



# BIOTECHNOLOGY AND THE THREAT OF BIOLOGICAL WEAPONS: AN INTERNATIONAL LAW PERSPECTIVE

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## ABSTRACT

*The increasing accessibility of advanced biotechnology has renewed global concern over the potential misuse of biological agents as weapons. Biological weapons pose a distinct danger because of their ability to cause mass casualties, disrupt public health systems, and create long-term environmental consequences without immediate detection. This paper analyses the international dimensions of biological weapons in the context of contemporary scientific developments, particularly genetic modification and synthetic biology. It reviews the historical use of biological warfare and assesses the effectiveness of international legal instruments, with specific reference to the Biological Weapons Convention. The study also examines the ethical responsibilities of scientists and states, emphasizing the protection of fundamental human rights such as the right to life and health. By identifying regulatory gaps and enforcement weaknesses, the paper highlights the challenges faced by existing governance mechanisms. It concludes that strengthening international cooperation, enhancing transparency, and promoting ethical oversight in scientific research are essential to prevent the hostile exploitation of biological science.*

**KEYWORDS:** *Biological Warfare, Synthetic Biology, Bioethics, Biological Weapons Convention, Global Security.*

## Introduction

In the contemporary era, the threat posed by biological weapons has been fundamentally transformed by rapid advances in biotechnology, genetic engineering, and life sciences. In order to inflict illness, death, or ecological harm on people, animals, or crops, these weapons intentionally employ harmful microbes like bacteria, viruses, fungus, or biologically generated toxins. Biological weapons are very difficult to identify, attribute, and respond to in a timely manner since, in contrast to conventional weapons, they frequently spread silently across populations before symptoms appear.<sup>2</sup> They differ from chemical and nuclear weapons due to their ability to proliferate within hosts and spread beyond the original target region, which amplifies their environmental and humanitarian effects. Because of their significant potential for widespread disruption and comparatively low development cost, biological weapons are frequently referred to as the "poor man's nuclear weapon." Biological agents can be created with generally accessible laboratory equipment and scientific knowledge, in contrast to nuclear weapons, which need substantial infrastructure and rare materials.<sup>3</sup> Access hurdles have been further reduced by the growth of commercial genetic engineering tools, private research organizations, and biotechnology labs. If applied improperly, the same methods used to produce genetically modified crops that are resistant to pests or drought can be changed to increase the transmissibility or survivability of dangerous infections. In the context of genetically modified organisms and synthetic biology, the moral challenge becomes

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<sup>2</sup> World Health Organization, Health Aspects of Chemical and Biological Weapons (1970), <https://apps.who.int/iris/handle/10665/39444>

<sup>3</sup> Malcolm Dando, Biological Warfare in the 21st Century, 4 Disarmament Forum 45 (2001), <https://unidir.org/files/publications/pdfs/biological-warfare-in-the-21st-century-en-401.pdf>

especially urgent. In agriculture and medicine, genetically modified organisms are frequently employed to enhance food security, create medicines, and fight illness. However, altering the genomes of plants, animals, or microbes can also result in the creation of organisms with malicious intent, such as microorganisms intended to target particular populations or crop diseases engineered to damage food sources.<sup>4</sup> The traditional lines separating the development of illegal biological weapons from peaceful scientific study have become hazier due to the convergence of civilian biotechnology and military potential. From a humanitarian perspective, biological weapons are against the fundamental tenets of international law, such as humanity, proportionality, and distinction. Their impacts are not limited to military objectives; they frequently disproportionately impact civilians, especially vulnerable groups including children, the elderly, and people with weakened immune systems. Biological hazards have equally catastrophic psychological effects since they can cause communities to become unstable long before physical harm occurs due to fear, uncertainty, and disinformation. The world's reaction to naturally occurring pandemics has shown how vulnerable economies and health systems may be in the face of infectious disease epidemics; this realization highlights the potentially disastrous consequences of intentional biological incidents.<sup>5</sup> This study looks at biological weapons from a global viewpoint, placing them in the context of current technology advancements, legal regulations, and historical practice. The role of biotechnology and *genetically modified organisms (GMOs)* in changing the nature of biological threats, the suitability of current legal frameworks like the *Biological and Toxin Weapons Convention*, and the pressing need for stronger global governance mechanisms to guarantee that scientific advancements are used to advance humanity rather than to destroy it are all given special attention.

### Historical evolution of biological warfare and scientific progress

Long before the scientific study of microbes, sickness has been used as a weapon in warfare throughout history. Even though the processes of transmission were poorly understood, early cultures saw that illness outbreaks may weaken enemy populations and interfere with military campaigns. Therefore, rather than intentionally manipulating infections, biological warfare in its early form depended on tainted water sources, decomposing corpses, or sick animals. These early methods show that, even lacking the precision that exists in current biotechnology, the weaponization of life precedes it.

During the *siege of Caffa in 1346*,<sup>6</sup> Mongol forces allegedly threw plague-infected corpses into the beleaguered city, which is one of the earliest known instances of biological warfare. This act shows an early awareness of contagion as a military technique, with the intention of spreading disease and breaking resistance. A recurrent theme in biological warfare is shown by the subsequent spread of plague throughout Europe: once disease is unleashed, it is impossible for the attacker to control it and frequently has unanticipated worldwide repercussions. Even in the era of genetic engineering, biological weapons are characterized by their unpredictable nature.

