Is Nanotechnology Prohibited by the Biological and Chemical Weapons Conventions

Robert D. Pinson
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By
Robert D. Pinson*

INTRODUCTION

The advent of nanotechnology promises to bring extensive developments to many aspects of our society. Because it combines physics, engineering, molecular biology, and chemistry, nanotechnology is expected to have a significant impact on drug delivery, computing, communications, defense, space exploration, and energy. Indeed, the effect of nanotechnology on the twenty-first century could be more significant than the "combined influences of microelectronics, medical imaging, computer-aided engineering, and man-made polymers developed in the past century." Currently, nanotechnology's greatest short-term potential lies in the area of materials, such as polymers. Nanotechnology improves the temperature at which plastics can be used, adds flame retardant properties, improves tensile strength, and even increases oxidation resistance. The fabric for stain-resistant khakis incorporates nanotechnology and is just an early example of the many possible short-term applications. Sensors will soon be built into all types of materials, including "gas sensors in car engines [and] toxin detectors in water supplies." While the effects may be vast, many will be so seamlessly integrated into existing materials as to go unnoticed.

While many industries have begun researching nanotechnology, the largest research and development programs are funded by national governments. One

* Associate, Lacy, Moseley & Crossley, P.C. J.D., 2003, University of Tennessee College of Law. B.A., 1998, Oberlin College. The author wishes to thank Professor Glenn H. Reynolds for his guidance in pursuing this article as well as providing inspiration throughout law school.

5. See Kelly Hearn, The Next Big Thing (Is Practically Invisible), CHRISTIAN SCI. MONITOR, Mar. 24, 2003, available at http://www.csmonitor.com/2003/0324/p17s03-wmcn.htm. Nanotechnology is on course "to be the largest government-funded science project since the space race
such project is a collaboration between the U.S. Army, the Massachusetts Institute of Technology (MIT), defense contractors, and the medical industry to design a “futuristic ‘battle suit’ for America’s soldiers that’s as thin as a scuba diver’s wet suit—but fit for a superhero.” The suit’s material is filled with beads containing magnetic particles that, when lined up, become fifty times stiffer than normal. Soldiers can use this capability to activate a magnetic field when they hear gunfire or create an instant splint for injuries. In Taiwan, researchers are developing a catalyst that converts poisonous carbon monoxide into less-harmful carbon dioxide through the use of gold-silver bimetallic nanoparticles.

In the 2003 fiscal year, the U.S. government budgeted $774 million for nanotech research, while Japan was expected to invest $810 million. Overall, the governments of Europe, China, Japan, Canada, and Singapore have “invested billions of dollars to advance their nanotechnology efforts.” Recently, President Bush signed into law the 21st Century Nanotechnology Research and Development Act. The law authorizes $3.7 billion over four years to fund “long-term nanoscale research and development leading to potential breakthroughs in such areas as materials and manufacturing, electronics, medicine and healthcare, environment, energy, chemicals, biotechnology, agriculture, information technology, and national security technology.” This act inserts into law what were once presidential initiatives and discretionary spending.

Of course, the prospect of nanotechnology has its drawbacks. A recent study of particular objects known as “nanotubes,” revered for their extraordinary strength and electrical conductivity, demonstrated that such objects tend to clump within the lungs, causing suffocation. Evidence also suggests that cells that break up foreign debris in the lungs have more difficulty processing nano-
tubes than larger debris particles. Thus, certain manifestations of nanotechnology may have unknown biochemical properties that are harmful to humans or other living organisms and must be researched before they are let loose in our world. As a result, a need exists for a regulatory regime that can minimize, if not prevent, such dangers from occurring.

Additionally, while significant improvements in military technology such as new battle armor can minimize casualties in combat, mature nanotechnology has the potential to exponentially increase casualties. A nanotech weapon can be more powerful than any known chemical, biological, or nuclear agent because of the incredibly small size of nanoparticles and their ability to penetrate any material or substance. It can be developed and programmed to attack machines. Nanotechnology can even be used to refine existing chemical or biological weapons to make them more potent, less detectable, and easier to produce. Additionally, because of nanotechnology's small size, it can easily be dispersed in the air or through food or water. With this deadly potential, certain types of nanotechnology may fall under the purview of the Chemical Weapons Convention ("CWC"), the Biological Weapons Convention ("BWC"), or both. The application of the CWC and BWC to nanotechnology is the focus of this article.

This article will first explore nanotechnology, its origins, and its developments in Part I. Part II will introduce and analyze the CWC and BWC Conventions and their relevant provisions. Next, Part III will apply the provisions of the CWC and BWC to uses of nanotechnology and examine problems with the CWC and BWC themselves. A discussion of the need for an alternative to these conventions, and other possible solutions, occurs in Part IV. Finally, this article will conclude with some observations on the way forward.

15. Id.
19. Id.
I. NANOTECHNOLOGY

A. The Origins of the Concept

Once the topic of science fiction, nanotechnology has now become reality.22 The word “nano” comes from the Greek word for dwarf.23 To scientists, the prefix “nano” means one-billionth of something, usually a unit of measurement.24 Thus, a nanometer is a billionth of a meter, or 0.000000001 meters. To put matters into perspective, a human hair is about 80,000 nanometers in width.25 Getting smaller, a human red blood cell is about a thousand nanometers in width, while an adenovirus is typically around 100 nanometers wide.26 A carbon nanotube, commonly understood as “a strip cut from single [sic] sheet of graphite and rolled into a tube until the cut edges join,” is about one or two nanometers in diameter.27

The idea of nanotechnology originates as far back as ancient Greece, when Democritus suggested “that the world was built of durable, invisible particles—atoms, the building blocks” of matter.28 A concept akin to nanotechnology was first suggested by Nobel Laureate Richard Feynman in 1959.29 In a speech entitled “There’s Plenty of Room at the Bottom,” Feynman discussed the possibility that mankind can “make a thing very small which does what we want”30 or “arrange the atoms one by one the way we want them.”31 The conceptual gap between micromachines and chemical substances was not fully bridged until much later.32


26. Id.

27. Id.

28. Id.


31. Id.

32. DREXLER, supra note 24, at 76.
Although the concept of nanotechnology has been used to include any technology operating around 100 nanometers, the original meaning, commonly defined as "molecular manufacturing," entails "manipulating matter on an atom-by-atom or molecule-by-molecule basis to attain desired configurations." The National Science and Technology Council defines nanotechnology as "the ability to work at the molecular level, atom by atom, to create structures with fundamentally new molecular organization and exploit the novel properties exhibited at that scale." While nature already has shown that this process is possible through its own "molecular machines"—cells and organelles—nanotechnology can surpass what natural organisms can create. Nanotechnology can enable the characterization and creation of new materials with extraordinary precision at the atomic level. This unprecedented level of precision would allow the enhancement in a material of any desired property.

The problem with defining nanotechnology is that it does not "stem from one established academic discipline." Generally, nanotechnology is the ability to measure, organize, and manipulate matter at the atomic and molecular levels. With mature nanotechnology comes absolute control over atoms and molecules and thus the ability to create almost anything. Nanotechnology is essentially control of the most basic building blocks of life and the universe around us. Ralph Merkle, a nanotechnology professor at the Georgia Institute of Technology (Georgia Tech), portrayed atoms as "nature's Lego set," describing nanotechnology as the arrangement of tiny Lego pieces to build whatever we want.
The first work on nanotechnology began in 1977, due to the path-breaking work of K. Eric Drexler, the first to create the concept of "assemblers"—nanoscale machines that can build other nanoscale machines. In 1981, the first technical paper was published in the Proceedings of the National Academy of Sciences. Only in the 1980s were instruments invented that had the capabilities Feynman spoke about in his 1959 speech. In 1985, the MIT Nanotechnology Study Group was formed and soon began an annual lecture series on nanotechnology. In 1986, Drexler published the first theoretical book on nanotechnology, Engines of Creation. The first course in molecular nanotechnology was offered at Stanford University in 1988, which then led to the first major conference on the subject in 1989. In 1991, Drexler co-authored Unbinding the Future, which framed nanotechnology in more practical ways, particularly with the use of hypothetical scenarios. Since Engines of Creation, what was once thought of as science fiction became more mainstream science and engineering. These days, a search in the news libraries of Westlaw or Lexis can reveal sometimes dozens of articles each day mentioning "nanotechnology."

