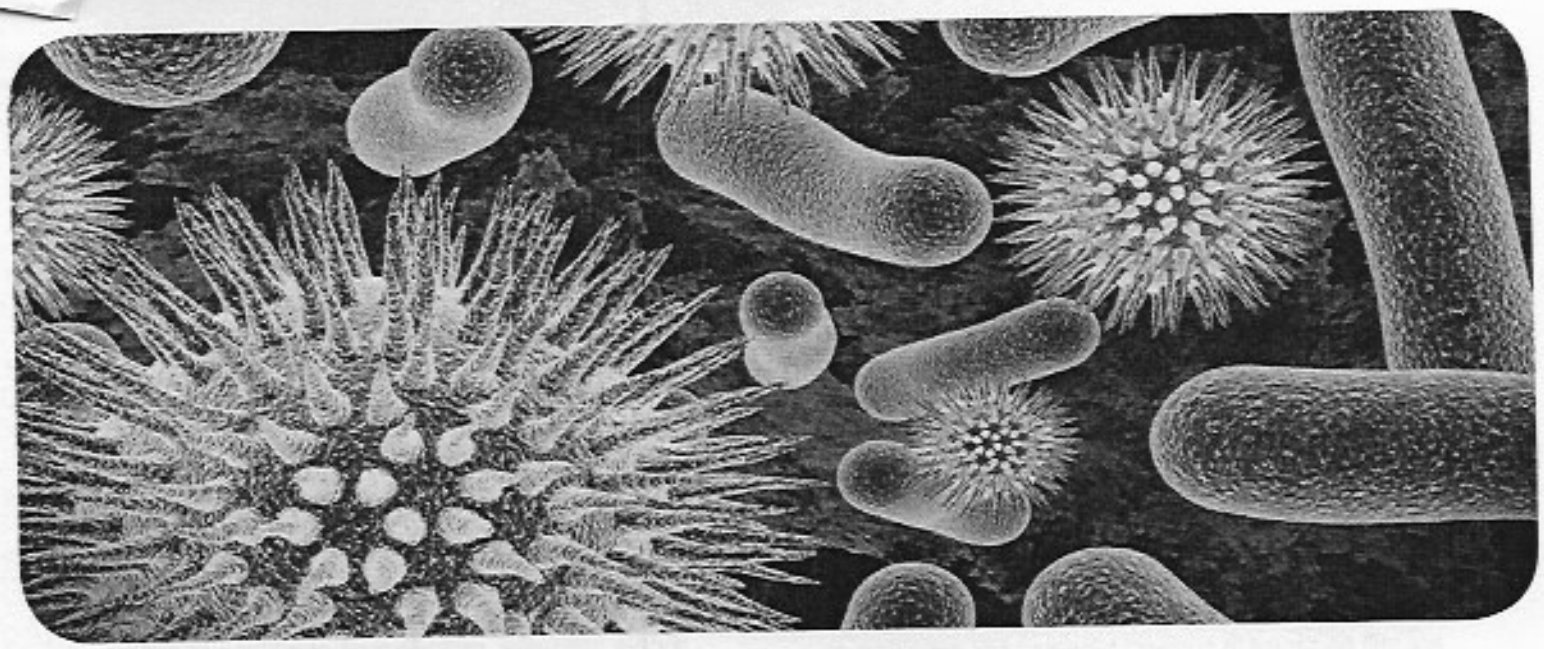


BUILDING AN EFFECTIVE DEFENSE AGAINST BIOLOGICAL THREATS: THE TECHNOLOGY ADVANTAGE

By Tara O'Toole M.D., MPH

"We have reached a critical mass of biological crises. Myriad biological threats, vulnerabilities and consequences have collectively and dramatically increased the threat to the nation."

