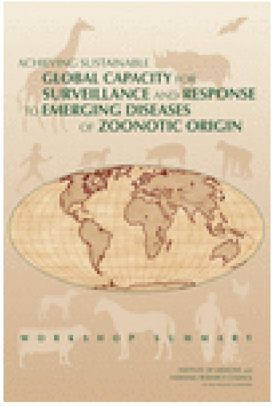

Achieving Sustainable Global Capacity for Surveillance and Response to Emerging Diseases of Zoonotic Origin: Workshop Summary

Alexandra Beatty, Kimberly Scott, and Peggy Tsai, Rapporteurs, Committee on Achieving Sustainable Global Capacity for Surveillance and Response to Emerging Diseases of Zoonotic Origin, National Research Council

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ACHIEVING SUSTAINABLE GLOBAL CAPACITY FOR SURVEILLANCE AND RESPONSE TO EMERGING DISEASES OF ZOONOTIC ORIGIN

WORKSHOP SUMMARY

Alexandra Beatty, Kimberly Scott, and Peggy Tsai, *Rapporteurs*

Committee on Achieving Sustainable Global Capacity for Surveillance and Response to Emerging Diseases of Zoonotic Origin

Board on Global Health
Institute of Medicine

Board on Agriculture and Natural Resources
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This document is a product of the cooperation and contributions of many people. The committee would like to thank all the speakers and participants who attended the workshop on June 25–26, 2008. Their presentations helped to set the stage for the fruitful discussions in the sessions that followed.

This workshop summary has been reviewed in draft form by persons chosen for their diverse perspectives and technical expertise in accordance with procedures approved by the National Research Council's Report Review Committee. The purpose of the independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards of objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following for their review of this document:

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Although the reviewers listed above have provided constructive comments and suggestions, they did not see the final draft of the report before its release. The review of this report was overseen by **Dr. David Challoner,** Vice President for Health Affairs, Emeritus, University of Florida. Appointed by the National Research Council, he was responsible for making certain that an independent examination of this document was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authors and the institution.

Preface

The Institute of Medicine (IOM) and National Research Council (NRC) convened a 2-day workshop titled "Workshop on Sustainable Global Capacity for Surveillance and Response to Emerging Zoonoses" in Washington, DC, on June 25 and 26, 2008. The goal of the workshop—as one of several planned data gathering sessions for the committee to meet their overall charge—was more narrowly focused to review the current global capacity to carry out surveillance to detect, report, and monitor emerging infectious diseases in both humans and animals. This included brief discussions that began to examine how these systems might inform the necessary responses to emerging and reemerging infectious diseases of zoonotic origin that would be discussed more in-depth in the committee's forthcoming consensus report. The workshop did not address, however, the details of any specific global or regional responses to any particular disease outbreak. The workshop did provide an opportunity for participants to examine the effectiveness of communication pathways among multidisciplinary practitioners and researchers, between the human and animal health constituencies, and between these professionals and the public.

This document is a summary of that workshop and is a companion to the full consensus report (anticipated for summer 2009) of the IOM/NRC Committee on Achieving Sustainable Capacity for Surveillance and Response to Emerging Diseases of Zoonotic Origin. For the complete study, the committee is charged with exploring how emerging zoonotic disease surveillance, prevention, detection, and response could be strengthened and sustained globally over time to reduce or eliminate outbreaks of zoonotic diseases in human populations.

During the latter half of the 20th century, complacency toward infectious diseases as a global threat had set in due to the success of vaccines and antibiotics. The reality, however, was far different. First, although vaccines were developed for a number of important diseases, they were not consistently available in quantities needed by some countries, and it has been difficult to develop vaccines for many major infectious causes of morbidity and mortality. Second, antimicrobial resistance has occurred because antimicrobials were introduced into clinical practice and it now constitutes a real crisis. Third, new or newly discovered or known infectious agents have acquired new virulence attributes and have been emerging and reemerging during the past 30 years. The global spread of HIV/AIDS, multiple-drug–resistant tuberculosis, drug-resistant malaria, diarrheal diseases, and an increasing number of human outbreaks of emerging zoonotic infectious diseases (any disease or infection that is naturally transmissible from vertebrate animals to humans)[1] discussed below are examples of the appearance of newly discovered or known agents over the last 30 years.

According to a recent, comprehensive literature review of more than 1,400 species of human pathogens—including viruses, bacteria, rickettsia, fungi, protozoa, and helminths—known to be infectious to human beings, 868 (61 percent) are zoonotic (Cleaveland et al., 2001; Taylor et al., 2001). In the same review, of 175 agents found to be associated with emerging infections, 132 (75 percent) were zoonotic agents (Taylor et al., 2001). The same authors found that zoonotic diseases were twice as likely to be associated with emerging or newly discovered infections as nonzoonotic pathogens. These pathogens are transmitted through direct contact from animals to humans and through air, water, food, and insect vectors.

The increase in infectious disease mortality from HIV/AIDS in persons 25 years of age and older, starting in the 1980s in the United States, was largely unforeseen (Armstrong et al., 1999). Even more catastrophic is the fact that AIDS has reversed the gains in life expectancy that had been achieved in Africa over the past 50 years (UNAIDS, 2004, 2006). Infectious diseases remain among the leading causes of death worldwide for children under 5 years of age (UNICEF, 2007). As we continue into the 21st century, infectious diseases are widely perceived as an unfinished agenda, and the ever-increasing potential of outbreaks or even pandemics caused by

[1]The World Health Organization state in their definition of zoonoses: "Animals thus play an essential role in maintaining zoonotic infections in nature. Zoonoses may be bacterial, viral, or parasitic, or may involve unconventional agents. As well as being a public health problem, many of the major zoonotic diseases prevent the efficient production of food of animal origin and create obstacles to international trade in animal products" (WHO, 2008c).

zoonotic diseases make them an important public health problem in both the developed and the developing world, emphasizing the need to prepare for them.

Since the 1980s, infectious diseases of zoonotic origin have become the focus of public health attention following several large and highly visible zoonotic infectious disease outbreaks around the globe. Some of the outbreaks of emerging zoonotic infections that have affected both human and animal populations and that have commanded attention worldwide include West Nile virus fever, human monkeypox, and *Escherichia coli* O157:H7 outbreaks in the United States; Hendra virus disease in Australia; Nipah virus encephalitis in Malaysia; Rift Valley fever in Africa; and HIV, Severe Acute Respiratory Syndrome (SARS), avian influenza, and dengue fever outbreaks globally. Of particular concern has been the relatively recent, unprecedented spread of a highly pathogenic avian influenza virus (H5N1)[2] throughout Asia, Europe, and into Africa, with transmission from infected poultry to humans having occurred in 15 countries as of June 2008. This has placed the world in Stage 3 of a World Health Organization (WHO) pandemic influenza alert,[3] with the threat of an influenza pandemic of tremendous concern around the world. In addition to mortality and morbidity in both human and animal populations, the costs of these outbreaks include severe impacts on national and international economies.

The disease outbreaks mentioned above and others have underscored the importance of developing an even better understanding of the conditions that give rise to the emergence of these diseases in both human and animal populations, and their routes and mechanisms of transmission between species. As more has been learned about them, including the nationally and globally observed serious health and economic impacts they have had, many have come to understand that multiple disciplines and sectors must work together to carry out effective disease prevention programs, disease

[2] Avian influenza is caused by Eurasian strain influenza A viruses, subtype H5N1. Serotyping is based on the hemagglutinin (HA) [with H5 standing for the fifth known type of this protein] and neuraminidase (NA), [with N1 standing for the first of several known types of this protein] on the surface of the influenza A virus.

[3] WHO has developed a six-phase pandemic alert system to inform the world of the seriousness of a threat and the need to launch more intense preparedness activities (with 1 = low risk of human cases, 6 = efficient and sustained human-to-human transmission). The designation and progression of phases are made by the Director-General. Each phase coincides with a series of recommended activities to be undertaken by WHO, the international community, governments, and industry. Changes in phases are triggered by several factors, including the epidemiological behavior of the disease and the characteristics of circulating viruses. In Phase 3, a new influenza virus subtype has been causing disease in humans, but there is no or very limited human-to-human transmission or it is not yet spreading efficiently and sustainably among humans (WHO, 2008b).

surveillance for the early detection of outbreaks, and disease outbreak response and control in both human and animal populations.

Several other IOM reports and workshop summaries have addressed many of the environmental, demographic, social, and other factors leading to the emergence or reemergence of infectious diseases, including *Microbial Threats to Health: Emergence, Detection, and Response*; *The Impact of Globalization on Infectious Disease Emergence and Control: Exploring the Consequences and Opportunities*; *The Emergence of Zoonotic Diseases: Understanding the Impact on Animal and Human Health*; and *Global Climate Change and Extreme Weather Events: Understanding the Contributions to Infectious Disease Emergence* (IOM, 2003, 2006, 2002, and 2008, respectively).[4]

During this 2-day workshop in June 2008, epidemiologists, laboratory scientists, researchers, policy makers, human and animal health clinicians, disease prevention and control experts, and others from around the world presented their personal views in 15-minute presentations about a set of topics. Those topics include the human–animal–ecosystem interface and its associated drivers that promote the emergence of infectious diseases; the value and limitations of existing global and regional human and animal health active and passive surveillance networks and systems; reporting standards, data collection, and information sharing; early warning systems for epizootic and zoonotic diseases in animals and humans respectively; and global and regional laboratory and epidemiology capacity. Participants were asked to discuss whether there is a need for sustainable global capacity for surveillance that could inform response to zoonoses; to explore how that capacity might be conceptualized and operationalized on different levels; and to identify stakeholders who would be expected to assume leadership roles to help achieve this capacity. Participants were also asked to consider and explore other critical elements for such an endeavor, including human and animal health infrastructure needs; governance and funding challenges; workforce collaboration and training needs; multidisciplinary data collection and data-sharing challenges; and the complex interactions of economic and trade policies, regulations, and structures with human and animal health needs.

This document is a summary of those presentations and discussions at the workshop; it is not intended to be a comprehensive examination of the subject matter. This summary is not a consensus report of the committee, nor does it include recommendations or endorsements of any formally convened committee of the IOM or the NRC. The material contained in this report is directly derived from the remarks and presentations of the

[4]These and other reports can be found at the website of the National Academies Press, www.nap.edu.

participants and the authors, and they do not necessarily represent the views of the convening committee, the IOM, or the NRC.

We greatly appreciate the support of the U.S. Agency for International Development for the activities of the Committee on Achieving Global Capacity for Surveillance and Response to Emerging Diseases of Zoonotic Origin. This committee has organized and convened this workshop in collaboration with the IOM and the NRC staff. The committee co-chairs wish to express their deep appreciation to the workshop presenters and participants (see Appendixes B and C), the committee members for their time and engagement in this study, and the following IOM staff: Patrick Kelley and Robin Schoen, board directors for Global Health and Agriculture and Natural Resources; Kimberly Scott, study director; Peggy Tsai, program officer; Mila González, research assistant; Sarah Jane Brown, senior program assistant; and Julie Wiltshire, financial associate, for their able assistance in the organization of this meeting. We also recognize the contributions of Allison Brantley, Sarah Bronko, Reine Homawoo, and Karen Imhof of the IOM and the NRC for their logistic support during the meeting. Finally, special thanks go to our lead author Alexandra Beatty, as well as Kimberly Scott and Peggy Tsai for their revisions to the draft workshop summary and response to the comments of the external reviewers.

Gerald T. Keusch, M.D.
Committee *Co-Chair*

Marguerite Pappaioanou, D.V.M., Ph.D.
Committee *Co-Chair*

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Acronyms and Abbreviations

AIDS	Acquired Immunodeficiency Syndrome
AI-watch	Avian Influenza-watch
ALERTA	Alerta Surveillance System in Peru
ArboNET	National surveillance system for arboviral diseases in the United States
BSE	Bovine spongiform encephalopathy
BSE-vCJD	Bovine Spongiform Encephalopathy and variant Creutzfeldt-Jakob disease
BSL	biosafety level
CDC	Centers for Disease Control and Prevention
CSREES	Cooperative State Research, Education, and Extension Service
DNA	Deoxyribonucleic acid
DoD	U.S. Department of Defense
DoD-GEIS	U.S. Department of Defense-Global Emerging Infections Surveillance and Response System
ECE	embryonated chicken eggs
EIN	Emerging Infections Network
ESSENCE	Electronic Surveillance System for Early Notification of Community-based Epidemics
EWORS	Early Warning Outbreak Recognition System

FAO	Food and Agriculture Organization of the United Nations
FELTP	Field Epidemiology and Laboratory Training Program
FMD	Foot-and-mouth disease
GAINS	Global Avian Influenza Network for Surveillance
GLEWS	Global Early Warning System
GOARN	Global Outbreak Alert and Response Network
GPHIN	Global Public Health Intelligence Network
H5N1	influenza A virus subtype H5N1
HAZMAT	hazardous materials
HIV	Human Immunodeficiency Virus
HPAI	highly pathogenic avian influenza
IEIP	International Emerging Infections Program
IOM/NRC	Institute of Medicine/National Research Council
KEMRI	Kenya Medical Research Institute
NAHLN	National Animal Health Laboratory Network
NCASP	National Companion Animal Surveillance Program
NWHC	National Wildlife Health Center
OIE	Office International des Epizooties (World Organization for Animal Health)
PAHO	Pan American Health Organization
ProMED	Program for Monitoring Emerging Diseases
ProMED-ESP	Program for Monitoring Emerging Diseases-Spanish
ProMED-FRA	Program for Monitoring Emerging Diseases-French
ProMED-Port	Program for Monitoring Emerging Diseases-Portuguese
ProMED-RUS	Program for Monitoring Emerging Diseases-Russian
RFV	Rift Valley fever
SARS	Severe Acute Respiratory Syndrome
UNICEF	United Nations Children's Fund
USAID	U.S. Agency for International Development
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey

WCS	Wildlife Conservation Society
WDIN	Wildlife Disease Information Node
WHO	World Health Organization
WISDOM	Wildlife Information System for Disease Observation and Monitoring

Summary

Epidemics of infectious diseases have been among the most frightening and disruptive of natural disasters at least since the Middle Ages, when recurring outbreaks of the plague killed millions of people. Today, conditions around the globe are ripe for the development of epidemics of zoonotic diseases (any disease or infection that is naturally transmissible from vertebrate animals to humans[1]) that have the potential to become pandemics. Many of these diseases, among them AIDS, Severe Acute Respiratory Syndrome, highly pathogenic avian influenza (HPAI-H5N1) and Bovine Spongiform Encephalopathy causing variant Creutzfeldt-Jakob disease in humans, have emerged recently as the patterns of human–animal contact have changed. What accounts for this upsurge in the incidence of this type of infectious diseases? Some of the answers from the June 2008 workshop convened by the Institute of Medicine and the National Research Council's Committee on Achieving Sustainable Global Capacity for Surveillance and Response to Emerging Diseases of Zoonotic Origin are outlined in Chapter 2 of this document.[2]

[1]The World Health Organization state in their definition of zoonoses: "Animals thus play an essential role in maintaining zoonotic infections in nature. Zoonoses may be bacterial, viral, or parasitic, or may involve unconventional agents. As well as being a public health problem, many of the major zoonotic diseases prevent the efficient production of food of animal origin and create obstacles to international trade in animal products" (WHO, 2008c).

[2]This document summarizes the views expressed by workshop participants. While the committee is responsible for the overall quality and accuracy of the document as a record of what transpired at the workshop, the views contained in the document are not necessarily those of the committee. Copies of the workshop presentations can be accessed at www.iom.edu/zoonotics.