Nanotechnology can bring about a new industrial revolution because it represents the control of matter at one of the most basic levels—atoms. Not only does nanotechnology involve the most precise control yet over matter, but it is also represents a new method of manufacturing. Instead of the "top-down" approach used in most current manufacturing that involves the removal of unwanted materials from larger groups of raw material, such as creating a sculpture from a block of stone, nanotechnology uses a "bottom up" approach to build larger objects using smaller units such as atoms or molecules. Notably, it is actually the "top-down" approach that is the oddity in nature. By placing atoms and molecules in certain arrangements, objects of "astonishing complexity" are created.
B. The Current State of Nanotechnology

With only basic control of simple nanostructures, nanotechnology is "still in its infancy."54 While we have a grasp of atoms and simple molecules as well as microstructures and larger devices, the current challenge involves the one to one-hundred molecular diameters range.55 A revolution in which our ability to manipulate and organize matter on such a small scale is just beginning.56 This is still in an exploratory phase; we have yet to "understand all of the scientific and engineering issues that define what can happen and what can be done in the nanoscale regime."57

A number of products using nanotechnology are already on the market. Clothing retailers such as Levi’s and Eddie Bauer already sell pants “that feel like cotton but on an atomic level include a coating that causes dirt, wine or ketchup to bead up and roll right off.”58 Nanogate, a German company, is marketing ceramics for bathtubs and sinks that prevent them from getting dirty.59 In the sunscreen industry, nanoscale titanium dioxide—an effective, popular sunscreen ingredient—has been developed so that it is transparent and therefore invisible on skin.60 In early 2003, the University of Michigan announced the use of nanoprobes to “image chemical activity inside living cells.”61 Several Fortune 500 companies, including IBM, Samsung, General Electric, and DuPont, are developing nanotechnology projects such as “faster, smaller computer memory; lower-powered, longer-lasting LED lighting; and display screens for laptops, phones and PDAs.”62 In Taiwan, researchers have developed a bimetallic nanoparticle made of gold and silver that can aid in the pre-production of fuel cells.63 Additionally, an extremely precise method of detecting cancer is being developed at Georgia Tech with the development of a “nano-spring” structure that reacts when it encounters a cancer protein molecule inside the body.64 Nanotechnology has also led to products to address modern health concerns, such as particles that kill bacteria, filters that more effectively purify water, and sensors that detect pathogens in food.65


55. See id.

56. Cf. id.


58. Beauprez, supra note 5.

59. Id.

60. Newberger, supra note 25, at 652.

61. H.R. 766 Hearings, supra note 37, at 25 (statement of Richard M. Russell, Associate Director for Technology, Office of Science and Technology Policy).


63. Yu-Tzu, supra note 9, at 2.


65. Hearn, supra note 5.
C. Policy Developments

On November 20, 2003, Congress passed the 21st Century Nanotechnology Research and Development Act (the "Act"). This legislation formalized the National Nanotechnology Initiative. In addition, it permanently entrenches nanotechnology as a federal government priority by creating the National Nanotechnology Program ("NNP") and providing a total of $3.7 billion during the years 2004-2008, most of which will go to the National Science Foundation and the Energy Department. The NNP will provide federally funded research; establish goals, priorities, grand challenges, and evaluation guidelines; invest in federal research and development programs; provide for interagency coordination; and establish interdisciplinary nanotechnology centers. The NNP will also research and address societal and ethical concerns related to nanotechnology. When signed into law, the Act will "set research goals, award[ ] grants, encourag[e] interdisciplinary research, ... and accelerat[e] the commercial application of nanotechnology advances." Many experts agree that such advances will cause more revolutionary products to emerge in the near future. In addition to funding research, the legislation provides for oversight of this research, creating "both a national advisory panel on nanotechnology, and a National Nanotechnology Coordination Office, with responsibility for filing regular reports with Congress and the White House" regarding the progress of the NNP.

D. Future Development

In the near term, most activity in nanotechnology will have to do with research rather than completed products. Currently, approximately 455 companies and 271 academic institutions and governmental entities worldwide are conducting nanotechnology research, and these figures will only increase in the next few years. The next stage of nanotechnology research will deal with the ability to position individual atoms or molecules with extreme precision. Subsequent stages will involve the construction of more accurate tools at the molecular level. As we build smaller and smaller devices, we will use those tools to build even smaller and more precise devices.

69. NanoBusiness Alliance Supports Rep. Boehlert's Introduction of the Nanotechnology Research and Development Act of 2003, BUS. WIRE, Mar. 11, 2003. The program will also address the societal and ethical concerns about nanotechnology. Id.
70. H.R. Hearings 766, supra note 37, at 6 (Hearing Charter).
72. GREENPEACE REPORT, supra note 39, at 21.
73. Id.
74. Fiedler & Reynolds, supra note 34, at 600.
75. Id. at 601. These tools are known as "protoassemblers." Id.
devices to assist in building even smaller ones. At some point, the industry will become “mature nanotechnology,” which is where much of the recent commentary has focused.

Commentators believe the most immediate impact of nanotechnology will occur in informatics, pharmaceuticals, energy, and defense. Informatics, consisting of electronics, magnetics and optics, will be enhanced through the improvement of information processing, transmission and storage devices, and flat panel displays. With regard to pharmaceuticals, nanotechnology will greatly enhance our ability to deliver drugs at the right time and in the right places. In the energy sector, research is focused on photovoltaic production, especially in the use of solar power. As for defense, the use of nanotechnology will increase military might, allowing more flexibility and efficiency for responding to threats:

In peacetime or crisis, nanocomputers may allow more capable surveillance of potential aggressors. In low-intensity warfare, intelligent sensors and barrier systems could isolate or channel guerrilla movements depending on local terrain. In conventional theatre war, nanotechnology may lead to small, cheap, highly lethal anti-tank weapons. Such weapons could allow relatively small numbers of infantry to defeat large assaults by large armoured forces. At nuclear conflict levels, accurate nanocomputer guidance and low nanomachine production costs would accelerate current trends in proliferation of ‘smart’ munitions. Rather than requiring nuclear weapons, nanotechnology enhancements to cruise missiles and ballistic missiles could allow them to destroy their targets with conventional explosives.

In addition to affecting weaponry, research is under way to reengineer the modern soldier by improving and lightening his gear for enhanced protection, survival, and mobility. New nanotech battle gear would resemble something out of science fiction; it would monitor the soldier’s physical condition, track his location, and even protect him from bullets and shrapnel. A suit could have the ability to change color to camouflage into its surroundings. A wounded soldier’s suit would send out a signal for help, administer medicines, and perhaps even turn soft fabric into a cast when necessary. Sensors may also be incorporated into the fabric to detect the presence of harmful chemical, biological...
cal, and even nanotechnological agents. Additionally, power for the soldier’s equipment may come from photovoltaic cells or thermoelectric devices incorporated into the suit itself.

The ultimate way to protect soldiers is to not use them in battle at all. Nanotechnology could be used to enhance automation and robotics so that humans will not need to go into combat. Indeed, the U.S. military is already working on an unmanned combat air vehicle with the goal of also having remote-controlled bombers, helicopters, and submarines. Drones have already dropped bombs and taken photographs and video of dangerous locations. Analysts believe that at the very least, unmanned aircraft “can be used for potentially dangerous environmental monitoring, such as checking air quality for chemical and biological weapons.”

By 2015, the world nanotech market is predicted to exceed $1 trillion. As a result, almost 800,000 workers may be needed to support that industry. In medicine, nanotech is expected to reduce the cost of patient care while improving quality of life. Nanotechnology’s effect is forecast to be widespread because it integrates such diverse fields as physics, engineering, biology, and chemistry. With advances in each of these fields, nanotech can have a positive impact on our quality of life—assuming the risks are properly managed.

