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OVERLAPPING PROHIBITIONS AND FRAGMENTED OVERSIGHT IN THE CHEMICAL AND BIOLOGICAL WEAPONS REGIMES

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Abstract

The Biological Weapons Convention and the Chemical Weapons Convention have long operated as parallel regimes with a manageable overlap around toxins. Advances in synthetic biology and metabolic engineering are now dissolving the production based heuristics that once made classification straightforward, raising the question of whether convergent agents fall into a governance gap. This paper draws on regime complexity theory, particularly Alter and Meunier's work on overlapping institutional authority, and constructivist accounts of weapons taboos from Price and Tannenwald to analyse the legal, institutional, and normative dimensions of that question. Through close textual analysis of both conventions and three case studies of overlapping agents, the paper argues that the legal prohibitions remain intact because both treaties anchor their scope in intended use rather than production method. The more consequential problem is institutional. The CWC's verification architecture has no parallel in the BWC, creating conditions in which emerging agents may be clearly prohibited yet practically invisible to the monitoring capacity of either regime. The paper concludes by proposing targeted reforms in treaty interpretation, national coordination, and joint scientific horizon scanning that could narrow the gap between prohibition and enforcement without requiring renegotiation of either convention.

1. INTRODUCTION

In August 2015, a research group at Stanford University published results in *Science* demonstrating that the brewer's yeast *Saccharomyces cerevisiae* could be engineered to convert simple sugars into the opioid hydrocodone through a biosynthetic pathway requiring more than twenty genetic modifications (Galanie et al., 2015).The paper was immediately recognized as a landmark achievement in metabolic engineering. Within weeks, the same team and independent commentators acknowledged a less welcome implication. The work also constituted a proof of concept for the biological manufacture of pharmacologically potent compounds outside any regulated pharmaceutical facility. The organism was biological. The product was chemical. The production method drew on techniques from both disciplines. And the resulting substance, if diverted to hostile purposes, would fall under the jurisdiction of two separate arms control treaties

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that were never designed to coordinate with each other.

This paper takes that awkward overlap as its starting point. The Biological Weapons Convention of 1972 and the Chemical Weapons Convention of 1993 remain the principal legal instruments prohibiting the development, production, and stockpiling of weapons that rely on disease or poison. For most of their operational history, the boundary between the two regimes was intuitive enough to function without much friction. Biological agents were living organisms or the toxins they produced. Chemical agents were synthetic compounds manufactured in industrial plants. The BWC covered the former. The CWC covered the latter. Toxins occupied a small zone of dual coverage that was treated as a redundancy rather than a problem (Tucker, 2007).

That arrangement is under growing pressure. Advances in synthetic biology, directed evolution, cell free protein synthesis, and computational chemistry have blurred the production pathways that once made classification straightforward. A novel peptide toxin can now be assembled through solid phase chemical synthesis without ever passing through a living cell (Fang et al., 2018). Conversely, engineered microorganisms can produce toxic chemicals that were previously obtainable only from petroleum feedstocks. The result is a class of agents and production methods that do not fit neatly into either treaty's customary domain of expertise, even though they may fall within the legal scope of both.

The central argument of this paper is that the convergence of chemistry and biology at the level of production and mechanism does not create a legal vacuum in the way that some commentators have suggested. Both the BWC and the CWC rely on general purpose criteria that prohibit agents based on intended use rather than origin or method of manufacture. A toxin produced synthetically is still a toxin under the BWC. A toxic chemical produced biologically is still a toxic chemical under the CWC. The more serious problem lies in the institutional and political infrastructure that surrounds these legal prohibitions. The CWC possesses a standing verification organization with inspection authority and declaration requirements. The BWC does not. When an ambiguous agent could plausibly be investigated under either regime, the practical question of which institution takes responsibility becomes a governance problem with real consequences for detection, attribution, and accountability.

The paper addresses three interlocking questions. First, how do the definitional structures of the BWC and CWC apply to agents produced through converging biological and chemical methods, and where do interpretive difficulties arise? Second, does the asymmetry between the two verification systems create conditions in which states could strategically classify ambiguous agents to minimize scrutiny? Third, what does technological convergence imply for the distinct political norms that underpin each convention?

