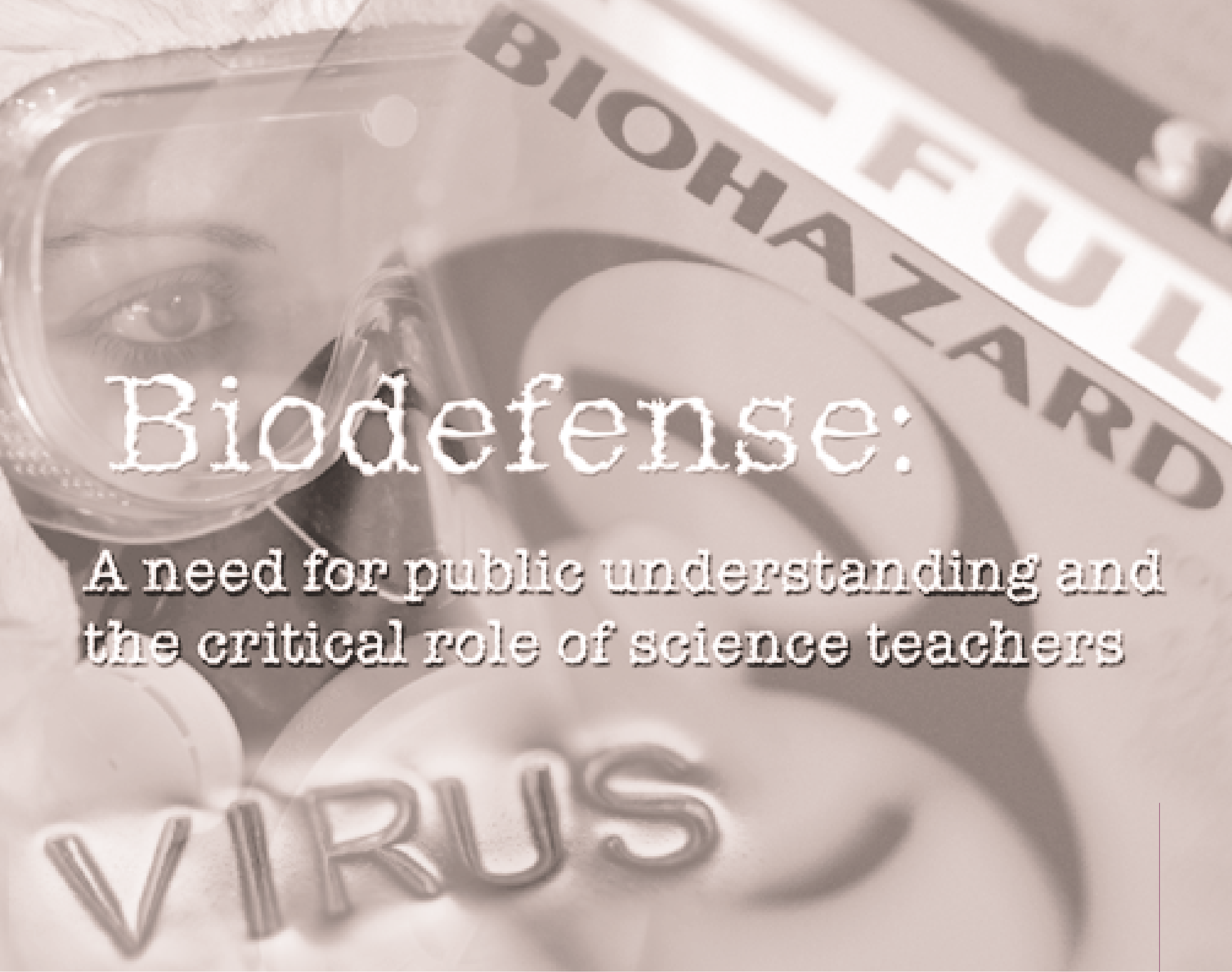
Biodefense:

A need for public understanding and the critical role of science teachers



Last fall's terrorist attacks raised questions many of us never contemplated. As students turned to their science teachers for answers, the role of those educators became paramount in increasing public understanding of biodefense. The following special section of The Natural Selection *addresses this topic in a way we hope helps teachers respond to their students' concerns.*

Facts about bioterrorism/biodefense

Bioterrorism and biodefense defined. *Bioterrorism* is the use of microorganisms or biological toxins to kill people, spread fear, and disrupt society. Others, like anthrax, are not contagious at all. *Biodefense* is the set of preparations society has to make to prepare for a bioterrorist attack, including stockpiling drugs, planning, research, and upgrading the public health system.

Bioterrorism can take many forms. Terrorist contamination of food or water is one possibility. But these are well protected, and it would be hard to affect a large number of people through these means. The most dangerous attack method is to spread microscopic particles of a biological agent through the air as an aerosol.

Many different organisms or toxins could be used as bioterror weapons. The Centers for Disease Control and Prevention (CDC) in Atlanta lists six bioterror agents as the most worrisome, all of which could be spread as an aerosol. Some diseases that terrorists might use, such as plague and smallpox, are contagious—they can spread from person to person.

A bioterrorist attack is not easy to pull off. Having a small sample of a deadly microorganism doesn't give someone the power to wipe out a city with a single blow. Labs across the country safely handle wet preparations of the germs that cause deadly illnesses such as anthrax with only simple precautions. The process of preparing a germ to cause widespread disease is

continued on page 14

Special Section: Biodefense

continued from page 13

often called "weaponization." To make a weapon that can be spread in the air, a terrorist would have to grow the germs into a larger culture, purify and dry them, and grind the dry material into microscopic particles, all without rendering the germs impotent. This process is very difficult, and requires techniques that are not easy to learn or invent.

