GENETICALLY ENGINEERED BIOLOGICAL WARFARE: A NEW GENERATION OF WEAPONS FOR MODERN WARFARE AND TECHNOLOGY

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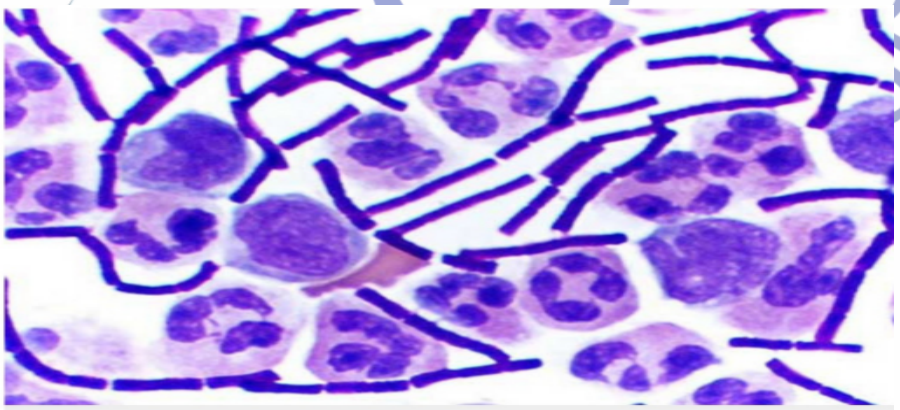

Figure 1: Gram stained cerebrospinal fluid showing gram-positive anthrax baccilli (purple rods). Courtesy of Wikimedia.

I. INTRODUCTION

Biological weapons are designed to spread disease among people, plants, and animals through the introduction of toxins and microorganisms such as viruses and bacteria. The method through which a biological weapon is deployed depends on the agent itself, its preparation, its durability, and the route of infection. Attackers may disperse these agents through aerosols or food and water supplies. Although bioweapons have been used in war for many centuries, a recent surge in genetic understanding, as well as a rapid growth in computational power, hasallowed genetic engineering to play a larger role in the development of new bioweapons. In the bioweapon industry, genetic engineering can be used to manipulate genes to create new pathogenic characteristics aimed at enhancing the efficacy of the weapon through increased survivability,

infectivity, virulence, and drug resistance. While the positive societal implications of improved biotechnology are apparent, the "black biology" of bioweapon development may be "one of the gravest threats we will face".

II. LIMITS OF PAST BIOWEAPONS

Prior to recent advances in genetic engineering, bioweapons were exclusively natural pathogens. Agents must fulfill numerous prerequisites to be considered effective military bioweapons, and most naturally occurring pathogens are ill suited for this purpose. First, bioweapons must be produced in large quantities. A pathogen can be obtained from the natural environment if enough can be collected to allow purification and testing of its properties. Otherwise, pathogens could be produced in a microbiology laboratory or bank, a process which is limited by pathogen accessibility and the safety with which the pathogens can be handled in facilities. To replicate viruses and some bacteria, living cells are required. The growth of large quantities of an agent can be limited by equipment, space, and the health risks associated with the handling of hazardous germs. In addition to large-scale production, effective bioweapons must act quickly, be environmentally robust, and their effects must be treatable for those who are implementing the bioweapon.

III. RECENT ADVANCES

As researchers continue to transition from the era of DNA sequencing into the era of DNA synthesis, it may soon become feasible to synthesize any virus whose DNA sequence is known. This was first demonstrated in 2001 when Dr. Eckard Wimmer re-created the poliovirus and again in 2005 when Dr. Jeffrey Taubenberger and Terrence Tumpey re-created the 1918 influenza virus. The progress of DNA synthesis technology will also allow for the creation of novel pathogens. According to biological warfare expert Dr. Steven Block, genetically engineered pathogens "could be made safer to handle, easier to distribute, capable of ethnic specificity, or be made to cause higher mortality rates".The growing accessibility of DNA synthesis capabilities, computational power, and information means that a growing number of people will have the capacity to produce bioweapons. Scientists have been able to transform the four letters of DNA —A (adenine), C (cytosine), G (guanine), and T (thymine)—into the ones and zer- oes of binary code. This transformation makes genetic engineering a matter of electronic manipulation, which decreases the cost of the technique. According to former Secretary of State Hillary Clinton, "the emerging gene synthesis industry is making genetic material more widely available [...] A crude but effective terroristweapon can be made using a small sample of any number of widely available pathogens, inexpensive equipment, and college-level chemistry and biology."

