1. THE DEPARTMENT OF DEFENSE GLOBAL EMERGING INFECTIONS SYSTEM

One of the great fallacies of the mid-20th century was that infectious diseases were nearing elimination. In the face of those prognostications, more than 25 new infectious diseases were recognized for the first time between 1975 and 2000. These new scourges included HIV, Ebola, Legionnaire’s Disease, Hantavirus pulmonary syndrome, deadly new strains of influenza, and new forms of drug-resistant bacteria and malaria. Rather than nearing extinction as a broad class of human suffering, infectious diseases remain the leading cause of death worldwide. The ability of microbes to adapt to new pressures, including antibiotic usage coupled with changes in society, technology, and the environment make it likely that the microbial threat will remain a threat to humanity, and even suggests the possibility of regional and global epidemics comparable to the worst in history.

Although naturally occurring microbial threats remain a perennial threat, the politics of international relations and terrorism result in the additional threat of the use of weaponized biological agents. The fall of the Soviet Union and the position of the United States as the sole global superpower, coupled with the growing sophistication of various state and nonstate sponsored adversaries, have contributed to a situation of increased risk of biological warfare (BW). In current circumstances, a glut of underemployed bioweaponeers combined with advances in the science of microbiology may empower otherwise weak adversaries to asymmetrically wage BW.

Infectious diseases are more than an issue of individual health. There has been an increasing appreciation of their effects on international trade, the stability of families, institutions, and societies, and military readiness. Under this broader context, the control of infectious diseases is increasingly seen as a fundamental element of national security. Such considerations in the early 1990s prompted groups such as the National Academy of Sciences, the Centers for Disease Control and Prevention (CDC), and the World Health Organization (WHO) to develop plans for addressing and mitigating the threat of emerging and re-emerging infectious diseases. The Department of Defense (DOD) figured heavily in the recommended actions from these deliberative bodies because of its wide spectrum of domestic and international assets for...
infectious disease surveillance, research, and control. These recommendations in June 1996 led to Presidential Decision Directive NSTC-7 on Emerging Infections. This directive formally expanded the mission of the DOD to support global surveillance, training, research, and response to emerging infectious disease threats.

The DOD Global Emerging Infections System (DOD-GEIS) is the centrally coordinated DOD response to the Presidential Decision Directive. Using Army, Navy, and Air Force preventive medicine and infectious disease personnel plus unique DOD assets such as the overseas medical research units in Egypt, Kenya, Peru, Thailand, and Indonesia and the availability of a global military health care network, DOD-GEIS has developed sophisticated programs to enhance surveillance for new and re-emerging infections; develop and integrate relevant military public health systems; improve prevention and control strategies; and leverage international and DOD public health infrastructure through the facilitation of training, networking, and capacity building.

DOD-GEIS surveillance has a primary focus on traditional military threats such as influenza and other respiratory diseases, drug-resistant malaria, and drug-resistant enteric organisms. However, the emergence of new or unfamiliar diseases to include agents of bioterrorism and BW is clearly of concern. These represent a particular challenge because available laboratory diagnostic methods may be nonexistent, very limited, or insensitive.

1.1. GEIS and Biodefense

Detecting new and reemerging infections, to include bioterrorism, not only requires laboratory capabilities but also prompt recognition of an aberration in community health. Delays in recognition can lead to considerable morbidity and mortality even when a specific preventive or therapeutic modality is available. Many of the disease emergences over the last 25 yr have been characterized by delayed recognition or diagnosis. For example, the appearance of West Nile encephalitis in New York City in 1999 was manifest as weeks of human and animal morbidity before the problem was recognized as an old disease in a new location.

Whether the goal is to detect a new syndrome such as AIDS or Hantavirus pulmonary syndrome or the insidious initial manifestations of a deliberate attack with a biological agent, the recognition across a population of unusual syndromes or a change in the frequency of common syndromes or symptom patterns may be an important harbinger. This is different from the traditional clinical and laboratory approach to public health surveillance that tends to focus on tracking well-defined diseases of public health significance. A complementary epidemiologic approach has been embraced by DOD-GEIS as key to maintaining a comprehensive, alert public health system. The concept of epidemiologists playing a central role in the detection of biological attacks and other emerging infections is not a new one. In 1952, Alexander Langmuir, the founder of CDC’s Epidemic Intelligence Service noted:

“The detection and control of saboteurs are the responsibilities of the FBI, but the recognition of epidemics caused by sabotage is peculiarly an epidemiologic function .... Therefore any plan of defense against biological warfare sabotage requires trained epidemiologists, alert to all possibilities, and available for call at a moment’s notice anywhere in the country.” (1)
The expectation is that early detection of emerging infections, to include deliberate biological attacks, will require a system of innovative techniques to detect a wide range of possible scenarios across a dispersed population. These may range from isolated cases, such as the anthrax letter attacks of Fall 2001, through small-scale events such as an attack against a group of people in a building or at a gathering, to a more extensive attack against one or more population centers. The mobility of modern society presents added challenges because cases from a common point infection may disperse across a community or even the globe. Case clusters would initially be undetectable at the level of clinicians or individual health care facilities but would require consolidation over larger catchment areas. Even more insidious, low-impact attacks may indicate “experiments” or failed attempts for a larger impact by a determined adversary. Thus, the goal is not only early detection of large and small outbreaks but also the rapid epidemiologic assessment of the situation so as to optimally deploy limited response assets and to empower civil leaders with credible information for risk communication to an anxious population. The DOD, as a result of having a singular global medical informatics backbone, is in a unique position to pioneer innovative approaches to community-based, near real-time detection of changes in health indicators. DOD-GEIS has made adaptation of these unique assets a feature of response to the President’s call for enhanced public health surveillance, systems research, and integration.

2. USING SURVEILLANCE TO IMPROVE BIODEFENSE

2.1. Need for Improved Disease Surveillance

The advent of relatively focal biological attacks in the United States in 2001 emphasized what has long been suspected—that the public health infrastructure had deteriorated over time and the medical system was not prepared for this contingency (2–4). We need to plan and be prepared to prevent illness and death that may result from a biological terrorist attack. Similar to any emerging infection, early detection is key to controlling the spread of an outbreak. Detection and control of a disease outbreak depends on a strong and flexible public health systems at local, state, and federal levels (5).

One of the primary goals of public health is to prevent disease in a community. Therefore, one must have knowledge of existing disease rates, risk factors for these diseases, and the effectiveness of preventive measures. The first step in gaining this knowledge is a working surveillance system that rapidly allows the public health practitioner to know the health status of the community. Indeed, public health surveillance is a core element of public health practice. Unfortunately, most infectious disease surveillance systems are passive and rely on practitioners voluntarily reporting to the public health system (6). Not only do reports often take weeks to months to receive, but gross underreporting is usually the norm. A recent review of reportable disease reporting in the US military revealed the Army centrally reported 45% of hospitalized reportable disease cases when compared to International Classification of Diseases, 9th Revision (ICD9) discharge diagnoses during the period January–June 2001 (7). The Navy and Air Force each reported 18% of these cases over the same time period (8,9). Additionally, most are based on laboratory results that, although improving the specificity of the report, increases the lag time between the onset of illness and the report.
being sent. In the previous review, of those diseases that were reported by the Army, 45% were reported within 1 wk of hospital discharge and 76% were reported within 1 mo (7). For bioterrorism, if the notification of something unusual occurring reaches the health department quickly, then the investigation, treatment, prophylaxis, and preventive measures can be started that much sooner. In many instances, early response can allow significant improvements in morbidity, mortality, and decrease costs (10). Therefore, we must improve our public health surveillance systems to allow rapid acquisition of important disease incidence information.

