Design for Biosecurity

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Lecture 7

Bioweapons Used in Warfare and Biological Weapon and Toxin Convention (BWC)

Welcome back to our seventh session of the second week. Before we dive into today's topic, let's briefly recap what we set out to accomplish at the start of the previous week. Our focus during the first week was to explore the multifaceted challenges posed by biosecurity, biowarfare, and bioterrorism. We also emphasized the crucial need for ongoing research and the development of advanced biosensors to counter these threats.

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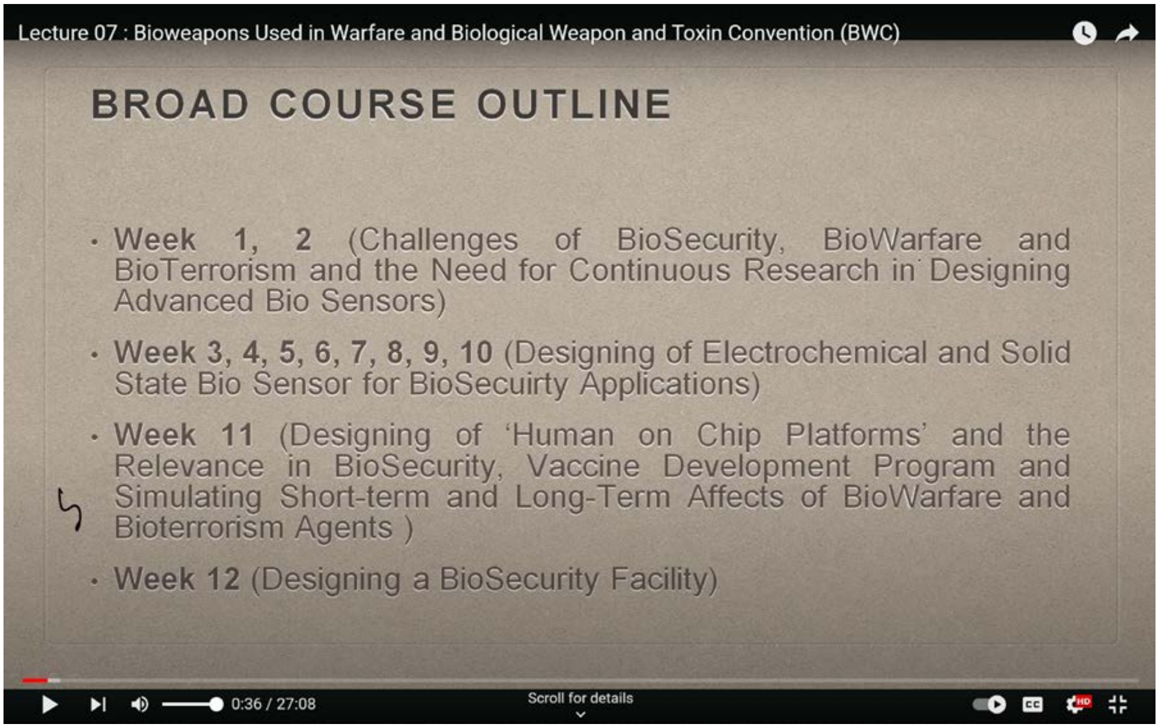

During the first week, we aimed to cover several key areas: agricultural security, which we have already discussed; livestock production; human health; pandemics; and bioterrorism, the latter of which we continue to explore.

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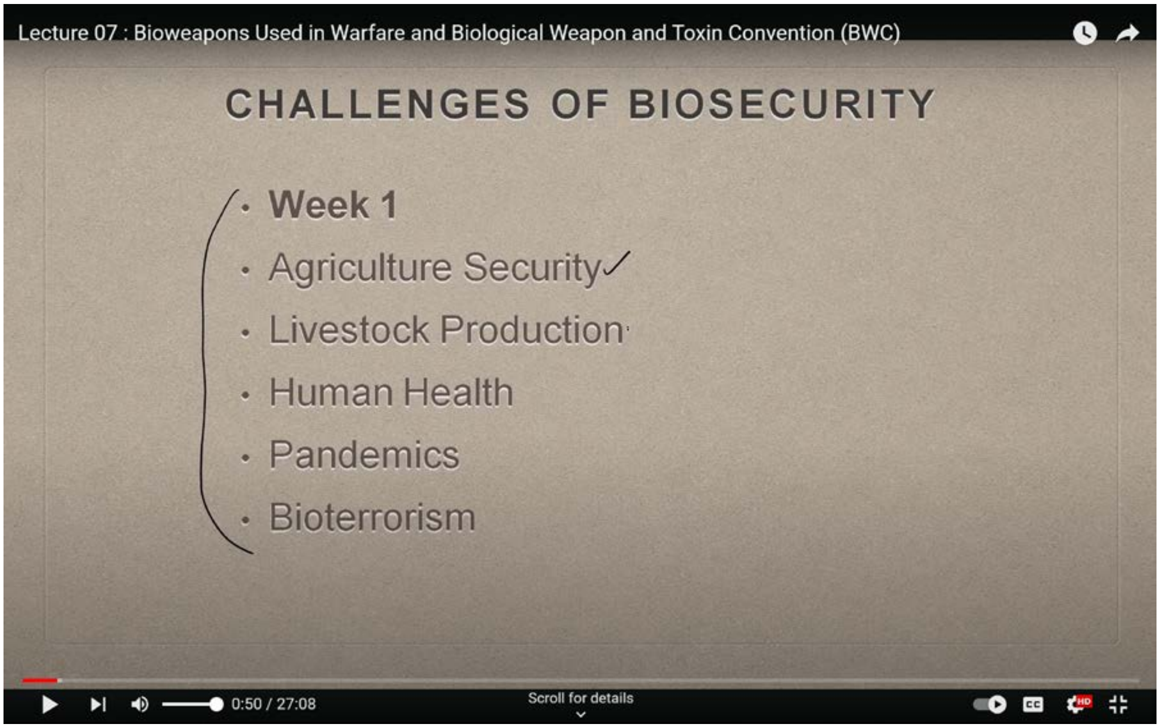

