

Science, technology and the CBW control regimes

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Advances in science and technology (S&T) can have both positive and negative effects on societies and the relations among them. In chemistry, biology and the life sciences more generally the intention of scientists doing cutting-edge research will generally be to better the human condition, such as through the development of new medicines. However, a considerable number of chemical compounds and micro-organisms have potential for harmful, as well as beneficial, effects.

Many toxic chemicals, their precursors, as well as pathogens and processes involved in their production have perfectly legitimate civilian applications. At the same time the history of chemistry and biology provides ample examples of new discoveries in these areas being used for weapons' purposes. Thus, the dual-use character of toxic chemicals and pathogenic micro-organisms is not just an abstract quality they possess. Rather, the different purposes to which these substances and organisms can be put have had profound implications on military thinking and—in the case of chemical weapons (CW)—the history of warfare. Any effort to control the use of toxic chemicals or pathogenic micro-organisms for offensive military purposes has to take into account the dual-use nature of many of these chemicals, organisms and related equipment and processes.

To give but a few examples, chlorine and phosgene—two of the major chemical warfare agents used in the First World War—are used on a large scale as industrial chemicals in a variety of applications. Among other uses, phosgene is used in pesticides, pharmaceuticals and dyes. Current industrial operations utilizing cyanide-based compounds include fumigation, processing of metal ore and fabrication of metal polishes. This dual-use character is equally pronounced in the biological weapon (BW) area, which has implications for the verification of the peaceful applications of both potential chemical and biological warfare agents.

The next section will provide a brief overview of past S&T advances and their use in offensive chemical and biological warfare programmes. This will be followed by a discussion of present control mechanisms for chemical and biological weapons (CBW) and how they relate to the state of development of the life sciences. The final section will analyse how the biotechnology revolution might impact the future of CBW controls. Given the availability of detailed analyses of some aspects of the biotechnology revolution and its impact on BW controls, in general this paper will focus more on the impact on CW controls.

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Past S&T advances and their use in CBW programmes

Scientific and technological advances in the second half of the nineteenth century were instrumental in enabling offensive CBW programmes. In the case of chemistry, it was a particular aspect of the industrial revolution that made chemical warfare during the First World War a possibility¹—the “large-scale liquefaction of chlorine gas and its packaging into pressure cylinders.”² This was accomplished in 1888 by the German company BASF.³

Therefore it does not come as a surprise that when large-scale use of CW first occurred, it was chlorine that was used: almost 150 tons of which were released by the German army on 22 April 1915 near Ypres on the Western front. As defences in the form of gas masks were developed against chlorine and phosgene, the first offensive-defensive chemical arms race ensued with CW agents like mustard gas being developed to overcome the respiratory protection that the masks afforded.⁴

Despite several peace treaties and the 1925 Geneva Protocol, chemical rearmament was taking place in the 1920s and 1930s. In the case of Germany, for example, this chemical rearmament stood in stark contrast to the obligations undertaken in the Versailles peace treaty signed after the First World War. Yet it was in Germany where civilian research into a new group of organophosphorous compounds led to the development and production of the first nerve agent, Tabun, in December 1936. This discovery was followed by the synthesis of Sarin in 1939 and Soman in 1944. After the Second World War civilian work to exploit the new group of toxic organophosphates continued, leading to the development of even more toxic compounds, some of which were introduced as pesticides but then had to be withdrawn due to their toxicity to man. One of these super-toxic compounds was adopted by the US military during the 1950s and became known as the VX chemical warfare agent.⁵

The use of biological agents in warfare goes back at least several hundred years.⁶ However, only with the advances in the scientific understanding of life and its underlying processes has a systematic utilization of pathogens or naturally produced toxic substances for warfare purposes been possible. The nature and scope of biological warfare has changed dramatically due to the revolution in the life sciences that began in the late nineteenth century. As Dando has shown for the “three generations of offensive biological warfare programs” of the twentieth century, all the military programmes were “developing on the back of growth in scientific knowledge.”⁷ According to his account, military BW programmes followed scientific discoveries in the areas of: *bacteriology*, providing the ground for the BW-based sabotage activities during the First and Second World Wars; *aerobiology*, providing for the knowledge to spread biological warfare agents over large geographic areas, and thereby giving non-contagious agents their potential to be used as mass casualty weapons; and *genetic engineering*, which played an important role in the offensive BW programme of the former Soviet Union.⁸

