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Scientific Change and the Security Environment

Biotechnology and security to 2025

by Malcolm Dando

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Introduction: the threat

Although there have been few major acts of bioterrorism to date (Leitenberg 2005), scientific discoveries about the nature of infectious diseases made at the end of the nineteenth century prompted the establishment of a series of offensive biological warfare programmes in major states throughout the twentieth century (Geissler and van Courtland Moon 1999, Wheelis *et al* 2006). These programmes led to the use of biological weapons against animals in the First World War, against people before and during the Second World War and against plants in Vietnam (Agent Orange being a synthetic analogue of a bioregulatory auxin).

Today, the United States appears to be concerned that there are still some state-level offensive biological weapons programmes (US Department of State 2005), even if conventional weaponisation and delivery of biological weapons remains very difficult for sub-state groups. However, it is also clear that offensive biological weapons programmes in the last century grew progressively more sophisticated as the life sciences developed, and it is therefore to be expected that future state and sub-state programmes will build on these ongoing advances in science and technology (Dando 1999).

It is in this context that current military perceptions of the changing nature of warfare are to be viewed. As General Rupert Smith has argued, modern wars will not be like the force-on-force clashes of the twentieth century but will have much more complex objectives than simply defeating the opposition's military forces. As he noted, we are likely to be involved in long-term conflicts 'among the people' (Smith 2005). It is no doubt because of the recognition of such complexities that the US Army published a new field manual on *Stability Operations* (Harlow 2008).

What is important here is to recognise that these new forms of warfare – in places like the Balkans, Sri Lanka, Afghanistan and Iraq – have eroded former distinctions between war, crime and major assaults on human rights. Moreover, these wars are being fought against people who are seeking political control – or worse – over civilian populations. In such circumstances Julian Perry Robinson (2008) has observed that 'because chemical weapons can lend themselves particularly effectively to such objectives, they may conceivably have a greater affinity to the new wars than they did to the old'.

The old distinctions between chemical and biological weapons have become increasingly meaningless as chemistry becomes indistinguishable from biology, and it is important to grasp the fact that these weapons are not just potential weapons of mass destruction, but can be used on a range of lesser scales. And the prevailing conditions to 2025 could be conducive to a resurgence of these weapons – unless very strenuous efforts are made to prevent that happening.

What, then, is the significance of developments in the life and associated sciences? It may have taken almost 100 years from Darwin's explanation of evolution to Watson and Crick's elucidation of the structure of DNA and nearly another 50 to the completion of sequencing of the human genome, but now the scope and scale of change is remarkable. *Newsweek* caught the current mood well when it compared developments in the life sciences in 2007 to the miracle year – 1905 – in physics (Silver 2007). Furthermore, these developments have come increasingly to the attention of the military.

The paradigm case in this regard is certainly the Australian 'mousepox' experiment, during which civil scientists inadvertently created a lethal pox virus by means which suggested that smallpox might be similarly genetically modified so that it could not be prevented by vaccination (Jackson *et al* 2001). The researchers were trying to find a means of dealing with plagues of rodents that can be a significant agricultural problem in Australia. They came up with the idea of adding the gene for a mouse egg protein to the viral genome, expecting that infected mice would generate an immune response and reject their own eggs. In order to increase this response the researchers then added the gene for the bioregulator IL-4 to the virus genome. In the event, the doubly-modified virus, which is normally benign, killed all the mice. It also killed large numbers of mice normally resistant to the unmodified virus and mice vaccinated against the virus.

This and other civil research that raises similar issues of potential misuse – the so-called 'dual-use dilemma' (Atlas and Dando 2006) – has also led to concerns in the academic community. In the United States, a series of reports by the National Academies was particularly important in bringing the issue to a much wider audience. The central question that came through in these reports was set out clearly by Professor Matthew Meselson:

> *Every major technology – metallurgy, explosives, internal combustion, aviation, electronics, nuclear energy – has been intensively exploited, not only for peaceful purposes but also for hostile ones. Must this also happen with biotechnology, certain to be a dominant technology of the twenty-first century?* (Meselson 2000)

In short, the developments in the life and associated sciences are going to make it increasingly cheap and easy for more and more states, sub-state groups and individuals to do greater and greater harm. Furthermore, the historical record suggests that it will be very difficult to stop major hostile applications of this powerful technology.

