is needed to set policy in this area: procedural studies (such as the proper protocols to inactivate anthrax spores, studies to determine which equipment works best for a given protocol, and which personal protective equipment (PPE) works best to protect the laboratory worker); behavioral studies and human reliability studies to be done to best instill a safety culture in the laboratory, to develop the best training material, to inspect laboratories in such a way as to improve safety over time, and to promote safe practices in routinized biological laboratory environments. In addition, comparative studies are needed for practices, engineering, laboratory set-ups, and equipment.

Developing greater expectations that all nations are doing what they should to prevent contagious public health threats will require further action and buy in from international organizations such as the WHO, OECD, as well as other nations. The next steps for this effort should be to continue to raise awareness that these governance issues are important for international consideration, and to work towards buy-in amongst international biosafety experts. International norms for biosafety are almost certain to be instituted after a major laboratory accident crisis; if we wait for that time, measures put in place during a crisis may be an over-reaction or an inappropriate reaction to what is actually needed. We should be forward-looking and put those protective measures into place to prevent such a catastrophe, now.

This report marks the conclusion of the activities within this research grant. Through this year-long research study the UPMC Center for Health Security (the Center) produced reports (A Synopsis of Biological Safety and Security Arrangements, and National Biosafety Systems Case Studies, which are provided as separate attachments), published an article in *Trends in Microbiology* (Cell Press), interviewed 21 international biosafety and security experts on the topic of international biosafety norms, and held a meeting of experts on June 28, 2016.

## Summary of Deliverables Produced

This report is a compilation of the findings and recommendations discovered pursuing the Naval Postgraduate School Project on Advanced Systems and Concepts for Countering WMD (PASCC) Grant No. N00244-15-1-0028 to provide funding support for research entitled "Improving Security through International Biosafety Norms" and marks the conclusion of the activities within this research grant.

The UPMC Center for Health Security proposed to investigate (1) Which biosafety norms are important components of a national biosafety program to improve security (2) How to build confidence among nations that research on high-consequence pathogens is being carried out safely in other nations and (3) What biosafety infrastructure is in place in a select group of case-study nations?

In furtherance of this research, the Center produced the following deliverables:

1. A **Synopsis of Biological Safety and Security Arrangements** *(provided as a separate attachment)*: This synopsis provided summaries of key international treaties, agreements, instruments, guidelines, multilateral engagement mechanisms, and information resources intended to guide national approaches to biosafety in research, clinical, and industrial laboratories. The major finding from this research was that there is a gap in international norms for biosafety; there are no clear expectations for how nations should protect against major laboratory accidents that could become an international problem. The synopsis was widely distributed to the Biological Weapons Convention Meeting of Experts (Geneva, August 2015) and Meeting of States Parties (Geneva, December 2015) and was described in remarks as a useful resource by the Department of State.

2. **Trends in Microbiology (Cell Press) article** *(provided in Appendix A):* This article described the findings of the Synopsis of Biological Safety and Security in a *Trends in Microbiology* editorial published by Cell Press, a highly regarded scientific journal with a high impact factor. (Gronvall GK, Rozo M. Addressing the Gap in International Norms for Biosafety. Trends in Microbiology.23(12):743-744. Available at http://dx.doi.org/10.1016/j.tim.2015.10.002)

3. **National Biosafety Systems Case Studies** *(provided as a separate attachment)*: This compilation of case studies examined current biosafety approaches and regulations for Brazil, China, India, Israel, Pakistan, Kenya, Russia, Singapore, the United Kingdom, and

the United States, in order to look for commonalities and differences. This effort is a first step towards the development of international biosafety norms. The major findings of this work was that while all nations examined do have some regulations having to do with biosafety, there are major gaps in the area of potentially consequential laboratory accidents and advanced biological techniques (i.e. synthetic biology) is largely not covered. Funding levels for biosafety were uniformly not available.

4. **Interviews with International Experts on Biosafety/Biosecurity** *(list of experts interviewed provided in **Appendix B**)*: Not-for attribution interviews with 21 experts in science, security, biosafety, as well as researchers who work in "high-consequence" areas were performed, in order to better understand existing biosafety norms, the scale of the problem of potentially consequential laboratory accidents, and possible mechanisms to govern this area, internationally. The interviews helped to set the stage for the July 28, 2016 meeting.

5. **International Biosafety Norms, Data Gaps, and the Future of Biosafety Meeting** *(list of meeting attendees provided in **Appendix C**):* Meeting of international experts in biosafety, security, and governance was convened at the UPMC Center for Health Security on June 28, 2016. The findings from this meeting are included in this report; the major takeaways are that there remains a gap in international norms for biosafety; there are complicating issues internationally that will make the process of developing international norms difficult (different perspectives internationally about intellectual property and genetically modified organisms or GMOs); and that biosafety scholarship is needed to provide data useful for policy decisions.

## The Problem of Consequential Accidents in Biocontainment Laboratories

Most accidents in biocontainment laboratories are limited to the researchers involved and possibly their close contacts. While these accidents are unfortunate events that may have severe consequences for those who are affected, these incidents would not typically become matters of international concern. However, laboratory acquired infections (LAIs) with particularly transmissible pathogens, including non-circulating human influenza strains, SARS, or engineered influenza strains could have consequences that go well beyond the laboratory, beyond borders, and would constitute a threat to national and global security. **It is the safety procedures surrounding these high-consequence pathogens, which have the potential to cause international spread, even the possibility of pandemics or national security crises, which were the focus of this project.**

High-consequence pathogens work requires not only careful attention and training of the researchers performing the work, but a system of biosafety training, engineered controls, monitoring, and a safety culture. However, not all laboratories are so equipped, staffed, supported, or have the necessary oversight mechanisms in place to safely conduct this work. Indeed, one of the major concerns about influenza gain-of-function of concern (GOFroc) research is that such GOF research will be performed elsewhere in the world, not in the few labs where it started which has the highest level of experience and safety systems. New research laboratories that may start this kind of work may have far less robust safety systems, health monitoring, and experience.

Consequential laboratory accidents have happened before, but thankfully with limited impacts to international human health: in 2003-4, there were multiple LAIs with SARS, but transmission was halted before the disease could spread widely. More recently, there have been a string of highly publicized laboratory accidents in the US that also, fortunately, did not significantly affect human health, but highlighted the potential for a laboratory accident to lead to additional infections and an international public health emergency. For example, at the US Food and Drug Administration (FDA), decades-old glass vials were discovered which were later found to actually contain live variola (smallpox) virus. Smallpox was declared eradicated by the World Health Organization (WHO) in 1980, and all laboratories that held samples of the virus were supposed to destroy them or send them on to the WHO, to be held at the only 2 laboratories allowed to keep them—the CDC and a Russian laboratory. Given that many years had passed and these samples were not either transferred or disposed of, this incident was indicative of poor inventory management procedures. No one was exposed to the smallpox virus in the course of this incident. In 2015, it was discovered that the US Army Dugway Proving Ground

shipped samples containing live anthrax to centers not registered to work with it. These samples were incompletely irradiated and some samples were determined to have live anthrax spores. The shipments involved every state and several countries. In addition to these incidents, there were recent potential exposures of anthrax and non-circulating influenza at the CDC.

These incidents demonstrate that human error is a problem in the laboratory. Fortunately, there is a great deal of technical guidance for researchers and institutions to achieve high levels of safety, to train workers, and to foster a laboratory environment that holds safety as a priority. However, a key piece is missing from the available guidance: national-level biosafety norms that could provide reassurance to other nations that consequential work is performed with appropriate and sufficient safety systems. For example, it would be helpful to know that potentially consequential research took place in an environment where there are national standards for the work, including for equipment maintenance, worker safety training, health monitoring, surveillance, and other myriad activities to help keep the researchers and the larger public safe, and that the nation has an adequate surveillance system in place to identify and limit potential outbreaks that could result from such accidents.

Without national-level standards and expectations for biosafety and interest in making sure that research institutions that perform potentially high-consequence research adhere to those standards, there will remain insufficient incentives to commit the resources required to achieve high levels of biosafety in individual laboratories and institutions. Without these kinds of norms, nations will not have confidence that all necessary steps are being taken in other nations to prevent a high-consequence laboratory accident from occurring, or to limit its consequences.