2.1.1. Historical Disease Outbreaks

Recent disease outbreaks in the United States demonstrate characteristics that serve as important lessons in developing surveillance systems. The outbreak of Legionnaires’ Disease in Pennsylvania in 1976 shows how an unknown pathogen acquired via respiratory exposure from a common source can present (11). This outbreak mimics a bioterrorist attack with an aerosolized agent. The situation was complicated by a population that dispersed after exposure, so cases appeared throughout the state. This can also happen with a bioterrorist attack and can confuse the investigation. In 2001, the index case of anthrax in Florida had recently traveled to North Carolina, which made the investigation and search for the source of infection that much more difficult. With the wide range of potential incubation periods inherent in agents that could be used for bioterrorism, similar scenarios should be anticipated. Surveillance systems that can rapidly compare diseases seen throughout the state or even the country are necessary.

Other lessons learned from recent disease outbreaks in the United States include the impact of zoonotic illnesses. With hantavirus infections in the southwestern United States, rodents brought the virus into homes as their populations expanded as a result of fluctuations in environmental conditions (12). In 1999, West Nile virus was first identified as an autochthonous disease in New York City (13). This event had features one would anticipate from a bioterrorist event, but most experts have determined this to have been a natural, accidental introduction. Human cases were preceded by deaths in wild and zoo-kept birds, although the significance of the association was not realized at first. Both of these outbreaks demonstrate the need to keep in mind both the ability of various vectors to transmit potential bioterrorist-induced disease and the impact of a new disease on other species.

2.1.2. Need for Early Recognition of Disease Outbreaks

Developers of surveillance systems must determine their priorities based on their objectives. Because surveillance can be used for many purposes, the reason for the surveillance is of the utmost importance in determining which qualities are essential. For surveillance systems that monitor long-term trends in disease rates or evaluate the effectiveness of a public health program, accuracy is needed more than timeliness. However, to rapidly detect and respond to a nascent disease outbreak, quickly acquiring disease incidence data and analyzing it is of crucial concern. Although accuracy is not unimportant to disease outbreak investigations, the initial notification of a potential outbreak can be based on less accurate data, as long as it allows more in-depth investigation after the alert. In fact, the entire purpose of disease outbreak surveillance is notification that a more thorough and accurate investigation needs to be performed.
This may be as simple as a phone call to a local clinic inquiring as to the status of patients or as comprehensive as door-to-door documentation of illness.

The early recognition that something unusual is happening in a community can improve the public health response, even before the entire investigation is completed. If evidence is sufficient that a disease of high morbidity or mortality is present, the initial presentation of that disease outbreak can suggest the initial or continuing means of exposure. For example, the disease may present in a way that suggests person-to-person spread. If this is the case, then certain preventive measures such as closing of schools, altering public gatherings, and so on, can be instituted even before the specific etiologic agent is identified. This was done during the influenza pandemic in 1918, before they knew the cause of the epidemic. Even with diseases of lower virulence, measures can be taken to decrease the potential spread of an illness, such as recommendations to confine new ill recruits to the hospital to decrease transmission in crowded barracks situations. Should the surveillance data suggest other transmission routes, such as water- or vector-borne, then early measures can target water distribution systems or integrated pest management operations.

Another important element that surveillance can provide is to identify whether the epidemic curve generates secondary cases, which would be expected with only a limited number of bioterrorist agents (e.g., plague or smallpox), or the kinetics yield a discrete “peak” more consistent with a nonpropagated outbreak.

Information rapidly obtained from a disease surveillance system can also assist in providing information to decision makers. Although not of the highest accuracy, initial information obtained by surveillance systems can include geographic information on disease occurrence, disease virulence, and general signs and symptoms of the illness. This information can then be used to determine at-risk populations and to inform people what symptoms they should look for, what they should do (stay home, seek medical attention) and what areas seem to be most affected. In addition, this basic information can help public officials best allocate limited resources. For example, if it is recommended that antibiotics be used for treatment, certain stockpiles of medication can be directed to the areas most impacted. Personnel resources can be similarly allocated.

Whereas early response based on nonspecific information can be very helpful, the best use of early recognition of a potential disease outbreak is the indication to conduct an investigation to find more accurate information. In particular, a specific microbiological diagnosis will be most helpful in instituting preventive measures. Often in clinical settings, especially with diseases of low severity, diagnostic specimens are not taken. If the disease is not severe, it is common practice to treat patients empirically and save time and money on laboratory tests that probably will not affect the outcome of the patient’s illness, as the patient often recovers before the laboratory diagnosis is obtained. However, the first cases in a disease outbreak, if investigated, can provide crucial information to prevent or limit the spread of the outbreaks through proper treatment and prophylactic protocols. For example, the index case of anthrax in Florida had meningal symptoms that prompted the physician to take cerebrospinal fluid for culture and Gram stain (14). The use of diagnostic tests allowed a more rapid recognition of the cause of the disease and assisted with recognition of future cases and the institution of preventive measures. In this case, the disease presentation and severity contrib-
uted to the taking of diagnostic specimens. In other disease outbreaks caused by pathogens such as Norwalk or influenza viruses, although there are appropriate preventive or treatment measures available, the lack of severity of the disease may result in few diagnostic tests performed. The result of this omission is that the outbreak can continue and future patients will not receive the most appropriate care as they could have with knowledge of the disease-causing agent. Nor will the most effective preventive measures be enacted at the earliest possible opportunity. Early indication of unusual disease patterns can allow health departments to request appropriate diagnostic tests on current and future patients in order to obtain the correct diagnosis quickly and improve the ability to prevent and treat future cases.

An additional way that surveillance systems can assist public health is in the ability to provide important demographic information that can assist in the outbreak investigation. If surveillance systems are linked to patient identifiers, then the investigators can rapidly perform chart reviews, determine geographic locations of high case density, and even contact the patient to determine current health status, risk factors, or to obtain diagnostic specimens. Although privacy concerns are paramount and must adhere to local law, it is in the course of proper public health practice that these investigations are carried out to protect the health of a community.

2.2. Ways to Improve Surveillance

For rapid detection of a bioterrorist attack or any disease outbreak, the speed of data acquisition and analysis must be improved to be of use in mitigation efforts. This can be done in various of ways, including instituting new data collection methods, using previously collected health data in new ways, and using nontraditional sources of data to track the health of a community. A summary of potential data sources is outlined in Table 1. A combination of many types of data sources may provide the most sensitive system.

2.2.1. Institution of a New Surveillance System

The most useful data can usually be obtained from surveillance systems that are designed specifically for the purpose intended. If tracking infectious disease incidence for bioterrorism detection is the purpose, then the surveillance system can be designed to capture information that can assist in this detection. Some of the data elements that might be of use are included in Table 2.

The most accurate information is obtained through active surveillance systems that continually query patients, providers, or other personnel on new potential cases. Although of great use in detecting unusual disease trends, these systems are often labor intensive and not well-accepted by those having to provide the information. One way to improve the acceptability is to give feedback to the provider or other person contributing the information to let them know how their work is assisting in disease detection, and also allow them to tailor their treatment regimens with the knowledge of surrounding disease trends. For the most rapid disease information transfer, the system should be automated and the data entered and reported electronically.