Changes in the human population and its behaviors, including intensifying means of food production and transport systems, more rapid travel and transport of people and animals across borders and continents, and changing patterns of land use have contributed to this upsurge. Other environmental changes and a host of additional factors have also contributed to conditions that favor the transmission of pathogens that develop in animal populations, then make the jump into human populations. Researchers and human and animal health advocates have focused on disease surveillance[3] as a particularly critical tool for detecting, monitoring, and facilitating response to control outbreaks of zoonotic diseases in humans, but questions remain as to how to make zoonotic disease surveillance more comprehensive and timely in animal populations in order to prevent or minimize the potential for outbreaks to occur in human populations.

THE CONVERGENCE OF FORCES RESPONSIBLE FOR ZOONOSES IN HUMANS

These newly identified diseases have emerged[4] primarily as a result of significant changes in human activity: population growth, changing patterns of human–animal contact, increased demand for animal protein, increased wealth and mobility, environmental changes, and human encroachment on farm land and previously undisturbed wildlife habitat. Other pathogens could follow a similar pathway.

Human factors that influence the development of pathogens include genetic and biological factors; social, political, and economic factors; human health, behavior, and attitudes; and activities such as transport and trade. Perhaps the most obvious change has been the growth in human population. At less than 3.5 billion in 1950, the world's population reached approximately 6.5 billion in 2005 and is projected to top 11 billion by 2100 (Kern, 2008). The largest proportion of human population growth is

[3]The World Health Organization defines surveillance as "the systematic ongoing collection, collation, and analysis of data for public health purposes, and the timely dissemination of public health information for assessment and public health response as necessary"; surveillance may be conducted by institutions of various kinds (WHO, 2008a).

[4]For purposes of this workshop summary, a human disease is considered emerging if it meets one or more of these characteristics: has nearly appeared or is newly recognized, is more difficult to treat, has an increased incidence, is widely distributed geographically or demographically, is severe or lethal, presents new complications, has a new mode of transmission, has substantial epidemic potential, or threatens regional of global health (Breiman, 2008). The National Institute of Allergy and Infectious Diseases, however, defines emerging and re-emerging diseases as the following: "emerging diseases includes outbreaks of previously known diseases whose incidence in humans has significantly increased in the past two decades. Conversely, remerging diseases are known diseases that have reappeared after a significant decline in incidence" (NIAID, 2008).

taking place in the least developed countries, those with the highest rates of poverty—and also those that are least equipped to monitor, detect, and control emerging diseases. Global population expansion has brought significantly increased challenges in sustaining the food supply and may have consequences to human and animal health. For example, an increased demand for protein and food of animal origin has resulted in noteworthy changes in basic animal husbandry practices to more intensive systems due to the increases in the number of animals kept. This in turn has altered disease exposure risks from livestock to humans and from wildlife to livestock.

Other changes made possible by technological advances have also affected the development of pathogens. One can now circumnavigate the globe in 24 hours and the fast-growing human population is moving more, and more quickly, than ever before. An estimated 1 billion people cross international borders every year. Humans are also transporting goods, particularly meat and other food, on a vast scale, which means that animals and pathogens can travel farther and faster than ever before.

Pathogens are also affected by changes in the environment, most of which are widely viewed as traceable to human activity. Climate and weather have changed in numerous ways around the world.[5] Changing temperature and humidity patterns, drought and desertification, novel weather patterns, and other changes have not only affected the geographic ranges in which species can thrive, but have also altered lifecycles and microclimates. These changed patterns are expected to affect the distribution and movements of pathogens and their vectors.

Finally, human encroachment on the environment can affect animal health and behavior. The availability of land for both domestic and wild animals has fallen considerably. Animal behavior and feeding preferences may be altered as they adapt to new ranges, and other factors may affect the balance within an ecosystem. Animals may also be exposed to new disease-causing agents as they move or come into contact with humans and other species, and their acquired resistance to new disease may be reduced by fast-paced changes in their environment.

These interactions provide ideal circumstances for pathogens that affect only animals to evolve first into agents that can cause primary infection in humans, through direct animal–human contact (e.g., canine-rabies), to those that can cause limited outbreaks through human–human contact, as well as through animal–human contact (e.g., Ebola). The next evolutionary stage is to an agent that can cause a sustained outbreak via animal–human or human–human contact (e.g., Chagus or influenza A). Eventually, given

[5]Data from the Intergovernmental Panel on Climate Change leave little room for doubt that the world is getting warmer (IPCC, 2007).

the right circumstances, a pathogen may develop into an agent transmitted only among humans (e.g., HIV).

SURVEILLANCE

Surveillance, which has been defined by the World Health Organization as "the systematic ongoing collection, collation, and analysis of data for public health purposes and the timely dissemination of public health information for assessment and public health response as necessary," is viewed by most experts in public and animal health as a particularly critical tool for protecting humans from zoonotic diseases and animals from epizootic diseases.[6] Surveillance is conducted by institutions of various kinds, and no single agency has either the mandate or the capacity to address the entire landscape of zoonotic disease. Looking worldwide, the World Health Organization (WHO), the World Organization for Animal Health (OIE), and the Food and Agriculture Organization of the United Nations (FAO) each play a role, and have been working to better coordinate their activities. Within the United States, the responsibility is spread across many government departments and programs, each with its own focus and interests. It would be inaccurate to describe current surveillance efforts around the world as a system, but they do interact in important ways.

Detecting Disease in Animals with Zoonotic Potential

A new zoonotic disease in humans could theoretically emerge from any animal population around the world, but some animal populations are more likely than others to serve as a reservoir for disease that could threaten humans. As a result, much of the current disease surveillance apparatus has developed in a somewhat ad hoc way, in response to growing awareness of specific kinds of threats. Several systems and programs have been especially important.

The Global Early Warning System (GLEWS) is one of several current efforts to coordinate and build on existing surveillance networks by pooling information collected by FAO, OIE, and WHO. GLEWS was devised as a means of improving the tracking of significant diseases among animals in high-risk areas and providing data analysis and early warnings to the international community. GLEWS was also designed to ensure that data are shared among institutions and agencies, rather than duplicated. The program's primary functions are disease tracking, information sharing,

[6]These principles would also pertain to animal health surveillance. Epizootic diseases are epidemics in animal populations.

verification of threats, epidemiological analysis, and support for urgent response to assess and control outbreaks.

Consistent standards and procedures applied across countries are a critical element of surveillance and response systems. OIE has developed standards that merge concerns about animal health and welfare, food safety, and public health; they include codes for both terrestrial and aquatic animal health. OIE has 172 member countries, and its objective is to engage each of them in a commitment to conduct surveillance, collect data, and rapidly disseminate data on both the presence of diseases being targeted and other epidemiological events. Although the 172 member countries are legally obliged to adhere to the organization's notification obligations and published standards, OIE provides a variety of resources to assist them. A decision tree is used to determine which diseases are of concern and should be tracked. OIE has developed a web-based system, the World Animal Health Information System, for managing the data collected and providing additional data resources.

While OIE focuses primarily on animals that are domesticated for food consumption, the U.S. Geological Survey conducts surveillance of wildlife and investigates disease outbreaks in U.S. wildlife populations. The health of wild animals is directly linked to that of both domestic animals and humans. Diseases among wild animals can also provide early warnings of environmental damage, bioterrorism, and other risks to human health.

Subsistence economies are particularly vulnerable to disease outbreaks among wild animals because they are directly dependent on them for survival, yet these societies are least likely to have adequate (or any) infrastructure and expertise for animal disease surveillance. Often, outbreaks among wild animals are not investigated until implications for human health are evident, but once these connections are clear, it may be too late to contain the disease. Wildlife diseases may have profound effects on an ecosystem, or be evidence of threats to an ecosystem. Moreover, once a wild population has been depleted or eliminated, there is no mechanism for its replacement, as there would be for a domestic population (e.g., Ebola is killing large numbers of great apes in equatorial Africa, while poultry stock has been replaced after culling for highly pathogenic avian influenza in regions of Asia). Wildlife populations can serve as reservoirs and hosts to diseases that also affect domestic animals; though they can then be a vital link in a cycle that could also include humans, they are frequently left out of the surveillance picture.

Current wildlife disease data are available from a number of sources, including international programs (e.g., FAO, OIE, Global Avian Influenza Network for Surveillance), which encompass only limited voluntary reporting, and U.S. sources (federal-, state-, university-based), which are not coordinated nationally. Most local data are not being shared or used.

Many workshop participants stressed that relevant health data regarding humans, domestic animals, and wildlife should ideally be coordinated to protect human health.

Targeted surveillance systems have developed in response to several specific threats or animal populations as well, one of which is Ebola, a disease that causes hemorrhagic bleeding in nonhuman primates. Ebola has affected fewer than 1,000 humans thus far, but its high fatality rate and the threat it poses to endangered primate species have made the possibility of large-scale outbreaks a particularly chilling prospect.

Surveillance of primates is important for several reasons. Populations of many primates are highly concentrated: roughly 80 percent of the world's gorillas and chimpanzees, for example, are located in Gabon and the Republic of Congo. These and other primates have been under tremendous pressure as a result of commercial hunting and many are now endangered. The ape population in Gabon has declined by more than half since 1983, and although counting these animals has been difficult, as many as 5,500 gorillas are estimated to have died from Ebola.

Researchers have been eager to understand exactly how Ebola spreads among these primates, and also whether interaction among different species of nonhuman primates—and possibly with other species, such as bats—may play a role. Investigators have concluded that the incidence of Ebola is most likely caused by a combination of multiple separate emergences and group-to-group spread of the disease, but they have not been able to identify the reservoir for the disease. In any case, primates serve as important sentinels, even though the risk of the disease spreading to other countries is small.

Bats are also carriers for viruses that are harmful to humans—perhaps including Ebola. Eight new zoonotic viruses that originated in bats have emerged since 1994, and there is significant potential for additional ones to emerge. Bats are an important sentinel species, in part because bats are the most diverse of all mammals (there are more than 1,000 species), comprise one-fifth of all mammal species, and can be found worldwide. They are also highly mobile and well adapted to human environments, which means they often share food sources and dwellings with people—and human–bat interaction is increasing as humans encroach on tropical forestland.

Surveillance of bats is challenging—it entails collection of blood and other body fluids, which can be highly infectious, and must often be carried out in difficult, remote terrain. Bats are very sensitive to disturbance, and colonies may move in response to investigation. Because testing every bat species would be impossible, the strategy must be to focus on so-called hot-spots where zoonoses are most likely to be found—meaning geographical areas with high biodiversity as well as high human population density.

Surveillance of any wildlife populations is important not only as an early warning system for diseases in humans, but also as part of an overall approach to sustaining the integrity of ecosystems worldwide. The Wildlife Conservation Society's (WCS's) goal is to protect wildlife and wild lands, and they conduct animal disease surveillance both in the wild and in controlled settings. One of their surveillance activities has focused on bushmeat (terrestrial wild animals hunted for food), as (1) the demand for wildlife food has increased significantly in many remote areas and (2) increased trade in wild animals, both legal and illegal, has meant increased interactions between humans and wild animals, and increased opportunities for disease.

Many of the diseases that humans contract from interacting with wildlife are easily preventable by following certain hygienic steps, particularly during animal handling and food preparation, but these disease prevention practices are not well understood by those who rely most on bushmeat for survival. For that reason, educating and training local populations are a priority for disease prevention and control. At the same time, populations that have daily contact with wild animals are in a good position to contribute to both surveillance and protection. The WCS also encourages countries and local authorities to see the importance of surveillance and to build their own capacity to collect and analyze samples.

The challenge of wild animal surveillance is identifying viruses with epidemic potential before they emerge or spread extensively. Yet, there are approximately 50,000 vertebrate species that each might normally carry 20 unique unknown viruses—translating into a global biodiversity of a million unknown vertebrate viruses, many of which are likely to be zoonotic.

Companion animals are also excellent sentinels for emerging infections that can affect humans, in part because they are much easier to monitor than wild animals. At least 170 million dogs and cats are kept as companion animals in United States, generally in close contact with their owners; companion animal ownership is growing in many developing countries as well. These animals are reservoirs for many diseases, such as leptospirosis, that affect humans, and they may be more sensitive to a fixed pathogen dose. They are also highly susceptible to threats such as bioterrorism and emerging diseases. Purdue University and Banfield® Pet Hospitals have collaborated to sponsor the National Companion Animal Surveillance Program (NCASP), which provides a range of health data with epidemiological significance.

NCASP maintains a database that enables it to respond quickly to an event by tracking illness outbreaks against baseline data. The data from Banfield® Pet Hospitals provide access to standardized, computerized medical records from more than 3.5 million annual veterinary patient visits in 49 states and from all major U.S. population centers. With each animal's unique identifier number, investigators can track disease events by neighborhood, track laboratory results and other health information, and obtain biological specimens when necessary. The kinds of data collected include records of companion animal demographics, exam observations, laboratory findings, medical notes, ailments diagnosed, and treatments.

These data can be integrated with data from other local, state, and national surveillance systems. However, participants noted a long-term investment will be needed to fully integrate animal data sources in the United States alone (including private- and state-run veterinary practices, diagnostic laboratories, and surveys). A further goal would be to integrate veterinary data with human health data, and with international data.

Diseases in Humans—Early Warning Systems

Like surveillance of animals, surveillance of zoonotic diseases that are affecting humans is focused on early warning. There are numerous programs and organizations contributing to this effort as well. One example is the Global Public Health Intelligence Network (GPHIN), originally developed by the Public Health Agency of Canada in collaboration with WHO. GPHIN is an automated, web-based data mining system to track and filter news reports of outbreaks from around the world. Subscribers include governments as well as nongovernmental organizations and agencies. The GPHIN network monitors news sources in at least seven languages around the world, and monitoring continues 24 hours a day, 7 days a week. Sources include websites, news wires, and other Internet-based information outlets. GPHIN tracks not only outbreaks of disease, but also contamination of food and water; natural disasters; and chemical or biological exposures caused by terrorism or accidents.

Once the surveillance provided by GPHIN has identified an outbreak, the Global Outbreak Alert and Response Network (GOARN) is activated. Also developed under the auspices of WHO, GOARN is a network of 200 partners, institutions, and organizations worldwide that provide coordination, expertise, and technical support to detect and respond to disease outbreaks. GOARN provides technical support to affected populations, investigates and characterizes disease events, and provides other support to resource-challenged nations.

Another system that tracks disease outbreak information around the world is ProMED-mail, a project of the International Society for Infectious Diseases that provides means of quickly disseminating infectious disease outbreak information. It has more than 40,000 subscribers in 160 countries who are the source of much of the data handled by the system. Volunteer rapporteurs and moderators with expertise in 22 areas search the Internet for information about emerging diseases, including official sources, then verify and disseminate it for volunteer subject-matter expert analysis to determine the need for further action within their system, including a posting to their subscribers.

Another disease surveillance system has been developed by the U.S. Department of Defense (DoD) to monitor and respond to infectious diseases that are a threat to military personnel or their families, reduce medical readiness, or present a risk to national security. The Global Emerging Infections Surveillance and Response System (GEIS) was established by a Presidential directive in 1996, in response to growing recognition of the potential threat infectious diseases pose to the military. DoD-GEIS focuses on respiratory illnesses, febrile illnesses, enteric disease, antimicrobial resistance, and sexually transmitted infections, but it also has a pilot program attempting to integrate both human and animal disease surveillance and information sharing.

