WEAPONS OF MASS DESTRUCTION

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JEAN PASCAL ZANDERS

Project Leader
SIPRI

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The Threat with Biological and Toxin Weapons
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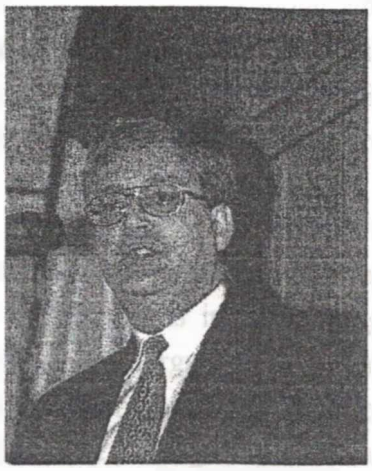

Dr Jean Pascal Zanders (Belgium) is Leader of the SIPRI Chemical and Biological Warfare Project since October 1996 and editor of the SIPRI Chemical & Biological Warfare Studies series. He was previously Research Associate at the Centre for Peace and Security Studies at the Free University of Brussels.

He has published extensively on chemical and biological weapon issues.

He is currently preparing a book on managing dual-use technology transfers in a proliferation environment and a military encyclopaedia volume on chemical and biological weapon armament and disarmament.

Introduction

Biological warfare is the intentional application of disease-causing micro-organisms or other entities that can replicate themselves—such as viruses, infectious nucleic acids and prions—against humans, animals or plants for hostile purposes. It may also involve the use of toxins, which are poisonous substances produced by living organisms, including micro-organisms (e.g., botulinum toxin), plants (e.g., ricin derived from castor beans) and animals (e.g., snake venom). Their synthetically manufactured counterparts are also biological weapons (BW) if they are used for warfare purposes.

Biological agents have the potential to cause mass casualties: on any given day over two billion people are estimated to be seriously ill. One-quarter of all deaths world-wide and about 50 per cent of all deaths in developing countries are attributed to infectious diseases. The World Health Organization estimated in 1999 that each year more than 13 million people die from infectious disease alone.[1] Biological weapons may thus cause casualties of the order of magnitude of a nuclear weapon (although they will not destroy infrastructure). In contrast to nuclear weapons, the number of casualties depends on several factors. Through evolution humans have developed several physiological defences against disease, and, in certain cases, have acquired immunity. However, in societies weakened by war, famine, drought, or other natural disasters, these natural defences may be weakened and people may become more susceptible to certain diseases, which can turn into epidemics. For example, the Spanish Flu, which broke out in war-torn Europe in 1918, ultimately claimed more fatalities world-wide than World War 1.[2]

Today, the principal tool against biological warfare is the 1972 Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction (Biological and Toxin Weapons Convention, BTWC). Since its entry into force in 1975 there have been some confirmed cases of material breaches and several other allegations of biological warfare and BW armament programmes. This has increased the calls to equip the convention with instruments to verify and enforce compliance. To date efforts to strengthen the BTWC by means of a supplementary legally-binding protocol have failed.

Besides its intrinsic weakness, the BTWC is also being challenged by rapid developments in biotechnology and genetic engineering. The convention contains a comprehensive ban on the development, production and possession of BW, and the parties to it have been able to reaffirm the prohibition in the light of the technological developments during the periodic review conferences of the convention.

Biotechnology and genetic engineering hold out many promises to improve the quality of life. At the same time, much of the knowledge can easily be converted for hostile purposes in order to improve the stability and virulence of existing warfare agents or even to create new agents based only on some components of an organism.

This paper summarizes the current status of the prohibitory norm against biological warfare and then discusses the challenges to the BTWC posed by proliferation concerns and technology development.

The norm against biological and toxin weapons

The 1925 Geneva Protocol

The notion of biological weapons was incorporated in an international agreement for the first time in the 1925 Geneva Protocol for the Prohibition of the Use in War of Asphyxiating, Poisonous or Other Gases, and of Bacteriological Methods of Warfare. As of 1 February 2003 there were 133 High Contracting States.

This document, which forms part of the Laws of War, does not address the issue of BW development, production and storage. Its value is also limited by its legal status as a contract among states that have ratified or acceded to it. As a consequence, it does not apply as regards non-parties and any party may consider it null and void as soon as another party breaks its contractual commitments. Several states expressed such an understanding in reservations. However, as a result of the practice of states and a series of resolutions adopted by the United Nations General Assembly since the late 1960s, many legal experts have expressed the opinion that the Geneva Protocol has entered customary international law and is therefore binding on all states irrespective of whether they have joined it or not.

Being a contract among states, the Geneva Protocol regulates state behaviour as regards other states and is therefore not applicable to sub-state entities like ethnic minorities. Nevertheless, through the principle of customary law, the core prohibition of non-use of chemical and biological weapons (CBW) has been extended to all forms of armed hostilities, including civil wars and ethnic conflicts.

The Geneva Protocol was violated several times with regard to chemical warfare (e.g., the 1933-36 war in Abyssinia and the 1980-88 Iran-Iraq war), but there are no confirmed violations with regard to biological warfare. (There are some allegations.)

At a minimum the Geneva Protocol has maintained the moral revulsion against the use of poison and disease as a method of warfare. Consequently, proponents of CBW armament programmes always faced the extra hurdles of justifying and convincing the military and the public of their necessity.

The 1972 Biological and Toxin Weapons Convention

At the heart of the current regime against BW is the BTWC. It was opened for signature on 10 April 1972 and entered into force on 26 March 1975. As of 1 February 2003, 147 states have ratified or acceded to the BTWC and another 17 have signed, but not ratified the convention.

By current standards the BTWC is a weak treaty because it lacks verification and enforcement mechanisms. Such mechanisms were envisaged in the original British draft treaties, but they were dropped in bilateral negotiations between the Soviet Union and the USA. A speedy conclusion of the BTWC discussions cleared the way to finalize the bilateral Strategic Arms Limitation Talks (SALT) in May 1972, which both countries viewed as of far greater importance to their respective national interests.[3] The absence of verification measures was highlighted in 1979 by the outbreak of anthrax near Sverdlovsk (now Yekaterinburg), which the West persistently attributed to a prohibited Soviet military BW programme, and by claims by the US Government that Soviet client states were waging biological warfare in South-East Asia (the so-called 'yellow rain' allegations). In 1992 President Boris Yeltsin all but acknowledged that the former Soviet Union, despite being a co-depository of the BTWC, had continued an offensive BW programme. Following the 1990-91 Gulf war, the United Nations Special Commission on Iraq (UNSCOM) uncovered an extensive Iraqi offensive BW programme. These findings proved the reality of BW proliferation. The March 1995 nerve agent attacks in the Tokyo underground and the subsequent realization that the religious sect responsible for them was also seeking BW have heightened awareness of proliferation to sub-state actors. The as yet unresolved case of the mail-delivered anthrax spores following the terrorist attacks of 11 September 2001 in the United States have underscored the fears of BW terrorism.