E. Why We Should Embrace Nanotechnology—Cautiously

The future will bring many beneficial uses for nanotechnology. Nanotech promises to enhance our quality of life through improved medical diagnosis, more efficient energy sources, and the creation of new materials in electronics, optics, and materials science. Additionally, more environmentally friendly manufacturing techniques will help “eliminate pollution, mitigate environmental hazards, detect contaminants, reduce emissions, avoid toxic leaks, and improve energy efficiency.”

Nanotechnology has many potential health benefits, such as programming special “nano-devices” called “dendrimers” to enter the body and destroy arte-

85. See McLaughlin, supra note 6.
87. NATIONAL NANOTECHNOLOGY INITIATIVE, supra note 45, at 24.
88. James John Bell, Exploring the ‘Singularity,’ THE FUTURIST, June 1, 2003, available at http://www.kurzweilai.net/articles/art0384.html?printable=1. Sadly, we could develop the technology to the point where teenagers could fight our battles as if the battles were mere video games.
90. Id.
91. Beauprez, supra note 5, at K1. This is more than twice the annual revenue of today’s pharmaceutical industry. Ellen McCarthy, Region Sees Big Market in The Little Things, WASH. POST, Oct. 16, 2003, at E1.
92. Beauprez, supra note 5, at K1.
93. Aronson, supra note 68, at 66.
94. Miller, supra note 1, at 5.
95. Id.
96. Id.
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Nanotechnology also has the potential to practicably use solar power on a massive scale, replace gasoline in cars with hydrogen and methane, and lighten vehicles to reduce fuel consumption. Over the long term, solar energy could become one hundred times more efficient, thus reducing the West's dependency on foreign oil. In addition to creating more energy sources, nanotechnology has the potential to reduce worldwide energy consumption by more than ten percent.

Unfortunately, many potentially negative effects from nanotechnology exist as well. The most commonly predicted risk is an accidental mutation or release of self-replicating nanorobots causing significant damage to the planet—some say even total destruction. This catastrophic doomsday scenario, however, is unlikely because no one is currently working on nanorobots; if we lack the ability to create normal sized robots, it is unlikely we will develop nanorobots anytime soon. This doomsday scenario is also of little concern compared to the very real risk of deliberate developments of weaponized nanotechnology. Nanotechnology's "microscopic size, easy dispersal, [potential] self-replication, and potential to inflict massive harm on persons, machines, or the environment" makes it a tempting weapon, especially to terrorists. More near-term nanotech developments could enable one to "assemble, molecule by molecule or chain by chain, any compound one desires." Thus, terrorists or countries may use this technology to create pure mixtures of dangerous toxins or chemical agents. In addition, mature nanotech could itself act as an artificial chemical or biological agent. Clearly, such developments point toward the prospect of a nanotechnology arms race.

The further development of nanotechnology appears inevitable because of its many potential benefits; one can only hope that the risks associated with it are also controllable. The most drastic course of action would be to stop all research and development of nanotechnology, but the safest way forward is to develop the technology and work to prevent accidents and misuse. The inevitability of the development of nanotechnology demonstrates the urgency to ben-

97. Reynolds, supra note 29, at 10683.
98. Maney, supra note 79, at 3B.
99. Id.
100. GREENPEACE REPORT, supra note 39, at 27. See id. at 29 (providing a chart of nanotechnology's potential applications for energy processing).
101. See Drexler, supra note 47, at 172-73, 241 (describing the so called "gray goo" problem); see also Accidents, Malice, Progress, and Other Topics, FORESIGHT BACKGROUND 2, REV. 1 (1987-91), at http://www.foresight.org/Updates/Background2.html.
103. Phoenix & Treder, supra note 17.
104. Wolfson, supra note 18, at 381.
105. Id.
106. Id.
107. Id.
108. See generally DREXLER, supra note 24, at 246-64; see also H.R. 766 Hearings, supra note 37, at 66 (statement of Christine Peterson, President, Foresight Institute).
efit from what it has to offer, but also to have a regulatory scheme in place to provide guidance and ensure safety.

II.
THE WEAPONS CONVENTIONS

A. Biological Weapons

1. Biological Warfare

Biological warfare, also known as "germ" or "bacteriological" warfare, is the use of living organisms or their infective material that are "intended to cause disease or death" and "depend for their effects on their ability to multiply" in the victim. While the origin of biological warfare is unknown, its first uses can be traced back to around 600 B.C. Such early uses involved spreading of infection through the use of corpses and filth, as well as the use of poisonous roots. Hannibal was known to catapult poisonous snakes at enemy ships and to leave poisoned wine for advancing enemy forces to drink as they looted the camp. In 1763, the British used smallpox against Native Americans by trading purposely-infected blankets.

The advantage of biological weapons is that they result in mass death without harming physical infrastructure. They are alluring because their "slow-acting effects resemble natural maladies, making it difficult for the victim to attribute damage to the enemy." Usually invisible, the particles enter the body or infect the food or water supply before anyone is aware of their presence. However, biological weapons are uncontrollable and unreliable and may linger, potentially causing harm to the invading attacker. Even worse, biological weapons can evolve and multiply out of control, risking contamination of the attacker's land.

2. Geneva Protocol

Although biological weapons have been used for millennia, the first international treaty regulating the use of such weapons was in 1925. The Geneva
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Protocol prohibited only the use of biological weapons, not their development, testing, production, or stockpiling. The Geneva Protocol also only applied to times of war, not during times of peace. Despite the existence of this treaty, countries continued to produce, stockpile, and even use biological weapons. In fact, two growing world powers, Japan and the United States, did not even ratify the Protocol. Additionally, several nations expressed reservations to the Protocol, effectively creating exceptions to the ban. These two factors significantly weakened the influence of the Protocol. In 1970, however, the United States destroyed its stockpile of such weapons, just as other nations began to push for an alternative to the Geneva Protocol.

3. Biological Weapons Convention ("BWC")

The BWC developed in 1972 as a result of U.S. resolve to rid both itself and the world of biological weapons. Negotiations for a stronger rule of law led to the BWC. Unlike the Protocol, the three major world powers—the United States, Russia, and the United Kingdom—ratified the BWC, lending it credibility.

The BWC bans the "development, production, stockpiling, acquisition, or retention of biological weapons or biological agents in types or amounts that are not justified for peaceful purposes." Unlike the Geneva Protocol, the BWC is an arms control treaty; its provisions apply at all times. While countries were allowed to join starting on April 10, 1972, the BWC did not take effect until March 26, 1975, at which time twenty-two states, including the Soviet Union, the United Kingdom, and the United States, joined the Convention. The BWC is of unlimited duration and had 147 members as of December, 2002. Sixteen countries have signed but not ratified the BWC—including Egypt and Syria—and thirty countries have failed to sign the BWC—including Israel and Sudan.

120. Paris, supra note 110, at 516.
121. Id. at 517.
122. Id.
123. Keefer, supra note 111, at 121.
124. Id. at 121-22.
125. Id.
126. Paris, supra note 110, at 517.
127. Keefer, supra note 111, at 122.
128. Id.
129. Id.
130. Dagen, supra note 118, at 546.
131. Id. at 547.
133. Id.
134. Id.
What distinguishes the BWC from other weapons conventions is that it is the “first disarmament treaty to completely ban an entire class of weapons.”\textsuperscript{135} The BWC prohibits the development, production, stockpiling, acquisition and retention of microbial or other biological agents or toxins in types and quantities that have “no justification for prophylactic, protective or other peaceful purposes.”\textsuperscript{136} All weapons, equipment, and means of delivery designed to use such agents are also prohibited when they are designed to be used “for hostile purposes or in armed conflict.”\textsuperscript{137} Article II is viewed as the nucleus of the BWC because it “provides for actual disarmament and sets a time limit for destruction of the weapons.”\textsuperscript{138} Article III prohibits members from transferring any of these agents, toxins, weapons, equipment, or means of delivery mentioned in Article I to other states or organizations, and also forbids them from encouraging any state or organization to acquire such materials.\textsuperscript{139} Article IV requires parties to ensure that the BWC is followed within their territory.\textsuperscript{140}