A worst-case attack would be very, very bad. Weaponized germs or toxins have a horrible potential for killing. For example, the letters sent to Senators Daschle and Leahy last October contained less than three grams of highly purified, dry anthrax spores with just the right particle size to get trapped easily in a person's lungs. If a terrorist spread 100 kilograms of this kind of spore preparation over a city under ideal conditions, millions of people would inhale enough spores to get respiratory anthrax. Without medical intervention, almost all these people would die. In addition to the injuries and death, devastating disruption from such an attack would spread far beyond the contaminated area, and decontamination would be dangerous, difficult, and very expensive.

Fortunately, this kind of worst-case scenario is unlikely. Carrying out a catastrophic attack is extremely difficult, and people *would* get medical attention. Antibiotics taken shortly after inhaling anthrax spores or plague germs would prevent people from ever getting sick at all, for example. Intensive medical care could save many of those who do.

We are not helpless. A growing understanding of the potential harm a bioterrorist attack could inflict—driven home dramatically by last October's anthrax attack—has led Congress to increase spending for biodefense. The extra money will go to improving the public health system—which has the added bonus of helping to stop naturally occurring disease outbreaks—improving disaster planning and coordination between government agencies, stockpiling drugs and vaccines for rapid delivery in a crisis, and conducting research on better treatments, diagnostic tests, and monitoring devices for potential bioterrorism agents.

–Robert Taylor

About Robert Taylor

Most of the stories in this special section of *The Natural Selection* were written by Robert Taylor, a science journalist and editor. After college, Taylor taught high school chemistry and biology for two years, then enrolled as a graduate student in chemistry at Georgetown University, earning his Ph.D. in 1993. Ultimately, he decided that talking to scientists about their work was more fun for him than doing science himself, so he took up science writing. After the terrorist attacks last fall, he left his editing job with the National Institutes of Health Office of Science Education to focus exclusively on issues surrounding bioterrorism and biodefense.

Robert Taylor

Fauci speaks out on biodefense

By Robert Taylor

Last fall, when terrorists mailed anthrax spores to news organizations in Florida and New York, and to Senate offices in Washington, D.C., keeping the public informed about the crisis quickly became a top national priority. And Anthony Fauci, director of the National Institute of Allergy and Infectious Diseases (NIAID) in Bethesda, Md., quickly emerged as a prominent national spokesman about the bioterrorist attack. For weeks he put in 18-hour days, fielding questions from the media and the general public while helping to craft the public health response to fast-moving events.

That immediate crisis has passed, but Fauci is still at the center of the nation's biodefense efforts. He is among the inner circle of government officials working to improve the nation's ability to cope with bioterrorism, and is in charge of NIAID's $1.7- billion-dollar bioterrorism research effort. The Natural Selection *spoke with Fauci in a May telephone interview.*

Q: **Let's start with the basics. What is "bioterrorism?"**
A: Bioterrorism is an extension of biological warfare, something that has gone on intermittently for a very long time. Biological warfare aims to use germs or biological toxins to kill or disrupt enemy troops. Bioterrorism is a little different, because it is

continued on page 15

aimed at civilian society. It is not necessarily intended to cause large amounts of destruction and death—although that would make it more efficient—but at inciting terror. So a bioterrorist weapon does not necessarily need to kill very many people, so long as it has the desired effect of immobilizing a society.

Anthony Fauci (Photo by Bill Branson, courtesy of NIAID/NIH.)

Q: **What is "biodefense?"**

A: Biodefense is the preparation for a medical response to a bioterror event. It includes everything you have to do medically to counter a bioterrorist event—diagnostics, therapeutics, vaccines, and other public health measures that would allow rapid mobilization and response. It is not law enforcement, or intelligence, or prevention. Those are very important, but not what we mean when we talk about biodefense.

Q: **How is bioterrorism different from other forms of terrorism?**

A: For one thing, it can in some forms spread from person to person. That is not true of all potential bioterror agents—anthrax is not contagious, for example. But smallpox, plague, or a deadly form of influenza—all of these are contagious. Another important difference is that bioterrorism is silent. When a bomb goes off, everyone knows something terrible has happened. If someone releases a chemical weapon like Sarin gas, right away people are going to start dropping and we will know that something bad is going on. But if a terrorist puts microbes into the population it might take days or weeks before we even know we have a problem.

Q: **During the anthrax crisis last fall only a few people died. Does this mean that the threat of bioterrorism is overblown?**

A: No, it is definitely not overblown. For example, there were just two to three grams of high-quality anthrax spores in the letters sent to Sen. Daschle and Sen. Leahy, which also included a warning. If two or three or four grams of this anthrax preparation were put without warning into the ventilation system of a big city subway system, or in the air intake of a large building, a lot more people would have gotten sick and died before we knew what was going on.

Q: **Without getting into specific diseases, what are a few things everyone should know about bioterrorism?**

A: First, although the risk of an attack at any specific place is small, and with some microbes the impact might be small, the potential harm is so large that we have to cast out a very broad net, with a lot of effort and a lot of resources. I do not want to seem melodramatic, but as the President says, we are at war against an enemy that has already shown it will stop at nothing to harm us, and which might have the capability to carry out a bioterror attack. There already has been a bioterrorist attack on us. And unlike classic warfare, we cannot predict when something is going to happen. We could go six months or a year with nothing happening, and suddenly have someone release Ebola in Madison Square Garden. That unpredictability makes this war in which we are involved unique.

Second, our society must adjust to the fact that we are always living with different small but hard-to-quantify risks. One of the problems during the anthrax attack was that because people were not used to dealing with this kind of risk, we were reluctant to say early on that the mail system, although very safe, is not 100-percent safe. The sooner we realize that we will never have a perfectly risk-free environment, the better we are going to deal with bioterrorism.

And third, we should all remember that the goal of bioterrorism is to instill terror in society. So we have to deal with it in a measured, calm way. For that to happen, we need to be much better prepared. This will involve a lot of government planning and preparation, including rebuilding the public health system which, because of our successes against infectious diseases in decades past, has fallen into some disrepair. But it also involves educating the public and helping them understand how public health decisions are made.