Despite its intrinsic weaknesses the BTWC has been able to retain its relevance through the periodic review conferences, during which the parties interpret the treaty provisions in the light of political and technological developments or try to devise mechanisms to enhance confidence in the treaty regime. In particular, the review process has reaffirmed the applicability of the core prohibition of Article I to the rapid developments and discoveries in the field of biotechnology.

The review conferences have also attempted to increase the transparency of activities relevant to the convention on a voluntary basis. During the Second Review Conference in 1986 the states parties agreed on annual data exchanges to serve as confidence-building measures (CBMs). However, participation in these confidence and transparency-building measures has been limited and is not systematic in most cases. In addition, the parties are only required to provide their declarations in one of the six UN languages and no organization has been designated to administrate, translate, distribute or analyse the submissions.

Despite its inherent weaknesses the BTWC encompasses a comprehensive prohibition of preparation for biological warfare. According to Article I, states parties cannot acquire or retain BW under any circumstances. The Fourth Review Conference of States Parties, held in 1996, formally expanded the interpretation of this article to cover BW use. The prohibition is reinforced by the requirement in Article II to destroy or divert all BW to peaceful uses and by the non-proliferation provision of Article III. However, the value of these articles is limited by the absence of verification instruments.

The BTWC contains some tools to deal with compliance concerns. Under Article V parties may consult and cooperate with each other to resolve an issue or may undertake to resolve the concern through appropriate international procedures within the framework of the United Nations and in accordance with its Charter. The Third Review Conference (1991) adopted a procedure strengthening Article V, whereby bilateral or other consultations among the states involved in a dispute must precede the formal consultative meeting. The depositories of the BTWC must convene such a formal consultative meeting within 60 days following the receipt of the request to hold such a meeting.[4] Any compliance concerns that cannot be resolved through consultation and co-operation may be referred to the UN Security Council, in accordance with the provisions of Article VI. In such a case, the BTWC parties are enjoined to co-operate with the Security Council during its investigation. The results of the investigation are to be conveyed to all BTWC parties. No party has ever lodged a complaint of a suspected violation of the BTWC with the UN Security Council.

Another cornerstone of the BTWC is Article X, which gives the parties the right to participate in the fullest possible exchange of equipment, materials, and scientific and technological information of relevance to the convention for peaceful purposes and encourages the parties to facilitate such exchanges. The article also orders states parties to implement the BTWC in such a way that it avoids hampering the economic or technological development of state parties. The implementation of Article X has

become more contentious as biotechnology plays an increasingly dominant role in economic and societal development but may also make it easier for a state to acquire an offensive biological warfare capability (e.g., in terms of a surge production capability for BW) or to develop novel types of agents. The export controls imposed by a number of industrialized states to prevent BW proliferation (which are co-ordinated in an informal arrangement, the Australia Group[5]) are viewed by some developing countries as discriminatory and a violation of the obligation not to hamper their economic or technological development. The issue has become so polarized that it is one of the main obstacles to strengthening the BTWC regime.

The question of verification and compliance enforcement has still not been resolved. A weak proposal for a monitoring regime, which was being negotiated by an Ad Hoc Group of states parties to the BTWC,[6] was rejected by the United States in the summer of 2001 because it would negatively affect its national interests. The 5th Review Conference, which had originally been scheduled between 19 November-7 December 2001, was hastily adjourned until November 2002 following a last minute surprise move by the United States to terminate the negotiation mandate of the Ad Hoc Group.[7] In 2002, the 5th Review Conference did not finalize its review of the operation of the BTWC, but instead adopted a proposal calling for a 6th Review Conference to be held no later than in 2006 and meanwhile to hold three annual meetings, which will be preceded by expert group meetings. The mandate of the groups is limited and all decisions are to be taken by consensus.[8] At present the efforts to strengthen the BTWC through a supplementary legally-binding document have stalled.

The 1993 Chemical Weapons Convention

As noted in the introduction, biological warfare can also involve the use of toxins—the poisons produced by living organisms. Their use, acquisition and stockpiling are also prohibited under the Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on Their Destruction (Chemical Weapons Convention, CWC). As of 1 February 2003, 148 states have become party to the CWC, while a further 26 have signed, but not ratified it.

Saxitoxin and ricin, which are specifically listed in the Annex on Chemicals of the CWC, are the subject of stringent controls regarding their transfer and production. All other toxins fall under the general prohibitions of the convention.

Challenges to the BTWC regime: proliferation concerns

After World War 2 the Soviet Union and the United States (and to a lesser extent the United Kingdom) were the principal states continuing research, development and production of offensive BW. The USA formally halted its programme in 1969 and proceeded to destroy existing BW stockpiles. This unilateral gesture helped to pave the way for the BTWC. The Soviet Union, however, did not reciprocate and even accelerated its BW armament despite the fact that it was one of the three co-depositories of the BTWC (the other two being the UK and the USA). The programme survived the 1991 break-up of the Soviet Union essentially intact, and, despite assurances by the Russian leadership, there remain considerable doubts as to whether Russia has terminated all of the activities prohibited under the BTWC. Most second-tier powers in Europe gradually abandoned their offensive BW programmes as they joined military alliances—the North Atlantic Treaty Organization (NATO) and the Warsaw Treaty Organization (WTO)—and relied on the respective nuclear deterrents for their security. Nevertheless, many countries continue to work on biological defence, protection and prophylaxis. These activities are expressly permitted by the BTWC.

Few countries other than those that had begun BW-related investigations before World War 2 are known to have started new biological warfare programmes. However, several of these countries are located in the highly volatile Middle East. Concerns about such activities were significantly heightened in the 1990s. After the 1990–91 Gulf War, international inspections by UNSCOM revealed the advanced and extensive nature of Iraq's BW programmes. The international community remains perplexed by Iraq's efforts to retain its biological warfare capability and its preparedness to forfeit millions of dollars in oil revenue under UN-imposed sanctions as a consequence.