ArboNET, a U.S. national surveillance system for arboviral diseases (those transmitted by hemophagic arthropods, e.g., mosquitoes and ticks) maintained by the Centers for Disease Control and Prevention (CDC) was developed in 1999 in response to the emergence of West Nile virus in the United States, and was expanded to cover other arboviral diseases in 2003. ArboNET is a comprehensive system that collects six types of data. Sources include health care providers, veterinarians, and commercial laboratories, who report information to a state or local health department. With these data it is possible to broadly see where disease reservoirs, transmission, and vectors are occurring and migrating. Collaborations among CDC, state and local health departments, and blood services agencies, as well as rapid turnaround, allow for quick response.

However, ArboNET provides only minimal clinical and laboratory data, and cannot confirm that patients meet case definitions. Moreover, potentially long delays between the time that cases occur and the time they are reported are beyond the network's control. Some of the data are not reportable by law, and the variable results may not be representative. Finally, this system works differently than those used for other notifiable diseases, which limits the potential for coordination.

The Emerging Infections Network (EIN), another project of the Infectious Diseases Society of America, is a network of infectious disease specialists who contribute clinical data to assist CDC in identifying emerging diseases. It began with the goal of establishing a permanent system to allow rapid communication about symptoms that clinicians see, how they are responding, and so forth—both among clinicians and with CDC. The goal was not to replicate systems already in place, but to fill gaps. EIN now has approximately 1,200 members who are pediatricians or internists throughout the country, as well as approximately 130 public health officials.

CAPACITY

The participants' examination of current surveillance systems made it clear that capacity is a primary issue in many parts of the world, and their look at several existing structures illustrates the need.

For example, laboratory standards have been established to protect humans, animals, and the environment. Both WHO and the U.S. government have published standards for humans and the environment, while OIE has developed standards for protecting animals and the environment. Among the key elements spelled out in laboratory standards are four containment or biosafety levels (BSL-1 through BSL-4) for handling pathogens. Many of the procedures for higher levels of biosafety are difficult for resource-constrained countries to establish or maintain. Specifically, BSL-2 laboratories are available and widely used, but few, if any, laboratories meet all the requirements for BSL-3 in resource-constrained countries. This means that many countries lack the capacity for virus isolation for influenza while BSL-4 laboratories are available in only a few of the wealthiest nations. High equipment costs are a principal impediment to setting up a laboratory that meets higher levels of containment.

Data from a 2007 FAO survey of 20 Western and Central African countries showed that most of them have adequate laboratory infrastructures and staff who have received basic training, though the quality of the facilities and the diagnostic performance are highly variable. Equipment is available, though in some cases no personnel are available to maintain it. On the other hand, two of the countries surveyed have no facilities, and an additional three have facilities that were not functioning at the time of the survey. Many laboratories need renovations or upgrades, and many staff need customized training on specific issues. Laboratories surveyed also lack reagents because of cost, lack of local suppliers, or rapid deterioration in extreme environmental conditions.

OIE Reference Laboratories—one or more laboratories designated as centers of expertise on one of the animal or human diseases that OIE monitors—play an important role in disease surveillance and response. Altogether, OIE has established a network of more than 160 Reference Laboratories in 32 countries, covering 95 diseases. These labs can assist countries in the diagnosis of index cases, confirm laboratory results, provide training on diagnostic techniques, and provide other kinds of support in the management and control of disease.

Tanzania is a resource-constrained country that faces challenges in establishing and sustaining laboratories, problems that many resource-challenged countries similarly encounter, and it is a critical country from an integrated human and animal health perspective. One third of the country is national park land, and it has great climatic diversity as well as extensive interaction among livestock, wildlife, and humans. Tanzania has a long tradition of collaborating with international partners for its laboratories, but economic fluctuations and changing levels of funding have resulted in significant cutbacks to the laboratory system. Today, Tanzania's new central veterinary laboratory has the capacity to deal with many emerging zoonotic and epizootic viruses and to diagnose a range of diseases. The country also has laboratories with traditional veterinary capacity.

But Tanzania's laboratories also lack sufficient equipment and trained personnel, and have not been able to fully comply with biosecurity and biosafety guidelines. All of these problems could be addressed with greater resources, but the government must address other challenges—such as hunger, widespread poverty, and need for educational improvements—in a very constrained economic climate. Despite the importance of animals and animal health to the macro economy (e.g., eco-tourism) and to individual livelihoods, these laboratories remain dependent on foreign donors.

The U.S. CDC has focused significant attention on building laboratory and epidemiological capacity in strategic locations that can serve regions with high threats but are low with resources. As part of a global strategy to monitor and respond to emerging infectious threats at the local, regional, and global levels, CDC has established the International Emerging Infections Program, which has five laboratories, located in China, Egypt, Guatemala, Kenya, and Thailand. The Kenya Medical Research Institute (KEMRI) laboratory in Nairobi was designed to establish diagnostic and epidemiological capacity, and it also conducts public health research and contributes to intervention strategies for high-impact diseases. The cornerstones of the program are surveillance, rapid response to outbreaks, training and building local capacity, and applied research. Its primary surveillance objectives are to identify and characterize emerging pathogens for human and select animal diseases, establish public health priorities in rural and urban settings, and provide a platform to evaluate the impact of interventions that have targeted high-priority diseases.

KEMRI has a national reporting system that uses integrated disease surveillance and response, and also conducts sentinel surveillance in hospitals and refugee camps. To work around the lack of computer capacity in remote regions, it has also been promoting the use of cell phones and text messaging to collect disease rumors for investigation as more countries invest in cell phone technology. Through its surveillance program, KEMRI hopes to understand the incidence and prevalence of zoonotic and epizootic diseases in coexisting human and animal populations, the risk factors for humans and animals, and the potential of animal sentinels to provide early warning.

Asia is another region with high population density, low resources, and high incidence of infectious disease. With half of the world's population and more than three-quarters of the world's poultry living in South Asia, policies that work across political borders are of paramount importance in containing diseases there. The sheer population density in India and China places a tremendous burden on their public health systems, and public health for that region is important to the whole world. Asia is considered a disease hotspot because it is particularly fertile ground for zoonotic pathogens to emerge both from wildlife and domesticated animals. Infectious diseases accounted for 25 percent of patient deaths in one of the region's largest hospitals for tropical diseases.

Within the United States, laboratories that provide veterinary diagnostic services are coordinated through the National Animal Health Laboratory Network. This network, created in response to a Department of Homeland Security directive, is designed to coordinate laboratory capacity at the state and federal levels for early detection of, rapid response, and appropriate recovery for animal health emergencies. The network currently includes partnerships with multiple laboratories, universities, and federal agencies.

ISSUES

Integrating resources that are dedicated to human health, animal health, and agricultural safety is a high-priority goal for many observers of this large and loosely linked animal and human disease surveillance network. Workshop participants also saw improved communication and information exchange as a goal, and mentioned that significant progress has been made.

Yet building on the existing system and improving its cohesion and effectiveness would be challenging for several reasons. The sheer volume of information is so great that coordinating all of it may be not only unworkable, but unnecessary. The existing systems were each created to serve a particular purpose; they have different missions and collect different kinds of information. Moreover, even within the United States, no federal agency has jurisdiction over the U.S. systems, and communication among them is imperfect.

Authority for systems around the world is even more dispersed. Within any single country, there are a range of issues and needs, therefore different systems have been developed to meet them. The incentives for sharing information and the potential benefits and risks that different groups must consider are an important part of the picture. Governments or ministers with responsibility for human and animal health, agriculture, or finance may take into account the risk of severe economic disruption, unrest, or other consequences when a disease outbreak is announced, and disease surveillance programs must provide countries and officials with strong incentives (and perhaps protections) to participate.

While there are regulations in areas such as disease management, laboratory work, and species management, many are not followed particularly at the international level. Developing countries are not able to pay for surveillance efforts, and may lack sufficient funds for computers, a reliable working electrical system, and access to the Internet. Thus multilevel communications are a challenge as data are not collected and reported, and information about evidence of disease or health practices is difficult to verify or disseminate. Developing countries may also lack human resource capacity to respond to an actual outbreak.

Consequently, some regions are poorly represented in surveillance systems, which are often hotspot regions with high likelihood of emerging diseases where surveillance is most needed. Many see the need to build capacity for sustainable, long-term surveillance and response as absolutely critical. Emerging infectious diseases are an integral aspect of larger concerns about global climate change and other environmental issues. Nevertheless, there has not been complete buy-in from the international community, and disease surveillance is too easily viewed as an "old-fashioned," smaller-scale activity by governments and other potential funders of surveillance efforts rather than a global public good. One risk of this semi-marginal status is that funding and attention come in the midst of a crisis, not in time for adequate planning, preparation, and protection. The compelling message is that sustained disease surveillance is a basic human and animal health necessity because ongoing interactions among humans, animals, and the environment will inevitably lead to disease emergence or re-emergence, which has the clear potential to disrupt or destabilize societies, trade, economies, and hence, national security. Thus, building an understanding of the importance of and commitment to disease surveillance, and the capacity and resources to comply with existing guidelines, are essential to improving surveillance for emerging infectious diseases of zoonotic origin worldwide.

1

Introduction

Epidemics of infectious diseases have been among the most frightening and disruptive of natural disasters since at least the Middle Ages, when recurring outbreaks of the plague killed millions of people. Researchers in the 19th century discovered that the plague was transmitted to humans by fleas from infected rats. Scientific research has since illuminated the causes of many epidemic diseases and has provided tools to control and in some cases eliminate them; by the middle of the 20th century, many researchers regarded the diseases as a significantly diminished threat. However, in the globally interconnected world of the 21st century, it is clear that the threat of epidemics and pandemics[1] remains a current, and even urgent risk. Publicity associated with the potential for the avian influenza virus to mutate in such a way that it is both easily transmitted from person to person while maintaining extreme virulence has highlighted the broader problem: Conditions around the globe are ripe for the development of epidemics of zoonotic diseases—any disease or infection that is naturally transmissible from vertebrate animals to humans[2]—that have the potential to become pandemic. Unlike other public health threats such as tubercu-

[1]The difference between an epidemic and a pandemic, while not precise, is one of scope, with a pandemic affecting a much larger number of people over a much wider geographic range than an epidemic. An epidemic is defined as "the occurrence in a community or region of an illness [or other health-related event] clearly in excess of normal expectancy." A pandemic has been defined by the Centers for Disease Control and Prevention as "a global disease outbreak" (PandemicFlu.gov, 2008).

[2]"Zoonoses may be bacterial, viral, or parasitic, or may involve unconventional agents" (WHO, 2008c).

losis and malaria, the emergence of these zoonotic diseases represents the potential of rare events with catastrophic consequences, as seen in the HIV epidemic and the 1918 influenza pandemic.

Although news stories tracking the path of cases of H5N1 avian influenza or highly pathogenic avian influenza (HPAI), or describing an outbreak of Ebola in Africa, have captured public attention, they have not always made clear the nature of the threat, the risk of infection, or the tools and structures available to human and animal health authorities to protect the public from infections with these diseases. Human diseases of animal origin—including AIDS, Severe Acute Respiratory Syndrome, HPAI, and Bovine Spongiform Encephalopathy (BSE, causing new variant Creutzfeldt-Jakob disease)—present threats to human health and animal trade. These and several other zoonotic diseases have emerged recently, as patterns of human–animal contact have been changing in noteworthy ways. Intensifying means of food production, more rapid travel and transport of people and animals across borders and continents, changing patterns of land use, and a host of other factors have contributed to conditions that favor the transmission of pathogens that develop from animal populations and then make the jump into human populations. To date, researchers and public health advocates have focused on surveillance[3] as the critical tool for detecting and monitoring outbreaks of zoonotic diseases in human and animal populations, but questions remain as to how to make zoonotic disease surveillance more comprehensive and timely in human and animal populations in order to prevent or minimize the potential for outbreaks to occur in human populations.

CHARGE TO THE COMMITTEE

With the support of the U.S. Agency for International Development, the Institute of Medicine and the National Research Council convened the Committee on Achieving Sustainable Global Capacity for Surveillance and Response to Emerging Diseases of Zoonotic Origin to investigate conditions in which these diseases emerge in human and animal populations, and ways to protect the public from them. The charge to the committee is found in Box 1-1. Members of the committee, whose biographies are included as Appendix A, include experts with a wide array of experience in multiple

[3]The World Health Organization defines surveillance as "the systematic ongoing collection, collation, and analysis of data for public health purposes, and the timely dissemination of public health information for assessment and public health response as necessary," and it may be conducted by institutions of various kinds (WHO, 2008a). These principles would also pertain to animal health surveillance.

BOX 1-1
Statement of Task

The Institute of Medicine and the National Research Council will convene an expert committee to provide consensus advice on the challenge of achieving sustainable global capacity for surveillance and response to emerging diseases of zoonotic origin such as avian influenza. The committee will address the following issues:

1. Review the emergence and spread over the last several decades of a diverse range of agents of zoonotic origin;
2. Summarize what is known about the causes underlying this growing phenomenon, trends in these factors, and the implications for long-term domestic and international development and security;
3. Assess the evolving nature, extent, and risks of animal and human interactions, focusing specifically on recent infectious disease events of international significance, such as H5N1 influenza;
4. Review the historic human and animal health responses to emergent zoonotic diseases along with lessons learned that may be applicable to future threats;
5. Review the current state of global systems for surveillance of zoonotic infections in human and animal populations;
6. Develop conclusions on the balance between emergency response to threats and establishing sustainable global surveillance capacity for early detection, mitigation, and characterization of known and unknown threats;
7. Identify and prioritize for the international context recommendations to strengthen and improve coordination of the human and animal health systems in order to achieve a sustainable and integrated institutional capacity for timely surveillance that could improve prevention of and response to zoonotic diseases across both realms; and
8. Explore options—including policy and regulatory options, such as international agreements—to mitigate and decrease the threat of emerging zoonotic diseases worldwide, and to improve coordination between governments and other relevant international organizations.

disciplines ranging from emerging infectious disease surveillance to veterinary medicine in developing countries to bioinformatics.

ORGANIZATION OF THE WORKSHOP SUMMARY

The committee held a 2-day workshop in June 2008 to begin its exploration of those issues, as summarized in this document. The workshop agenda and a list of participants are included in Appendixes B and C, respectively. The workshop provided an overview of the patterns observed in studies of zoonotic diseases and of the likely future trends in the emergence of these diseases, described in Chapter 2, and then addressed several currently active surveillance systems for detecting potential zoonotic diseases in animal populations, which are described in Chapter 3. Chapter 4 discusses early warning systems for identifying emerging zoonotic diseases in humans, and Chapter 5 describes current laboratory and epidemiological capacity in several countries and laboratories. Chapter 6 summarizes the wide-ranging discussion of these issues at the end of the workshop.

The purpose of the workshop was to gather information to help the committee address issues in the Statement of Task (Box 1-1). The information provided in the workshop summary is directly derived from short presentations and remarks made by workshop participants. The document has been shaped to produce a readable narrative and does not necessarily follow the order of the presentations at the workshop. With the exception of brief background statements, this summary is limited to what was discussed at the meeting and the PowerPoint presentations used by the speakers, whose biographies are included in Appendix D. The materials in this document do not necessarily represent the view of the committee, the Institute of Medicine, or the National Research Council. The committee will, however, draw on the information provided in this workshop summary to develop a consensus report with recommendations that will address the enumerated items in the Statement of Task. The committee plans to issue its consensus report and recommendations in summer 2009.

