Old Norms and New Technologies: The Prospects for 21st Century Biowarfare

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Abstract: International norms, and later laws, proscribing biological weapons have existed for centuries. So too has the Western tradition of Just War placed injunctions on indirect and non-lethal weapons despite claims by their proponents that they would be more humane for combatants. But in the 21st century new biotechnologies are emerging that call into question the rights of enemy combatants, civilian populations in target areas, and soldiers who will be physically augmented to pursue battlefield objectives. This paper examines publicly announced R&D programs currently sponsored by the US military and other advanced industrial nations and whether doctrine is keeping pace with established rules of warfare. From the Quikclot used to reduce fatalities in Iraq, and thereby potentially prolong public support for the war, to plans for 'direct effect' weapons that will cause organ failure with the press of a button, what do new applications of biotechnology in warfare mean for how we understand human rights in the Just War tradition?

> Imagine soldiers having no physical limitations . . . water and power being available whenever and wherever they are needed . . . mechanical systems as autonomous and adaptable as living things. What if, instead of acting on thoughts, we had thoughts that could act? Indeed, imagine if soldiers could communicate by thought alone . . . or communications so secure there is zero probability of intercept. Imagine the threat of biological attack being inconsequential. And contemplate, for a moment, a world in which learning is as easy as eating, and the replacement of damaged body parts as convenient as a fast food drive-thru. As impossible as these visions sound or as difficult you might think the task would be, these visions are the everyday work of the Defense Sciences Office…
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> Enhanced human performance…is born from the realization that with the emphasis on technology in the battle space the human is rapidly becoming "the weakest link." Soldiers having no physical, physiological, or cognitive limitations will be key to survival and operational dominance in the future…
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> The exoskeleton initiative will provide mechanical augmentation extending individual performance. Metabolically dominant warfighters of the future will be able to keep their cognitive abilities intact, while not sleeping for weeks. They will be able to endure constant, extreme exertion and take it in stride. Success in metabolic engineering will be visible, because I will be the first volunteer to be transformed.
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> Michael Goldblatt, Director, Defense Sciences Office
> Defense Advanced Research Projects Agency
> Speech to funding grantors
> (Goldblatt, 2002)

While our species has employed various organic substances, including bacteria and material from plants and animals, in warfare and political intrigue throughout recorded history, scientific advances are expanding the potential range of uses of biological material for both offensive and defensive purposes. The 2001 anthrax attacks raised public consciousness about the potentialities of these lines of research, while also spurring major investments by governments, militaries, and the private sector into biotech. While this growth also expanded the potential for rogue actors to ultimately acquire the new biotechnologies and turn them against their creators, they also ensured that the world's leading military powers would continue to enjoy the asymmetric advantage that biological weapons research programs have conferred upon them for the past century.

Although concerns over biological warfare, and later bioterrorism, stemmed directly from superpower bacteriological weapons programs and then the possibility that the material could be obtained or duplicated by violent non-state groups, there are many more facets to the roles of biotechnology in international security. There is no question of the possibility that many biotechnologies could be turned to military purposes – the process has already begun. And the effects – such as a greatly reduced proportion of American deaths from combat wounds in the Iraq War – have significant consequences for both the willingness of hegemonic states to use force and for less powerful actors to be able to offer resistance.

Other potential uses of new biotechnologies in military operations conducted by the United States in theaters from South Asia to South America raise a host of further ethical questions. Would bioweapons be legitimate to use in the War on Terror? Would it be more or less legitimate to employ agents that attacked agriculture, such as the opium-producing poppies that the Taliban use to finance their activities, than humans? How about weapons that did not

permanently damage people in target areas, but incapacitated them by disrupting their basic neurological functions? Advances across a wide spectrum of biotechnologies and substantial investments by the defense sectors of major powers necessitate identifying such questions and developing ethical principles upon which to base future doctrines.

Biological Weapons and the Ethics of Warfare

Biotechnology has existed throughout recorded human history, dating back to the fermentation of wine and bread leavened with yeast, but the term itself was not coined until 1919 by Hungarian engineer Karl Ereky. (Melson, 2003: 2) The United States Office of Technology Assessment defines biotechnology as "any technique that uses a living organism, or parts of organisms, to make or modify products, to improve plants or animals, or to develop microorganisms for specific uses." Other definitions include material patterned after living organisms but not necessarily using them as components (biomimetics).

Bioethics, as defined by *The American Journal of Bioethics,* is the "study of moral issues in the fields of medical treatment and research. The term is also sometimes used more generally to describe ethical issues in the life sciences and the distribution of scarce medical resources." The field has been influenced by the ancient Greek Hippocratic Oath for physicians to "do no harm," but also by the violations against human subjects by the Nazi regime and subsequent advances in reproductive and genetic research. (Caplan and McGee, 2004)

Such a discipline might at first glance appear to be highly philosophical and compartmentalized from the operational concerns of military planning and of homeland security. But warriors, statesmen, and administrators have long wrestled with how to appropriately integrate biotechnology with military force. More broadly, they have also been forced to address

whether certain types of unconventional weapons and tactics are permissible; and particularly the use of such force against non-combatants, one potential avenue for biotechnology that has already been pursued by at least one leading state military. Therefore, with scientific developments offering an ever-expanding range of roles for biotechnology that outstrips the ability of doctrine to keep pace with every new advance, scholars and practitioners of national security can at least turn to established principles on the ethics of warfare to provide precedent.

Bioweapons and the Just War Tradition

Although international laws, or at least reciprocal agreements, limiting biological weapons (BW) do not appear until after World War I, history is replete with both admonitions against the use of toxins in battle and the establishment of norms that otherwise limited their use. The role of international norms against BW, although they have not universally held, bears special examination in attempting to explain why they have not been used more widely. In *The Chemical Weapons Taboo*, Richard Price examines another category of twentieth century unconventional arms with a long lineage of historical antecedents and notes that, like BW, chemical weapons (CW) were typically not used even when opponents lacked the capacity to respond in kind, nor in situations in which military planners expected them to have great utility (such as eliminating Japanese defenders hiding in caves in World War II.) As with many new technologies of warfare (including crossbows, submarines, and machine guns) CW were initially condemned as immoral by status quo powers because they provide a potential asymmetric advantage to rising powers. It is this type of challenge to the hierarchy of the international system rather than any particular destructive capacity or cruelty in their effects that makes unconventional weapons (chemical, biological, radiological and nuclear or CBRN) normatively unpalatable. (Price, 1997: 2-6) As Hedley Bull (2002: 48) noted, nuclear weapons introduced

into the international system the possibility of the final fulfillment of ultimate Hobbesian anarchy, in which "the weakest has strength enough to kill the strongest."