The determination that there is no nation-level guidance for biosafety was made empirically, through an examination of key international treaties, agreements, instruments, guidelines, multilateral engagement mechanisms, and information resources intended to guide national approaches to biosafety in research, clinical, and industrial laboratories. The **Synopsis of Biological Safety and Security Arrangements**, produced through this project, summarizes the benefits and limitations of all of these agreements in promoting biosafety, and their individual contributions towards minimizing the global risk and consequences of laboratory accidents. Some of the agreements analyzed include the World Health Assembly 58.29, the International Health Regulations (2005), the Global Health Security Agenda (2014), the Biological Weapons Convention, The G8 Global Partnership Against the Spread of Weapons and Materials of Mass Destruction, and many other agreements. Though there is an extensive array of existent governmental mechanisms related to biology, biosafety is a major gap. There remains a need for international norms for the biosafety and governance of those pathogens that have increased potential to spark a pandemic.

Considering the pace and progress of biotechnology, the lack of international norms for national biosafety in high-consequence pathogen research is concerning. Taking steps to develop internationally agreed-upon standards for biosafety for work with highly contagious organisms has the potential to provide reassurance to other nations that scientific research is performed safely, and that a laboratory acquired infection may be caught before developing into a pandemic.

**Biosafety comparisons, worldwide**

By describing a variety of biosafety governance approaches in these nations, we hoped to find areas of commonality which could be further developed into international norms. For that reason, we examined the governmental policies and regulations for biosafety in research laboratories in the nations of Brazil, China, India, Israel, Pakistan, Kenya, Russia, Singapore, the United Kingdom, and the United States. These countries were chosen in order to reflect geographical diversity and diversity in GDP and science base. Online database searches for government documents, websites, media reports, and biosafety reviews were used to identify existing biosafety guidelines for each assessed nation and identify regulatory agencies, laboratory staff training programs, and incident response and reporting requirements. Additionally, information was collected regarding current notable research priorities, research and development investments, and global biotechnology rankings to provide a well-rounded overview of each nation's biological research capacity and interest and their existing investments in biosafety. It should be noted that this research did not address the success of implementing the relevant legislation and regulations.

We found that all case study nations had national biosafety guidelines and regulatory bodies responsible for oversight and compliance. Nonetheless, information availability was extremely variable, making comparisons difficult. The quantity and quality of information available varied widely between countries, which may be due to differences in scope or transparency of the biosafety programs or due to differences in priorities for biosafety regulation. The incentives behind biosafety regulation are varied, ranging from agricultural development to infectious disease control to biotechnology investments. National-level research priorities contributed significantly to the emphasis placed on developing biosafety legislation and oversight. It is therefore possible that there are resulting gaps in regulation for non-priority areas.

Important for consideration of potentially high-consequence laboratory accidents in the future, we found that advanced or synthetic biology is not consistently addressed by national-level biosafety policy. Some nations have very strict regulatory policies for advanced or synthetic biology, and others only address it in a limited capacity or from a very specific perspective (e.g., genetically modified crops). Finally, funding information for biosafety was generally unavailable.

The lack of information about funding may be a function of transparency, but it also could be that biosafety is incorporated into larger budgets and not “called out” as a separate item. Additionally, the biosafety funding may be spread across a number of governmental agencies rather than being a single budget item.

This project provided essential ingredients towards developing international biosafety norms for high-consequence research; a synopsis of biosafety-related international agreements that exposed the gap in biosafety norms for high-consequence research; case studies which demonstrated variability in biosafety requirements on the national level; and considerations from an international group of biosafety and security experts about important components of national biosafety programs.

## International Biosafety Norms, Data Gaps, and the Future of Biosafety (Meeting)

A meeting of biosafety, national security, and governance experts was held at the UPMC Center for Health Security's offices in Baltimore, MD, on June 28, 2016. Meeting attendees (listed in **Appendix C**) discussed whether and/or how nations may have common expectations regarding the biosafety practices of other nations, when engaged in research that has the potential to lead to international spread. In addition, they discussed how data gaps for biosafety and biosafety practices may be filled, as a lack of data has been blamed for biosafety lapses as well as policy development difficulties (such as for gain-of-function research); and to discuss the future needs and priorities for biosafety, in the face of a changing research and biotech landscape.

The meeting agenda (**Appendix D**) was informed by the other deliverables from this research effort, such as the survey of available international mechanisms that influence biosafety (published July 2015); case studies of national biosafety systems to determine what elements are in common (published July 2016); and interviews with experts in science, security, biosafety, as well as researchers who work in "high-consequence" areas (as captured in the meeting slides, found in **Appendix E**).

Findings drawn from the discussion included the following:

1. *There was general agreement that the premise of the meeting was sound.* There is a need for norms and expectations on a national level to promote biosafety in research laboratories, in order to prevent an internationally consequential accident with a contagious pathogen.

2. *Defining terms and concepts clearly, and for an international audience, is an important step towards international norms to protect against high-consequence laboratory accidents.* The focus of this meeting was a specific, internationally consequential result of a biosafety lapse in a research laboratory. Separating this issue from other more general laboratory concepts will be important. Even terms such as "biosafety" and "biosecurity" can be challenging to use for communication in an international context, and require concisely framed definitions and words**.** Biosafety is defined by the WHO as the containment principles, technologies, and practices that are implemented to prevent unintentional exposure to pathogens and toxins, or their accidental release; biosecurity refers to the institutional and personal security measures designed to

prevent the loss, theft, misuse, diversion or intentional release of pathogens and toxins. However, in some languages, the words for biosafety and biosecurity are essentially the same, and in French, the terms that are used for these concepts are confusing: biosûreté for biosecurity and biosécurité for biosafety.

3. *Separating international discussions about the safety of contagious pathogen research from other complicating biosafety issues will be a challenge; internationally controversial issues including intellectual property, the precautionary principle, and regulation of genetically engineered organisms will inevitably complicate those discussions.* For much of the world, biosafety and biosecurity are related to the control and regulation of genetically modified organisms (GMOs). The US has a much more pro-actionary approach to GMOs compared to European nations, as well as Europe-influenced nations; thus, regulatory regimes for biosafety around the world reflect these differences. The US regulates "recombinant DNA" manipulation within laboratories, but not nearly as strictly as GMO-centered regulatory regimes.

4. *Given the difficulty in establishing international norms for biosafety in the absence of an accident-induced epidemic, non-governmental organizations may have an unusually important role to play in making this an issue that deserves attention.* Similar to the role that NTI has played in the nuclear security world, an NGO that prioritizes international harmonization of biosafety standards, to create acceptable norms, promote them, and evaluate nations for compliance could help this issue receive more attention. In fact, historically the establishment of international norms often arises through or is catalyzed by the work of civil society.

5. *Many biosafety protections are focused on individual laboratory workers, but the benefits that we were discussed in our meeting were focused on the safety of the community outside the lab, including national or even international communities.* There is a need for safety norms that address both populations, and for clarity in addressing the population threat.

6. *Should the strategy pursued by the US and other nations to give assistance to resource-poor nations in biosafety be rethought?* Theoretically, a biological laboratory incident that could result in a Public Health Emergency of International Concern (PHEIC, under the IHR 2005) could come from anywhere where there is any biological research. However, the US prioritizes assistance based upon where there is an intersection of security needs and safety needs. A more expansive approach may be required to address this issue, perhaps in collaboration with other donor countries.

7. *There have been several recent changes that make international biosafety and the recommendations that come from this meeting a more important issue now: 1. Emergence of biotechnologies and other tools to manipulate genomes which have the potential to produce pathogens which would be more difficult for public health measures to control and 2. An increase in national laboratory capacities around the world.* The emerging technology issue is self-evident. Just a few years ago, CRISPR, the technology that allows genomes to be manipulated and changed more easily, was invented. It is already available as a kit for DIY Bio amateurs at a reasonable price. The increase in national capacities is in partly a result of the increased attention to the International Health Regulations and the Global Health Security Agenda; instead of relying on countries to ship their samples to other nations with advanced laboratory capacity, there has been an intensive effort to boost laboratory capacity within countries.