— Report of the Bipartisan Blue Ribbon Study Panel on Biodefense, 2015

Summary

The United States faces significant and growing national security threats from increasingly frequent and disruptive natural epidemics of infectious disease and potentially from covert biological weapons attacks on civilian populations. Strategic adoption of existing and emerging biotechnologies, and use of digital communications and analytical tools could greatly improve epidemic detection and management. Specifically, the United States needs to:

- *Harness the growing power of biotechnology* to rapidly design and test diagnostics and vaccines fast enough to combat an outbreak and to enable manufacture of such countermeasures at scale; and
- *Integrate already available digital technologies* and analytical capabilities into public health practice.

Implemented and resourced appropriately, a national technology strategy for biodefense could significantly enhance the Nation's ability to defend against potentially existential biological threats.

Biological Threats, Natural and Manufactured

The frequency and impact of naturally occurring disease outbreaks are rising as a result of accelerating changes in land use, massive urbanization without adequate sanitation and nutrition, and global trade and travel. The 2014-15 Ebola outbreak in West Africa demonstrated the social and economic disruption that accompanies epidemics. Epidemics can also be politically destabilizing. An outbreak of a disease that is more easily spread than Ebola could kill millions of people and cause trillions of dollars in economic damage, as influenza did in 1918.

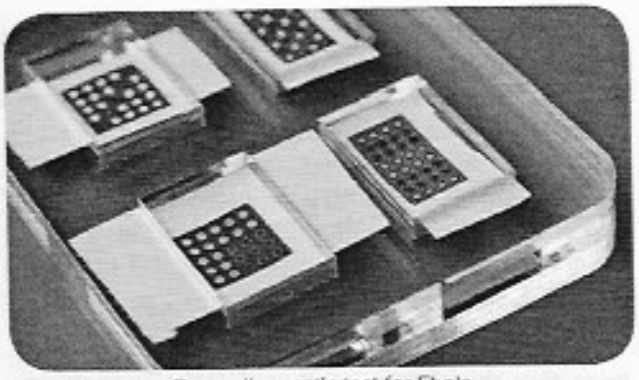
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2. ***Available diagnostic tools are expensive and difficult to deploy.*** The diagnostic test for Ebola used in Africa was complex and time consuming, and detected infection only at certain periods after exposure. A faster, cheaper test was not available until nearly a year into the outbreak, cost more than West African nations could afford, and required refrigeration in a region with limited access to electricity.

3. ***Our capacity to collect, curate, and analyze medical and logistical information during outbreaks is inefficient and lags behind routine data collection capabilities in the private sector.*** Ron Klain, President Obama's "Ebola Czar", was charged with bringing order to the chaotic U.S. response. In 2016, Klain told a roomful of public health professionals that when he assumed his role, "the data then available were not what we needed to guide decisions." The available information was incomplete, untimely, hard to comprehend and often unreliable, due to a lack of resources in West Africa and disorganization among multiple governments, international and non-governmental organizations, independent researchers, and private sector donors and volunteers involved in the response. Even wealthy countries face profound issues gathering and making sense of data in timeframes needed to inform operational decisions. During the initial stages of the 2009 flu – arguably the most prepared for epidemic in history – CDC's electronic tracking and analysis system broke down and could not be fixed, and analysts reverted to using Microsoft Excel to manage the epidemic.

Towards an Effective Biodefense

Fortunately, the lack of technological progress in biodefense is receiving much needed attention. The Bipartisan Blue Ribbon Study Panel on Biodefense called for more technological innovation, particularly in the development of new vaccines and medicines. More recently, the President's Council of Advisors on Science and Technology (PCAST) recommended that the country set a goal of being able to produce new vaccines within six months of a biological attack. The good news regarding problems in data collection, curation and analysis is that several other industries face analogous problems and have developed technology capabilities that public health workers can begin to leverage.