The mix of countries with a chemical or biological warfare programme changes continuously and it is difficult to make firm statements about which countries possess such weapons. Claims of proliferation may refer to a past programme or an allegation of use made decades ago. Since the terrorist attacks of 11 September 2001 there has been a narrowing of the focus on a few countries that are considered to be of extreme proliferation concern, support terrorism, and are generally hostile to Western interests. The attempts to isolate them from the rest of the international community is reflected by the use of terms such as 'rogue states' or 'axis of evil'. Nevertheless, US sources place a limited group of countries in a core list of suspected BW proliferators. According to recent US Department of Defense (DOD) reports, seven countries have a BW programme: China, India, Iran, Iraq, North Korea, Pakistan and Russia.[9] Nevertheless, some countries are conspicuously absent. Egypt, Israel, South Korea and Taiwan are not

included although they are named in the August 1993 Office of Technology Assessment report Proliferation of Weapons of Mass Destruction: Assessing the Risks.[10] In 1999 the US Central Intelligence Agency (CIA) and the now defunct Arms Control and Disarmament Agency (ACDA) claimed that up to 12 countries are pursuing offensive BW programmes, including China, Egypt, Iran, Iraq, Libya, Russia, and Syria.[11] In the opening plenary session of the Fifth Review Conference of the BTWC on 19 November 2001 the USA publicly accused Iran, Iraq, North Korea, Libya, Sudan and Syria of having offensive BW programmes. It also stated that there were several other proliferators but refused to name them.[12]

There is greater uncertainty about whether the programmes are offensive or defensive or about their level of sophistication. It is also unclear at what point a country should be considered a BW proliferator. The criteria to be considered include: if it has the scientific, technological and industrial base to support a BW programme; if it has an R&D programme, if it produces BW; if it stockpiles them, if it deploys BW with the armed forces; or if there is clear evidence that BW have been assimilated into military doctrine. The criteria by which a state is judged may differ from country to country. Moreover, a country which has an antagonistic relationship with the state making the intelligence assessment is at greater risk of being deemed a proliferator than one which enjoys a friendly relationship. The perceived intent of a state is a major subjective component in the threat assessment. Thus the 1997 US DOD report said that Libya lacked the scientific and technical base for a BW programme and that Syria was believed to possess the biotechnical infrastructure to support a BW programme.[13] According to the CIA and ACDA reports North Korea may be able to wage biological warfare, Sudan may be interested in BW, and there is insufficient evidence to determine whether Taiwan is developing activities prohibited under the BTWC.[14] The variations in the lists indicate the uncertainties involved in naming suspected BW proliferators. Determining the status of the BW programme for an individual proliferant state is even more complicated for an outside analyst: the descriptions range from 'possessing the biotechnical infrastructure', 'various stages of development' and 'in the process of seeking such a capability' to having 'an offensive BW capability'.

Continuing concerns about Russia

Doubts about the termination of Russia's BW programme, as decreed by then President Boris Yeltsin in April 1992, persist. Factors that may contribute to a continuation of the offensive BW programme include institutional and bureaucratic interests, the enduring social and economic crisis, a further deterioration of relations with the West and with Russia's neighbours, a continuing focus on the re-establishment of Russia's status as a superpower, and the prospect of an inefficient protocol to the BTWC (whose negotiation is now suspended).[15]

The dire social and professional conditions in which the former Russian BW specialists currently live significantly increase the risk of a 'brain drain' to countries that may be interested in acquiring BW. Since Yeltsin's 1992 decree the BW-related establishments have laid off large numbers of personnel, while the remaining staff work under Spartan conditions and often go without pay for long periods.[16] The feared mass exodus of BW scientists and technicians does not appear to have materialized, although some BW specialists are known to have sought contracts abroad.[17] Russia has nevertheless tried to prevent proliferation with new legislation. In January 1998 then Prime Minister Viktor Chernomyrdin issued a directive, which prohibits Russians from engaging in foreign economic activities concerning goods and services potentially applicable for nuclear, biological and chemical (NBC) weapons or missile delivery systems.[18] In May 1998 the Russian Federal Currency and Export Control Service issued a procedural explanation of the functioning of the export control system created by the federal directive. Today, President Putin may be prepared to bring Russia within full compliance of the BTWC and allow a greater degree of transparency regarding activities of relevance to the convention, although the question of transparency into the activities in the former BW-related establishments remains.

At the heart of the concern about Russia's compliance with the convention is that there is no verification or monitoring of activities in the former BW facilities. After having confronted Russia with detailed evidence of its prohibited BW programmes the United States, the United Kingdom and Russia agreed in September 1992 to reciprocal visits to respective BTWC-relevant facilities.[19] The trilateral verification and transparency exercises soon faltered and the lack of any access to some key facilities has increased international suspicion of Russian non-compliance. Meanwhile the Russians closed some key facilities to foreign researchers, and in August and September 2002 a US Congressional delegation was refused access to one of the former Soviet BW facilities, despite the fact that the United States is providing Russia with millions of dollars to increase security and retrain the Soviet scientists.[20]

The Iraqi conundrum

After the 1991 Gulf War the United Nations Security Council (UNSC) adopted Resolution 687 on 3 April 1991, which among other things created UNSCOM. This body had two basic functions: to inspect and oversee the destruction or elimination of Iraq's CBW and ballistic missile capabilities; and to monitor Iraq over the longer term to ensure its continued compliance with the obligations of Resolution 687.[21] In 1999 UNSCOM was disbanded following a period in which Iraq systematically obstructed UNSCOM inspections and exploited the political disagreement among the permanent members of the UN Security Council to its advantage. On 17 December 1999 the Security Council adopted Resolution 1284 which replaced UNSCOM with the United Nations Monitoring, Verification and Inspection Commission (UNMOVIC).[22] In November 2002 weapons inspections of Iraq resumed, after UNSC Resolution 1441 gave UNMOVIC a strengthened mandate.[23]

The accounting of Iraq's BW-related activities remains incomplete. Within its first year of operations UNSCOM found evidence that Iraq's initial declarations about a small BW research programme were incorrect and incomplete. It continued to uncover details, but it was not until Iraq was forced to admit that it had an offensive BW programme, which included the production of biological warfare agents, in July 1995 and the defection of Lieutenant General Hussein Kamal the next month that the extent of the Iraqi BW programme was fully appreciated. The Iraqi concealment efforts nonetheless continued. In 1998 further evidence was found that Iraq had weaponized biological warfare agents, including the filling of warheads for the Scud ballistic missile.[24]

The UNSCOM experience revealed two troubling issues with respect to the future BTWC regime. First, the UN Security Council proved to be unable or unwilling to deal with Iraq's systematic violations of its own resolutions because some members succumbed to short-term interests. As few cases will be as clear-cut as that of Iraq, this raised serious doubts about the ability or willingness of the UN Security Council to uphold fundamental norms in the name of the international community when confronted by a determined and persistent violator. For major disarmament treaties, such as the BTWC and CWC, the Security Council is the ultimate arbiter in the case of material breaches. UNSC Resolution 1441 offers opportunities to re-establish its authority in this respect.