8. *An underused lever for governance in the biological sciences is the pressure for scientists to publish in high end journals.* Working on controls/standards for publication is an opportunity to push for increased controls for biosafety for dealing with especially consequential research, and efforts should be made to consider how this lever can be productively used to enhance safety.

9. *There is a great need to generate biosafety data.* The need for laboratory incident/accident data is well understood; efforts are underway in the US government to improve the data surrounding these safety issues. In addition, there is a need for procedural studies (such as the proper protocols to inactivate anthrax spores, which equipment works best for a given protocol, which personal protective equipment (PPE) works best to protect the laboratory worker. There are innovations that could make a difference– in engineering, and behavior, to improve the safety of the laboratory. There are behavioral studies – also known as studies on Human Reliability and performance - to be done to best instill a safety culture in the laboratory, to develop the best training material, to inspect laboratories in such a way as to improve safety over time, and to promote safe practices in routinized biological laboratory environments. In addition, comparative studies are needed for practices, engineering, laboratory set-ups, and equipment.

10. T*here is a need for more biosafety research to be performed; the type of scholarship needed for generating biosafety data may not require a separate biosafety PhD or Master's program.* The elements for what is needed can be found in other disciplines, including occupational safety, management science, or psychology. However, the

necessity is funding. Right now, this work isn't being funded so it is not being performed.

11. *Incident and accident reporting will only work if it is anonymous.* Universities and research institutions are generally averse to reporting incidents, particularly when they can bring a great deal of negative publicity to the institution.

12. *Defining a "near miss" biological incident so that it is clear to all who might need to report one is an important task*. There are a variety of interpretations for what constitutes a potentially avoided accident in a biological laboratory. It will be important to define this in such a way as to promote learning from the event. Also, if biocontainment was not actually breached (i.e., there were redundant systems that did not fail) that should be noted in the reporting language, so as to not provoke undue alarm.

13. *The World Health Organization (WHO) and Organisation for Economic Co-operation and Development (OECD) may be institutions situated to put forward international norms for a broader community of nations, as the health and economic consequences are within their purview.* With funding, such an effort would have the imprimatur of an international body and may thus be more likely to be received better on an international scale.

14. *A more formal process for developing emerging biosafety standards could lead to greater expectations of safety.* Currently, biosafety guidelines for emerging laboratory techniques (such as CRISPR) or for emerging viruses (such as Zika) are developed through an informal collaboration of biosafety officers and experts. This informal process could become more formalized within the biosafety community earlier in the research process and include publication of results that could be widely disseminated in the biosafety and science community.

## Recommendations for future work

There are 3 broad categories to be pursued for future work, to support the development of international norms for biosafety.

1. **Engage international partners.** Potential international partners including the WHO, OECD, or UN should be engaged to formally consider the importance of this issue. Develop a plan to discuss it in the community of nations, with the ultimate goal of developing international biosafety norms for work that could have potential to lead to international spread of infectious disease. We have demonstrated empirically that this a gap in international agreements, but this will need to be accepted and discussed in international meetings of experts (including biosafety association meetings), and in meetings sponsored by an broadly respected and known international organization.

2. **Develop a biosafety research agenda.** There is general agreement among experts that there is not enough data in biosafety to inform policymaking. A next step would be to report on exactly what kinds of data are required first, to develop a prioritized research agenda, to determine what kinds of organizations should perform the research, and to recommend what organization(s) should be funding the research.

3. **Initiate a process to develop consensus standards for biosafety when needed.** Currently, biosafety guidelines for emerging laboratory techniques (such as CRISPR) or for emerging viruses (such as Zika) are developed through an informal collaboration of biosafety officers and experts. A better solution would be to set up an expert committee to publish a series of consensus papers on biosafety topics. Such a board could be activated upon short notice when new techniques/virus(es) are to be incorporated into biological research.

CellPress

Science & Society

# Addressing the Gap in International Norms for Biosafety

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There is currently a lack of national-level norms for biosafety. Considering that a laboratory accident involving a contagious pathogen could have long-term consequences that extend beyond an individual incident into the practice of science more broadly, it is in the interests of scientists everywhere that international norms are developed.

For most research scientists, biosafety is a local concern. There are procedures to work safely in the laboratory that need to be followed, as well as taught to incoming students and post-docs. There are institutional biosafety committees, which review registrations for recombinant DNA work as well as infectious agents, animal protocols, and clinical trials. Many research institutions also have biosafety officers who provide advice on biological risks, and ensure compliance with the relevant regulations and guidelines. But, while most scientists deal with biosafety locally within their institution, how biosafety is practiced, regulated, and funded on an international level should be a concern of every scientist. As pathogens do not confine themselves to international borders, a laboratory accident involving a contagious pathogen could potentially have far-reaching effects around the world – not only as a direct impact of the breach of containment but on the overall practice of science.

Most accidents in biological science laboratories are limited to the researchers involved and possibly their close contacts. While these accidents are unfortunate events that may have severe consequences for those directly affected, they would not typically become matters of international concern. However, laboratory-acquired infections (LAIs) with particularly transmissible pathogens, including noncirculating human influenza strains, the severe acute respiratory syndrome (SARS) coronavirus, or other contagious pathogens, could have consequences that go well beyond the laboratory. In large part, it was these biosafety concerns that fueled the decision by the US government in early 2015 to pause funding for influenza gain-of-function (GOF) research while the risks and benefits of that research are analyzed (http://www.whitehouse.gov/blog/2014/10/17/doing-diligence-assess-risks-and-benefits-life-sciences-gain-function-research). Investigators first touched off the controversy in 2011–2012 with their development of a form of the H5N1 avian influenza virus that was transmissible between mammals [1,2]. While these researchers were widely acknowledged to be experienced in working with virulent strains and to have taken many biosafety precautions, fears were raised that such work could easily be replicated in laboratories with less robust safety systems, health monitoring, or experience, and could trigger a pandemic.

Unfortunately, these fears are merited: biosafety is uneven throughout the world, and almost always underfunded. The costs to staff, train, retrain, and implement good practices are often considered less important than other costs, such as funding the research itself. Furthermore, a system of detailing and reporting biosafety issues to a national or international body is often lacking. Biosafety breaches are embarrassing for the laboratory workers who made the mistakes, as well as for the research institution, and so even if biosafety lapses are detected, they may not be reported. The researcher may feel stigmatized, especially if the relationship with the supervisor and the institution is poor, and a culture of best biosafety practices has not been established. Therefore, how often accidents occur, or result in direct harm to the laboratory worker, is almost completely unknown.

In recognition of the fact that individual laboratory workers carry the most personal risk from LAIs, resources have been committed to boost biosafety at the local level. There is excellent guidance available for researchers, laboratories, and research institutions to adhere to high biosafety practices, and provide biosafety professional training pertaining to each individual discipline and type of work. There are also standards classifying pathogens at varying levels of biocontainment [Biosafety level-1 (BSL-1), BSL-2, BSL-3, and BSL-4] and what corresponding engineering controls should be in place to manage biorisks within a research institution, whether they pose risks to humans, livestock, or plants. The World Health Organization (WHO), the Food and Agriculture Organization of the United Nations (FAO), the World Organization for Animal Health (OIE), the Centers for Disease Control and Prevention (CDC), professional societies [including the American Biological Safety Association (ABSA), European Biological Safety Association (EBSA), and Asia Pacific Biosafety Association (A-PBA)] aim to bring technical information to practitioners, enhance laboratory safety practice, and promote biosafety standards.

However, while there is an abundance of information for individual researchers and institutions to work in biological systems safely, there is much less guidance at the international level. There are no international norms that would govern biosafety precautions with particularly dangerous pathogens, or detail how much nations should be spending on biosafety oversight as a proportion of research funding, or describe what components of biosafety systems are essential for oversight. Furthermore, there is a dearth of cross-disciplinary considerations, for example concerning those laboratory workers who deal with animal health as well as food safety. To come to this troubling conclusion, we performed an extensive analysis of key international treaties, agreements, instruments, guidelines, multilateral

engagement mechanisms, and information resources intended to guide each individual nation's approach to biosafety in research, clinical, and industrial laboratories (http://www.upmchealthsecurity.org/our-work/publications/synopsis-of-biological-safety-and-security-arrangements). We identified the benefits and limitations of each in promoting biosafety, and how they contribute towards minimizing the global risk and consequences of laboratory accidents.