Present CBW control mechanisms and their relationship to developments in the life sciences

The CBW control regimes go back to the 1925 “Protocol for the Prohibition of the Use in War of Asphyxiating, Poisonous, or Other Gases, and of Bacteriological Methods of Warfare”. The Protocol was originally conceived as a response to the widespread use of CW during the First World War, and only upon a Polish initiative were “bacteriological methods of warfare” included into the Protocol text. It entered into force in 1928 and has currently 133 member states. Today, the CBW regimes revolve around two international treaties: the Biological and Toxin Weapons Convention (BWC)⁹ and the Chemical Weapons Convention (CWC).¹⁰

The CWC was opened for signature in January 1993 and entered into force on 29 April 1997. It bans the development, production, use and retention of CW and requires states possessing CW to destroy them over a ten-year period. The dual-use problem led to the inclusion in the CWC of the so-called general purpose criterion. According to this provision, toxic chemicals that could be misused as CW are not prohibited altogether. Negotiators of the CWC also realized that the area the convention regulates would be subject to advances in S&T. They have therefore provided for a procedure to review these developments at CWC review conferences and created the Scientific Advisory Board (SAB) to advise the Organisation for the Prohibition of Chemical Weapons (OPCW) on S&T matters.

Chemical warfare agents and means for their production are based on long-established, well-known and proven technologies. Thus, a potential proliferator determined to operate a clandestine CW programme does not necessarily have to look for the latest developments in chemistry or related disciplines to obtain a militarily significant CW capability. Nevertheless, at least three developments are taking place in both the civilian and military applications of chemistry that might well change the way we (need to) think about chemical warfare agents and the ways and means to prevent the misuse of toxic chemicals for offensive military purposes. Two of these developments—the evolution of chemical industry, and the renewed interest in “non-lethal” weapons—are directly linked to the CW control regime and its effectiveness. The third one, the impact of the biotechnology revolution on the long-term viability or robustness of the CW control regime, will be discussed in the final section.

EVOLUTION OF THE CHEMICAL INDUSTRY

Two developments in the chemical industry pose particular challenges to the verification of the peaceful applications of toxic chemicals. First, there is a clear trend away from the continuous production of large quantities of a chemical in a facility specifically designed for the purpose. Rather, many companies increasingly rely on the use of smaller, more versatile production facilities, which can be adapted from the production of a batch of one chemical to another one in a short period of time. Such facilities could easily fall through the cracks of the declaration and inspection system of the CWC. Utilization of such batch-production facilities would theoretically enable a potential proliferator to distribute the production of CW precursor chemicals or even chemical warfare agents themselves among a number of such facilities to avoid detection.

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Secondly, over the last decade a considerable number of traditional chemical firms were broken up and replaced by so-called “industrial parks”. This poses a potential problem for verification under the CWC as the convention’s definitions that form the basis for the verification measures assume the existence of plant sites—which were prevalent in the late 1980s when the CWC was negotiated. A good example of this trend is the transformation of the former Hoechst AG near Frankfurt, Germany into an industrial park with more than seventy-five international life-science and chemical companies, employing more than 22,000 people.¹¹ In order to maintain an effective and efficient industry verification system under the CWC, developments like these have to be monitored closely, and the verification procedures have to be adapted to the changed environment. As debates during the First CWC Review Conference, held in 2003, have shown, however, many CWC states parties are not inclined to support such an adaptation. Instead they argue that the OPCW’s industry verification activities should remain unchanged, thereby risking that the regime will become irrelevant due to developments in the chemical industry at some point in the future.¹²

INTEREST IN "NON-LETHAL" WEAPONS

Equally important, renewed interest in so-called "non-lethal" CW threatens to undermine the current control regime and calls into question its future robustness. If there was the need for a wake-up call to raise awareness of this problem, this was most certainly provided by the use of a "fentanyl-derivative"—as it was called by Russian authorities—to end the Moscow theatre hostage crisis in 2002.¹³ However, this incident represents just the tip of the iceberg, as Russia is not the only state interested in utilizing "non-lethal" CW in a number of police and military scenarios other than war. Certainly the US military shows a strong interest in developing this kind of capability.¹⁴

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Even if truly non-lethal CW were technically feasible, is it questionable whether their use would have the effect to merely incapacitate temporarily and not lead to the death of those exposed to the agents. Again, the Moscow theatre scenario offers some insights: Russian security forces obviously had orders to shoot the hostage-takers, which were incapacitated by the gas used in the theatre. Although this might have been the best way to ensure that none of the hostage-takers would be able to detonate their explosives, it reveals a central weakness of the argument of proponents of "non-lethal" CW. These incapacitants are often used in conjunction with lethal military force and in this context act mainly as a force multiplier and not as a life-saving tool. Exactly the same pattern of "non-lethal" CW usage occurred during the Viet Nam War, in which the US military employed 10 million pounds of the irritant CS.