Many of these new data source systems have been tried in various of situations. Some have been used in event-driven scenarios—that is, for a limited time period around an event of high public exposure and, thus, higher than usual potential threat of
Table 1
Potential Sources of Data for Infectious Disease Surveillance

| Typical health surveillance | Reportable diseases
|                           | Laboratory-based surveillance
|                           | Specific disease surveillance (e.g. influenza)
| Existing health data not normally used for surveillance | Billing data with diagnostics for inpatients and outpatients
|                           | Prescription and over-the-counter pharmacy sales
|                           | Laboratory test ordering and results
|                           | Radiology test ordering and results
|                           | Intensive care unit admissions
|                           | Emergency room utilization
|                           | Medical advice call-in lines
|                           | Internet hits for medical information
|                           | 911 calls or ambulance run information
|                           | Data from medical examiner
| Nonhealth data sources     | School and work absenteeism
|                           | Road and transit usage
|                           | Entertainment venues usage
|                           | Weather data
|                           | Vector data

| Table 2
Example of Ideal Data Fields for Disease Outbreak Investigations |
|------------|--------------------------------------------------------------|
| Age        | Gender                                                       |
| Onset of illness | Symptoms                                                   |
| Vital signs | Work/school/day care and home locations of patient          |
| Recent travel | Potential exposures through day care or restaurants       |
| Any ill contacts | Attended any recent large public events                |
| Occupation | Underlying illnesses                                        |
| Medications used or prescribed | Lab tests ordered and results |

bioterrorism (15). They have also been used on an ongoing basis in some localities with varying amounts of participation and automation. Although the experience to date has been that these systems have the potential to provide very useful and timely information, they have had varying degrees of acceptance and utility. The greatest detriment has been the need for additional work for the healthcare provider to enter the
information. A decrease in data entry resulting from providers’ lack of time is often realized when the data is needed the most (e.g., during an outbreak situation). An additional problem for those used only during or after an event is the lack of pre-existing data for comparison. Surveillance systems need to provide more than a snapshot in time to be useful. In fact, the definition of surveillance includes the criteria of “ongoing” (16). Public health surveillance must demonstrate change or lack of change in disease rates over time. Therefore, if a surveillance system is only used for a 2- to 3-wk time period, it will be very difficult to determine abnormal patterns of disease incidence because the baseline rate is not established.

2.2.2. Use of Previously Existing Health Data for New Surveillance Methods

There are many sources of health data that exist for reasons other than public health surveillance. Many of these serve a logistic or financial purpose. Some examples are outpatient and inpatient diagnostic coding for insurance claims purposes, tallies of hospital admissions or emergency room visits for personnel allocation, or records of pharmacy prescriptions for legal documentation. With the increasing use of an electronic medical record, other information such as laboratory test ordering and results, radiology orders and results, and even vital signs can be retrieved from electronic databases. Although many of these sources were not created for a public health surveillance purpose, the amount of information available that can be useful for tracking disease trends is absolutely astounding.

Because these sources of data were not intended for surveillance, some aspects of their collection, format or content may not be ideal for monitoring disease trends. First, and most important, the data may not be collected in a timely fashion, or it may be difficult to retrieve soon after collection. An example of this is insurance claims data for billing purposes that may take weeks to be processed. Second, the data may not be in an ideal or even electronic format, making useful retrieval difficult. Third, information may not be available that would make it ideal for a surveillance system. For example, if a system is designed to track diarrheal illnesses, certain information such as recent travel or eating history would be beneficial but is unlikely to be available on an electronic database. However, although not ideal, the data can still be useful for public health purposes.

Finally, issues with privacy may complicate access to data. The privacy issues are both personal and commercial. To access personal medical information, stringent privacy protection elements must be in place. Even without specific identifying information such as name or social security number, demographic information such as date of birth, gender, race, address, or even zip code can be used in aggregate to identify someone. Therefore, care must be taken to ensure that the data are held securely, and any information released for use by various public health personnel must have appropriate anonymity algorithms in place to ensure that identity is not gleaned from basic demographic information. Access to information by law enforcement agencies for leads or clues in a bioterrorist attack may also need to be considered.

The other concern is the sensitivity regarding commercial privacy. Many sources of data are held by for-profit hospitals, clinics, pharmacies, and other contracting agencies. Access to the data might be hindered by the desire of these organizations to keep the data private to protect their profits and methods from competitors. These are legiti-
mate concerns and may necessitate strict legal agreements between data sources and recipients.

2.2.3. Use of Nontraditional Sources of Data for Detection of Disease Outbreaks

In addition to previously collected health-related data, there are other sources of information that might prove useful for early warning of a disease outbreak. As people become ill, they demonstrate certain behaviors that may be measurable. These could include changes in road or public transit use, a decrease in the use of entertainment venues such as restaurants and movie theaters, or an increase in school or work absenteeism. There is also information such as weather conditions or changes in vector populations that may prove useful in predicting conditions that foster disease outbreaks (17,18). However, many of these sources of data are not yet proven to be of use in disease outbreak prediction or detection; indeed most have not yet even been captured for that purpose. Because there are less privacy concerns resulting from no medical information being included, these sources may be easier to obtain and may be worth investigating further.

2.3. Examples of New Surveillance Systems

Several new surveillance systems using various data resources are being developed by states, cities, academic institutions, private companies, and federal institutions including the DOD. Many of these have demonstrated remarkable utility in monitoring the health status of communities. A sample of some of these systems are outlined here.

2.3.1. New York City Diarrheal Diseases Surveillance

New York City has three complementary systems to monitor for outbreaks of diarrheal illness. They include sales of over-the-counter antidiarrheal medications, the number of stool samples submitted for testing, and the incidence of gastroenteritis in nursing home populations (19,20). The first two are examples of nontraditional health indicator surveillance methods, whereas the third represents a form of specific health surveillance initiated for a specific purpose. Through monitoring of sales of over-the-counter drugs, the New York City Department of Environmental Protection has been able to detect anomalies in sales data that could herald a gastrointestinal outbreak (20). Similarly, in retrospect, one of the first changes recorded during a Cryptosporidium outbreak in Minnesota was the increase in over-the-counter antidiarrheal medication sales (21). The monitoring of laboratory test ordering such as stool sample submissions as opposed to laboratory test results allows a much more rapid notification of a potential change in disease incidence. These systems trade specificity for sensitivity but quickly recommend investigations to determine what disease agent is causing illness.

2.3.2. New York City 911 Disease Surveillance

In 1998, the New York City Department of Health began monitoring chief complaints for 911 calls in the city (22). The calls are coded with a diagnosis from a specific list. They chose to monitor those potentially indicative of an influenza outbreak such as “difficulty breathing” or “sick.” Review of data previous to 1998 revealed a temporal association between a rise in calls for these complaints and annual influenza outbreaks. Since its inception, the system has detected influenza outbreaks earlier than
any other traditional influenza surveillance system in New York City and provides information on long-term historical cycles of respiratory disease (22).

2.3.3. University of Pittsburgh Emergency Room Surveillance

The University of Pittsburgh has developed a surveillance system using routinely generated outpatient data from emergency rooms for real-time outbreak and disease surveillance (RODS). This system utilizes ICD9 codes generated by the triage nurse at the time of presentation to the emergency room and by the clinician who sees and diagnoses the patient. Using sophisticated algorithms, RODS is able to detect changes in the number of patients presenting with certain types of symptoms and diseases, taking into account such confounders as day of the week, time of day, season, and other variables (23,24).