For example, among the international arrangements which directly concern biosafety and biosecurity is the 2005 World Health Assembly (WHA) Resolution 58.29 on Enhancement of Laboratory Biosafety. This resolution urges WHO Member States (which include all members of the United Nations except Liechtenstein) to adhere to principles that would increase biosafety. However, there is no assessment of whether the WHA guidance has been adopted by any Member State, or that sufficient funds have been committed to training, equipment, and other resources and infrastructure required in order to maintain safe and productive laboratories. There is no independent mechanism to monitor adherence to principles through reporting or external review, and countries do not need to report on their adherence to the resolution. More importantly, the document does not provide guidance for implementing a national biosafety system, such as how to develop training standards, designate governmental regulations, or enact a system for reporting and monitoring LAIs. The proportion of need for technical assistance by the Member States also exceeds the capacity of the WHO to provide.

Another example is the 2005 International Health Regulations (IHR) [3], which requires nations to detect and respond to disease threats; functioning laboratories are integral in that mission. The laboratories that are part of the IHR assessment are primarily medical and public health laboratories which would be used in the course of surveillance and diagnosis of disease. Research, industrial, and commercial laboratories are not explicitly covered under IHR obligations. Also, despite the requirement for WHO Member States to have established IHR core capacities by 2012, over 80% of countries have either requested an extension or have not reported on these critical capacities, so even the capacities of those laboratories that are included are currently unknown (http://apps.who.int/gb/ebwha/pdf_files/EB132/B132_15-en.pdf?ua=1). In response to the poor implementation rates of the IHR 2005 standards, the United States, along with 30 countries and international organizations, put forth the Global Health Security Agenda in February of 2014, which focuses attention on implementing IHR standards in resource-constrained countries. However, the biosafety issues associated with potentially consequential research are not just in such resource-constrained countries but also in places that are at the leading edge of technological development, so the appropriate target may instead be research centers in well-resourced countries.

Considering the pace and progress of biotechnology, the lack of international norms for national biosafety programs is concerning. To develop them, it is up to biosafety experts, scientists, and their professional associations to determine what are the reasonable combinations of biosafety activities and oversight mechanisms that should be standard from one research-producing nation to another. Without national-level standards for biosafety, and interest in making sure that research institutions that perform potentially high-consequence research adhere to those standards, there will remain insufficient incentives to commit the resources required to achieve high levels of biosafety in individual laboratories and institutions. It is also in the interests of nations to encourage that these standards be developed and promulgated: taking steps to develop internationally agreed-upon standards for biosafety for work with contagious organisms has the potential to provide reassurance to other nations that scientific research is performed safely, and that an LAI may be caught, and stopped – before developing into a pandemic.

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http://dx.doi.org/10.1016/j.tim.2015.10.002

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2. Russell, C.A. *et al.* (2012) The potential for respiratory droplet-transmissible A/H5N1 influenza virus to evolve in a mammalian host. *Science* 336, 1541–1547
3. World Health Organization (2008) *International Health Regulations (2005),* WHO Press

Spotlight

# Programming Bacteriophages by Swapping Their Specificity Determinants

Moran G. Goren,[1,‡] Ido Yosef,[1,‡] and Udi Qimron[1,*]

**Bacteriophages, bacteria's natural enemies, may serve as potent antibacterial agents. Their specificity for certain bacterial sub-species limits their effectiveness, but allows selective targeting of bacteria. Lu and colleagues present a platform for such targeting through alteration of bacteriophages' host specificity by swapping specificity domains in their host-recognition ligand.**

Bacteriophages are viruses that propagate in bacteria and usually kill them. Ever

## Appendix B: Expert Interview List

1. Kavita M. Berger, PhD, Scientist, Gryphon Scientific
2. Rocco Cassagrande, PhD, Founder, Managing Director, Gryphon Scientific
3. Gerald Epstein, PhD, Assistant Director for Biosecurity and Emerging Technologies, National Security and International Affairs Division, Office of Science and Technology Policy
4. Maureen Ellis, MS, Director of International Programs at MCE Biosafety Consulting, Executive Director, International Federation of Biosafety Associations
5. Daniel Feakes, MA, Chief, BWC Implementation Support Unit, United Nations Office for Disarmament Affairs
6. Ron Fouchier, PhD., Department of Virology, Erasmus MC
7. Matthew B. Frieman, PhD, Associate Professor, Microbiology and Immunology University of Maryland, School of Medicine
8. Jo L. Husbands, PhD, Scholar/Senior Project Director, National Academies of Sciences, Engineering, and Medicine
9. Michael J. Imperiale, PhD, Arthur F. Thurnau Professor, University of Michigan
10. Barbara Johnson, PhD, RBP, Owner, Biosafety Biosecurity International
11. Rebecca Katz, PhD, MPH, Associate Professor, Department of International Health Co-Director Center for Global Health Science and Security, Georgetown University
12. Yoshihiro Kawaoka, PhD, MS, DVM, Professor of Virology, Department of Pathobiological Sciences, University of Wisconsin
13. Fillippa Lentzos, PhD, Senior Research Fellow, Department of Social Science, Health and Medicine, King's College, London
14. Susan Coller Monarez, PhD, Deputy Assistant Secretary for Strategy and Analysis Office of Policy, Department of Homeland Security
15. Allison Mistry, MS, MA, Scientist, Gryphon Scientific

16. Maureen O'Leary, PhD, MBA, CBSP, Director, Environmental Health & Safety Dartmouth College

17. Carissa Meyer, PhD, Senior Analyst, Gryphon Scientific

18. Kathryn Nixdorff, PhD , Professor, Department of Microbiology and Genetics, Darmstadt University of Technology, Germany

19. Christopher John Park, MS, Director, Biological Policy Staff, Bureau of International Security and Nonproliferation Department of State

20. Erin M. Sorrell, PhD, MSc, Assistant Research Faculty, Department of Microbiology and Immunology, Georgetown University

21. Jim Welch, Executive Director, Elizabeth R. Griffin Foundation

## Appendix C: Meeting Attendees

1. Martin Adams, MS, Biosecurity Specialist, Global Scientific Solutions for Health
2. Kavita M. Berger, PhD, Scientist, Gryphon Scientific
3. Naomi Egel, Research Associate, International Institutions and Global Governance Program, Council on Foreign Relations
4. Gerald L. Epstein, PhD, Assistant Director for Biosecurity and Emerging Technologies, National Security and International Affairs Division, Office of Science and Technology Policy
5. Stuart Evenhaugen, MS, Senior Risk Analyst, Strategy, Planning, Analysis and Risk (SPAR), Office of Policy, U.S. Department of Homeland Security
6. Julie E. Fischer, PhD, Research Associate Professor, Department of Microbiology, Georgetown University
7. Ashley Grant, PhD, MPH, Senior Biological Scientist, Government Accountability Office
8. Gigi Gronvall, PhD, Senior Associate, UPMC Center for Health Security
9. Jo L. Husbands, PhD, Scholar/Senior Project Director, National Academies of Sciences, Engineering, and Medicine
10. Michael J. Imperiale, PhD, Arthur F. Thurnau Professor, University of Michigan
11. Tom Inglesby, MD, Chief Executive Officer and Director, UPMC Center for Health Security
12. Barbara Johnson, PhD, RBP, Owner, Biosafety Biosecurity International *(on phone)*
13. Piers D. Millett, PhD, Principal, Biosecure *(on phone)*
14. Allison Mistry, MS, MA, Scientist, Gryphon Scientific
15. Stuart L. Nightingale, MD, Consultant (contractor), Office of Science Policy, Office of the Director, National Institutes of Health
16. Maureen O'Leary, PhD, MBA, CBSP, Director, Environmental Health & Safety, Dartmouth College

17. Patricia Olinger, JM, RBP, Assistant Vice President, Office of Research Administration, Executive Director, EHSO, Emory University and Director of Global Programs, Elizabeth R. Griffin Foundation