A post-war analysis of the operational use of CS declassified in 1979 could find no report of its use against non-combatants or to save civilians and concluded that "the reduction in casualties has not been in enemy or non-combatant personnel but, rather, friendly troops, as a result of using CS to make other fires more effective."¹⁶

Before the First CWC Review Conference a number of contributions on S&T developments of relevance to the CWC were made by NGOs, including the International Union of Pure and Applied Chemistry, which were then taken up by organs of the OPCW, most notably the SAB, and states parties individually.

In its report to the Review Conference, the SAB noted that *inter alia* it:

was aware of concerns about the development of new riot control agents (RCAs), and other so-called "non-lethal" weapons utilising certain toxic chemicals (such as incapacitants, calmatives, vomiting agents, and the like). ... [B]ased on past experience and the fact that many of these compounds act on the central nervous system, it appears unlikely from a scientific point of view that compounds with a sufficient safety ratio would be found. ...

The SAB stressed the importance that all new toxic chemicals, no matter what their origin or method of synthesis, are covered by the Convention's definition of CW¹⁷

S&T issues did not have a prominent position on the agenda of the Review Conference. However, S&T issues—more specifically the Report of the SAB as submitted to the conference by the Director-General—resurfaced in the Review Document, both in the sections on general verification provisions and on activities not prohibited under the CWC.

Although the topics of “non-lethal” weapons and chemical incapacitants received considerable attention in the run-up to the meeting, discussion on them was almost completely suppressed during the Conference. Two states parties—New Zealand and Switzerland—made explicit reference during the General Debate to the dangers emanating from “non-lethal” weapons to the regime, however the only opportunity to discuss these matters publicly arose at the “Open Forum on the Chemical Weapons Convention”, hosted by the OPCW and supported by a number of NGOs. The Open Forum included a panel discussion entitled “The Chemical Weapons Ban and the Use of Incapacitants in Warfare and Law Enforcement”. Not surprisingly, then, the text of the Review Document did not contain any language explicitly referring to incapacitants or “non-lethal” weapons. However, the document did contain language in relation to the definitions in Article II of the Convention, pointing out that these were found by the conference to adequately cover developments in science and technology.

Turning now to biological weapons, the BWC stipulates in its Article I that:

Each State Party to this Convention undertakes never in any circumstances to develop, produce, stockpile or otherwise acquire or retain:

(1) 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.* [emphasis added]

Like in the case of the CWC, the general purpose criterion not only makes it clear that peaceful uses of the biosciences are legitimate undertakings for states parties to the BWC, but also allows the use of pathogenic organisms or toxins in quantities and for purposes other than use as weapons. However, unlike the CW control regime, there are neither verification provisions foreseen in the BWC nor has an international organization been set up to oversee the implementation of the regime provisions. Due to the collapse in 2001 of the Ad Hoc Group’s efforts to negotiate a legally binding verification protocol to the BWC, which would have provided for these structures and mechanisms, states parties are left to address S&T advances at the BWC review conferences and include their assessment as to relevant S&T developments and their impact on the BW control regime in the final documents issued by these conferences.

At the First BWC Review Conference in 1980 the reaffirmation of the comprehensive scope of Article I merely stated that “The Conference believes that Article I has proved sufficiently comprehensive to have covered recent scientific and technological developments relevant to the Convention.”¹⁸ The brevity of this statement is not surprising as the biotechnology revolution was still in its infancy.

With advances in biotechnology and genetic engineering steadily progressing, the Second Review Conference in 1986 saw the need to be more specific in its Final Declaration by mentioning the fields that states parties were most concerned about being misused. Therefore, the 1986 Final Declaration singled out “the fields of microbiology, genetic engineering and biotechnology, and the possibilities of their use for purposes inconsistent with the objectives and the provisions of the Convention”. It continued that “Article I applies to all such developments” and “that the Convention unequivocally applies to all natural or artificially created microbial or other biological agents or toxins whatever their origin or method of production.”¹⁹

The Final Declaration of the Third Review Conference in 1991 basically repeated that of 1986. States parties at the Fourth Review Conference in 1996, however, felt the need to add to the

previous statement by pointing out that “any application from genome studies” was covered by the BWC’s prohibitions as well.²⁰ Thus, the states parties proved to be very perceptive of future applications of scientific breakthroughs and included genome studies applications well before the human genome was decoded.