In order to prevent the proliferation of biological weapons, the BWC incorporates a method for addressing alleged violations.\textsuperscript{141} In Article VI, a party alleging violations by another party may file a detailed complaint with the United Nations Security Council.\textsuperscript{142} If an investigation is commenced, all parties must cooperate pursuant to Articles VI-VII.\textsuperscript{143} These enforcement provisions, however, are criticized for their lack of verification measures.\textsuperscript{144} Article X is also significant in that it discusses peaceful scientific research and development, allowing parties to participate in any legitimate, peaceful activities involving biological agents.\textsuperscript{145} This appears to include defensive, commercial, and health-related applications. Article X provides for the facilitation of the “fullest possible exchange of equipment, materials and scientific and technological information” for the use of biological agents and toxins for peaceful purposes.\textsuperscript{146} While Article XI allows for amendments to the BWC, Article XII provides for a conference “to review the operation” of the BWC “with a view to assuring that the purposes and the provisions of the BWC are being realized.”\textsuperscript{147} The remaining articles deal with duration, withdrawal, the signing and ratification process, and other administrative issues.\textsuperscript{148}

\begin{thebibliography}{99}
\bibitem{135} Id.
\bibitem{136} BWC, supra note 21, art. I, 26 U.S.T. at 587, 1015 U.N.T.S. at 166.
\bibitem{137} Id.
\bibitem{138} Paris, supra note 110, at 519.
\bibitem{139} See BWC, supra note 21, art. III, 26 U.S.T. at 587, 1015 U.N.T.S. at 167.
\bibitem{140} Id., art. IV, 26 U.S.T. at 588, 1015 U.N.T.S. at 167.
\bibitem{141} Dagen, supra note 118, at 547. See also BWC, supra note 21, art. VI, 26 U.S.T. at 588, 1015 U.N.T.S. at 167.
\bibitem{142} See id.
\bibitem{143} Id., arts. VI-VII, 26 U.S.T. at 588-89, 1015 U.N.T.S. at 167. See also Dagen, supra note 118, at 547.
\bibitem{144} Dagen, supra note 118, at 548.
\bibitem{145} Paris, supra note 110, at 519; see also BWC, supra note 21, art. X, 26 U.S.T. at 590, 1015 U.N.T.S. at 167-68.
\bibitem{146} Id.
\bibitem{147} Id., arts. XI-XII, 26 U.S.T. at 590-91, 1015 U.N.T.S. at 168.
\end{thebibliography}
In addition to the definition of prohibited biological agents provided above, the BWC also prohibits toxins, regardless of their properties. Agents created using recombinant DNA or genetic engineering that fit this definition are also included under the BWC. While the BWC does not explicitly prohibit the “use” of biological weapons, the Final Declaration of the 1996 Treaty Review Conference reaffirmed that the Convention prohibits this type of use.

B. Chemical Weapons

1. History

While not as old as biological weapons, chemical weapons have been used extensively in war, particularly in World War II and most recently by Iraq. The Geneva Protocol banned the wartime use of chemical weapons in the form of poisonous gas, but unfortunately the Protocol failed to effectively remove such weapons from the battlefields. Chemical weapons were apparently used by both sides during the Iran-Iraq war and by Saddam Hussein against the Kurds in the early 1980s. Because the Geneva Protocol failed to prevent the development, proliferation, and use of chemical weapons, the need for a new treaty was recognized.

2. What Are Chemical Weapons Under the CWC?

Recognizing the inadequacies of the Protocol and the growing proliferation of chemical weapons, the Conference on Disarmament was authorized by the United Nations to “negotiate a multilateral convention that would completely and effectively prohibit the development, production, stockpiling, and transfer of these weapons.” On January 13, 1993, the CWC was opened for signature. After the requisite sixty-five countries ratified it, the CWC entered into force on April 29, 1997.

149. See Paris, supra note 110 and accompanying text. Oddly enough, the BWC does not specifically mention any covered agents. Biological warfare is the “wartime use of living organisms, usually micro-organisms, for hostile purposes, such organisms causing disease or death in man, animals, or plants following multiplication within the target organism.” Elizabeth A. Smith, International Regulation of Chemical and Biological Warfare: “Yellow Rain” and Arms Control, 1984 U. Ill. L. Rev. 1011, 1011 n.6 (1984) (quoting Howard S. Levie, Humanitarian Restrictions on Chemical and Biological Weapons, 13 U. Tol. L. Rev. 1192 (1982)).
150. Smith, supra note 149, at 1044.
151. Id. at 1044 n.222.
152. Rissanen, supra note 137.
154. Id. at 762-63.
155. Id. at 809.
156. Id. at 809-10.
157. Id. at 810.
159. Id. For a listing of the signatory nations, see http://www.opcw.org/html/db/members_ratifyer.html.
The Chemical Weapons Convention defines "chemical weapons" as, together or separately:

(a) Toxic chemicals and their precursors, except where intended for purposes not prohibited under the Convention, as long as types and quantities are consistent with such purposes;

(b) Munitions and devices, specifically designed to cause death or other harm through the toxic properties of those toxic chemicals specified in subparagraph (a) above, which would be released as a result of the employment of such munitions and devices;

(c) Any equipment specifically designed for use directly in connection with the employment of munitions and devices specified in subparagraph (b).\textsuperscript{160}

The definition of chemical weapons in subparagraph (a) is intentionally broad to prohibit known and unknown toxic chemicals, including those developed in the future, in "types and quantities that cannot be justified" for the defined permitted purposes.\textsuperscript{161} This definition attempts to encompass any chemical agents that may be developed in the future. Subparagraphs (b) and (c) also prohibit any munitions and devices specifically designed to release chemical weapons, including spray tanks and canisters, as well as any equipment specifically designed to be used solely in connection with such munitions and devices.\textsuperscript{162} This all-inclusive definition seeks to not only prevent the existence of banned substances, but to also prohibit the development, possession, and use of items normally associated with chemical warfare, such as gas canisters and the trucks that carry them. However, because of the language "directly," dual-use munitions and their components are not banned as long as they do not otherwise meet the definition of a chemical weapon.\textsuperscript{163} Members are therefore allowed to possess tanks, aircraft, and other weapon systems with the potential to deliver or carry chemical weapons, if they are needed to participate in conventional warfare.\textsuperscript{164}

The term "toxic chemical" is defined as "any chemical which through its chemical action on life processes can cause death, temporary incapacitation or permanent harm to humans or animals."\textsuperscript{165} The definition includes all such chemicals, "regardless of their origin or their method of production, and regardless of whether they are produced in facilities, in munitions or elsewhere."\textsuperscript{166} The wording of this definition is intended to cover toxins, organic chemicals, inorganic chemicals, and chemicals produced by binary and multicomponent

\textsuperscript{160} CWC, supra note 20, art. II, 1974 U.N.T.S. at 319-20.
\textsuperscript{162} Id. at *63. Perhaps this equipment refers to equipment used to assemble the munitions and devices or to deliver them to the battlefield (that is, launchers).
\textsuperscript{163} Id. at *64.
\textsuperscript{164} Id.
\textsuperscript{165} Id. at *23-24.
\textsuperscript{166} Id. (parentheticals omitted).
Article II of the CWC defines which chemicals are considered chemical weapons.