18. Christopher John Park, MS, Director, Biological Policy Staff, Bureau of International Security and Nonproliferation, Department of State

19. Ryan Ritterson, PhD, Senior Analyst, Gryphon Scientific

20. Michelle Rozo, PhD, Postdoctoral Fellow, Austere Environments Consortium for Enhanced Sepsis Outcomes (ACESO), Henry Jackson Foundation

21. Erin M. Sorrell, PhD, MSc, Assistant Research Faculty, Department of Microbiology and Immunology, Georgetown University

22. Daniel M. Sosin, MD, MPH, FACP, Acting Director, Division of Select Agents and Toxins, Office of Public Health Preparedness and Response

23. Christopher Viggiani, PhD, Director, Biosafety and Biosecurity Policy, Office of Science Policy, Office of the Director, National Institutes of Health

24. Jim Welch, Executive Director, Elizabeth R. Griffin Foundation

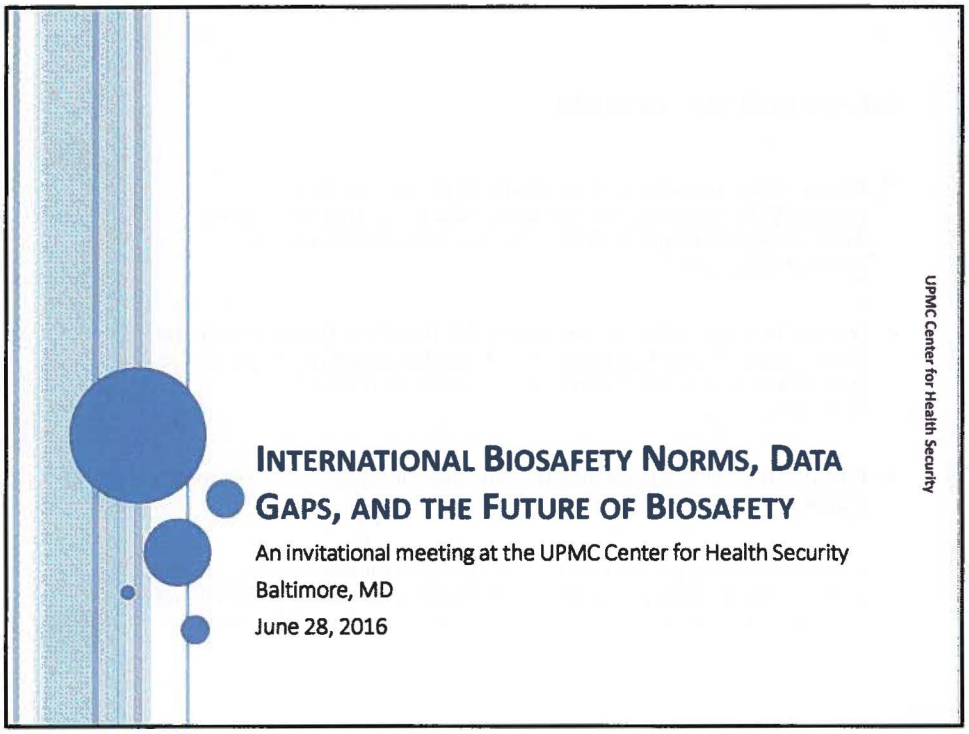
25. Neal Woollen, DVM, MSS, PhD, COL, VC, USA, Director, DoD BSAT Biosafety Program Office

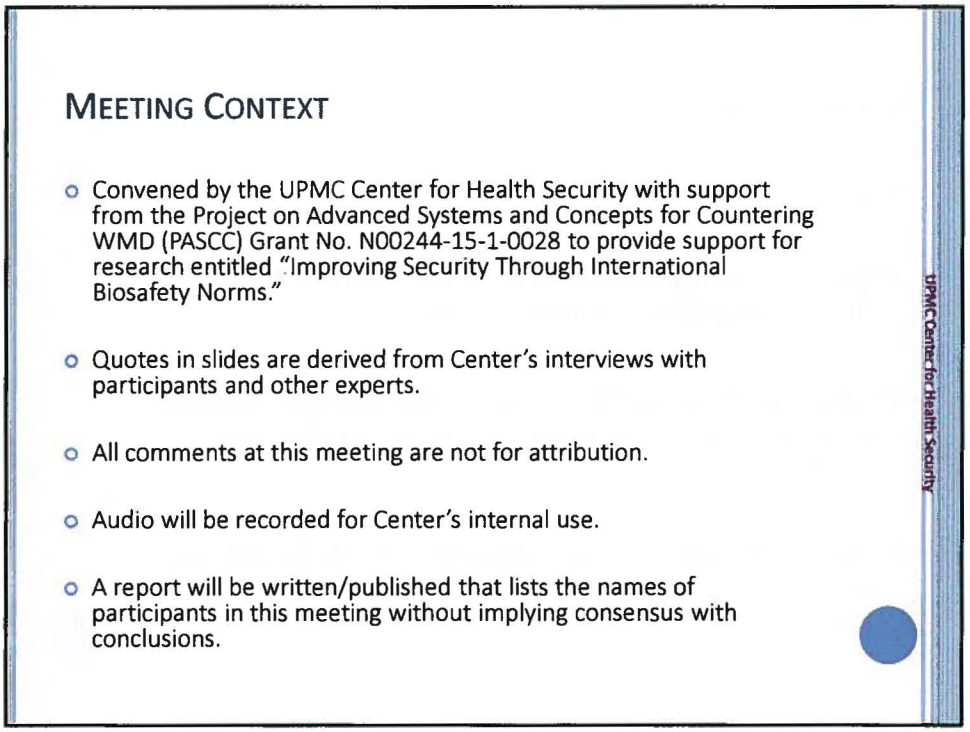
26. Jaime Yassif, PhD, Program Officer, Biosecurity and Pandemic Preparedness, Open Philanthropy Project

27. Kenneth B. Yeh, MS, Principal Scientist, Biosurveillance Division, MRIGlobal

28. Hannah Collins, Research Assistant, UPMC Center for Health Security

Appendix D: Meeting slides (PAGE 23 in TOC)



## GOALS FOR THIS MEETING

- Discuss whether and/or how nations may have common expectations regarding the biosafety practices of other nations, when engaged in research that has the potential to lead to international spread.
- Discuss how data gaps for biosafety and biosafety practices may be filled; a lack of data has been blamed for biosafety lapses as well as policy development difficulties (such as for gain-of-function research).
- Discuss the future needs and priorities for biosafety, in the face of a changing research and biotech landscape.
- Discussion today will be used as input to the meeting report, as well as for briefing slides presented to DoD officials, as well as other USG and international audiences about current biosafety challenges.

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## BASIS FOR MEETING

Meeting agenda informed by and derived from:

- Survey of available international mechanisms that influence biosafety (published July 2015);
- Case studies of national biosafety systems to determine what elements are in common (to be published July 2016);
- Interviews with experts in science, security, biosafety, as well as researchers who work in "high-consequence" areas.

