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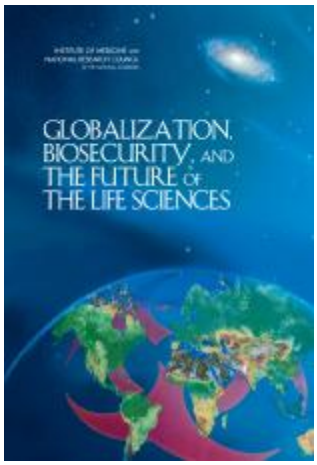
REPORT IN BRIEF



GLOBALIZATION, BIOSECURITY, AND THE FUTURE OF THE LIFE SCIENCES (2006)

For thousands of years, humans have been manipulating plants and animals to help address changing societal and environmental needs. The discovery of the structure of DNA in 1953, followed by the invention of DNA recombinant technology two decades later, paved the way for the potential to manipulate genes directly and in such a way that an organism can be altered in a single generation. Then in 2001, scientists finished the first draft of the human genome sequence, representing a shift in the way biology is studied and opening a gateway to vast possibilities for life sciences research.

Today, life sciences knowledge, materials, and technologies are advancing with tremendous speed. Every day in laboratories around the world, scientists and engineers in the life sciences are using sophisticated technologies to identify pharmaceuticals for the treatment of cancer and other chronic diseases, improve agriculture, develop environmental remediation technologies, improve biodefense capabilities, and create new materials and energy sources. Moreover, other fields not traditionally viewed as biotechnologies—such as materials science, information technology, and nanotechnology—are converging with biotechnology in unforeseen ways and enabling the development of previously unimaginable applications.

At the same time, bioterrorism and the proliferation of knowledge and understanding of fundamental life processes have led to increased concern about how the rapid advances in genetic engineering and biotechnology could enable the production of “next generation” biological weapons. This report examines current trends and future goals of research in the life sciences that could lead to a new generation of biological threats over the next five to ten years. It explores the threat posed by rapid, unpredictable growth and widespread dissemination of life sciences and associated technologies, and identifies the best approaches for anticipating, identifying, and mitigating these dangers.

A GLOBAL PERSPECTIVE IS CRITICAL

New advances in the life sciences and related technologies are being generated not just domestically, but also internationally. The top position that the United States has enjoyed in this field has been dependent on the flow of foreign scientific talent, but it is now threatened by the increasing globalization of science and the international distribution of technologies. The increasing pace of scientific discovery abroad and the fact that the United States may no longer hold a monopoly on these leading technologies means that the country is, as never before, dependent on international collaboration.

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TABLE 2-1 Current and Near-Future Applications of Advancing Technologies

Sectors	Trend	Goal	Key Enabling Technologies
Pharmaceuticals	Development of designer drugs ("personalized medicine"); genotype profiling	Individual and genome- specific drugs	Gene and protein chip (i.e., microarray), biomedical databases (i.e, information technology), computing
	Improved drug delivery	Alternative routes for drug administration	Nanotechnology, aerosol technology, microencapsulation, transdermal delivery technologies
Medicine	Improved diagnosis	Automated genomic tests	Databases, gene and protein chips
	Better treatments for infectious disease	Provide cures for difficult-to-treat or untreatable infections	Biomedical and genome databases, high- throughput screening of compound structural libraries, nanotechnology
	Gene therapy	Identify and treat defective genes	Databases, gene chip, high-performance computing
	Xenotransplantation	Develop rejection-free tissues and organs for transplantation	Databases, animal modeling, recombinant methods
Agriculture	Transgenic crops	Development of disease, pest, and environmental insult-resistant crops; manufacture of biological products	Genome sequencing methods, databases
Biomaterials	Artificial tissue and organs	Develop tissue, stem cell, and other engineering methods	Databases, transgenic crops/animals, nanotechnology
	Biopolymers	New materials for biological and industrial applications	Databases, computing, transgenic crops/animals, nanotechnology
Biodefense	Strengthening biodefense capabilities	Improvement and production of vaccines and prophylactics, rapid diagnostics, pathogen detectors, and forensics	Gene chips, databases, nanotechnology, detector hardware
Computing	Performance improvement	Faster computing for intensive analysis and filtering; convergence of technologies	Grid computing and supercomputers
	Expansion of biotech-specific applications	Develop and strengthen biotech-specific software	Advanced software and search algorithms

Source: Adapted from presentation by Terence Taylor in *An International Perspective on Advancing Technologies and Strategies for Managing Dual-Use Risks: Report of a Workshop* (NRC, 2005).

NECESSARY ACTIONS TO REDUCE RISK

A wide range of actions is required to successfully manage the biological threats that face society. This report presents a broad-based, intertwined network of steps—a *web of protection*—for reducing the likelihood that the technologies will be used in harmful ways. The actions suggested in the following recommendations, taken in aggregate, will likely decrease the risk of inappropriate applications or unintended misuse of the technologies.