The purposes not prohibited under the CWC as mentioned above in subparagraph (a) are listed in Paragraph 9 of Article II and include:

(a) Industrial, agricultural, research, medical, pharmaceutical or other peaceful purposes;
(b) Protective purposes, namely those purposes directly related to protection against toxic chemicals and to protection against chemical weapons;
(c) Military purposes not connected with the use of chemical weapons and not dependent on the use of the toxic properties of chemicals as a method of warfare; and
(d) Law enforcement including domestic riot control purposes. 168

With this language, the CWC allows use of toxic chemicals and their precursors, as long as they are of a type and quantity consistent with one or more of these enumerated purposes. 169 Thus, countries may still use these chemicals for such purposes as "gaining confidence in chemical defense training and equipment and using riot control agents for chemical defense training" as well as for purposes "not dependent upon the toxic properties of the chemicals as a method of warfare, such as the use of toxic chemicals as fuels, lubricants or cleaners." 170 Finally, countries may still use toxic chemicals for law enforcement, although the type used must be consistent with that purpose. 171

3. The Chemical Weapons Convention Regulatory Scheme

The CWC prohibits the development, production, stockpiling, and use of chemical weapons. 172 Because it is so easy for a country with a modem chemical industry to produce chemical weapons, the CWC creates a powerful regime to oversee the parties and ensure that they comply with the objectives of the CWC. 173 The key to the CWC is its verification procedure—every party to the agreement is subject to the verification measures. 174 This requires an "elaborate mechanism for monitoring all production and acquisition of various chemicals." 175

The Verification Annex of the CWC describes the verification process. Part II has multiple sections dealing with the general verification process. Section A describes how inspectors are designated and how members subject to inspection can accept or reject specific inspectors. 176 However, once an inspection is announced, the subject country cannot reject any inspector on that inspec-

167. Id. at *64-65.
168. Id. at *23-24.
169. Id. at *73.
170. Id. at *73-74.
171. Id. at *74. Something like nerve gas cannot be used for "capturing escaping prisoners."
174. Id.
175. Id. at 812.
Section B grants diplomatic privileges and immunities to inspectors, their assistants, and observers. Many of these immunities and privileges are similar to those held by regular diplomats and inspectors under the Intermediate-Range Nuclear Forces Treaty and the Strategic Arms Reduction Treaty. Section C contains the arrangements regarding "points of entry, respective rights and obligations when more than one State is involved in an inspection . . . administrative arrangements, and use of approved equipment." Section D describes the required pre-inspection activities of notice, entry, transit, and briefings. Section E sets forth the general rules for conduct of inspections, including "provisions on safety and communications, inspection team and inspected State Party rights, and provisions on the collection, handling and analysis of samples, extension of inspection duration, and debriefing by the inspection team." The rest of Part II discusses the final report of the inspectors and how the general provisions apply also to more specific provisions in the Verification Annex.

Two innovative aspects of the CWC make it more advanced than other weapons treaties. First, a series of "Schedules" determines the level of regulation for dual-use substances; second, challenge inspections may occur, with some limitations, at any facility where reasonable doubt exists regarding compliance with provisions of the CWC. Three Schedules exist that divide precursor chemicals according to the ease of using them to make a prohibited substance and their legitimate, non-prohibited value.

Schedule 1 covers "supertoxic lethal chemicals" that:
(1) are actual warfare agents;
(2) pose a high risk of potential use as chemical weapons;
(3) are key precursors with chemical structures closely related to chemical weapons;
(4) pose a high risk of conversion into chemical weapons; or
(5) have little use for purposes other than chemical weapons.

Schedule 2 deals with chemicals that have some legitimate commercial uses, but are also key precursors posing a significant threat to CWC objectives. Schedule 3 contains chemicals that are "several steps removed from warfare agents," but have properties similar either to chemicals used in weapons

177. Id.
179. CWC S. TREATY DOC., supra note 161, at *265. For a list of the specific provisions, see id. at *267-73.
180. Id. at *276.
181. Id. at *296-97.
182. Id. at *312-316.
185. Kellman, supra note 115, at 812.
186. Id. at 812-13.
or important precursors to chemicals in Schedules 1 or 2. Because chemicals and facilities vary based on their potential risks to the purpose of the CWC—the prohibition and destruction of chemical weapons—the chemicals are broken down into three categories based "on increasing utility in civilian production and a decreasing perception of risk." Each Schedule has differing limits on production, verification regimes for source facilities, and requirements for declarations. The determining risk is based on "the toxicity of the chemical, its potential use in the chemical weapons production process, and the purpose for which it has been, is currently, or could be used." While most known toxic chemicals have already been placed in the Schedules, the placement of future additions depends on "the potential for use in an activity prohibited by the [CWC]; the volume of peaceful production; past history of use as a chemical weapon; and level of toxicity." The level of regulation lessens as the Schedules descend: Schedule 1 requires the highest level of regulation and Schedule 3 requires the lowest.

Challenge inspections serve to complement routine inspections, deterring violations and gathering information without hampering members' development. If a member suspects another's noncompliance, it may request an inspection at any location or facility. Upon such request, the country under suspicion must "make every reasonable effort" to demonstrate compliance. "If suspicions remain, an inspection team will arrive after twelve hours' [sic] notice, and the inspected state must transport the team to the challenged facility within twenty-four hours." After negotiating the terms and extent of the inspection, the inspectors have eighty-four hours to complete their inspection unless an extension is allowed by the inspected nation. Through the use of routine and challenge inspections, the CWC attempts to sufficiently detect violations while also protecting national security, commercial secrets, and privacy rights of the member nations and their chemical industries.

III. DO THE WARFARE TREATIES APPLY TO NANOTECHNOLOGY?

A. The Concept

In 2001, Glenn H. Reynolds suggested that nanotechnological devices developed for military use may fall under the BWC or the CWC. While noting...
that such devices "would be functional equivalents of chemical and biological weapons," Reynolds speculated that they most likely do not fall under the purview of either of the two treaties. Arguably, nanotechnological weapons would somehow work differently than chemical or biological weapons; however, there are such great similarities between natural molecular technology and nanotechnology that there may be no justification for separating the two. This determination ultimately depends on the use and function of the nanotechnology and does not apply universally.

B. Biological Weapon Under the BWC?

Certain types of nanotechnology fit a portion of the current definition of a biological weapon; something used with the intent to kill or cause disease and which is able to multiply in the victim to cause the intended effect. However, it is unclear whether any nanotechnologies fit the aspect of the definition about being a living organism. While some types of nanotechnology may resemble bacteria or viruses, the fact that they are mechanically assembled seems to indicate that they cannot be classified as living organisms.

Article I of the BWC prohibits the development, production, and possession of “[m]icrobial or other biological agents, or toxins whatever their origin or method of production . . .” Assuming microbial or biological agents should be considered living things, can a toxin be something inorganic or artificially created? Since the phrase “whatever their origin or method of production” relates to toxins because of the comma placement, it seems to include so-called mechanical devices that could result from mature nanotechnology. In this sense, one can argue that nanotechnology—particularly nanorobots—can be treated as a toxin if it causes harm similar to other already known toxins. However, because the BWC seems to deal only with biological organisms or products thereof, a strong argument can be made that the artificially assembled products that nanotechnology would produce cannot possibly fit under the BWC. Perhaps the only way nanotechnology can fall under the BWC’s prohibitions without a doubt is if it were used to artificially create exact replicas of known biological weapons or toxins. Only then would it clearly be covered since no difference would exist between the natural product and the “artificial” version. However, nanotechnology as a field is much broader than these narrow “biological replica” applications.

Another issue arises with the “prophylactic, protective or other peaceful purposes” language in the BWC. It can be argued that almost any biological agent or toxin can be maintained for one of these reasons. Self defense, training,
improvement of safety, or vaccination are perfectly legitimate reasons for keeping stockpiles of some of the worst biological weapons. Of course, very low quantities would be required because of the organism's ability to grow in the right medium. The same goes for nanotechnology, especially if it is able to self-replicate upon command. It may be argued, however, that possessing the types of nanotechnology that even remotely resemble a biological weapon is not justified, even for other peaceful purposes. In this sense, universal assemblers—nanotech devices that can construct anything—would likely be treated as biological weapons. But it would be overkill to ban such a valuable tool that can do so much more.

Uses of nanotechnology that were beneficial to humanity would most certainly fit under the peaceful purposes exception. For example, nano-devices used to prevent diseases would likely be for a "prophylactic, protective or other peaceful purpose." Performance-enhancing nanotechnology could also be a peaceful purpose, even if it is used in soldiers, because the technology itself would not be used as a weapon. It would only make a current "conventional" weapon—our soldiers—more lethal. In addition, refinements of already existing conventional weapons by nanotechnology would be allowed under the BWC because the underlying weapon is not a biological agent or toxin. Even if it were treated as a biological weapon, it would still be allowed under the BWC because it would be for a protective purpose, which is allowed under Article I.