Q: **What is government doing to prepare for a bioterrorist attack?**

A: Oh, a lot. I am actually quite pleased with the response, and some of the early results. We are working hard on preparedness planning and better coordination between federal agencies and between federal and local officials. And the President's budget for biodefense includes new money for rebuilding the public health infrastructure. Here at NIAID we are doing research to develop better new drugs and vaccines for the high-priority agents—the ones mostly likely to be used by terrorists. For example, just months ago we had only 15 million smallpox vaccine doses on hand—a very precarious position to be in. So we did a study to see if we could dilute the vaccine but still retain its effectiveness and, lo and behold, we now have over 75 million doses. At the same time, we have contracted to make a new supply of the vaccine, and we have undertaken research to develop a much safer vaccine. So while there is an enormous amount of work left to do, we have made a lot of progress.

Special Section: Biodefense

VRC Director sees the need for positive response in anthrax aftermath

By Laura Engleman

To Vaccine Research Center (VRC) Director Gary Nabel, the glass is half full. "There is potential to learn and grow from our experience with the anthrax scare," he said. "If we respond in the right way, we can help create a safer world in terms of public health, so we can better cope with the range of organisms that are out there."

The VRC is part of the National Institute of Allergy and Infectious Diseases (NIAID) at the National Insitutes of Health (NIH) and was created by former President Bill Clinton to develop an AIDS vaccine. The VRC's work also will provide the basis for research on vaccines for other diseases.

Nabel said national concerns about bioterrorist agents are no different than those about natural outbreaks of diseases such as HIV/AIDS, influenza virus, tuberculosis, and malaria. "In many ways, some groups are doing artificially what happens naturally with certain microbes," he noted.

The anthrax scare, which left Nabel and his colleagues without mail for about a week, has actually led to a number of positives responses, such as reminding the public about the importance of vaccines. "For many years, there has been a small subset of people suspicious of vaccines," Nabel said. "Now there is a greater awareness of the value of vaccines and their ability to liberate people from concern about particular microorganisms."

Nabel joined the National Institutes of Health in 1999 from the University of Michigan in Ann Arbor, where he was the

continued on page 17

NIAID's research agenda

The NIAID Counter-Bioterrorism Research Agenda for CDC Category A Agents describes two separate arms of biomedical research: basic research, which will continue to provide the framework for scientific and medical advances, and applied research, which will move laboratory developments into products that can be used to protect the public from disease. (The complete agenda is available online at *http://www.niaid.nih.gov/dmid/pdf/biotresearchagenda.pdf*.) The agenda divides research on each Category A microbe into six key elements:

- *Microbial biology.* Increased basic research will help scientists acquire comprehensive information on the biology and disease-causing mechanisms of potential bioterror pathogens. Such information, which includes sequencing of each microbe's genome, will provide the information needed to develop new drugs and vaccines to combat possible bioterrorism-caused diseases.
- *Human immune response.* Increased research on the basic components of the human immune system will enable scientists to develop safe and potent vaccines, highly accurate diagnostic tests, and broadly acting drugs that boost overall immunity to a range of pathogens.
- *Vaccines.* Vaccines are one of the most effective ways to protect people from infectious diseases, and accelerated research on new vaccines is underway. New Ebola and anthrax vaccines will soon enter human testing, and research on improved smallpox and tularemia vaccines is ongoing. Additional research has been conducted on ways to stretch current smallpox vaccine stockpiles for the short term.
- *Treatments.* The increase in antibiotic resistance among bacteria and the relative scarcity of effective antiviral drugs make treatment research imperative. Scientists will use information gained from basic studies of a microbe's biology and genetic makeup to develop compounds that specifically destroy that organism or its toxins. Research on new treatments for pathogens such as smallpox and anthrax are currently underway.
- *Diagnostics.* An effective response against a bioterrorist attack requires rapid, accurate identification of both natural and bioengineered microbes. Information on a pathogen's sensitivity to available drugs will also help doctors quickly treat anyone who has become infected. New early warning and diagnostic tests are a key part of NIAID's bioterrorism research agenda.
- *Research resources.* Research on the five general areas above requires a broad range of resources including genomic information, novel reagents, animal models of disease, and high-containment laboratories and clinical facilities. NIAID will provide those resources in part by building the necessary facilities, establishing collaborations with industry, and training new scientists with varying expertise.

(Source: "NIAID Unveils Counter-Bioterrorism Research Agenda," NIAID News, March 14, 2002.)

Henry Sewall professor of internal medicine and professor of biological chemistry as well as a Howard Hughes Medical Institute investigator. He is well known as a molecular virologist and immunologist for his work in the fields of HIV, cancer, and Ebola virus research.

Nabel noted that "we didn't do a bad job" handling the anthrax crisis, but "it has been a wake-up call about how to respond in the future." Among questions raised:

- Which biological agents are we really prepared for?
- How can we harness technology to help us deal with an outbreak?
- What should our approaches be regarding the vaccine supply?
- Can we make better vaccines?

"These are 'looking at the forest' kinds of lessons," Nabel said. "We've taken a lot for granted in terms of public health, and we shouldn't." The chief role of NIH, he said, is to be "the science engine that drives improvements in public health," including research, new targets for treatment, and new vaccines.

In March, NIAID released its counter-bioterrorism research agenda, describing the institute's accelerated research plan for the most threatening agents of bioterrorism (see p. 16). The agenda outlines the research NIAID will undertake to help protect civilian populations from diseases such as smallpox, anthrax, and plague, should they be unleashed intentionally. The plan includes short-, intermediate-, and long-term research goals and describes specifically how bioterrorism countermeasures will be developed for each microbe, including diagnostics, therapies, and vaccines.

Accelerated research on new vaccines is underway.