The recognition of this quality of BW has no doubt colored the estimation of their value throughout history. Surviving evidence demonstrates that military and political theorists of the ancient world and medieval period proposed proscribing bioweapons on normative grounds. But they also recognized, much like in the international society of the nineteenth and twentieth centuries, that the strategic appeal of unconventional weaponry militated in favor of developing guidelines for appropriate offensive and defensive strategies:

> The Brahmanic Laws of Manu, a code of Hindu principles first articulated in the fifth century B.C., forbade the use of arrows tipped with fire or poison. Written in India a century later, Kautilya's *Arthashastra*, one of the world's earliest treatises on war and realpolitik, advocates surprise night raids and offers recipes for plague-generating toxins, but it also urges princes to exercise restraint and win the hearts and minds of their foes. (Tharoor, 2009)

Based on a number of proclamations by key strategists, it appears that the Roman Empire developed a strong norm against biowarfare. "The Roman military historian Florus denounced a commander for sabotaging an enemy's water supply, saying the act 'violated the laws of heaven and the practice of our forefathers.'" (Tharoor, 2009) There are few recorded attempts of efforts made to poison other armies, and the jurist Valerius Maximus stated firmly that "war is waged with arms, not poison." (Guillemin, 2005: 3) However, this statement was made in reaction to the poisoning of wells by Germanic tribes desperate to slow the advancing Legions, (CBWInfo.com, 2005) providing evidence in support of the hypothesis that CBRN are most strongly condemned when they are used to foil status quo major powers.

The condemnation of enemy tactics as violating martial tradition is hardly surprising, but it is less clear why the Romans appeared to largely reject biowarfare. The Legions were known to poison water supplies with botulin from decaying animals during sieges, (Roberts, 2003: 15) so the prohibition was not complete. While the explanation may lie in Rome's particular military or political culture, it is also likely that its overwhelming advantage in conventional force usually made it unnecessary to resort to less certain unconventional weapons. (Price, 1997: 23)

Tu Mu, a ninth century commentator on Sun Tzu's *The Art of War,* argued that it was imperative to camp upriver from the enemy to deny them the opportunity to poison your water supply (Sun, 2009: 166) Niccolo Machiavelli (1521: 67-68), in his own version of *The Art of War,* noted that strategies for victory included luring the enemy to defeat by glutting them on food and wine, with some generals from the classical period poisoning them for good measure. However, military victory through poisoning and guile appears to have been generally proscribed during the Medieval period. "German gunners in the late Middle Ages pledged not to use 'poisoned globes' or any poison since to use such devices was considered unjust and 'unworthy of a real soldier'… In 1675 French and German armies [also] agreed not to use poisoned weapons against each other." (Roberts, 2003: 25)

However, there is evidence that these norms were not taken to apply to the Other, which is to say groups outside of what was defined as the civilization or international society of the time. For instance, witnesses to the use of poison (burning rags dipped in a liquid that produced a noxious smoke) in 1456 by defenders of Belgrade against Turkish invaders commented that such a practice should never be used against fellow Christians, but that it was effective and may be permissible against other Muslim forces in the future. (Price, 1997: 36) Given the Clash of Civilizations frame imparted by some on counterterrorism efforts against transitional Islamists

and the deployment of Western troops as occupation forces throughout the Islamic world, it is of no small consequence to consider whether policymakers or individual troops are more willing to employ biotechnology against human targets viewed as alien.

The widespread norm of poisons being inappropriate weapons against rival soldiers also often has not appeared to extend to civilians. The Roman willingness to poison the water supply of population centers while generally avoiding attempts to poison opposing armies was echoed in the twentieth century by the Hitler regime, which studiously avoided the use of chemical weapons against Allied forces but experienced no qualms about their use against civilians in concentration camps. Japan in the same period used BW against non-combatants, both civilians and prisoners of war, but made no recorded successful attempts to use them as offensive weapons on the battlefield. (Guillemin, 2005: 84-85; Klotz and Sylvester, 2009: 46, 48)

CBRN weapon use against domestic enemies or targets has attracted international condemnation but not retaliation. The deployment by the Hussein regime of chemical weapons against opponents within Iraq was later used by the United States as evidence that it might be willing to use CBRN weapons against Western adversaries as well. This was despite the fact that it had elected not to load them into the SCUD missiles it launched at Israel in 1991 in an attempt to provoke that country's entry into the Gulf War. Less remarked upon at the time was Iraq's use of CW against Iranian forces during the war between those two states in the prior decade, perhaps because Iran presented a greater challenge to the international hierarchy and norms of just warfare: A number of its forces who were targets of unconventional Iraqi attacks were irregulars equipped to be human bombs. (Dobson and Payne, 1987: 219-222)

Still, the ban on BW use against conventional enemies gathered strength as modernity made biotechnology and the germ theory of pathogenicity more accessible. The poisoning of

water supplies by desperate, retreating Confederates in the American Civil War "led to the issuance by the US Army of General Order No. 100 which stated 'The use of poison in any manner, be it to poison wells, or food, or arms, is wholly excluded from modern warfare.'"[1] (Roberts, 2003: 83)

Subsequently, the norm was internationalized rapidly. During the 1874 Brussels Conference that banned poisoned projectiles, there was apparently no stated opposition to the proposal among the participants. And although the United States was the sole opponent of the ban on CW-loaded artillery shells enacted by the Hague Conference of 1898, it supported prohibitions on poison or poisoned weapons by the 1907 Hague Conference, and it championed the 1925 Geneva Protocol that banned both CW and BW. (Price 1997: 8, 19; Roberts, 2003: 84)

Chemical and biological weapons were therefore proscribed before they were ever used on the battlefield, a development that coincided with the development of modern norms of the acceptable conduct of warfare. And because civilians were not targets of CW attacks in World War I, Price (1997: 12) argues that the global public never became accustomed to them, or inured by them. The norms against chemical and germ warfare were so entrenched by World War II that President Roosevelt could declare in 1943 that "I have been loath to believe that any nation, even our present enemies, would or would be willing to loose upon mankind such terrible inhumane weapons…Use of such weapons has been ruled out by the general opinion of civilized mankind." (Krickus, in Walkin, 1986: 414)

Of course, the United States by this point had produced tons of select agents to be used in disease bombs, as did the other major belligerents in the war. The research scientists who served

[1] The United States did at least debate the development of CW during the Civil War, with one proposal to the Secretary of War arguing that projectiles containing liquid chlorine would disable targets as effectively as breaking their limbs. While the author did note the questionable morality of such a strategy, he nonetheless contended that it would humanely "lessen the sanguinary nature of the battlefield." (Christopher 1994: 203)

as architects of the American BW program opposed first use primarily on strategic rather than moral grounds, arguing that it would initiate a destructive tit for tat exchange: "The likelihood that bacterial warfare will be used against us will surely be increased if an enemy suspects that we are unprepared to meet it and to return blow for blow." Similarly, Admiral William Leahy reported that he warned Roosevelt in 1944 that "the reaction can be foretold – if we use it, the enemy will use it." And he also added that the use of BW "would violate every Christian ethic I have ever heard of and all of the known laws of war. It would be an attack on the noncombatant population of the enemy." (Guillemin, 2005: 29, 60)