2.3.4. Harvard University Outpatient Surveillance

A similar system has been developed by the Harvard University Medical School, the Massachusetts Department of Public Health, and the CDC using data from the Harvard Vanguard Medical Associates, a large group practice located in eastern Massachusetts (25). They used ICD9 codes generated at 14 health clinics that provide ambulatory care including scheduled appointments and same day and urgent care visits in greater Boston. In one study looking at lower respiratory diagnoses, they demonstrated daily and seasonal variation, as well as differences by age groups and gender. With census tract information, they were able to track changes in disease occurrence geographically.

2.3.5. Web-Based Surveillance System

A consortium of private companies have developed the computerized surveillance and response tool Lightweight Epidemiology Advanced Detection and Emergency Response System (LEADERS) (26,27). This system includes not just surveillance tools but the ability to track response assets geographically and share them among various emergency response and medical groups via an application service provider. Another element is a rapid diagnostic module using polymerase chain reaction techniques (26). The surveillance module contains the ability to design a computerized information sheet requesting specific information for disease monitoring in emergency rooms. This information is entered via the website and then shared among participating medical facilities. Statistical analysis can be performed with this data for detection of abnormal levels of illness (27). LEADERS also has the ability to pull various information from a computerized medical record and analyze it to detect variations indicative of a disease outbreak.

2.3.6. New Mexico’s Emergency Room Surveillance

Researchers at the Sandia National Laboratory, Los Alamos National Laboratory, University of New Mexico, and the New Mexico Department of Health have developed a surveillance method using newly gathered data to detect changes in disease patterns in emergency room visits in New Mexico (28). The system, the Rapid Syndrome Validation Project (RSVP), uses handheld computers with touch screens for the provider to enter basic demographic and diagnostic data on their patients. Its added features include a direct reporting link to the health department for patients with sufficiently suspicious disease patterns and immediate feedback to the practitioner on information of disease patterns being seen in the area.
2.3.7. DOD-GEIS Outpatient Surveillance System

The GEIS has also developed a surveillance system using outpatient (both emergency room and outpatient clinics) data generated at military treatment facilities (MTFs). The Electronic Surveillance System for the Early Notification of Community-based Epidemics (ESSENCE) uses ICD9 diagnostic codes generated by the healthcare provider near the time of patient visit to track various potential infectious disease patterns. The ICD9 codes are divided into seven syndrome groups most likely to represent infectious disease presentations. Outpatient data from all MTFs are received from a central server and processed to demonstrate changes in visits for the various syndrome groups. As with most of the other surveillance systems, the data can be displayed demographically by age and gender and geographically by zip code. Provision of this information on a secure website allows sharing of the data with appropriate public health personnel.

2.4. The Ability of ESSENCE to Detect Outbreaks

ESSENCE has detected many fluctuations in diseases since the pilot project was first instituted for the national capital area in 1999. These include expected yearly influenza epidemics as well as other random disease outbreaks. After September 11, 2001, the system was expanded to include coverage of all MTFs that contribute outpatient data into this electronic system. This includes all but the most forward deployed military forces, including installations in Asia and Europe.

2.4.1. Detection of Annual Influenza Outbreaks

Influenza outbreaks occur during the winter season in most of the temperate world, including the United States. Each year's influenza epidemic has different characteristics including the timing and length of peak activity, and the severity of the outbreak. However, there is always a yearly increase in people presenting for influenza-like illness (fever and cough or sore throat), pneumonia-related deaths, and isolation of influenza viruses from laboratory samples. Using ESSENCE to follow visits that have been coded by the provider as any kind of respiratory ailment, we can follow respiratory illness year round and detect within 2–3 d when any outbreaks begin, including the yearly influenza epidemics.

The data collected by ESSENCE can be compared to data from more traditional surveillance systems, such as that collected by the CDC. Figure 1 shows both surveillance systems for influenza season 1999–2000 using sentinel physicians who report the percent of patients who meet the case definition of influenza-like illness (ILI). To make a direct comparison, we have figured the ESSENCE data in a similar format as the CDC data by calculating the percent of visits on a weekly basis for a respiratory illness. The average percent of patients with a respiratory complaint is higher than that seen with the CDC surveillance. This is expected, because they do not have to meet the same stringent ILI case definition. The codes included in the respiratory syndrome group are listed in Table 3, which are less restrictive, as a patient only has to be diagnosed with one of these to be included. Regardless, the similarity of the epidemic curve is striking, and ESSENCE detects the influenza outbreak as well as more traditional data sources. The benefit of ESSENCE is that the data are received in 1–3 d and do not require additional work by the provider, whereas the CDC data are not available for public consumption for a longer period of time. It also requires the sentinel physicians to perform additional work to create this dataset.
Fig. 1. Comparison of ESSENCE data in the national capital area and national CDC influenza data for 1999–2000.

Table 3
ICD9 Codes Included in the Respiratory Syndrome Group

| ICD9 code | Description                          |
|-----------|--------------------------------------|
| 003.22    | Pneumonia, salmonella                |
| 020.3     | Plague, primary pneumonic            |
| 020.4     | Plague, secondary pneumonic          |
| 020.5     | Plague, pneumonic NOS                |
| 021.2     | Tularemia, pulmonary                  |
| 022.1     | Anthrax, pulmonary                    |
| 031.0     | Disease, pulmonary d/t mycobacteria  |
| 031.8     | Disease, mycobacterial NEC           |
| 031.9     | Disease, mycobacterial NOS           |
| 032.0     | Diphtheria, faucial                   |
| 032.1     | Diphtheria, nasopharyngeal            |
| 032.2     | Diphtheria, anterior nasal            |
| 032.3     | Diphtheria, laryngeal                |
| 032.89    | Diphtheria NEC                       |
| 032.9     | Diphtheria NOS                       |
| 033.0     | Whooping cough, Bordetella pertussis |
| 033.1     | Whooping cough, Bordetella parapertussis |
| 033.8     | Whooping cough NEC                   |
| 033.9     | Whooping cough NOS                   |
| 034.0     | Sore throat, streptococcal           |
| 052.1     | Varicella pneumonitis                |

(continued)
### Table 3 (continued)