To answer these questions, the paper combines close textual analysis of treaty provisions and review conference documents with a small number of concrete case studies drawn from published scientific and policy literature. The theoretical framework draws on the regime complexity literature in international relations, particularly the work of Karen Alter and Sophie Meunier (2009) on overlapping institutional authority, and on constructivist accounts of weapons taboos, particularly Richard Price (1997) and Nina Tannenwald (1999). The objective is not to catalogue every emerging technology that might complicate arms control but to provide a structured assessment of where the existing governance architecture is genuinely strained and where it is more resilient than current anxieties suggest.

The paper proceeds as follows. Section 2 reviews the historical development of the two treaties. Section 3 examines the scientific developments that have weakened the production based heuristic for classification. Section 4 analyses the legal boundary between the conventions. Section 5

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presents case studies. Section 6 evaluates verification and institutional coordination. Section 7 offers recommendations, and Section 8 concludes.

2. Historical Foundations: Two Treaties, Two Logics

The prohibition of chemical and biological weapons did not begin as two separate projects. The Geneva Protocol of 1925, formally titled the Protocol for the Prohibition of the Use in War of Asphyxiating, Poisonous or Other Gases and of Bacteriological Methods of Warfare, addressed both categories in a single instrument (Geneva Protocol, 1925). The Protocol was a direct response to the extensive use of chlorine, phosgene, and mustard gas during the First World War, and its drafters included bacteriological methods largely as an afterthought, prompted by wartime fears of deliberate plague dissemination that never materialized on the Western Front. The result was a prohibition on use that covered both domains but said nothing about development, production, or stockpiling. States remained free to maintain arsenals as long as they did not deploy them first.

The subsequent bifurcation into two distinct treaties was not a natural consequence of scientific taxonomy. It reflected specific political calculations during the Cold War. The BWC emerged first, opening for signature in 1972. Its negotiation was made possible largely by President Nixon's unilateral renunciation of the United States biological weapons programme in November 1969, a decision driven less by arms control idealism than by a Pentagon assessment that biological weapons were militarily unreliable and strategically destabilizing in ways that offered no clear advantage to the United States (Carus, 2015). With the principal Western obstacle removed, the Soviet Union and its allies agreed to separate biological weapons from the stalled chemical weapons negotiations that had been underway at the Conference of the Committee on Disarmament since the early 1960s. The BWC was concluded relatively quickly, but its speed came at a cost. The treaty contained no verification mechanism, no standing organization, and no formal procedure for investigating alleged violations beyond the possibility of lodging a complaint with the United Nations Security Council under Article VI (Sims, 2001).

The CWC followed a much longer and more contentious path, opening for signature only in 1993 and entering into force in 1997. Its negotiations were complicated by the genuine military utility of chemical weapons, the extensive dual use character of the chemical industry, and the reluctance of several states to accept intrusive inspections of commercial facilities. The eventual outcome was a convention of remarkable institutional ambition. The CWC established the Organisation for the Prohibition of Chemical Weapons as a permanent body headquartered in The Hague, created detailed declaration requirements for states parties, and authorized both routine inspections of declared facilities and challenge inspections of undeclared sites (Krutzsch & Trapp, 2023). The verification architecture was imperfect from the start, and challenge inspections have never been invoked, but the institutional infrastructure existed in a way that had no parallel in the biological weapons regime.

The one area where the two treaties explicitly overlapped from the beginning was toxins. Article I of the BWC prohibits "toxins whatever their origin or method of production," a phrase that was deliberately chosen during the negotiations to ensure that synthetically manufactured toxins could not escape the convention's scope by virtue of having been produced in a chemistry laboratory rather than extracted from a living organism (Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction, 1972). The CWC, for its part, includes specific toxins such as ricin and saxitoxin in its Schedule 1 and defines toxic chemicals broadly enough to encompass any chemical that can cause death, temporary incapacitation, or permanent harm through its

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action on life processes. This dual coverage was understood at the time as a prudent redundancy. If a toxin slipped through the cracks of one regime, the other would catch it. What the drafters did not anticipate was that the same logic of overlap would eventually extend far beyond the narrow category of classical toxins to encompass an expanding range of agents and production methods that blur the distinction between the two conventions at a much more fundamental level.