In 1947, during the early Cold War period in which it continued to build its industrial-scale BW program, the United States submitted a draft resolution to the United Nations adding biological arms to the category of weapons of mass destruction(WMD) that already contained nuclear and chemical weapons. (Guillemin, 2005: 12) The following year, the testimony during the Nuremburg trials of Holocaust perpetrators who had committed deadly and dehumanizing medical experiments led to the 1948 UN Genocide Convention that prohibited acts targeting particular groups for physical or emotional harm, as well as the prevention of human reproduction, which would preclude bioweapons that attacked particular ethnicities. The destruction of noncombatants in death camps, as well as by firebombing and nuclear attacks in World War II, had by this point rendered WMDs morally unacceptable because they inevitably killed innocent civilians. (Christopher 1994: 210)

Norms against CBRN weapon usage held during the Cold War, with a possible significant exception being the mass deployment of defoliants by the United States in Vietnam. Although apparently a marginal view, proponents of unconventional weapons continued to argue

that they would be more humane tools of warfare than conventional arms, and would save lives in counter-insurgency operations:

> Non-lethal weapons are a class of weapons unique to CB [chemical/biological] warfare. Nonlethal CB weapons pose a new type of problem for proponents of the just war doctrine…We must ask whether specifically nonlethal CB agents are more humane than conventional and nuclear armaments. Shall we wage a completely non-lethal war because of these agents?... Suppose the United Nations had access to non-lethal weapons and were able to use such weapons in the Congo conflict, for instance, the Katangese army and the white mercenaries could have been subdued while the number of casualties would have been reduced by one-quarter to one-half. The question can be put this way: if such weapons are available to us, are we immoral in sticking to conventional warfare? (Krickus, in Walkin, 1986: 420-421)

However, both the Geneva Protocol and the BWC prohibit the use of either lethal or non-lethal biological weapons, and the 1977 Additional Protocol I to the Geneva Protocol prohibits states from targeting civilians with non-lethal weapons or intentionally causing superfluous injuries such as blinding. It also prohibits weapons that result in a widespread, long-lasting or severe effect to natural environment. While constrained by norms against particular non-lethal weapon technologies, states might still make humanitarian arguments for particular technologies to be exempted in the name of saving of lives. (Fidler, in Lewer, 2002: 28-31)

Bioweapons and the Just War tradition

And yet international agreements are based upon centuries of tradition and developed philosophy and, even if the precepts have not been fully upheld, they still shape and constrain the logic of appropriateness for BW usage. Most prominent among them is the Just War Theory advanced in the early seventeenth century by the Dutch philosopher and political official Hugo Grotius. In the Grotian conception that laid a foundation for international law, advanced in *On*

the Law of War and Peace (1625), war is an occasionally necessary evil that is bound by constraints on its legitimate purpose and conduct. With the goal of limiting the evils of warfare, Just War Theory requires viewing all individuals as possessing equal universal human right regardless of their particular religion or national origin. (Krickus, in Walkin, 1986: 412)

Among the tenets of the Just War doctrine of *Jus in Bello,* or the legitimate conduct of warfare, is *Mala in Se*, which prohibits combatants from using weapons or methods which are "evil in themselves."[2] Paul Christopher includes in this category "weapons whose effects cannot be controlled, like biological agents," presumably meaning that deliberately released bacteria and viruses are likely to cause collateral damage. He notes elsewhere that non-combatants are typically regarded as "innocents," and that attacking them is therefore a war crime. (Christopher, 1994: 169, 196)[3]

It is equally unacceptable that uninvolved civilians may be harmed, even well after the termination of the conflict, by stray BW vectors. Whereas the effects of CW would typically be confined to the battlefield before they dispersed, biological agents might be dispersed over wider areas and some agents could survive for years. (Krickus, in Walkin, 1986: 416) Reports of high rates of plague in Japanese-occupied China well after the termination of the activities of Unit 731, which conducted activities including anthrax on civilians and the dissemination of insect-borne pathogens, testing and similar reports near former Biopreparat facilities in Central Asia, lend credence to this view. (Alibek, 1999: 16, 124-132)

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[2] Definitions of this type of weapons include those that cause superfluous injury and unnecessary suffering such as specific diseases, abnormal physiological or psychological states, or permanent disfigurement. They also include weapons that produce a field mortality of greater than 25 percent or hospital mortality greater than 5 percent. (Rappert, 2005: 217)

[3] Grotius also argued that those who used poison to assassinate rulers deserved "fear of disgrace." (Price, 1997: 24)

But what of BW that do not injure bystanders, but only their intended targets? New direct effect weapons offer that potential. And, as both Price and Christopher note, there is no obvious reason why CBRN weapons should be viewed as more morally abhorrent than guns or conventional explosives that also kill and maim. In the Just War tradition, however, there is a ban on inflicting "unnecessary" suffering, which is measured by the degree to which it continues after the belligerent ceases to be a combatant. This would include poisoned weapons that produce infections that debilitate or kill the target after they have been wounded and ceased to be a threat.[4] (Christopher, 1994: 106-107, 201, 205)

Just War tradition does permit the type of reciprocal attacks that have been the cornerstone of state biowarfare doctrines since their initiation in the Interwar period. Reprisals are acceptable against violators of the CBRN weapons norms, provided that the attack was a deliberate policy and not an unapproved act by a renegade individual, (a General Ripper in *Dr. Strangelove,*) because they might be an effective means of preventing additional violations. (Christopher, 1994: 196) Such action would be permissible as a Double Effect, in which an otherwise objectively evil act was not intended as an end in itself, but rather as a means to reducing levels of destruction. Reprisal attacks can therefore constitute *Jus ad Bellum*, or legitimate reasons for war, and some scholars argue that even the killing of non-combatants and the use of poison weapons are acceptable in this context.[5] (Walzer, 1977: 153, 215)

Non-lethal weaponry

[4] For example, "American soldiers in WWII were known to rub excrement on their bullets in order to cause infections," which Christopher (1994: 205) describes as a violation of *Jus in Bello* because enemy forces who had been shot were already no longer combatants. (Christopher 1994: 205)

[5] Presumably, however, the perpetrators of all forms of warfare believe that they are fighting to ensure future stability and less bloodshed as a result, which would seem to make the Double Effect a sincere argument for exoneration by any and all belligerents.