The final flaw in the BWC is the absence of an effective verification process. A verification regime for the BWC is difficult because "any nation with a developed pharmaceutical industry has the potential to make biological weapons." The small amount of the agent required to create a biological weapon also makes verification difficult. Additionally, the materials used to create biological weapons are difficult to monitor because they are commonly "dual use technologies that can be used legitimately for pharmaceutical purposes." Finally, due to the competitive market for pharmaceuticals and biotechnology, private firms are reluctant to "volunteer information that could compromise their economic advantage."

While it is possible to stretch the language of the BWC to include some uses of nanotechnology as biological weapons, one can easily justify the position that these uses are beyond the prohibitions. The only categories of nanotechnology proposed that may possibly fall under the purview of the BWC are the nanodevices that act like other biological weapons and the "artificially created" biological agents and toxins that are exactly like their natural forms. These come closest to the definition of a biological weapon, although as previously stated, doubt exists as to whether they would be considered "living organisms."

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204. Id.
206. Id.
207. Id.
208. Id.
In addition, the BWC is riddled with so many loopholes that the exceptions essentially swallow the rule, thus rendering the BWC ineffective. Furthermore, even if such uses were effectively prohibited, the BWC lacks an effective verification and enforcement regime.\textsuperscript{209} No method would exist to guarantee that prohibited uses of nanotechnology were not being developed. Absent military action,\textsuperscript{210} no one would be able to make sure the rules were being followed. Should a terrorist organization or rogue state develop nanotechnology, regulation under the BWC would not allow for discovery of this development until after the fact.\textsuperscript{211}

\textbf{C. Chemical Weapon Under the CWC?}

The CWC is a different story because a higher likelihood exists that specific uses of nanotechnology will fall under its provisions. The CWC defines chemical weapons as "[t]oxic chemicals and their precursors, except where intended for purposes not prohibited under this Convention."\textsuperscript{212} This "purposes not prohibited" language is pivotal, and it is where I begin my analysis.

The first subset of non-prohibited purposes includes "[i]ndustrial, agricultural, research, medical, pharmaceutical or other peaceful purposes."\textsuperscript{213} The phrase "other peaceful purposes" appears to represent peaceful purposes similar to those purposes listed just before it. This entire group encompasses the full spectrum of regular commercial uses of chemicals—purposes which are allowed under the CWC.

The use of nanotechnology in fabrics and coatings in non-military capacities would fall under either the "industrial" or "other peaceful purposes" and could not be considered a toxic chemical. Nano-sensor systems would also satisfy a non-prohibited purpose if used for research, medicine, or regular commercial activities like tracking cars, boats, or planes. In general, the use of performance-enhancing nanotechnology would comply with this first category of permitted purposes even if developed by the military because it could not be considered a toxic chemical under the CWC since it would not "cause death, temporary incapacitation or permanent harm."\textsuperscript{214} Additionally, nano-devices used to cure or prevent diseases, cancers, and other illnesses would fall within the "medical" and "pharmaceutical" purposes.

The next category of permitted purposes includes "[p]rotective purposes, namely those purposes directly related to protection against toxic chemicals and

\begin{itemize}
\item \textsuperscript{209} See Dagen, supra note 118.
\item \textsuperscript{210} The recent invasion of Iraq is a perfect example of this.
\item \textsuperscript{211} This is especially true considering the small amounts of self-replicating nano-devices required to have an efficient program. Note that even when they were parties to the BWC, nations like the Soviet Union/Russia and Iraq continued to develop and possess biological weapons. Dagen, supra note 118, at 548 n.88. It seems likely that such deceitful acts will continue with the evolution of nanotechnology.
\item \textsuperscript{212} CWC, supra note 20, art. II, 1974 U.N.T.S. at 319.
\item \textsuperscript{213} Id., art. II, at 322.
\item \textsuperscript{214} Id., art. II, at 320.
\end{itemize}
to protection against chemical weapons." Any product or device created by nanotechnology to defend against chemical weapons would fit under this purpose since its sole function would be protective. However, such a product or device could easily become an offensive weapon but still be allowed under the CWC. Materials using nanotechnology to destroy such agents, even if used by the military, would also fall under the protective purpose provision. However, other nanotechnology-added properties within the same material not directly related to protection against chemical weapons would possibly need to meet another exception, such as those discussed in the paragraphs immediately above and below. Similar devices implanted into the body would also fit under this exception because they have the same defensive and protective quality.

The final category of permitted purposes includes "[m]ilitary purposes not connected with the use of chemical weapons . . . ." Such purposes for nanotechnology include all battle gear, sensors, and other nano-materials used in and on equipment, vehicles, boats, planes, and other similar objects in the military. Along these same lines, any remote-controlled vehicles or combat platforms would qualify under a permitted purpose if they used nanotechnology, as they likely would not be connected with chemical weapons. Additionally, any toxic property that these items may possess likely would not be the reason for harming or killing another. Since these are predominantly conventional weapons and weapons systems, they would not fall under the CWC, which was intended to cover chemical and not conventional warfare. To argue otherwise would be similar to arguing that bullets are toxic because they cause death by interacting with the flesh and bone of a human person. Thus, the use of nanotechnology for conventional weapon purposes would be "permitted" military purposes under the CWC. Additionally, many nanotechnology uses could fit under more than one of these categories, strengthening the argument that they are permitted under the CWC because the exceptions are so broad.

The next question is whether any use of nanotechnology would be viewed as a "toxic chemical" pursuant to the CWC. This classification covers "any chemical which through its chemical action on life processes can cause death, temporary incapacitation or permanent harm to humans or animals." Certain types of nanotechnologies easily fit under this definition because they naturally interact with their hosts chemically. Relevant uses are the nano-germs and nano-assassins that essentially act like chemical and biological weapons, but are

215. Id., art II, at 322 (emphasis added). This category must be broadly interpreted, including "civilian measures against industrial poisoning and the like, as well as military measures against the use of chemical weapons . . . . Protective military measures, however, must be of a purely defensive character." Cipolat, supra note 158, at 409.
217. Cipolat, supra note 158, at 409.
218. Id. (discussing how uses of chemicals for "conventional weapons purposes, such as the production of rocket fuels, explosives, incendiaries or similar generating ammunitions" are permitted military purposes).
220. Id.
completely man-made as opposed to grown or cultivated. Because the origin and method of production are unimportant, the only remaining issue is whether these types of nanotechnology are "chemicals." While they may not be chemicals in the sense originally conceived of by the CWC drafters, nanotechnology might still be perceived as a functional equivalent and thereby covered under the CWC.

One observer has noted that the term "toxic chemical" covers "virtually all chemicals" because any chemical can cause harm or death "provided that its quantity is high enough." This observation misses the point. The drafters had a class of chemicals in mind: chemicals that cause harm or death in small-to-reasonable doses. As such, caffeine should not be viewed as a "toxic chemical" under the CWC just because a high dosage can kill. Despite these concerns, nano-germs and nano-assassins that are similar in nature to a chemical weapon, especially considering the malicious intent behind their function and design, have the greatest chance of being covered by the CWC. It is possible these nanotechnologies could be characterized as a chemical, their interaction with living organisms causing harm or death. These nanodevices could be prohibited as a toxic chemical under the CWC, as they would have no purpose other than causing harm or death to humans or animals.

A more interesting and pressing issue is whether nanotechnology designed to attack and destroy machines or inorganic objects should be considered a chemical weapon. Such technology cannot be considered a toxic chemical because it does not cause "death, temporary incapacitation or permanent harm to humans or animals." While the CWC may apply to inorganic chemicals, this type of technology does not have the requisite effect on living organisms. Because of the broad purposes allowed as exceptions under the CWC's ban, most uses of nanotechnology would not fall within its prohibitions. It seems that something more is needed to protect against the dangers of nanotechnology.

IV.
A NEW TREATY?

A. The BWC and the CWC Are Inadequate With Regard to Nanotechnology

The BWC and the CWC are inadequate as forms of regulation of nanotechnology. In fact, while the CWC is more effective than the BWC in controlling its target weapons, one can argue that both are wholly ineffective as weapons conventions even as to biological and chemical weapons.