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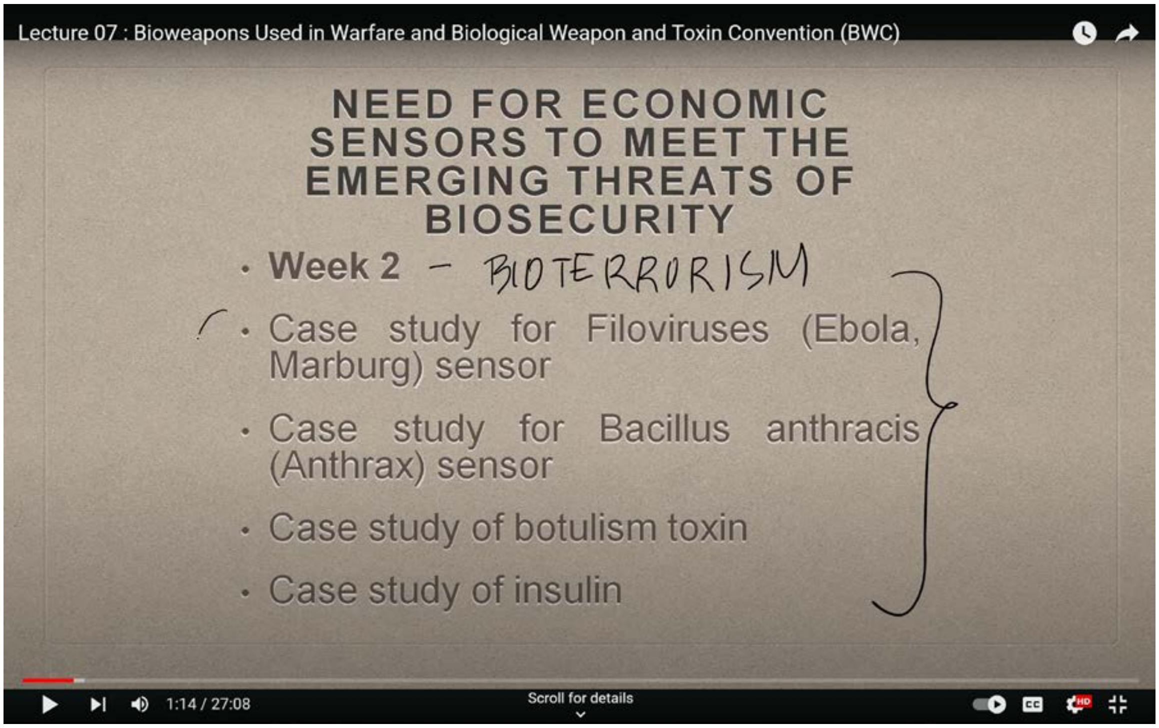

Moving into the second week, our plan was to delve into some of the spillover effects of bioterrorism.

This week, we will examine four distinct case studies. Three of these are related to biosensors developed for microbial origins, and the fourth pertains to the molecule insulin, particularly in its role in diabetes. By extending the discussion of bioterrorism into this week, we aim to provide a comprehensive understanding of why these topics were specifically chosen and their global impact. Our selection was not random; it was made to raise awareness at local, national, and global levels, as biosecurity will be a defining issue of this century.

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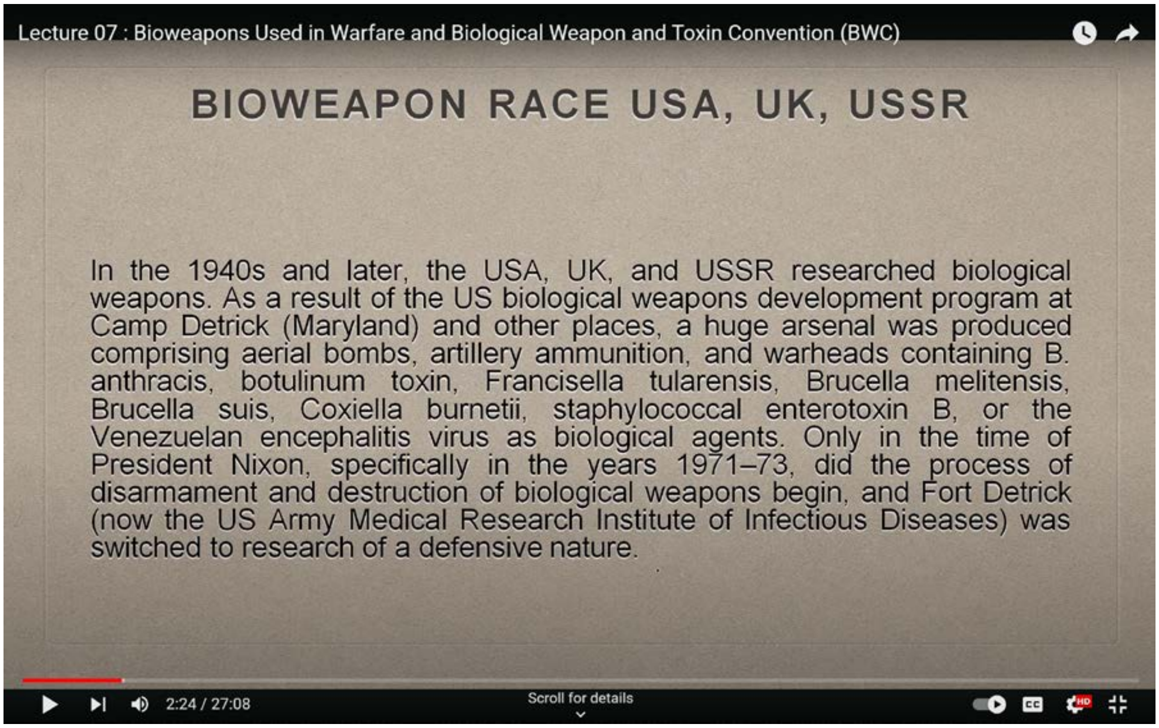

Building on this foundation, let’s continue from where we left off in our last class. We had begun discussing the bioweapons race among the USA, UK, and USSR. To pick up from the end of the sixth lecture, in the early 1940s and beyond, these three nations were heavily invested in the research and development of biological weapons. In fact, records reveal that the USSR's involvement in bioweapon research began as early as 1920.