Second, under UN Security Council Resolution 687 Iraq was forced to become a state party to the BTWC. States normally voluntarily engage in an international agreement and the legal consequences of this move have not yet been the subject of much learned debate. Nevertheless, since 1991 one state party is in continuous material breach of the BTWC. This material breach does not concern as much the presence of a BW programme before the Gulf War (which under the 1969 Vienna Convention on the Law of Treaties Iraq should not have had as a signatory state to the BTWC), as it does Iraq's persistent concealment efforts and the concomitant refusal to destroy all its BW and related installations and equipment after becoming a full party to the BTWC. None of the other states parties have taken up this condition in order to restore treaty compliance under Article VI of the BTWC (which allows a state party to lodge a complaint with the UN Security Council) or through the procedure of convening a formal consultative meeting of states parties under Article V.[25]
They probably felt that the UN Security Council was already addressing the issue through UNSCOM, and now through UNMOVIC. The fact that Iraq remains in material breach of the BTWC has still not been formally addressed in the context of the BTWC.

As of 1 February 2003, Iraq still has not provided UNMOVIC with further details of its present or past BW programmes, its BW stockpiles and the destruction of these stockpiles if such actions were indeed undertaken. The lack of such evidence and the unwillingness to co-operate with the UNMOVIC inspectors carries the risk that the UN Security Council will find Iraq in material breach of its obligations under Resolution 1441, which could lead to military action under US leadership.[26]

Sub-state proliferation threats

In 1994 and 1995 the Japanese religious cult Aum Shinrikyo carried out two attacks with the nerve agent sarin. Police investigations into the cult's activities showed that it had also been investigating pathogens and toxins and had attempted several times to release them, apparently with no effect. As a consequence of these events, the threat projections of terrorism with CBW were no longer hypothetical scenarios. Since then most studies have focussed on the potential consequences of such future attacks: relatively small amounts of chemical or biological warfare agents are claimed to be able to produce huge numbers of casualties—according to some estimates, hundreds of thousands. However, the reasons why the Aum Shinrikyo sarin attacks produced relatively few casualties, why the cult was unable to produce a viable biological warfare agent or why such events did not occur earlier are currently not or only unsatisfactorily explained.

Theoretically, some military-grade agents can produce large numbers of fatalities and casualties. The processes for manufacturing and disseminating the most lethal and complex biological warfare agents in sufficient quantities to obtain such effects are nonetheless complex. Despite large investments, Aum Shinrikyo's BW programme experienced considerable problems. Three factors in particular contributed to this outcome. First, some of the people in charge of the programme may have been bright and skilled university graduates, but the support staff in the laboratories consisted of unskilled cult members who had been selected on the basis of their loyalty in order to reduce the risk of information leaks. Their inexperience negatively affected the quality of the research and development. Second, the cult lacked functional specialization: the people responsible for the research on the pathogens and toxins were also responsible for designing the laboratories and dissemination devices and were in charge of the agent production, the preparation and execution of the terrorist operations in Tokyo, and so on. No single person can combine all these qualifications.
Third, the programme was dependent on external sources of supply, and it had to be conducted in secrecy because, unlike a state seeking BW, a terrorist organization does not enjoy freedom from prosecution. These factors, taken together, considerably complicate the acquisition of such weaponry.[27]

A scenario published in the SIPRI Yearbook 2000 describes how a cult disseminates anthrax over a busy shopping centre. The agent is of a type and quantity similar to that which was accidentally released from a military microbiology facility in Sverdlovsk in 1979.[28] Given realistic conditions, about 20–30,000 persons could be exposed to the cloud of spores. However, only around 300 people concentrated in a relatively narrow area would be infected but not necessarily killed. This contrasts with the many predictions that such use would result in mass casualties over large areas.[29] In reality, such an incident would nevertheless place a heavy burden on the authorities in terms of medical response and decontamination. Yet, if they were prepared to treat the approximately 30,000 exposed people with antibiotics within a few days after the incident the consequences would be limited. Without any medical treatment most of the 300 infected people would die. Different environmental conditions (e.g., in a large sports stadium an estimated 1500 out of 30000 people present would acquire an infective dose) or the choice of a highly contagious agent would place different strains on the response services.

Letters containing anthrax spores were delivered to members of the US Congress and the US media in the aftermath of the terrorist attacks of 11 September 2001, killing five people and infecting a further 17. The fine quality of the spores suggests that a military laboratory—most likely located inside the USA—was used in their preparation,

but until today the perpetrator or perpetrators have not been found. The incidents demonstrated how people who were not normally considered as being at risk from a biological terrorist attack (postal workers, secretaries and members of the public) became the first victims and how such types of attack may close down facilities despite the low number of casualties. The extensive and costly clean-up operations were also hampered by the lack of consensus about what constitutes a safe environment following decontamination. Military standards to ensure the continuation of operations on the battlefield cannot be applied in a civilian setting.[30]

The mail-delivered anthrax spores demonstrated the potential of such attacks for widespread social and economic disruption. Earlier preoccupation with terrorism involving CBW focussed on the potential to cause large numbers of casualties. The probability of such events occurring remains low, because of the technological challenges involved in the development, manufacture and dissemination of CB agents, and the demands these challenges place on the organizational structure of the terrorist entity. However, beyond causing human casualties, acts of terrorism can be directed at generating economic sabotage or disruption. Agricultural terrorism comes easily within reach of single-issue groups, criminals and less-structured organizations. Biological agents arguably offer the prospect of large-scale economic disruption as they can be used to infect livestock or destroy crops. Given the time needed for an animal or plant disease to develop the attack will invariably stretch over a prolonged period of time and the demand for containment, remediation and compensation will draw in authorities ranging from the local to the national levels of governance. The economic damage will not be limited to the destruction of produce, but will also affect other enterprises that depend on agricultural activities and international trade. Countries, regions or communities that depend on monocultures for their livelihood are particularly at risk.

Governments face a multitude of biological terrorism threats, but the most catastrophic scenarios involving mass casualties, though possible, are not likely to occur. (Catastrophic scenarios involving non-conventional weapons, which feature in many policy debates, are often made plausible by insistence on the existence of a threat posed by state-sponsored terrorism.) Nevertheless, because of the potential consequences for the targeted society of a terrorist attack with BW, governments must be prepared for such an attack. The key issue is thus to devise and execute balanced policies. Overreaction can lead to countrywide anxiety and paranoia. In such an atmosphere, hoaxes may become as efficient—especially in terms of economic terrorism—as actual attacks with BW.

