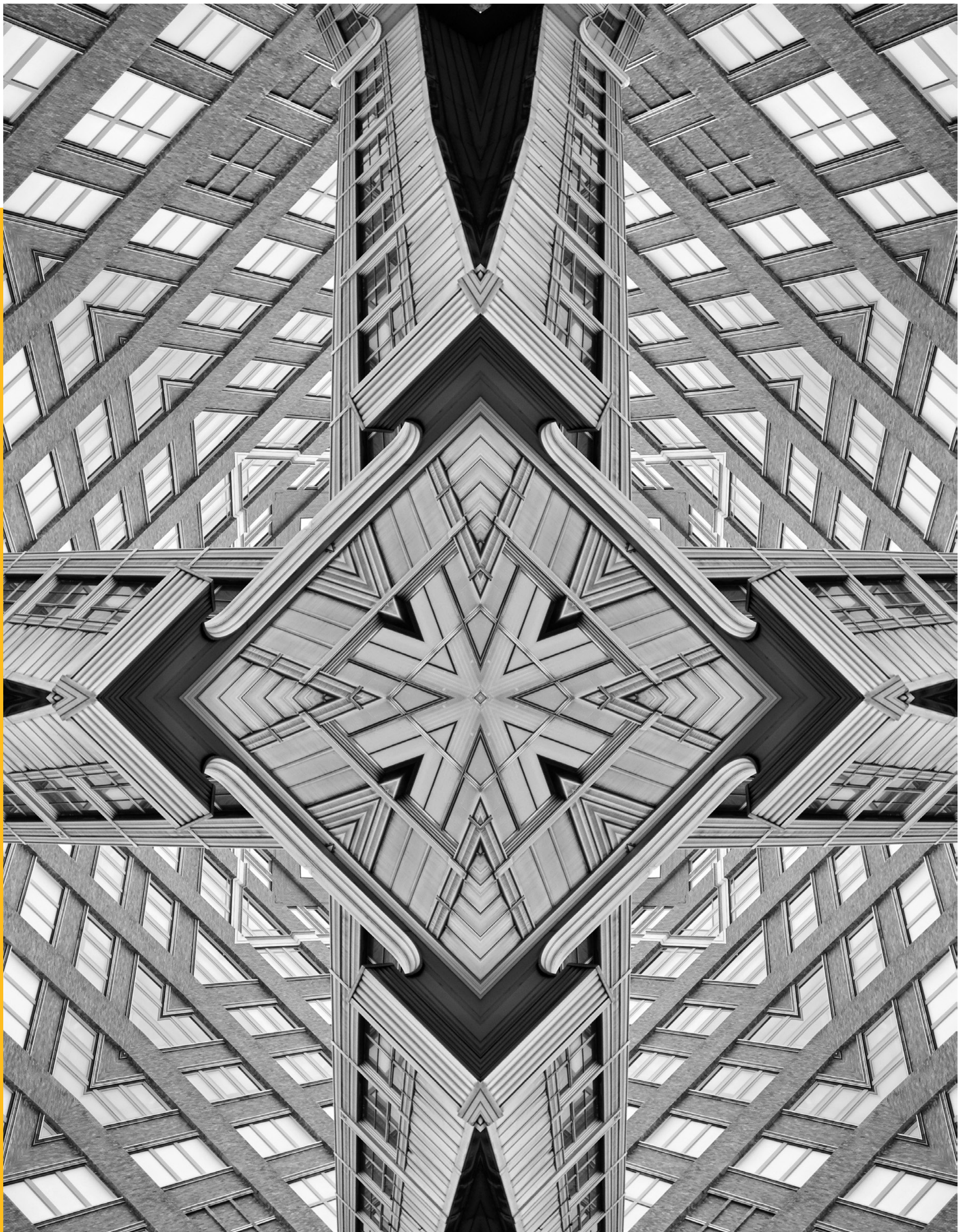
OBSERVER RESEARCH FOUNDATION

Occasional Paper



ISSUE NO. 405 AUGUST 2023

Navigating Considerations of Global Governance, National Strategies, and Ethics in Biowarfare

Shravishtha Ajaykumar

Abstract

Biological weapons can come from naturally occurring microbes and viruses; but innovations in genomic editing are opening up new, potentially more threatening avenues for their development. These innovations can cause or spread disease or resist known therapeutic approaches. Addressing such threats of biowarfare requires obtaining reliable and informative taxonomies for the pathogens and timely and effective responses. This, in turn, calls for coordinated efforts between physicians, policymakers, representatives in defence, the public health community and the private sector. This paper discusses the historical and contemporary landscape of biowarfare, and outlines global and national efforts to govern and address innovations in biowarfare due to rapidly emerging technology. It ponders how India can leverage the Quadrilateral Security Dialogue to enhance disarmament efforts and promote ethical considerations for bioweapons innovation.

Attribution: Shravishtha Ajaykumar, "Navigating Considerations of Global Governance, National Strategies, and Ethics in Biowarfare," *ORF Occasional Paper No. 405*, August 2023, Observer Research Foundation.

Introduction

The term 'biotechnology' can refer to any of its various use cases in agriculture, climate management, DNA studies, and many other domains with human life at the core of innovation.[1] It is a field of technology aimed at domains such as improving human health, environmental protection, preservation of biodiversity, scientific innovation, and improved agriculture.[2] In 2005, the Organisation For Economic Co-Operation and Development (OECD) Ad Hoc Statistics Group on Biotechnology defined 'biotechnology' as the application of science and technology for parts, products, and models of living organisms for application in goods, services, research and development.[3] These definitions were expanded to include DNA/RNA, proteins and other molecules, cell and tissue culture and engineering, processing of biotechnologies, gene and RNA vectors, bioinformatics, and nanobiotechnology.

In the field of security, biotechnology research is a vast space, embracing goals such as providing healthy food for soldiers, increasing preparedness in natural disasters and emergencies, and deploying emergency healthcare.[4,5] Biotechnology has contributed to the enhancement of human life in many ways, but like many innovations, provokes a dual-use dilemma: While biotechnology can assist in improving healthcare and food security, the same technology can be used to perpetuate harm or the threat of harm for geopolitical and strategic purposes—or what is known as biowarfare. 'Biowarfare' refers to the intentional use of biological agents (e.g., bacteria, viruses, fungi, and toxins) as weapons in war scenarios.

This paper focuses on the use of biological agents in warfare and describes historical instances of biological weapon use and emerging technologies with future use potential. It highlights governing structures, outlines India's perspective of biowarfare, and explores how the country can leverage its multilateral alliances to enhance biological weapons deterrence.

Historical Mapping and Contemporary Use of Biological Warfare

Biological weapons can potentially be more dangerous to civilian populations than conventional and kinetic weapon systems, as even minute quantities can cause mass casualties depending on the agent used. The use of biological weapons also adds an element of deniability; if the result is not or cannot be effectively traced back to a source due to its potentially significant area of impact or it is mimicking a natural outbreak, the users of biological weapons could escape accountability.[6] Dual-use for harm is an externality of biotechnology, as with many technological innovations. Thus, in biological warfare,[a] the irremovability from human life augments social and geopolitical concerns around use.[7]

Historically, warfare has included biological weapons.[8] This use, even when small in scale, has warranted awareness, regulation, and monitoring discussions to aid strategic and deterrence efforts. As Table 1 shows, the intentional use of microorganisms (or their toxins) as weapons is not an uncommon practice and it has had notable impact for decades. The evolution of biowarfare over time can be divided into three periods:[9,10]

1. Leading up to the 1900s, when biological weapons and toxins were used for political espionage.

2. 1900-1945: This period was characterised by the emergence of small and unsophisticated national biowarfare programmes (e.g., Germany, Japan, the Soviet Union, and the United States) and the use of biological weapons in the First and Second World Wars.

3. After 1945: Broader access to biological agents and the progress made in the field of biotechnology allowed biowarfare programmes to be more accessible even to small groups and individuals. During this period, the lethal potential of biowarfare agents increased due to developments in genetic engineering.

---

a Biological warfare or biowarfare has traditionally been categorised as the use of biological agents that are manufactured or naturally occurring for national security and strategic outcomes by state and non-state actors. However, with innovations in synthetic biology and DNA mapping, these definitions need to become more inclusive of emerging technology.