The United States’ Biological Weapon Development Program, primarily based at Fort Detrick, Maryland, resulted in the creation of an extensive arsenal that included aerial bombs, artillery ammunition, and warheads loaded with agents such as anthrax, botulinum toxin, and tularemia. However, a significant shift occurred during the presidency of Richard Nixon between 1971 and 1973, when the disarmament and destruction of biological weapons began. Fort Detrick was subsequently repurposed into the U.S. Army Medical Research Institute of Infectious Diseases, focusing on defensive research. Despite this, biological weapon research continued in other parts of the world.

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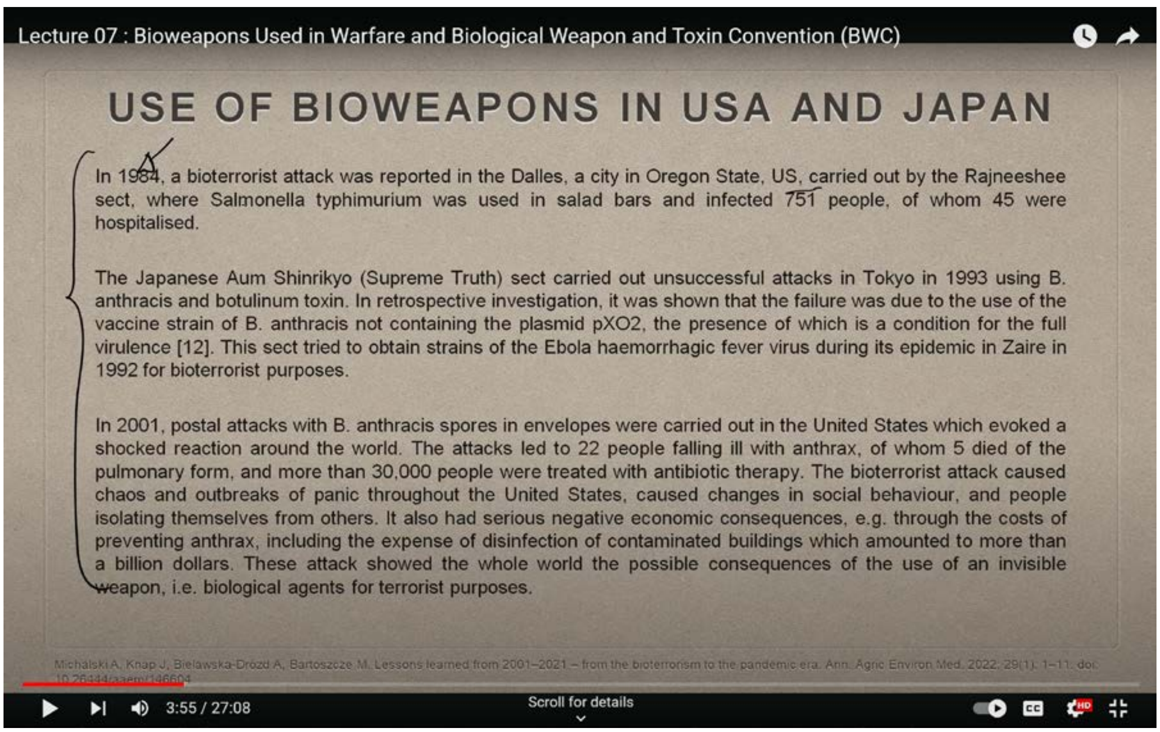

Now, let’s explore the use of bioweapons in the United States and Japan. The first documented evidence of a bioterrorist attack in the U.S. came in 1984 in Dallas, Oregon. This attack was orchestrated by followers of Osho Rajneesh, who used Salmonella typhimurium to contaminate salad bars, resulting in the infection of 751 people, with 45 of them requiring hospitalization. Remarkably, this incident occurred after the Biological Weapons Convention (BWC) had been established in 1972. I have yet to discuss the specifics of the convention, as I wanted to first highlight some examples.

Another significant event took place in 1993, this time in Tokyo, Japan. The Aum Shinrikyo sect, also known as the Supreme Truth, attempted an attack using anthrax and botulinum toxin. However, the attack failed because the strain of anthrax used was a vaccine strain that lacked the necessary plasmid PXO2, which is crucial for virulence.

It became evident that the understanding of DNA structure, coupled with advancements in Polymerase Chain Reaction (PCR) technology, revolutionized the field of biological weapons development. These technological breakthroughs allowed for the rapid production of specific nucleic acids, thereby accelerating the race for engineering biological weapons.

In the presence of virulent conditions, the sect sought to obtain a strain of Ebola, a virus responsible for hemorrhagic fever, from Zaire in 1992. Let's take a closer look at the timeline: 1984, 1993, and then 2001. By 2001, the world had entered the 21st century, and with it came a severe and unforgettable attack.

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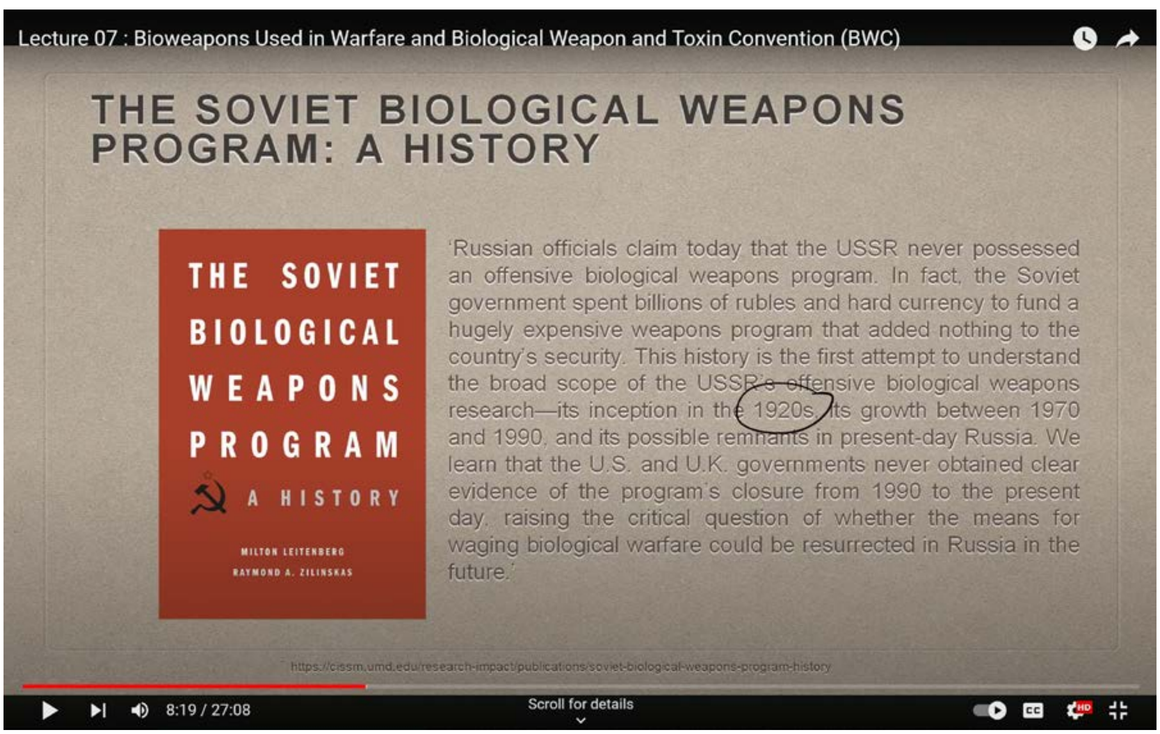