| ICD9 code | Description |
|-----------|-------------|
| 055.1     | Pneumonia, postmeasles |
| 055.2     | Otitis media, postmeasles |
| 073.0     | Ornithosis w/pneumonia |
| 079.0     | Infection, adenovirus |
| 079.1     | Infection, ECHO virus |
| 079.2     | Infection, Coxsackie virus |
| 079.3     | Infection, rhinovirus |
| 079.6     | Infection, respiratory syncytial virus |
| 079.82    | SARS associated coronavirus |
| 079.88    | Infection, chlamydial NEC |
| 079.89    | Infection, viral NEC |
| 079.98    | Infection, chlamydial NOS |
| 079.99    | Infection, viral NOS |
| 381.00    | OM, acute nonsuppurative NOS |
| 381.01    | OM, acute serous |
| 381.03    | OM, acute sanguinous |
| 381.04    | OM, acute allergic serous |
| 381.4     | OM, chronic nonsuppurative NOS |
| 381.50    | Salpingitis, Eustachian NOS |
| 381.51    | Salpingitis, acute Eustachian |
| 382.00    | OM, acute suppurative NOS |
| 382.01    | OM, acute suppurative w/drum rupture |
| 382.02    | OM, acute suppurative in disease CE |
| 382.4     | Otitis suppurative NOS |
| 382.9     | Otitis media NOS |
| 460       | Nasopharyngitis, acute |
| 461.0     | Sinusitis, acute maxillary |
| 461.1     | Sinusitis, acute frontal |
| 461.2     | Sinusitis, acute ethmoidal |
| 461.3     | Sinusitis, acute sphenoidal |
| 461.8     | Sinusitis, acute NEC |
| 461.9     | Sinusitis, acute NOS |
| 462       | Pharyngitis, acute |
| 463       | Tonsillitis, acute |
| 464.00    | Laryngitis, acute, w/o obstruction |
| 464.01    | Laryngitis, acute w/ obstruction |
| 464.10    | Tracheitis, acute, w/o obstruction |
| 464.20    | Laryngotracheitis, acute w/o obstruction |
| 464.21    | laryngotracheitis, acute w/ obstruction |
| 464.30    | Epiglottitis, acute w/o obstruction |
| 464.31    | Epiglottitis, acute w/ obstruction |
| 464.4     | Croup |
| 464.50    | Supraglottis, unspecified w/o obstruction |
| 464.51    | Supraglottis, unspecified w/ obstruction |
| 465.0     | Laryngopharyngitis, acute |
| ICD9 code | Description |
|-----------|-------------|
| 465.8     | Acute URI of other multiple sites |
| 465.9     | Acute URI of unspecified site |
| 466.0     | Bronchitis, acute |
| 466.1     | Bronchiolitis, acute |
| 466.11    | Bronchiolitis, acute, d/t RSV |
| 466.19    | Bronchio acute d/t infectious organism |
| 478.9     | Disease, upper respiratory NEC/NOS |
| 480.0     | Pneumonia, adenovirus |
| 480.1     | Pneumonia d/t respiratory syncytial virus |
| 480.2     | Pneumonia d/t parainfluenza virus |
| 480.3     | Pneumonia d/t SARS |
| 480.8     | Pneumonia d/t virus NEC |
| 480.9     | Pneumonia d/t virus NOS |
| 481       | Pneumonia d/t pneumococca virus |
| 482.0     | Pneumonia d/t Klebsiella pneumoniae |
| 482.1     | Pneumonia d/y Pseudomonas |
| 482.2     | Pneumonia d/t Hemophilus influenzae |
| 482.30    | Pneumonia d/t Streptococcus NOS |
| 482.31    | Pneumonia d/t Streptococcus Group A |
| 482.32    | Pneumonia d/t Streptococcus Group B |
| 482.39    | Pneumonia d/t Streptococcus NEC |
| 482.40    | Pneumonia d/t Staphylococcus NOS |
| 482.41    | Pneumonia d/t Staphylococcus aureus |
| 482.49    | Pneumonia d/t Staphylococcus NEC |
| 482.81    | Pneumonia d/t anaerobes |
| 482.82    | Pneumonia d/t Escherichia coli |
| 482.83    | Pneumonia d/t gram-negative NEC |
| 482.84    | Pneumonia d/t Legionnaires' disease |
| 482.89    | Pneumonia, bacterial NEC |
| 482.9     | Pneumonia, bacterial NOS |
| 483.0     | Pneumonia d/t Mycoplasma pneumoniae |
| 483.1     | Pneumonia d/t Chlamydia |
| 483.8     | Pneumonia D/T organism NEC |
| 484.1     | Pneumonia in cytomegalic inclusion disease |
| 484.3     | Pneumonia in whooping cough |
| 484.5     | Pneumonia in anthrax |
| 484.6     | Pneumonia in aspergillosis |
| 484.7     | Pneumonia in systemic mycoses |
| 484.8     | Pneumonia in other infectious disease CE |
| 485       | Bronchopneumonia, organism NOS |
| 486       | Pneumonia, organism NOS |
| 487.0     | Influenza w/pneumonia |
| 487.1     | Influenza w/respiratory manifestation NEC |
| 487.8     | Influenza w/manifestation NEC |
| 490       | Bronchitis NOS |

(continued)
Table 3 (continued)

| ICD9 code | Description |
|-----------|-------------|
| 494.1     | Bronchiectasis with acute exacerbation |
| 511.0     | Pleurisy w/o effusion or TB |
| 511.1     | Pleurisy, w/bacterial effusion, not TB |
| 511.8     | Pleurisy, effusion NED, not TB |
| 511.9     | Effusion, pleural NOS |
| 513.0     | Abscess, lung |
| 513.1     | Abscess, mediastinum |
| 514       | Congestion/hypostasis, pulmonary |
| 518.0     | Collapse, pulmonary |
| 518.4     | Edema, acute lung NOS |
| 518.81    | Failure, acute respiratory |
| 518.82    | Insufficiency, pulmonary NEC |
| 518.84    | Respiratory failure, acute & chronic |
| 519.2     | Mediastinitis |
| 519.3     | Disease, mediastinum NEC |
| 769       | Syndrome, respiratory distress |
| 782.5     | Cyanosis |
| 784.1     | Pain, throat |
| 786.00    | Abnormality, respiratory NOS |
| 786.05    | Shortness of breath |
| 786.06    | Tachypnea |
| 786.07    | Wheezing |
| 786.09    | Abnormality, respiratory NEC |
| 786.1     | Stridor |
| 786.2     | Cough |
| 786.3     | Hemoptysis |
| 786.52    | Painful respiration |
| 786.7     | Abnormal chest sounds |
| 786.9     | Symptoms involving respiratory system/chest NEC |

NOS, not otherwise specified; NEC, not elsewhere classified; d/t, due to; w/, with; w/o, without; OM, otitis media; CE, classified elsewhere; URI, upper respiratory infection; RSV, respiratory syncytial virus; SARS, severe acute respiratory syndrome; TB, tuberculosis.

2.4.2. Detection of Multiple Gastrointestinal Outbreaks Nationwide

In January 2002, the ESSENCE system detected spikes in the gastrointestinal ICD9 syndrome code group at the Marine Corps Recruit Depot in San Diego, CA, Fort Monmouth, NJ, Aberdeen Proving Ground, MD, and Fort Leonard Wood, MO (see Fig. 2). Because of the near-simultaneous occurrence of these outbreaks, investigations were undertaken to determine the potential source and cause and also to ensure that nothing else suspicious occurred that could be considered a warning of a bioterrorist attack. The largest outbreak occurred in San Diego, and a medical records review was conducted to ascertain the characteristics of the outbreak.
On investigation, the earliest record of gastrointestinal illness occurred in a Marine who worked in the dining facility. He was ill for 3 d before being evaluated and removed from working with food. Within 2 d of the onset of his illness, illness began to occur in many different trainee companies. The epidemic curve representing unique individuals as recorded by ESSENCE is shown in Fig. 3. It is possible that after initial spread via food, spread continued person-to-person in the barracks environment. Diagnostic studies of stool specimens revealed Norwalk-like viruses that are known to spread not only by water and food but also airborne between people.

Investigations at Fort Leonard Wood and Aberdeen Proving Ground also revealed an afebrile illness of acute onset and short duration characterized by vomiting and diarrhea. No stool samples were available for analysis, but the clinical picture points to a Norwalk-like virus as well. Preventive medicine personnel were notified and told to be on a heightened alert for more gastroenteritis cases at these and other installations. The ability of ESSENCE to demonstrate outbreaks in disparate locations and to compare the results of investigations can assist in detecting bioterrorist attacks.