Table 1: Significant, Large-Scale and Recorded Use of Biowarfare

Era	Toxin Carrier	Toxin	Impact
Pre-World War I	Bacteria	Agroterrorism (glanders and Anthrax)	Germany shipped infected livestock to Americanised countries to disrupt the food chain pre-World War I.
World War II	Insect	Flea vector (plague)	The Japanese Army developed the Uji Bomb[11] and sprayed allies with infected pathogens, killing approximately 100,000 people.
	Insect	Agroterrorism: potato beetle	France and Germany attempted to use insects such as the potato beetle to destroy crops.
	Insect	Lice vector (typhus)	The Soviets used typhus-infected lice against German troops.
	Insect	Mosquito vector (yellow fever)	The Canadian military used Aedes aegypti[b] to transmit yellow fever.
	Bacteria	Anthrax and waterborne organisms	Japanese Army Units 731 and 100 are said to have experimented on humans with aerosolised Anthrax.
	Bacteria	Tularemia	Allegations of Soviet use against Germans
Korean War	Toxin	T2 mycotoxin	Allegation of US use against North Korea in 1952

b Commonly known as the yellow fever mosquito

Historical Mapping and Contemporary Use of Biological Warfare

Era	Toxin Carrier	Toxin	Impact
Cold War	Insect	Vectors	US and Canadian military research and development on using fleas, flies, and mosquitoes to transmit infection.
	Bacteria	Plague and tularemia	US and Russia developed techniques for aerosolising plague and tularemia.
	Bacteria	Anthrax	April 1979: An inhalational anthrax outbreak was reported near the Soviet Institute of Microbiology and Virology at Sverdlovsk, USSR.
	Toxin	T2 mycotoxin	Allegation of Soviet/Vietnamese use in Cambodia and Laos in 1975–1981
	Toxin	Aflatoxin	Iraq 1980: evidence to suggest work to weaponise aflatoxin
Present	Bacteria	Anthrax	Japan 1990–1995: Aum Shunrikyo sect attempts to develop aerosolised anthrax and botulinum toxin
	Bacteria	Anthrax / Amerithrax	United States, 2001: After the attacks on the twin towers, many received letters laced with anthrax resulting in the death of 5 Americans, with 17 others falling ill.[12]
	Toxin	Ricin	United States, 1 November 2011: 3 men arrested by the Federal Bureau of Investigation for planning a ricin attack on US government offices
	Toxin	Ricin	United States, April 2013: Letters containing ricin mailed by an unknown perpetrator to the President and a Senator were intercepted before delivery to their recipients

Source: Michael D Christian. "Biowarfare and Bioterrorism."[13]

The biowarfare capabilities of states have varied across time, ranging from small-scale attacks on stakeholders to larger events that aimed at livestock and agriculture. These attacks, and the uncertainty of scale of impact, contribute to geopolitical tensions; in response, international bodies such as the United Nations Institute for Disarmament Research and the World Health Organization are seeking to supervise biotechnology innovation.[14]

As seen in Table 1, the different uses of biological weapons have expanded the definition of 'biotechnology in warfare' to include various organic carriers, capability objectives,[c] and the influence of organic weapons.[15] Spencer (2001) defines the use of biological weapons in war or "bioterrorism" as "the usage of microorganisms as guns of catastrophic impact, which may be defined as the class or approach of use of a weapon gadget that outcomes in a good-sized terrible effect on a nation's bodily, mental or monetary well-being, thereby inflicting a primary amendment of habitual activity."[16]

Therefore, 'biowarfare' is an umbrella term for the state use of biological weapons in war zones, deterrence strategies and research for defence potential. Meanwhile, 'bioterrorism' refers solely to the use of biological weapons by state or non-state actors against civilian populations.[17] These definitions assist in identifying the use of biological weapons outside of war zones; the susceptibility of non-humans, such as farm animals, and crops, to bioterrorism and agroterrorism[d] remains consistent. Further, as bioterrorism does not target humans directly, the deniability of accountability is more significant than in biowarfare.

---

c To describe the capability and related actions to be tested and demonstrated, used to impact a clearly defined set of tasks, in this example, under the impact of biowarfare.

d This sub-category of bioterrorism impacts animals, ecology and crop yields, resulting in harm to human life.

Genomic Editing and Synthetic Biology

Genetic engineering, first developed in the 1970s, manipulates DNA or RNA, setting the foundation for genomic editing in the present day.[18] This technology has developed at a rapid pace in the last decade, influencing research and development in biomedicine and technology as well as applications in agriculture in the form of Genetically Modified Organisms or GMOs.[19]

Genomic editing has three prevalent subtypes: zinc-finger nucleases (ZFNs); transcription activator-like effector nucleases (TALENs); and clustered regularly interspaced short palindromic repeat (CRISPR)–Cas-associated nucleases.[20] An extension of CRISPR-Cas are two methods for identifying viral vulnerability or presence in genetic samples. These are specific high-sensitivity enzymatic reporter unlocking (SHERLOCK) and the DNA endonuclease-targeted CRISPR trans reporter (DETECTR).[21] Genomic editing tools like CRISPR-Cas hold promise in applications for immunotherapy, cancer research, and vaccine development.[22] Its offshoots—SHERLOCK and DETECTR—can identify the presence of viruses or lack thereof in any organism, even if asymptomatic. These two together offer a unique contemporary solution of biodefence[e] to threats of limited traceability and uncontrolled scope of impact in biowarfare.[23]

However, these innovations in genomic editing also contribute to the dual-use dilemma. Genomic editing has other uses that could heighten the potential threat of future biowarfare tactics in the following ways:

1. Genomic Editing and Gain of Function Research:[f] Synthetic biology[g] and genetic editing offer options for repairing genetic defects in living organisms; however, the same can be used to enhance the harmful aspects of viruses and increase the potential of biohacking. An example of this is creating dangerous covert viruses that use harmless bacteria

---

e Biotechnology solutions to outcomes of biowarfare or bioterrorism.
f Mutating a gene to create a new molecular function or a new pattern of gene expression.
g Redesigning organisms to solve problems in medicine, manufacturing and agriculture.

as carriers. This has been demonstrated in experiments conducted by infecting copy DNA (cDNA or DNA reconstructed to imitate an existing strain) with an RNA virus with poliovirus, influenza, and coronavirus.[24] To counter malicious biohacking and genetic editing, the US Defence Advanced Research Projects Agency (DARPA) is exploring its Insect Allies Program to defend crops against biological threats using Horizontal Environmental Genetic Alteration Agents (HEGAAs).[25]

Gain of Function Research has, in recent years, referred to a series of experiments attempting to reduce the impact of the H1N1 virus on humans.[26] This ability to alter the potency and manipulate the effect of a virus on other organisms creates concerns of dual use.[27] For example, due to the dual use of potency manipulation of a virus, this research was paused in 2012. It was revived in 2017, with the US government lifting the ban and outlining assisting regulations to oversee the Gain of Function and prohibit government funding.[28,29]

2. Antimaterial Weapons: Some types of bacteria and fungi are used to break down plastic and carbon sources. Research is ongoing on enhancing plastic-degrading enzymes to assist in climate change control.[30] These enzymes, used incorrectly and maliciously, can destroy and degrade infrastructure and harm the ecology and humans as conventional bioweapons do.

Current Global Biowarfare Capabilities

Nation-States with Bioweapon Capabilities

There are a number of countries listed in open-source documents suspected of being non-compliant in the use of biological or chemical weapons.[31,32] J Tucker and K Vogel (2000) have highlighted countries with programmes and capabilities in biological warfare, including China, Egypt, North Korea, Iran, Israel, Russia, and Syria. This list also includes (by incorporating chemical warfare with biological warfare research) Burma, Cuba, India, South Korea, Laos, Pakistan, and Taiwan.[33] The James Martin Centre for Non-Proliferation Studies, in its 2008 roster, also listed China, Egypt, North Korea, Iran, Israel, Russia, and Syria as suspected purveyors of biowarfare programmes.[34] The list also included Canada, Germany, and India, and reiterated other larger countries with past programmes and research in biowarfare, like Russia and China.[35]

To compare the level of biowarfare capabilities, this paper ranked the countries based on the commonalities in these three studies, factors outside of biowarfare (such as chemical warfare), and the rankings given to them present in all three studies. The categories are Advanced, Intermediate, and Novice[h] Biowarfare Capabilities (Table 2).

While the three studies mentioned above list countries with suspected or past biowarfare programmes, that by Mezzour et al. (2014)[36] showed the capabilities of countries that have also conducted biotechnology-focused research and nuclear research and have nuclear weapons capabilities. Thus, due to the academic pillar of their methodology, the resultant ranking differs from the one presented in the preceding three studies, as shown in Table 2.

---

h Countries' presence in the three lists on non-proliferation is mentioned as highly ranked; it is characterised as "Advanced." If it is on all categorisations except the US DoS, it is characterised as "Intermediate." If it is listed by J Tucker and K Vogel and not on the other lists, it is characterised as "Novice" due to its reliance in ranking on chemical weapons and not biological armaments alone.