IV. TECHNIQUES TO ENHANCE THE EFFICIENCY OF BIOWEAPONS

Scientists and genetic engineers are considering several techniques to increase the efficacy of pathogens in warfare.

i. Binary Biological Weapons

This technique involves inserting plasmids, small bacterial DNA fragments, into the DNA of other bacteria in order to increase virulence or other pathogenic properties within the host bacteria.

ii. Designer Genes

According to the European Bioinformatics Institute, as of December 2012, scientists had sequenced the genomes of 3139 viruses, 1016 plasmids, and 2167 bacteria, some of which are published on the internet and are therefore ac- cessible to the public. With complete genomes available and the aforementioned advances in gene synthesis, scientists will soon be able to design pathogens by creating synthetic genes, synthetic viruses, and possibly entirely new organisms.

iii. GENE THERAPY

Gene therapy involves repairing or replacing a gene of an organism, permanently changing its genetic composition. By replacing existing genes with harmful genes, this technique can be used to manufacture bioweapons.

iv. STEALTH VIRUSES

Stealth viruses are viral infections that enter cells and remain dormant for an extended amount of time until triggered externally to cause disease. In the context of warfare, these viruses could be spread to a large population, and activation could either be delayed or used as a threat for blackmail.

v. HOST-SWAPPING DISEASES

Much like the naturally occurring West Nile and Ebola viruses, animal viruses could potentially be genetically modified and developed to infect humans as a potent biowarfare tactic.

vi. DESIGNER DISEASES

Biotechnology may be used to manipulate cellular mechanisms to cause disease. For example, an agent could be designed to induce cells to multiply uncontrollably, as in cancer, or to initiate apoptosis, programmed cell death.

vii. PERSONALIZED BIOWEAPONS

In coming years it may be conceivable to design a pathogen that targets a specific person's genome. This agent may spread through populations showing minimal or no symptoms, yet it would be fatal to the intended target.

V. BIODEFENSE:

In addition to creating bioweapons, the emerging tools of genetic knowledge and biological technology may be used as a means of defense against these weapons.

i. HUMAN GENOME LITERACY

As scientific research continues to reveal the functions of specific genes and how genetic components affect disease in humans, vaccines and drugs can be designed to combat particular pathogens based on analysis of their particular molecular effect on the human cell.

ii. IMMUNE SYSTEM ENHANCEMENT

In addition to enabling more effective drug development, human genome literacy allows for a better understanding of the immune system. Thus, genetic engineering can be used to enhance human immune response to pathogens. As an example, Dr. Ken Alibek is conducting cellular research in pursuit of protection against the bioweapon anthrax.

iii. VIRAL AND BACTERIAL GENOME LITERACY

Decoding the genomes of viruses and bacteria will lead to molecular explanations behind virulence and drug resistance. With this information, bacteria can be engineered to produce bioregulators against pathogens. For example, Xoma Corporation has patented a bactericidal/permeability-increasing (BPI) protein, made from genes inserted into bacterial DNA, which reverses the resistance characteristic of particular bacteria against some popular antibiotics.

iv. EFFICIENT BIO-AGENT DETECTION AND IDENTIFICATION EQUIPMENTS

Because the capability of comparing genomes using DNA assays hasalready been acquired, such technology may be developed to identify pathogens using information from bacterial and viral genomes. Such a detector could be used to identify the composition of bioweapons based on their genomes, reducing present-day delays in resultant treatment and/or preventive measures.

v. NEW VACCINES:

Current scientific research projects involve genetic manipulation of viruses to create vaccines that provide immunity against multiple diseases with a single treatment.

vi. NEW ANTIBIOTICS AND ANTIVIRAL DRUGS

Currently, antibiotic drugs target DNA synthesis, protein synthesis, and cell-wall synthesis processes in bacterial cells. With an increased understanding of microbial genomes, other proteins essential to bacterial viability can be targeted to create new classes of antibiotics. Eventually, broad-spectrum, rather than protein-specific, anti-microbial drugs may be developed.

VI. FUTURE OF WARFARE

"The revolution in molecular biology and biotechnology can be considered as a potential Revolution of Military Affairs (RMA)," states Colonel Michael Ainscough, MD, MPH. According to Andrew Krepinevich, who originally coined the term RMA, "technological advancement, incorporation of this new technology into military systems, military operational advancement, and organizational adaptation in a way that fundamentally alters the character and conduct of conflict" are the four components that make up an RMA. For instance, the Gulf War has been classified as the beginning of the space information warfare RMA. "From the technological advances in biotechnology, biowarfare with genetically engineered pathogens may constitute a future such RMA," says Ainscough. In addition, the exponential increase in computational power combined with the accessibility of genetic information and biological tools to the general public and lack of governmental regulation raise concerns about the threat of biowarfare arising from outside

the military. The US government has cited the efforts of terrorist networks, such as al Qaida, to recruit scientists capable of creating bioweapons as a national security concern and "has urged countries to be more open about their efforts to clamp down on the threat of bioweapons". Despite these efforts, biological research that can potentially lead to bioweapon development is "far more international, far more spread out, and far more diverse than nuclear science [...] researchers communicate much more rapidly with one another by means that no government can control [...] this was not true in thenuclear era," according to David Kay, former chief U.S. weapons inspector in Iraq . Kay is "extraordinarily pessimistic that we [the United States] will take any of the necessary steps to avoid the threat of bioweapons absent their first actual use" . "There are those who say: 'the First World War was chemical; the Second World War was nuclear; and that the Third World War – God forbid – will be biological'".

VII. REFERENCES

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