The twentieth century saw the start of the shift from ordinary biological warfare to programs motivated by science. In order to damage cattle and transport animals headed for Allied soldiers, Germany used biological weapons including anthrax and glanders during *World War I*.<sup>7</sup> These initiatives represented the first systematic application of microbiological science for military goals, even if they had no significant impact on the conflict. Significantly, these acts took place at a time when bacteriology and medicine were rapidly advancing, showing how scientific advancement can be misused for harmful purposes.

Advances in microbiology, immunology, and industrial-scale production led to a sharp increase in biological weapons research during *World War II*. Biological weapons programs were started by a number of states and were frequently justified as deterrents or defence measures. But *Japan's Unit 731*<sup>8</sup> operation was a serious misuse of scientific expertise. Large-scale biological agent deployment and human experimentation served as examples of how scientific advancement, when unrestrained by moral principles, can enable grave human rights abuses.

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<sup>4</sup> United Nations Office for Disarmament Affairs, Biological Weapons,

<https://www.un.org/disarmament/biological-weapons>

<sup>5</sup> National Research Council, Biotechnology Research in an Age of Terrorism (2004),

<https://nap.nationalacademies.org/catalog/10827>

<sup>6</sup> Mark Wheelis, Biological Warfare at the 1346 Siege of Caffa, 8 Emerging Infectious Diseases 971 (2002),

[https://wwwnc.cdc.gov/eid/article/8/9/01-0536\\_article](https://wwwnc.cdc.gov/eid/article/8/9/01-0536_article)

<sup>7</sup> Jeanne Guillemin, Biological Weapons 23–26 (2005),

<https://cup.columbia.edu/book/biological-weapons/9780231137545>

<sup>8</sup> Sheldon H. Harris, *Factories of Death* (1994),

<https://www.routledge.com/Factories-of-Death/Harris/p/book/9780415091059>

Research on biological weapons increased during the post-war era during the Cold War, especially when molecular biology and genetics started to progress. The *Soviet Union's massive secret program* demonstrated how genetic and microbiological knowledge could be institutionalized inside military structures, even after the country signed the *Biological and Toxin Weapons Convention*. The 1979 Sverdlovsk anthrax event highlighted the risks associated with modifying germs, whether they are naturally occurring or genetically created, and revealed the threats of such concealment.<sup>9</sup>

Modern biotechnology and genetically modified organisms (GMOs) were appearing in civilian situations at the same time. The possibility of altering diseases was further increased by methods like genetic modification and recombinant DNA technologies, which were first created to enhance agriculture and medicine. The historical overlap between civilian biotechnology and military biological programs set the stage for current concerns about dual-use research and genetic engineering abuse.

### Covert programs, biotechnology, and the dual-use dilemma

During the Cold War, secret initiatives like *Project MKNAOMI*<sup>10</sup> in the US made the convergence of biological science and military policy very clear. Toxins and biological agents were developed and stored for possible use in covert operations as part of this covert project. The fact that these projects exist shows how biological science breakthroughs, such as early genetic engineering methods, were incorporated into national security strategies. The idea that biological agents could offer strategic advantages in secret wars was represented in Project MKNAOMI and related initiatives. However, because the same scientific knowledge could not be neatly divided between offensive and defensive aims, they also exposed the inherent instability of dependence on biological weapons. Due of biotechnology's dual-use nature, studies carried out for reasonable agricultural or public health goals could also enhance military capabilities. The United States acknowledged that biological warfare was incompatible with moral leadership and global stability when it decided to give up biological weapons in 1969.<sup>11</sup> The conclusion that biological weapons could not be consistently controlled once they were released had an impact on this decision in addition to moral considerations. This realization is especially pertinent now as genetic engineering and genetically modified organisms (GMOs) have made it possible for humans to modify life at the molecular level while also raising the possibility of abuse. The dual-use problem has gotten worse in the modern world. Advanced genome sequencing, synthetic biology, and *CRISPR-Cas9* are examples of genetic alteration technologies that have transformed agriculture and medicine.<sup>12</sup> Increased food yields, disease resistance, and pharmaceutical innovation have all been facilitated by GMOs. However, these same technologies can be used to create resistance to current medical treatments, change host specificity, or increase pathogenicity. As a result, the line separating illegal weapons development from defence research has become more and more unclear.

International law's problem is not with technology per se, but with controlling intent. GMOs and biotechnology are not intrinsically dangerous; the risk comes from intentional abuse. The Biological and Toxin Weapons Convention and other existing legal frameworks were created during the early stages of genetic engineering. Because of this, they find it difficult to effectively handle the risks associated with contemporary biotechnology, especially when research is carried out in civilian labs under the idea of actual scientific investigation.