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## INTERVIEWS OF EXPERTS

- Kavita Berger, Gryphon Scientific
- Rocco Cassagrande, Gryphon Scientific
- Gerald Epstein, DHS
- Maureen Ellis, International Federation of Biosafety Associations
- Daniel Feakes, BWC Implementation Support UNit
- Ron Fouchier, Erasmus MC
- Matthew Frieman, University of Maryland
- Jo Husbands, NAS
- Michael Imperiale, University of Michigan
- Barbara Johnson
- Rebecca Katz, Georgetown University
- Yoshihiro Kawaoka, University of Wisconsin
- Filippa Lentzos, King's College, London
- Susan Coller Monarez, DHS
- Allison Mistry, Gryphon Scientific
- Maureen O'Leary, Dartmouth
- Corey Meyer, Gryphon Scientific
- Kathryn Nixdorff, Technical University Darmstadt
- Christopher Park, Department of State
- Erin Sorrell, Georgetown University
- Jim Welch, Elizabeth R. Griffin Research Foundation

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## AGENDA

- 9:30 – 10:00 am Breakfast
- 10:00 – 10:30am Introduction to the meeting, and introductions around the room
- 10:30 – 12:30pm International norms for biosafety: a possibility and/or a necessity for nations?
- 12:30 – 1:00pm Break to pick up lunch
- 1:00 – 1:45pm Technical data gaps for biosafety: whose job is it to fill them?
- 1:45 – 2:00pm Break
- 2:00 – 2:45pm Future landscape for biosafety: how to position the field for old and new challenges?
- 2:45 – 3:00pm Discussion wrap-up

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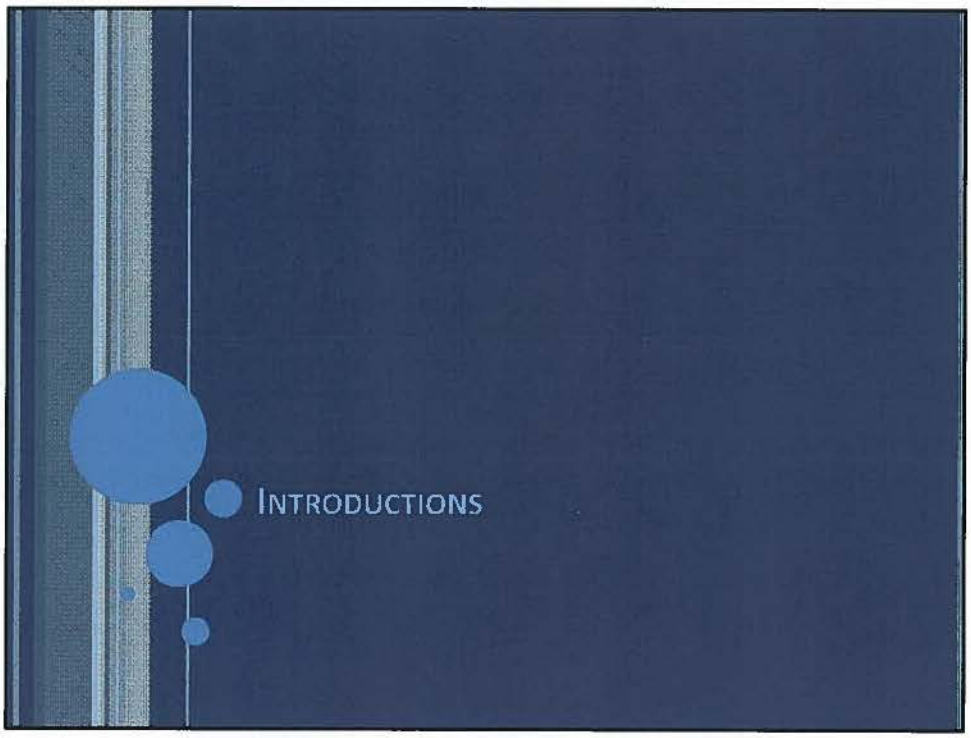
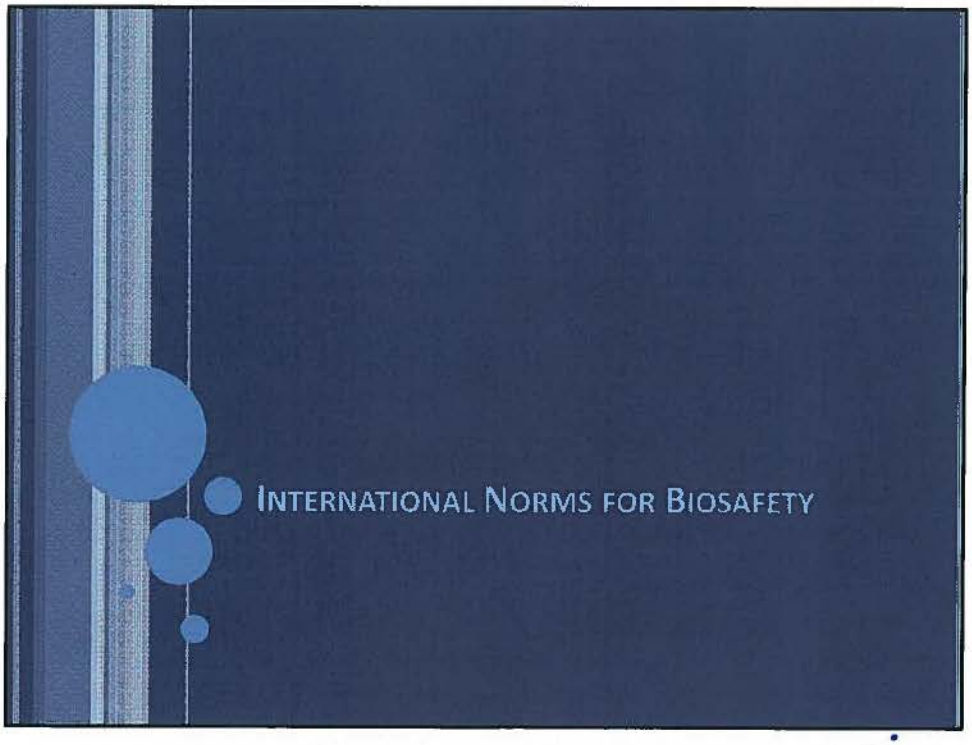

INTRODUCTIONS


INTERNATIONAL NORMS FOR BIOSAFETY

## How Might a Laboratory Accident Develop into an Event of International Consequence?

- Numbers of laboratory accidents and laboratory acquired infections (LAI) are unknown, presumed under-reported.
- LAI are assumed to largely be consequential only for near-contacts and laboratory workers.
- Contagious pathogen could → spread beyond laboratory→ spread beyond borders→ international incident
- Novel and/or contagious pathogen could → spread beyond laboratory → spread beyond borders → major "man-made" outbreak → PHEIC that is difficult to control.

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## Recent Example

- Biosafety was a concern about so-called GOF influenza research. Researchers at the center of controversy acknowledged to have world-class facilities, world-class experience and training. But:
  - What happens when similar work is replicated in facilities where this isn't the case?
- While this cross-boundary concern was highlighted by the GOF example, it is not the only scenario where an accident could be an international problem.
  - Unmodified pathogens such as SARS, MERS, influenza.
  - Advanced research: Viral-mediated delivery of an oncogene (Maddalo, D. et al. Nature 516, 423–427 (2014)

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## NATIONAL LEVEL RESPONSIBILITY?

- Technical guidance exists for laboratory workers, PI's, research institutions, about how to prevent accidents and mitigate consequences in the event of an accident.
  - BMBL, CWA 15793, WHO guidance, etc.
- Focus for this meeting is at the broader national policy level– what is the responsibility for a government to prevent accidents (through training, regulations, oversight, etc.) and to mitigate consequences should an accident occur?

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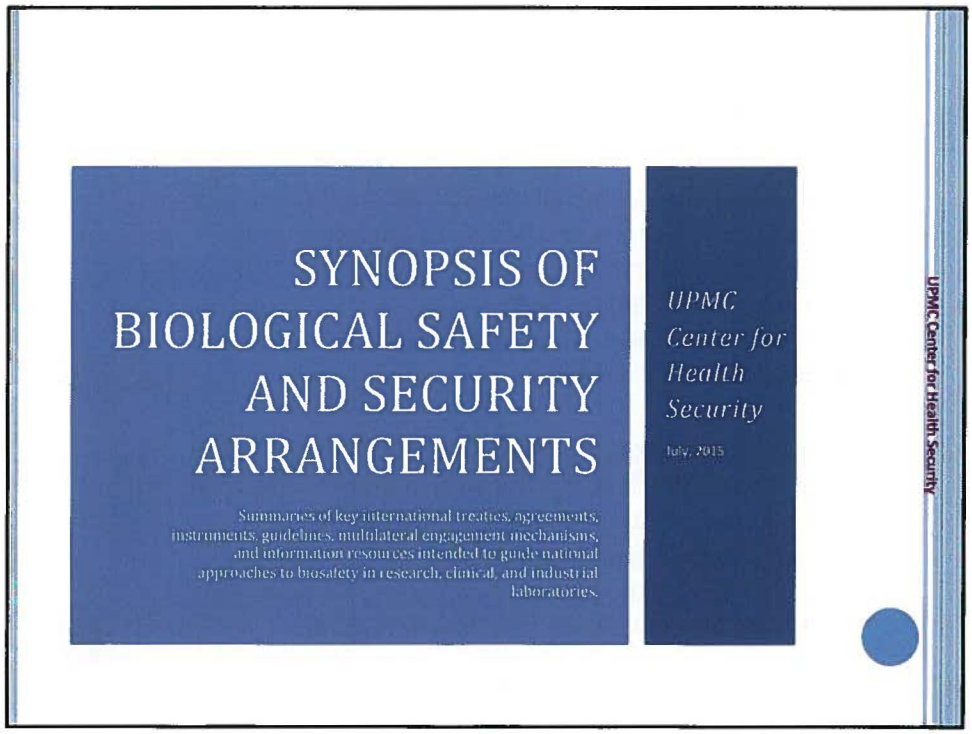