3. What Scientific Convergence Changes

For most of the twentieth century, a simple heuristic guided the classification of weapons agents. If a living organism produced it, or if it was a living organism itself, the BWC applied. If it was manufactured in a reactor or a flask through chemical synthesis, the CWC applied. The heuristic was never perfectly precise, but it was good enough to allow the two regimes to operate in parallel without generating serious jurisdictional disputes. Three categories of scientific development have now undermined that heuristic to the point where it can no longer be relied upon as a practical guide.

The first and perhaps most consequential development is the maturation of cell free protein synthesis. Traditional biotechnology required living cells as production platforms. You engineered a bacterium or a yeast strain, grew it in a fermenter, and harvested the protein of interest. The living organism was an essential intermediary, which made the biological character of the process obvious. Cell free systems dispense with the organism entirely. They use lysates containing the molecular machinery of translation, ribosomes, transfer RNAs, and associated enzymes, to assemble proteins directly from DNA templates in a test tube (Erik et al., 2011). The process is biochemically biological but operationally indistinguishable from a chemical manufacturing workflow. In 2012, researchers demonstrated the production of functional botulinum neurotoxin domains using cell free expression systems, a result that carried obvious implications for biosecurity because it showed that the most lethal known protein toxin could be produced without maintaining any living culture that would trigger conventional biosafety monitoring (Vilkhovoy et al., 2020). The product is unambiguously a toxin under the BWC. But the production method looks, to any inspector trained in chemical weapons verification, like a chemical process.

The second development runs in the opposite direction. Advances in metabolic engineering have made it increasingly feasible to use biological organisms as production platforms for substances that are traditionally classified as toxic chemicals. The Stanford yeast work discussed in the introduction is the most prominent example, but it is not isolated. Researchers have engineered *Escherichia coli* to produce 1,4 butanediol, an industrial chemical previously manufactured exclusively from petrochemical feedstocks (Yim et al., 2011). They have used cyanobacteria to synthesize ethylene, a commodity chemical central to the plastics industry. The underlying principle is the same in each case. You insert a heterologous metabolic pathway into a host organism, and the organism converts simple carbon sources into a target molecule that happens to be a well defined chemical compound. If the target molecule is toxic, the question of whether the resulting weapon is "biological" or "chemical" becomes genuinely difficult to answer. The production platform is biological. The product is chemical. The mechanism of harm may involve either chemical toxicity or receptor mediated biological disruption, depending on the specific compound.

The third development concerns the expanding category of bioregulators. These are endogenous signaling molecules, neuropeptides, cytokines, and hormone analogues that regulate physiological processes at extremely low concentrations. Examples include substance P, a neuropeptide involved in pain transmission and neurogenic inflammation, and endothelin, one of the most potent vasoconstrictors known. Bioregulators are chemically definable, often small enough to be synthesized through solid phase peptide chemistry,

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and toxic at doses measured in micrograms per kilogram of body weight. They do not replicate like pathogens, which makes them poor candidates for traditional biological warfare. But they also do not resemble the industrial chemicals on the CWC schedules, which were selected primarily because of their historical use in warfare or their role as precursors to nerve agents. A weaponized bioregulator would cause harm through a mechanism that is fundamentally biological, binding to specific cell surface receptors and triggering cascades of physiological dysfunction, yet the agent itself could be produced, stored, and delivered using methods identical to those used for classical chemical weapons (Dando, 2020).

What these three developments share is that they sever the link between production method and agent identity that the old heuristic relied upon. A toxin can be made without an organism. A toxic chemical can be made by an organism. A bioregulator can be made either way and does not fit comfortably into the historical categories that shaped either treaty's schedules and verification procedures. The OPCW Scientific Advisory Board has acknowledged this convergence explicitly, noting in its 2013 report that "advances in the life sciences and chemistry are blurring the distinction between chemical and biological weapons" and recommending that the organization monitor developments in synthetic biology more closely (OPCW, 2013)The BWC review conferences have been slower to address the issue directly, though the 2016 Final Document noted the relevance of developments in science and technology to the implementation of the convention (BWC, 2017)

The critical point for the legal analysis that follows is that these scientific developments do not, by themselves, create gaps in treaty coverage. The general purpose criteria of both conventions are broad enough to capture novel agents regardless of how they are produced. What they do create is a gap in institutional recognition and practical oversight. When an agent no longer looks like the kinds of weapons that the drafters of each convention had in mind, the likelihood that it will be declared, inspected, or investigated under either regime decreases substantially. The prohibition may remain intact on paper. The machinery for enforcing it may not.