### GMOs, modern biotechnology, and the evolving biosecurity landscape

The quick development of genetic engineering and contemporary biotechnology has completely changed how biological materials are studied, created, and used in industry, agriculture, and medicine. Increased agricultural output, disease-resistant crops, innovative vaccines, and novel therapeutic interventions are just a few of the previously unheard-of advantages brought about by technologies like genetically modified organisms

<sup>9</sup> Milton Leitenberg, *The Soviet Biological Weapons Program* (2012), <https://www.hup.harvard.edu/books/9780674069712>

<sup>10</sup> U.S. Senate, Church Committee Report, Book I (1976), <https://www.intelligence.senate.gov/resources/intelligence-related-commissions>

<sup>11</sup> President Richard Nixon, Statement on Biological Weapons (1969), <https://www.presidency.ucsb.edu/documents/statement-chemical-and-biological-defense-policies-and-programs>

<sup>12</sup> National Research Council, *Biotechnology Research in an Age of Terrorism*, supra note 4.

(GMOs), synthetic biology, and gene-editing tools like CRISPR-Cas9.<sup>13</sup> However, when compared to the historical and current discourse around biological weapons, these same technological advancements have simultaneously produced serious biosecurity issues. The conventional divide between military biological capabilities and civilian scientific advancement has been reduced by the dual-use nature of biotechnology, which allows peaceful scientific research to be reused for hostile or harmful goals.

One of the most prominent and most contested uses of biotechnology is GMOs. *Genetically modified crops* have been developed in agriculture to increase output, resist pests, resist chemicals, and adjust to challenging weather conditions. These developments are frequently promoted as remedies for environmental stress and worldwide food insecurity. However, from a biosecurity standpoint, it is theoretically possible to alter diseases or microbes in ways that increase virulence, treatment resistance, or environmental persistence using the same methods used to introduce advantageous traits into crops. The confluence between biological weapons research and agricultural biotechnology highlights how difficult it is to regulate contemporary science without hindering innovation.

In most civilian circumstances, the connection between genetically modified organisms (GMOs) and biological weapons is indirect, but at the level of scientific methods, it is deeply interconnected. GMO development and sophisticated biological weapons research are based on methods like gene splicing, recombinant DNA technologies, and microbial manipulation. For example, the ability to edit bacteria or viruses to avoid immune responses or resist antibiotics is similar to the ability to modify genetic sequences to promote specific features in plants. As a result, the regulation of information, equipment, and research settings that could encourage abuse has replaced the conventional stockpiling of biological weapons as a source of international concern.<sup>14</sup>

The obstacles to entry for advanced biological research have also been greatly reduced by modern biotechnology. *Genetic engineering* can be carried out in comparatively small laboratory settings using commercially available technology, in contrast to the construction of nuclear weapons, that requires for substantial infrastructure and rare materials. Global biosecurity faces significant problems as a result of this broadening of science, regardless of its positive effects on research and education. Monitoring and controlling potentially hazardous research operations is becoming more challenging due to the growth of biotechnology startups, private laboratories, and academic research institutions, particularly in countries with weak regulatory systems.<sup>15</sup>

These worries are made worse by the development of synthetic biology. With the use of digital genetic sequences, scientists can develop whole new biological systems or replicate already-existing species thanks to synthetic biology. Theoretically, this technology may be used to create new organisms with unforeseen features or bring back viruses that have been destroyed. When combined with genetically modified organisms (GMOs), synthetic biology broadens the definition of biological risk to include manufactured living forms whose behaviour and ecological impact may not be completely understood. This brings up moral, legal, and security issues that were not intended to be addressed by current international agreements like the *Biological Weapons Convention (BWC)*. Adopted in 1972, the Biological Weapons Convention prohibits the creation, manufacture, and storage of biological weapons. But it was written during a time when genetic engineering was only getting started. GMOs, gene editing, and synthetic biology are therefore not specifically covered by the Convention. As biotechnology advances, this legal gap has becoming more noticeable. Although the BWC places a strong emphasis on disarmament and nuclear disarmament, it does not have a strong verification system or comprehensive standards for keeping an eye on dual-use research. As a result, national legislation, ethical review committees, and voluntary scientific standards play a major role in regulating GMO-related biosecurity threats.

GMO regulations in many nations prioritize human health, food security, and environmental safety over biosecurity. The possible effects of genetically modified crops on biodiversity, human consumption, and ecological balance are usually assessed in risk assessments. Although these factors are important, they frequently fail to take into account the wider consequences of genetic modification technologies when they are used maliciously. Under the pretence of legitimate scientific study, state or non-state actors may exploit the limitations created by this separate regulatory structure to develop biological weapons.

In the context of non-state actors, the relationship between GMOs and biotechnology and bioterrorism is especially troubling. Biotechnology advancements may be used by extremist or terrorist organizations to induce

<sup>13</sup> World Health Organization, Ethics and Governance of AI for Health (2021), <https://www.who.int/publications/i/item/9789240029200>

<sup>14</sup> OECD, Biological Resource Centres (2001), <https://www.oecd.org/sti/emerging-tech/biological-resource-centres.htm>

<sup>15</sup> Ibid note 13.

psychological panic, economic disruption, or widespread destruction. Modern biotechnology enables smaller parties to experiment with genetic alteration at comparatively little expense, in contrast to conventional biological weapons projects, which were historically connected to state players. The availability of online scientific literature, open-source genetic databases, and commercial DNA synthesis services has enhanced the viability of such threats, even though the technical knowledge needed is still substantial.