The first of the reports by the National Academies, *Biotechnology Research in an Age of Terrorism*, was produced by a committee chaired by Gerald Fink and published in 2004. The committee argued that there were at least seven classes of experiment of sufficient concern to warrant some kind of biosecurity review. For example, one such class '[w]ould demonstrate how to render a vaccine ineffective', as in the mousepox experiment. The committee's list of experiments focused only on microbial agents, but noted that they expected that 'it will be necessary to expand the experiments of concern to cover a significantly wider range of potential threats' (Committee on Research Standards and Practices to Prevent the Destructive Application of Biotechnology 2004).

The committee also suggested that the United States should set up a national board to provide guidance on how an oversight system should be designed and implemented. The National Science Advisory Board for Biosecurity has subsequently grappled with these problems in an almost entirely open and transparent manner, but we should probably not expect too much from this oversight system. It will be useful for awareness-raising and as a precautionary measure in very unusual, extreme cases, but few experiments of concern are likely to be modified or prevented by such a mechanism.

Nevertheless, the follow-on report, *Globalization, Biosecurity, and the Future of the Life Sciences*, produced in 2006 by a committee chaired by Stanley Leman and David Relman, greatly widened the areas of concern. As indicated by the word 'globalization' in the report title, this committee stressed the fact that the biotechnology revolution was taking place in many different countries around the world and, crucially, recommended that a much broader perspective on the threat spectrum needed to be adopted, 'beyond the classical "select agents" and other pathogenic organisms and toxins, so as to include, for example, approaches for disrupting host homeostatic and defence systems and for creating synthetic organisms' (Committee on Advances in Technology and the Prevention of their Application to Next Generation Biowarfare Threats 2006). Homeostatic systems include those that regulate our blood pressure and balance; our defence systems are our innate and adaptive immune systems that deal with invading microorganisms.

The committee argued that it was very difficult to forecast what significant developments might arise as the revolution in the life sciences continued, but they suggested that various groupings of biotechnologies might provide a useful framework to consider such developments. These technologies were concerned, for example, with the acquisition of novel biological or molecular diversity, with directed design, with production, delivery and 'packaging' and with understanding and manipulation of biological systems.

A 2008 report, *Emerging Cognitive Neuroscience and Related Technologies*, from a committee chaired by Christopher Green, illustrates the need to think much more widely than pathogens and genomics. As this committee's report demonstrated, our knowledge of the nervous system may now allow precise disruption of key circuits by those with hostile intent while nanotechnology could provide the means to get disruptive bioregulators across the blood-brain barrier. This barrier protects the brain from chemicals that might be harmful, but bioregulators can be effective at very low concentrations so that such a nanotechnology-based mechanism for increasing the effective dose opens up the possibility of many people being attacked at the same time.

The military implications of such developments were considered by three analysts from the US Defense Intelligence Agency (Petro *et al* 2003) in a paper for the journal *Biosecurity and Bioterrorism*. They suggested that we should think of a future of biological agent development in three overlapping phases. The first would consist of the traditional unmodified agents but since, at least hypothetically, defences could be designed against all such traditional agents, the attacker would move to modify these agents, for example by adding genes conferring antibiotic resistance. As the number of modifications that could be made is relatively limited, at least in theory, the defence would eventually be able to design countermeasures.

At this point, according the report's authors, a very significant change could take place:

> *Emerging biotechnologies likely will lead to a paradigm shift in BW agent development; future biological agents could be rationally engineered to target specific human biological systems at the molecular level....allowing BW agent developers to identify biochemical pathways critical for physiological processes and engineer ABW [Advanced Biological Warfare] agents to exploit vulnerabilities...* (Petro *et al* 2003).

So they see a future in which attacks could come from traditional pathogens, modified traditional pathogens or specifically designed Advanced Biological Warfare agents of many different types aimed to disrupt many different physiological processes.