Challenges to the BTWC regime: technology developments

Biological warfare is closely correlated to the knowledge of diseases. Until the end of the 19th century biological weapons as thought of today were inconceivable because the propagation of disease was not understood. Consequently, there were no carriers (vectors) to manipulate. Nevertheless, despite the fact that people may have had certain (erroneous) understandings of disease and its causes, they were able to exploit these understandings to their advantage in armed conflict. In antiquity, for example, it was widely believed that outbreaks of disease were caused by bad odours emanating from the soil. This insight was in some cases applied to draw the enemy into areas known to be particularly infectious in certain seasons. Thucydides, for example, relates how the Athenians were forced to break their siege of Syracuse on Sicily after having suffered virulent epidemics during two consecutive summers. The Syracusians had reportedly succeeded in drawing the Athenians into the nearby disease-ridden marshes during the summer and autumn using the ruse of negotiating their surrender. The defenders likely knew when they had to avoid the marshes.[31]

Until the early 20th century armies habitually lost more personnel to disease than to combat. The knowledge that disease can ravage even strong armed forces contributed to the practice of dumping animal carcasses in water supplies and the catapulting of corpses into besieged cities. These practices were fairly widespread during antiquity, the Middle Ages and the Renaissance. It has been suggested that the 14th century plague epidemic in Europe was caused in this way, after Mongol forces had catapulted plague-infested cadavers into the Genoese city of Caffa (now Fedosia) in the Crimea in 1346.[32] (Recent investigations question this account of events or even whether the so-called 'black death' was in fact plague.) During the 1861-65 US Civil War dead animals were still used to pollute drinking water.[33]

In the 18th century there was a growing understanding of disease as an unhealthy condition of the body. The causes of disease and many forms of propagation remained obscure, but the understanding led to the conscious manipulation of disease to attack opposing forces in the knowledge that one's own troops were less likely to suffer the same consequences. There are several reports of the deliberate use of smallpox and other diseases as a means of warfare during the wars in North America.[34] This new understanding of disease also contributed significantly to health protection. Disease prevention took an important qualitative step with the development of a smallpox vaccine in 1798. Health protection became a major factor in winning military campaigns.[35]

By 1914 microbiology had advanced considerably: major bacterial diseases had been isolated and cultivated; the existence of viral diseases had been discovered (although the pathogens were not yet well understood); and parasitic diseases were being studied. There was an improved understanding of disease transmission, which contributed to better prophylaxis, prevention and countermeasures. German agents in the United States applied the new insights and techniques for hostile purposes in World War 1, although the sabotage operations were not directed against humans.[36] (There were some other Allied allegations, but the available evidence is inconclusive.) During the period between the two world wars the first apprehensions of BW programmes were expressed. The better understanding of disease transmission in the 1920s and 1930s and the experience of the Spanish Flu epidemic at the end of World War 1 increased concern about biological warfare. (This concern was already reflected in the Geneva Protocol.) Based on faulty intelligence and fear of vulnerability, several countries—including France, Germany and the United Kingdom—began to consider the feasibility of biological warfare and the suitability of certain pathogens for weaponization.[37] In World War 2 only Japan actually released pathogens in military operations and had an extensive research and development programme based on human experiments.[38] Several other belligerents embarked on huge offensive and defensive BW programmes, which they would continue to varying degrees during the cold war. The Western countries eventually halted their offensive BW programmes through unilateral decisions or as a result of their adherence to the BTWC; the former Soviet Union expanded its BW programmes despite being a co-depository of the BTWC.

However, even before the BTWC entered into force in 1975 scientific breakthroughs began to challenge the disarmament regime.[39] In 1973 the first gene was cloned; three years later the first company to exploit technology based on rDNA was founded in the USA. In a move that stimulated biotechnology to become a major determinant of industrial development and would have a major impact on the creation of a verification regime for the BTWC, the US Supreme Court ruled in 1980 that micro-organisms may be patented.[40] That same year the first patent for the construction of rDNA was awarded; by the end of 1981, more than 80 biotechnology companies had been established world-wide. In 1982 the first animal vaccine and pharmaceutical product—human insulin—based on rDNA technology was approved for use in Europe and the USA. Since then, the number of companies and the range of technologies being explored and applied have increased dramatically.

The revolution has continued along two main lines: genomics and proteomics. Rapid DNA sequencing technology laid the foundation for genomics. The genome is the totality of the genetic material of an individual organism. Each cell holds a complete copy of the genome. It consists of chromosomes, which contain genes that are made of the chemical DNA. In genomics information is extracted from the complete DNA sequences of organisms and then analysed and catalogued.[41]

Proteomics systematically analyses the protein expression of healthy and diseased tissues. The proteome is the complete profile of proteins expressed in a given tissue, cell or biological system at a given time.[42] Proteins are any of a very large group of complex combinations of amino acids. They are basic constituents of any living organism and are necessary for the chemical processes in them. Genome sequencing projects are providing insights into the amino acid sequences, although full knowledge of their structure and processes is still required to understand the biological role of proteins.[43] This will, in turn, improve the understanding of disease. Protein therapy will probably play an important part in the future treatment of diseases. Because protein therapy can specifically target diseased cells or tissue, the destruction of healthy cells or tissue can be prevented.

Together, genomics and proteomics represent powerful experimental and modelling techniques that enable the modification of living organisms and their products in precise and predictable ways. They also enable small molecules to be designed to interact in specific ways with proteins in order to predictably alter their functioning.[44]

Potential application of biotechnology to biological warfare

The core of the future biological warfare threat will probably not consist of large weapon stockpiles. It will more likely be made up of the capability to produce warfare agents (and their antidotes or prophylaxis) on a large scale in a short time frame in a crisis. Biotechnology may improve biological warfare capabilities through product and process improvements. Product improvements may involve the genetic modification of pathogens or the creation of novel agents, as well as the development of new equipment for analysis and production. Process improvements relate to the way in which the agents are manufactured. Optimization of production processes, for instance, can lead larger production batches in shorter time frames or to the use of smaller, less conspicuous equipment (such as fermentors), which would make it easier to hide the BW programme in legitimate activities and installations. Examples of activities include:[45]

- Existing pathogens could be modified by genetic engineering to make them more virulent or more resistant to known drugs, vaccines and therapies; to make their effects more predictable and controllable; or to make them more resistant to environmental stresses (e.g., UV rays in sunlight, meteorological conditions, shock after the explosion of the munition) after their release into the atmosphere.
- The large-scale production of certain agents (especially toxins) that were previously difficult to acquire would be possible. In particular, micro-organisms could be genetically altered to produce toxins or bioregulators.
- Modification of antigenic properties can lead to the evasion of the immune defence mechanism of an organism. This could also make detection and identification of the agent by immunological diagnostic tests more difficult, if not impossible.
- Genomic information could be exploited for the specific targeting of certain genetic properties of an organism using, for example, techniques of gene therapy.

R&D in biotechnology leads to many 'enabling technologies', which lay the foundation for future product and process improvements. Of particular importance today are the automation of sequencing in genome projects; bioinformatics, which contributes greatly to the storage and analysis of research data; and the advances in combinational chemistry and high throughput screening of compounds.