2

The Convergence of Forces Responsible for Zoonoses

Marguerite Pappaioanou, one of the co-chairs of the Committee, opened the meeting, by welcoming committee members, invited speakers, and other guests. The workshop participants were from Africa, Asia, Europe, Latin America, and the United States and brought a wide spectrum of expertise, experience, and background to the discussions. Pappaioanou reviewed the purpose of the workshop, which was to obtain information for the committee to consider in its deliberations in meeting the committee's charge described in Chapter 1.

Sponsor representative Dennis Carroll of the U.S. Agency for International Development used the public and political responses to growing recognition of the potential threat posed by highly pathogenic avian influenza (HPAI) virus H5N1, which he described as "one part sensation and one part puzzlement," to illustrate the issues surrounding surveillance. The sensation, he explained, was the looming specter of a pandemic and the puzzlement was "Is it really going to happen?" In response, he noted, the U.S. Congress has significantly increased its support for federal government efforts both to preempt a pandemic and to prepare for one.

Carroll explained that the public attention to H5N1 was important for two reasons. First, the risk is undeniable. This particular virus exists and is in circulation. It has the potential to mutate into a pathogen that can spread rapidly among humans and have a high fatality rate. The influenza epidemic of 1918 and other more recent epidemics illustrate the significant threat of diseases to human life and health. However, Carroll noted, the vastly increased mobility of today's human population is one factor that could make an H5N1 epidemic a more sweeping public health emergency than the world has ever faced.

Second, and perhaps more important, is the fact that "H5N1 is a wake-up call." The H5N1 threat raises questions of how the virus has had the opportunity to spread globally as quickly as it has, how novel this threat may be, and what potential exists for other zoonotic diseases to emerge in the same way. Carroll presented a list of infectious diseases and pathogens that have emerged since 1973, shown in Figure 2-1, to demonstrate the scope of the potential threat posed by zoonotic diseases.

These newly identified diseases have emerged primarily as a result of significant changes in human activity, including population growth, increased demand for animal protein, increased wealth and rapid travel by people and their animals, changes to the environment, and human encroachment on farm land and previously undisturbed wildlife habitats. Other pathogens could follow a similar pathway. Thus, Carroll explained, *it is very important for policy makers to understand the kind of surveillance and action that will be needed to protect the public and the benefits they provide, and it is up to the scientific and public health community to make this case*. He suggested that the current status of global surveillance systems

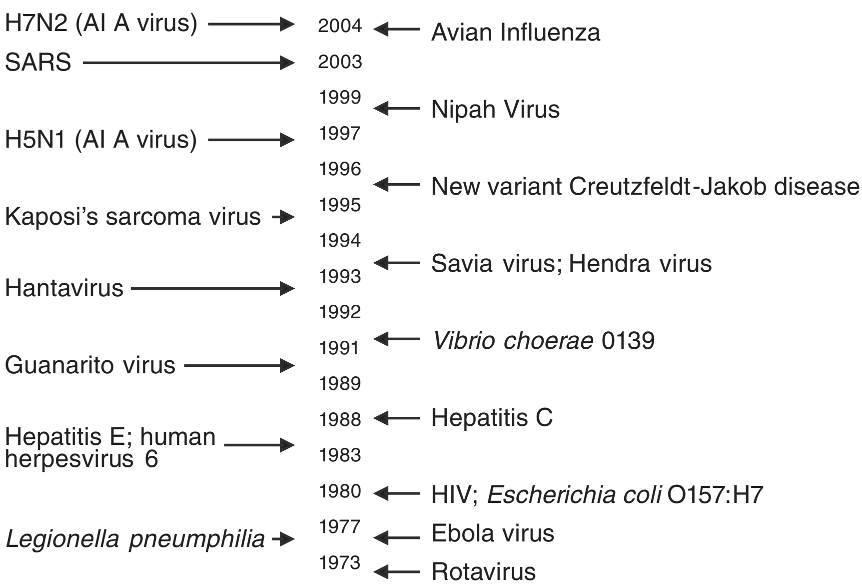

FIGURE 2-1 Infectious diseases and pathogens newly identified from 1973–2004.
SOURCE: Carroll (2008).

in both human and animal populations and the strength of the veterinary health systems are insufficient to preempt a pandemic or to handle an emerging one. "What's needed," in his view, "is a new paradigm, a means for tapping expertise from all sectors, and thinking in a broadly preventive way, to reform animal husbandry and alter the ways people and industries interact with domestic animals and wildlife." The interactions among many factors—from rapid mass transportation to increased consumption of animal protein to wilderness encroachment—have intensified the threat posed by zoonotic diseases. The global community involved with disease surveillance and coordination will be needed to confront this challenge.

HOW ZOONOSES DEVELOP

Tracee Treadwell of the Centers for Disease Control and Prevention (CDC) provided a detailed look at the interacting forces that lie behind the emergence of new zoonoses and the reemergence of existing ones. Not long ago, researchers thought infectious diseases were a problem of the past. Figure 2-2 shows that mortality rates from infectious disease in the

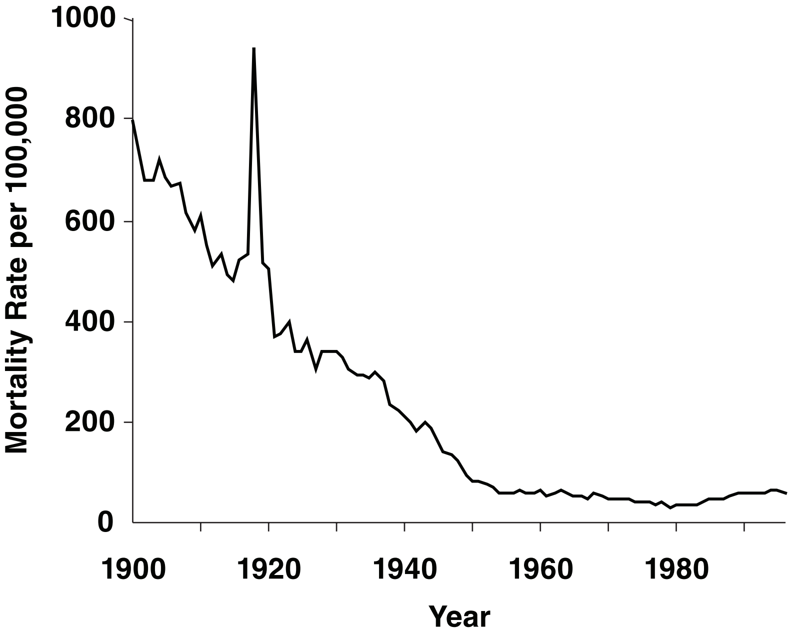

FIGURE 2-2 Infectious disease mortality rate in the United States, 1900–1996.
SOURCE: Armstrong et al. (1999). Reprinted with permission of *JAMA*.

United States have declined dramatically since 1900. As recently as 1976, Treadwell noted, Lewis Thomas, then Dean of the Yale Medical School, remarked that there are "no new diseases to be discovered."

Although the United States has not recently experienced anything approaching the sharp spike in the graph representing deaths caused by the influenza pandemic in 1918, a number of significant epidemics caused by other infectious diseases with the potential to spread globally have occurred in the past 15 years. Treadwell explained that most of the epidemics in the past 15 years listed in Table 2-1 were either zoonotic in origin or likely to be proven as such once ongoing research is complete.

This upsurge in the emergence of infectious diseases, as listed in Table 2-1, relates to noteworthy changes in the human population and human behaviors. As noted by Jones and colleagues (2008), many places around the world can be described as "hotspots" of emerging infectious disease. These include areas of high biodiversity and high human population density, which may be changing the human–animal–ecosystem interface with increasingly frequent and complex contact. Treadwell provided a detailed look at the interactions among humans, animal, and the environment—and the ways these interactions affect the development of pathogens—to set the context for discussion of how to prevent, monitor, and respond to developing diseases most effectively.

TABLE 2-1 Select Significant Outbreaks of Emerging Diseases (1993–2007)

Date	Disease/Pathogen (location or agricultural/food crop affected if specified)
2007	Progressive inflammatory neuropathy
2006	*E. coli* (spinach, lettuce)
2005	H5N1 influenza
2004	Marburg virus
2003	Severe Acute Respiratory Syndrome (SARS)
2002	Noroviruses
2001	Anthrax
2000	Rift Valley fever
1999	West Nile virus
1998	Nipah virus (Malaysia)
1997	H5N1 influenza (Hong Kong)
1996	BSE and new variant Creutzfeldt-Jakob disease (United Kingdom)
1995	Ebola virus (Zaire)
1994	Plague (India)
1993	Hantavirus

SOURCE: Treadwell (2008).

HUMAN FACTORS

The human factors that influence the development of pathogens include genetic and biological factors; social, political, and economic factors; human health, behavior, and attitudes; and activities such as transport and trade. In each of these areas, the human population has changed dramatically in recent years. Perhaps the most obvious change has been the growth in human population. The world's population was less than 3.5 billion in 1950, but reached approximately 6.5 billion in 2005 and is projected to top 11 billion by 2100 (Kern, 2008). As demographer Thomas Malthus predicted 200 years ago in his treatise *An Essay on the Principle of Population*, population expansion has presented significantly increased challenges in sustaining the food supply. The most significant challenges have included the increased consumption of animal protein and products, and the changing practices of animal husbandry and production. Figure 2-3 shows the increase in consumption in the developed and developing parts of the world since 1983.

In 2007, Treadwell observed, more than 21 billion animals were produced, and demand for animal protein is projected to grow by 50 percent by 2020. To meet this demand, agricultural businesses have developed new husbandry practices by increasing production of food animals (par-

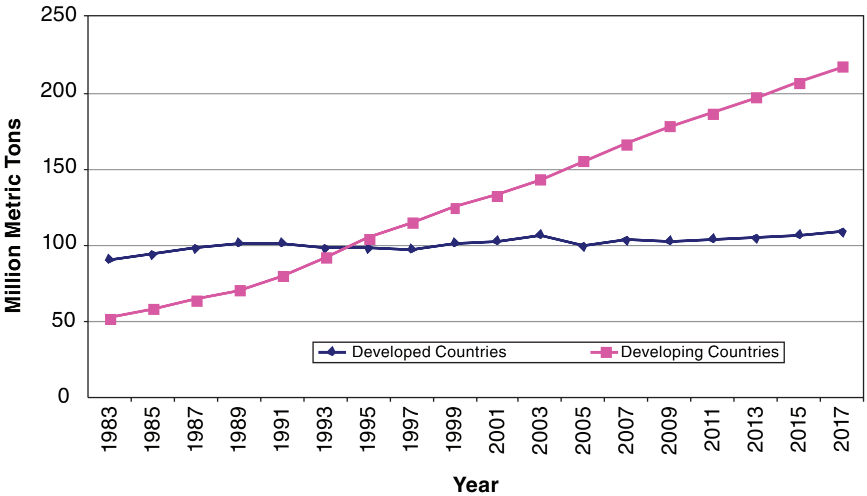

FIGURE 2-3 World meat consumption projections from 1983–2017.
SOURCE: Created with data from Organisation for Economic Co-operation and Development/Food and Agriculture Organization of the United Nations (2008).

ticularly poultry, swine, and cattle) and confining these large numbers of animals in concentrated animal feed operations, and resource-poor farmers are raising these animals on small crop-livestock farms[1] that are typically land-constrained. Treadwell mentioned that there are approximately 800 million worldwide poor who own livestock; of those poor who are livestock keepers, more than 70 percent and 95 percent in Africa and Asia, respectively, depend on livestock for their livelihoods (Ayalew et al., 2005; Devendra et al., 2005). These farmers, Treadwell said, have few resources to vaccinate or protect their animals against parasites and other pathogens, creating a situation where large numbers of confined animals are more susceptible to disease. Demand for animal protein has also meant an increase in consumption of bushmeat,[2] as well as illegal smuggling of bushmeat and other animal products. Large quantities of animal waste, high-density animal production, and increased interaction with infected bush animals have all played a role in the transmission of pathogens. Chapter 3 provides a detailed look at how this occurs with specific species.

Technological advances have also affected the development of pathogens. Treadwell noted that a billion people cross international borders every year—or 25 persons per second. They are also transporting goods, including meat and other food, on a vast scale, which means that animals and pathogens can travel farther and faster than ever before. Treadwell pointed out that the economic value of global trade in 2006 was $12 trillion, and that six million documented food shipments enter the United States every year, though only a fraction of those are inspected. Significantly more are probably imported illegally, she added.

The largest proportion of human population growth is taking place in the least developed countries, where poverty rates are the highest. As the human population has grown, it has also shifted to dwelling in urban areas. Treadwell reported that by 2030, 60 percent of the world's population is expected to live in cities. By 2015 there will be 22 megacities (metropolitan areas characterized by extremely high density and populations of

[1]Animals raised in a mixed crop-livestock system have multiple purposes including providing milk, meat, fiber, hides, manure for soil amendment, traction, and as a means of accumulating assets (Devendra et al., 2005).

[2]"Bushmeat" is a term commonly used for meat of terrestrial wild animals, killed for subsistence or commercial purposes throughout the humid tropics of the Americas, Asia, Australia, and Africa. The types of wild animals hunted for meat affect a broad range of species (some endangered or threatened), including elephants, ungulates, apes and other primates, rodents, and birds. The Association of Zoos and Aquariums notes: "Bushmeat hunting and meat preparation may expose people to emerging infectious diseases, such as Ebola and SIV (simian immunodeficiency virus, which as been identified as the origin of HIV/AIDS). Bushmeat is a short-term 'band-aid' which cannot ultimately resolve the long-term plight driving it: lack of food security, scarcity of jobs, and growing human population pressures" (Eves et al., 2002).

more than 10 million people) in the world, 17 of which will be located in developing countries. More than three billion people already live in urban areas (UNPD, 2007); and among urban dwellers in developing nations, 78 percent live in poverty. Urban slum dwellers in developing countries may have significant contact with both domestic and wild animals, and high concentrations of both people and animals provide prime conditions for the emergence of zoonoses.

ENVIRONMENTAL FACTORS

Pathogens are also affected by environmental changes, most of which are widely viewed as traceable to human activity. Changes in temperature and humidity patterns, drought and desertification, novel weather patterns, and other changes have affected the geographic ranges in which species can thrive and have altered lifecycles and microclimates.[3] These changed patterns are expected to affect the prevalence, competency, distribution, and movements of vector-borne human and animal pathogens and their vectors (Harvell et al., 2002; Sutherst, 2004).

Treadwell spoke of how changes in climate and weather patterns can affect how people grow and harvest food, fiber, and fuel, as well as the habitats of both animals and humans. Both she and Carroll acknowledged that with pollution and the greater demand for natural resources, people and livestock are encroaching more and more on wild lands and into new environments that expose them to novel pathogens through increased exposure to previously isolated wildlife. The health of the animals may also be impacted by changes on the landscape through altered stress physiology, metabolism (directly through temperature changes, indirectly through diet changes), and inbreeding as populations decline or are isolated. As habitat loss and human encroachment continue, wildlife animals will need to change how they move to accommodate their new surroundings. For example, suburban sprawl disrupts the migration pathways and habitats of wildlife, so they must turn to backyards and parks—previously the animals' habitat—for food. This leads to increased contact between humans and wildlife and greater opportunities for disease transmission.