2.5. Evaluation of New Surveillance Systems

The CDC has issued recommendations on the evaluation of surveillance systems (4). Surveillance systems should be periodically evaluated to ensure they are efficient and effective. As these new health indicator surveillance systems are still mostly unproven, special emphasis should be placed on their evaluation and subsequent improvement. Information on what aspects made the system more efficient or useful should be made available to others who are developing similar systems.

Fig. 2. (opposite page) Example of ESSENCE data detecting multiple simultaneous GI outbreaks at Aberdeen Proving Ground, MD, Fort Monmouth, NJ, Fort Knox, KY, and Marine Corps Recruit Depot in San Diego, CA.

Fig. 3. Epidemic curve of individual cases at MCRD, San Diego, CA.
The attributes of simplicity, flexibility, data quality, acceptability, sensitivity, predictive value positive, representativeness, timeliness, and stability should be assessed during an evaluation (4). Some attributes will be more important to some surveillance systems than for others. Early warning systems for infectious disease outbreaks will rank timeliness first, with acceptability, flexibility, sensitivity, and representativeness coming closely thereafter. The data quality and predictive value positive, although still important, will be less important than for a specific reportable disease. If a surveillance system is somewhat inaccurate, but is consistently inaccurate then it can still be quite useful in detecting fluctuations in disease incidence. Additionally, the grouping of cases into larger syndromes done in many of these surveillance systems represents larger categories that compensate for minor variations in diagnoses.

In addition to the traditional attributes to consider, new surveillance systems based on automated data sources will have other concerns. These include standard user interface, data format and coding, compatible hardware and software, quality assurance, and strict adherence to security and confidentiality (5).

At the end of a surveillance system evaluation, recommendations should be made to improve the system. However, efforts to improve some attributes may detract from others. After accounting for elements that cannot be changed (e.g., security restrictions that may impede timeliness, but cannot be removed), those elements that are most important should be identified and given highest priority for improvement.

Although the pressure is often apparent to rapidly start using data for surveillance before first evaluating its usefulness, we must continue to prove the effectiveness and sensitivity of data sources before establishing them as reliable public health information. Care must be taken to ensure that the data being utilized has meaning in the public health community and that the output being generated is derived from appropriate information. With the great amount of data available for analysis, it may be tempting to try to use as much as possible to find an answer. Each data source must be able to stand alone as a useful tool, although it may be more useful in combination with other sources.

In addition, the issue of false-positives must be considered. The surveillance systems should be set at an alert level that is as sensitive as possible without overburdening the responders. In many cases, the “false”-positive may not actually be “false,” it may just be a small outbreak of little consequence that has low morbidity and no mortality and rapidly resolves without revealing a source. Evaluation of these incidents may prove difficult, but attempts should be made to ascertain the true false-positive rate.

2.6. The Future of Health Indicator Surveillance Systems

As previously described, there are many initiatives to develop surveillance systems using traditional and nontraditional data sources. Probably the best system will use a combination of many data sources to achieve the highest sensitivity and specificity—a system of systems. The need for extreme timeliness will drive the creation of new, time-sensitive surveillance.

2.6.1. Integration of Military and Civilian Systems

To have the most sensitive surveillance system, information from as many segments of society as possible is important. This is termed the representativeness of a system—if it concentrates on only one geographic, ethnic, or socioeconomic section of a population, then it cannot accurately represent the status of the entire community. Similarly,
if a surveillance system only takes information from military beneficiaries, it will miss important other elements, both geographically and socioeconomically, in tracking disease rates.

Current ESSENCE surveillance information includes data from active duty, retirees, and family members, and thus, has a good representative slice regarding gender and age range. However, there are geographic areas that are not as well-represented if only military data are available. As Fig. 4 demonstrates, the density of use of MTFs by military beneficiaries in the national capital area varies across the region. Integration of civilian health data from local hospitals, health maintenance organizations, and regional billing centers is being collected through collaboration with civilian academic

Fig. 4. (A) Density of outpatient visits for defined syndromes captured by ESSENCE at MTFs in the national capital region. (B) Same map for data captured from a civilian HMO.
institutions. We find that the civilian data complement the military data very well by providing information on geographic areas that are not as well-represented in the military catchment (Fig. 4). In addition to the outpatient data, other civilian sources, such as over-the-counter pharmacy sales, school absenteeism, and veterinary information (e.g., wildlife die-off, veterinary clinic chains) is being added to the surveillance system. Again, a system of systems is the most sensitive way to detect variations in disease rates, and these systems must include collaborations between many organizations and institutions.

2.6.2. Nationwide Integration and Access

The CDC is developing the National Electronic Disease Surveillance System (NEDSS) to improve the management of and enhance currently existing surveillance systems (5). This will allow public health professionals to more rapidly detect and respond to outbreaks of infectious diseases, whether from natural sources or bioterrorism. It will use standard data formats to electronically link many different surveillance systems. In addition, it will provide a communications infrastructure to allow rapid communication between different public health sectors and provide agreements on data access, sharing and confidentiality (5). Recent funding by the Department of Health and Human Services will assist in providing funds to local and state health departments to assist in this integration. This type of system will greatly improve the current state of surveillance, with many current systems running on different platforms, including many paper-based systems. In particular, there are large government suppliers of health data, such as Medicare and Medicaid, that already have health-related databases that should be made available through a national plan. All state, local, and military health departments should assist in building a national network of information.

Although a national system is needed, the information must still be viewed and interpreted locally. The ownership of surveillance systems must be kept with the local users, who will be the ones to respond. However, the data should be available and shared across jurisdictions to give state and national epidemiologists the tools to evaluate a composite view of health status and to monitor for spread of infectious disease outbreaks.

3. LABORATORY SURVEILLANCE AND CAPABILITIES TO IMPROVE BIODEFENSE

3.1. Laboratory-Based Surveillance

Traditional surveillance systems rely heavily on laboratory reporting to track infectious disease trends. Because laboratory diagnoses provide the most specific information in an infectious disease surveillance system, they are essential for accurate monitoring. Although lab-based surveillance is not yet very timely, it is still of critical importance, especially in the evaluation of specific preventive measures. In bioterrorism defense, laboratory surveillance allows the public health community to track the spread of certain types of disease agents and, therefore, understand what pathogens are circulating in a given area. In bioterrorism detection, new or unusual strains can potentially be a strong indicator that an intentional attack has occurred (29). The strain of Salmonella causing illness in The Dalles, OR, in 1984 was one of the principal
clues in determining that the outbreak was intentional (30). With emphasis on cutting costs in healthcare, many patients are treated empirically without the benefit of microbiological diagnoses, especially when the illness is not severe or when the test result may arrive too late to benefit the patient (31). However, with recent increasing threats of bioterrorism in the United States, the need for laboratory-based surveillance is greater than ever.

3.1.1. DOD Laboratory-Based Global Influenza Surveillance

The DOD-GEIS has sponsored the Air Force influenza surveillance program since 1997. This program was initiated in 1976 under the title Project Gargle. Since then, the influenza surveillance program has used sentinel sites worldwide to isolate, identify, and study circulating influenza viruses (32). It is a part of the WHO global surveillance network and supplies isolates and reports to the CDC, WHO, and the Vaccines and Related Biological Products Advisory Committee.