However, it is crucial to understand that GMOs and biotechnology are not intrinsically harmful. On the other hand, they are essential for sustainable development, medical innovation, and illness prevention. The *COVID-19* pandemic demonstrated how biotechnology may be used quickly to create vaccines, diagnostic instruments, and treatments. But it also revealed flaws in international administration and readiness. The epidemic served as a reminder that biological threats, whether intentional, unintentional, or natural, can have major impacts on the entire world. Interest in strengthening biosecurity frameworks without impeding scientific advancement has increased as a result of this experience.<sup>16</sup>

In the discussion of GMOs, biotechnology, and biological weapons, ethical issues play a significant role. It is the moral obligation of scientists and researchers to make sure that their work is done for the good of society and peace. The idea of "responsible science," which emphasizes responsibility, transparency, and knowledge of dual-use dangers, has grown in popularity. In biotechnology programs, ethical training and instruction are increasingly seen as crucial instruments for avoiding abuse. The scientific community can act as a first line of defence against the weaponization of biological science by cultivating a culture of accountability.

In order to address the biosecurity issues raised by GMOs and contemporary biotechnology, international cooperation is essential. National boundaries are irrelevant to biological dangers, and unilateral regulatory actions are inadequate. Effective governance requires standardizing biosafety regulations, exchanging best practices, and bolstering global monitoring systems. In this regard, it is necessary to reconsider and possibly broaden the BWC in order to specifically include new biotechnologies. While lowering the possibility of the development of biological weapons covertly, cooperative supervision mechanisms, transparency in research operations, and confidence-building initiatives could increase trust between governments.

In conclusion, there is a complicated and complex relationship between GMOs, biotechnology, and biological weapons. Although GMOs have greatly advanced global development and agricultural innovation, the technologies that underpin their development also pose substantial biosecurity risks. Modern biotechnology's dual-use nature calls for a balanced strategy that protects against abuse while advancing science. International collaboration, ethical standards, and legal frameworks must all change as biotechnology advances. In order to safeguard mankind from the abuse of one of its most potent scientific instruments, addressing these issues is a worldwide necessity rather than just a concern of national security.

### **International legal frameworks governing biotechnology, GMOs, and biological weapons**

The governance of contemporary biotechnology and the regulation of biological weapons are governed by a complex network of international legal instruments, many of which were created long before genetic engineering and genetically modified organisms were common. The use of biological agents for hostile purposes has always been prohibited by international law, but it has found it difficult to keep up with the quick scientific progress that defines modern biotechnology. As GMOs, synthetic biology, and gene-editing technologies change both civilian research and possible military capabilities, the gap between legal standards and scientific realities has become more apparent.

The Biological Weapons Convention (BWC), a significant development in arms control legislation, is the cornerstone of global biological disarmament. The Convention forbids the creation, manufacture, acquisition, and stockpiling of poisons and microbiological or other biological weapons meant for hostile use. But the BWC was written during a time when biotechnology was mostly restricted to simple microbiological methods. Consequently, GMOs, recombinant DNA technology, and synthetic biology are not specifically mentioned in the Convention. This absence has significant consequences because many contemporary biological hazards originate from genetically modified organisms produced by legal scientific methods rather than from traditional infections.<sup>17</sup>

The BWC lacks a legally obligatory verification and enforcement mechanism, notwithstanding its extensive restrictions. The BWC mainly relies on voluntary compliance, trust, and confidence-building initiatives, in contrast to nuclear weapons treaties that rely on inspections and monitoring organizations. This

<sup>16</sup> WHO, COVID-19 Strategic Preparedness and Response Plan (2020),

<https://www.who.int/publications/i/item/strategic-preparedness-and-response-plan-for-the-new-coronavirus>

<sup>17</sup> Biological Weapons Convention, Apr. 10, 1972,

[https://treaties.un.org/Pages/ViewDetails.aspx?src=TREATY&mtdsg\\_no=XXVI-1](https://treaties.un.org/Pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVI-1)

fundamental flaw becomes especially troublesome in the case of biotechnology and genetically modified organisms (GMOs), since it is intrinsically challenging to discriminate between peaceful research and unlawful activity. The methods used to modify viruses for hostile goals can be the same as those used to improve crop resistance or create vaccinations. As a result, the lack of verification procedures makes it possible for abuse to occur under the goal of civilian study.<sup>18</sup> GMO regulation is heavily influenced by international trade and environmental agreements in addition to the BWC. The *Convention on Biological Diversity established the Cartagena Protocol on Biosafety*,<sup>19</sup> which governs the transboundary transfer of live modified organisms. Its main goal is to shield human health and biodiversity from any dangers posed by genetically modified organisms. Although the Protocol places a strong emphasis on risk assessment, informed consent, and precautionary principles, its primary focus is still on the environment rather than security. Its efficacy in addressing the wider biosecurity consequences of genetic engineering technology is limited by its limited reach.<sup>20</sup> In a similar way, state regulation of genetically modified organisms is influenced by the framework of the *World Trade Organization (WTO)*,<sup>21</sup> specifically the Agreement on the Application of Health and Biological Measures. These regulations aim to strike a compromise between health and safety concerns and trade liberalization. However, long-term biosecurity issues are frequently subordinated to market access and economic interests in trade-based regulatory frameworks. Because of this, there is often little coordination between the goals of arms control, trade regulation, and environmental preservation in international GMO governance.