The research agenda was developed by NIAID scientists and reviewed by an outside panel of experts from academia, industry, and government. The plan focuses on the Category A diseases as described by the Centers for Disease Control and Prevention (CDC): anthrax, smallpox, plague, tularemia, viral hemorrhagic fevers, and botulism. Those diseases cause high death rates or serious illness, are relatively easy to spread, could cause public panic, or require special steps for public health preparedness. NIAID plans to develop research plans for CDC Category B and C agents in the near future.

Although national attention on bioterrorism and biodefense certainly have taken on new proportions since Sept. 11, NIAID points out on its Web site that the U.S. has recognized its vulnerability to chemical or biological attack since the Tylenol scare of 1982 (when packages of Tylenol were contaminated with cyanide and the era of tamper-proof packaging dawned). The 1984 *salmonella* contamination of salad bars by the Rajneesh cult, to prevent Oregon voters from reaching the polls, represented the first well-documented bioterrorist attack in the U.S. More recently, the bombings of the World Trade Center and the Alfred Murrah Federal Building, the uncovering of advanced biological weapons programs in Iraq and the former Soviet Union, and the Aum Shinrikyo nerve gas attack on the Tokyo subway focused concern on possible biological or chemical terrorist attacks against the U.S.

Because a potential biological attack on a civilian population differs markedly from well-established military plans for defense, the need for public education is paramount. The civilian population, NIAID points out, includes a diversity of age and health conditions not seen among troops, and probably the first recognition of an attack will be a disease outbreak. Therefore, the first line of a response to a civilian attack will stress rapid diagnosis and antimicrobial or antitoxin therapy.

Nabel emphasized the important role that science teachers can play to educate students and the public about infectious diseases. He recalled his 10-year-old daughter coming home from school one day to report that only five kids out of 20 had been in class. Seventy-five percent of the students were absent with an infection whose cause was unknown. "So many people walk around the world today and don't understand the basics of how infectious diseases are transmitted—what risks people expose themselves to through society in everyday life," Nabel stressed. "What is the microbial world? How does the body defend itself? Teachers can frame issues of bioterrorism as a perversion of the natural ecology of our world."

He believes it is better to be "forewarned and forearmed with knowledge and education than to be uninformed and unable to make decisions." The anthrax incident is an excellent case in point for scientific literacy, Nabel added. Teachers also can share their enthusiasm and passion for studying scientific questions, with the hope of encouraging some students to pursue a career in science.

Responding to the concerns of some teachers who don't want to frighten their students, Nabel noted that risks are part of life. "Many more people died in car accidents during the time of the anthrax outbreaks (than from anthrax)," he said. "You have to find a level of comfort for yourself.

"When I think realistically about the threats to my children and your children, I worry more about existing natural outbreaks (HIV/AIDS, influenza virus, drug-resistant TB, meningitis, mononucleosis, herpes viruses) than things like anthrax. The idea of improving public health to eliminate nature's bioterrorism is a more realistic concern."

Special Section: Biodefense

Smallpox: How much should we worry?

By Robert Taylor

For public health authorities, the bioterrorist threat that really keeps them up nights is smallpox. This disease—highly contagious, excruciatingly painful, untreatable, and often lethal—has killed more people than any other in human history. But variola major, the virus that causes smallpox, has been extinct in the wild since before 1980. Officially, the only samples are in two high-security storage facilities, one in Atlanta and the other in Siberia.

So why worry? Unfortunately, no one can be certain that all old samples of the smallpox virus have been destroyed. Several countries, including Iraq, are thought to have an active interest in developing smallpox as a weapon. The now-defunct Soviet Union had a massive biological weapons program until the early 1990s, and manufactured weaponized smallpox *by the ton,* ready for use in an apocalyptic war with the United States. Many experts say smallpox samples likely linger on in cold storage somewhere. That means a terrorist might be able to acquire the virus and deliberately unleash it.

A smallpox attack could mean disaster. During the summer of 2001, political and public health figures participated in a "war game" style simulation of a smallpox attack, called Dark Winter. The exercise cast real-life politicians as government officials, supported by a cast of public health officials, emergency response directors, and news reporters. The scenario envisioned 3,000 smallpox primary infections caused by an air release of the virus in shopping malls in three states.

As the script for the exercise unfolded, the number of secondary smallpox cases skyrocketed, shortcomings in government planning and response became woefully apparent, and the paltry 15 million doses of vaccine on hand were quickly exhausted. Within two weeks, 16,000 total cases were reported in 25 different states as the disease spread. Economic disruption was severe. New vaccine wouldn't be available for another month. The President, played by ex-Senator Sam Nunn of Georgia, was advised that within a few weeks the number of infections could top 300,000, with about 100,000 deaths. Mercifully, that's where the game ended.

Not everyone is sure that a smallpox attack would be as bad as portrayed in Dark Winter, however. To model how an outbreak would progress, the Dark Winter authors assumed that each case of smallpox would generate about 10 new infections. The rate of infection was higher than this in a 1972 outbreak in Yugoslavia, when a man unwittingly carried the virus back from the Middle East and sparked Europe's last smallpox epidemic. By vaccinating virtually the entire country's population of 20 million and employing draconian quarantine measures, Yugoslav authorities stopped the epidemic after 175 infections, and 35 deaths. But critics say that the Dark Winter assumptions were too gloomy. A more likely estimate of the number of subsequent infections each primary case would cause is somewhere between just above one and about six, they say, making the outbreak far easier to contain.

The real consequences of a smallpox attack will remain uncertain until put to the test—something everyone hopes will never happen. In the meantime, the Dark Winter exercise has helped to encourage better planning, and spurred the government to increase the stockpile of smallpox vaccine, which now stands at about 100 million doses and climbing. A recently reported government plan calls for as many as 500,000 medical and emergency workers to be vaccinated in the near future, and for an immediate mass vaccination campaign if the disease re-emerges.