Influenza is a highly contagious virus and has the potential to undergo major antigenic shift, which could expose much of the population to a virus to which they have no underlying immunity. Infection with influenza virus can incapacitate the victim, and it can be a lethal infection, especially in the very young and very old. If antigenic shift results in an especially virulent form, as apparently occurred in 1918, a disease with high mortality in all age groups may occur. For these reasons, the DOD strives to protect its servicemembers against this disease. This is done not only through annual vaccination programs, but also through the Air Force’s active surveillance program to monitor isolates throughout the world and anticipate any changes that may require new vaccines or other preventive measures.

The influenza surveillance program is an example of a highly successful system to monitor changes in microbiological flora nationally and internationally to effect appropriate preventive measures. Strengthening of systems such as this, especially those that monitor diseases that could be used as or engineered into a lethal bioweapon, is essential for biodefense.

3.1.2. The Naval Health Research Center’s Respiratory Disease Laboratory

In addition to the Air Force influenza program, the Naval Health Research Center (NHRC) in San Diego, CA surveys bacterial and viral respiratory pathogens at military installations in the United States (34). Population-based surveillance for febrile respiratory pathogens at basic training centers includes testing for influenza, parainfluenza, respiratory syncytial virus, and adenovirus. As major military installations, especially those that house recruits, could be bioterrorist targets, an active surveillance system that is confirmed by laboratory testing is crucial to monitor the health of these populations, follow changes in circulating pathogens, and evaluate preventive measures. NHRC also conducts surveillance on common bacterial causes of respiratory illness, in particular, *Streptococcus pyogenes* and *S. pneumoniae*, both of which can cause severe disease, especially in crowded recruit populations. Most importantly, with both the Air Force and NHRC surveillance systems, data are available for public health interpretation via websites.

3.1.3. Antibiotic Resistance Surveillance

The growing natural resistance of many bacteria to commonly used antibiotics is an additional reason to improve laboratory based surveillance. Tracking the incidence of
antibiotic resistant bacteria and monitoring changes over large geographic areas can greatly assist in addressing and mitigating this growing concern. The possibility of engineering disease agents to be antibiotic-resistant is already described, and laboratories must retain the capability to rapidly determine antibiotic sensitivity (33). Electronic laboratory files can provide a large amount of information and can be linked to pharmacy data to monitor the use of antibiotics, as well as resistance patterns (34). Recent studies have demonstrated that electronic laboratory reporting greatly increased the number, completeness, and timeliness of reports received (35). The DOD-GEIS is working with military and commercial laboratories to improve surveillance of antibiotic resistance patterns (36).

3.2. Laboratory Response to Bioterrorism

The public health and hospital laboratories will remain key players in biodefense. Even if detected quickly, only through rapid and accurate diagnosis will a bioterrorist attack be mitigated to the greatest extent possible. It is essential that all laboratories are trained to suspect and recognize potential biological terrorism agents, and furthermore, that the laboratory knows the appropriate reference chain for any suspicious or unusual pathogens. To assist in this endeavor, the Association of Public Health Laboratories with the CDC has developed a network of civilian laboratories designated as the Laboratory Response Network (LRN) (37).

The LRN is a pyramidal structure in which the lowest (Level A) of four levels of laboratories provides initial evaluation and sample referrals to increasingly more sophisticated laboratories. Each level has different responsibilities in the detection, confirmation, and typing of specimens and different requirements to save suspected or known bioterrorism agent isolates (37,38). The network is evolving rapidly as the plans and procedures are developed and distributed. An understanding of the LRN and collaboration with clinical laboratories to quickly mobilize available resources will greatly increase the ability to recognize a bioterrorism attack and implement appropriate curative and postexposure disease prevention measures. Additional information about the LRN, including lab protocols, is available through the CDC website (http://www.bt.cdc.gov).

3.2.1. The Virtual Public Health Laboratory Directory

Advances in laboratory technology in recent years has fostered the question of how to provide these new techniques at every laboratory level. However, many of these new tests are performed on an ad hoc basis, may be unlicensed, and require specific expertise to run them. A system designed to optimize the delivery of advanced technology cannot rely on the physical presence of these capabilities at every level. However, an inventory of available resources that is updated and provides contact information and instructions on how to obtain reference testing can easily be made available through a Web-based system (39). For this reason, the DOD-GEIS is developing a virtual public health lab directory to accomplish this mission.

Within the DOD alone, there are numerous medical laboratories located throughout the world that have a wide range of testing capabilities. Some are research laboratories, whereas others are hospital-based. Within the research community, there are a large number of specialized tests that could be available, but there is no established DOD
system to define or facilitate coordination or communication. Most hospital clinicians may have no idea that a DOD laboratory can provide a specific test, let alone how to contact them or send it. Several of these assays are not performed under the regulatory controls necessary for clinical laboratory certification, nor do they represent devices licensed by the Food and Drug Administration because of their research status. Along with improvements in the Web-based linkages, attention needs to be placed on validation of these procedures. In addition, the CDC and state and university laboratories can provide assistance in specialized areas, and may be easier to use as a result of proximity. However, there are no formal support agreements between DOD and state laboratories. During a time of crisis, lack of an established plan can result in confusion and wasted time.

In light of these issues, it was decided at a Military Public Health Laboratory Symposium held in 1999 that the DOD medical system must become aware of the availability and accessibility of specialized laboratory testing worldwide (40). In addition, lines of communication must be opened within the DOD and with civilian partners to ensure the most prudent use of resources. The first step in addressing these concerns will be the release of the DOD virtual public health lab directory, a joint collaborative effort between the DOD-GEIS and the Armed Forces Institute of Pathology. In addition, efforts to archive and store clinical specimens of interest from those with known or potential infectious disease etiologies for future study is also being undertaken.

4. CONCLUSION

The US military has been involved with developing defenses against biological warfare for many decades. These efforts have featured research into vaccines, therapeutics, diagnostics, and various other countermeasures. Most of the doctrine developed has been based on battlefield scenarios in which deployed forces are arrayed against a defined enemy. However, the specter of biological terrorism on the homeland perpetrated by a unique set of actors with nontraditional agendas raises many new challenges to old defensive assumptions. One of these is the greatly increased challenge of defining, recognizing, and responding to an unexpected threat before its full consequences are felt. It is clear that with the homeland as a potential target, some of the approaches to threat mitigation that are appropriate to a fielded military force are less practical to communities of civilians or garrison military structures. An important ally in this threat to internal national security is the public health community and a key function of the public health community is the ongoing assessment of community health through surveillance. DOD-GEIS has assumed a pioneering role in creating new public health systems to meet this unprecedented challenge. Many of the innovations made possible by the military’s unique global medical information systems are equally beneficial detecting naturally occurring and deliberate outbreaks of infectious diseases. However, it is only through partnering with civilian public health agencies that it will be possible to apply these techniques on the scale necessary to build a truly national civil biodefense infrastructure needed for early detection and effective management of these threats. In numerous readiness exercises, the need for crisp and accurate information has been seen as central to effective crisis management. Public health surveillance is thus a foundation stone in any comprehensive system for biodefense.
REFERENCES

1. Langmuir, A. D. and Andrews, J. M. (1952) Biological warfare defense: the Epidemic Intelligence Service of the Communicable Disease Center. *Am. J. Public Health* 42, 235–238.