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## GAPS IN INTERNATIONAL NORMS FOR BIOSAFETY

I. ARRANGEMENTS WHICH DIRECTLY CONCERN BIOSAFETY
- WHA 58.29
- International Health Regulations (2005)
- Global Health Security Agenda (GHSA)
- CEN Workshop Agreement on Laboratory Biorisk Management (CWA 15793)
- WHO Biosafety Guidance
- The Cartagena Protocol on Biosafety (CPB)
- OIE Biological Threat Reduction Strategy

II. ARRANGEMENTS IN WHICH BIOSAFETY IS AN INFERRED COMPONENT
- The Biological Weapons Convention
- The G8 Global Partnership Against the Spread of Weapons and Materials of Mass Destruction
- Sequencing Screening Agreements
- WHO Smallpox Agreement
- International Air Transport Association Dangerous Goods Regulations

III. ARRANGEMENTS WHICH DO NOT HAVE A BIOSAFETY COMPONENT, BUT WHICH ARE BIO/BIOSECURITY RELATED
- UN Security Council Resolution 1540
- The Australia Group
- Proliferation Security Initiative (PSI)

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## WORLD HEALTH ASSEMBLY (WHA) RESOLUTION 58.29 ON ENHANCEMENT OF LABORATORY SAFETY (2005)

- Urges WHO member states to adhere to principles that would increase biosafety
- No follow-up assessment of whether the guidance has been adopted or whether sufficient funds have been committed to training, equipment, and other resources and infrastructure required in order to maintain safe and productive laboratories
- No reporting mechanism
- Does not provide guidance for implementation of a biosafety system within a nation (i.e. developing training standards, regulations, or system for reporting and monitoring LAIs).

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## INTERNATIONAL HEALTH REGULATIONS (2005)

- Requires nations to detect and respond to disease threats; functioning laboratories are integral in that mission
- Laboratories part of IHR assessment primarily are medical and public health laboratories which would be used in the course of surveillance and diagnosis of disease.
- Research, industrial, and commercial laboratories not explicitly covered.
- Despite the requirement for WHO member states to have IHR core capacities, most have not reported/implemented.

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## GLOBAL HEALTH SECURITY AGENDA (2014)

- Focuses donor attention on implementing IHR standards in resource constrained countries.
- Not necessarily the right target, as leading edge of technological development (not resource constrained) may be more vulnerable to biosafety issues of international consequence.

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# NATIONAL BIOSAFETY SYSTEMS

Case studies to analyze current biosafety approaches and regulations for Brazil, China, India, Israel, Pakistan, Kenya, Russia, Singapore, the United Kingdom, and the United States

*UPMC Center for Health Security*

July, 2016

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## CASE STUDY CATEGORIES

- Categories for analysis: Pathogen Categorization, relevant regulations and legislation, regulatory and oversight agencies, biosafety associations, presence/absence of biosafety officers and institutional biosafety committees, accident and incident reporting, synthetic biology, training requirements, laboratory numbers, research status, funding for biosafety.

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## Case Study Findings

- Biosafety regulation exists in all 10 nations.
- Information availability was extremely variable, making comparisons difficult.
- The incentives behind biosafety regulation are varied, ranging from agricultural development, infectious disease control, or biotechnology investments: National-level research priorities contributed significantly to the emphasis placed on developing biosafety legislation and oversight. Therefore, it is likely that there are gaps in regulation.
- Advanced or synthetic biology is not specifically addressed.
- Funding information for biosafety was generally unavailable.

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## Case Studies

- Brazil:
  - Biosafety in Brazil is largely focused on the oversight of genetically modified organisms (GMOs), but there is a pathogen select agent list and pathogen categorization similar to the US.
  - Biosafety oversight largely derives from Law 11.105, called the "Biosafety Law," which delineates major government responsibilities and regulations for biosafety, with responsibilities in the Ministries of Health and Agriculture.
  - Brazil has a National Association of Biosafety (AnBio) that promotes national biosafety training and outreach. There is currently no oversight for university labs that do not conduct GMO research.

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## CASE STUDIES

- China:
  - China's biosafety policies were consolidated and made more comprehensive after SARS, specifically after a laboratory-acquired SARS infection in 2003.
  - China has been observed to have a "shortage of officials, experts, and scientists who specialize in laboratory biosafety," increasing the challenge of implementing the new regulatory measures since 2004.
  - Laboratory accidents or non-compliance must be reported to the institution and appropriate national authorities, as necessary. If there is a resulting laboratory-acquired infection, the laboratory is closed during the investigation and required to be "recertified to work at the appropriate biosafety level prior to resuming operations." China's biosafety regulations recommend criminal investigations for lab managers that do not follow biosafety protocols.

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## CASE STUDIES, CONT.

- Summary for India:
  - Biosafety in India is primarily focused on genetically modified (GM) agricultural research and ensuring environmental safety. This is evidenced by the Indian definition of biosafety as "the need to protect the environment including human and animal health from the possible adverse effects of the Genetically Modified Organisms (GMOs) and products thereof derived from the use of modern biotechnology."
  - The Environment Protection Act (EPA) of 1986 created room for the development of India's first biosafety regulations, the 1989 Rules for the Manufacture/Use/Import/Export and Storage of Hazardous Microorganisms, Genetically Engineered Organisms or Cells.
  - Each research institution working with rDNA or GMOs is required to have an Institutional Biosafety Committee (IBSC) that reports to the Ministry of Environment, Forests, and Climate Control (MoEFCC) and Department of Biotechnology (DBT), who together provide oversight for biological research institutions.

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## WHAT WE HEARD

- Developing common expectations that could be developed into norms is a challenge.
  - "Everything that has been tried for biosafety has not worked as a global system... the biosafety world is not a unified group."
  - "In the international context... much more focused on GMOs than in the US."
  - "The European System for biosafety is engrained into the law, with house and safety legislation. It is much more advanced than the US."
  - "The scale of the work going on in China is astounding, and it doesn't appear to be capturing the focus of western researchers"
  - "Outside of the northern world, GOF is not an issue, and does not resonate outside of resource rich countries. GOF is an "ivy league discussion."
  - "There needs to be room for the question, 'do we as a society want you to do that sort of thing?' for research directions"
- Who should lead to develop norms?
  - "I could not imagine a conversation happening in the BWC context, because this is a sovereign nation issue, about the health of your population."
  - "The US has not done a good job getting the international community engaged. They should be leading by example."
  - "It's difficult to implement changes internationally without significant funding to do so."
  - "I don't think anyone really cares what the US decides... America can't strong-arm other countries."

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## DISCUSSION

- Should there be international norms for biosafety?
  - If so, for which research? And by what mechanism– an existing one (i.e. BWC, IHR, G8) or a new one?
  - Should international norms for biosafety be promulgated by nations or by others (e.g. professional societies, biosafety associations, scientists engaged in work with biosafety consequences)?
- What is a reasonable expectation for one nation to have of another regarding oversight of biosafety and biosafety standards?
- What are the components of national-level biosafety norms that would be expected? We heard several issue sets mentioned: education and training; oversight; funding for biosafety as a proportion of research; collection of accident/incident information; engineered controls standards; scientific merit review processes; biosafety approval processes; presence of an national level scientific advisory group.