Facts about smallpox

Smallpox is caused by variola virus. The incubation period is about 12 days (range: 7 to 17 days) following exposure. Initial symptoms include high fever, fatigue, and head and back aches. A characteristic rash, most prominent on the face, arms, and legs, follows in two to three days. The rash starts with flat red lesions that evolve at the same rate. Lesions become pus-filled and begin to crust early in the second week. Scabs develop and then separate and fall off after about three to four weeks. The majority of patients with smallpox recover, but death occurs in up to 30 percent of cases.

Smallpox is spread from one person to another by infected saliva droplets that expose a susceptible person having face-to-face contact with the ill person. Persons with smallpox are most infectious during the first week of illness, because that is when the largest amount of virus is present in saliva. However, some risk of transmission lasts until all scabs have fallen off.

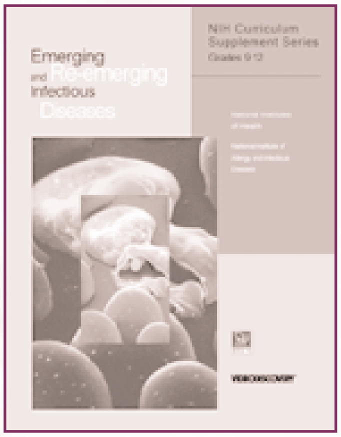
The last natural smallpox infection occurred in 1977. Routine vaccination against smallpox ended in the U.S. in 1972. The level of immunity, if any, among persons who were vaccinated before 1972 is uncertain; therefore, these persons are assumed to be susceptible.

There is no proven treatment for smallpox but research to evaluate new antiviral agents is ongoing. Patients with smallpox can benefit from supportive therapy (intravenous fluids, medicine to control fever or pain, etc.) and antibiotics for any secondary bacterial infections that occur.

(Source: Centers for Disease Control and Prevention, reproduced with authorization.)

Herd immunity and the smallpox scare: An activity for your classroom

By April Gardner



The Centers for Disease Control and Prevention (CDC) in Atlanta and the Institute for Viral Preparations in Moscow maintain the only officially known stocks of the virus that causes smallpox, held solely for research purposes. But what if terrorists found and released this virus? How could we protect ourselves?

Students may have learned in their biology studies that there is a vaccine that prevents smallpox. They likely will assume that everyone in the United States should be vaccinated to prevent a smallpox epidemic. Vaccinating everyone would be expensive, logistically difficult, and dangerous—the smallpox vaccine kills about five out of every one million people who take it. Fortunately, even unvaccinated people could be protected by a phenomenon called herd immunity. Unvaccinated people in the population may be protected by this herd immunity. But how many are “enough”?

The high school curriculum supplement *Emerging and Re-emerging Infectious Diseases,* developed by BSCS with support from the Office of Science Education (OSE) and the National Institute of Allergy and Infectious Diseases (NIAID) at the National Institutes of Health (NIH), includes an activity that will help students answer this question. The CD-ROM packaged with the supplement contains a simulation of the spread of disease through a population. Students use the computer simulation to vary the virulence, disease duration, and likelihood of infection for various infectious diseases and determine their impact on whether an epidemic of the disease occurs. They investigate further by considering three real diseases: smallpox, measles, and polio. Students learn that a different proportion of the population must be vaccinated to achieve herd immunity, and that it is not necessary to vaccinate 100 percent of a population to prevent an epidemic of any of these diseases.

During Exercise TOPOFF 2000, LCpl Michael Martella (foreground), LCpl J.B. Little, LCpl S. Cochran, and PFC C. Markley of the U.S. Marine Corps Chemical Biological Incident Response Force (CBIRF) under the command of Joint Task Force Civil Support treat a simulated non-ambulatory terrorist attack victim at Portsmouth, N.H. (Photo by Master Sgt. Steven Turner, USAF.)

The curriculum supplement also includes activities to differentiate emerging (new or newly recognized infectious diseases) and re-emerging (well-known and previously well-controlled diseases that are increasing in incidence) diseases. Smallpox would fall into the latter category, should the virus be released. Students who complete the module also learn the factors associated with the emergence and re-emergence of infectious diseases and how epidemiologists investigate and try to prevent these infectious diseases.

Emerging and Re-emerging Infectious Diseases is available **FREE** to teachers. You can request a print copy of the supplement online at *http://science-education.nih.gov/supplements*. A Web version of the supplement is available at *http://science-education.nih.gov/supplements/nih1/diseases/*.

April Gardner is a BSCS staff biologist.

Web resources for teachers

- The Centers for Disease Control and Prevention (CDC) has a bioterrorism site: *http://bt.cdc.gov*
- The National Institute of Allergy and Infectious Diseases (NIAID) also has a bioterrorism site: *http://www.niaid.nih.gov/publications/bioterrorism.htm*
- The Johns Hopkins Center for Civilian Biodefense Strategies is a think tank devoted entirely to bioterrorism: *http://www.hopkins-biodefense.org*. It includes a good summary about the Dark Winter smallpox simulation; see link at the bottom of the home page.
- The Center for Infectious Disease Research and Policy (CIDRAP), affiliated with the University of Minnesota, specializes in infectious disease issues, especially bioterrorism: *http://www1.umn.edu/cidrap*
- The National Academy of Sciences has a good list of bioterrorism resources at *http://www.nap.edu/shelves/first/*
- Risk communication specialist Peter Sandman has an interesting (and long) article about communicating during a bioterrorism crisis: *http://www.psandman.com/col/part1.htm*
- Monterey Institute Center for Nonproliferation Studies has a good list of resources on biological and chemical weapons, with an emphasis on nonproliferation: *http://cns.miis.edu/research/cbw/index.htm*

Special Section: Biodefense

Teaching about terror

By Robert Taylor

After last year's terrorist attacks, Americans felt threatened. Besides an epidemic of sleepless nights, in schools across the country students suddenly bombarded their science teachers with questions about biological, chemical, or radiological weapons.