Table 2: Historical and Contemporary Global Biowarfare Capabilities

Country	Status	Ranking as Given by Mezzour et al.[i]
Russia	Advanced	Advanced
China	Advanced	Intermediate
Iran	Advanced	Advanced
Iraq	Advanced	Advanced
Syria	Intermediate	Advanced
Libya	Intermediate	-
North Korea	Intermediate	Advanced
Egypt	Intermediate	Advanced
Israel	Intermediate	Advanced
Burma	Novice	Intermediate
Cuba	Novice	-
India	Novice	Advanced
South Korea	Novice	-
Laos	Novice	-
Pakistan	Novice	Advanced
Taiwan	Novice	Advanced

Outside of these lists, protections on biowarfare and weapons, and by extension standards for maintenance and monitoring need to be implemented in the countries mentioned above and in others as well. A necessity for this is unreported research, development, and procurement of biological weapons. The lists mentioned above do not mention the most technologically advanced countries globally, such as Finland, the US and Japan.[37] While they might not have any biowarfare research ongoing, concerns remain.

i Scores over 0.66 are shown as "Advanced." Scores over 0.33 are shown as "Intermediate."

Current Global Biowarfare Capabilities

Non-State Biowarfare Capabilities

Non-state actors are also part of the landscape of biowarfare. The Al-Qaeda, for example, is said to be in possession of biological weapons. Reports from refereed journals have pointed to the alleged involvement of the former Soviet Union in assisting the Al-Qaeda in sourcing these agents.[38] Other countries and regions like Kazakhstan, the Czech Republic, Afghanistan, and East Asia are also said to have relations with Al-Qaeda in sourcing and purchasing biological weapons, toxins and agents.[39]

Individuals and small parties have often been seen trying to access biological weapons on the darknet.[40] The Interpol has created an 'Operational Manual on Investigating Biological and Chemical Terrorism on the Darknet' and formed the National Biosecurity Working Group (NBWG)[41,42] to assist law enforcement officials in identifying and mitigating instances of bioterrorism.

Neuroscience and Technology Application in Warfare

Similar to biological weapons, genetic editing and synthetic biology innovations have also led to developments in neuroscience that could, potentially in the next decade, include manipulating brain functions in warfare.[43] These can consist of using biological agents that impact neurological ability:[44]

1. Neuropharmacological and pharmacological agents[j] that enhance or inhibit an individual's neurological functioning. These can include Amphetamines, MDMA, LSD, and Ketamine.

2. Neuromicrobial agents,[k] including anthrax or gene-edited bacterium, that can spread viruses.

3. Organic Neurotoxins like Bungarotoxin, Conotoxins, and Najatoxins.

4. Neurotechnological devices[l] like transcranial neuromodulatory systems, direct-delivery nanosystems, and neuro nanomaterial agents that can help with enhanced delivery and absorption of chemicals.

The use of these features of neurotechnology in warfare is currently unregulated. Moreover, the strategic use of neurobiological data and automation features can enhance the potential use of neuroscience in bioterrorism and biowarfare by altering brain functioning, improving it for allies and inhibiting it for targets.[45]

---

j These are biochemical drugs or toxins that can either heighten an individual's senses or increase susceptibility to stimuli, thus increasing vulnerability.
k Biological agents and toxins that have an impact on neurological functioning and perceptions.
l Nanodevices or chemicals that aid in the delivery of neurobiological toxins and agents.

Challenges in Detection

Describing the epidemiology of agents of bioterrorism is a massive challenge for several reasons.

First, there are unknown factors involved, including the scope of bioterrorism, applications and impact of emerging technology, and the effect of automation on the creation of biological and chemical agents. Further, with the speed of developments in emerging technology, it is hard to gauge the future impacts of biological weapons or the forms biological weapons might take.[46]

Second, as will be discussed in a latter section of this paper—while the Biological Weapons Convention bans the use of biological weapons, there are no verification or investigation mechanisms and the authorities rely on self-reporting.[47] Furthermore, since military or state organisations have conducted most of the work on bioweapons, only a small proportion of these activities have been publicly reported. There is limited publicly available knowledge on the monitoring of research in the field of biological weapons and biotechnology innovations outside of defence.[48]

Methods for Detection

The first step in monitoring the use of biological weapons and preventing acts of bioterrorism is to identify them over naturally occurring outbreaks. While both warrant disaster management, identifying both, assists in highlighting levels of deterrence and disaster management.

1. Sanger Sequencing: Unlike traditional forms of warfare, biological warfare and bioterrorism can be covert and untraceable to its source. The impact on living organisms and dependence on living organisms to transfer and carry biological agents and toxins results in a challenging outcome in distinguishing between manufactured events (terrorism) and natural phenomena (epidemics). Some popular methods to

determine the origin include the classic Sanger sequencing,[m] devised by Fred Sanger.[49] Sanger sequencing, by outlining genome evolution, can predict natural evolution and points of human intervention that would lead to the studied outcome (in these cases, carrying a virus or biological/neurobiological toxin).[50]

2. Radosavljevic and Belojevic's Method: More recently, a scoring system was developed by Vladan Radosavljevic and Goran Belojevic[51] that helps differentiate between bioterrorism incidents and epidemics. These investigators use an approach that assesses an incident's qualitative and quantitative characteristics. These traits fall into three groups that are scored: people (cases), places (spatial distribution), and time. Out of a total of 14, a score of 8 or higher in this system indicates that an event is "more likely" to be artificial (deliberate or accidental) than a naturally occurring epidemic.

For example, in the case of an H1N1 virus outbreak, the three groups would include the number of people affected at first instance and the number of unexpected cases, the non-response to medication, and the clustering of the outbreak. The second category for analysis would include spatial distribution, including limited plausibility for natural occurrence based on ecology, and simultaneous outbreaks in other regions without travel or infection. Finally, the third pillar would be time distribution, requiring such outbreaks to happen in concurrence or immediacy.

This system has helped establish a required level of situational awareness that clinicians cannot achieve in a hospital setting. Therefore, the effective judgment of the origin of an outbreak needs implementation at the public health level rather than that of the individual clinician.

3. Global Adoption of Identifying Outbreak Source: The North Atlantic Treaty Organization (NATO) and the US Centers for Disease Control and Prevention (CDC) developed another method to determine the scope of an act of bioterrorism versus that of an epidemic. This method,

m Deriving data on origin of biological weapons by tracing genome evolution cycles and reconstructing them in reverse.

similar to Radosavljevic and Belojevic's, outlines the plausibility of a natural outbreak by measuring certain features of the outbreak:[52,53]

- Identification of a cluster of cases (large numbers of patients from a similar geographic area with similar symptoms)
- High and rapid fatality among cases
- Many casualties within the first 72 hours may indicate a microorganism attack or within minutes to hours, which may be due to a toxin.
- A lower attack rate in people indoors than outdoors.
- Abnormally high prevalence of respiratory-related disease in diseases commonly cause non-pulmonary syndromes when acquired in nature.
- Casualty distribution aligned with wind direction.
- An illness type highly unusual for the geographic area
- The appearance of a category A, B, or C disease (as defined by the CDC)
- Increased numbers of affected animals, of varying species, in a designated geographic area
- Witness to the attack or discovery of an appropriate delivery system

If the outbreak scores high on these markers in the checklist, there is an increased plausibility of a manufactured act of bioterrorism.

4. High Throughput Sequencing: In the early 2000s, high-throughput sequencing (HTS) [also known as massively parallel sequencing (MPS) technology or next-generation sequencing (NGS)] was introduced. This technology functions as Sanger Sequencing does; however, due to its improved multiplexing capabilities,[n] this method allows whole-

n Ability to monitor the matrices of virus, fungi, and other biological agents in increased speeds and real time.

genome sequencing (WGS) of single microorganisms (viruses, bacteria, and fungi) or multiple organisms within an environmental sample. It can simultaneously address multiple DNA/RNA strains for more thorough, cost-effective and time-effective outcomes.[54]

In 2014, the HTS approach was introduced into routine diagnostics and used to study outbreaks and transmission and to genotype highly resistant organisms. In collaboration with molecular microbiologists and infection control specialists, clinical microbiologists and infectious disease specialists often rely on HTS to identify sources, detect outbreaks, transmit pathways, pathogen evolution, and identify the dynamics of multidrug-resistant pathogens.[55]

The predominant benefits of HTS over classical Sanger sequencing are:

i. High-throughput capability: Hundreds of thousands of sequencing reactions may be carried out in parallel, allowing complete sequencing of a whole bacterial genome in a few run-throughs.

ii. An available protocol for identity and genotyping may be implemented for all microorganisms.

iii. DNA cloning is eliminated, solely relying on library preparation in a cell-loose system.

iv. No earlier know-how approximating the collection of a specific gene/genome is required because HTS can examine the DNA templates randomly disbursed at some stage in the complete genome, after which a de novo genome meeting[o] may be implemented.

v. No need for isolation, and the lifestyle of the microorganism of interest is incredibly essential. Many traces cannot develop in lifestyle media, permitting the identity of microorganisms and those formerly undetected via more traditional methodologies.

o Translates to 'novel genome sequencing', it categorises genome sequencing that does not have a reference genome to align to.

vi. Cost (generally less than US$1,000) in keeping with the genome, relying upon the genome length) and the discount in turnaround time (only some hours).[56]

Widespread use of microbial forensics, including the methods mentioned above, requires educating the forensics community. Implications of such methods need to include reporting by private sector organisations of research and innovation activities, monitoring of the same and transparency requirements, including applying legal and trustworthy standards for genetic data protection and accuracy of generated data. These include correct use of databases and information tools. End users (crime scene investigators, lawyers, judges, juries) must utilise these innovations to contend with the use of biological weapons and address naturally occurring outbreaks.