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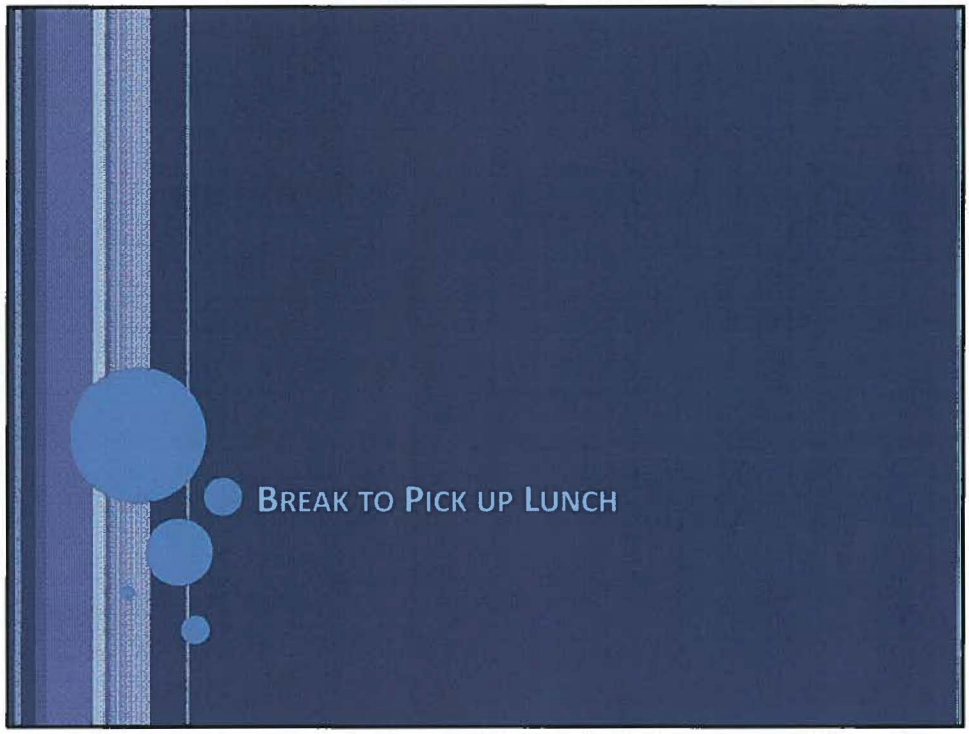
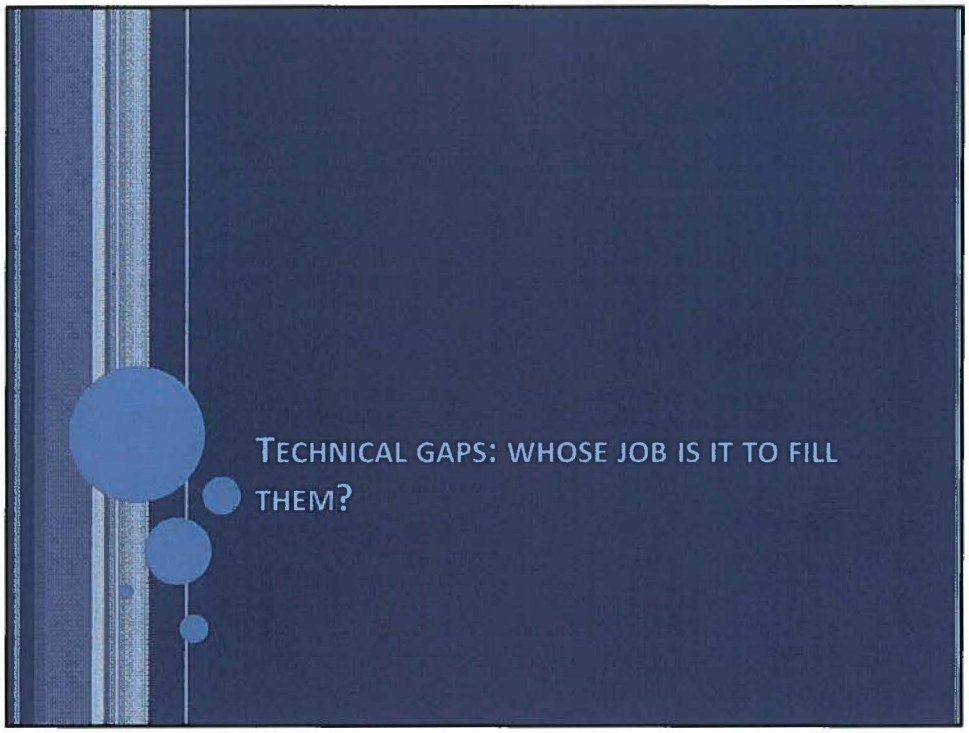

Break to Pick up Lunch


Technical gaps: whose job is it to fill them?

## Inadequate Data surrounding Biosafety– what we heard

- "We have considerable knowledge gaps: unknown error rate in laboratories; unknown best PPE; what ideal lab set-ups are. We don't know what's effective and what's not. No one is doing that research, no one is going to fund that research."
- "In biosafety, there is a wealth of experience and practitioners. Not as strong of an academic discipline. There's a lot of behavioral methods that need to be studies, otherwise you don't know what will work."
- "Those who do the work view it as a personal attack with regard to how safely they conduct the work."
- "There is not a lot of sharing of biosafety or biosecurity practices between institutions."
- "You'd get more robust recommendations to change safety if you studied behavior. I haven't seen anyone do a study like that. It might not be sexy research, but the payoff would be huge."

**Are we getting the biosafety information we need both for safety and to develop appropriate policy?**

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## Role of Data in: Biosafety Incidents and Public Controversies


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## WHAT KINDS OF DATA ARE MISSING

- Need for laboratory incident/accident data is well understood; efforts are underway.
- Procedural studies (inactivation, equipment, PPE)
- Innovations that could make a difference– engineering, behavioral;
- Behavioral studies:
  - building a safety culture;
  - training inspectors who aim to promote safety;
  - Promoting safe practices in routinized biological laboratory environments;
  - Comparative studies of practices, engineering, laboratory set-ups, equipment.

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## WHO SHOULD PROVIDE AND FUND MISSING DATA?

- Should there be an academic discipline for biosafety/occupational safety in a biological laboratory context? (i.e. PhD or masters program in addition to an auditor role ) Who should/would fund that?
- Should the RAC or NSABB or NIH be involved?
- Episodic, consensus recommendations for handling new pathogens, developed by biosafety professionals, similar to clinical best practices: how to handle a new pathogen, what should be in place in the laboratory/safety training?

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# Future Landscape for Biosafety

## Industrialization of Biology

- Replacing chemical engineering processes, or resource-intense harvesting from nature
- Examples in tires, adhesives, flavorings, cosmetics, mining, pharmaceuticals
- Typically large, multidisciplinary teams
- Funded by big businesses and *nations*
- Global synthetic biology market: $2.7 billion in 2013. Expected to grow to $11.8 billion in 2018

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## Personalization of Biology

- Tools are accessible and increasingly powerful (CRISPR kits!).
  - iGEM
  - DIY Bio

- Applications may be personally and immediately relevant.

DogPile ID

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## How will science be practiced in the future?

- Assumption is that biological research will continue to expand.
- Low resource vs. high resource settings
- Private industry vs. academic vs. kitchen


DIY BIO

**Ask a biosafety professional your question**

Submitted questions are sent to a panel of professional biosafety experts.

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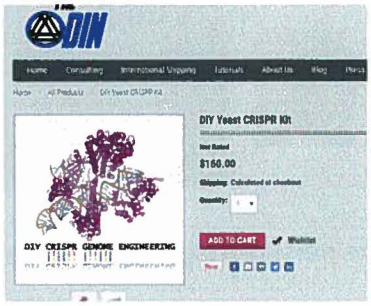
## ADVANCED TECHNIQUES ≠ ADVANCED LABORATORIES.






## NATIONAL BIOSAFETY POLICIES – 10 YEARS FROM NOW

- How and who should promote biosafety in all of these environments? What is the national responsibility to ensure safety? What is the international (e.g. WHO) responsibility towards safety? What is the private sector responsibility?
- How can other nations' systems for biosafety be supported to address these changes in the increased numbers of ways that bioscience is practiced?