2. O’Toole, T. (2001) Emerging illness and bioterrorism: implications for public health. *J. Urban Health* 78, 396–402.

3. Inglesby, T. V., Grossman, R., and O’Toole, T. (2001) A plague on your city: observations from TOPOFF. *Clin. Infect. Dis.* 32, 435, 436.

4. Khan, A. S. and Ashford, D. A. (2001) Ready or not - preparedness for bioterrorism. *N. Engl. J. Med.* 345, 287–289.

5. Centers for Disease Control and Prevention. (2001) Updated guidelines for evaluating public health surveillance systems: recommendations from the guidelines working group. *MMWR* 50, 1–30.

6. Thacker, S. B. and Berkelman, R. L. (1998) Public health surveillance in the United States. *Epidemiol. Rev.* 10, 164–190.

7. Army Medical Surveillance Activity. (2001) Completeness and timeliness of reporting of hospitalized notifiable cases, US Army, January 1995–June 2001. *MSMR* 7, 12–15.

8. Army Medical Surveillance Activity. (2001) Completeness and timeliness of reporting of hospitalized notifiable cases, US Navy, January 1998–June 2001. *MSMR* 7, 16–19.

9. Army Medical Surveillance Activity. (2001) Completeness and timeliness of reporting of hospitalized notifiable cases, US Air Force, January 1998–June 2001. *MSMR* 7, 20–23.

10. Kaufmann, A., Meltzer, M., and Schmid, G. (1997) The economic impact of a bioterrorist attack: are prevention and postattack intervention programs justifiable? *Emerg. Infect. Dis.* 3, 83–94.

11. Fraser, D. W., Tsai, T. R., Orenstien, W. et al. (1977) Legionnaires’ disease: description of an epidemic of pneumonia. *N. Engl. J. Med.* 297, 1189–1197.

12. Centers for Disease Control and Prevention. (1993) Outbreak of Hantavirus infection—Southwestern United States, 1993. *MMWR* 42, 495, 496.

13. Fine, A. and Layton, M. (2001) Lessons from the West Nile viral encephalitis outbreak in New York City, 1999: implications for bioterrorism preparedness. *Clin. Infect. Dis.* 32, 277–282.

14. Centers for Disease Control and Prevention. (2001) Update: investigation of anthrax associated with intentional exposure and interim public health guidelines, October, 2001. *MMWR* 50, 889–893.

15. Khan, A. S., Morse, S., and Lillibridge, S. (2000) Public-health preparedness for biological terrorism in the USA. *Lancet* 356, 1179–1182.

16. Thacker, S. B. (2000) Historical development, in *Principles and Practice of Public Health Surveillance*, 2nd ed. (Teutsch, S. M. and Churchill, R. E., eds.), Oxford University Press, New York.

17. Thomson, M., Connor, S., O’Neill, K., and Meert, J.-P. (2000) Environmental information for prediction of epidemics. *Parasitol. Today* 16, 137, 138.

18. Dowell, S. F. (2001) Seasonal variation in host susceptibility and cycles of certain infectious diseases. *Emerg. Infect. Dis.* 7, 369–374.

19. Miller, J. R. and Mikol, Y. (1999) Surveillance for diarrheal disease in New York City. *J. Urban Health* 76, 388–390.

20. Mikol, Y., Miller, J., and Ashendorff, A. (2000) Diarrheal disease surveillance programs: New York City’s experience. International Conference on Emerging Infectious Diseases. Centers for Disease Control and Prevention, Atlanta, GA.

21. Proctor, M. E., Blair, K. A., and Davis, J. P. (1998) Surveillance data for waterborne illness detection: an assessment following a massive waterborne outbreak of Cryptosporidium infection. *Epidemiol. Infect.* 120, 43–54.
22. Pavlin, J. A., Kelley, P. W., Mostashari, F., et al. (2002) Innovative surveillance methods for monitoring dangerous pathogens, in *Institute of Medicine (US). Biological Threats and Terrorism: Assessing the Science and Response Capabilities*. National Academy of Sciences, Washington, DC, pp. 185-196.

23. Connolly, C. (2002) Bush promotes plans to fight bioterrorism. *The Washington Post* (Feb 6) Sect A, 3.

24. Espino, J. U., Tsui, F. -C., and Wagner, M. Realtime outbreak detection system (RODS). Available from http://www.health.pitt.edu/rods/rods.htm. Accessed on 11 Feb 2002.

25. Lazarus, R., Kleinman, K. P., Dashevsky, I., DeMaria, A., and Platt, R. (2001) Using automated medical records for rapid identification of illness syndromes (syndromic surveillance): the example of lower respiratory infection. *BMC Public Health* 1, 9.

26. Idaho Technology inc. Detection and identification of bio-warfare agents. Available from http://www.army-technology.com/contractors/nbc/idaho. Accessed on 2/11/2002.

27. Schafer, K. LEADERS (Lightweight Epidemiology Advanced Detection & Emergency Response System). Available from http://www.tricare.osd.mil/conferences/2001/agenda.cfm. Accessed on 2/12/2002.

28. New Mexico Department of Health. Rapid Syndrome Validation Project (RSVP) Project Description. Available from http://epi.health.state.nm.us/rsvpdesc/default.asp. Accessed on 2/11/2002.

29. Pavlin, J. A. (1999) Epidemiology of bioterrorism. *Emerg. Infect. Dis.* 5, 528–530.

30. Torok, T. J., Tauxe, R. V., Wise, R. P., et al. (1997) A large community outbreak of salmonellosis caused by intentional contamination of restaurant salad bars. *JAMA* 278, 389–395.

31. Skeels, M. R. (2000) Laboratories and disease surveillance. *Mil. Med.* 165(Suppl 2), 16–19.

32. Canas, L. C., Lohman, K., Pavlin, J. A., et al. (2000) The Department of Defense laboratory-based global influenza surveillance system. *Mil. Med.* 165(Suppl 2), 52–56.

33. Alibek, K. and Handelman, S. (1999) *Biohazard: The Chilling True Story of the Largest Covert Biological Weapons Program in the World: Told from the Inside by the Man Who Ran It*. Random House.

34. O’Brien, T. F., Eskildsen, M. A., and Stelling, J M. (2000) The complex processes of antimicrobial resistance and the information needed to manage them. *Mil. Med.* 165(Suppl 2), 12–15.

35. Effer, P., Ching-Lee, M., Bogard, A., Ieong, M.-C., Nekomoto, T., and Jernigan, D. (1999) Statewide system of electronic notifiable disease reporting from clinical laboratories. Comparing automated reporting with conventional methods. *JAMA* 282, 1845–1850.

36. Davis, S. R. (2000) The state of antibiotic resistance surveillance: an overview of existing activities and new strategies. *Mil. Med.* 165(Suppl 2), 35–39.

37. Gilchrist, M. J. R. (2000) A national laboratory network for bioterrorism: evolution from a prototype network of laboratories performing routine surveillance. *Mil. Med.* 165(Suppl 2), 28–31.

38. Centers for Disease Control and Prevention. (2000) Biological and chemical terrorism: Strategic plan for preparedness and response. *MMWR* 49(RR-4), 1–14.

39. Asher, M. S. (2000) A civilian-military virtual public health laboratory network. *Mil. Med.* 165(Suppl 2), 1–4.

40. Bolton, J. C. and Gaydos, J. C. (2000) Workshop group B: a Department of Defense (DOD) directory of public health laboratory services for infectious agents and public health laboratory system. *Mil. Med.* 165(Suppl 2), 66–69.