Guidelines for Biological Weapon Deterrence

As the potential of biological weapons increase with innovation, national security establishments are being tasked to accord greater attention to deterrence. For example, gene editing has been cited in the US Director of National Intelligence Annual Report 2016, citing suspected development of biological and chemical weapons in states like the Democratic People's Republic of Korea, the People's Republic of China, Russia, and the Islamic Republic of Iran. The same report highlights concerns around biochemical weapons used by Syria and the Islamic State.[57]

Apart from the speculated use by state and non-state actors, emerging technology in this field has also resulted in academic interest in security and strategy in the field of biological weapon use, i.e., biosecurity.[58] The US's CDC has identified and classified a list of potential bioterrorism agents.[59] Agents identified by the CDC are accepted by most authorities worldwide as top priority for preparation and research. Others like Relman expand on this list to include agents that have seen heavy use and research by previously significant military programmes and may hold significance in future research and service.[60]

Although the danger of large-scale bioterrorism is low, the potential for use at smaller scales and in tandem with other warfare tactics is still prevalent.[61,62] As shown in Table 1, Anthrax, a lethal agent commonly used in small-scale attacks on high-level stakeholders, has impacted the surrounding populations.[63]

Certain mechanisms are in place to mitigate the threat.

Biological Weapons Convention

While detection methods for biological weapons are advancing, the ethical guidelines and global regulations have remained constant. As mentioned in earlier sections, the Biological Weapons Convention (BWC) is a legally binding treaty banning the use, development, and trade of biological weapons. After being discussed and negotiated at the United Nations Forum on Disarmament since 1969, the BWC was launched on 10 April 1972 and entered into force on 26 March 1975. It currently has 183 Parties.[64]

BWC prohibits:[65]

1. Development, inventory, acquisition, storage, and manufacture of weapons, equipment, delivery vectors, biological agents, and toxins.

2. Acquisition or assisting in acquiring agents, toxins, weapons, equipment, and means of transport to be used as weapons.

The Convention further requires States' Parties to destroy or divert "drugs, poisons, weapons, equipment and means of transport" for peaceful purposes within nine months of the Convention's entry into force. These include the weaponisation of biological agents such as Anthrax, Smallpox and Tularemia; and the weaponised use of dual-use toxins such as clostridium botulinum toxin, staphylococcal enterotoxin-B (SEB), conotoxin, clostridium botulinum (BTOX), chimaera pathogens and other derived biotoxins.[66] The BWC limits the use of pathogens listed above for offensive use. However, it does not ban research on such pathogens for biological weapons deterrence.[67]

The treaty permits signatory states to consult with one another and cooperate, bilaterally or multilaterally, and address compliance concerns. It also allows States to complain to the UN Security Council (UNSC) if they believe other member states are in violation of the Convention. The UNSC can investigate complaints, though this power has never been invoked. The Council's voting rules give China, France, Russia, the United Kingdom, and the United States veto control over decisions, including those on conducting BWC investigations.[68]

In June 2023, the BWC established its Biological Weapons Convention National Implementation Measures Database, which allows users to track all national signatories, national programmes and interactions between nations in the field of biological weapon use, research and deterrence.[69] The BWC also regularly convenes for review conferences and in March 2023 established a Working Group to enhance implementation measures, expanding these to legally binding measures where possible and assisting in expanding and strengthening the Convention.[70] The Working Group is charged with prioritising scientific and technological research and development and economic growth as a product of international cooperation in the field of biotechnology.[71] The BWC has seen success in its standards by keeping its fundamentals clear and focusing on the scope of impact of biological weapons rather than altering the need for impact assessment based on the evolution of technology. That is, while biotechnology evolves and innovations in this field emerge, the scope of impact is still measured in human life alteration.

Addressing Limitations

While the BWC has taken steps in limiting the use of biological weapons, some limitations necessitate a rethinking of the treaty.

1. The treaty has been flagrantly violated in the past. For example, the Soviet Union, a party to the treaty and one of its depositaries, maintained an extensive offensive biological weapons programme after ratifying the BWC. While Russia claims that the programme is no longer live, questions about its remnants have not been satisfactorily put to rest.[72]

In November 2001, the US alleged that Iraq and North Korea had violated the treaty's terms. The US also expressed concern about compliance by signatories Iran, Libya, and Syria.[73]

With the new working group established in the ninth review conference in March 2023, possible legal guarantees for non-compliance can be discussed and outlined to address this limitation.

2. In 2020, the powers attributed to the UNSC countries to collaborate in the case of disaster management of 'non-traditional' geopolitical issues, especially concerning biological weapons or epidemic outbreaks, were tested. Amid the SARS-Cov-19 outbreak in early 2020, the UNSC could not find a common stance and did not respond effectively until later in July, when they passed Resolution 2532 to cease fire globally and prioritise tackling the pandemic. This delayed response indicated the lack of cooperation at the UNSC level despite BWC and UNSC guidelines creating a foundation for effective and timely responses.[74]

As this resolution has already been passed, it can act as an example for future disaster management in case of epidemics. However, there needs to be a more substantial representation of global efforts over national interests in the UNSC to encourage this.[75]

3. The definitions of the BWC have been intentionally inclusive and vague to avoid limited classification. Despite this, they are not inclusive of neuropharmacological agents or neurotechnological innovation to augment delivery systems, gene editing, nanoengineering outcomes for biological weapons, use of biological weapons to impact infrastructure and non-living landscapes, and the possibility of using neurotechnology and humans as biological weapon agents.[76,77]

Expanding the definition of what consists of biological weapons will target this limitation, as would the newly established working group reviewing this list regularly with upcoming innovations.

The Cartagena Protocol and Nagoya Protocol

The United Nations Conference on Environment and Development (UNCED) established The Convention on Biological Diversity in 1992 to oversee technology and knowledge transfer with relevance to biological diversity and sustainability.[78] The Convention on Biological Diversity, however, does not limit; rather, it enhances research in biotechnology while prioritising safety and curbing threats to diversity. To achieve these goals, the Cartagena Protocol was established and adopted to ensure "the safe transfer, handling and use of living modified organisms resulting from modern biotechnology that may have adverse effects on the conservation and sustainable use of biological diversity, also taking into account risks to human health, and specifically focusing on transboundary movements."[79] Currently, the protocol has 173 parties with 103 signatures.[80]

The Convention on Biological Diversity in 2010 also established the Nagoya Protocol.[81] The protocol, with 140 signatories, aims to facilitate "fair and equitable sharing of the benefits arising from the utilisation of genetic resources, including by appropriate access to genetic resources and by appropriate transfer of relevant technologies, taking into account all rights over those resources and to technologies, and by appropriate funding, thereby contributing to the conservation of biological diversity and the sustainable use of its components."[82,83]

Addressing Limitations

While the Cartagena Protocol oversees the sustainable and safe impact of biotechnology on living organisms and includes any transfer of biological agents that may harm ecology and human health, the Nagoya Protocol oversees responsible data sharing and benefit sharing in gene editing. Each protocol, on its own—and the two in combination—are unable to cover the gap.

The knowledge transfer of gene editing is encouraged, and biological agents that may come in chemical form, including neurobiological agents, are not covered. This creates a gap in guidelines for the potential knowledge transfer for developing neurobiological agents and using humans as agents of transfer.[84] Similar to the need to expand on definitions as with the BWC, the Convention of Biological Diversity can either encourage new protocols to include neurobiological agents and human carriers or create addendums to existing protocols with regular review processes.