Along with certain chemical agents, many bioweapons could be defined as non-lethal weapons. The United States Department of Defense describes non-lethal weapons as "discriminate weapons that are explicitly designed and employed so as to incapacitate personnel or material, while minimizing fatalities and undesired damage to property and environment." The primary object of this category of armament is to target the resolve of the recipients rather than to inflict damage; indeed, recognizable physical damages may not be among the effects of the weapons. Still, it is somewhat problematic to term particular types of weapons as lethal or non-lethal when conventional arms actually kill only about one quarter of the casualties that they produce and when a small percentage of supposedly non-lethal weapons such as rubber bullets do produce fatalities. (Rappert, 2001: 567-568)

Historically, the use of non-lethal conventional weapons on the battlefield was regarded as "evil in itself" because they would leave behind maimed victims rather than simply killing. In the Saint Petersburg Declaration of 1868, which occurred between the first Geneva Convention and the Hague Conventions, a commission comprised of representatives of numerous European militaries "affirmed that the only legitimate object of war should be to weaken the military force of the enemy, which could be sufficiently accomplished by the employment of highly destructive weapons. With that fact established, the delegates agreed to prohibit the use of less deadly explosives that might merely injure the combatants and thereby create prolonged suffering of such combatants." The delegates therefore agreed to ban explosive projectiles weighing less than 400 grams or any small arms ammunition bearing incendiaries or reactive chemicals.[6] (Krickus, in Walkin, 1986: 420-421)

[6] Price (1997: 34) describes the Hague regime as a declaration of self-restraint by the strong, one intended to delegitimize the use of BW by weaker actors seeking to level the playing field. In this regard it was very much like the BWC seventy years later.

Incapacitatants, including BW agents, have traditionally been dismissed as ineffective tools of warfare, often because their effects are often not immediate and involve too much uncertainty beforehand. (Klotz and Sylvester, 2009: 30) These criticisms of the expected lack of utility conferred by BW, however, have been constructed around active combat scenarios in which otherwise conventional and roughly symmetrical forces are confronting each other.

But incapacitants, which include simple biotechnologies like pepper sprays, are also used by domestic law enforcement agencies and by military organizations for crowd control during peacekeeping missions. Critics charge that such devices lead to a greater readiness to use force against civilians, in some instances being used as forms of punishment rather than to prevent greater violence. (Rappert, 2001: 563, 568, 575) By making "physical conflict more likely by making it less costly," non-lethal weapons are arguably "contributing to the militarization of police forces and the paramilitarization of militaries." (Rappert, 1999: 741-742)

Indeed, after the difficulties it encountered in waging effective urban warfare in Mogadishu in 1993, the Pentagon began intensive research into non-lethal weapons, including colored strobe lighting and synthetically produced odors to nauseate crowds. At approximately the same time, the FBI consulted with counterparts in Moscow about the feasibility of using Soviet technology to broadcast subliminal messages to cult leader David Koresh, who was holding hostages in a protracted standoff with law enforcement, in an attempt to persuade him that the voice of God was ordering him to stand down.[7] (Barry and Morganthau, 1994)

By virtue of such advances in non-lethal weapon technologies, scientific developments come to shape not only doctrine by how relations are constituted between actors including

[7] Although this novel approach was apparently not taken, and the standoff ended with the deaths of dozens of unarmed cult members, the situation could have been worse: Nine years later, Russian efforts to end a hostage standoff at a Moscow theater that relied upon a supposedly non-lethal knockout gas killed over one hundred of the hostages, whereas the terrorists up to that point had killed only one.

soldiers, police, protesters, rioters, insurgents and bystanders.[8] Power relationships change with the advent of new technologies, and also with the ease with which – perhaps bloodless – violence might be enacted. And with these changes also come new sets of questions concerning the conduct of Just War. (Rappert, 1999: 746-748)

The Scope of Biotechnology and Bioweaponry

The heavy investment in biotech by the United States Department of Defense signals that it will be not be rogue actors or terror groups that wield bioweapons most effectively in the 21st century. Instead, the leading states that are already the most capable actors in the international system will continuously integrate emergent biotechnologies into their military and national defense infrastructures and extend their dominance. This process will closely resemble the Revolution in Military Affairs (RMA) that occurred during the last thirty years of the twentieth century, as the United States adapted its forces to exploit advances in new information technologies. The RMA, first described by the Soviet military intelligence in the 1970s and then witnessed by the world during the unexpectedly uneven 1991 Gulf War, occurred because the United States employed its competitive advantage in integrated computer systems. Rather than a single transformative device, like the atomic bomb, the steady accretion of advanced technologies augmenting existing equipment came to inform doctrine and strategies.

The term asymmetric warfare is meant to describe efforts by weaker participants in military confrontations to frustrate the advantages of the stronger power by guerilla tactics or other unconventional methods not envisioned in force planning. (Mack, 1975) However, high technology also offers asymmetric advantages to the best-equipped actors, and American

[8] Klotz and Sylvester (2009: 29) argue that incapacitants used for domestic law enforcement purposes are also illegal under the BWC. Under the terms of the Convention, however, select agents may be retained for "protective or peaceful purposes" which could be argued to include force protection and crowd control.

military planners sought to use the advances of the RMA to field forces that no state competitor could match. Their goals included "dominant maneuver" capability on the battlefield in bringing dispersed resources to bear against targets, "precision engagement" capability delivered by smart weapons, and "full dimension force protection" against all anticipated threats. (Rizwan, 2000)

Expanding asymmetric warfare advantages is also the goal of military applications of new biotechnologies. Much of the research is conducted under the auspices of the Pentagon's Defense Advanced Research Projects Agency (DARPA) rather than legacy programs remaining from the era of bacteriological weapons stockpiles. Established in 1958 as a response to the launch of the first Sputnik satellite by the Soviet Union the year before, DARPA was intended to promote "high-risk – high-payoff" R&D in areas beyond the immediate envisioned needs of military planners. (Van Atta, 2008: 20, 23, 27)

Similarly, the Pentagon Office of Net Assessment (ONA), which envisions potential future strategic environments and challenges, has also promoted biotech R&D as a defense priority. In 2002, the ONA recommended revising Federal regulations to allow experimental biotechnologies to be brought to the battlefield more readily. It also called for facilitating a greater partnership with private sector researchers by restricting anti-trust laws to permit quicker product development. (Armstrong and Warner, 2003)

Whether in collaboration with the private sector or directly from their own research facilities, leading state military programs are already implementing biotech innovations that have already had significant impacts beyond the realistic aspirations of non-state actors. The lives of thousands of Coalition troops have been saved by biotechnologies deployed in Iraq and Afghanistan, and other projects being implemented will enable soldiers to fight more effectively under more adverse conditions than previously possible. In short, rather than being curtailed by

asymmetric defenses, the power projection capabilities of the strongest actors in the international system will increase markedly during the twenty first century.