4. The legal boundary between the BWC and CWC

The most common claim in the emerging literature on weapons convergence is that novel agents fall into a gap between the two treaties. This claim is intuitively appealing but legally imprecise. A careful reading of the treaty texts reveals that the gap is not one of prohibition but of institutional recognition and practical enforcement. Understanding this distinction is essential before moving to the case studies and verification analysis that follow.

Article I of the BWC obliges each state party never to develop, produce, stockpile, or otherwise acquire or retain "microbial or other biological agents, or toxins whatever their origin or method of production, of types and in quantities that have no justification for prophylactic, protective or other peaceful purposes" (Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction, 1972). The phrase "whatever their origin or method of production" was inserted during the negotiations at the insistence of several Western delegations who wanted to ensure that synthetic toxins could not escape the convention's reach by being manufactured in a chemistry laboratory rather than extracted from a living organism (Sims, 2001). The general purpose criterion embedded in the final clause is equally important. The prohibition does not attach to a fixed list of agents. It attaches to any biological agent or toxin that lacks a legitimate peaceful justification in the type and quantity at issue. This means that a novel peptide toxin produced through solid phase chemical synthesis, a bioregulator manufactured in an engineered yeast strain, and a classical pathogen cultivated in a fermenter are all equally covered as long as their intended purpose is hostile.

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Article II of the CWC defines chemical weapons to include "toxic chemicals and their precursors, except where intended for purposes not prohibited under this Convention, as long as the types and quantities are consistent with such purposes" (Article II – Definitions and Criteria, 1997). The convention then defines a toxic chemical as "any chemical which through its chemical action on life processes can cause death, temporary incapacitation or permanent harm to humans or animals." This definition makes no reference to the origin of the chemical. A toxic compound produced by an engineered microorganism is a toxic chemical under the CWC just as surely as one produced from petroleum feedstocks in an industrial reactor. The general purpose criterion operates in the same way as its BWC counterpart, anchoring the prohibition in intended use rather than production method (Krutzsch & Trapp, 2023).

The legal consequence of these parallel definitions is that a significant and growing class of agents falls under both conventions simultaneously. This is not a new observation. As early as 2003, the OPCW Scientific Advisory Board noted that the overlap between the two regimes was likely to expand as biotechnology advanced (OPCW, 2003). What has changed is the scale and practical significance of the overlap. When the only shared agents were a handful of classical toxins like ricin and saxitoxin, the dual coverage was a minor administrative curiosity. When the shared domain potentially includes bioregulators, synthetic peptide toxins, and biologically manufactured toxic chemicals, the overlap becomes a central feature of the governance landscape.

It is important to resist the temptation to treat this dual coverage as a problem of legal uncertainty. The treaties do not contradict each other. An agent that is both a toxin under the BWC and a toxic chemical under the CWC is prohibited under both. The state party's obligation is cumulative, not ambiguous. The real difficulty arises at the next level of analysis, where legal prohibition must be translated into practical governance. Three distinct questions are routinely conflated in discussions of the BWC and CWC boundary, and separating them clarifies where the genuine problems lie.

The first question is whether an agent or activity is prohibited. As the analysis above demonstrates, the answer for most emerging agents of concern is yes, under one or both conventions. The second question is whether a state is required to declare the relevant activity to an international body. Here the asymmetry becomes significant. The CWC requires states to declare facilities that produce scheduled chemicals above specified thresholds and permits the OPCW to inspect those facilities. The BWC has no comparable declaration or inspection requirement. The third question is whether an international body has the authority and technical capacity to investigate an alleged violation. The OPCW can conduct challenge inspections and deploy analytical expertise to identify unknown chemicals. The BWC has no standing inspectorate and relies on the United Nations Security Council for investigation of complaints, a mechanism that has never been successfully invoked (Revill et al., 2019).