International Standards Organisation

In November 2019, the ISO released a comprehensive set of standards on biorisk management, i.e., mitigating leakages from laboratories that conduct research and intelligence on biotechnology and its subparts. These standards include maintaining records and establishing biorisk management principles that enable laboratories and related facilities to mitigate biorisk.[85]

Figure 1. ISO's Biorisk Management System Model (In top-down pyramid view)

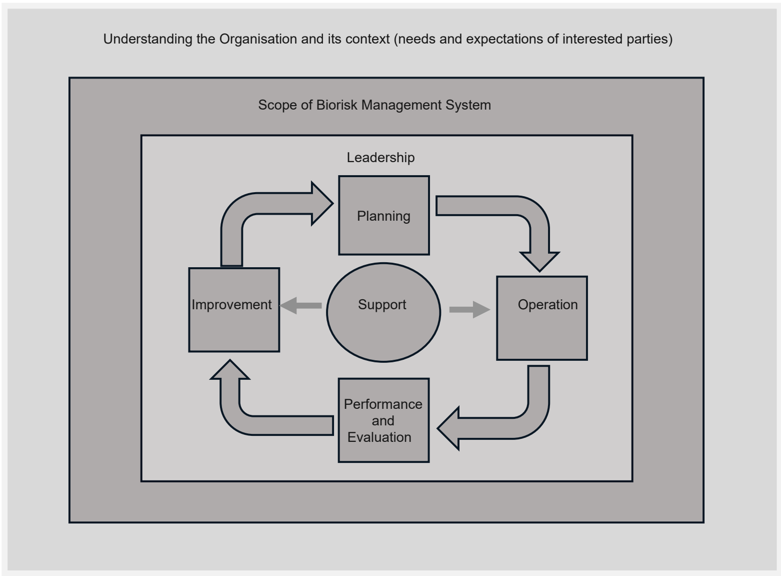


Image Source: ISO 35001:2019: Biorisk management for laboratories and other related organisations.[86] *To oversee safety in biolabs and prevent accidental leaks.*

As shown in Figure 1, while the ISO standards are comprehensive, the model is presented for management. This framework and model have been adapted from another ISO Standard, ISO 45001 on Occupational Health and Safety management system — Requirements with guidance for use. While its application in most civilian cases of biorisk management may be transferrable for the purposes of biowarfare, the ISO misses on an imperative need for monitoring and international standards on dual-use biotechnology.

Guidelines for Biological Weapon Deterrence

Addressing Limitations

The standards presented by the ISO depend on self-governance and implementation, not calling to action any global authorities or national organisations to take charge of implementation and increased accountability. Governments should establish bodies that will ensure that biological labs are certified to follow ISO rules by encouraging funding or subsidies in research to those who are certified and completely compliant.

World Health Organization

The World Health Organization (WHO) too, has an outbreak toolkit that can be used to investigate suspected or natural outbreaks and epidemics.[87] The toolkit has four overarching stages.

Stage 1: To detect, alert and report any possible cases of bioattacks/epidemics.

Stage 2: To begin information gathering and evaluation.

Stage 3: To increase and supplement the base data collected by adding environmental data, clinical information, technological assistance and statistical plausibility.

Stage 4: To conduct field investigations which, unlike most other standards, include the psychogenic impacts beyond toxicological and environmental impacts.

Stage 5: The final results of the study and investigation which may be released in form of a public report, or can be used for internal determination.

This framework is often used to investigate alleged bioattacks. Further, the UN Secretary-General has the authority to investigate the possible use of bioweapons.[88]

Guidelines for Biological Weapon Deterrence

Addressing Limitations

Bureaucratic delays between WHO and the UN Secretary General's office slows the process of detection and there is a need for a third-party or subsidiary organisation that can expedite.[89] Establishing a coordinating authority that removes these delays will reduce the time allocated to monitoring, assessment and reporting of bioterrorism or epidemic instances.[90]

> "Although the danger of large-scale bioterrorism is low, there is potential for use at smaller scales and in tandem with other warfare tactics."

The Regulatory Landscape in India

India has strong biotechnology capabilities but has focused its efforts outside of biowarfare and biological weapon deterrence.[91,92] The country's priority has been on research and development, as seen in the National Biotechnology Development Strategy 2021 – 2025.[93] Research in recent years has engaged public health as its main outcome, including diseases like cancer, tuberculosis, and malaria, as can be noted with the scope of biological data collection for biotechnology research by biobanks in India.[94,95]

India's current regulations around biotechnology development are inclusive, with guidelines on data and benefit sharing in biotechnology, guidelines for gene editing, and Biosafety Programme.[96,97,98] There are significant gaps in the guidelines, however. For one, while they address the need for funding and innovation in the field of biotechnology, the Biosafety Programme has not been updated to include human carriers or neurobiological agents as weapons.[99] This results from isolated expertise and knowledge mismatch between scientists and policymakers.

To lead the strategy and deterrence in the biowarfare landscape, India must be equipped to detect or respond to biological threats from both natural and artificial sources. India must raise awareness, bridge science and policy, and mobilise resources. An essential part of biological weapons is the risk of impact on human life and ecology, and thus necessary to consider in deterrence. India is also vulnerable to these risks due to its high population density, weak public health infrastructure, low public health spending, and lack of training and awareness on biosecurity and measures.[100]

When naturally occurring infectious agents such as disease-causing viruses accidentally escape storage facilities, naturally evolve, or are manipulated to be used as biological weapons—all life is compromised. Therefore, despite India's growing biotechnology capacity in academic and industrial settings, it must be equipped to detect or respond to threats from either source.

The Regulatory Landscape in India

India has signed a 10-year defence framework agreement with the US, which includes provisions for "a lightweight, protective suit effective in chemical and biological hazard environments.[101] However, this move does not explicitly discuss a need for deterrence strategies. India needs to further strategic realignment of the Department of Biotechnology, National Disaster Management Agency, and Defence Research and Development Organisation to address the gap in biotechnology applications in strategy and security. This realignment will create a resurgence in focus on biotechnology research in disaster management and security applications.

The most significant gaps can be seen from a political and governance perspective. Having a single agency that looks after the process of biotechnology innovation, including in the field of defence, does not need to replace existing authorities, like the Department of Biotechnology. An organisation (akin to the Indian Space Research Organisation, or ISRO, for the space industry) can act as a coordinating authority to ensure all agencies have strategic alignment. This agency will also assist in staff capacity building and regular training in detecting and reporting biological threats. It could remove the issue of siloing, as it will not be concerned with only scientific innovation, as the Department of Biotechnology is, nor only strategic use of biotechnology, as any defence-led organisation might be.

India has also been a significant member of multilateral alliances with similar interests in technological advancement and utility for human life enhancement. One such multilateral alliance is the Quad Security Dialogue or Quad.

Leveraging the Quad

The Quad of the US, Australia, India, and Japan began their maritime cooperation after the 2004 Indian Ocean tsunami. Today, the four countries have a much broader range of interests, including security, economic and health issues.[102] So far, the four have focused their biotechnology efforts on biopharmaceuticals, genomes, agricultural biotechnology, and industrial biotechnology.[103]

India and the US have both been listed as countries with biowarfare capabilities and awareness, as shown in previous sections, determined by including academic research and historic participation in biowarfare. However, these two countries have not been listed under any suspected lists of contemporary biowarfare activities. Australia and Japan, too, have aligned themselves with the BWC.[104,105]

The Quad can be a powerful platform in influencing the landscape of biological warfare in the following ways:

1. Collaboration and a united front: All four countries have a vested interest in biotechnology innovation and the landscape of biological weapons deterrence, as characterised by their participation in the Cartagena Protocol, Nagoya Protocol, and the USA-India defence framework bilateral agreement.

Australia, too, through its Defence Science and Technology Organisation (DSTO) under the Department of Defence operates the Biological Defence Research. This office seeks to ensure biodefence in areas where biological weapons may be used and enhance Australia's participation in biological weapons deterrence.[106] For its part, Japan is also a member of the Australia Group[p] under the BWC and maintains strong controls and reports over the trade and transfer of biological agents.[107] India, the US, and Australia are also members of the Australia Group.[108]

---

p All participants in the Australia Group are States Parties to both the BWC and the Chemical Weapons Convention. They maintain records of international trade and transfer of any biological/chemical agent. These measures assist in even indirect participation in encouraging the spread and use of chemical and biological weapons.

In this area, there can be collaborations to represent common interests and increase focus on biosecurity. The 'One Health' initiative already provides a framework for international collaborations focusing on human health and that of other living organisms.[109] While this is for naturally occurring outbreaks, a similar mechanism can be adapted to highlight disaster management in the case of bioattacks. Furthermore, with the Quad, WHO can highlight this initiative, which can in turn further the interests of the Quad countries concerning bioweapons disarmament and biorisk management and monitoring.

2. Setting an example to enhance standards: The Quad can further align itself on the current controls and standards on laboratories and present any further standards that should be implemented as discussed in the section on the ISO biorisk management standards, self-reporting leakages and identification of any "lab-specific issues".

The Quad countries also have biobanks monitored and overseen by national regulations or guidelines.[110,111,112,113] By creating monitoring standards for other forms of biotechnology research and data sharing standards within this platform, the Quad can encourage monitoring and data sharing of non-strategic biological and biotechnological laboratories and setting standards, thus, for the rest of the world.