The continuous and accelerating progress in various areas of the life sciences between the Fourth and the Fifth Review Conferences was reflected in a number of submissions by states parties to the Fifth Review Conference, held in 2001. As the US statement explained:

Since the 4th Review Conference in 1996, there have been significant advances in the field of biotechnology. ... Of special interest to the BWC are applications in directed molecular evolution (i.e., genetic modification), proteomics, bioinformatics, and vaccinology. The number of countries which are developing and enhancing their biotechnology capabilities continues to grow as the applications continue to expand into commercial sectors²¹

South Africa focused in its contribution “exclusively on developments in terms of biocontrol agents and plant inoculants”,²² thereby reminding states parties that the prohibitions of the BWC apply to biological warfare against plants—and animals, for that matter—as well. Unfortunately, due to the failure to negotiate a Final Document during the Fifth Review Conference, these interpretations by BWC states parties concerning scientific advances of relevance to the BWC have not been recorded in a consensual document.

In sum, the CW control regime in terms of organizational structures and processes is much better equipped to deal with S&T advances that might endanger the effectiveness and robustness of the

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regime than the BW control regime is. However, as the examples of the changes in the chemical industry and the resurgent interest in chemical incapacitants show, when it comes to tackling S&T challenges head on, the willingness of CWC states parties to engage in these issues leaves much to be desired.

The biotechnology revolution and the future of CBW controls

It is commonly assumed that the biotechnology revolution and the increased utilization of genetic engineering will only impact the BW control regime, and not (or only marginally) the CW control regime. Yet what is often overlooked is the fact that many of the products flowing from the biotechnology revolution that can impact life processes at various levels are basically chemical compounds. All chemical compounds that have toxic properties fall under the prohibitions of the CWC. More specifically, the dangers stemming from uncontrolled twenty-first century chemistry are twofold: first, new toxic biochemical compounds, which are highly effective at low dosage levels, could be developed and used as CW. This would undermine the prohibitory norm against CW. The second danger lies in the possible circumvention strategies for the production of known—or novel—CW agents that these new technologies might offer to a determined proliferator. Developments with respect to both of these areas are likely to challenge our current understanding of what is a chemical weapon.

The chemistry of the twenty-first century is a far cry from the one of the 1980s, which guided negotiations for the CWC verification regime. Chemistry now utilizes other scientific disciplines and technologies in its quest for new chemical compounds. Especially in the area of drug development and delivery, scientific and technological advances in biotechnology and genomics, robotics,²³ information technology²⁴ and nanotechnology²⁵ act as enablers of combinatorial chemistry and high throughput screening, which in turn have become the driving forces in pharmaceutical research and development.²⁶

The genomics revolution, in particular progress in functional genomics (the ability to attribute specific functions to a particular gene), furthers our understanding of fundamental life processes at a molecular level. To mention but a few examples, such research is concerned with allergies and immunology, breathing, sleep and depression. Clearly, all of this work is geared towards a better understanding of disease origins at the genetic level in order to treat or cure these diseases. However, the use of a “knock-out gas” in the Moscow theatre crisis serves as a powerful reminder that drugs with perfectly legitimate medical applications might be turned to a different use. Although in the Russian case this use was by state authorities, the spread of technologies and knowledge brings such misuse potential well within the reach of sub-state groups like terrorist organizations.

The biotechnology revolution is producing vast amounts of new data, both in relation to genomes that are sequenced and new chemical compounds that are produced by combinatorial means and have to be screened for their properties and potential as new drugs. According to a conservative estimate,²⁷ more than 1 million such compounds are screened each year in the US alone, 50,000 of which are subsequently eliminated from further consideration because of their toxic properties. Yet developments in this area are progressing rapidly as well: in order to reduce drug development times a new information system called DrugMatrix was developed by three US companies.²⁸ This system contains a 2,000 drug reference set and “models the new entity’s probable effects (biological, toxicological, and clinical)”. The misuse potential of a system that allows for the identification of new chemical compounds according to their toxicity is obvious. As data mining algorithms become more elaborated,²⁹ the potential to identify specific toxic effects of chemical compounds and exploit them for malign purposes will increase.