Troop health and survivability

Despite the mechanization and increased destructive power of warfare in the mid-nineteenth century, it was not until World War II that wartime combat deaths exceeded those off the battlefield. This shift, due to advances in combat medicine, permitted American and British forces to conduct forward operations with reduced fatalities. Advances in biotechnology are responsible for the continuation of this trend into more current conflicts with similar results. (Frank, 2007)

When the United States invaded Iraq in 2003, many of its soldiers and Marines were treated with $90 bandages produced by an Oregon-based company called HemCon Inc. The military ordered 26,000 of these dressings, made from a shrimp shell extract called chitosan, which stopped arterial bleeding within a minute of application to wounds. Another bandage, developed by the American Red Cross but with limited use because of its $1,000 price tag, was made of clotting proteins extracted from human blood. By contrast, a powdered coagulant manufactured by Z-Medica called QuikClot that could be poured directly onto wounds was issued in first-aid kits, initially to Marines and then across service branches. QuikClot is a granular substance that can be poured directly onto a wound, almost instantly forming a clot that stops bleeding. A hemostatic agent in QuikClot draws water molecules out of blood and promotes accelerated clotting. (Allen, 2003) However QuikClot generated both a heat-giving exothermic reaction and complaints by recipients that they were receiving burns as a result, sometimes making it difficult for doctors to remove damaged tissue. By 2010, both the United

States Army and Marines had switched to providing QuikClot Combat Gauze in first aid kits instead. (Cavallaro, 2010) Other options are available as well:

> Biological materials are now known that have excellent adhesive properties and can help stop bleeding. These include adhesives from barnacles…. Biosealants with excellent adhesive properties might be developed (e.g., by modifying protein biopolymers), and individual soldiers might carry them in their backpacks. The biosealant would act as a "super glue" to stop bleeding and hemorrhaging until the injured soldier could be evacuated to a more permanent treatment setting. (Committee, 2001:36)

The use of biotechnologically advanced coagulants to treat severe combat injuries had a substantial effect on the first wars of the twenty-first century: "The ratio of [American] combat-zone deaths to those wounded has dropped from 24 percent in Vietnam to 13 percent in Iraq and Afghanistan. In other words, the numbers of those killed as a percentage of overall casualties is lower." However, while fatalities are down, the continuation of casualties has meant bearing the increased costs of more survivors with amputations and psychological damage. Still, because reductions in public support for wars are attributed to high fatality rates, contemporary military planners are more interested than ever in minimizing costly operations. (Knickerbocker, 2006)

By the time of the War on Terror, 55 percent of battlefield deaths were due to excessive blood loss. (Armstrong and Warner, 2003) But the development of rapid coagulants sharply reduced the rate of combat deaths and may have sustained the American public's tolerance for the Iraq and Afghanistan missions. The potential implication is that democracies may become more willing to engage in future wars if the human costs of doing so are minimized.

Biotech is being employed along these lines across a variety of projects: "Technologies are under investigation to fully restore complex tissues (muscle, nerves, skin, etc.) after traumatic injury, and most dramatically, to develop neural-controlled upper extremity prostheses that fully

recapitulate the motor and sensory functions of a natural limb." (DARPA, "Restorative Biomedical Technologies") A fully-functional prosthetics program termed HAND "is developing the fundamental research that will enable the use of neural activity to … restore natural function through assistive devices. By directly harnessing the ability of neural pathways to operate natural systems, the HAND program seeks to provide means of restoring the lives of injured warfighters." (DARPA, "Human-Assisted Neural Devices") Clinical trials are underway on accompanying neural-controlled prosthetic devices "almost identical to a natural limb in terms of motor control and dexterity, sensory feedback … weight, and environmental resilience." (DARPA, Revolutionizing Prosthetics) That this research is being conducted by the Pentagon rather than private sector medical companies speaks to its perceived strategic value.

Gene therapy is another biotechnology of interest to advanced militaries: "Knowing a soldier's genetic profile could be useful for many reasons. Having such information could assist in selecting individuals for certain missions. Is a particular soldier well suited for high altitudes based on genetic factors related to his blood oxygen carrying capacity?" (Armstrong and Warner, 2003)

In the treatment of injuries, human stem cells that can regenerate and replace otherwise irreparably damaged cells could be used to potentially replace impaired organs. (Committee, 2001: 37) Another option for delivery is by engineered vectors such as viruses. In 2005, researchers were able to restore enough damaged cochlear hair cells in deafened guinea pigs to recover 50-80 percent of their hearing levels. The therapy was delivered by adenoviruses engineered both to render them harmless and to produce a hair growth stimulant. (Coghlan, 2005)

> By 2025, it is likely that somatic gene therapy will be developed to the point that it can be used to direct the synthesis of protein therapeutics in individual soldiers,

> thus obviating the need for implantable devices. For example, gene therapy agents could be transfected into cells by bombarding a patch of skin with DNA-coated pellets from a gene gun. As the cells are sloughed off, expression of the therapeutic protein would naturally cease but could be renewed by another application of the agent. By 2025, reliable and robust means of delivering DNA constructions to other cell types will also become available. In fact, much or all of the technology implanted into the individual soldier will probably be derived from the individual's own cells rather than from fabricated devices. (Committee, 2001: 70)

Indeed, in October 2011, researchers published the results of a study that succeeded in generating stem cells from specific patients for use in regenerative therapy. (Stein, 2011)

Another possibility is neural or cortical implants such as prosthetic retinas, both to treat injuries and to offer enhanced abilities. "As the risks and costs associated with neural implants are reduced, they may be used to increase the visual and hearing acuity of unimpaired individuals to levels well above average. Soldiers possessing these extraordinary faculties would be well suited to gathering intelligence and performing long range reconnaissance missions." (Committee, 2001: 38)

Human enhancement

Efforts to field augmented troops represent new approaches to the use of biotechnology in warfare, a qualitative shift away from traditional but uncertain bacteriological weapons to entirely new strategies for assuring battlefield dominance. As proponents of this biotech approach envision it, "futuristic, 'superhuman' capabilities of individual soldiers could enable small units to operate for extended periods of time, carry the fight to remote locales, and endure harsh extremes of climate." (Committee, 2001: 7) Although seemingly fantastic, billions of

dollars have already been spent on several programs directed toward fielding various types of "Augments."

As with biotechnologies to increase survivability, introducing mechanically or biologically augmented living soldiers offers multiple benefits for states with the capacity to do so. It also raises a host of political and ethical questions without clear answers. Certainly, there would be tactical advantages for militaries whose personnel are able to operate more effectively than their adversaries under difficult conditions. And the boon of losing fewer servicemen to injury, and being able to return those who are injured to the front lines more quickly, is evident. But there are also broader potential national and international political impacts. Democratic governments, which endeavor to avoid costly or risky wars, (Mueller, Sigmund Gartner and Segura, 1998; Reiter and Stamm, 2002) might be tempted to exert their power as their conventional force advantages grow, and as the costs of providing for disabled veterans diminish.