The authors of this seminal paper go on to suggest various ways in which the United States should prepare for what might happen if their forecast is correct. However, if an offence-defence arms race should break out, particularly one involving state programmes applying the cutting edge of current life sciences research, it is very difficult to envisage anything other than a very long period of offensive dominance, since there appear to be an endless number of ways in which dire harm could be caused by those with malign intent. As Professor Meselson (2000) has warned, 'a world in which these capabilities are widely employed for hostile purposes would be a world on which the very nature of conflict had radically changed. Therein could lie unprecedented opportunities for violence, coercion, repression, or subjugation'.

The most dangerous and costly scenario that can be envisaged is a situation in which we have failed to *prevent* large-scale offensive application of the modern life and associated sciences to the complex warfare that is most likely to characterise coming decades. It is against that background that we must examine the current state of the prohibition regime and assess what might be done now to strengthen the restraints it includes.

The prohibition regime

The mechanism that has been developed to prevent the use of chemical and biological weapons is centred on three international agreements: the 1925 Geneva Protocol; the 1972 Biological and Toxin Weapons Convention; and the 1993 Chemical Weapons Convention. The 1925 Geneva Protocol is now widely accepted as customary international law that bans the use of chemical and biological weapons. The 1972 Biological and Toxin Weapons Convention (BTWC) adds a series of other controls to this ban on use, such as Article I that forbids States Parties 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' (BTWC 1972).[1]

The BTWC has a number of other key articles, such as Article IV which requires the national implementation of the Convention and Article XII which provides for the five-yearly Review Conference. However, the BTWC has two key weaknesses: it has no adequate verification system to ensure that States Parties are living up to their obligations and it still lacks a major international organisation to guide its further development. Efforts to correct these deficiencies during the 1990s failed in 2001 (Dando 2002) and since then an Inter Sessional Process (ISP) has provided for annual meetings to take place between Review Conferences in order to 'promote common understanding and effective action' on issues where agreement seems more likely to be possible.

While these annual meetings have not addressed the Convention's major weaknesses, they have led to improvements, for example in national implementation of the Convention and, crucially for the discussion here, a much greater involvement of scientists from industry, academia and national academies. The process began with the 2005 meetings on codes of conduct, but it rapidly became clear – both from States Parties' statements (Australia 2005) and from other research – that practising life scientists had very little knowledge of the Convention or of the danger that would be posed in the event of their work being misused for hostile purposes, despite raising awareness being regarded as an important means of supporting the prohibition in agreed *Final Declarations* from the 1986 Second Review Conference onwards.

Without an awareness of these issues, it is clear that scientists can contribute little to the development and implementation of codes of conduct or research oversight systems. It is therefore not surprising that when States Parties returned to examine the responsibilities of scientists they had much more specific conclusions rather than the general statements of previous agreements. An expert-level meeting in August 2008 and the States Parties meeting in December of that year considered issues such as oversight, education, awareness-raising, and the development of codes of conduct to help prevent misuse of scientific technologies. Box 1 below highlights relevant excerpts from the report of the Meeting of States Parties.

While other means of strengthening prohibitions on the misuse of biological and chemical weapons remain contentious, at least in regard to education there is a detailed and agreed-upon agenda. Furthermore, while a survey of education at the university level in Europe indicates that a major reason for the current lack of awareness is that biosecurity issues are not included in the curriculum, there do appear to be opportunities to include such material in the growing number of courses in bioethics (Mancini and Revill 2008). Similar conclusions may also be drawn from a survey of university-level teaching in Japan (Minehata and Shinomiya 2009).

1. It should be understood that toxin here has a wide meaning, including chemicals and bioregulators such as neurotransmitters, hormones and cytokines (for example, the IL-4 used in the mousepox experiment).

Box 1: Report of the Meeting of States Parties to the BTWC, December 2008

26. States Parties recognized the importance of ensuring that those working in the biological sciences are aware of their obligations under the Convention and relevant national legislation and guidelines, have a clear understanding of the content, purpose and foreseeable social, environmental, health and security consequences of their activities.... States Parties noted that formal requirements for seminars, modules or courses, including possible mandatory components, in relevant scientific and engineering training programmes and continuing professional education could assist in raising awareness and in implementing the Convention.