The practical implication is that an agent may be clearly prohibited under both treaties yet effectively invisible to the verification machinery of either. If a state produces a novel bioregulator through an engineered microbial platform and classifies the activity as biological research, the CWC's declaration and inspection provisions may not be triggered because the facility does not produce scheduled chemicals. The BWC's confidence building measures may capture some information about the facility, but participation is voluntary and the detail provided is often minimal. The prohibition remains legally intact. The capacity to detect noncompliance does not.

This distinction between legal coverage and institutional reach is the analytical thread that connects the case studies, verification analysis, and normative discussion in the sections that follow.

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5. Case Studies

Abstract legal analysis only takes the argument so far. This section tests the claims developed above against three concrete examples that illustrate different dimensions of the boundary problem. Each case has been selected because it is well documented in the scientific and policy literature and because it exposes a distinct governance difficulty rather than simply confirming that novel agents exist.

5.1 Ricin and saxitoxin: the established overlap

Ricin and saxitoxin are the most frequently cited examples of agents that fall under both the BWC and the CWC, and they remain useful starting points precisely because their dual status is no longer contested. Ricin is a ribosome inactivating protein derived from the castor bean plant *Ricinus communis*. It is listed in Schedule 1 of the CWC's Annex on Chemicals and is simultaneously a toxin under Article I of the BWC (Audi et al., 2005). Saxitoxin, a paralytic shellfish poison produced by marine dinoflagellates, occupies the same dual position. Both agents were weaponized during the twentieth century. The United States produced ricin munitions during the Second World War, and the Soviet biological weapons programme reportedly explored saxitoxin as an assassination tool (Alibek & Handelman, 1999).

The governance significance of these cases lies not in their novelty but in what they reveal about the practical operation of dual coverage. Under the CWC, ricin production above 100 grams per year at a single facility triggers declaration obligations and is subject to OPCW inspection. Under the BWC, ricin is covered by the general purpose criterion but generates no comparable reporting requirement. The result is that the CWC's verification machinery provides the primary mechanism for detecting illicit ricin production, while the BWC's prohibition provides the broader normative and legal framework. The two regimes complement each other in this instance, but the complementarity depends entirely on the CWC's schedules and thresholds doing the practical work. If a novel toxin with similar lethality were developed that did not appear on any CWC schedule, the declaration and inspection triggers would not apply, and the BWC's institutional weakness would become the binding constraint on detection.

5.2 Engineered biological production of toxic chemicals

The Stanford yeast work discussed earlier provides a more challenging case. Galanie and colleagues demonstrated the complete biosynthesis of thebaine and hydrocodone in engineered *Saccharomyces cerevisiae* by introducing a pathway of more than twenty foreign genes drawn from poppy, bacterium, and rat genomes. The end products are well defined chemical compounds with known pharmacological and toxicological profiles. The production platform is a living organism. The process involves fermentation, a technique familiar to both the pharmaceutical and the chemical industries(Galanie et al., 2015).

From a treaty perspective, the classification question is genuinely difficult. Hydrocodone is a toxic chemical under the CWC's general purpose criterion because it acts on opioid receptors in the central nervous system and can cause death through respiratory depression at sufficient doses. It is not, however, listed on any of the CWC's three schedules, which means that its production would not trigger the declaration and inspection obligations that apply to scheduled chemicals. At the same time, the engineered yeast strain itself could be considered a biological agent under the BWC if it were developed for hostile purposes, since Article I covers "microbial or other biological agents" without restricting the definition to pathogens. The organism is the delivery mechanism. The chemical is the payload. Neither treaty's verification architecture is well suited to monitoring a facility that looks like a brewery but produces a substance with the toxicity profile of a nerve agent.

The OPCW Scientific Advisory Board flagged precisely this category of concern in its 2013

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report, noting that advances in synthetic biology could enable the production of scheduled chemicals through biological routes that would be difficult to detect using conventional chemical inspection methods (OPCW, 2013). The Board did not conclude that a legal gap existed, but it acknowledged that the practical capacity to verify compliance was being eroded.