221. See id.
222. Cipolat, supra note 158, at 401.
223. Almost any everyday chemical (milk, for example) can be applied to this scenario. It seems odd that the CWC was written to cover all chemicals and does not expressly state such a fact. The types of chemicals contemplated by the CWC are those that cause injury by simple contact with living organisms.
225. CWC S. TREATY DOC., supra note 161, at *64-65.
The BWC was drafted at a time when advanced biological weapons were improbable; they were seen as "unreliable, slow in action, and unpredictable in effect."\(^{226}\) Today, we know that these views were incorrect. Additionally, because many biological agents are dual-use, creating a verification regime for the BWC is difficult, if not impossible.\(^{227}\) Recent events demonstrate that the BWC is ineffective in banning biological weapons. In 1992, Russia, a member of the BWC, admitted to violating its provisions.\(^{228}\) Iraq, another member, is also infamous for its alleged violations of the BWC.\(^{229}\) These incidents weaken the BWC's effectiveness as a treaty because the treaty relies on an enforcement process—international pressure—that has clearly failed.\(^{230}\) The BWC cannot even enforce compliance on members that are highly suspected of violating its provisions.

While the CWC is a stronger, more complete weapons treaty than the BWC, it still contains many flaws, and commentators have raised concerns as to the CWC's ability to sufficiently diminish the threat of chemical weapons.\(^{231}\) The first concern is that the CWC does not extend to terrorist groups; thus, "they are left unrestricted in their capacity to produce chemical or biological weapons."\(^{232}\) The second concern is that the CWC does not apply to nations that do not ratify its provisions.\(^{233}\) Such nations can produce and sell chemical weapons without being monitored in their activities.\(^{234}\) Finally, compliance cannot be fully ensured because military force is not authorized to do so,\(^{235}\) leaving the parties to the CWC with economic sanctions as their greatest sanction.

The CWC, like the BWC, was not written with nanotech in mind. Therefore, manipulating the language to attempt to fit nanotechnology is inappropriate—and often awkward. First, most uses of nanotechnology cannot fit under the phrase "toxic chemicals and their precursors" in the CWC.\(^{236}\) Being a toxic chemical is the strongest argument for coverage of nanotech under the CWC for uses like nano-germs and nano-assassins. However, because of the vagueness of the word "chemical," any country can argue that nanotech is not covered under this term and thus not prohibited. Because of this vagueness, the CWC should not be relied on as a regulatory scheme for nanotech. Second, the list of purposes allowed as exceptions under the CWC\(^{237}\) encompass almost every pre-

\(^{226}\) Paris, supra note 110, at 548.

\(^{227}\) Id. at 549. An effective verification regime is a daunting task that many will likely not respect or even support because of the vast number of biological agents, coupled with the use of these agents to develop cures.

\(^{228}\) Dagen, supra note 118, at 548 n.88.

\(^{229}\) Id.

\(^{230}\) Id.


\(^{232}\) Id.

\(^{233}\) Id. North Korea and Libya are examples of such nations.

\(^{234}\) Id. at 552-53.

\(^{235}\) Id. at 553.

\(^{236}\) See CWC, supra note 20, art. II, 1974 U.N.T.S. at 319.

\(^{237}\) See id. at 319-20; see also notes 172 to 175 and accompanying text.
dicted use of nanotechnology. Even the uses that most closely resemble chemical weapons—namely, nano-germs and nano-assassins—may be classified under one or more of these allowed uses.

Since neither the BWC nor the CWC are effective as they stand, perhaps each may be amended. Under Article XI of the BWC, amendments must be approved by a majority of the members.\(^{238}\) These amendments, however, do not apply unless a member accepts the amendment.\(^{239}\) Thus, if a nation or nations do not like the amendment, they will not have to abide by it. Therefore, attempting to amend the BWC would be futile because it would not be automatically binding. As for the CWC, amendments may be made “only through a stringent, formal amendment process requiring the support of a majority of all States Parties with no State Party casting a negative vote, followed by ratification or acceptance by all the supporting States Parties.”\(^{240}\) Again, a member must accept an amendment in order for it to be binding upon that member. Additionally, no member may vote against the amendment. Such a process makes an effort to amend the CWC a futile task.

**B. A New Treaty is Necessary**

The unique development and characteristics of nanotechnology complicate attempts to fit it within current definitions and classifications.\(^{241}\) Even though most, if not all, nanotechnologies are not covered by current weapons treaties, it does not follow that outdated documents should be amended to regulate the growth of this spectacular and dangerous technological revolution. Something new is required: a device that accounts for the novelties of nanotechnology while allowing for change as the new technology matures. Proponents and critics of nanotechnology have at least one thing in common: a belief that nanotech needs to be developed in the open and that a wide range of interests must participate in discussions on the future development and use of nanotechnology.\(^{242}\) The use of currently existing treaties and regulations fail because of the unique nature of nanotechnology. While they may be sufficient for the worst types of uses, something is needed to cover all of nanotechnology because so many different possibilities exist for its misuse.

Regulation of nanotechnology will be difficult because of three unique characteristics: invisibility, micro-locomotion, and self-replication.\(^ {243}\) Nanotechnology is unique because it will be the “first complex constructions intentionally engineered to accomplish human purposes at a microscopic (or sub-microscopic) level.”\(^ {244}\) This property causes problems because of the difficulty of regulating what one cannot see. A jurisdictional problem arises from na-
nototechnology's micro-locomotion. The existence of "free ranging nanites" will "radically challenge traditional understandings of macro-boundaries and barriers."\textsuperscript{245} Even human skin will be an open space to many nano-devices.\textsuperscript{246} Self-replication, although not a necessary property of nanotechnology, may become essential for the "economical production of complex nano-mechanisms in useful quantities."\textsuperscript{247} Regulation is of the utmost importance in this area because without it a "population of carelessly designed self-replicating nanites could grow exponentially, without a ready 'off switch.'"\textsuperscript{248} With all these elements to consider, the existence of even the simplest nano-device requires a total and complete transformation of "society's current legal and normative structures."\textsuperscript{249} Three key areas where regulation of nanotechnology will be particularly difficult are monitoring, ownership, and control.\textsuperscript{250} These areas will require most of the focus of regulatory policies.

\textbf{C. What to Regulate}

While more research is required about the dangers associated with nanotechnology, it appears that most uses are harmless and need not be regulated. Perhaps a new nanotechnology treaty can prohibit not only the use of nanotechnology to cause physical or economic harm to living organisms and inanimate objects, but also the development of anything that could possibly do such harm. To enforce this new treaty, an oversight group might be created and given full and complete access to anything they require. A method of recourse can be established if this oversight group reveals any private or commercial information not related to a prohibited act. Penalties sufficiently severe to cause compliance are necessary. Perhaps military action or substantial economic sanctions can serve as inducements. Sanctions under this new regime must be effectively more than a slap on the wrist, even for the United States.

Regarding the types of nanotechnology to be covered under a treaty, most do not likely need to be included. For example, most common products that are merely enhanced with nanotechnology, like materials, computers, and solar panels, need not be included. What should be included are self-assemblers and other forms of nanotechnology that either duplicate themselves or possess the ability to create anything. This is important because universal assemblers might be used to instantly reform existing matter into a batch of terrible toxins. This

\textsuperscript{245.} Id.
\textsuperscript{246.} Id.
\textsuperscript{247.} Id.
\textsuperscript{248.} Id.
\textsuperscript{249.} Id.
\textsuperscript{250.} Id. All three properties mentioned above will pose novel issues to the ability to monitor nanotechnology. No longer will people be able to "observe all the socially relevant activities in their own surroundings." Id. The government must find a way to police nanotechnology without endangering individual privacy—a very difficult balance. New tort actions will likely develop based on trespass where invisible objects enter someone's property, or even his/her person, without consent. Cf. id. at 215. Control, as well as responsibility, will be the most important aspects of regulation. The new realm of "nano-space" opens up entire worlds to society, and may leave critical gaps in existing laws.
type of activity is impossible to monitor and prevent. Thus, preemptive constraints must be placed upon these devices so that they are unable to create certain types of products. Additionally, nanotech inventions that involve medicine and drug delivery may have to be heavily regulated because these uses are similar to chemical and biological weapons and can be easily converted to perform prohibited tasks.