I vividly recall that time, as I was in my second year in the United States. The attack began in Florida and quickly spread across the country. The group responsible for this attack employed a particularly insidious method: they placed the pathogen inside envelopes. The concept was deceptively simple and dangerously effective. When someone opened the envelope, they would unknowingly inhale the pathogen. This innovative design allowed the weapon to be sent through the mail, undetected, to any location in the world.

In 2001, the United States experienced a postal attack involving anthrax spores concealed within envelopes, which sent shockwaves across the globe. The attack resulted in 22 cases of anthrax infection, with five people succumbing to the pulmonary form of the disease. Moreover, over 30,000 individuals required antibiotic treatment to prevent infection. This incident had a profound impact on me, as I mentioned in our previous class.

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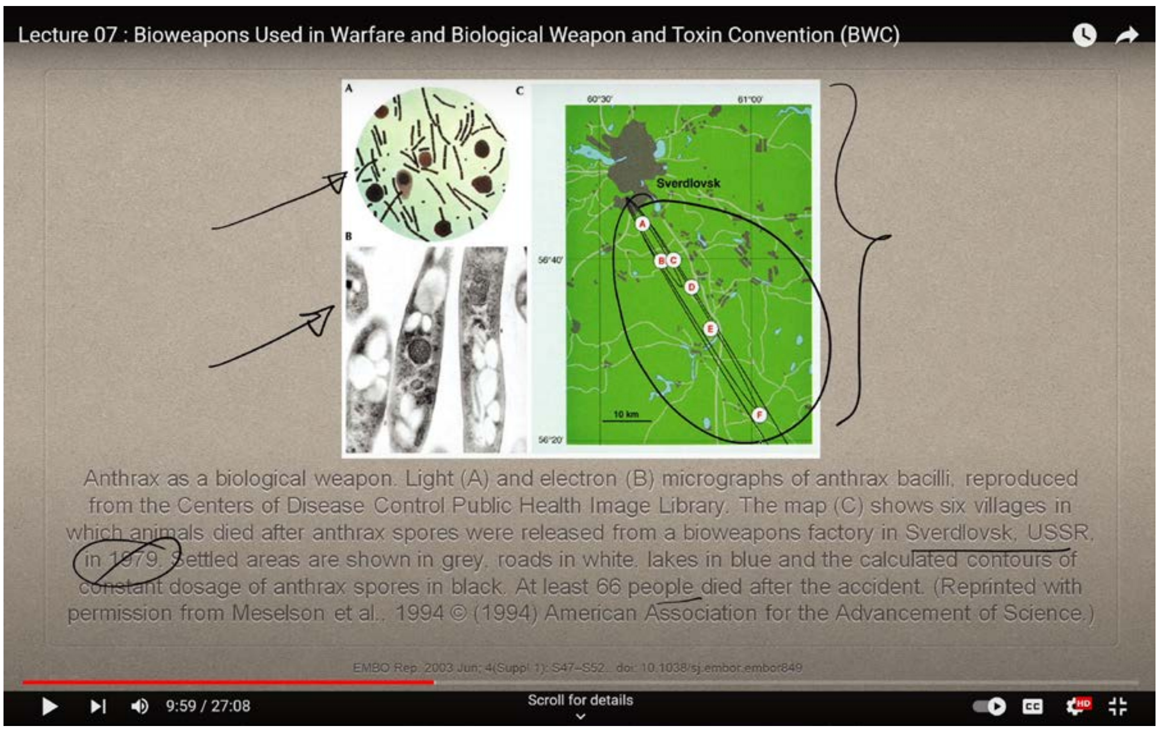

One of the critical issues during such attacks is the lack of preparedness. Typically, when a strain of a pathogen is conserved, there are no corresponding vaccines or antidotes stockpiled. This is similar to the lack of stockpiles for pathogenic viruses. So, when an attack occurs, there is a scramble to pull from existing inventories and begin producing the necessary countermeasures. This process is time-consuming, and in the interim, significant human and animal losses can occur. The 2001 anthrax attack stands as one of the most harrowing instances of bioweapons usage in recent history, instilling a deep sense of fear among the public and causing significant disruptions in the stock market.