27. States Parties agreed on the value of education and awareness programmes:

(i) Explaining the risks associated with the potential misuse of the biological sciences and biotechnology;

(ii) Covering the moral and ethical obligations incumbent on those using the biological sciences;

(iii) Providing guidance on the types of activities which could be contrary to the aims of the Convention and relevant national laws and regulations and international law;

(iv) Being supported by accessible teaching materials, train-the-trainer programmes, seminars, workshops, publications, and audio-visual materials;

(v) Addressing leading scientists and those with responsibility for oversight of research or for evaluation of projects or publications at a senior level, as well as future generations of scientists, with the aim of building a culture of responsibility;

(vi) Being integrated into existing efforts at the international, regional and national levels.

Source: Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction (2008)

The more recent Chemical Weapons Convention (CWC) is acknowledged to be much stronger than the BTWC, having both a verification system based on declarations, visits and the possibility of challenge inspections, and a major Organization for the Prohibition of Chemical Weapons (OPCW) to underpin its operation. Under Article 2.1 of the Convention, chemical weapons are defined as 'toxic chemicals or their precursors, except where intended for purposes not prohibited by the Convention, as long as the types and quantities are consistent with such purposes', while toxic chemicals are defined as 'any chemical, regardless of its origin or method of production, which, through chemical action on life processes, can cause death, temporary incapacitation or permanent harm to humans or animals' (OPCW 2005).

The CWC therefore has the same kind of sweeping 'General Purpose Criterion' as that embodied in Article I of the BTWC. It also covers toxins (in the broad sense of the BTWC) and so there is an overlap between these two conventions in regard to such 'midspectrum' agents lying between traditional living biological pathogens and classical lethal chemical agents such as nerve agents or mustard gas.

Unfortunately, there is an ambiguity at the heart of the CWC, as one of the allowable peaceful purposes is defined as 'law enforcement including domestic riot control purposes' (OPCW 2005: Article II.9(d)). It could thus appear that there is a broad category of legitimate law enforcement chemicals of which standard riot control agents are only a part. As the term 'law enforcement' is not defined in the Convention and States Parties are not required to report what chemicals they have for such purposes, it was pointed out at the time the agreement was negotiated that there might be a loophole which allowed new technologies – particularly for so-called 'non-lethal' incapacitating chemicals – to be developed (*Chemical Weapons Convention Bulletin* 1994). It is in that context that the use of the opiate fentanyl (or derivatives) to break the Moscow theatre siege in 2002 was of such concern, as it could be an indication of how the prohibition on the use of chemical weapons might be eroded by some states seeking to utilise new technologies in novel weapon systems (Crowley 2009).

Despite these concerns, the CWC is widely regarded as having been successful, albeit with delays, in overseeing the destruction of the huge stocks of lethal chemical weapons produced during the Cold War. However, as that process comes to an end, the need for a much more comprehensive verification system looms on the horizon.

The United States essentially rejected the proposed verification system for the BTWC in 2001 because it argued that a system adequate to ensure compliance would pose too great a risk to commercial and national secrets, whereas an inadequate system that protected such secrets would give a false sense of confidence. The drafters of the CWC were aware that they could not monitor the production of all possible toxic chemicals so they defined for the purpose of verification activities a subset that were agreed to be of major concern. However, the negotiators also knew that there were many civil facilities that could be capable of producing chemical weapons. These were termed 'Other Chemical Production Facilities' and have begun to come under the purview of the OPCW inspection system (Mathews 2009).

One way to increase confidence in compliance with the Convention would be to considerably increase the number of such facilities subject to inspection, but that may not be an easy matter to agree as it could clearly lead to the same kinds of objection as the United States had to the BTWC verification protocol. For example, one critical point of disagreement is that some states want production by synthesis to be limited only to mean production by chemical synthesis and not to include production by biological synthesis. This would greatly limit the scope of verification, as production by biological processes will clearly continue to grow.

What should be done now?