The new treaty must also be all-encompassing, covering all groups, countries, and corporations, as well as all situations whether in a time of peace, war, or in between. All the loopholes and gaps left open in treaties like the BWC and CWC must be closed. Additionally, this new treaty may have to be forced upon all nations because if some countries do not sign or are allowed to have "exceptions," the treaty's purpose would be wasted. Coverage must be total or else a nanotechnology arms race will surely result.

D. How to Regulate

An outright ban on nanotechnology is infeasible. Since nanotechnology is already being used and developed, it is too late for a total ban—even if that would be desirable, which it would not be. To quote Professor Reynolds, "[W]hen nanotechnology is outlawed, only outlaws will have nanotechnology .... All that a nanotechnology ban will achieve is to ensure that the good guys are at a disadvantage."251 While a moratorium on nanotechnology research and development is unworkable, the concerns underlying those calls for prohibition are not without merit.252 However, a total ban on nanotechnology would actually "make things worse since rogue states will then hold a monopoly on a powerful technology, while the civilized world will lack the wherewithal to deploy countermeasures."253

That said, the "precautionary principle" of international law may nevertheless require the prohibition of nanotechnology. Although still vaguely defined,254 the precautionary principle says that "when there is any risk of a major disaster, no action should be permitted that increases the risk."255 If an action promises both substantial benefits and the risk of major disasters, as is the case with nanotechnology, no balancing of these benefits and risks should occur and the action must be prohibited.256 This preventative policy arose from "the understanding that scientific certainty is often achieved too late for the development of effective legal policy responses to environmental threats" and

253. Id. at 9.
254. Lin-Easton, supra note 29, at 120-21. The precautionary principle is predominantly discussed in international environmental law. Id.
256. Id. The opposing view (what Dyson calls "libertarian") considers risks unavoidable, with no possible course of action (or inaction) to eliminate those risks. Id.
uncertainty should not "be used as a reason for delaying measures to prevent environmental harm." 257

Although the precautionary principle calls for an outright ban on technology, this can be lifted if four criteria are met: (1) the proponents of the technology bear the burden of proving its safety; (2) all alternatives, including inaction, must be fully considered; (3) the developers of the technology have a duty to prevent harm; and (4) the development process must be open and informal. 258 The precautionary principle can apply to nanotechnology because it poses a risk of harm to the environment, most notably the "gray goo" problem. 259

While it would be wise to take into consideration the underlying tenets of the precautionary principle, an outright ban would not be feasible at this time. Alternatively, we cannot leave the development of nanotechnology unabated. A middle ground must be sought where some regulation exists. A regulatory regime over nanotechnology can be neither overly burdensome nor too loose. 260 In the case of the former, unnecessary rules could stunt the growth of nanotechnology or even lead to no growth at all. 261 In the case of the latter, the "lack of necessary rules or vigilance could lead to safety hazards" and potential proliferation. 262 Additionally, too little regulation could block the ability to subsequently develop stricter guidelines while too much regulation would likely create a black market or lead to technology flight.

A moderate regulatory regime should "focus more on preventing deliberate destructive uses than prevention of accidents." 263 Access could be limited, at least for the nanotechnological uses that are deemed dangerous—for example, to licensed professionals or registered researchers. 264 Although extremely difficult because of nanotechnology's inconspicuous nature, export controls could be put in place to prevent its spread to "hostile or irresponsible nation-states" or terrorist groups. 265 Finally, potentially dangerous nanotechnologies could be designed and programmed to be inherently safe. 266 Replicating nano-devices could be developed so that mutations would be difficult or impossible. 267 Additionally, nano-devices could be designed so they would be unable to exist outside of a controlled environment, such as a laboratory. 268

257. Lin-Easton, supra note 29, at 120.
258. Id. at 122-23.
259. Ironically, proponents of nanotechnology promise that it will be the best method for cleaning up the environment. Id. at 124. It would be a shame to have a process designed to protect the environment actually prevent the restoration of that very same environment.
260. Fiedler & Reynolds, supra note 34, at 603.
261. Id.
262. Id.
263. Reynolds, supra note 252, at 14.
264. Id. As a corollary, the profession of "nanotechnologists" could adopt ethics guidelines, just as lawyers and physicians have, to delineate the expectations and restrictions of the profession. Id. This would particularly aid in calming public concern for this potentially dangerous technology.
265. Id.
266. Id. at 15.
267. Id.
268. See Drexler, supra note 24, at 258.
Similarities exist between nanotechnology and another recent discovery: biotechnology. While biotechnology is not as small or diverse as nanotechnology, "relatively simple and straightforward rules" have been developed to prevent biotechnology's expected catastrophes.269 Those guidelines require "the use of organisms that [could not] readily survive outside the laboratory, reasonable containment precautions, and limits on research involving the genetic alteration of particularly dangerous kinds of organisms—human pathogens, for example."270 Such rules may apply more effectively to nanotechnology because of nanotechnology's increased propensity to elude current regulations and their spheres of coverage.

In fact, such guidelines already exist. The Foresight Guidelines, created by the Foresight Institute in 1999, "are designed to foster safeguards that will protect against accident and abuse, while allowing [nanotechnology] to flourish."271 The Guidelines are more of a set of recommendations than regulations; thus, they can be amended to conform to experience and scientific knowledge.272 The underlying philosophy is "first, do no harm."273

Some of the important Development Principles contained in the Foresight Guidelines include:

Artificial replicators must not be capable of replication in a natural, uncontrolled environment.

Evolution within the context of the self-replicating manufacturing system is discouraged.

Any replicated information should be error free.

[Nanotechnology] device design should specifically limit proliferation and provide traceability of any replicating systems.274

In addition, the Guidelines contain provisions regarding specific design aspects of nanotechnology.275 These provisions set forth recommended designs to protect mutation and proliferation as well as provide safety mechanisms that reduce the risk that harmful nanotechnology will be created.276

While not perfect, these Guidelines are a start. We should also heed the lessons of the BWC and CWC's flaws. For example, because nanotechnology is still a fledgling industry, a regulatory scheme must be developed quickly before private corporations can unite and protect their intellectual product and competitive edge. Like the pharmaceutical industry with respect to the CWC, nanotech companies should be prevented from implementing a verification and inspection regime to protect their profit margins. If a set of guidelines setting forth protec-

269. Fiedler & Reynolds, supra note 34, at 606.
270. Id.
272. Reynolds, supra note 252, at 17.
273. Id. This appears at least similar in nature to the underlying philosophy of the precautionary principle, yet it does not go the way of total prohibition. The Guidelines are a more moderate approach.
274. Reynolds, supra note 29, at 10687.
275. Id. at 10688.
276. See id.

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tions and threats can be effected, then perhaps a weapons convention that serves as more than a formal declaration of intent may be established.

CONCLUSION

As K. Eric Drexler stated, nanotechnology can "bring the ultimate tools of destruction," but it is not inherently dangerous.277 With proper guidance, Drexler predicted we could use nanotechnology to "build the ultimate tools of peace."278 Although the benefits of nanotechnology tempt one to allow it to grow unrestricted, we must take heed of the potential risks such a powerful tool promises. Since almost anything can be built—and matter can be almost completely controlled—if nanotechnology lives up to its reputation, it seems obvious to conclude that nanotechnology must be regulated. But how?

Current treaties such as the BWC and CWC are inadequate because they are outdated and were drafted without a major development like nanotechnology in mind. Institutions like the BWC and CWC are already set and cannot be easily adapted to accommodate new advances in technology. In addition, the uses and purposes of nanotechnology are expected to be so diverse that existing regimes cannot properly discern harmful from helpful uses.

A new regulatory system must be set up with all potential uses in mind so that the advantageous uses can come to fruition while the harmful uses can be prevented and proscribed. Because this regime will be adopted before the technology fully takes off, it does not have to worry about already existing intellectual property rights or privacy concerns. It will take a "create at your own risk" type of approach that can disregard trivial concerns and focus on safety measures and the proper maturation of the technology. Thus, if a new treaty can be crafted having learned the lessons from the deficiencies of the BWC and CWC, it should be able to handle nanotechnology however, whenever, and wherever it develops.

277. DREXLER, supra note 47, at 239.
278. Id.