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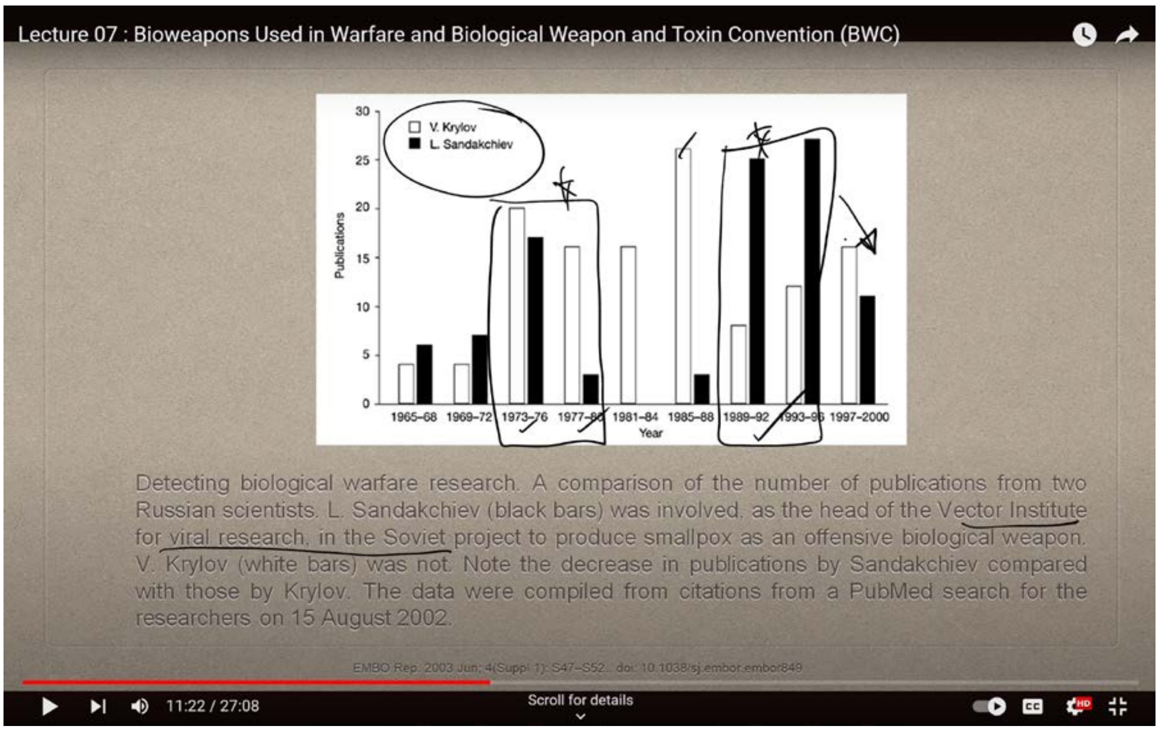

From this point, we transition to discussing the Soviet Union’s bioweapon program. The Soviet Union, or former USSR, maintained its bioweapon program under a shroud of secrecy throughout the communist regime. Very little was known about it for many years, but it is documented that their efforts in this area began as early as 1920.

For those interested in learning more, I recommend the book The Soviet Biological Weapon Program: A History by Milton Wittenberg and Raymond Zelinskis. This book provides a thorough exploration of the historical development of Russia’s biowarfare agents and offers insights into their secretive program. There is evidence, which I will show you, indicating that the USSR was running an exceptionally large and covert bioweapon program.

One of the earliest examples involves their work on developing anthrax as a bioweapon. In 1979, a catastrophic event occurred at a Soviet facility located in Sverdlovsk (now Yekaterinburg), within the former USSR. Due to a leak at this facility, anthrax spores were released into the surrounding environment, resulting in the deaths of 66 people. The spread of the anthrax spores was significant, and the map before you illustrates the radius of this spread.

This tragic incident stands as a clear piece of evidence of the dangers inherent in running such programs. It highlights the immense challenges involved in securing these labs, which, in many ways, are akin to safeguarding a nuclear arsenal.

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The second significant point to highlight is the evidence suggesting that a sophisticated program was indeed underway, as reflected in the publication record of two authors associated with the Vector Institute for Viral Research in Moscow. If you examine the chart of their publications, you'll notice a remarkable spike in output during the 1970s and 1980s. These spikes are particularly striking, and although there’s a minor peak afterward, the most notable drop occurs after 1996.

This decline is intriguing and can be linked to the events of Glasnost and Perestroika, which ultimately led to the dissolution of the Soviet Union. Up until that point, the bioweapon program appeared to be moving forward with concerted effort. However, from that time until now, spanning roughly 24 years from 2000 to 2024, especially during Putin's era, we have little information about the current state of their programs. It's difficult to believe they have ceased their activities, especially considering the ongoing conflict with Ukraine. Yet, our knowledge is limited, relying mainly on indirect sources.

Another piece of evidence involves the use of bioweapons against plants. Hmong refugees from Laos, who had collaborated with American forces during the Vietnam War, accused the Soviet Union of attacking them with biological and chemical weapons. The alleged toxin warfare agent, known as "Yellow Rain," bears a striking resemblance to a substance called "Yellow Spot," which is actually bee feces. For those familiar with honeybees, their excretions often leave yellow spots on leaves or even on clothing, such as a white shirt. Detecting this substance is exceptionally challenging without a highly sensitive sensor, which underscores the importance of understanding and developing advanced biosensors.

This discussion ties into the broader context of sensor technology and its critical role in future generations. There must be a comprehensive database for sensors, enabling quick identification of potential toxins, much like identifying different threats using a well-maintained database.

While discussing the Vietnam War, from 1962 to 1975, it's also essential to note the extensive use of chemical herbicides, including Agent Orange and Agent White, among others. These compounds were deployed primarily to defoliate mangrove forests, which provided cover for the Vietnamese guerrilla forces. The US and Republic of Vietnam militaries used these herbicides to improve visibility around military installations and, for a brief period, to destroy enemy crops. Both the US Air Force and the US Chemical

Corporation were involved in purchasing and deploying these tactical herbicides throughout the long, 15-year conflict.