5.3 Bioregulators and peptide toxins

Bioregulators present the most conceptually demanding case. Substance P, a neuropeptide of eleven amino acids, mediates pain signaling, neurogenic inflammation, and bronchoconstriction. At high concentrations delivered by aerosol, it could theoretically cause mass incapacitation through respiratory distress (Dando, 2020). It is small enough to be synthesized through standard solid phase peptide chemistry, which means it could be produced in a facility indistinguishable from a pharmaceutical peptide manufacturing plant. It is also producible through recombinant expression in bacterial systems.

The classification difficulty is acute. Substance P is a chemical compound with a defined molecular formula, which brings it within the CWC's definition of a toxic chemical. Its mechanism of action is receptor mediated biological signaling, which gives it a fundamentally biological character. It is not a pathogen and does not replicate, which makes it a poor fit for the BWC's traditional focus on infectious agents. It is not a classical toxin in the sense of being a secondary metabolite produced by a living organism for defensive purposes. It is, in the language of the BWC, arguably a toxin "whatever its origin or method of production," but that interpretation has never been tested in a review conference or legal proceeding. Dando (2015) has argued that bioregulators represent the most serious challenge to the existing arms control architecture precisely because they sit at the intersection of the two regimes without being clearly legible to either.

5.4 What the cases demonstrate together

The three cases illustrate a pattern. The legal prohibition remains robust across all three. The institutional capacity to detect, investigate, and verify compliance degrades as the agents move further from the historical categories that shaped each treaty's verification design. Ricin and saxitoxin are manageable because they are explicitly scheduled under the CWC. Engineered biosynthesis of toxic chemicals exposes the limits of schedule based verification. Bioregulators expose the limits of both regimes' capacity to recognize agents that do not resemble the weapons their drafters imagined.

6. Verification and Institutional Coordination

The case studies in the previous section demonstrated that legal prohibition and practical detectability are not the same thing. This section examines why that gap exists by comparing the verification architectures of the two regimes and assessing whether the institutional asymmetry creates conditions that strategic actors could exploit.

The CWC's verification system is the most intrusive arms control mechanism ever established. States parties are required to declare all facilities that produce, process, or consume scheduled chemicals above specified thresholds, and the OPCW conducts routine inspections of those facilities to verify the accuracy of declarations (Krutzsch & Trapp, 2023). The convention also authorizes challenge inspections, which allow any state party to request an inspection of any facility on the territory of another state party on short notice, subject to a vote by the Executive Council. In practice, challenge inspections have never been invoked, partly because the political threshold for requesting one is extremely high and partly because the managed access provisions give the inspected state significant latitude to protect sensitive information unrelated to the convention (Tucker, 2007).Nevertheless, the mere existence of the mechanism, combined with the routine

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inspection programme and the OPCW's analytical laboratory capacity, gives the CWC a verification infrastructure that is qualitatively different from anything available under the BWC.

The BWC's compliance arrangements are, by comparison, almost entirely voluntary. The confidence building measures agreed at the Second Review Conference in 1986 and expanded at the Third Review Conference in 1991 ask states to exchange information about high containment facilities, unusual disease outbreaks, and biological defence programmes (Sims, 2001). Participation rates have remained low, typically around fifty to sixty states out of more than 180 parties, and the quality of the information submitted varies enormously. There is no standing inspectorate, no declaration requirement, and no formal mechanism for investigating suspicious activities short of lodging a complaint with the United Nations Security Council under Article VI, a step that no state has ever completed successfully. The failed attempt to negotiate a legally binding verification protocol between 1995 and 2001, which collapsed when the United States withdrew its support under the Bush administration, left the BWC with institutional arrangements that have not been substantially updated since the early 1990s.

The asymmetry matters for the governance of convergent agents in a specific and concrete way. If a state develops a novel toxic compound through an engineered biological production platform, the practical question is which regime's machinery would detect the activity. The CWC's declaration requirements would only be triggered if the compound appeared on one of the three schedules or if the facility met the threshold criteria for unscheduled discrete organic chemicals. A bioregulator or a novel peptide toxin would almost certainly not meet either condition. The BWC's confidence building measures might capture some information about the facility if the state chose to declare it, but the voluntary nature of the process means that a state with something to hide would have little incentive to provide detailed information. The result is a situation in which the most rigorous verification tools are attached to the regime whose categories are least likely to capture the emerging threat, while the regime whose categories are most relevant lacks the tools to verify compliance.