Many of these products and processes are being researched and developed for civilian application in medicine, pharmaceuticals, and agriculture, as well as for purposes that are legitimate under the BTWC, such as defence, detection, protection and

prophylaxis. However, their investigation also generates considerable knowledge about the potential offensive use of certain substances to interfere with the biological processes in humans, animals and plants. In certain cases, the offensive properties of known or potential biological warfare agents are being actively investigated in order to develop adequate defensive technologies and procedures. Such activities raise the question whether they are permissible under the BTWC. The question may be difficult to answer, because it ultimately depends on the intentions of the state conduction such research and development programmes. Transparency may be the key as greater secrecy will make the international community less inclined to accept the benign purpose of these programmes.

Preventing the misuse of biotechnology for prohibited purposes

Strengthening the BTWC regime

The characteristics of the technologies relevant to the BTWC pose a significant challenge to the convention and its future verification and monitoring regime. In the post-cold war era with its increased attention on proliferation the concept of verification needs to be expanded, if not reconsidered. Depending on the type of treaty, verification mechanisms are tailored to certify the absence or presence of treaty-controlled items and their destruction, if required. Other verification mechanisms can be included to monitor the use or consumption of certain goods that may pose a threat to the treaty objectives. Under a future BTWC regime, verification will have to focus on keeping technology transfers as transparent as possible (and thereby contribute to the building of confidence). Only minute amounts of pathogens, genetic materials or other cell components are needed to start R&D and production of BW. Therefore, it is highly unlikely that a mechanism of accounting of material balances, like the one used under the nuclear safeguards system, can be adapted to monitor BTWC-relevant transfers. (The model already proves to be problematic under the CWC.[46])

Proliferation studies principally focus on the transfer patterns of tangible objects, such as agents and equipment, and the threat of the immediate realization of the dual-use potential of these objects, whereby the recipient countries (or sub-state actors) of concern acquire technology developed for civilian use and apply it instantly for the purpose of acquiring BW. Yet, at the core of the biotechnological revolution is information: data collection and processing, knowledge, techniques and skills. This information core permeates the society in which the development takes place. However, with today's globalization and growing interdependence it inevitably diffuses across national borders. While lateral proliferation processes are undeniably taking

place, the greatest challenge to the future BTWC regime may actually come from a sudden massive application of civilian biotechnology for the purpose of acquiring a biological warfare capability by a state party facing a security threat.

If a future verification regime of the BTWC is to remain relevant for many decades, it will require mechanisms to deal with the possibility of instant realization of the dual-use potential of biotechnology. In addition to the traditional verification and monitoring of the destruction and non-production of BW in states parties, it will have to incorporate an understanding of biotechnology and technology transfer processes that goes beyond mere products (agents, production equipment, etc.). The aim of this new set of tools is to render transparent technology transfers between economic units (e.g., individuals, laboratories, companies, etc.) within a state party and between economic units across national boundaries (including states and transnational companies and organizations). All economic units involved in a transaction will share the responsibility of ensuring that the dual-use potential of the technologies is not realized. The explicit commitment by the economic unit, whether a supplier or a recipient, to uphold this responsibility will then become a key component for granting the transfer license. The principle also applies to scientific and student exchanges as in-depth background knowledge will enhance the transparency about the institute's and the individual's activities. The national authorities and the international organization to be set up under a future legally-binding instrument will monitor the transparency of all relevant technology transfers. This mechanism of shared responsibilities between suppliers and recipients can facilitate assistance to countries such as Russia as confidence in the compliance with the BTWC will grow, while making it much harder for future Iraq or representatives of terrorist organizations to acquire the BW-relevant technologies.

This set of tools will nonetheless have to be supplemented with extensive positive security guarantees in order to reduce the disproportionate military advantage a state party might gain from defecting from the treaty. These guarantees do not solely entail the right of access to assistance and protection (subject to the transparency conditions mentioned above), but also involve dynamic decision-making procedures in order to be able to respond swiftly and decisively in the case of a rapidly developing crisis. If adequately implemented, the mechanisms to enhance the transparency of technology transfers may be able to provide sufficient advance warning of an impending massive transfer of civilian technology for prohibited purposes.

Addressing the threat of terrorism with biological agents

Given the uncertainties and the wide range of plausible scenarios of terrorism with biological agents, it may be opportune to identify generic and cost-effective countermeasures, which can also contribute to a society's overall health and safety standards. Among such measures are investments in the health infrastructure so that there is a good regional distribution of emergency wards and a spare capacity of beds. It may be sound policy to fund the establishment of an adequate number of specialized laboratories in geographically distributed hospitals for rapid identification of rare pathogens in order to be able to rapidly give first responders and other emergency personnel information about the nature of the infection. Annual refresher and training courses for doctors and other medical staff can be used to familiarize them with unusual diseases in order to improve their ability for rapid and accurate diagnoses. Other important investments are in areas of compatible communications technologies for the different emergency services and adequate field detection and diagnostic equipment for the civil emergency units, and the creation of sufficient supplies of medication and equipment. Recurring realistic exercises must be conducted in order to test and improve procedures and equipment.

Legal and political instruments developed and implemented before an act of biological terrorism takes place make up a second group of generic, cost-effective measures. In particular, anti-terrorism provisions in national criminal law ought to be based on the general purpose criterion (GPC) of the BTWC and the CWC (with regard to toxins, but also with regard to any other toxic substance). The GPC basically holds that any manipulation or possession of pathogens, toxins and poisonous substances for purposes that are not explicitly permitted by either convention is prohibited. The incorporation of the GPC in national legislation (whether as part of laws to make the prohibitions in the international conventions applicable to natural and legal persons on the territory or under the jurisdiction of a state party or as part of criminal law) enables law enforcement authorities to apprehend terrorists or criminals before they have committed their act on the grounds that their possession of agents or equipment cannot be justified under the terms of the BTWC and the CWC. Ideally states co-ordinate their legislation with each other, especially in the framework of political, economic or security regional arrangements, so that terrorists cannot exploit the legal weaknesses of one country to prepare their attacks against targets in another country. Through international co-operation under the BTWC and the CWC programmes can be set up to assist parties to the conventions in drafting adequate national legislation if they request so.

For the civilian authorities it is equally important to realize that the military standards for chemical and biological decontamination differ fundamentally from those required in a civilian setting. Military standards for decontamination are governed by operational necessity on the battlefield and under certain circumstances military commanders have to accept chemical or biological casualties. There is no such tolerance for casualties in civil society. However, if the civilian standards are set at unnecessarily low levels or, worse, no commonly accepted levels have been adopted, then the normalization of activities will be considerably delayed and cause more social disruption and economic losses than the actual terrorist attack.