The technology revolution across the life sciences will not only affect drug development but also drug delivery. As one recent review of the field has outlined, “currently, the most potential is offered by pulmonary delivery, i.e. inhalation of drugs to the deep lung.”³⁰ In order for this to be effective it is necessary to create “drug particles or droplets ... in the range [of] 1–5 microns.”³¹ This is exactly the particle size that was sought in the weaponization of known CW and BW agents, making the dual-use aspects of new discoveries in this realm all too clear. The potential of misuse is compounded by the application of nanoparticles, which could either be used to increase the susceptibility of lung tissue to a CW agent or be directed at specific target tissue in the human body, such as in order to block defence mechanisms.³²

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Similarly, with respect to the BW control regime, S&T developments—such as in the fields of neurology and immunology—are racing ahead.³³ As no control mechanisms exist, the gap between the technologies that should be monitored and controlled and the actual controls being agreed upon and implemented is widening constantly. If this situation persists for much longer it is questionable whether the political will can be mustered to set up a multilateral system of controls that would actually provide warning of a misuse of cutting-edge life-sciences research.

Around the time of the Fifth BWC Review Conference, several developments in the life sciences occurred that many observers saw as opening wide the door for potential misuse. The “contentious research” in question involved:³⁴

- unintentionally potentiating the virulence of the mousepox virus through inserting an IL-4 gene into the mousepox genome;
- synthesis of the poliovirus genome from “chemically synthesized oligonucleotides that were linked together and then transfected into cells”, thereby creating an infectious virus from scratch;³⁵ and

- transfer of the virulence factor of *variola major* (which causes smallpox) into the *vaccinia* virus, which is of much lower virulence and usually used for vaccinations against smallpox.

Concerns expressed over these experiments in the media and policy communities (mostly in the United States) led the US National Academies of Science to establish a committee to investigate ways to prevent S&T advances from being misused for hostile purposes.³⁶ The so-called Fink Committee issued a set of recommendations to address the new environment in which the life sciences are operating and to prevent scientific advances from being misused by states or terrorist groups in BW programmes, while at the same time “enabling legitimate research to be conducted.”³⁷ The Fink Committee’s recommendations included *inter alia* “self-governance by scientists and scientific journals to review publications for their potential national security risks” and the establishment of a National Science Advisory Board for Biodefense (NSABB) “to provide advice, guidance, and leadership for the system of review and oversight ...”.³⁸

With a view to the recommendation concerning restrictions on the publication of problematic research a number of journal editors had already imposed restrictions on themselves before the publication of the Fink Committee’s report: in January 2003 a group of thirty-two journal editors agreed on guidelines related to “Scientific Publication and Security”. After first being published in *Science*, the statement also appeared in February in the *Proceedings of the National Academy of Sciences* and in *Nature*. The authors of the statement:

recognize that the prospect of bioterrorism has raised legitimate concerns about the potential abuse of published research, but also recognize that research in the very same fields will be critical to society in meeting the challenges of defense. ... We recognize that on occasion an editor may conclude that the potential harm of publication outweighs the potential societal benefits. Under such circumstances, the paper should be modified, or not be published.³⁹

The NSABB has been established in the office of the director of the National Institutes of Health.⁴⁰ The NSABB advises on and recommends “specific strategies for the efficient and effective oversight of federally conducted or supported dual-use biological research, taking into consideration both national security concerns and the needs of the research community.”⁴¹ The Board is composed of a maximum of twenty-five voting members whose areas of expertise cover *inter alia* genomics, bacteriology, virology, laboratory biosafety and biosecurity, public health, pharmaceutical production, bioethics, national security, intelligence and law enforcement. In addition, more than a dozen government departments and agencies are ex officio members of the board.⁴²

Although these parallel controls of S&T that are increasingly taking shape in the United States point in the right direction, they face the same shortcomings as do the deliberations by BWC states parties in the so-called new process created by the last BWC Review Conference: both of these attempts

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do not lead to coordinated action at the international level and are thus decoupled from developing the regime as a whole. At the very least these shortcomings would have to be remedied to make a substantial contribution to BW control efforts. Moreover, in the area of CW controls some of these measures would have to be taken on board as well. In order to prevent the misuse of twenty-first century chemistry, CWC implementation cannot continue as if the regime existed in a time warp. Otherwise, S&T advances in chemistry, biology and the life sciences in general can be expected to again leave their mark on military thinking and the history of warfare.