The question of whether states would deliberately exploit this asymmetry requires careful handling. The claim that states engage in "regulatory arbitrage" by classifying ambiguous agents under the weaker regime is analytically plausible but empirically difficult to demonstrate. States do not publicly announce their classification decisions for weapons programmes that they deny having. The most that can be said with confidence is that the structural conditions for such behaviour exist and that the historical record of biological weapons programmes, including the Soviet Biopreparat complex and the South African Project Coast, demonstrates that states have been willing to exploit institutional weaknesses when they could do so without detection (Gould & Folb, 2002). Whether the specific mechanism of cross regime classification has been used remains an open question that would require intelligence data not available in the public domain.

What is observable is the institutional disconnect between the two regimes at the operational level. The OPCW and the BWC Implementation Support Unit in Geneva have no formal mechanism for sharing information, coordinating scientific assessments, or conducting joint horizon scanning exercises. Their scientific advisory bodies operate independently and publish on different timelines. Their review cycles are not synchronized. This institutional fragmentation means that even when both regimes technically cover the same agent, the practical governance response is likely to be siloed rather than coordinated (Revill et al., 2019).

7. Recommendations for Strengthening Governance

The preceding analysis suggests that the governance deficit created by scientific

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convergence is real but narrower than some commentators have claimed. The legal prohibitions remain intact. The institutional weaknesses are significant but not insurmountable. The normative foundations are under pressure but have not collapsed. This section proposes three categories of reform that could address the most pressing problems without requiring the politically implausible step of renegotiating either treaty.

The first and most immediately achievable recommendation concerns treaty interpretation. Both the BWC and the CWC rely on general purpose criteria that are broad enough to cover novel agents regardless of production method, but the practical application of those criteria to emerging technologies has not been clarified through formal review conference statements or expert guidance. The BWC Review Conferences could issue a consensus statement affirming that the phrase "toxins whatever their origin or method of production" in Article I extends to synthetically manufactured peptides, bioregulators, and other biologically active compounds that do not replicate but cause harm through physiological disruption. Such a statement would not alter the legal text but would reduce the interpretive ambiguity that states could exploit to argue that novel agents fall outside the convention's scope . Similarly, the OPCW Conference of the States Parties could adopt a decision clarifying that the CWC's general purpose criterion applies to toxic chemicals produced through biological routes, including engineered fermentation and cell free synthesis, regardless of whether the resulting compound appears on any of the three schedules. The OPCW Scientific Advisory Board has already recommended steps in this direction, and formalizing those recommendations through a conference decision would give them greater political weight (OPCW, 2018).

The second recommendation addresses the institutional disconnect at the national level. Most states parties implement the BWC and the CWC through separate domestic authorities that rarely coordinate. The national authority responsible for CWC declarations and inspections is typically housed in a foreign ministry or a defence department, while the BWC focal point is often located in a public health agency or a different branch of the foreign ministry entirely. This structural separation means that information about dual use research facilities, unusual procurement patterns, or suspicious biological production activities may not reach the officials responsible for chemical weapons compliance, and vice versa. States could address this problem through relatively modest administrative reforms, such as establishing interagency working groups that bring together CWC and BWC national authorities, creating shared databases of facilities that produce agents of concern under either convention, and developing joint training programmes for inspectors and compliance officers. These reforms would not require new legislation or international agreements. They would require only a recognition that the chemical and biological dimensions of weapons proliferation can no longer be managed in isolation.

The third recommendation concerns scientific horizon scanning at the international level. Both the OPCW and the BWC have mechanisms for monitoring developments in science and technology, but those mechanisms operate independently and produce outputs that are not systematically compared or integrated. The OPCW Scientific Advisory Board publishes detailed reports on emerging chemical and biological technologies. The BWC Meeting of Experts discusses scientific developments but lacks a standing advisory body with comparable technical depth. A practical step forward would be to establish a joint scientific working group composed of experts from both regimes, tasked with producing an annual assessment of technologies that are likely to blur the chemical and biological boundary in the coming decade. The working group would not need enforcement authority or a large budget. Its value would lie in

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providing both regimes with a shared factual basis for anticipating governance challenges before they become crises.