It is possible for governments and public authorities to take wide-ranging preventive measures against biological terrorism without resorting to mass mobilization of national resources as if the country is waging total war. Such measures are generic and cost-effective. Moreover, they are no dead investments. Society as a whole will benefit greatly from the improvements in the health and emergency infrastructure and emergency procedures. These can all be applied in the event of natural disasters or major industrial accidents (although certain aspects will necessarily be specific to biological terrorism). However, it is important for the governments and public authorities to realize that counter- and preventive measures must be taken before a biological terrorist incident occurs and that such preparations take several years before achieving maximal effectiveness. Here is a clear and present responsibility of parliaments and governments.

Notes

[1] World Health Organization, *Removing Obstacles to Healthy Development*, WHO document WHO/CDS/99.1 (WHO: Geneva, 1999), URL <http://www.who.int/infectious-disease-report/pages/ch1text.html#TopAnchor>.

[2] World Health Organization, *Health Aspects of Biological and Chemical Weapons*, Unofficial draft report, Geneva, 17 August 2001, p. 8. (This report was released by the WHO following the terrorist strikes of 11 September 2001 and the fear of follow-on attacks with chemical or biological weapons.)

[3] Sims, Nicholas A., 'Four decades of missed opportunities to strengthen the BWC: 2001 too?, *Disarmament Diplomacy*, no. 58, June 2001, p. 15.

[4] Final Document of the Third Review Conference of the Parties to the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction, Part II, Final Declaration, BTWC Third Review Conference document BWC/CONF.III/22, 27 Sep. 1991, Article V. In 1997 Cuba invoked this mechanism following a claim that the United States had released an insect pest from a plane. The matter was closed following the presentation of the conclusions of the consultative meeting in December 1997, although it did not confirm Cuba's claim or fully exonerate the United States. Zanders, J. P. and Hart, J., 'Chemical and biological weapon developments and arms control', *SIPRI Yearbook 1998: Armament, Disarmament and International Security* (Oxford University Press: Oxford, 1998), pp. 479–80; and Zanders, J. P., French, E. M. and Pauwels, N., 'Chemical and biological weapon developments and arms control', *SIPRI Yearbook 1999: Armament, Disarmament and International Security* (Oxford University Press: Oxford, 1999), p. 586.

[5] For an overview of the functioning of the Australia Group and the international debate surrounding it, see Anthony, I. And Zanders, J. P., 'Multilateral security-related export controls', *SIPRI Yearbook 1998: Armament, Disarmament and International Security* (Oxford University Press: Oxford, 1998), pp. 386–94. The Australia Group documents are available from URL <http://www.australiagroup.net/index.html>.

[6] For a summary of the history of the negotiations and the contents of the last version of the draft protocol before the negotiations collapsed, see Zanders, J. P., Hart, J. and Kuhlau, F., 'Biotechnology and the Future of the Biological and Toxin Weapons Convention', SIPRI Fact Sheet (Stockholm International Peace Research Institute: Stockholm, November 2001), available from URL <http://projects.sipri.org/cbw/research/cbw-papersfactsheets.html>.

[7] Zanders, J. P., Hart, J. and Kuhlau, F.., 'Chemical and biological weapon developments and arms control', *SIPRI Yearbook 2002: Armament, Disarmament and International Security* (Oxford University Press: Oxford, 2002), pp. 673–77.

[8] UN Department of Disarmament Affairs, Draft Decision of the Fifth Review Conference of the States Parties to the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) Weapons and on Their Destruction, document BWC/CONF.V/CRP.3, 6 November 2002. Review conference documents are available from URL <www.opbw.org>.

[9] Office of the Secretary of Defense, *Proliferation: Threat and Response* (US Department of Defence: Washington, DC, November 1997) and *Proliferation: Threat and Response* (US Department of Defence: Washington, DC, January 2001), via Defense Link, URL, <http://www.defenselink.mil/>.

[10] Office of Technology Assessment, *Proliferation of Weapons of Mass Destruction: Assessing the Risks* (US Government Printing Office: Washington, DC, August 1993), p. 15.

[11] Lauder, J. A., Special Assistant to the Director of Central Intelligence for Nonproliferation, 'Unclassified statement for the record on the worldwide WMD threat to the Commission to Assess the Organization of the Federal Government to combat the Proliferation of Weapons of Mass Destruction', 29 Apr. 1999, URL <http://www.odci.gov/cia/public_affairs/speeches/archives/1999/lauder_speech_042999.html>. Arms Control and Disarmament Agency, 'Adherence to and compliance with arms control agreements', 1998 report submitted to the Congress, Washington, DC, 1999, URL http://state.gov/www/global/arms/reports/annual/comp98.html>. Central Intelligence Agency, Nonproliferation Center, 'Unclassified report to Congress on the acquisition of technology relating to weapons of mass destruction and advanced conventional munitions, 1 January through 30 June 1999', Washington, DC, Feb. 2000, URL <http://www.odci.gov/cia/publications/bian/bian_feb_2000.html>.

[12] Bolton, J. R., Statement to the Fifth Review Conference of the Biological Weapons Convention, US Mission to the United Nations, Geneva, 19 November 2001.

[13] Office of the Secretary of Defense (1997), note 9.

[14] See note 11.

[15] Lilja, Petra, Roffey, Roger and Westerdahl, Kristina S., *Disarmament or Retention: Is the Soviet Biological Weapons Programme Continuing in Russia?* (Swedish National Defence Research Establishment: Umeå, December 1999), p. 10. Tucker, Jonathan B., 'Biological weapons in the former Soviet Union: An interview with Dr. Kenneth Alibek', *Nonproliferation Review*, vol. 6, no. 3 (Spring–Summer 1999), p. 9.

[16] Smithson, Amy E., *Toxic Archipelago: Preventing Proliferation from the Former Soviet Chemical and Biological Weapons Complexes*, Report no. 32 (Henry L. Stimson Center: Washington, DC, Dec. 1999, p. 16.

[17] Tucker, Jonathan B., 'Biological weapons in the former Soviet Union: An interview with Dr. Kenneth Alibek', *Nonproliferation Review*, vol. 6, no. 3 (Spring–Summer 1999), p. 6.

[18] Russia: stricter export controls imposed on goods usable in arms production, Russian Federation Government Directive no 57 (22 January 1998), *Rossiyskaya Gazeta* (Moscow), 18 February 1998, p. 1 in 'Russia: Chernomyrdin decree on dual-use goods export controls', FBIS-TAC-98-048, 21 February 1998.

[19] Joint Statement on Biological Weapons by the Governments of the United Kingdom, the United States and the Russian Federation, 10-11 September 1992, document available from URL <http://projects.sipri.org/cbw/docs/cbw-trilateralagree.html>.

[20] Warrick, J., 'Russia denies US access on bioweapons', *Washington Post*, 8 September 2002, p. 25

[21] The task of inspecting, destroying and removing all of Iraq's nuclear weapon capabilities was assigned to the International Atomic Energy Agency (IAEA). UNSCOM's mandate also included to assist and cooperate with the IAEA in its work in Iraq.