The development of advanced gene-editing tools and synthetic biology has further complicated the worldwide legal environment. Traditional conceptions of biological agents under international law are challenged by synthetic biology, which makes it possible to create organisms that might not exist in nature. The question of whether current legal frameworks can adequately govern biological elements that might never physically traverse borders is raised by the ability to synthesize genetic material using digital sequences. Because genetic information can be electronically communicated and materialized anywhere in the globe, the concept of jurisdiction itself becomes unclear in this situation. The control of biotechnology and biological weapons also touches on humanitarian law and international human rights law. The norms of international humanitarian law, such as distinction, proportionality, and needless suffering, would be violated by the employment of biological agents in armed conflict. From the standpoint of human rights, basic rights including the right to life, health, and a safe environment are threatened by biotechnology abuse. Although these legal frameworks offer normative direction, they do not have precise practical guidelines for dealing with the hazards associated with advanced biotechnology and genetically modified organisms in non-conflict situations.

States carry out their international commitments at the national level by enacting laws pertaining to scientific research, public health, and biosafety. However, national regulatory strategies differ greatly, resulting in disparate protection levels. Certain nations have strict control procedures for genetic engineering research, such as licensing regulations and ethical review committees. Others advocate more lax regulatory policies in favour of economic expansion and technological advancement. Because biological hazards originating in one jurisdiction might have worldwide repercussions, this discrepancy jeopardizes collective security.

International regulation is made more difficult by non-state actors. Modern biotechnology is becoming more and more accessible to private organizations, academic institutions, and individuals, in contrast to traditional arms control frameworks intended to limit state activity. The ability of international law to directly govern these actors is limited; instead, it depends on domestic enforcement and state accountability. This gap is especially worrisome when it comes to bio-terrorism, since non-state actors may use legal loopholes to obtain or create dangerous biological agents through genetic alteration. Proposals to strengthen the BWC through new protocols, improved confidence-building techniques, and greater transparency in biological research have all been made in an attempt to solve these issues. Some academics support the establishment of an international oversight organization for biotechnology that is comparable to the *International Atomic Energy Agency*. Such an organization might support best practices, facilitate inspections, and give states technical support. However, agreement on such reforms has been hindered by concerns about scientific independence, sovereignty, and unequal technical capacities.

A more comprehensive legal strategy is becoming more and more important when it comes to GMOs. The wider security consequences of genetic engineering technologies are not taken into consideration when GMO

<sup>18</sup> Ibid. art. I.

<sup>19</sup> Cartagena Protocol on Biosafety,  
<https://bch.cbd.int/protocol>

<sup>20</sup> Rebecca Katz et al., Strengthening the BWC, 47 *Bulletin of the Atomic Scientists* 38 (2011),  
<https://thebulletin.org/2011/05/strengthening-the-biological-weapons-convention>

<sup>21</sup> WTO, SPS Agreement,  
[https://www.wto.org/english/tratop\\_e/sps\\_e/spsagr\\_e.htm](https://www.wto.org/english/tratop_e/sps_e/spsagr_e.htm)

regulation is seen exclusively as an environmental or agricultural problem. A more effective response to new biological threats might be provided by an all-encompassing framework that connects environmental law, public health, human rights, and arms control. This would necessitate reconsidering biosecurity as an all-encompassing approach that includes prevention, preparation, and responsible innovation rather than only defence against weapons.

In conclusion, international legal frameworks related to GMOs, biotechnology, and biological weapons are still fragmented and ill-prepared to handle modern issues. Although significant normative principles are established by current treaties, the realities of contemporary genetic science are not sufficiently reflected in them. To ensure that biotechnology serves humanity's interests without turning into a destructive tool, it is imperative to update legislative definitions, strengthen international cooperation, and improve supervision systems. To protect both human dignity and international security, the legislation must change in line with scientific advancements.

### **Ethical and human rights dimensions of biotechnology, GMOs, and biological weapons**

In current discussions about biological weapons and international biosecurity, the ethical consequences of biotechnology and genetically engineered organisms are crucial. Because biological technologies, in contrast to conventional weapons, function within the private spheres of life, health, and the environment, their abuse presents both a serious moral dilemma and a security risk. When used improperly, the same scientific instruments that make it possible to avoid disease, ensure food security, and progress medicine also endanger human life and dignity. Biotechnology is at the nexus of ethics, human rights, and international security due to this dual-use problem.