But teaching about terror, while not easy, is not a bad thing, said Anthony Fauci, director of the National Institute of Allergy and Infectious Diseases (NIAID). To mount an effective response against these unconventional threats, the general public must understand them, and because these threats involve science, science teachers have a role to play. "It is by understanding these risks, these microbes, chemicals, and other potential threats, that we will be able to respond in a much more organized, intelligent, and effective way," said Fauci.

First comes the problem of what to teach. Weaponized anthrax spores, Sarin nerve gas, and radioactive cesium dust aren't part of the standard science curriculum. Teachers can be hard put to find good information. Fortunately, the Internet has a huge amount of information about the science behind different terrorist threats, and many Web sites have done a good job collecting and presenting it for different audiences (see Web resources, p. 19).

When it comes to bioterrorism, getting across the basics of how public health decisions are made is one of the best things teachers can do, noted Monica Schoch-Spana, a Senior Fellow at the Center for Civilian Biodefense Strategies in Baltimore, Md. "People need to understand what public health is all about, including how we control disease outbreaks, what a vaccine is, how antibiotics work, what antibiotic resistance is, and how we fight it," she said. If the public is reasonably familiar with these issues, people will cooperate much more effectively with authorities after a bioterrorist attack, she added. "People won't take their medicine if they don't trust the doctor," she said—and familiarity breeds confidence.

"Many students brought up the topic regarding smallpox and anthrax," said Anna Kong, who teaches at Stone Academy, an inner-city school in Chicago. "Some students confessed anxiety and fear that they and their families would be at risk of being harmed by bioterrorism. Even though I was feeling anxious myself, I was very cautious not to add to their discomforts and uncertainty," which stemmed, Kong felt, from lack of information.

Paula Henderson (middle) teaching biology at Newark High School, Newark, Del.

Paula Henderson, a biology teacher at Newark High School in Newark, Del., agreed that it is critical to give students accurate and timely facts. "I think it is important that students understand the basics of issues where biology makes the news so that they are able to listen to material being presented and pick out the important points," she said. "They also need to be able to recognize when something is being exaggerated by the media for the sake of a story."

Peter Sandman, a risk communication consultant in Princeton, N.J., who advises the Centers for Disease Control and Prevention (CDC) on bioterrorism crisis communications, noted that–for adults or children–the emotional reaction to unlikely but appalling threats is complex. According to Sandman, authorities tend to focus on the "hazard"–how likely a risk is to do actual harm. The public, however, zeroes in at a level of "outrage," a combination of fear, anger, and uncertainty. Outrage depends not on statistical risk, but on factors such as whether people have any choice about being put in danger, whether they can take any active steps to limit the threat, and how familiar the risk is to them. For this reason, experts' perceptions of hazard and the public's degree of outrage often fail to align—which will be no surprise to anyone who has tried to teach teenagers about the health risks of smoking.

What makes communicating about unconventional terrorism unusual is that until an incident happens, outrage hardly exists. But after an event, outrage is sure to be universal and extraordinarily high, whether the hazard is real or imagined.

continued on page 21

continued from page 20

And, noted Sandman, the fear will not necessarily be for personal safety. People also will dread having to watch more death and destruction of their fellow citizens on TV.

Teachers can best deal with outraged and curious students by understanding what Sandman calls "the seesaw of risk communication." In general, he said, if a communicator focuses on one aspect of a crisis—say, how that threat is statistically very small—the public will focus on the opposite—say, how outraged it feels to be in any danger at all.

For any form of catastrophic terrorism, the "reassurance seesaw" is the most important. "To calm our fears, you should express those fears for us rather than insisting they are exaggerated," he said. That means a teacher should be straightforward about how bad catastrophic terrorism can be. That doesn't mean you should only communicate doom and gloom, Sandman emphasized. Instead, recognize the fears underneath, but go on to put them into context.

For bioterrorism, this means first acknowledging that we live in a world in which people who hate us also may be both willing and able to attack us with biological weapons. Once your audience sees you calmly recognize this fact, it will be ready to hear that the probability of attack at any one place and time is low and that society is by no means powerless to cope. The ultimate goal is to move people toward the center of the seesaw—away from both denial and paralytic fear, toward a state of rational, well-informed concern.

"Students' real concern is can this happen to them? What kind of treatment is there? Can we vaccinate everyone?" said Carole Wheeler, a teacher at Pine Creek High School in Colorado Springs, Colo.

Greg Nichols, a teacher at New Options Middle School in Seattle, said his students asked similar questions, including, "Can they get to us?" "I was on the spot," he said. "What do I tell them? Yeah, they *could* get to us." He said he doesn't believe in minimizing the situation because "they're not stupid; they understand. I think a lot of the population underestimates what a middle schooler can handle," Nichols commented. "I call them Frosted Mini-Wheats ™: adult on one side, kid on the other."

Sandman agreed. "The conventional wisdom is that young people are somehow more fragile than adults, but I don't think that's so," he said. Adolescents need to be listened to and allowed to vent more than others, but they don't really need to be coddled, Sandman believes. "The best thing to do is be as straight as possible with them—in the end, they'll hear you better."

A member of the U.S. Marine Corps Chemical Biological Incident Response Force, under the command of Joint Task Force Civil Support, has the filter removed from his gas mask during the decontamination phase of a scenario during Exercise TOPOFF 2000. (Photo by Staff Sgt. Steven Pearsall)

Foam co-developer Maher Tadros demonstrates application of the new chem-bio decontamination foam from a pressurized canister. The foam could be sprayed from handheld canisters or from trucks, or it could be incorporated into the fire sprinkler systems of high-profile government or military buildings. (Photo courtesy of Sandia National Laboratories.)

Special Section: Biodefense

Johns Hopkins fellow 'Kwik' to learn about biodefense

By Robert Taylor

Gigi Kwik

Gigi Kwik, a fellow at the Johns Hopkins University Center for Civilian Biodefense Strategies in Baltimore, is on the leading edge of a new, if somewhat esoteric, career wave—the bioterrorism expert.