It is worth acknowledging the limits of these proposals. None of them addresses the fundamental asymmetry between the CWC's verification architecture and the BWC's institutional weakness. That asymmetry will persist as long as the political conditions that prevented the adoption of a BWC verification protocol in 2001 remain in place, and there is little reason to expect those conditions to change in the near term. The recommendations offered here are deliberately modest because modest reforms that can be implemented within the existing treaty framework are more likely to produce tangible results than ambitious proposals that require political consensus that does not currently exist. The objective is to narrow the gap between legal prohibition and practical governance, not to close it entirely.

9. Conclusion

This paper began with a deceptively simple question. When synthetic biology and modern chemistry produce agents that blur the boundary between the biological and chemical categories, do the existing arms control treaties still apply? The answer, as the preceding analysis has shown, is more layered than either the optimists or the alarmists in this debate tend to acknowledge.

The legal prohibitions remain intact. The general purpose criteria of both the BWC and the CWC anchor their prohibitions in intended use rather than in production method or disciplinary origin. A toxin manufactured through solid phase peptide synthesis is prohibited under the BWC. A toxic chemical produced by an engineered yeast strain is prohibited under the CWC. The phrase "whatever their origin or method of production" in Article I of the BWC was inserted precisely to anticipate the kind of technological convergence that is now unfolding, and the CWC's definition of toxic chemicals is similarly agnostic about how the substance in question was made. The claim that novel agents fall into a legal vacuum between the two treaties is, on close reading, not supported by the treaty texts.

The institutional picture is considerably less reassuring. The CWC possesses a standing verification organization with declaration requirements, routine inspections, and analytical laboratory capacity. The BWC relies on voluntary confidence building measures and a Security Council complaint mechanism that has never been successfully invoked. When an emerging agent could plausibly be investigated under either regime, the practical question of which institution takes responsibility becomes a genuine governance problem. The case studies examined in this paper illustrate a consistent pattern. Legal coverage holds across all three categories of agents. Institutional detectability degrades as the agents move further from the historical prototypes that shaped each treaty's verification design. Ricin and saxitoxin are manageable because they are explicitly scheduled. Engineered biosynthesis of toxic chemicals exposes the limits of schedule based verification. Bioregulators expose the limits of both regimes' capacity to recognize agents that do not resemble the weapons their drafters imagined.

The normative dimension adds a further layer of complexity. The chemical and biological weapons taboos developed through different historical trajectories and carry different degrees of political force. Technological convergence risks creating a space in which agents are too chemical for the biological taboo to activate and too biological for the chemical taboo to apply with full force. The Moscow theatre incident of 2002 offers a cautionary example of how classification uncertainty can dilute political condemnation even when the hostile use of a toxic agent is beyond dispute.

The recommendations offered in the previous section are deliberately modest. Clarifying treaty interpretation through review conference statements, improving coordination between national authorities, and establishing joint scientific horizon scanning mechanisms would not

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resolve the fundamental asymmetry between the two verification architectures, but they would narrow the gap between legal prohibition and practical governance in ways that are achievable within the current political constraints.

Several avenues for future research remain open. The empirical question of whether states have deliberately exploited the boundary between the two regimes to avoid scrutiny cannot be answered definitively with publicly available data, but the structural conditions for such behaviour deserve closer examination as more information about historical weapons programmes becomes available. The technical question of how verification methods might be adapted to detect biological production of scheduled chemicals, or chemical production of biological toxins, requires collaboration between arms control scholars and laboratory scientists that has so far been limited. And the normative question of whether a broader prohibition on poisoning and deliberate disease could supplement the existing categorical taboos without weakening them deserves more sustained theoretical attention than this paper has been able to provide.

The boundary between chemistry and biology was never as clean as the treaty architecture assumed. It is now dissolving faster than the institutions built to police it can adapt. The treaties themselves are more resilient than their critics suggest. The governance infrastructure that surrounds them is not. Closing that gap is the central challenge for arms control in the age of synthetic biology, and it is a challenge that neither convention can meet alone.

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