The concept of respect for human life<sup>22</sup> is central to the ethical discussion. By indiscriminately targeting humans and creating pain that is frequently uncontrollable and irreversible, biological weapons fundamentally breach this concept. The ethical obligation of states and scientists is greatly increased when biotechnology is utilized to manipulate organisms, whether they are pathogens or genetically modified species. By definition, genetic alteration modifies the fundamental components of life. Although this modification might be acceptable for medicinal or agricultural uses, its weaponization is a clear violation of moral standards that put human wellbeing and ecological balance first. A crucial framework for analysing the effects of biotechnology abuse is provided by human rights law. The creation and use of biological weapons directly threaten the right to life, which is protected by international agreements like the *International Covenant on Civil and Political Rights*<sup>23</sup> and the *Universal Declaration of Human Rights*. Toxins or pathogens with genetic engineering have the potential to create intergenerational harm, long-term health issues, and widespread mortality. Poorly regulated GMO trials may expose communities to unanticipated hazards even in non-weapon scenarios, posing important concerns about consent, accountability, and governmental responsibility. Discussions on genetically modified organisms (GMOs) and biotechnology also involve the right to health. Through the development of vaccinations, diagnostic tools, and novel treatments, genetic engineering advancements have made a substantial contribution to public health. However, biotechnology can weaken rather than benefit health systems if it is applied carelessly or without sufficient supervision. In addition to being unethical, the intentional modification of diseases to increase spread or resistance will overburden the healthcare system and disproportionately harm vulnerable groups. The human rights aspect of biological dangers is further highlighted by this unequal impact. When assessing the dangers of GMOs and biotechnology, environmental ethics are also very important. When released into the environment, genetically engineered organisms may have unexpected interactions with ecosystems. Although many GMO applications seek to increase sustainability, it's not always clear what the long-term ecological effects will be. From the standpoint of human rights, future generations' rights to a safe and healthy environment may be violated by degradation of the environment brought on by careless genetic engineering. These environmental dangers are increased when biotechnology is associated with military or hostile goals since ecological harm may be intentional or unintentional.<sup>24</sup>

Another crucial ethical issue is the idea of informed consent. Before taking part in trials, participants in medical and scientific environments must be properly informed of the potential hazards and benefits, according to ethical norms. However, impacted populations are not given the chance to provide their approval

<sup>22</sup> Universal Declaration of Human Rights,

<https://www.un.org/en/about-us/universal-declaration-of-human-rights>

<sup>23</sup> International Covenant on Civil and Political Rights,

<https://www.ohchr.org/en/instruments-mechanisms/instruments/international-covenant-civil-and-political-rights>

<sup>24</sup> CESCR, General Comment No. 14 (Right to Health),

<https://www.refworld.org/docid/4538838d0.html>

when it comes to biological weapons or secret biotechnology research. In a similar vein, societies exposed to genetically modified organisms may not engage meaningfully in decision-making if regulatory procedures are transparent. Autonomy and self-determination are violated, and democratic values are weakened by this exclusion.

The ethical discussion of biotechnology frequently focuses on the topic of scientific responsibility<sup>25</sup>. It is becoming more and more expected of researchers using genetic modification technology to prepare for the possibility of their work being abused. Beyond the immediate results of study, the ethical duty to "do no harm" has wider societal consequences. In the context of genetically modified organisms and biological weapons, this means recognizing the potential for scientific advancements to be exploited for criminal purposes. Institutional review procedures, codes of conduct, and ethical guidelines are crucial instruments for cultivating a culture of accountability within the scientific community.

States play an equally important role in maintaining moral principles. It is the responsibility of governments to regulate biotechnology in a way that upholds human rights and promotes innovation. This entails creating clear legal frameworks, guaranteeing public involvement, and avoiding the militarization of biological research. States run the risk of permitting actions that could result in human rights violations when they fail to properly regulate GMOs and biotechnology, whether through negligence, a lack of oversight, or the wilful exploitation of scientific discoveries.

Global disparities in access to technology also present ethical issues. While many emerging nations depend on foreign technology and knowledge, advanced biotechnology is concentrated in a few technologically advanced states. This gap raises moral questions about exploitation, reliance, and disproportionate risk exposure. In the context of biological weapons, less developed countries may be particularly at risk since technologically advanced states may have a larger capacity to produce or fight against biological threats. Therefore, concerns of equity and shared responsibility must be addressed through ethical governance.

The ethical governance of GMOs and biotechnology is greatly influenced by public perception and trust. Even when it comes to positive scientific advancements, public fear and resistance can be increased by misinformation, secrecy, and a lack of transparency. On the other hand, transparency and responsibility can boost public trust and lessen the possibility of abuse. In order to ensure that technical advancement is in line with societal values and human rights standards, ethical governance requires both meaningful involvement with society and legal regulation.

In conclusion, there is a close connection between the ethical and human rights aspects of biotechnology, genetically modified organisms, and biological weapons. The ability to control life involves a considerable amount of responsibility, necessitating rigorous evaluation of moral standards, legal requirements, and societal ramifications. Although biotechnology has the potential to revolutionize human progress, its abuse threatens both global security and fundamental rights. To ensure that biotechnology continues to be a force for good rather than a destructive tool, ethical governance that is based on respect for human dignity, environmental protection, and scientific accountability is crucial.

### **Bio-terrorism, non-state actors, and emerging biotechnological threats**

The scope of security risks has changed dramatically as a result of biotechnology's evolution, especially with regard to the growing significance of bio-terrorism and the involvement of non-state actors.<sup>26</sup> Biological weapons were traditionally linked to state-sponsored military initiatives that were created in extremely covert and regulated settings. However, technological and financial obstacles have been reduced by developments in genetic engineering, synthetic biology, and GMO-related technologies, making advanced biological instruments more widely available outside of governmental control. Global worries about the possible abuse of biotechnology by terrorist organizations, criminal networks, and other non-state actors have grown as a result of this change. The intentional release or use of biological agents to injure, frighten, or disturb civilian populations is referred to as "bio-terrorism."<sup>27</sup> Biological attacks, in contrast to traditional terrorism, may go unnoticed for long stretches of time, enabling infections to spread covertly before symptoms appear. The problem is made considerably more complicated by the introduction of genetic alteration and biotechnology. Public health systems and law enforcement organizations around the world face previously unheard-of difficulties due to the potential for genetically modified viruses that are more contagious, resistant to treatment,