3. Reviewing assessment methods: Angela Kane, a disarmament advocate and diplomat, has advocated for the Joint Assessment Mechanism (JAM) under the Nuclear Threat Initiative (NTI). The JAM is proposed to be housed under the UN Secretary General's Office and expedite the assessment of suspect biological events.[114] The NTI would act as a subsidiary office reporting directly to the UN Secretary-General on any exploitation or non-compliance of the BWC. A collaboration like the Quad can also align itself with newer assessment methods like JAM, and advocate for its adoption by the UN and WHO to ensure future epidemics and bioattacks are detected and contained faster.

4. Prevent non-state actors from accessing weapons: The Quad countries can align their border control and cybersecurity authorities with Interpol for collaboration and cooperation to curb the traceable purchase and trade of biological agents and weapons. This can be done using mechanisms established by Interpol, like the Operational Manual on Investigating Biological and Chemical Terrorism on the darknet to trace purchases online and a National Biosecurity Working Group (NBWG) to align trade between the Quad countries. These measures will assist in curtailing individual and non-state actor access to bioweapons and can be a step in the right direction to make the Quad a change-maker in the field of disarmament.

> "The Quad can be a powerful platform in influencing the landscape of biological warfare."

Future Challenges

Biowarfare is no longer a naturally occurring agent that impacts all life. With innovations, there is scope for newer bioweapons and biowarfare.

- Genome editing and synthetic biology have made it possible to identify and impact only certain groups of people with a bioweapon and manipulate the potency of existing viruses or diseases in carriers.[115] Concerns around this include the potential grave impacts on local ecosystems and people. Guidelines and guarantees around the use of genome editing, synthetic biology and biometric informatics for weapons need to be highlighted.

- With the advent of Artificial Intelligence and growth in data sets, the scope of bioactive components and toxins being expanded upon by AI is possible.[116] Policies around this area need to ensure that AI in warfare is not permitted to help develop chemical compounds that can be used to create toxins.

- Biolabs are the basis of research and innovation in biological and chemical agents. However, such research and innovation can be conducted outside traditional biolabs. What comprises a biolab and the basic requirements to be certified as a biolab must be redefined. With technologies overlapping and innovating, leakages are also possible from non-traditional and non-biological labs, and thus contemporary definitions are required. Such redefining will help monitor efforts and government intervention in case of leaks and track sales and purchases of biological and chemical agents, even in small amounts.

Future Challenges

- Dual-use dilemmas need to be expanded. As seen in the brief section on neurobiological weapons, some are used as recreational drugs. Specifically, how drugs allowed in free trade can be misused by malicious parties need to be considered. Thus, expanding definitions in dual-use concerns will help monitor and mitigate the trade and transfer of neurobiological agents.

- War gaming,[q] running simulations or controlled experimentation of biological weapons need to be introduced to ensure the applicability of biodefence measures, the scope of impact of bioattacks, and mitigation tactics.

> "Artificial Intelligence could possibly expand the scope of bioactive components and toxins for biowarfare."

q Includes a variety of methodologies that assist in strategic decision-making and the development of strategies.

Conclusion

Bioterrorism may seem a distant possibility to the average citizen, and yet biological weapons have been used for centuries. In recent years, the focus on potential biolab leakages, possible bioattacks, and biotechnology solutions has increased discussions on biowarfare and deterrence. Other than nation-states, criminals and terrorists often see biological weapons as a plausible alternative to conventional weapons. This is because biological weapons are relatively cheap to produce, microbes are relatively available, are quickly produced and supplied without being detected.

Biowarfare standards by the Biological Weapons Convention guide signatory nations; those by the International Standards Organisation outline best practices for biolabs and other organisations; and rules set by the Interpol govern non-state actors. However, due to the lack of global and social accountability, none of these standards is infallible. There is a need to incorporate rapid forms of assessment at a global level; this can include incorporating updated detection methods like High Throughput Sequencing at national and international levels, associated with a body that focuses on monitoring and detection like the Joint Assessment Mechanism under the Nuclear Threat Initiative. It is also essential to highlight the power of microbiological forensics while meeting the expectations of law enforcement, the public, policymakers, and the scientific community.

At the global, multilateral, and national levels, the solution to future biological weapons deterrence consists of the same four steps: presenting a united front against bioweapons; enhancing present-day standards to be future-proof by holding regular review cycles to include updating technology and ensuring reduced timelines between such review processes; enhancing assessment methods and monitoring agencies; and reassessing the focus on non-state actors in the landscape of biowarfare.

Shravishtha Ajaykumar *is Associate Fellow at ORF's Centre for Security, Strategy and Technology.*

Endnotes

1. "What Is Biotechnology?," *University of Pennsylvania,* https://biotech.seas.upenn.edu/what-is-biotechnology/.
2. Der-Chin Horng, "International Law on Biotechnology," *International Law and Institutions,* http://www.eolss.net/sample-chapters/c14/e1-36-13.pdf.
3. "A Framework for Biological Statistics," *Organisation for Economic Co-Operation and Development,* https://www.oecd.org/sti/inno/34935605.pdf.
4. Farhath Khanum et al., "Health Food for Soldiers," *Defence Life Science Journal*, April 2017, https://core.ac.uk/reader/333718720.
5. Syed Mohsan et al., "Role of Drone Technology Helping in Alleviating the COVID-19 Pandemic," *Micromachines (Basel),* September 25, 20, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9612140/.
6. Katherine Charlet, "The New Killer Pathogens: Countering the Coming Bioweapons Threat," *Foreign Affairs,* April 17, 2018, https://www.foreignaffairs.com/world/new-killer-pathogens.
7. H.J. Jansen et al., "Biological warfare, bioterrorism, and biocrime," *Clinical Microbiology and Infection,* June 2014, https://www.sciencedirect.com/science/article/pii/S1198743X14641732.
8. James W Martin et al., "History of biological weapons: from poisoned darts to intentional epidemics," *Medical aspects of biological warfare* (2007), https://books.google.co.in/books?hl=en&lr=&id=7LkTsiaJCukC&oi=fnd&pg=PA1&dq=biological+weapons+a+history&ots=GyMy89A_ZJ&sig=qsip_rLzAAcCkt41rWDha4RDgRI&redir_esc=y#v=onepage&q=biological%20weapons%20a%20history&f=false.
9. Stefan Riedel, "Biological warfare and bioterrorism: a historical review," *Proceedings (Baylor University. Medical Center),* vol. 17.4 (2004), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1200679/.
10. H.J. Jansen et al., "Biological warfare, bioterrorism, and biocrime."
11. "Duties of Unit 731," *Pacific Atrocities Education*, https://www.pacificatrocities.org/dutiesofunit731.html.
12. "Amerithrax or Anthrax Investigation," *Federal Bureau of Investigation*, May 17, 2016, https://www.fbi.gov/history/famous-cases/amerithrax-or-anthrax-investigation.
13. Michael D. Christian, "Biowarfare and bioterrorism," *Critical care clinics* (2013), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7127345/#bib6.

Endnotes

14. James W. Martin et al., "History of biological weapons: from poisoned darts to intentional epidemics."

15. R. C. Spencer, "Potential bio-terror agents," *Journal of Hospital Infection* (2007), https://www.sciencedirect.com/science/article/abs/pii/S0195670107600085.

16. R. C. Spencer, "Potential bio-terror agents,"

17. Manuela Oliveira et al., "Biowarfare, bioterrorism and biocrime: A historical overview on microbial harmful applications," *Forensic Science International,* June 20, 2020, https://www.sciencedirect.com/science/article/pii/S0379073820302280.

18. Hongyi Li et al., "Applications of genome editing technology in the targeted therapy of human diseases: mechanisms, advances and prospects," *Signal Transduction and Targeted Therapy* (2020), https://www.nature.com/articles/s41392-019-0089-y#citeas.

19. Hongyi Li et al., "Applications of genome editing technology in the targeted therapy of human diseases: mechanisms, advances and prospects"

20. Hongyi Li et al., "Applications of genome editing technology in the targeted therapy of human diseases: mechanisms, advances and prospects"

21. Margaret E Kosal, "Emerging Life Sciences and Possible Threats to International Security," *Orbis* (2020), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7515815/#.

22. Hongyi Li et al., "Applications of genome editing technology in the targeted therapy of human diseases: mechanisms, advances and prospects"

23. Mujahed I. Mustafa et al., "SHERLOCK and DETECTR: CRISPR-Cas Systems as Potential Rapid Diagnostic Tools for Emerging Infectious Diseases," *Journal of Clinical Microbiology,* Vol. 59, No. 3, February 18, 2021, https://journals.asm.org/doi/10.1128/jcm.00745-20.

24. David P Clark et al., "Biological Warfare: Infectious Disease and Bioterrorism," *Biotechnology,* July 24, 2005 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7150198/.