Support the Free and Open Exchange of Information

Overall, society has gained from advances in the life sciences because of the open exchange of data and concepts. Conversely, restrictive regulations and constraints on the flow of information are not likely to reduce the risk that technologies will be used with harmful intent. In fact, they will make it more difficult for society to protect itself against threats and will limit the potential for advances in the life sciences. New developments in the life sciences and related technologies are essential to countering the future threat of bioterrorism; therefore, policies and practices that promote the free and open exchange of information in the life sciences should be supported.

Broaden the "Threat Spectrum"
U.S. national biodefense programs currently focus on a relatively small number of chemicals, chosen because of their history of development as potential biological weapons. Recent advances in understanding bioregulatory compounds, signaling processes, and the regulation of human gene expression—combined with advances in chemistry, synthetic biology, nanotechnology, and other technologies—have led to new concerns. A broader perspective on the "threat spectrum", or types of possible threats, is needed. This should be done by incorporating new scientific methodologies that allow for more rigorous risk assessment over time. This will require engaging the scientific community in new ways and strengthening the scientific and technical expertise available to the security communities so that they are better equipped to anticipate and manage a diverse array of threats.

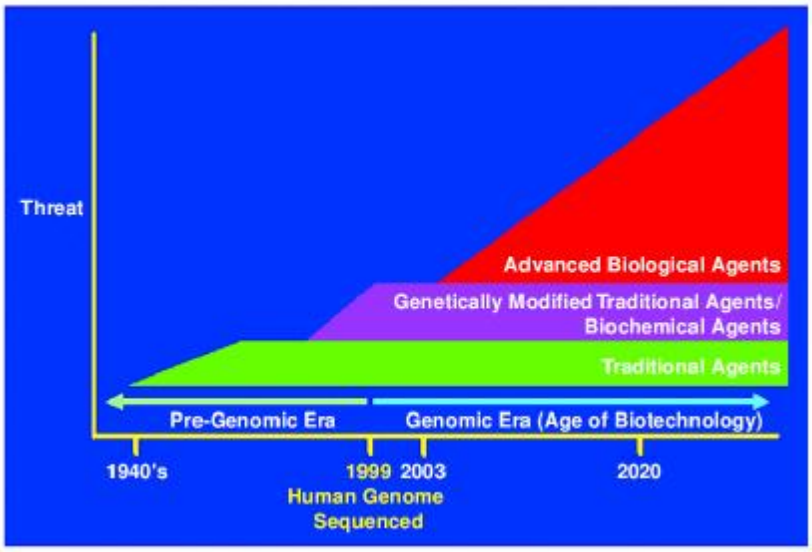

FIGURE 1-3 Timeline describing impact of biotechnology on biological warfare threat. Reprinted with permission from *BioSecurity and Bioterrorism: Biodefense Strategy, Practice, and Science* 1(3), 2003.

Strengthen and Enhance Scientific and Technical Expertise
Preventing misuse of technologies requires governments to be able to anticipate future threats and understand their implications. An independent advisory group of scientists in the basic and applied life sciences should be created to work closely with the national security community to predict future biological threats based on analysis of current and future science and technology, and current intelligence. The best available science should inform the concepts, plans, activities, and decisions of the intelligence, law enforcement, homeland security, and public policy communities about advancing technologies and their potential impact on the development and use of future biological weapons. It is also important to build a robust and sustained analytical capability within the national security community. Finally, information regarding biological threats should be shared and coordinated between the U.S. security community and its international counterparts.

Adopt and Promote a Common Culture of Awareness and a Shared Sense of Responsibility
A proactive strategy against next-generation biological threats will require collective global action. National and international codes of ethics and conduct for life scientists should be developed to help mitigate risks. Programs promoting beneficial uses of technology in developing countries should also be supported. Additionally, globally distributed, decentralized, and adaptive approaches to monitor and address the misuse of technologies derived from the life sciences should be developed. Specifically, a network of scientists who can recognize when technologies are being misused should be created. This group would provide counseling to scientists that appear to be using technologies inappropriately and report such activities to national authorities when the risk seems high.

Strengthen the Public Health Infrastructure

An effective civil defense program requires a well-coordinated public health response, and this can only occur if there is strong integration of well-funded, well-staffed, and well-educated local, state, and federal public health authorities. Despite substantial efforts since September 11, 2001, there is still no infrastructure in place to deal rapidly, effectively, and in a clearly coordinated manner when faced with a catastrophic event such as a large-scale bioterrorism attack. There is a critical need to strengthen the public health infrastructure and response and recovery capabilities to be prepared for possible biological threats. This should be done through greater coordination of local, state, and federal public health agencies and improved detection of biological agents and disease outbreaks. Finally, incentives should be provided for the development and production of vaccines for biological agents.

FUTURE CONSIDERATIONS

Continuing advances in the life sciences and related technologies are essential to countering the future threat of bioterrorism. The recommendations outlined above are key to addressing threats due to misuse of such technologies. Nonetheless, there is no guarantee that continuing advances in the life sciences and the new technologies they spawn will not be used with the intent to cause harm, and it remains unclear how the country's response to a future biological attack will be managed. How will the responses of multiple federal agencies be effectively integrated, and who will control operations and ensure that they are adequately interfaced with local and state governments and public health agencies? What *is* clear is that the development of an effective way of integrating the actions of the government agencies can provide the nation with the most necessary tools to meet future biosecurity challenges.

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