<sup>25</sup> UNESCO, Universal Declaration on Bioethics and Human Rights (2005),

<https://www.unesco.org/en/legal-affairs/universal-declaration-bioethics-and-human-rights>

<sup>26</sup> Bruce Hoffman, Inside Terrorism (2006),

<https://cup.columbia.edu/book/inside-terrorism/9780231126990>

<sup>27</sup> Ibid note 25.

or challenging to identify. Rather than purpose, the connection between GMOs and bioterrorism is mostly based on similar scientific methods. It is theoretically possible to convert genetic modification methods used to improve crop resistance or create medicinal therapies to change microbes for detrimental purposes. It is now possible to precisely and effectively alter genetic material because to developments in gene editing, especially CRISPR-based technology. Despite the fact that these technologies are mostly employed for peaceful purposes, their dual-use potential poses significant risks when control is inadequate or non-existent. Non-state actors are in a unique position to take advantage of these gaps. Terrorist groups frequently look for strategies that minimize operating expenses while maximizing psychological impact. These goals are in line with biological agents, particularly those created using contemporary biotechnology. In contrast to chemical or nuclear weapons, biological materials are very easy to carry and can be grown covertly. The potential that non-state actors will try to create or get genetically modified biological agents is further increased by the worldwide accessibility of scientific publications, internet training resources, and commercial DNA synthesis services.<sup>28</sup>

The use of GMOs in agricultural bioterrorism is another serious issue. Without specifically targeting human populations, genetically modified plant pathogens or pests could be used to harm crops, interfere with food supplies, and destabilize economies. Food security and livelihoods may suffer long-term effects from such attacks, which may be challenging to identify. This type of bioterrorism might cause severe social and economic disruption in nations that rely heavily on agriculture, showing the connection between biotechnology, national security, and development. When talking about new risks, the involvement of biotechnology labs and research facilities is crucial. Monitoring efforts are made more difficult by the growing number of private and dispersed research institutions, even though the majority of laboratories are subject to ethical standards and regulatory supervision. Gaps that could be knowingly or unintentionally exploited are created by the lack of consistent international standards for biosafety and biosecurity. Biological risks can be caused by accidental releases, insider threats, and insufficient training, making it difficult to distinguish between intentional harm and negligent conduct.

Traditionally, surveillance, intelligence sharing, and disaster preparation have been the main focuses of international responses to bioterrorism. However, these policies frequently fall behind advances in technology. Genetically modified organisms and genetic information communicated digitally may not be sufficiently covered by legal frameworks intended to deal with conventional biological weapons. Because it can be difficult to identify the source of a biological attack, particularly one employing modified organisms, both politically and scientifically, the difficulty of attribution further compromises accountability.

In order to lessen the effects of bioterrorism, public health systems are essential. Limiting injury requires early discovery, quick action, and clear communication. By facilitating the creation of diagnostics, vaccines, and therapies, biotechnology itself can act as a defensive tool. However, different countries have different healthcare infrastructures, which results in different levels of preparation. Global gaps in biosecurity and response ability may be increased by developing countries' increased exposure.

It's equally important to recognize the psychological effects of bioterrorism. Even the possibility of a biological attack may lead to widespread fear and instability in society. Fear and uncertainty are strong weapons. These impacts can be increased by rumours and false information, especially in the digital era. In this regard, fighting biological dangers requires not only scientific and legal measures but also transparency, public trust, and reliable information.

A broad and forward-thinking approach is needed to prevent the misuse of biotechnology by non-state actors. Strengthening biosafety regulations, encouraging ethical scientific conduct, and strengthening international cooperation are crucial steps. Education and awareness among scientists, policymakers, and the public can help identify risks early and promote a culture of responsibility. In an interconnected world, incorporating biosecurity considerations into GMO and biotechnology governance frameworks is no longer optional.

In conclusion, one of the most urgent issues in the era of current biotechnology is the emergence of bioterrorism and the participation of non-state actors. Although genetic engineering and GMOs have greatly benefited society, their dual-use potential requires careful monitoring and flexible governance. Working together across different fields and national boundaries, legal regulation, ethical responsibility, scientific innovation, and public involvement are all necessary to address these new dangers. The promise of biotechnology can only be maintained while reducing dangers with such an overall approach.