Major powers with both conventional and asymmetric biotechnological edges over rivals may similarly be open to the use of force to maintain their positions if they are secure in the knowledge that they are well beyond the capabilities of opponents to match them. The advent of nuclear weapons is credited with reducing the number of interstate wars, with the effect of entrenching the hegemony of the technologically advanced states that wield them. RMA advances gave the United States such a lop-sided advantage in its early post-Cold War interventions (zero combat deaths during nearly three months of NATO missions during the Kosovo War,) and its initial easy success in toppling Saddam Hussein from power in Iraq led, temporarily, to rapprochement efforts by "rogue" regimes Iran and Libya to avoid the same fate.

While advanced equipment is responsible for these successes, biotech now offers the opportunity to enhance the performance of the combatants themselves.

> [DARPA] is engaged in the development of designer drugs that will increase cognitive functioning, including attention span and alertness after periods of sleep deprivation. Another area for future research is "neural prostheses" that will enable commanders to monitor the vital signs of soldiers in the field or even to permit the control of UAVs directly by pilots in remote locations. (Huang and Kosal, 2008)
>
> In 2002, DARPA launched the Augmented Cognition (or AugCog) initiative, a project dedicated to developing a headband that monitors brain activity. Among the objects is to determine if military personnel in the field are receiving too much sensory input to process effectively, and send alternative information instead. A 2005 trial of the device resulted in subjects doubling their recall, and improving 500 percent increases in measured working memory. (*The Economist*, February 27, 2010)

While Augments would be able to receive more situational information on the battlefield through neural devices, processing it effectively is another matter. Technologies developed through the AugCog and Enabling Stress Resistance projects might alert commanders that individuals are suffering mental or physical exhaustion. Another approach would be to "develop quantitative and integrative neuroscience-based approaches for measuring, tracking, and accelerating skill acquisition and learning while producing a twofold increase in progression in an individual's progress through stages of task learning." Reminiscent of the neural training uploads for particular weapons systems and martial arts in the science fiction *Matrix* films, results would be achieved through the "development of neurally based techniques for maintenance of acquired skills [and on] preferential brain network activation." (DARPA, "Accelerated Learning")

Other biotechnologies would provide physical enhancements to Augments. The field of biomimetics seeks to mimic useful naturally occurring characteristics in living organisms. For example, ants and spiders can lift loads dozens of times their own weight, and horses can withstand freezing temperatures without thick hair. "Understanding how horses and other animals overcome drastic changes in their environment would be extremely useful. As a measure of the importance of biomimesis, the Army has declared biomimetics one of its Strategic Research Objectives (primary focus areas for basic research)." (Committee, 2001: 14-15)

Power projection

Unless the R&D invested in these projects proves futile, the United States Department of Defense is indeed on its way to developing not just super-soldiers, but essentially comic book super-heroes. Mentally and physically enhanced soldiers with access to regenerative medical treatments not available to their enemies will be far from the full extent of the impact of the biotech RMA. One $3 billion program, begun in 2002, is intended to create a "metabolically dominant soldier" who will be enabled by gene therapy to lift up to 800lbs, block pain receptors for days, and "run at Olympic sprint speeds for 15 minutes on one breath of air" (Sokolove, 2007)

And if neural or cybernetic prostheses and gene therapy do not produce a Superman – or Captain America – the contributions of other research programs may still permit the fielding of a biomimetic Spiderman:

> The Z-Man program will develop biologically inspired climbing aids that will enable an individual soldier to scale vertical walls constructed of typical building materials without the need for ropes or ladders. The inspiration for these climbing aids is the way geckos, spiders, and small animals scale vertical surfaces…. The overall goal of the program is to enable an individual soldier using Z-Man

> technologies to scale a vertical surface while carrying a full combat load. (DARPA, "Z-Man")

Endowing troops with the ability to scale vertiginous surfaces obviates classical applications of biowarfare: No need to hurl plague-ridden corpses over fortifications when you can simply walk up them instead. This is perhaps the most outlandish example of how biotechnologies are being developed to aid in military power projection capabilities, but it is by no means the only one. Another biomimetic project aims to increase the efficiency of human swimmers by 80 percent and double their speed by giving them oscillating foils based on the propulsion mechanisms used by some fish and sea birds. (DARPA, "PowerSwim") And a project to achieve Rapid Altitude and Hypoxia Acclimatization would permit the fielding of troops (perhaps in potential battle zones such as the Hindu Kush or the Himalayas) with "novel pharmacological, biological, and technological approaches to adapt to high altitudes (4,000–6,000 meters.)" (DARPA, "RAHA")

Exotic Weaponry

Whether with a host of already-unveiled cybernetic insect spies (Callaway, 2009), or a company of super-soldier Augments with the abilities of insects, the United States and its technologically advanced allies and competitors are assuming the capacity to wage conventional warfare and espionage in a manner that will not soon be available to internal or regional adversaries or to non-state antagonists. But it is in the area of novel bioweapons where hegemonic actors stand poised to offer attacks against which their adversaries could mount no possible defense. Currently many potential lines of research are banned under the terms of the BWC, but even if state actors abide by its terms, private sector breakthroughs will continue to

have dual-use capabilities that can be studied. Indeed, some of them have already caused outbursts of political violence internationally.

One private sector advance with far wider implications is the use of a "Terminator" gene that would either ensure that organisms are incapable of reproduction, or a type that would destroy its own cells if exposed to certain enzymes. Rather than a speculative technology, Terminators are a reality that has been causing international tensions since their commercial introduction in the mid-1990s. Specifically, various American seed companies with a significant export market to developing countries, among them, Delta and Pine Land Inc., have incorporated Terminators into wheat and rice, ensuring sterility after the first yield and the necessity of repurchasing seed annually. After the introduction of Terminator crops in rural India led to riots and attacks against foreign holdings by irate farmers, the Indian government was spurred to invest in the development of India's own biotech industry. (*The Asian Age*, 1998)

Again, however, the dual-use potential of many biotechnologies means that the easy destruction of crops and livestock does not need to remain the province of multinational corporations. The military implications of Terminator genes and vectors bearing agricultural pathogens are obvious. The real question is whether or not states are willing to target food supplies through the release of engineered vectors that would cross-pollinate targeted crops with Terminator genes. Such a strategy could be viewed as a form of direct sanctions more humane than conventional warfare or, alternatively, as unjust collective punishment.

Direct-effect weapons

As one biodefense specialist put it, "If one can disrupt unit loyalty through fear or another emotion, the army would cease to exist as a fighting force. Claustrophobia would make soldiers

tear off their protective face mask. Fear, thirst, accelerated heart rate, hypermotility of the gut – these would be the desired peptide effects" [of proteomic weapons.]