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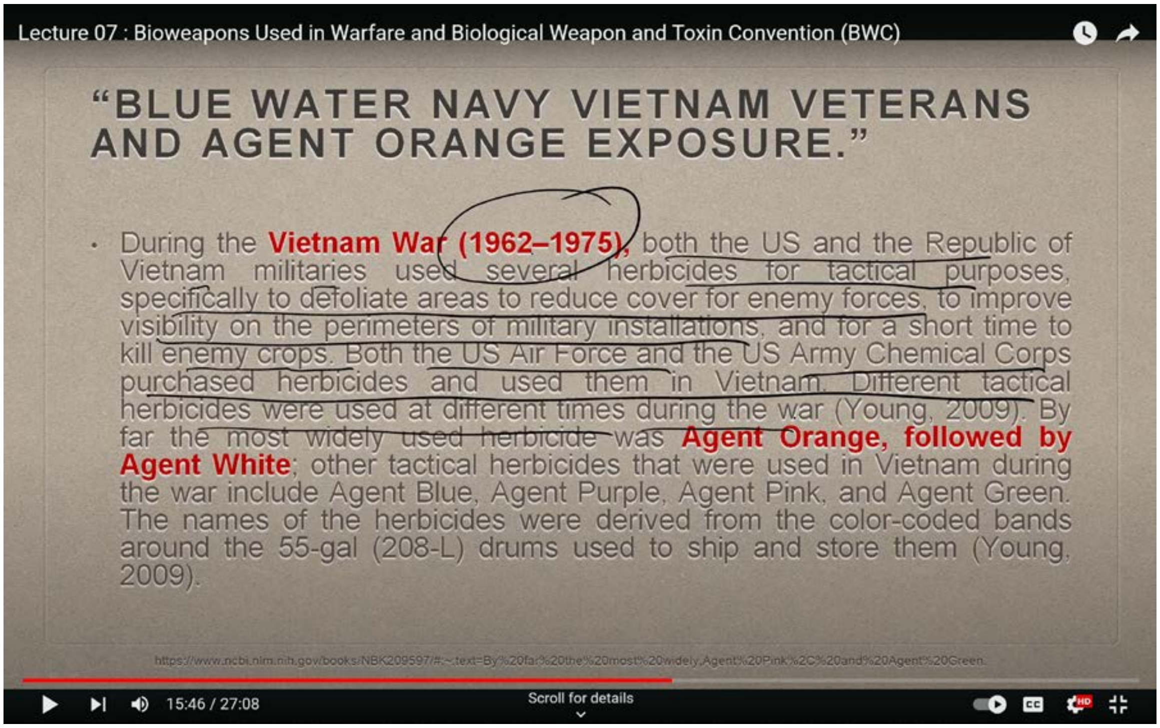

This situation illustrates how chemical agents, which are man-made rather than naturally occurring, can devastate an ecosystem's biosecurity. The biodiversity of the region was severely affected by these chemical warfare agents, showing that the threats to our biological resources extend far beyond microbes.

Moreover, these herbicides were shipped all the way from the United States to Vietnam, emphasizing the global reach and impact of such chemical agents in warfare.

The sailors exposed to these chemicals suffered from a range of severe health issues, including cancer, respiratory disorders, neurological disorders, and more. While wars may be won on the battlefield, they often result in significant long-term human health losses. The chemicals involved in these operations, such as 2,4,5-T, 2,4-dichlorophenoxyacetic acid, and 2,4-D, were central to the operation known as Ranch Hand. This operation utilized C-123 aircraft equipped with herbicide spray apparatuses that could release droplets measuring between 320 and 350 micrometers with a rapid settling velocity.

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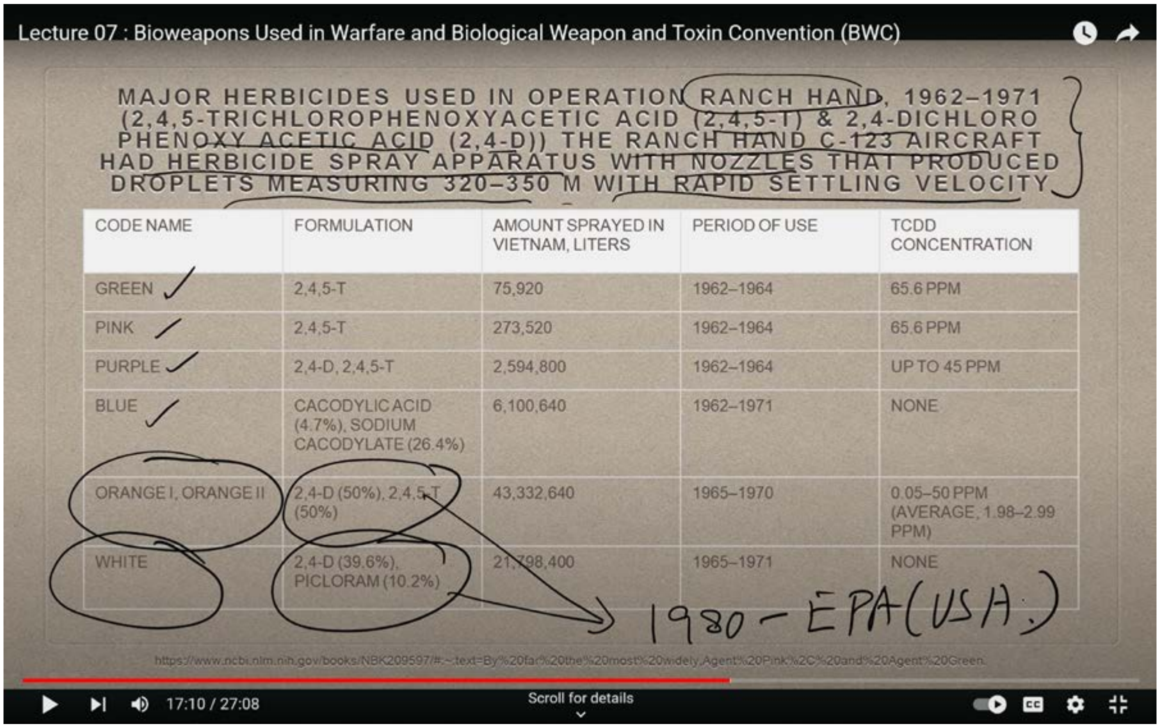

When we look at modern times, where Unmanned Aerial Vehicles (UAVs) are employed in various operations, it’s remarkable to think that even in the 1970s, aircraft were already being used for biological warfare. The operations were codenamed with colors like green, pink, purple, and blue, with the most dangerous chemicals being orange and white. The devastating impact of these chemicals led to the Environmental Protection Agency (EPA) in the United States banning their production in the 1980s due to their extreme carcinogenic properties. These chemicals caused widespread damage not only to Vietnam's biogeographic region but also to U.S. sailors, army personnel, and the local population, all of whom suffered long-term health consequences.

These events serve as stark reminders that we must be exceedingly cautious before deploying such agents, regardless of the purpose. Unless absolutely necessary, we should always reconsider their use. In response to the dangers posed by biological and toxin weapons, the Biological Weapon and Toxin Convention (BWC) was established in 1972.