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<sup>28</sup> UN Office on Drugs and Crime, Guide to Implementing the BWC (2019), <https://www.unodc.org/unodc/en/terrorism/publications.html>

## Future challenges, policy reforms, and global bio-governance in the age of biotechnology

Global government faces a contradictory problem as biotechnology advances. On the one hand, scientific advancement offers answers to some of the most important issues facing humanity, such as sustainable development, illness prevention, food insecurity, and climate resilience. However, the same technological capabilities that make these advancements possible also make biological weapons, bioterrorism, and unintentional ecological disaster more dangerous. The current legal, ethical, and institutional frameworks are under growing pressure as genetically modified species and advanced genetic engineering techniques become increasingly common. Managing this dual-use issues without obstructing scientific advancement is the international community's main challenge.<sup>29</sup> The speed at which technology is developing is one of the biggest concerns of the future. Gene editing, synthetic biology, and biological research powered by artificial intelligence are all developing more quickly than regulatory frameworks can keep up. Conventional legislative procedures are slow, based on agreement, and sometimes completely out of step with scientific reality, especially on an international level. Due to this mismatch, there are regulatory blind spots where potentially hazardous biotechnology uses could arise without sufficient scrutiny. This disparity is especially evident when it comes to genetically modified organisms (GMOs), since regulatory attention is frequently restricted to environmental and food safety issues rather than more comprehensive biosecurity implications. A variety of global governance is another important problem. Currently, there are several legal frameworks that regulate biotechnology, including national biosafety frameworks, trade laws, environmental agreements, arms control treaties, and public health restrictions. These regimes frequently function independently, which leads to conflicting standards, overlapping mandates, and enforcement gaps. For example, the Biological Weapons Convention does not directly control the production of genetically modified organisms, but it does address the ban of hostile biological activity. On the other hand, GMO rules under commerce or environmental law fail to take safety issues into into account. The world's ability to effectively respond to new biological dangers is weakened by this fragmentation. Therefore, policy reform must move toward an integrated bio-governance model, which would acknowledge biotechnology as a cross-cutting issue that demands coordination across legal disciplines and policy sectors. By incorporating biosecurity considerations into GMO regulation, research funding decisions, and scientific education, existing gaps can be filled. This approach would not only strengthen prevention mechanisms but also encourage responsible innovation by integrating ethical and security awareness within the scientific process itself.<sup>30</sup>

The Biological Weapons Convention's reform is still of greatest significance. Although the BWC creates an important legal ban on biological weapons, its impact in the current biotechnology environment is limited by institutional drawbacks. Important actions involve encouraging international cooperation, increasing transparency in biological research, and strengthening confidence-building initiatives. Many academics have argued for the development of a monitoring or verification system that can handle dual-use research while maintaining scientific freedom. Small improvements could greatly increase it's application in addressing GMO-related biosecurity hazards, regardless of ongoing political opposition.

It is impossible to minimize the importance of states in the future of *bio-governance*.<sup>31</sup> Governments need to make investments in strong national regulatory frameworks that strike a balance between safety and development. This involves upholding responsibility in both public and commercial research institutions, strengthening laboratory control, and updating biosafety regulations. Strengthening capacity is another duty of the state, especially in developing nations where regulatory infrastructure may be lacking. Global inequalities in biosecurity preparation can be lessened with international support and technology-sharing agreements.

Another significant feature of future change is *ethical training and scientific education*. The scientific community has to promote an environment that values accountability as biotechnology becomes more widely available. Rather than being a secondary consideration, moral awareness needs to be a fundamental part of scientific methodology. Training programs that focus on responsibility for the environment, human rights implications, and dual-use concerns can enable researchers to identify and reduce potential dangers. Such

<sup>29</sup> United Nations Secretary-General, Our Common Agenda (2021),

<https://www.un.org/en/common-agenda>

<sup>30</sup> IPCC, Sixth Assessment Report (2022),

<https://www.ipcc.ch/assessment-report/ar6>

<sup>31</sup> Joshua Lederberg, The Threat of Biological Weapons, 401 Science 20 (1999),

<https://science.sciencemag.org/content/401/6753/20>

education can help guarantee that genetic modification technologies are used ethically and transparently when it comes to GMOs.

The future of bio-governance will also be shaped by public confidence and participation. Transparency, responsibility, and meaningful interaction are critical for societal acceptance of GMOs and biotechnology. Public opposition increases when regulatory actions are thought to be unclear or motivated only by financial gain. Involving communities, civil society organizations, and independent experts in inclusive governance models can enhance the policy results and strengthen legitimacy. Given the significant social and environmental consequences of biotechnology, this is of special importance.

Additional opportunities and difficulties are presented by emerging technologies like *digital biology and artificial intelligence*. artificial intelligence-based biological research can speed up discovery and enhance disease tracking, but it can also make it easier to create dangerous biological agents. Traditional regulatory systems are made more difficult by the digital storage and transfer of genetic data, since biological risks might now come from information rather than physical things. It need creative regulatory thinking that goes beyond traditional boundaries and classifications to address these dangers.

Future biosecurity issues are made more complex by degradation of the environment and climate change. Changing ecosystems could lead to new incentives for genetic modification in agriculture, change disease patterns, and raise the chance of viral transmission. GMOs may help increase climate adaptation, but their use needs to be carefully controlled to prevent unexpected ecological effects. Therefore, long-term global stability depends on incorporating environmental sustainability into biosecurity approaches.

In conclusion, a thorough and flexible approach is required for the regulation of biotechnology, genetically modified organisms, and biological weapons in the future. The difficulties that are beyond are not only legal or technological but also deeply moral and political. The need to exploit humanity's increased ability to control life itself becomes crucial. Effective sustainable government requires strengthening international collaboration, updating outdated legal frameworks, encouraging moral scientific behaviour, and including the general public. Biotechnology can only continue to be a tool for human advancement rather than a cause of worldwide instability through such coordinated and forward-thinking actions.