Political unrest was also identified by Treadwell as being able to affect the environment as well as plant and animal life. She provided examples of war, complex humanitarian emergencies, disasters related to or exacerbated by the built environment (e.g., flooding associated with the breakage of a dam), or bioterrorism as all potentially having lasting impacts on the envi-

[3]Data from the Intergovernmental Panel on Climate Change leave little room for doubt that the world is getting warmer (IPCC, 2007).

ronment. Those changes can affect the types of plant food available in an area and, in turn, affecting the balance between predators and prey.

ANIMAL FACTORS

Finally, the growing human population, changes in human activity, and changes in the environment can affect animal health and behavior. Developed nations in particular have seen a considerable reduction in the availability of land for both domestic and wild animals. Animals may behave differently in changed habitats or as they adapt to a new geographic range. Their health and feeding preferences may be altered, and other factors may affect the balance within an ecosystem. Changes in animal population balances (for instance, predator/prey relationships or vector control mechanisms) can impact disease transmission risk, and an overabundance of some animals (such as deer in the United States) and underabundance of others (such as amphibian loss and mosquito control) both also impact disease risk. Animal health and reproductive capacity may be compromised by pollution exposure; animals may be exposed to new disease-causing agents as they move or come into contact with humans and other species; and animals' acquired resistance to disease may be reduced by fast-paced changes in their environment.

CHALLENGES

"If you put all of these things together, what do you have? You have an absolute melting pot for disease emergence, reemergence, and persistence," Treadwell explained. Figure 2-4 illustrates how these various developments interact to promote the emergence of new diseases, and the reemergence and persistence of existing ones.

These interactions provide ideal circumstances for pathogens that once affected only animals to evolve into agents that can cause primary infection in humans. Examples include rabies, transmitted through direct animal–human contact, and Ebola, which can cause limited outbreaks through animal–human contact and then human–human contact. The next evolutionary stage is to an agent that can cause a sustained outbreak via animal–human or human–human contact (e.g., Chagus or influenza A). Eventually, given the right circumstances, a pathogen may develop into an agent transmitted only among humans (e.g., HIV). These stages are illustrated in Figure 2-5. This picture of pathogen development illustrates the changing and complicated interactions among animals and humans as the critical factor in the evolution of pathogens.

The challenge for controlling emerging diseases with such complex etiology is that no single agency has either the mandate or the capacity

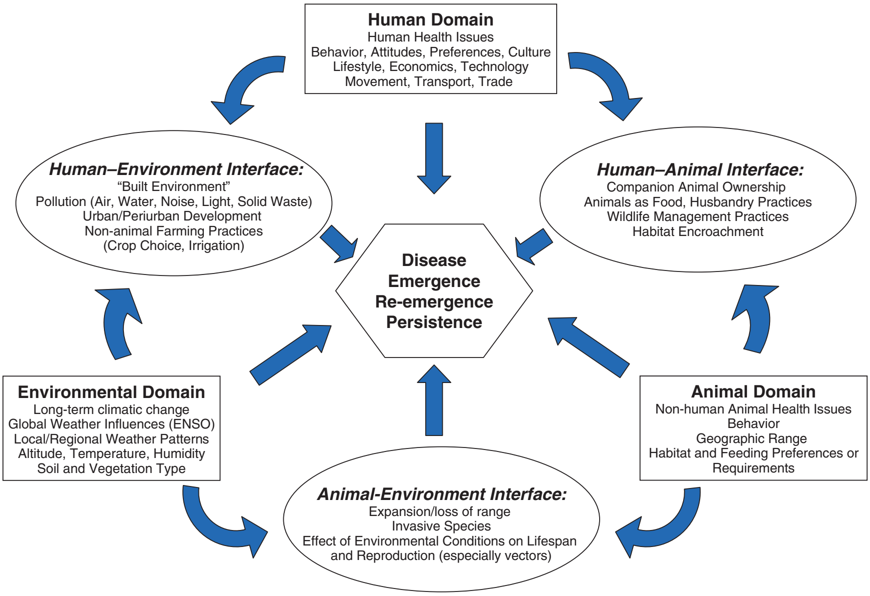

FIGURE 2-4 Human–animal–ecosystem domain interface.
SOURCE: Treadwell (2008).

to address the entire landscape of zoonotic disease, Treadwell explained. Globally, the World Health Organization (WHO), the World Organization for Animal Health (OIE[4]), and the Food and Agriculture Organization of the United Nations (FAO) each play a role, and have been working to better coordinate their activities. Within the United States, the responsibility is spread across many government departments and programs, each with its own focus and interests. Table 2-2 highlights the principal focus of the seven U.S. government agencies that play a role in zoonotic disease control.

The Centers for Epidemiology and Animal Health at the U.S. Department of Agriculture (USDA) Animal and Plant Health Inspection Service are mandated to provide timely information and technical services on foreign animal diseases and agriculturally related animal diseases. While not explicitly mandated, their work and the work of many other agencies listed in Table 2-2 crosses over into the realm of zoonotic diseases. Treadwell said the National Center for Zoonotic, Vector-borne, and Enteric Diseases at CDC has been working closely with colleagues across various agencies (as listed in Table 2-2) that are concerned about controlling zoonotic diseases.

[4]Office International des Epizooties, commonly known as the World Organization for Animal Health.

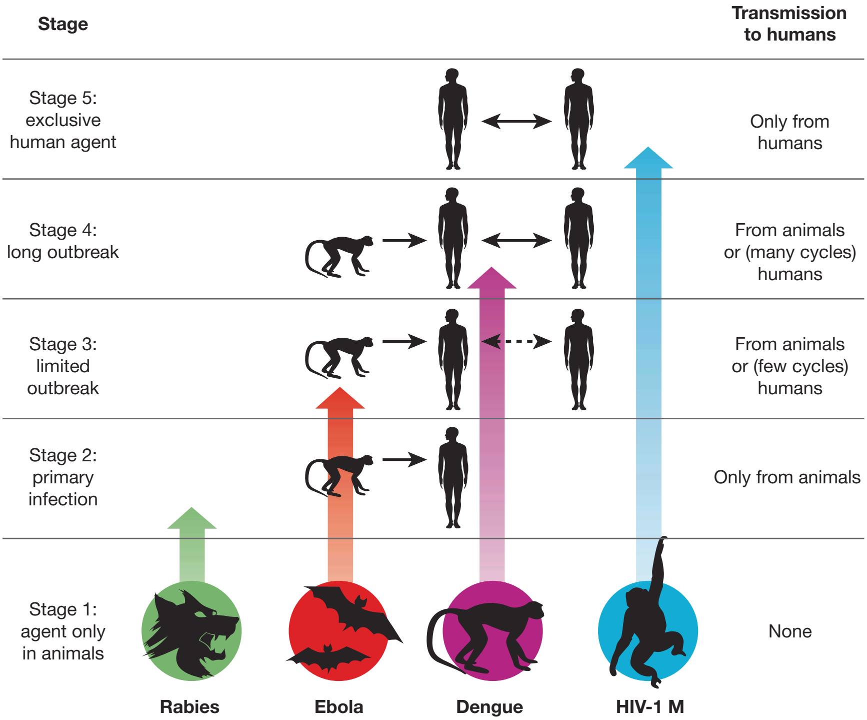

FIGURE 2-5 Five stages through which pathogens of animals evolve to cause diseases confined to humans.
SOURCE: Wolfe et al. (2007). Reprinted with permission of *Nature*.

Another CDC effort, called BioPHusion, analyzes data such as numbers of hospital visits and reports of related conditions in order to develop policies and procedures targeted to specific risks. MicrobeNet, another CDC resource, is a curated, non-redundant sequence reference database that provides both phenotypic and genotypic information on an expanding number of ribosomal gene sequences.

These examples are just a few of the efforts to improve disease prevention and surveillance to emerging pathogens, more of which are discussed in Chapters 3 and 4. But Treadwell enumerated some challenges that face policy makers, researchers, and others concerned about preventing and responding to emerging zoonoses. The challenges include:

TABLE 2-2 U.S. Government Agencies Concerned with Zoonotic Disease Control

Agency	Focal Orientation
Agency for International Development (Department of State)	International development—increasing involvement in improving capacity to detect and respond to zoonoses, primarily avian influenza
Department of Agriculture	Animal health—focus on economic threat to U.S. agriculture and quality of animal therapies
Department of Commerce	Marine mammals—protecting, conserving, and managing marine species
Department of Defense	Force protection—general health threat to soldiers (potential bioweapon threat)
Department of Health and Human Services	Human health—minimization/mitigation of public health threat of zoonoses
Department of Homeland Security	Bioterrorism—preventing/controlling access to potential biothreats
Department of the Interior	Wildlife—protecting wildlife populations and inspecting wildlife shipments imported to the United States

SOURCES: NRC (2005); Treadwell (2008).

- The roles that governments, educational institutions, and the private sector should play are not entirely clear, which leaves the possibility of gaps and overlaps.
- The health of humans, animals, and the environment all exist on a continuum, so integrated strategies are needed that consider each factor.
- Tremendous health disparities exist among human (and animal) populations, which present pressing moral and ethical concerns that need to be addressed.
- Because these diseases can show up in diverse communities, diverse tools and strategies are needed to detect and respond effectively to future diseases.
- The potential impact of an outbreak could be unprecedented; and thus call for an unprecedented response. The impact could go far beyond tragic health outcomes and have profound effects on economies.

Treadwell closed with the observation that the factors that allow for a microbial storm are already well entrenched. Consequently, the biggest challenge may be for those in a position to understand the risk to effectively promote a "one world–one health"™ way of thinking, which will provide the grounding for necessary shifts in habitual or traditional ways of thinking and acting.[5]

Participants in a panel discussion were asked to consider the existing configuration of institutions concerned with zoonotic disease, and how those institutions and their relationships might need to change. They offered a variety of observations on the situation Treadwell had described. Committee co-chair Gerald Keusch opened the discussion with the observation that although a global surveillance system is the critical goal, international health organizations "do not exist in a vacuum" and they must interact with other institutions in the public and private sectors—at the national and international levels—as well as the academic community. They are critical components of a civil society, but the committee wants to consider carefully whether the current configuration of institutions is the most effective one for addressing the problem of zoonotic diseases.

Discussant Nancy Cox offered lessons that CDC had learned from HPAI. She noted that recent outbreaks had provided examples of effective reporting, but that follow-up investigation—of how many infections have actually occurred, for example—was less effective. CDC received funding to implement systematic surveillance, she explained, which enabled the agency to more fully view the complexity of the undertaking. Not only did CDC have to navigate relationships with the USDA, the livestock industry, and veterinarians at the state level and in diagnostic laboratories, but CDC also found a need to develop specific standard operating procedures to ensure that all concerned would have the opportunity to prepare and respond, but that the public would not be needlessly frightened away from perfectly safe activities.

The tracing of H5N1 and Severe Acute Respiratory Syndrome (SARS) viruses also illustrates the kinds of mechanisms that are most effective. In Vietnam, Cox explained, close cooperation between the human and animal health sectors made it possible to trace bird viruses and follow the pathway of disease spread. Much of the work was made possible by genetic research indicating that the source of the viruses was in southern China.

One vital component in cooperation is transparency, Cox said. Because viruses do not recognize political borders, sharing information about infections and measures to control them—such as culling large numbers of birds, or addressing entrenched cultural practices that increase risks including the

[5]The American Veterinary Medical Association defines the term "one world–one health™" as "the collaborative efforts of multiple disciplines working locally, nationally, and globally to attain optimal health for people, animals, and our environment" (AVMA, 2008). The concept was first proposed by veterinary epidemiologist and parasitologist Dr. Calvin W. Schwabe, who used the term "one medicine" in the 1960s to capture the vital importance of considering medical and veterinary issues jointly in the study of zoonotic diseases (Schwabe, 1984; Kahn et al., 2008). "One world–one health" is a trademark of the Wildlife Conservation Society.

preference to purchase live poultry—are absolutely necessary to identify and control emerging viruses. She noted that this transparency is critical because H5N1 is only the best known of many potentially lethal avian influenza viruses. The challenge in developing the partnerships that make transparency possible is "finding the resources to do the things that we all know need to be done," Cox said.

Stéphane de La Rocque of FAO echoed the importance of the one world–one health™ approach, noting that FAO responded to high-profile diseases such as SARS, West Nile virus, and Rift Valley fever by actively collaborating with multiple government agencies and others. Nevertheless, those who run surveillance systems are always trying to catch up with new manifestations that need to be tracked. "For many diseases, you will see no clinical sign in animals if you do not have your active surveillance system, if you don't go in the field, if you don't go to sample, or if you don't have a good diagnostic chain," he explained. He believes the answer is strong support for sustainable surveillance, including diagnostic capacity. The challenge is what he described as an "erosion of expertise." In many cases, as new or reemerging diseases appear—such as Bluetongue that is reemerging in Europe via a new vector—not enough researchers with relevant expertise are available where and when they are needed to identify the ecology of the disease and to work in the field.

This point was reinforced by Marlo Libel, of WHO's Pan American Health Organization (PAHO), who explained that a key challenge for the organization has been to work with individual countries to identify and characterize risks in order to mobilize the necessary resources. Libel noted that cooperation has increased among the health services in Latin American countries, but added that changes in ecosystems have created new high-risk areas that favor the development of new pathogens and the reemergence of existing ones, such as yellow fever. Surveillance that can detect epizootic diseases (epidemics in animal populations) in domestic and wildlife populations early on is critical to protecting the human population, he asserted.

In Latin America, Libel observed, more laboratories need the appropriate quality control and biosafety capabilities to deal with samples safely and to test them quickly. Furthermore, he sees a need for more standard operating procedures for communicating and coordinating among the research centers, universities, and other institutions. WHO, through PAHO, is working with institutions in this region to build capacity for the necessary risk assessment, he said, but improving communication about the risks requires engaging in the political contexts involved, and making sure that decision makers have evidence-based information they need to make assessments and provide resources. An additional policy challenge, which has been a focus for FAO, OIE, and WHO, is to fine-tune the balance of investments in the surveillance and early warning systems with those required to make sure countries and institutions can respond adequately to the risks those systems identify.

Alejandro Thiermann of OIE also focused on the sustainability of surveillance systems. He noted that OIE was founded in the 1920s to collect and share information on animal health in order to prevent disease dissemination and to promote trade. That goal remains the mission of the organization's 172 member nations, but Thiermann reminded the group that each nation has unique circumstances and pressures, as well as different veterinary infrastructures. Moreover, many of the problems under discussion are perhaps likeliest to develop in areas of the world with the weakest veterinary infrastructures. Thus the immediate challenge is for the world to support disease monitoring in those areas that need it, while *the longer term challenge is to develop greater political will to support a truly global approach to surveillance*. Many of these issues were raised again in subsequent discussions.

3

Current Surveillance Systems for Detecting Zoonoses in Animals

After exploring why surveillance is critically important, and the issues and challenges it poses, workshop participants discussed the existing surveillance systems throughout the world. Surveillance, which has been defined by the World Health Organization (WHO) as "the systematic ongoing collection, collation, and analysis of data for public health purposes, and the timely dissemination of public health information for assessment and public health response as necessary," may be conducted by institutions of various kinds (WHO, 2008a). These principles would also pertain to animal health surveillance. The presentations explored the current state of surveillance efforts for zoonotic diseases, with an eye to identifying gaps in their effectiveness and challenges for improving them. The discussion addressed several existing domestic and international surveillance systems and covered a variety of animal populations (see Appendix D for a table that provides a synthesis of these systems).