[22] A summary of the UNSCOM findings and discrepancies with the Iraqi declarations and a comparative analysis of the UNSCOM and UNMOVIC mandates are contained in Wahlberg, M.; Leitenberg, M. and Zanders, J. P., 'The future of chemical and biological weapon disarmament in Iraq: from UNSCOM to UNMOVIC', *SIPRI Yearbook 2000: Armaments, Disarmament and International Security* (Oxford University Press: Oxford, 2000), pp. 560–75.

[23] UN Security Council Resolution 1441 (2002), 8 November 2002. Document available from <http://www.un.org/Depts/unmovic/>.

[24] Wahlberg, *et al* (note 22), pp. 560–75.

[25] The procedure was adopted at the Third Review Conference of the BTWC in 1991. Final Document of the Third Review Conference of the Parties to the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction, Part II, Final Declaration, document BWC/CONF.III/22, 27 September 1991, Article V. It was invoked by Cuba on 30 June 1997 in order to investigate an alleged US attack with biological warfare agents in October 1996 (See note 4).

[26] See 'An Update on Inspection', briefing by Dr Hans Blix, Executive Chairman of UNMOVIC, to the UN Security Council, 27 January 2003, URL <http://www.un.org/Depts/unmovic/Bx27.htm>.

[27] For more detailed analysis, see Zanders, J. P., 'Assessing the risk of chemical and biological weapons proliferation to terrorists', *Nonproliferation Review*, vol. 6, no. 4 (fall 1999), pp. 17–34. Zanders, J. P., Karlsson, E. , Melin, L., Näslund, E. and Thaning, L., 'Risk assessment of terrorism with chemical and biological weapons', *SIPRI Yearbook 2000: Armaments, Disarmament and International Security* (Oxford University Press: Oxford, 2000), pp. 537–58.

[28] Zanders, *et al* (note 27), pp. 549–54. The computer simulation was prepared and run by the Swedish National Defence Research Establishment (FOA), Umeå, Sweden. In the Sverdlovsk incident an estimated 4 billion respirable spores became airborne and approximately 65 people died.

[29] In order to generate 4 billion respirable anthrax spores, a total of approximately 80 billion would have to be released. Such an amount can easily be suspended in a few litres of solution. With optimal distribution and inhalation this number could infect approximately 4–5 million people (the infective dose is assumed to be 8000–10000 inhaled spores). However, this estimate is of limited value since only a small fraction of the released spores would reach people because of the dispersion in the atmosphere. An even smaller fraction of the amount would be respirable. Zanders, *et al* (note 27), p. 550.

[30] For a detailed overview of the attacks with mail-delivered anthrax spores, see Zanders, *et al* (note 7), pp. 696–703.

[31] Moreover, contemporary military practice warned commanders not to build troop camps in unhealthy areas, such as marshlands. In order to lure the Greeks into staying during the second summer, the Syracusians reportedly offered to negotiate the surrender of the city. Grmek, Mirko Drazen, 'Les ruses de guerre biologiques dans l'Antiquité' [Biological warfare ruses in Antiquity], *Revue des Études Grecques*, vol. 92 (1979), pp. 150–51; 153 and 156.

[32] Wheelis, M., 'Biological warfare before 1914', in Geissler, E. and van Courtland Moon, J. E. (eds.), *Biological and Toxin Weapons: Research, Development and Use from the Middle Ages to 1945*, SIPRI Chemical & Biological Warfare Studies no. 18 (Oxford University Press: Oxford, 1999), pp. 13–15.

[33] Poupard, J. A. and Miller, L. A., 'History of biological warfare: catapults to capsomeres', in Zilinskas, R. A. (ed.), 'The Microbiologist and Biological Defense Research', *Annals of the New York Academy of Sciences*, vol. 666 (31 Dec. 1992), p. 10.

[34] Poupard, J. A., Miller, L. A. and Granshaw, L., 'The use of smallpox as a biological weapon in the French and Indian War of 1763', *ASM News*, vol. 55, no. 3, American Society of Microbiology (1989); and Wheelis (note 32), pp 17–27.

[35] Poupard and Miller (note 33), pp. 12–13

[36] Wheelis, M., 'Biological Sabotage in World War I', in Geissler and van Courtland Moon (note 32), pp. 39–51.

[37] See the various chapters in Geissler and van Courtland Moon (note 32).

[38] See Williams, P. and Wallace, D., *Unit 731. Japan's Secret Biological Warfare in World War II* (The Free Press, New York, 1989); and Harris, S. H., *Factories of Death. Japanese Biological Warfare 1932-45 and the American Cover Up* (Routledge, London, 1994).

[39] Biotechnology may be broadly defined as any technique that uses living organisms or parts of organisms to make or modify products, improve plants or animals, or develop micro-organisms for specific uses. In this sense biotechnology is thousands of years old (e.g., fermentation processes). In the narrow sense of the industrial use of recombinant deoxyribonucleic acid (rDNA), cell fusion and novel bioprocessing techniques, the history of biotechnology goes back some three decades.

[40] The fear of loss of propriety information as a consequence of visits by international inspectors is a politically potent argument advanced by opponents of multilateral arms control and disarmament.

[41] Wheelis, M. And Dando, M., 'New technology and future developments in biological warfare', *Disarmament Forum*, no. 4 (2000), p. 44; and Bioinformatics glossary, URL <http://www.incyte.com/glossary/index.shtml>.

[42] Bioinformatics glossary, URL <http://www.incyte.com/glossary/index.shtml>.

[43] Baker, D. and Sali, A., 'Protein structure prediction and structural genomics', *Science*, vol. 294, no. 5540, 5 October 2001, p. 93.

[44] Wheelis, M. And Dando, M., 'New technology and future developments in biological warfare', *Disarmament Forum*, no. 4 (2000), p. 44.

[45] Dando, M., 'Benefits and threats of developments in biotechnology and genetic engineering', *SIPRI Yearbook 1999: Armament, Disarmament and International Security* (Oxford University Press: Oxford, 1999), pp. 596–611; Nixdorff, K. and Bender, W., 'Ethics of university research, biotechnology and potential military spin-off', *Minerva* (2002, forthcoming); and Wheelis, M. And Dando, M., 'New technology and future developments in biological warfare', *Disarmament Forum*, no. 4 (2000), pp. 45–48

[46] Zanders, J. P.; Hart, J.; Kuhlau, F. and Sutherland, R., 'Maintaining the Effectiveness of the Chemical Weapons Convention', SIPRI Policy Paper (SIPRI: Stockholm, October 2002), available at URL <http://projects.sipri.se/cbw/research/cwc_policypaper2.pdf>.