A different avenue of potential development in biotechnological attacks is a shift away from infectious agents to targeting human bioregulators, natural substances in the body that control automatic processes such as blood pressure and immune responses. Former Soviet bioweaponeer Ken Alibek claimed that the Soviet Union pursued this research into "direct effect weapons" the 1980s to circumvent the BWC. The result would not actually be an illness, but the turning of the body against itself through disruption.[9] (Preston, 2009: 313-314)

The field of genetic protein decoding and engineering of this kind is known as proteomics. (Committee, 2001: 15) Understanding the functions of proteins is key to opening entirely new frontiers in medicine – and warfare. Already, researchers have destroyed targeted cancer cells by using engineered nano-particles to deliver genes only to the tumor and not to healthy neighboring tissue. Once the genes were inserted, they stimulated the production of a protein that selectively destroys the cancer. (BBC News, 2009)

Chinese researchers Guo Ji-wei and Xue-sen Yang (Military Review, 2005) directly address the security applications of such efforts in proteomics, arguing

> Direct-effect weapons … can cause destruction that is both more powerful and more civilized than that caused by conventional killing methods like gunpowder or nuclear weapons … A military attack, therefore, might wound an enemy's genes, proteins, cells, tissues, and organs, causing more damage than conventional weapons could. However, such devastating, nonlethal effects will require us to pacify the enemy through postwar reconstruction efforts and hatred control… [W]e could create a microbullet out of a 1

[9] Huang and Kosal (2008) report that the United States Air Force has considered and rejected one type of bioregulator attack: The development of a neuropharmaceutical aphrodisiac, to be sprayed over enemy ground forces, intended to function as a "gay bomb."

> micron tungsten or gold ion, on whose surface plasmid DNA or naked DNA could be precipitated, and deliver the bullet via a gunpowder explosion, electron transmission, or high-pressured gas to penetrate the body surface. We could then release DNA molecules to integrate with the host's cells through blood circulation and cause disease or injury by controlling genes.

Just War in the Biotech Age

All of these aspects of biotechnology raise ethical questions that cannot be easily dismissed. BW programs have already produced tremendous costs in lives and financial resources. They have also borne the promises of saving lives in future wars and of providing more humane and reversible weapons, and these promises have been used throughout modern history to justify BW research. But all of the potential promises and perils of biotechnology can be examined in the context of ethical decisions that must be confronted not only by researchers and scientists, but by the political and military leaders who elect to fund and implement biotechnologies – or who refrain from doing so.

Shifts in whether non-lethal weapons are viewed as either malicious or merciful have as much to do with technological advances – from picric acid 150 years ago to proteomics – as they do with different and evolving constructions of meaning. Rappert (2001: 565) notes that "diametrically opposed interpretations have been offered, for instance, on whether the deployment of such weapons helps to escalate or to minimize conflict." These views are pertinent not only to whether it is permissible to use particular types of advanced BW such as reversible direct effect weapons but also, and perhaps more challengingly, how to respond to them in kind – not to mention bioterrorist incidents.

One relevant question that must be asked is what is an appropriate proportional response to the use of biological weapons by both state and non-state actors? Unlike a nuclear attack, there

are many gradations of potential biological attacks against the United States, and it is not evident that any or all of them justify the type of nuclear retaliation threatened against bioweapon proliferator Iraq in the confrontations of the 1990s and 2000s. Instead, a new host of questions of Just War arise with advances in biotechnology.

As the Amerithrax case demonstrates, it may be several years before the perpetrator of a significant biological attack is even identified. Are Cold War-type threats of massive retaliation credible when adversaries are amorphous, or justifiable when a period of years has passed since the occurrence of the attack? Even if a suitable target for retaliation against a non-state actor like al Qaeda could be determined, what would be an appropriate response to an ineffectual use of anthrax against vaccinated military personnel? Can democracies or their publics justify a CBRN response to a CBRN attack even if it did not produce massive casualties?

Or what if an agent such as brucellosis, which only incapacitates, were to be used instead? Some speculated in 2001 that the limited anthrax attacks were salami tactics that would break down the taboo against biological attacks by accustoming the global public to their use. The probable failure of future bioterror attacks to provide a casus belli for massive retaliation will erode the deterrent credibility of both nuclear and conventional forces. Also, deterrence will fail if state actors believe they can mask the source of biological attacks, which is easier to do with biological than with other weapons.

Examination of the values underlying national security policymaking is an essential step in developing a net assessment of the impact of biotechnology on international security. In the century since the advent of WMDs, often marked by the use of chlorine gas at Ypres in April, 1915, the norm influencing international laws and most national defense policies has been that

unconventional warfare is to be avoided if at all possible. The primary rationales proffered have been fear of uncontrollable escalation and unavoidable indiscriminate civilian casualties.

However, advances in biotechnology are obviating the familiar balance of terror of afforded by twentieth century bacteriological armaments. The overall advantage still remains with the industrially and scientifically advanced major state powers because of their growing capacity to target resources that are not conventional military targets. Yet these developments raise doctrinal questions that require thoughtful consideration.

Unconventional attacks seem likeliest to occur when the attacker's vital interests are unlikely to be threatened in a reciprocal fashion. If a state-sponsored terrorist group used a genetically engineered lethal virus against Americans, it seems unlikely that the United States would respond in kind against the populace of either state sponsors or host states, favoring instead conventional punitive attacks. But public sentiment could begin to shift in favor of in-kind retaliation if biotech attacks continue, particularly if more "humane" responses such as bioregulator disruptions are available. Alternatively, biotech attacks against industrial or agricultural targets appear to offer a low-cost form of coercion and might be more attractive than military interventions. (Guillemin, 2005: 7)

It is therefore imperative that the parameters for acceptable military and counter-terrorism usage of advanced biotechnologies be prior to any such incidents. While retributive symmetrical attacks are permitted under international agreements on bioweapons, and while states have historically reserved the right to first use of BW if attacked, even extending to allies of the attackers, it is not clear that retributive attacks against civilian populations constitute Just War. (Guillemin, 2005: 5) For example, if an Iranian-backed non-state group such as Hezbollah

used a genetically engineered lethal virus against Americans, could the United States respond in kind against Tehran?

Even an attempted non-lethal response would likely be problematic. As noted, even armaments intended to incapacitate but not to kill rioting or protesting mobs have still killed or seriously wounded hundreds of targets. (Rappert, 2005: 214) The major state BW programs also developed "nonlethal" weapons like brucellosis, which causes intense illness over several days but not more than that. Obviously such an outbreak would incapacitate opposing troops and civilian defenders much as the botulants and purgatives used in sieges in the ancient world did, and it would also raise the question of an appropriate response. But given that approximately two percent of those infected die from brucellosis, it is difficult to guarantee such an attack would be truly non-lethal, and the same holds true for the deployment of other emerging biotechnologies with military applications.[10] (Guillemin, 2005: 7)

When bringing military force to bear against either non-state actors or against other state militaries, which emerging biotechnologies are consistent with traditions of Just War? Many new genomic weapons under development could easily be made non-lethal, but does that mean that they are actually more humane, a view articulated only over the past 150 years of human history? Modern biological weapons were conceived a century ago as terror weapons to demoralize civilian populations, and the newest iterations continue to bear that potential. It is not difficult to imagine a scenario in which everyone's blood pressure in Khyber Pakhtunkwha suddenly rises to dangerous levels with the promise made by leaflet that conditions will be returned to normal once the location of al Qaeda's leadership is revealed. But would such a move be justifiable?