Paper diagnostic test for Ebola
Credit: Wyss Institute at Harvard University

Rapid vaccine scale-up, development, and testing are essential to biodefense. Protecting the healthy during disease outbreaks is a priority best served by vaccines. Vaccines have been among the most effective interventions of modern medicine and are recognized as the most cost-effective and practical means of protection against large, lethal epidemics. A central component of any effective U.S. biodefense strategy must include strategic investments in academia and the biotech and pharma industries to *develop the capacity to rapidly design new vaccines and manufacture them at scale.* In the past decade, significant advances in immunology and in biotechnologies have produced "an embarrassment of riches" regarding new ways to design and make vaccines. But the profit margins of vaccines compare poorly to those garnered by therapeutic drugs, and old, outmoded means of vaccine manufacture remain the norm. Vaccine candidates will be useless unless we also develop the means to produce them rapidly in quantities needed for trials and deployment, and develop the means to conduct trials faster. The Ebola vaccine trials offer several lessons on what is possible and what must be fixed.

Rapid diagnostic tests are strategically important tools in controlling epidemics. Without rapid, practical diagnostics, it is very difficult to know who is infected, who presents a threat to others, and who is immune and able to safely care for the afflicted. These determinations in turn have profound implications for epidemic control and prudent use of scarce resources. The availability of rapid diagnostics for screening and confirming infection would make it much easier to quench epidemics, even without effective vaccines. Many effective diagnostic technologies are available and more are coming, including cheap, easy-to-use tests that could be invaluable during outbreaks. But market failures and regulatory uncertainty are

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Compared to a natural disease outbreak, an attack with a biological weapon (BW) would likely occur with no warning, would infect more people more quickly, and prove more lethal and terrifying than a natural epidemic. An effectively aerosolized pathogen can be delivered in much higher doses than are transmitted naturally, shortening the time between exposure and onset of symptoms. Pathogens can now be engineered to resist treatments or vaccines, or to evade diagnostic tests.

BWs have been known and used since antiquity. From the 1940s through the end of the program in 1969, the U.S. developed *BWs as lethal, and with an area of effect as large as nuclear weapons.* States including Iran, China, Syria, Russia, and North Korea are still engaged in suspect bioweapons activities, as assessed in 2015 by the U.S. State Department. The threat of biological attack by non-state actors also is growing, enabled by the increasing availability of the people, knowledge, equipment and materials required to build BWs. The technological obstacles overcome in secret by the U.S. BW effort have since been solved, automated and made commercially available by the pharmaceutical industry in its quest for better medicines. The misuse of biotechnology is extremely difficult to detect. Nuclear weapons development requires investments and the production of specialized nuclear materials useful only in weapons. Biological weapons can be built quickly and cheaply, and their construction closely resembles a broad array of legitimate work.

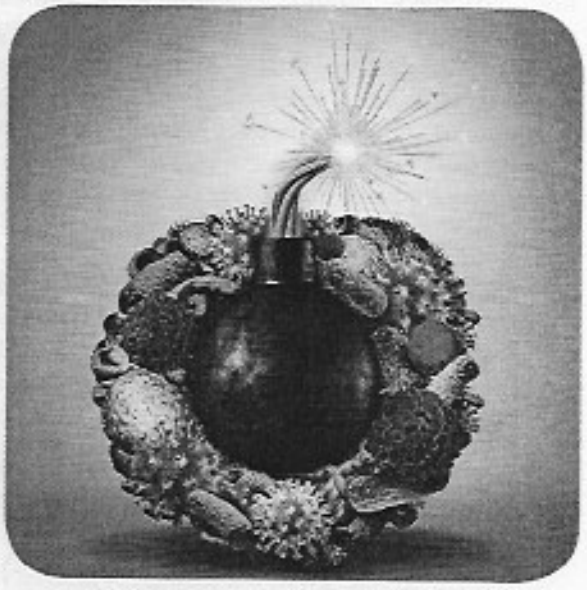
Current U.S. Biological Defense Posture is Inadequate and Outdated

Despite the fact that natural and intentional disease outbreaks are and will be a threat to national security, almost two decades of federal investment have failed to improve our intelligence against biothreats, our capability to develop and produce vaccines and treatments, and our capacity for public health epidemic response.