A new zoonotic disease could theoretically emerge from any animal population around the world, but some animal populations are more likely than others to serve as a reservoir for diseases that could threaten humans. Thus, much of the current disease surveillance apparatus has developed in a somewhat ad hoc way, in response to growing awareness of specific kinds of threats.

THE GLOBAL EARLY WARNING SYSTEM

The review of animal surveillance systems began with a discussion of the Global Early Warning System (GLEWS), one of several current efforts to coordinate and build on existing surveillance networks. GLEWS, described by Stéphane de La Rocque of the Food and Agricultural Organization of the United Nations (FAO), is a system for pooling information collected by FAO, the World Organization for Animal Health (OIE), and WHO. GLEWS was devised to improve the tracking of significant diseases among animals in high-risk areas, and to provide data analysis and early warnings to the international community. In place for only a year as of the June 2008 workshop, GLEWS was also designed to ensure that data collection efforts are shared among institutions and agencies, rather than duplicated. The program's primary functions are disease tracking, information sharing, verification of threats, disease analysis, and support for urgent response to outbreaks.

The GLEWS team has three working groups, each focused on a different aspect of the task: disease tracking, analysis and risk assessment, and response. The GLEWS team follows information available through a variety of channels to track rumors about diseases. They are currently monitoring highly pathogenic avian influenza (HPAI), Rift Valley fever, and foot-and-mouth disease; they hope to expand their operations to cover additional zoonotic and other diseases, such as African Swine Fever, rinderpest, and rabies. The GLEWS team mines a variety of media (such as the ProMED global electronic reporting system for outbreaks, the Global Public Health Intelligence Network, and AI-watch) as well as country reports and other data collected by FAO, and information from the European Commission, OIE, and agencies of the United Nations (including WHO, which has representatives in nearly every country in the world). The event tracking system includes a record listing each initial report, follow-up, actions taken, requests for assistance, and changes in status of the event.

In collaboration with a variety of other centers with specific expertise, the GLEWS team analyzes the data collected in order to provide public health warnings in the form of long- and short-term forecasts. Based on this analysis, the GLEWS team puts out disease alerts, and also has the capacity to develop recommendations for coordinated responses to animal health emergencies and provide assistance to local authorities.

The basic premise of GLEWS is that the team will never leave an event open; that is, they will track every rumor until they can either establish that it is not a risk or identify a clear warning that needs to be addressed and made public. Among the challenges for the GLEWS program, de La Rocque explained, is that of confidentiality. It is not uncommon for government officials to be reluctant to release information about a potential disease outbreak for fear of trade disruption or other reasons, and OIE is similarly unable to disseminate information unless it has been officially sent by the chief veterinary officer of their member governments. To address this problem, GLEWS staff have established three levels of confidentiality to verify data they uncover from informal and official country sources. The top level of confidentiality classifies information sharing only among the three coordinating organizations (FAO, OIE, and WHO); the second level allows information to be disseminated with their collaborating centers; and the last level is for public dissemination. Establishing these levels of confidentiality allows information to be shared more readily between GLEWS partners without publicly disseminating information that has not been officially released by the country involved. In other cases, institutions and agencies in an affected region may have unclear lines of authority or conflict over roles and responsibilities. Thus, GLEWS is working to promote common guidelines that countries can use when faced with a potential outbreak. As of the June 2008 workshop, the GLEWS operation was in its infancy.

STANDARDS OF THE WORLD ORGANIZATION FOR ANIMAL HEALTH

As de La Rocque had noted, it is critical to have consistent standards and procedures applied across countries as an element of surveillance and response systems. Alejandro Thiermann of OIE described the standards that his organization has developed. The OIE has 172 member countries, and its objective is to engage each of them in a commitment to conduct surveillance, collect data, and rapidly disseminate data on both the presence of diseases being targeted as well as "other epidemiological events of an unusual nature," Thiermann explained. Specifically, OIE's objectives are to:

- Encourage member countries to conduct surveillance and collect, analyze, and disseminate all animal health information necessary to minimize spread of disease in consistent ways;
- Safeguard world trade by establishing health standards for animals and animal products, provide guarantees of the safety of animal food and protect animal welfare, and follow biological standards for diagnostic tests and vaccines; and
- Provide expertise and encourage international solidarity in the control of animal diseases, and improve infrastructure, the legal framework, and resources for veterinarians.

The 172 member countries are legally obliged to adhere to the notification obligations and the organization's published standards, and OIE provides a variety of resources to assist them in doing so. A decision tree is used to determine which diseases are of concern and should be followed. The OIE has developed a web-based system, the World Animal Health Information System, for managing the data collected and providing additional data resources. Each member country can add data, and the system provides a simple and rapid method for countries to meet their reporting and other obligations. Maps and geo-coordinates assist with event location, and posted data are available to member countries.

The OIE also offers other veterinary support services in 29 countries, including 160 reference laboratories and 20 centers for collaboration. In all, member countries have access to a staff of more than 130 experts covering 83 diseases.

The OIE standards are designed to provide international guidelines that merge concerns about animal health and welfare, food safety, and public health. The OIE standards draw on the Sanitary and Phytosanitary Measures developed by the World Trade Organization, and are in harmony with those of other standard setting bodies such as the Codex Alimentarius (food safety) and the International Plant Protection Convention. The OIE standards include codes for:

- Terrestrial animal health;
- Aquatic animal health;
- Diagnostic tests and vaccines for terrestrial animals; and
- Diagnostic tests for aquatic animals.

A process of regularly reviewing and updating the standards is integral to the system so that it can be adapted quickly as new information about a disease alters scientific consensus on the best procedures for responding to it. Thiermann closed with some observations about why the OIE system is so important. Its key principles—early detection, transparency, notification, and rapid response—depend on a combination of technical ability and political will, he explained. Thus, the challenge of improving and sustaining the effort is two-fold: encouraging countries to see surveillance as a global public good, and developing the necessary infrastructure to accomplish the task. The infrastructure may include laboratory networks, veterinary capacity, public- and private-sector involvement, informed farmers, and other factors. The OIE's role is especially valuable when issues of international trade or competition among nations complicate questions of authority and responsibility. By mediating disagreements, providing objective analysis and procedural standards, and in many cases supplying the necessary infrastructure, OIE helps countries to view surveillance as a global priority and to do their part in supporting their own veterinarians, farmers, and other professionals in sustaining vigilance.

WILDLIFE DISEASE SURVEILLANCE AND INVESTIGATION

Although OIE focuses primarily on animals that are domesticated for food consumption, the health of wildlife is directly linked to that of both domestic animals and humans. Diseases among wild animals can also provide early warnings of environmental damage, bioterrorism, and other risks to human health. Joshua Dein and Scott Wright, both of the U.S. Geological Survey (USGS), provided background on both surveillance of wildlife and the investigation of disease outbreaks in wildlife populations.

Wright began by noting that the investigation of disease outbreaks among wildlife is a complex enterprise, involving not only many steps, but also many fields of expertise, as illustrated in Figure 3-1. The complexity begins with the significant variation around the world in the ways humans interact with different kinds of wild animals. A primary difference exists between cultures whose subsistence depends on agriculture and wildlife, and in which direct contact is thus a feature of everyday life, compared to more prosperous societies, in which interaction takes place primarily in the context of leisure activities. Because some subsistence economies are directly dependent on animals for survival, disease outbreaks among wildlife can have a dramatic impact under these circumstances. Yet these societies are least likely to have adequate (or any) infrastructure and expertise for animal disease surveillance particularly in wildlife. Wright stressed that the degree of support for investigation in any society depends on understanding

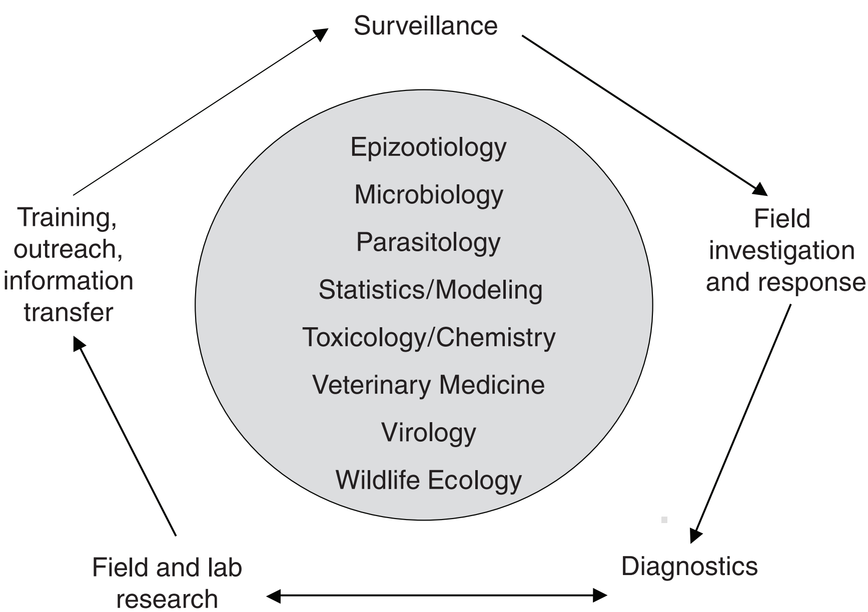

FIGURE 3-1 Complexity of disease investigation in wildlife populations.
SOURCE: Dein and Wright (2008).

the potential threats to human health, trade, local well-being, and national economies—there is little interest in potential threats to wildlife on their own. Both H5N1 and West Nile virus, for example, kill wild birds in very large numbers, Wright explained, but neither would have been likely to be investigated thoroughly if they had not had implications for human health.

But waiting for connections to human health to show up may be too late, Wright explained. Diseases in wildlife often show up in the form of noticeable concentrations of carcasses, but these may not be noticed if no one is looking for them. In the case of marine life, dead animals may only be visible if they wash up on shorelines, but widespread die-offs in other wild populations may easily be missed as well. Even when an incident is noticed and reported to local officials, they may not recognize the significance of the incident or be aware of the steps they should take. Thus, the focus for those concerned with wildlife health is moving local information to the regional, national, and global levels—a considerable challenge.

The approach to this challenge taken by the USGS National Wildlife Health Center, which is the only federal laboratory in the United States dedicated to wildlife disease investigation, is depicted in Figure 3-1. It is based on the premise that there are no mandates for reporting disease among wild animals, so the focus is on training and spreading the word through webcasts, podcasts, and other means to try to replicate the steps followed in veterinary and human medicine. Each step can yield a basis for research, Wright noted, and many diseases that are currently being studied were only recently identified through formal investigation.

Few countries are in a position to conduct disease investigations in wildlife, Wright described, but he stressed the importance of wildlife disease investigation. Wildlife diseases may have profound effects on an ecosystem, or be evidence of threats to an ecosystem. Moreover, once a wild population has been depleted or eliminated, there is no mechanism for its replacement, as there would be for livestock. Wild populations can serve as reservoirs and hosts to diseases that also affect livestock and companion animals; although they can then be a vital link in a cycle that could also include humans, they are frequently left out of the surveillance picture.

In Wright's view, a truly effective wildlife disease prevention program is critical to protecting human health. He identified the following requirements for establishing and sustaining such a program:

- Greater awareness and understanding of the importance of wildlife health;
- Substantial resources to build or improve capabilities;
- Mandatory reporting for wildlife diseases;
- Standardization of observations and reporting; and
- A global clearinghouse for reporting.

Some data are currently available from a number of sources, including data from international programs (e.g., FAO, OIE, Global Avian Influenza Network for Surveillance) which encompass only limited voluntary reporting, and data from U.S. sources (federal-, state-, university-based) which are not coordinated nationally. Most local data, he explained, are located in file cabinets or desk drawers and are not being shared or used. Ideally, health data regarding humans, domestic animals, and wildlife should be coordinated.

Dein picked up on the issue of available surveillance data to demonstrate the gaps in wildlife data. Figure 3-2 shows mortality for white males, and Figure 3-3 shows mortality for all terrestrial wild animals in the United States, respectively, both from the past 20 years. The gaps in the wildlife map do not necessarily indicate that no wild animals died in those U.S. counties during the period covered, but rather that there were no data reported or reported data were not available to the National Wildlife Health Center (NWHC). Similar reporting gaps exist in wildlife surveillance in countries around the world. To address them, the NWHC has developed a Wildlife Disease Information Node (WDIN) as part of the USGS National Biological Information Infrastructure. The goals for the program are to

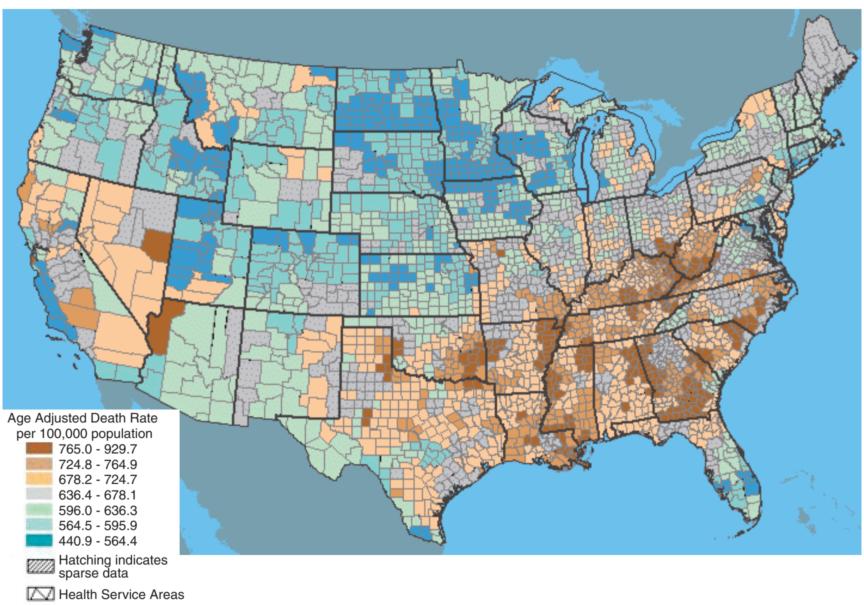

FIGURE 3-2 All-cause mortality for white males in the United States, 1988–1992.
SOURCE: Dein and Wright (2008).

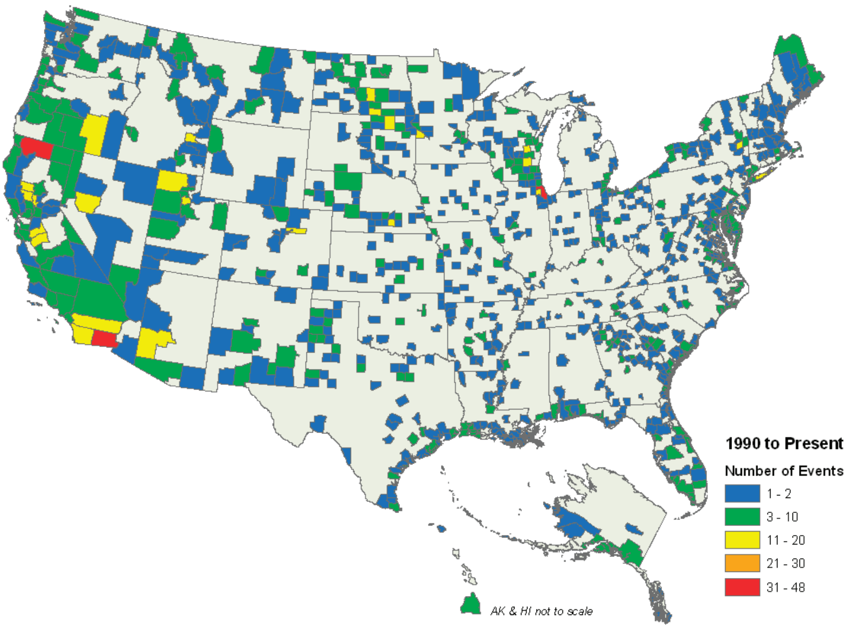

FIGURE 3-3 Wildlife mortality events, 1990–2008.
SOURCE: Dein and Wright (2008).

build tools and resources within the wildlife health community and to connect wildlife data to existing surveillance systems for animals and humans, Dein said. The WDIN staff maintain numerous resources on a publicly available website, and also put out daily reports that summarize disease events. They also collaborate with other programs, including the Canary database of literature about animals as sentinels of human environmental health hazards. This database is maintained by the Yale School of Medicine and the Highly Pathogenic Avian Influenza Early Detection Data System, an avian influenza database maintained by the U.S. Departments of Agriculture and the Interior.