25. David P Clark et al., "Biological Warfare: Infectious Disease and Bioterrorism"

26. W. Paul Duprex et al., "Gain-of-function experiments: time for a real debate," *Nature Reviews Microbiology*(2015), https://www.nature.com/articles/nrmicro3405.

27. W. Paul Duprex et al., "Gain-of-function experiments: time for a real debate"

28. United States Congress, "S.3012 - 117th Congress (2021-2022): Viral Gain of Function Research Moratorium Act," *United States Congress*, October 19, 2021, https://www.congress.gov/bill/117th-congress/senate-bill/3012.

Endnotes

29. Todd Kuiken, "Oversight of Gain of Function Research with Pathogens: Issues for Congress," *Congressional Research Services*, May 26, 2022, https://crsreports.congress.gov/product/pdf/R/R47114.

30. K P Saalbach, "Biological Warfare," *Biomedical Sciences, Encyclopaedia of Microbiology,* January 1, 2019, https://osnascholar.ub.uni-osnabrueck.de/handle/unios/17758.

31. Margaret E. Kosal, "Emerging Life Sciences and Possible Threats to International Security"

32. Daniel R. Coats, "Statement for the Record Worldwide Threat Assessment of The US Intelligence Community," *Director of National Intelligence, United States of America*, February 13, 2018, https://www.dni.gov/files/documents/Newsroom/Testimonies/2018-ATA---Unclassified-SSCI.pdf.

33. Jonathon B. Tucker et al., "Preventing the Proliferation of Chemical and Biological Weapon Materials and Know-How," *James Martin Center for Non-Proliferation Studies* (2000), https://www.nonproliferation.org/wp-content/uploads/npr/tucker71.pdf.

34. "Chemical and biological weapons: Possession and programs past and present," *James Martin Center for Non-Proliferation Studies*, March 2008, https://www.nonproliferation.org/wp-content/uploads/2016/03/2008-Chemical-and-Biological-Weapons_-Possession-and-Programs-Past-and-Present.pdf.

35. "Chemical and biological weapons: Possession and programs past and present"

36. Ghita Mezzour et al., "Systematic Assessment of Nation-States' Motivations and Capabilities to Produce Biological Weapons," *Carnegie Mellon University,* May 2014, http://ra.adm.cs.cmu.edu/anon/home/ftp/usr0/ftp/isr2014/CMU-ISR-14-103.pdf.

37. "Public Health Security and Bioterrorism Preparedness and Response Act of 2002," *United States Congress* (2002), https://www.govinfo.gov/content/pkg/STATUTE-116/pdf/STATUTE-116-Pg594.pdf#page=68.

38. Sammy Salama et al., "DOES INTENT EQUAL CAPABILITY? Al-Qaeda and Weapons of Mass Destruction," *Nonprolifieration Review,* November 2005, https://www.nonproliferation.org/wp-content/uploads/npr/123salama.pdf.

39. Sammy Salama et al., "DOES INTENT EQUAL CAPABILITY? Al-Qaeda and Weapons of Mass Destruction,"

40. "Bioterrorism," INTERPOL, https://www.interpol.int/en/Crimes/Terrorism/Bioterrorism.

41. "Bioterrorism"

42. Bioterrorism-Capacity Building and Training," INTERPOL,https://www.interpol.int/en/Crimes/Terrorism/Bioterrorism/Bioterrorism-Capacity-building-and-training.

Endnotes

43. Joseph DeFranco et al., "Redefining Neuroweapons: Emerging Capabilities in Neuroscience and Neurotechnology," *PRISM* 8, no. 3 (2019), https://www.jstor.org/stable/26864276.

44. James Giordano et al., "Neurotechnologies as weapons in national intelligence and defense – An overview," *Synesis*: A Journal of Science, Technology, Ethics, and Policy 2, no. 1 (2011), http://www.synesisjournal.com/vol2_no2_t1/GiordanoWurzman_2011_2_1.pdf.

45. Joseph DeFranco et al., "Redefining Neuroweapons: Emerging Capabilities in Neuroscience and Neurotechnology"

46. National Research Council (US) Committee on Research Standards and Practices to Prevent the Destructive Application of Biotechnology, "Biotechnology Research in an Age of Terrorism," *National Academies Press* (2004), https://pubmed.ncbi.nlm.nih.gov/25057686/.

47. Manish, "The BWC Review: Issues and Challenges," *Institute for Defence Studies and Analyses,* December 2016, https://idsa.in/cbwmagazine/bwc-review-issues-and-challenges.

48. James Giordano et al., "Neurotechnologies as weapons in national intelligence and defense – An overview"

49. Barto E Slatko et al., "Overview of Next-Generation Sequencing Technologies," *Current Protocols in Molecular Biology,* April 16, 2018, https://currentprotocols.onlinelibrary.wiley.com/doi/abs/10.1002/cpmb.59.

50. Barto E. Slatko et al., "Overview of Next-Generation Sequencing Technologies"

51. Radosavljevic et al., "Unusual epidemic events: a new method of early orientation and differentiation between natural and deliberate epidemics," *Public Health* (2012), https://www.sciencedirect.com/science/article/pii/S0033350611003507.

52. Manoj Karwa et al., "Bioterrorism and Critical Care," *Critical Care Clinic* (2003) https://pubmed.ncbi.nlm.nih.gov/12699324/.

53. "NATO Handbook on the Medical Aspects of NBC Defensive Operations, Part II–Biologic," *US Department of Defense, Department of the Army* (1996), http://www.fas.org/nuke/guide/usa/doctrine/dod/fm8-9/2toc.htm.

54. Manuela Oliveira et al., "Microbial forensics: new breakthroughs and future prospects." *Applied Microbiology and Biotechnology* (2018), https://link.springer.com/article/10.1007/s00253-018-9414-6.

55. Manuela Oliveira et al., "Microbial forensics: new breakthroughs and future prospects"

Endnotes

56. Manuela Oliveira et al., "Microbial forensics: new breakthroughs and future prospects"

57. Margaret E Kosal, "Emerging Life Sciences and Possible Threats to International Security"

58. "Dual – Use Reseach," *National Institute of Health,* https://oir.nih.gov/sourcebook/ethical-conduct/special-research-considerations/dual-use-research.

59. "Bioterrorism Agent and Diseases," *Centre for Disease Control and Prevention,* https://emergency.cdc.gov/agent/agentlist-category.asp.

60. David A Relman. "Bioterrorism–preparing to fight the next war". *New England Journal of Medicine*. January 12, 2006, https://www.nejm.org/doi/full/10.1056/NEJMp058078

61. Manoj Karwa et al., "Bioterrorism and Critical Care"

62. Bob Graham et al., "The threat of bioterrorism," *Disaster Medicine and Public Health Preparedness* (2011), https://pubmed.ncbi.nlm.nih.gov/21908693/.

63. Thomas V Inglesby et al., "Anthrax as a biological weapon, 2002: updated recommendations for management," *JAMA* (2002), https://pubmed.ncbi.nlm.nih.gov/11980524/.

64. "History of the Biological Weapons Convention – UNODA," *United Nations*, https://www.un.org/disarmament/biological-weapons/about/history/.

65. "Fact Sheets & Briefs - The Biological Weapons Convention (BWC) At A Glance," *Arms Control Association,* https://www.armscontrol.org/factsheets/bwc.

66. Daniel Gerstein et al., "Rethinking the Biological and Toxin Weapons Convention," *Health Security,* December 1, 2017, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5734154/.

67. "Fact Sheets & Briefs - The Biological Weapons Convention (BWC) At A Glance"

68. "Fact Sheets & Briefs - The Biological Weapons Convention (BWC) At A Glance"

69. "Soft Launch of the Biological Weapons Convention National Implementation Measures Database," *United Nations Institute of Disarmament Research,* https://unidir.org/events/soft-launch-biological-weapons-convention-national-implementation-measures-database.

70. "The BWC Working Group: setting the scene for the organizational meeting," *Bioweapons Prevention Project Report 1* (2023), https://www.cbw-events.org.uk/BWC23-01.pdf.

71. "The BWC Working Group: setting the scene for the organizational meeting" *1*

Endnotes

72. David Hoffman, "Russia Challenged to Disclose Status of Biological Weapons," *The Washington Post Research Archives,* February 26, 1998, https://www.washingtonpost.com/wp-srv/inatl/longterm/russiagov/stories/disclose022698.htm.

73. "Fact Sheets & Briefs - The Biological Weapons Convention (BWC) At A Glance"

74. UN. Security Council, "Resolution 2532 (2020) / adopted by the Security Council on 1 July 2020," UN. Security Council (2020), https://digitallibrary.un.org/record/3870751?ln=en.