[10] Likewise, the 2002 biodefense debate over mass smallpox vaccinations in the United States was ultimately determined by the expected deaths of a small percentage of recipients.

In the Middle Ages, when poisons were being used to assassinate numerous kings, emperors, and popes, rulers and religious leaders went to lengths to portray these bioweapons as uncivilized because they undermined the idea of war and political intrigue as being the "sport of kings" and the prerogative of the powerful. The asymmetric advantage conferred upon poisoners by the available biotechnology of the time undermined the class structure of warfare and prompted calls to respect the chivalry of the "fair fight" that would continue to favor the best-entrenched actors. The Hague Conferences held during the autumn of the Concert of Europe regime were similarly intended to discredit the use of munitions that would confer an asymmetric advantage upon the attacker, and this approach would presumably have been expected of anti-imperial forces. (Price, 1997: 25, 34) Similarly, little outcry is now being raised against the new biotechnologies of warfare by the principal powers of the modern international system, which are developing them and who expect to reap the greatest asymmetric advantages.

In the genomic age, when it will be possible to press a button and cause the adversary's kidneys to fail, military doctrines of *Jus in Bello* will require new examination. There must also be a recognition that new powers, such as China, that were never a part of the Western Grotian tradition might not share the same normative perspectives on the use of advanced biotechnology on the battlefield. Even seemingly simple questions, such as the responsibilities of states to retired augmented soldiers, will require new doctrines. If an individual has been physically or genetically modified in an irreversible fashion, are they permanently property of the state? If not, what agency will prevent them from abusing their abilities upon return to civilian status?

Debates over the appropriate roles of various biotechnologies in society and in warfare date back centuries. It is the advent of new genomic rather than pathogenic weapons, and genetically engineered soldiers with biomimetic gear who have tremendous advantages over

ordinary opponents, that represent a new challenge for the ethics of warfare. The electronic communications revolution is similarly creating tensions between state security and civil liberties in the area of biodefense. As biotechnologies continue to emerge and progress, these debates will only multiply and intensify throughout the next century of modern biological warfare.

Many recent analyses of the impact of trends in biotechnology conclude that the United States and other leading developed nations will experience a reversal of fortunes as the technology they developed proliferates to rogue states and terrorist groups. Koblentz (2009: 21) argues that knowledge proliferation means that the capacity to wage biological warfare is extending even to private individuals, and that greater international instability will result. The technology of biological warfare, in this view, is weighted toward offense, does not provide an effective strategic deterrent, and practical constraints on development and usage are eroding. Hope for the prevention of biological warfare lies in the fact that genetic science is sufficiently advanced that pathogens can be identified quickly and defenses mounted.

These interpretations, focused almost exclusively on the historical development of pathogens in classical state biological weapons programs, miss the mark on the likeliest impacts of biotechnology on international security. The first lies in the continued applicability of the logic of deterrence. The ability to decode genomes carries not only technical, but political implications as well because it is now possible to identify the sources of engineered pathogens. Fears that the 2001 Amerithrax attacks were the work of al Qaeda, encouraged in the letters sent by the perpetrator, faded quickly once it was established that the anthrax spores were from the domestic Ames strain used in research by the United States military. Although it was not initially possible based on this information to identify one culprit among thousands with access to the samples, this changed with scientific breakthroughs made during the course of the investigation. The case

illustrated that perpetrators can be identified and punitive measures taken by law enforcement or military means. The availability of genetic fingerprinting means that deterrence through the threat of retaliation remains a possibility even in the face of anonymous attacks.

However, while the logic of deterrence remains intact, the new dilemma that emerges is the question of what constitutes an appropriate response to an attack using biotechnology? The use of transmissible pathogens, such as bubonic plague or Ebola, or of highly lethal infectious agents such as anthrax, to produce mass casualties is generally accepted as employment of a WMD. But what about attacks that produce only disruptions? Are in-kind responses justified? Is overwhelming force appropriate, and against which targets? These ethical questions must ultimately be addressed by governments and the citizens who empower them.

The second major consequence of the full range of biotechnological advancement is that the most technologically advanced actors, already the most powerful in the international system, will gain even greater military edges over their rivals and non-state actors. The application of biotechnology to warfare is not a new concept, but the successful integration of recombinant engineering, enzymology and fermentation with conventional power projection capabilities is a development of the RMA that is only beginning to be recognized.

The technology to make the most sophisticated uses of biotech, including direct effect attacks manipulating the genomes of targets, will only be within the reach of the most advanced state actors. Rather than being the "poor man's nuclear weapon," twenty first century biotechnology will actually provide a decided asymmetrical advantage to major powers that will complement their superiority in conventional forces. Technologically advanced states will be far more likely to be able to counter classical "germ warfare" like anthrax attacks by rogue states

and non-state groups than will be actors bereft of a biotech industry to mount defenses against vectors that introduce Terminators, or proteomic weapons that disrupt human bioregulators.

What these biotechnologies do not disrupt is order within the international system. In the past, advances in weapons technology have been condemned as immoral in part because the most powerful actors, whether states or rulers, viewed them as challenges to their hegemony. Today, terrorists and rogue states are imputed to have a desire to use bioweapons, meaning to release pathogens against civilian targets, but few outcries have been heard over the legitimacy of the advantages conferred by other biotechnologies upon what are already the strongest actors.

Given that rapid advancements in biotech with security applications, or at least implications, are occurring largely beneath the public radar, it is imperative that both policymakers and publics begin to establish parameters for the acceptable use of biotech in warfare – and in peacetime – rather than allow events to overtake them.

New developments in biotechnology will afford the United States, and likely China and other major state actors, with a decisive advantage in power projection. To do so, however, governments must be willing to incorporate not only advances in defensive and production capabilities, but also the use of engineered organisms that will target enemy food supplies, natural resources, and even civilian physiology. This does not necessarily mean turning to bioterrorism, but it does carry implications as profound as the development of nuclear weapons. And as some biotechnology developments will destabilize the international system to a degree, (as some states find their economic output outdated while others assume even greater production capacity), it is incumbent on policy makers to prepare carefully today for a tomorrow that is rapidly approaching.

Many of these developments are already occurring without an informed public debate and, indeed, many of the biotechnologies outlined in this paper doubtless seem too fantastical to warrant serious consideration. But just as most of the public and decision-makers would have dismissed the plausibility of atomic weapons before Hiroshima, and were unaware before the invasion of Afghanistan that drones were already in existence, so too are the seemingly far-fetched qualities of advanced biotechnology already manifesting themselves in force planning and budgeting in the United States and elsewhere.

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