Dein used the diagram shown in Figure 3-4 to illustrate the potential for cooperation among many agents involved with wildlife who could contribute to an ideal disease reporting system. Currently, he explained, an effort is underway to improve communication and approaches to this model for synthesizing U.S. wildlife disease data. The Wildlife Information System for Disease Observation and Monitoring (WISDOM) is being designed as a platform for both collecting wildlife disease data and disseminating it as

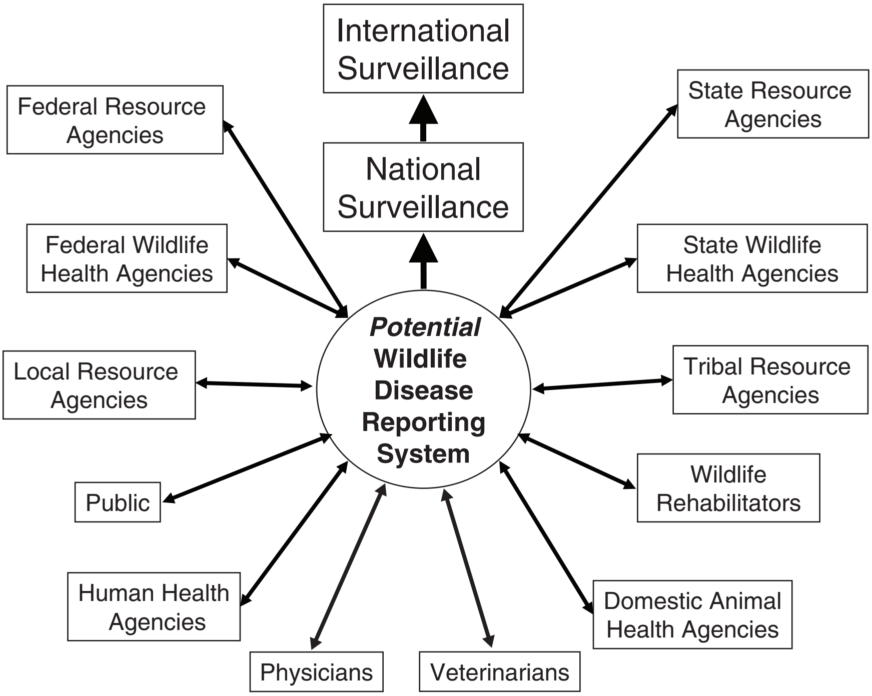

FIGURE 3-4 Proposed structure for a wildlife disease reporting system.
SOURCE: Dein and Wright (2008).

needed. At the same time, as has been discussed, OIE, FAO, and WHO are all contributing to wildlife surveillance internationally.

Dein suggested, however, that the existing infrastructure is "minimal" and that the challenge is not just to increase awareness of the ways in which wildlife can affect the health of domestic animals and humans, but to broaden understanding of shared risk. He pointed out that new threats may come from a newly emerging virus or "some garden variety [pathogen] like tuberculosis or plague." He closed with the observation that "a lot of [the] technological issues are more easily overcome than the people issues, and the mission issues," such as the best way to share data, which data are most useful, getting permission to share them, and acting on them.

EBOLA SURVEILLANCE IN NONHUMAN PRIMATES

Targeted wildlife disease surveillance systems have been developed in response to several specific threats to human and animal populations as well. One disease under targeted surveillance is Ebola, which causes widespread hemorrhages in nonhuman primates. Ebola has affected fewer than 1,000 humans (CDC, 2002), but its high fatality rate, as well as the threat it poses to endangered nonhuman primate species, has made the possibility of large-scale outbreaks a particularly chilling prospect. Pierre Rollin of the Centers for Disease Control and Prevention (CDC) described recent efforts to develop a surveillance system for Ebola fever in nonhuman primates, and some of the challenges that remain.

Rollin began with an overview of some of the most notable outbreaks of diseases caused by filoviruses, which cause severe hemorrhagic fever in humans and other primates and include both the Ebola and Marburg viruses. The first case of Marburg on record was an outbreak in Marburg, Germany, in 1967. Ebola (named for a river in the democratic Republic of Congo) did not emerge in humans until 1976, when three outbreaks among humans were linked to contact with primates. A 1989 outbreak in nonhuman primates in a laboratory in Reston, VA, was detected because of an unusually high number of monkey die-offs and resulted in the euthanasia of 500 monkeys. Rollin mentioned that the outbreak was exacerbated by poor quarantine practices that enabled animal-to-animal transmission of Ebola, and this outbreak demonstrated how highly infectious the Ebola virus is and the vital importance of working with rigorous laboratory safety standards and husbandry practices. The Reston outbreak occurred among monkeys that had been imported from the Philippines for research purposes. Researchers were unable to trace the precise origin in the Philippines, though a single facility in that country was associated with several other outbreaks among nonhuman primates. Nevertheless, procedures for testing animals that are shipped, controlling infections, and conducting surveillance in these populations were put into place after that outbreak in Reston.

Rollin outlined the reasons why surveillance of these diseases is so important, even though so few humans have been affected to date. Populations of many nonhuman primates are highly concentrated—roughly 80 percent of the world's gorillas and chimpanzees, for example, are located in Gabon and the Republic of Congo—and they are extremely susceptible to these diseases. These and other primates have been under tremendous pressure as a result of commercial hunting, and many are now endangered. The ape population in Gabon has declined by more than half since 1983, and although counting these animals is very difficult, as many as 5,500 gorillas are estimated to have died from Ebola.

Researchers have been eager to understand exactly how the disease spreads among these primates, and whether interaction among different species of nonhuman primates and possibly other species such as bats may play a role. The biggest question, Rollin explained, has been whether the virus is "spread from one area to the other like a big wave of an epidemic, or whether you have a multi-emergence in different areas." To help answer that question, a number of groups have worked together to set up a surveillance system called the Animal Mortality Monitoring Network in collaboration with the Gabonese and Congolese ministries of forestry and environment, and wildlife organizations including the Wildlife Conservation Society (WCS), the Programme de Conservation et Utilisation Rationelle des Ecosystèmes Forestiers en Afrique Centrale, and the World Wildlife Fund.

As is the case in so many disease surveillance contexts, with the variety of groups involved, coordination and other logistical challenges need to be overcome. Animal die-offs may be missed if carcasses in the wild are not noticed and reported, and the risk of infection from the carcasses is great. Because the carcasses decompose quickly, onsite investigation is very important, but special equipment and procedures are necessary to protect investigators from infection.

Nevertheless, investigators have concluded that the incidence of Ebola in nonhuman primates is most likely caused by a combination of multiple, separate emergences and group-to-group spread of the disease. They have not yet been able to identify the reservoir for the disease, and Rollin indicated that recent results suggest the possibility that nonhuman primates are actually just accidental hosts for the pathogen. In any case, they serve as important sentinels for risk to local human communities, even though the risk of the disease spreading to other countries is small.

GLOBAL SURVEILLANCE OF BATS

Why are bats important from a surveillance perspective? Bats are carriers for viruses that are harmful to humans—perhaps as reservoir hosts for Ebola, as Rollin hypothesized. Peter Daszak of the Consortium for Conservation Medicine (and a member of the workshop convening committee), described his work and the work of his colleagues and collaborators on surveillance in bat populations. Daszak explained that 8 new zoonotic viruses that originated in bats have emerged since 1994 (see Box 3-1), and there is a significant potential for additional ones to emerge. Furthermore, Daszak added that understanding the ecology of host species is critical to evaluating risk of zoonotic disease transmission.

There are more than 1,000 species of bats, and they are the most diverse of all mammals. One-fifth of all mammal species are a type of bat, and bats can be found all over the world, Daszak said. They are highly mobile and often well adapted to human environments, which means that they often share both food sources and dwellings with people. Human–bat interaction is quite common in developing countries such as Bangladesh and increasing as humans encroach on tropical forestland such as Sumatra.

BOX 3-1
Zoonotic Viruses That Originated in Bats Since 1994, with Year of Outbreak or Discovery

1994—Hendra virus
1997—Australian fruit bat lyssavirus
1997—Menangle virus
1999—Nipah virus
2001—Tioman virus
2005—SARS-like coronavirus
2005–06*—Ebola/Marburg virus
2007—Melaka virus

SOURCE: Daszak and Epstein (2008).

* PCR evidence published.

Nipah virus, which emerged in swine and swine workers in Malaysia in 1999, illustrates why bats are so important. Investigators were initially puzzled by the connection between bats, pigs, and swine workers; they then conducted surveillance to better understand the pattern of disease transmission. Researchers tested various bat colonies in Malaysia and determined that these fruit bats carried Nipah virus and that the virus circulated within these colonies. Using satellite collars to track bat movements in the region, they found that bats migrate across a broad range, leading researchers to discard the notion that the widespread outbreak was caused by human effects on the bats' migratory patterns. They then turned their attention to the pigs that became ill from the virus and by coughing transmitted the virus to humans. Researchers concluded that fruit bats (reservoirs of Nipah virus) fed from orchards with swine farms, and the infected pigs amplified and aerosolized the virus that consequently infected swine workers. Using mathematical models of a simulated outbreak, researchers found that outbreaks among swine workers and pigs occurred when migratory bats reintroduced the virus into a swine population that had previously been exposed and developed partial immunity, which allowed the epidemic to spread for a long time and essentially become endemic. This led to the realization that bats, while overlooked, will be important to study because they are high-risk reservoirs for zoonotic disease transmission.

Thus, a clear surveillance challenge is to identify viruses with this kind of epidemic potential before they emerge or spread extensively. But finding such pathogens is tricky, to say the least. There are approximately 50,000 vertebrate species, Daszak pointed out, with the conservative assumption that each might normally carry 20 unique unknown viruses, and translating into a global biodiversity of a million unknown vertebrate viruses, many of which are likely to be zoonotic. Currently, 2,000 viruses are known, so, Daszak noted, "we are underestimating the global diversity of viruses by 99.8 percent." Moreover, the challenges of surveillance in bats are considerable. It entails collection of blood and other body fluids, which can be highly infectious, then testing the specimens by serology and viral culture, and recording the age and condition of animals. The collection of specimens must often be conducted in difficult, remote terrain, and it can be difficult to locate colonies. Bats are very sensitive to disturbance, and colonies may move in response to investigation. Furthermore, accurately identifying species can be difficult.

Because it would be impossible to test every species of bat, the strategy must be to focus on so-called hotspots—areas with high biodiversity as well as high human population density—where zoonoses are most likely to be found. Jones and colleagues (2008) identified such hotspots in Figure 3-5. By conducting "smart surveillance," researchers are able to target their resources and efforts in areas where human–animal interaction is most likely to provide conditions favorable to zoonoses.

Daszak explained that the Consortium for Conservation Medicine's surveillance efforts in wildlife species has been dependent on the work of local,

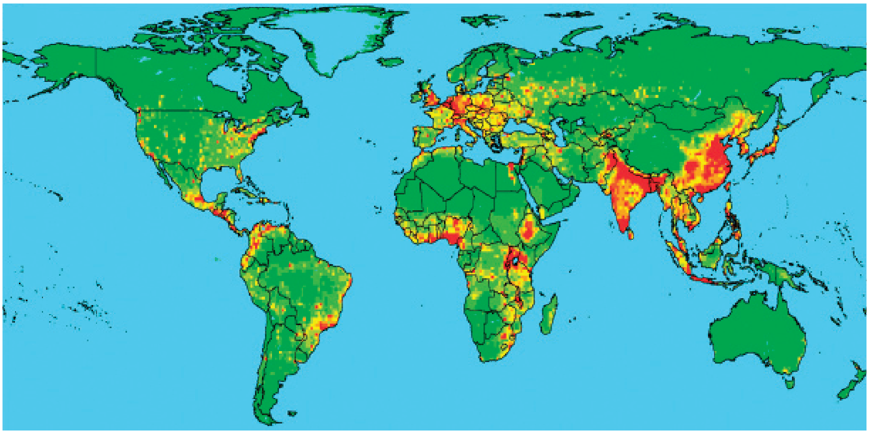

FIGURE 3-5 Emerging infectious disease hotspots. Hotspots are indicated in red and include areas of high biodiversity and high human population density, which may correlate to high connectivity between humans and wildlife.
SOURCE: Jones et al. (2008). Reprinted with permission from *Nature*.

talented field workers and veterinarians at their field sites worldwide, and stressed the importance of building local laboratory capacity and the use of a central database available for scientists to coordinate future research. The Consortium has been working on standardized methodology for bat surveillance, and has been collaborating with colleagues from different disciplines to understand the ecology of potential host species in wildlife.

SURVEILLANCE OF BUSHMEAT AND EXOTIC ANIMALS

William Karesh of the Wildlife Conservation Society (WCS) picked up on the theme that surveillance of wildlife populations is important not only as an early warning system for diseases in humans, but also as part of an overall approach to sustaining the integrity of ecosystems worldwide. The WCS's overall mission is the protection of wildlife and wild lands, and they also operate and oversee the Bronx Zoo and other animal centers. Thus, their mission also encompasses stewardship of captive wildlife, so they are able to conduct surveillance both in the wild and in controlled settings.

Karesh's focus was on surveillance of animals used for bushmeat, that is, meat of wild animals hunted for food. He noted that the demand for wildlife as a source of food has increased significantly in many areas, such as remote areas where workers are cutting down forest trees. Increased trade in wild animals, both legal and illegal, has also meant increased interactions between humans and wild animals, and increased opportunities for disease transmission. Karesh pointed out that the illegal trade has likely grown even faster than legal trade, though it is impossible to quantify. To give a sense of the scope, he noted that authorities had recently confiscated a planeload of 10,000 pounds of turtles being smuggled out of Indonesia.

Many of the diseases humans contract from interacting with wildlife are easily preventable by following certain hygienic steps, particularly during animal handling and food preparation, but these disease prevention practices, Karesh said, are not well understood by those who rely most on bushmeat for survival. For that reason, educating and training local villagers on the importance of surveillance and ways to prevent infection of themselves, family members, and neighbors have been a big focus of the WCS surveillance efforts. At the same time, populations that have daily contact with wild animals are in a good position to contribute to both surveillance and protection, so the WCS has worked to engage them in that effort as well. Above all, the goal of the WCS has been to encourage countries and local authorities to understand the importance of surveillance, and to build their own capacity to collect and analyze samples.

Karesh used several examples to illustrate the ways diseases can emerge as a result of changing patterns of interaction between humans and wild animals. Severe Acute Respiratory Syndrome, for example, was linked to growing live animal markets in Asian nations (these markets are growing in number and are found worldwide) where numerous animal species are housed together, each bringing different organisms into the mix, and expanding the opportunities for disease transmission.