75. Bruno Charbonneau, "The COVID-19 test of the United Nations Security Council," *International Journal* (2021), https://journals.sagepub.com/doi/10.1177/0020702020986897.

76. Joseph DeFranco et al., "Redefining Neuroweapons: Emerging Capabilities in Neuroscience and Neurotechnology"

77. Rain Livoja et al., "Are Enhanced Warfighters Weapons, Means, or Methods of Warfare," *International Law Studies* (2018), https://digital-commons.usnwc.edu/cgi/viewcontent.cgi?article=1723&context=ils.

78. "Cartagena Protocol on Biosafety to The Convention on Biological Diversity," *Convention on Biological Diversity* (2000), https://www.cbd.int/doc/legal/cartagena-protocol-en.pdf.

79. "Cartagena Protocol on Biosafety to The Convention on Biological Diversity"

80. "List of Parties – Cartagena Protocol," *Convention on Biological Diversity,* https://www.cbd.int/information/parties.shtml#tab=1.

81. "Nagoya Protocol on Access to Genetic Resources and The Fair and Equitable Sharing of Benefits Arising From Their Utilization to The Convention on Biological Diversity," *Convention on Biological Diversity* (2010), https://www.cbd.int/abs/doc/protocol/nagoya-protocol-en.pdf.

82. "Parties to the Nagoya Protocol" *Convention on Biological Diversity,* https://www.cbd.int/abs/nagoya-protocol/signatories/

83. Nagoya Protocol on Access to Genetic Resources and The Fair and Equitable Sharing of Benefits Arising From Their Utilization to The Convention on Biological Diversity"

84. Rain Livoja et al., "Are Enhanced Warfighters Weapons, Means, or Methods of Warfare?" s

85. "ISO 35001:2019(En) Biorisk Management for Laboratories and Other Related Organisation," *International Standards Organisation,* https://sabs.isolutions.iso.org/obp/ui#!iso:std:iso:35001:ed-1:v1:en.

86. "ISO 35001:2019(En) Biorisk Management for Laboratories and Other Related Organisation"

Endnotes

87. "Outbreak Toolkit," *World Health Organization*, https://www.who.int/emergencies/outbreak-toolkit.

88. "Angela Kane on Reducing Global Catastrophic Biological Risks and the Importance of Personal Connections in Diplomacy," *The Nuclear Threat Initiative*, October 13, 2022, https://www.nti.org/atomic-pulse/angela-kane-on-reducing-global-catastrophic-biological-risks-and-the-importance-of-personal-connections-in-diplomacy/.

89. "Angela Kane on Reducing Global Catastrophic Biological Risks and the Importance of Personal Connections in Diplomacy"

90. "Angela Kane on Reducing Global Catastrophic Biological Risks and the Importance of Personal Connections in Diplomacy"

91. Mezzour et al., "Systematic Assessment of Nation-States' Motivations and Capabilities to Produce Biological Weapons," http://ra.adm.cs.cmu.edu/anon/home/ftp/usr0/ftp/isr2014/CMU-ISR-14-103.pdf

92. "India Biological Overview," *Nuclear Threat Initiative*, https://www.nti.org/analysis/articles/india-biological/#recent.

93. "National Biotechnology Development Strategy 2021-25," *Department of Biotechnology, Ministry Of Science & Technology,* https://dbtindia.gov.in/sites/default/files/National%20Biotechnology%20Development%20Strategy%202021-25.pdf.

94. BK Yadav et al., "Biobanking in India and its importance in cancer research," *Edorium Journals Cancer* (2017), https://www.edoriumjournalofcancer.com/archive/2017-archive/100005C01BY2017-yadav/100005C01BY2017-yadav-full-text.php.

95. "Department of Biotechnology," *Department of Biotechnology, Ministry of Science & Technology*, https://dbtindia.gov.in/.

96. "Biotech -PRIDE Guidelines," *Department of Biotechnology, Ministry of Science & Technology,* July 2021, https://dbtindia.gov.in/sites/default/files/uploadfiles/Biotech%20PRIDE%20Guidelines.pdf.

97. "Rules for the Manufacture, Use, Import, Export, and Storage of Hazardous Microorganisms, Genetically Engineered Organisms or Cells," *Indian Council of Agricultural Research Biosafety Portal,* https://biosafety.icar.gov.in/rules-for-the-manufacture-use-import-export-and-storage-of-hazardous-microorganisms-genetically-engineered-organisms-or-cells/.

98. "Biosafety Program," *Department of Biotechnology, Ministry of Science & Technology,* https://dbtindia.gov.in/regulations-guidelines/regulations/biosafety-programme#.

99. "Biosafety Program"

Endnotes

100. Shruthi Sharma, "Biological Risks in India: Perspectives and Analysis," *Carnegie Endowment for International Peace,* December 9, 2020, https://carnegieendowment.org/2020/12/09/biological-risks-in-india-perspectives-and-analysis-pub-83399.

101. Jim Garamone, "U.S., India Sign 10-Year Defense Framework Agreement," *US Department of Defense*, June 4, 2015, https://apps.dtic.mil/sti/pdfs/AD1176997.pdf.

102. "Quad," *Australian Government Department of Foreign Affairs and Trade,* https://www.dfat.gov.au/international-relations/regional-architecture/quad.

103. Dirk van der Kley, "Shaping the Quad's DNA: How Can Quad Countries Manage Biotech's Opportunities and Risks," *National Security College, The Australian National University*, November 2021, https://nsc.crawford.anu.edu.au/sites/default/files/publication/nsc_crawford_anu_edu_au/2021-11/shaping_the_quads_dna_how_can_quad_countries_manage_biotechs_opportunities_and_risks_0.pdf.

104. "The Australia Group Relationship with the Biological Weapons Convention," The Australia Group - Biological Weapons Convention, https://www.dfat.gov.au/publications/minisite/theaustraliagroupnet/site/en/bwc.html.

105. "Japan's Disarmament and Non-Proliferation Policy Third Edition," MOFA, https://www.mofa.go.jp/policy/un/disarmament/policy/pamph0603.html.

106. "Revised Forms for the Submission of the Confidence-Building Measures," *United Nations Office at Geneva*, United Nations Office of Disarmament Affairs, April 1, 2015, https://www.nti.org/analysis/articles/australia-overview/.

107. "Relationship with the Biological Weapons Convention," *Australia Group in Biological Weapons Convention,* https://www.dfat.gov.au/publications/minisite/theaustraliagroupnet/site/en/bwc.html.

108. "Australia Group Participants," *Australia Group in Biological Weapons Convention,* https://www.dfat.gov.au/publications/minisite/theaustraliagroupnet/site/en/participants.html.

109. "One Health Initiative," *World Health Organization,* https://www.who.int/teams/one-health-initiative.

110. "Guidelines for sustaining DBT- Bio-Banks and Cohorts," *Department of Biotechnology, Ministry Of Science & Technology,* https://dbtindia.gov.in/sites/default/files/uploadfiles/Biobank-Cohort-%20sustainability%20guidelines.pdf.

111. Heather L Harrell et al., "Biobanking Research and Privacy Laws in the United States." *The Journal of Law, Medicine & Ethics* (2016), https://pubmed.ncbi.nlm.nih.gov/27256128/.

112. Porter Gerard, "The Regulation of Human Genetic Databases in Japan," *SCRIPRT-ed,* September 2004, https://www.researchgate.net/publication/26396519_The_Regulation_of_Human_Genetic_Databases_in_Japan.

Endnotes

113. Don Chalmers, "Biobanking and Privacy Laws in Australia," *The Journal of Law, Medicine & Ethics* (2015), https://pubmed.ncbi.nlm.nih.gov/26711411/#:~:text=There%20is%20no%20formal%20biobank,International%20data%20sharing%20is%20permitted.

114. "Angela Kane on Reducing Global Catastrophic Biological Risks and the Importance of Personal Connections in Diplomacy".

115. Shambhavi Naik, "Reevaluating Bioweapons amid Global Political Fragility," Observer Research Foundation, January 13, 2023, https://www.orfonline.org/research/reevaluating-bioweapons-amid-global-political-fragility/.

116. Thi Tuyet Van Tran et al., "Artificial Intelligence in Drug Toxicity Prediction: Recent Advances, Challenges, and Future Perspectives," *Journal Of Chemical Information and Modelling,* May 8, 2023, https://pubmed.ncbi.nlm.nih.gov/37125780/#:~:text=Recently%2C%20artificial%20intelligence%20(AI),thus%20saving%20time%20and%20money.

ORF OBSERVER RESEARCH FOUNDATION

Ideas . Forums . Leadership . Impact

20, Rouse Avenue Institutional Area,
New Delhi - 110 002, INDIA
Ph. : +91-11-35332000. **Fax :** +91-11-35332005
E-mail: contactus@orfonline.org
Website: www.orfonline.org