The evolution of both the CWC and the BTWC is steered through five-yearly major Review Conferences. The next few years are important because the 2011 Seventh Review Conference of the BTWC and the 2013 Third Review Conference of the CWC, if successful, could greatly strengthen the prohibition regime against the threats arising from the rapid and extensive advances in the life sciences and other associated sciences and technologies. However, should States Parties fail to face up to these challenges the whole prohibition regime could become increasingly fragile in the following decades.

Open public discussions of the major issues that need to be tackled, and the options available in these Review Conferences, have hardly begun, despite the importance of what is at stake. In regard to the BTWC, there must be lingering fears among some observers that there could be a repeat of the disastrous outcome of the 2001–2 Fifth Review Conference when it was not possible to agree a *Final Declaration* because of disagreements over verification, although it is to be hoped that the better atmosphere that has developed in the two Inter Sessional Process meetings of 2003–5 and 2007–9 will promote more constructive discussions. Yet it appears that a return to the core business of working out a legally-binding verification regime, however desirable (Kelle *et al* 2010), is also unlikely. What seems most likely is that States Parties will agree to something in between. The salient question here is how far the eventual agreement can be pushed towards progressive implemented measures that really do strengthen the Convention.

The improved atmosphere of the Inter Session Process meetings is due partly to the fact that while States Parties have been required to discuss and promote common understandings and effective action on the topics of these annual meetings, they have not had to negotiate agreements on what must actually be done. Clearly, not enough implementation of practical measures has resulted from the first two ISP series of meetings. Yet there is also a perceived risk that if proper negotiations and the involvement of state capitals are necessitated, then a great deal more than just a better atmosphere could be lost.

The ISP meetings have resulted in a much greater involvement of civil society (particularly scientists and scientific organisations) in the discussions of how to strengthen the Convention. This has produced a wide-ranging and fluid discussion and more expertise is now available to the delegations. Indeed, some observers have suggested that the highly formal and rather secretive activities of States Parties in regard to the CWC, rather than being a model for the future of the BTWC, indicate that parties to the CWC might have much to learn from the increasing involvement of civil society in the ISP meetings of the BTWC.

What, then, might be done to strengthen the BTWC at the Seventh Review Conference of 2011? Nicholas Sims, the premier historian of the Convention, suggested what might be realistically possible in two papers for a Pugwash[2] meeting in Geneva in December 2009 (Sims 2009a and 2009b). The obvious next step is to build on the success of the 2006 Sixth Review Conference in establishing the Implementation Support Unit (ISU) for the BTWC. A small expansion of the unit from three to five permanent secretariat members could allow it to effectively support an expansion of ISP annual meetings from 2012–16 through to the next Review Conference in 2017. Sims suggests that a new series of ISP meetings could continue to deal with a set topic each year and to receive reports on the process of universalising the Convention and on the work of the ISU. However, it could also take on a regular agenda of other items such as the national reporting and review of implementation of the Convention under the 'Accountability Framework' proposed by Canada in 2006 (Canada 2006) and a 'Consolidation Agenda' covering, for example, accession to, and removal of reservations from, the 1925 Geneva Protocol.

To better address the rapid advances in relevant science and technology Sims also suggests that this too could be a regular item on the agenda of the meetings and perhaps be backed up by the work of a Scientific Advisory Panel. With such an expanded agenda it would be necessary to consider giving three weeks each year (one week at expert level and two weeks for States Parties) to these meetings on the international calendar. The hope would be that such an expansion, successfully carried through to the Eighth Review Conference in 2017, would lay secure foundations for a further step forward then.

The 2013 Third Review Conference of the CWC has also received little public attention, but States Parties will face at least two very difficult scientific issues at that review (OPCW 2009). First there is the problem of how to deal with the specific issue of the interest in some states in new forms of so called 'non-lethal' chemicals for law enforcement, and secondly there is the more general problem of reorientation of the verification system to deal with non-proliferation effectively once the destruction of the last century's lethal chemical stocks is completed. Dealing with these problems, as with the problems of the BTWC, will require much greater knowledge and involvement of civil society, particularly the scientific community, than there has been in the past. Only in that way will these crucial issues concerning the possibility of a radical deterioration in the nature of future warfare be brought up to a sufficiently high level on the political agenda of major states.

2. See www.pugwash.org/about.htm

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