Notes

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3. See F. Aftalion, *op. cit.*, p. 91.
4. On this and the subsequent developments in gas warfare during the First World War see H. Crone, 1992, *Banning Chemical Weapons*, Cambridge, Cambridge University Press, pp. 16–19; SIPRI, 1971, *The Problem of Chemical and Biological Warfare. Volume I: The Rise of CB Weapons*, Stockholm, Almqvist and Wiksell, pp. 26–58.
5. See SIPRI, *op. cit.*, pp. 71–75.
6. See M. Wheelis, 1999, "Biological Warfare Before 1914", in E. Geissler and J. Ellis van Courtland Moon (eds), *Biological and Toxin Weapons: Research, Development and Use from the Middle Ages to 1945*, SIPRI Chemical & Biological Warfare Studies, no. 18, Oxford, Oxford University Press, pp. 8–34.
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8. See J. Tucker, 1999, "Biological Weapons in the Former Soviet Union: An Interview with Dr. Kenneth Alibek", *The Nonproliferation Review*, vol. 6, no. 3 (Spring-Summer), pp. 1–10, quote from p. 2.
9. Also known as the BTWC. See <www.opbw.org> for the convention's text and most review conference documents issued over the thirty-year history of the BWC.
10. See <www.opcw.org> for the CWC's text and other useful related information.
11. See <www.industriepark-hoechst.com/standortfolder_englisch_.pdf>, last accessed 25 November 2003.
12. A. Kelle, 2003, "The CWC after its first review conference: is the glass half full or half empty?", *Disarmament Diplomacy*, no. 71 (June/July), pp. 31–40.
13. See P.E. Wax, C.E. Becker and S.C. Curry, 2003, "Unexpected "Gas" Casualties in Moscow: A Medical Toxicology Perspective", *Annals of Emergency Medicine*, vol. 41, no. 5 (May), pp. 700–705.
14. See the website of the Sunshine Project for documentation of the US non-lethal weapons programmes, at <www.sunshine-project.org>.
15. See SIPRI, *op. cit.*, p.129.
16. Editorial, 2003, "'Non-Lethal' Weapons, the CWC and the BWC", *The CBW Conventions Bulletin*, no. 61 (September), p. 2.
17. OPCW, *Note by the Director-General. Report of the Scientific Advisory Board on Developments in Science and Technology*, document RC-1/DG.2, The Hague, 23 April 2003, p. 15.
18. *Final Declaration of the First Review Conference*, document BWC/CONF.I/10, p. 2, at <www.opbw.org/rev_cons/1rc/docs/final_dec/1RC_Final_Doc.pdf>, last accessed 12 July 2004.
19. *Final Document of the Second Review Conference*, document BWC/CONF.II/13/II, p. 3, at <www.opbw.org/rev_cons/2rc/docs/final_dec/2RC_Final_Doc.pdf>, last accessed 12 July 2004.
20. *Final Document of the Fourth Review Conference*, document BWC/CONF.IV/9, at <www.opbw.org/rev_cons/4rc/docs/final_dec/4RC_final_dec.pdf>, last accessed 12 July 2004.
21. The US submission to the Review Conference, as well as all other national assessments, is contained in *Background Paper on New Scientific and Technological Developments Relevant to the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction*, document BWC/CONF.V/4, pp. 13–22, quote from p. 13, at <www.opbw.org/rev_cons/5rc/docs/rev_con_docs/i_docs/V-04.pdf>.
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27. See M. Wheelis, 2002, op. cit.
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33. See the contributions of Kathryn Nixdorff and Malcolm Dando in this volume.
34. See the summaries of the three cases in National Research Council of the National Academies, Committee on Research Standards and Practices to Prevent the Destructive Application of Biotechnology, 2004, *Biotechnology Research in an Age of Terrorism*, Washington, DC, The National Academies Press, pp. 24–29.
35. *Ibid.*, p. 27.
36. *Ibid.*
37. *Ibid.*, p. 32.
38. *Ibid.*, pp. 4–12.
39. "Statement on Scientific Publication and Security", reprinted in National Research Council of the National Academies, 2004, *Biotechnology Research in an Age of Terrorism*, Washington, DC, The National Academies Press, pp. 98–99.
40. See the NSABB's website at <www.biosecurityboard.gov/>.
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42. *Ibid.*, p. 2.