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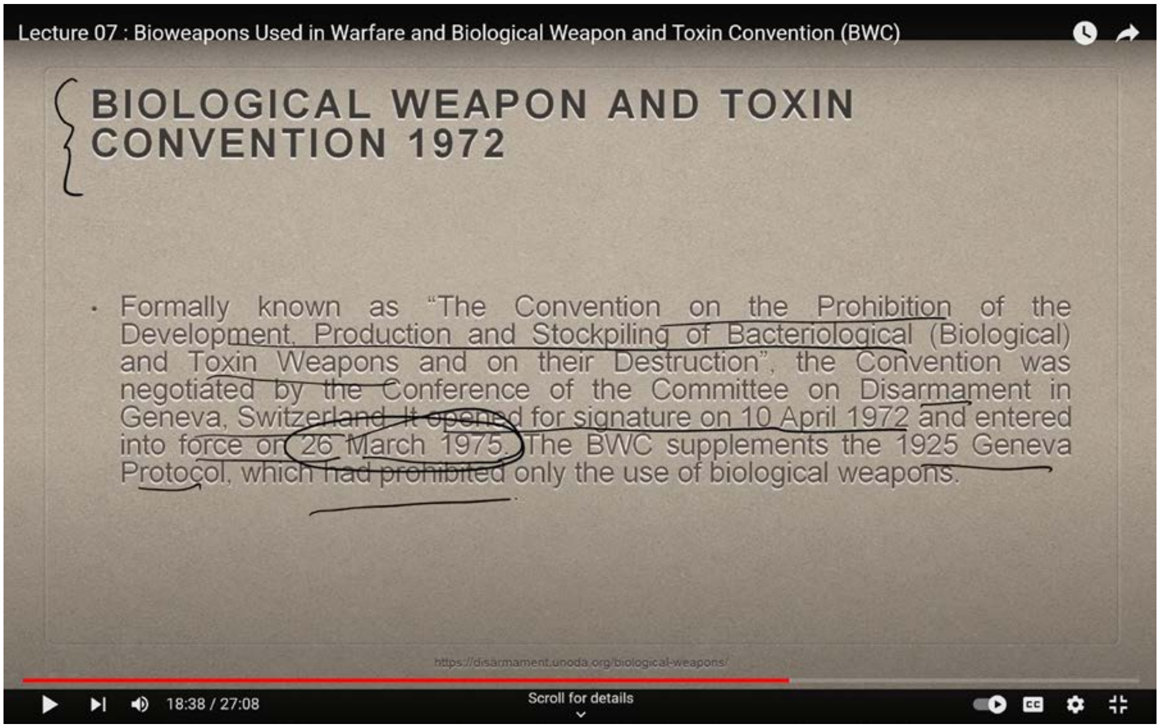

It's important to note that these wars and events were unfolding concurrently with the creation of this convention, formally known as the Convention on the Prohibition of the Development, Production, and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction. The BWC was part of disarmament efforts in Geneva, Switzerland, opening for signature on April 10, 1972, and coming into force on March 26, 1975.

The BWC supplements the 1925 Geneva Protocol, which prohibited the use of biological weapons. The convention includes several critical articles, such as the commitment never to develop, produce, stockpile, acquire, or retain biological weapons under any circumstances. It also mandates the destruction of existing biological weapons and prohibits their diversion for peaceful purposes. Additionally, it requires member states to take national measures necessary to prevent the development, production, stockpiling, acquisition, and retention of biological weapons within their territories and under their jurisdiction.

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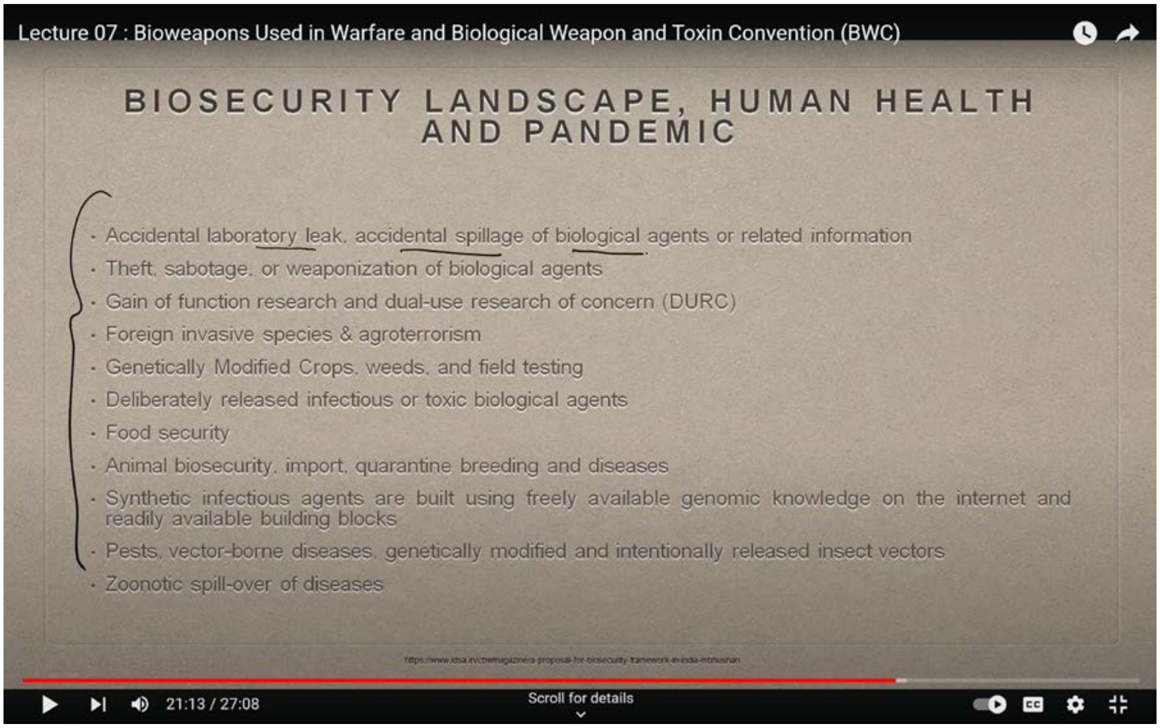

While these laws exist, they are, after all, human-made, and the extent to which they are followed is crucial. In our current era, where molecular biology techniques are rapidly advancing, and global disruptions are becoming more frequent, it is imperative that biosecurity protocols evolve alongside these challenges. If the problems we face are increasing in arithmetic progression, then biosecurity measures must advance in geometric progression. Massive investments in biosecurity measures and antidotes are necessary, as future wars are likely to be fought in this domain. The COVID-19 pandemic is merely a glimpse of a new kind of warfare, one that is far more sophisticated than anything witnessed in 13th century.