Biodefense is not a policy or budget priority for any single agency. A plethora of federal agencies is responsible for different aspects of biodefense, making it extremely difficult to forge an effective national biodefense strategy. The authorities for managing public health are divided among federal agencies such as the Centers for Disease Control and Prevention (CDC) and more than 3,000 state, local, territorial and tribal public health organizations, posing daunting logistical, communications, and operational problems. These and many other challenges have been pointed out in detail by a succession of high-level reports and critiques.

This institutional disorganization has impeded the nation's ability to solve three key technology issues contributing to our ineffective national biodefense posture:

1. ***Conventional methods for creating vaccines and medicines are too slow.*** While the Ebola virus has been recognized as a top biothreat since the late 1990s, the U.S. did not have any vaccine or therapeutic drugs ready for human use against this virus at the time of the 2014 Ebola outbreak, despite tens of billions spent by the National Institutes of Health and Health and Human Services for medical countermeasure development. Pre-clinical Ebola vaccine candidates existed in 2014, but a rapid way to test their safety and efficacy was neither not in place, nor was there a plan to manufacture the vaccine. To fill the gap, two drug companies – Merck and GSK – generously offered *ad hoc* support to manufacture enough of the experimental vaccines to conduct human trials. But the epidemic was waning by the time the vaccines were ready, making it difficult to reach firm conclusions about the vaccines' effectiveness. (It was reported in December 2016 that a small, randomized trial of people believed to be direct or indirect contacts of persons infected with Ebola virus were successfully protected against infection, using a vaccine developed by Health Canada and manufactured by Merck.)



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hampering the availability of such tests. The federal government should investigate and reform current counterproductive payment barriers that make the development of new diagnostics an unattractive investment, despite the fact that better diagnostics benefit patients and decrease health care costs. In addition, federal investment in establishing curated collections of pathogens to enable faster validation and FDA approval of new diagnostics would be highly cost-effective.

Importing the digital revolution into public health practice will save lives and money and decrease the severity of social and economic disruption caused by epidemics. Effective control of large, fast-moving epidemics is impossible without near-real time awareness of facts on the ground. U.S. biodefense strategy must ensure that leaders receive basic and time sensitive information critical to informing key decisions in epidemic management. This is not the case today. After decades of failed attempts to build comprehensive electronic "biosurveillance" systems, we should consider a more targeted approach to ensure that useful analysis reaches decision-makers – including the President and governors – in a timely manner. Policies to ensure that, during health emergencies, relevant data are shared and made available to public health service agencies, medical officials and the public will be needed.

Many of the tools needed to develop this capability are already deployed by the private sector and researchers for the analysis of so-called "big data". A significant industry is devoted to developing, testing, and selling tools that collect, curate and analyze data at the scale of the entire internet; indeed, such tools are keystones of the digital revolution. Yet few of these (now routine) capabilities have been integrated into U.S. public health practice. Unless the federal government institutes a practical approach to gaining situational awareness during public health emergencies, it will be very difficult to implement a viable biodefense, particularly against large-scale bioweapons attacks.

Why Has the U.S. Not Yet Built a Robust Biodefense?

The Blue Ribbon Study Panel on Biodefense wrote that, "The Nation has not come to fully appreciate the severity of the biothreats, and our leaders have not demonstrated the political will to fully address it." This is certainly true, but it is also the case that the Nation's people and leaders do not yet appreciate the need for a biodefense technology strategy, or potential of current and emerging technologies to protect against biothreats.

The U.S. has the capacity to build a robust biological defense, but it cannot be constructed *during* a lethal epidemic or biological attack. Game-changing advances in biotechnology and the life sciences are making biodefense more feasible by the day. These advances are also expanding the access to powerful dual-use capabilities. Do we have the foresight to build an effective biodefense before the country needs it?

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