"A few days ago I heard [presidential homeland security advisor] Tom Ridge telling Congress how hard it would be to find enough biological weapons analysts," said Kwik. "I thought, 'hey, that's what I am.'"

Kwik, who last year hung up her lab coat to enter the world of biodefense policy analysis and research, heads a project that looks for new ways to prevent advances in biology and medicine from being twisted into bioterrorist weapons. Government is currently taking a "top-down" approach to the problem, meaning that it tries to impose solutions through regulation, laws, and commands from the top, said Kwik, citing recently passed legislation that tightens legal regulations on shipping, storing, and controlling access to deadly pathogens as an example.

But that approach only goes so far. A more subtle problem is the possible perversion of good research for evil purposes, she added. For example, pharmaceutical researchers are working to improve systems for administering drugs to patients as breathable aerosols. This "direct to the lungs" route of drug delivery could be very beneficial to people with serious lung diseases such as cystic fibrosis. But the techniques that researchers are developing to turn drugs into dry, fluffy powders with the particle size that lets them be retained deep in the lungs also might be used by terrorists to turn toxins or dried germ preparations into biological weapons. And given that science depends on free exchange of ideas, results, and methods, just trying to clamp down on access to information about the manufacturing techniques is extraordinarily difficult, she said.

Kwik's project attacks the problem from the bottom up, interviewing scientists conducting research that could be misused in order to get their ideas about what would work to limit the danger. This approach has the added benefit of initiating a dialog with scientists whose work might be a target for government restriction, she said. "If you don't get the scientists to cooperate, and to see the importance of not letting their work be abused, the top-down approach won't work, and might kill off the very research you're trying to protect," she said.

Kwik is a little surprised to find herself studying scientists to help defend against bioterrorism, partly because her interest in science became apparent relatively late. "I've played the piano my whole life, and I started college as a piano major. But in my sophomore year, I wanted to take something different, so I took Biology 101. I loved it—I didn't do very well in it, but I loved it."

The not-doing-well part didn't last long, however. She finished her undergraduate degree in biology in 1993, worked for two years in New York City as a lab technician, then enrolled as a Ph.D. candidate in biology at Johns Hopkins. After completing her degree in 2000, she took a post-doctoral position at the U.S. Army Medical Research Institute of Infectious Diseases in Frederick, Md., where she worked on the mechanism of action of bacterial toxins. She came to the Center for Civilian Biodefense last August, just in time for the anthrax crisis.

Kwik said that biodefense is a fascinating field, but the constant focus on how people might misuse brilliant, lifesaving research is not always easy. "I'm continually learning how best to think about all this but not be depressed," she said. Since October's anthrax attacks, that's gotten harder. "But once you become committed to this, you just have to work on it," she said. "We feel a real sense of urgency."

Biofact:

Scientists from State University of New York at Stony Brook have created a polio virus from scratch for the first time, leading to speculation about the use of synthetic viruses as bioweapons.

According to the *New York Times*, the work was financed by the Pentagon as part of a program to develop biowarfare countermeasures. Scientists constructed the virus using its genome sequence, available on the Internet, as their blueprint. Eckard Wimmer, professor of molecular genetics and microbiology at Stony Brook and project director, said the synthetic virus sends a warning that terrorists might be able to make biological weapons without obtaining a natural virus. The development also could mean that even if polio is completely eradicated worldwide in the next few years, vaccinations still might be needed to protect the public against a lab-made version.

(Photo courtesy of the World Health Organization, http://w3.whosea.org.)

Biology really matters

By Donald Kennedy

Donald Kennedy

Does biology matter? If so, why? And if it does, does that not make biology a critical national need?

In the first place, the living world provides a wonderful way in which to get youngsters seriously interested in science. When BSCS Executive Director Rodger Bybee and I, along with a distinguished company of collaborators, produced *Teaching About Evolution and the Nature of Science* for the National Academy of Sciences (NAS), it seemed entirely natural to make teaching about the process of evolution a key to understanding how to teach young people about how science works in a more general way.

Perhaps equally important, understanding biology is key to unlocking some of the most pressing and challenging public policy problems we face as a society. Climate change and its impact on people and societies; regulations regarding cloning and the use of stem cells; the role of genetics and culture as determinants of human capacity and human behavior–all these are issues with which contemporary American society can expect a continuing struggle.

Biology education gains significance in the context of two quite different desirable outcomes. First, we need to capture and train promising young people so they can specialize in order to extend the domain of discovery. Surely that will be a requirement if we hope to extend the frontier in the basic sciences to help society resolve these pressing policy problems. But experts alone cannot do the job, and that takes us to a second purpose. A more general public understanding of the science base underlying each of these challenges will be a prerequisite for sound political and social decision-making. Thus, the achievement of "science literacy" is an objective just as vital as the recruitment of specialists. This requires us to teach biology, and to teach it well, not just for the especially interested and capable of our students, but for *all* of them.

This is a familiar mission for BSCS. Early in its history, BSCS accomplished important changes in the way the subject is taught, by training thousands of teachers and by producing the most path-breaking, comprehensive textbooks we have ever had. Beyond that, and perhaps even more important, BSCS played a major role in knitting together a professional community of researchers and teachers at all levels. In the 1960s and early 1970s especially, academic research scientists and secondary-school teachers came to know one another, share experiences and solutions, and develop mutual respect. It made a real difference. The deferred consequences are fortunately still visible. At the National Science Teachers Association (NSTA) meeting in San Diego earlier this spring, I saw both the imprint of BSCS materials on the way we are teaching now and an encouraging level of interaction between K-12 teachers and university folks.