You don't need massive armies or large-scale weapons to wage this type of warfare, which brings us to the crucial question: What exactly are we securing? This is the essence of biosecurity. When we discuss the biosecurity landscape concerning human health and pandemics, we are addressing several critical issues. These include accidental laboratory leaks, unintentional spillage of biological agents or related information, theft, sabotage, and the weaponization of biological agents. Additionally, we must consider gain-of-function research and dual-use research of concern, the introduction of foreign invasive species, and agro-terrorism.

For example, by introducing harmful weeds or genetically modified crops, one could potentially devastate native crops, thereby threatening food security. In such a scenario, there would be no need for conventional warfare; the economy of the targeted system would collapse swiftly. Animal biosecurity is also at risk, encompassing areas like import, quarantine, breeding, and the spread of diseases. Synthetic infectious agents can now be created using readily available genomic information, which is accessible to anyone with internet access. This makes the threat landscape even more complex, with pest and vector-borne diseases, genetically modified insect vectors, and zoonotic spillover of diseases all in the mix.

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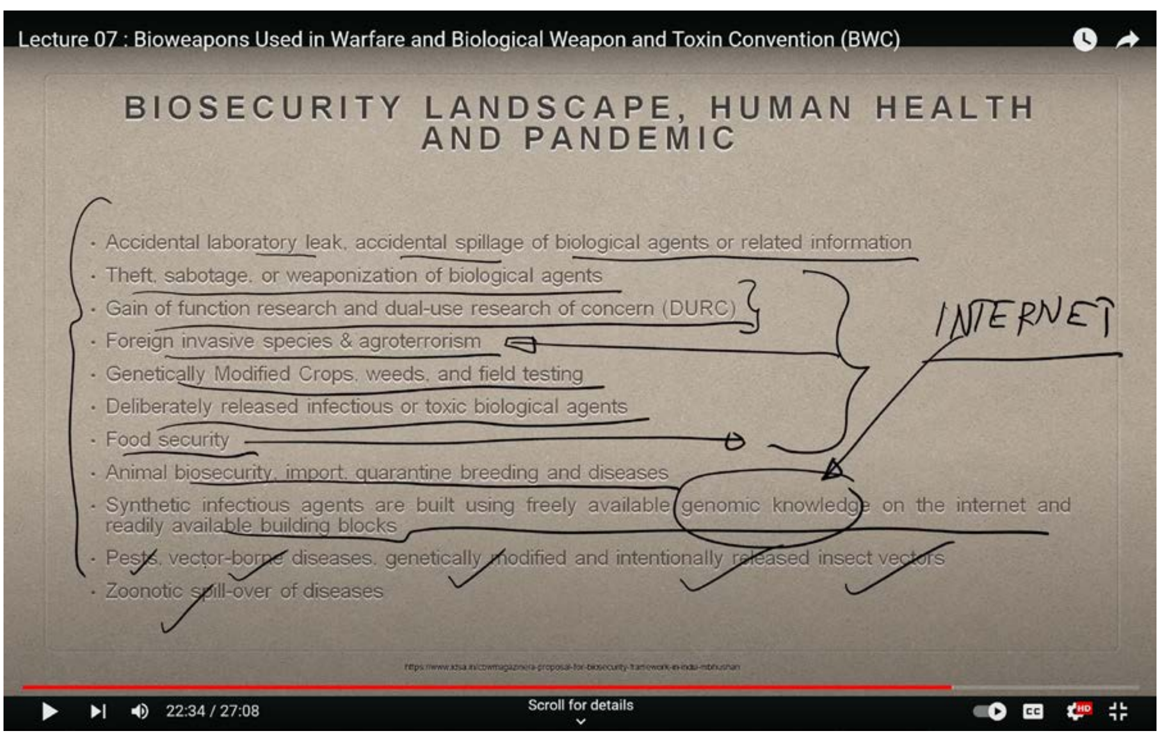

This biosecurity landscape underscores the importance of investing in the development of next-generation biosensors. These sensors are crucial for creating antidotes, even for diseases that do not yet exist. We are entering an era where data mining and simulation will play pivotal roles, allowing us to run long-haul simulation studies to develop various antidote molecules, antibodies, and vaccines. However, the most critical aspect is ensuring we have robust detection systems in place, including DNA-based sensors, RNA-based sensors, protein-based sensors, chemical sensors, and cell-based sensors. These must be rapid and highly effective.

In the coming classes, I will cover topics such as Ebola, filovirus, insulin, and anthrax, exploring how we can design these different types of sensors. I will also revisit instances that I may not have fully covered when discussing various bioterrorist agents. This approach will help you focus on the research areas that interest you the most and understand the critical areas of this field.

At the end of the day, it's essential to remember the role of chemicals in biosecurity. Whether it's a microbe producing a specific chemical that infects your system, the microbe itself acting as an agent, or another chemical causing harm, these are all challenges we must address. For example, consider the historical case of Napoleon Bonaparte, who ingeniously flooded a region to increase the mosquito population, thereby spreading malaria. This was a highly innovative tactic for his time, and history provides us with many such lessons.

Understanding biology, biosecurity, and the design and engineering of biosensors is an incredibly challenging and dedicated field of study. Over the next several weeks, we'll dive deep into these fundamentals. For those of you interested in this area, rest assured that it is a field that will continue to grow, given the ever-present threats that have persisted since at least the 13th century, and likely even earlier. These challenges will endure as long as civilization itself.

So, I'll stop here. In our next session, we'll discuss filoviruses like Ebola and Marburg, along with the sensors associated with them, as well as anthrax and insulin. This will give us a better understanding of the different types of sensors, their necessity, and what is currently available. Thank you.