What are the especially formidable challenges that lie ahead, and what do they tell us about the need for more and better biology teaching? Here's a powerful message: The Hart-Rudman Commission Report, issued well before the terrorism incidents of September 2001, concluded that domestic terrorism is the number one threat to national security. But it found in the same analysis that widespread scientific illiteracy ranked as the number two threat. What an interesting and unexpected linkage between problem and solution! Dealing with the threats of terrorism, which are likely to involve infectious agents or radiation, will demand an understanding of epidemiology, of processes of infection and contagion, and of human exposure to toxic agents including radiation. Without any understanding of that kind of science, how can people be expected to evaluate and support designs for deterrence or response? Thus, science literacy (Hart-Rudman problem number two) is essential for dealing with terrorism (Hart-Rudman problem number one). How could the linkage be plainer?

One doesn't have to turn to possible future events to show how important biological understanding is to contemporary policy. The cloning debate now underway in Congress cries out for a clear distinction between "reproductive cloning" and "therapeutic cloning." The purposes of the two are quite distinct, ethically as well as biologically. Yet a deep confusion about what is embraced under "therapeutic cloning" has led the House bill and the corresponding proposal in the Senate to include language that would criminalize serious and worthwhile experiments in somatic-cell nuclear transfer. No one wants baby factories; but neither do we need a bill that would punish experiments undertaken to evaluate the prospects for replacing damaged or deficient tissues.

As to climate change, the debate about what to do rages on, but it is being waged amid a cloud of public confusion between what is well known and well understood on the one hand and what is the outcome of a set of model predictions on the other. Plainly, there is room for some debate about how much (say) a future doubling of pre-industrial atmospheric carbon dioxide levels would affect average global temperature. But some of those who deny the prospect of future climate change–and there are still many of them–appear not to know that the "greenhouse effect," and the role of carbon dioxide as a greenhouse gas, was firmly established more than 100 years ago and is in no doubt whatever.

And, of course, the chronic, troubling controversy about evolution–whether it should be taught in schools, and whether, if taught, it should be accompanied by attention to "creationist" theories–cries out continually for more education and more science literacy. As we pointed out in the introduction to *Teaching about Evolution and the Nature of Science,* half of all American citizens believe that human beings did

continued on page 24

Special Section: Biodefense

continued from page 23

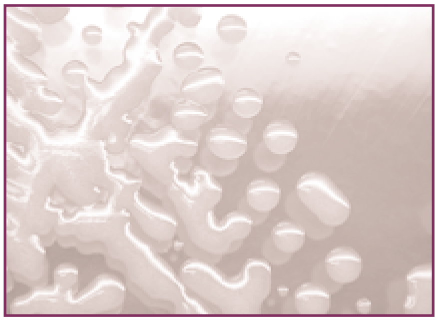
not arise from pre-existing forms. How can we expect such citizens to understand, for example, that we really have learned something from the use of animal models in medical research? As long as many Americans accept that unfalsifiable religious convictions can be discussed as serious alternatives to scientific findings, we can expect some difficulty in extending science literacy through schooling.

Thus, I believe that the challenge to good teaching of biology has never been greater. BSCS can continue to play a central role in making it better; here I offer a short list of personal hopes. We can start to limit the overdoses of vocabulary and comprehensive "information" that now overstuff too many biology textbooks. It is time to show how science works by making careful choices among possible exemplary cases–chosen from a menu that is far too large to be offered as a smorgasbord. In making those choices, we can give students a terrain map without showing them every hillock. We can reinforce the *National Science Education Standards* by emphasizing inquiry and inducing active student participation at every point at which that is possible. Finally, we can emphasize the centrality of evolution by concentrating on the whole organism, the unit on which selection acts. That, it seems to me, puts the focus in the right place, illustrating, as Dobzhansky once put it, that "Nothing in biology makes sense, except in the light of evolution." And it engages, and eventually may capture, the natural interest of young people in living creatures, and in nature writ large.

Donald Kennedy, a biologist by training, is the Bing Professor of Environmental Science, emeritus, and President emeritus of Stanford University, Stanford, Calif. Also editor-in-chief of Science, the journal of the American Association for the Advancement of Science, Kennedy works on a variety of problems at the intersection of science and public policy. He is a former Commissioner of the U.S. Food and Drug Administration and a member of the National Academy of Sciences, the Institute of Medicine, the American Academy of Arts and Sciences, and the American Philosophical Society. The opinions expressed in this essay are those of the author.

Sandia National Laboratories researcher Mark Tucker examines two petri dishes: one with a simulant of anthrax growing in it, the other treated with a new decontaminating foam developed at Sandia. The nonhazardous foam begins neutralizing both chemical and biological agents in minutes. (Photo by Randy Montoya, courtesy of Sandia National Laboratories.)

Facts about anthrax



Bacillus anthracis *capsule production on bicarbonate agar medium. (Photo courtesy of Larry Stauffer, Oregon State Public Health Laboratory.)*

Anthrax is an acute infectious disease caused by the spore-forming bacterium *Bacillus anthracis*. Anthrax most commonly occurs in hoofed mammals and can also infect humans.

Symptoms of disease vary depending on how the disease was contracted, but usually occur within seven days after exposure. The serious forms of human anthrax are inhalation anthrax, cutaneous anthrax, and intestinal anthrax.

Initial symptoms of inhalation anthrax infection may resemble a common cold. After several days, the symptoms may progress to severe breathing problems and shock. Inhalation anthrax is often fatal.

The intestinal disease form of anthrax may follow the consumption of contaminated food and is characterized by an acute inflammation of the intestinal tract. Initial signs of nausea, loss of appetite, vomiting, and fever are followed by abdominal pain, vomiting of blood, and severe diarrhea.

Direct person-to-person spread of anthrax is extremely unlikely, if it occurs at all. Therefore, there is no need to immunize or treat contacts of persons ill with anthrax, such as household contacts, friends, or coworkers, unless they also were also exposed to the same source of infection.

In persons exposed to anthrax, infection can be prevented with antibiotic treatment. Early antibiotic treatment of anthrax is essential–delay lessens chances for survival. Anthrax usually is susceptible to penicillin, doxycycline, and fluoroquinolones.

An anthrax vaccine also can prevent infection. Vaccination against anthrax is not recommended for the general public to prevent disease and is not available.