Karesh closed with a description of the Global Avian Influenza Network for Surveillance (GAINS), a project of the WCS that has been supported by CDC and the U.S. Agency for International Development since 2006. This effort is focused on monitoring information about the influenza virus in wild birds and sharing that information internationally. The program is a network involving partners in 36 countries, as well as web-based data and other resources. GAINS staff have worked to train others for data collection and mortality investigations at the local level and then to compile data from colleagues around the world (the database is the WISDOM program described above).

SURVEILLANCE OF INFECTIOUS DISEASES IN COMPANION ANIMALS

Companion animals are excellent sentinels for emerging infections that can affect humans, in part because they are much easier to monitor than wild animals. Larry Glickman of the University of North Carolina at Chapel Hill described current procedures and challenges in this sector. He also cited other reasons companion animals are good sentinels. First, at least 170 million dogs and cats are kept as companion animals in the United States, generally in close contact with their owners. Companion animal ownership is just as common in other developed countries and is growing in many developing countries as well. Companion animals are reservoirs for zoonotic and parasitic diseases that are transmissible to humans, such as leptospirosis, and Glickman speculated that companion animals may be more sensitive to a fixed pathogen dose. They are also highly susceptible to several biothreat agents of concern. Table 3-1 lists some biothreat agents that may occur naturally in companion animals.

Recognizing the importance of monitoring companion animals, Purdue University and Banfield®, The Pet Hospital, with funding from CDC, collaborated to sponsor the National Companion Animal Surveillance Program (NCASP). Glickman explained that the program's broad focus was designed to address a range of health events in companion animals. Specifically, the program can provide:

- Real- and near real-time information on health-related events among companion animals in the United States;
- Detailed statistical analysis to identify space–time clusters of events and characterize host and environmental risk factors;

TABLE 3-1 Biothreat Agents in Dogs and Cats

Category A Disease/Agent[a]	Occurs Naturally In[b]
Anthrax (*Bacillus anthracis*)	Dogs and cats
Botulism (*Clostridium botulinum* toxin)	Dogs and cats
Plague (*Yersinia pestis*)	Cats and dogs
Smallpox (*Variola major*)	Not documented
Tularemia (*Francisella tularensis*)	Cats and dogs
Viral hemorrhagic fevers (filoviruses and arenaviruses)	Not documented

[a]Category A diseases or agents refer to pathogens that are rarely seen in the United States but are considered high-priority agents because they pose a national security risk.
[b]Species of greatest or equal susceptibility listed first.
SOURCES: CDC (2003); Glickman (2008).

- Alerts to the occurrence of potential acts of bioterrorism, emerging zoonoses, and toxic chemical exposures;
- Syndromic surveillance and multihazard situational awareness;
- Potential to adapt to chemical spills and contamination from toxic waste sites to monitor both acute and chronic health outcomes; and
- A resource for pharmacoepidemiological research.

NCASP maintains a database that enables it to respond quickly to an event, such as Hurricane Katrina, by comparing illness outbreaks to baseline data. The partnership with Banfield®, The Pet Hospital, provides access to standardized and computerized medical records from more than 3.5 million annual veterinary patient visits in 49 states and all major U.S. population centers. Each animal's unique identifier number makes it possible for investigators to track disease events by neighborhood, as well as to track lab results and other health information and obtain biological specimens when necessary. The kinds of data collected include records of companion animal demographics, exam observations, laboratory findings, medical notes, ailments diagnosed, and treatments.

These data can be integrated with data from other local, state, and national surveillance systems. The Banfield® system also streamlines communications with veterinarians, for example, by sending an alert that when making a diagnosis of a flu-like illness, they should collect and submit a specimen for testing according to protocols provided. "We can then identify those pathogens," Glickman explained, "map the geographic occurrence, and share that information with our colleagues in epidemiology at the state health department, but also with others who might need to know, such as the makers of influenza vaccines." NCASP monitors influenza-type illnesses in dogs, cats, and birds, which may bring H5N1 into the United States.

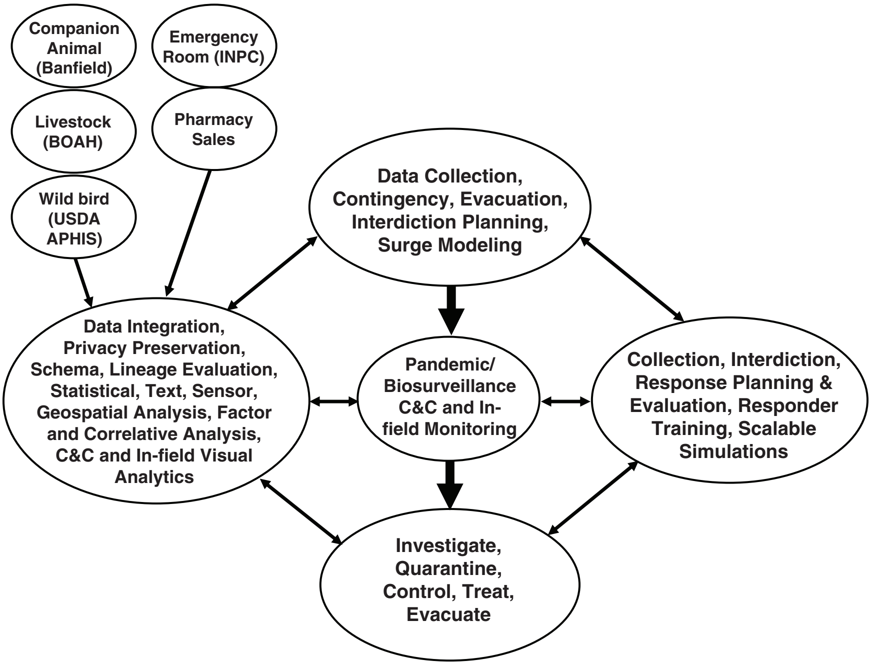

FIGURE 3-6 Ideal data integration from multiple animal species.
SOURCE: Glickman (2008).

They are also interested in vector-borne pathogens, so they have a system for collecting information on the occurrence of fleas and ticks in the companion animal population, and collect specimens when needed.

The goal for NCASP is to integrate the data from animal species and humans, as shown in Figure 3-6. However, Glickman explained, a long-term investment will be needed to fully integrate animal data sources just within the United States (including private and state-run veterinary practices, diagnostic laboratories, and surveys). This investment would not include integration with human health data, or expanding such a system internationally.

DISCUSSION

Discussion of the overall picture of animal surveillance opened with the observation that the presenters, representing various sectors, had not previously had the opportunity to meet and collaborate as a whole group. Although many had previous contact with one another, they agreed that the full breadth of the human and animal surveillance enterprise is not ordinarily addressed in any one venue. The challenges of coordinating this large and loosely linked network were a key topic.

Coordination

For the question posed by the committee regarding the multitude of disease information systems, participants offered a number of reasons why international human and animal disease surveillance systems are not more coordinated. One participant noted that each of the existing systems were all created for very different reasons, each with different missions. They also collect different kinds of information, so it is a challenge to "pick the parts that are going to interface." Part of this interfacing problem is terminology—"What do you call species? What do you call an age class? What do you call a disease?" One participant observed that these questions complicate information sharing. Information technology issues can pose another obstacle, and although they are potentially solvable, developing compatible systems requires not only the will but also, often, a significant amount of work, resources, and time.

Coordination also requires confidence and trust, others noted. "You have to go step by step and have some success stories to show that you are not just trying to get data and to do your own business," one participant asserted. In order to cooperate with organizations that may be based around the world, for example, people need to understand the importance of the effort and the vital role they can play.

Lack of Mandate for Overall Coordination

Perhaps more important, a participant offered, is that "what we don't have is a group of individuals, an agency, or an institution that looks at the overall picture across human and animal populations, looks at the current surveillance system, the information that each provides and how they link and how they either complement, synergize, or have no relationship with each other." No federal agency has jurisdiction over multiple systems, and it was noted that companion animals may be the only group not overseen by any federal agency. It was suggested that what is needed is not, perhaps, a super agency, but rather a super group that tries to answer some of these questions and provide coordination and linkages, rather than put together piecemeal approaches to deficiencies within individual systems.

Participants noted that regulations exist in areas such as disease management, laboratory work, and species management, but many are not followed particularly at the international level. Therefore, as many discussants pointed out, building an understanding of the importance of disease surveillance may be more fruitful than expanding regulatory authority. Moreover, several participants observed, the mandate or requirement is in many cases less important than making sure that the capacity and resources to comply are in place where they are needed. "If you look just in the United States, the number of state and federal wildlife people who are out in the field on a daily basis have a huge amount of information that they could provide. They don't have the resources to do it. They don't have the time to do it, though they would have no objection to providing those data."

Targeting the Effort

A related issue was the importance of focusing whatever efforts could be made in the areas of greatest need. As one participant noted, "There are some tremendous things going on in sampling the wildlife population worldwide now, but really when you compare that to the biodiversity that is out there, you could be sampling millions and millions and millions more animals." A key strategy is education—"getting folks to understand where the information is useful." Another noted, "We are depending on biologists who go into caves and work with bats to tell us there is a [greater] die-off going on compared to what they normally see, and trying to train them to understand baseline mortality versus something unusual and then call us and consult with us, and we will work with them to try to figure out where to go next." Providing the mechanisms, incentives, training, and resources to people who are on the ground and have the opportunity to observe health events in animals is perhaps the best platform on which to build a comprehensive, internationally linked system.

Some observed that a significant infrastructure is in place, and needs to be better coordinated, but others pointed out that sustaining the effort remains a challenge. One participant noted: "I have seen it so many times. You set up the surveillance system and there's some donor funding, some exterior funding. That stops and the thing collapses—that is clearly not the way we want to do it."

4

Diseases in Humans: Early Warning Systems

Effective disease surveillance systems that can detect outbreaks of emerging zoonotic diseases in human populations early are critical for giving health officials the opportunity to rapidly respond and apply interventions to control the outbreak as soon as possible. Representatives from several global infectious disease surveillance systems that operate to detect diseases in human populations, and which were identified by the committee during the workshop planning period, were invited to present an overview of these systems and the lessons that have been learned in (1) what is needed to improve the effectiveness of these systems, (2) how they could be linked to animal disease surveillance systems, and (3) the challenges that have been encountered and overcome in the conduct of disease surveillance, and identifying remaining gaps.

The discussion of animal disease surveillance in the earlier session clearly emphasized the close link between the health of wild and domestic[1] animals and the health of humans. The ideal disease surveillance system, described by those focusing on animal health, was an interconnected system across species where outbreaks in animal populations could be detected and risks of human exposure could be identified early on and addressed to minimize or prevent disease in humans. Surveillance for zoonotic diseases in humans is similarly focused on early warning. The next section summarizes

[1]Domestic animals are animals that have been bred selectively in captivity and thereby modified from their ancestors for use by humans who control the animals' breeding and food supply (see http://asci.uvm.edu/course/asci001/domestic.html).

the presentations that were made to provide an overview of several global infectious disease surveillance systems and lessons learned.

GLOBAL PUBLIC HEALTH INTELLIGENCE NETWORK

Several options are available to monitor and track emerging zoonotic diseases in humans. Marlo Libel, of the Pan American Health Organization, described one that uses an automated process to track and filter news reports of outbreaks from around the world. The Global Public Health Intelligence Network (GPHIN), which was originally developed by the Public Health Agency of Canada in collaboration with the World Health Organization (WHO), is a web-based system to which users can subscribe for a fee. Users include governments around the world as well as nongovernmental agencies and organizations. Current subscribers include the Centers for Disease Control and Prevention (CDC), WHO, the World Organization for Animal Health (OIE), the Food and Agriculture Organization of the United Nations, the European Centre for Disease Prevention and Control, and the European Commission.

According to the GPHIN website, the network has multilingual capacity and monitors news sources and translates documents in seven languages (Arabic, English, French, Russian, Simplified and Traditional Chinese, and Spanish) via the Internet; with plans to add languages in the future. Libel noted that Portuguese and Farsi have been added to the multilingual capacity. Monitoring continues 24 hours a day, 7 days a week. Sources include websites, news wires, and other Internet-based information outlets. GPHIN tracks not only outbreaks of human disease, but also information related to animal and plant diseases, such as S*treptococcus suis* and soybean rust. Also tracked are contamination of food and water; natural disasters; product or drug safety; and chemical or biological exposures caused by terrorism or accident.

The system automatically filters the information, Libel explained, identifying duplicate reports and assigning a relevancy score, based on criteria built into the program. According to its website, "if the filtering identifies information about an event of significant public health risk, this information is automatically forwarded to GPHIN users by e-mail. The results of the relevancy filtering is then analyzed by the Agency's [Public Health Agency of Canada] GPHIN officials to ensure accuracy of the automated process." Libel noted that additional analyses by the human experts precede any publication with an alert that is then distributed automatically to subscribers.

GPHIN is designed to pay particular attention to a small number of human diseases that are of particular concern for even one case per the International Health Regulations: influenza, polio, Severe Acute Respiratory Syndrome, smallpox, all of which are examples considered to pose an international public health emergency. "We have to have a system in the countries able to detect any case, one case" of those four diseases, Libel said. For another set of diseases—including cholera, pneumonic plague, yellow fever, Ebola, meningitis, and others—a variety of criteria have been established for analysts to determine whether an outbreak is a "public health emergency of international concern."

Once GPHIN issues an alert, further investigation begins. Table 4-1 shows the number of disease events that were reported to and verified by WHO between 2001 and 2008, based on alerts from GPHIN.

TABLE 4-1 Disease Events Verified by World Health Organization, January 2001 to April 2008

Total events	2001	2002	2003	2004	2005	2006	2007	2008
2,415	192	244	509	374	324	296	321	155

SOURCE: Libel (2008).

GLOBAL OUTBREAK ALERT AND RESPONSE NETWORK

Once the GPHIN system has identified an outbreak, Libel explained, the Global Outbreak Alert and Response Network (GOARN) goes into action. Also developed under the auspices of WHO, GOARN is a network of 200 partners, institutions, and organizations worldwide that provide coordination, expertise, and technical support for rapid identification, confirmation and response to outbreaks of international importance. Libel listed GOARN's primary goals as the following:

- Assist countries with disease control efforts by ensuring rapid, appropriate technical support to affected populations;
- Investigate and characterize disease events and assess the potential for rapidly emerging epidemic disease threats; and
- Support national outbreak preparedness by ensuring that responses contribute to sustained containment of epidemic threats.

To provide a sense of the scope of GOARN's efforts, Libel noted that the network and its partners coordinated responses in 63 countries, mobilizing more than 500 experts in response to 97 events between 2000 and 2007. Figure 4-1 provides an overview of the structure of the GOARN network.

The GOARN process begins with an initial screening and verification of the reported outbreak, followed by an assessment of the risk the outbreak poses. A response strategy is quickly developed, and necessary operations begin. One key to the value of GOARN is the capacity to provide a wide range of special, scientifically based expertise and advice, targeted to the outbreak, which may include:

- Operational and technical coordination;
- Logistics, security, and finance;
- Laboratory support;
- Epidemiological investigation;
- Infection control and containment;
- Clinical management;
- Field communications;
- Information management, media relations, and social mobilization;

and

- Expertise in environmental health or medical anthropology.

The availability of this pool of expertise is particularly important in countries with few resources, and has been instrumental in the effective response to outbreaks such as the Marburg virus in Africa. Another benefit, he explained, is that WHO can also use informal sources of information

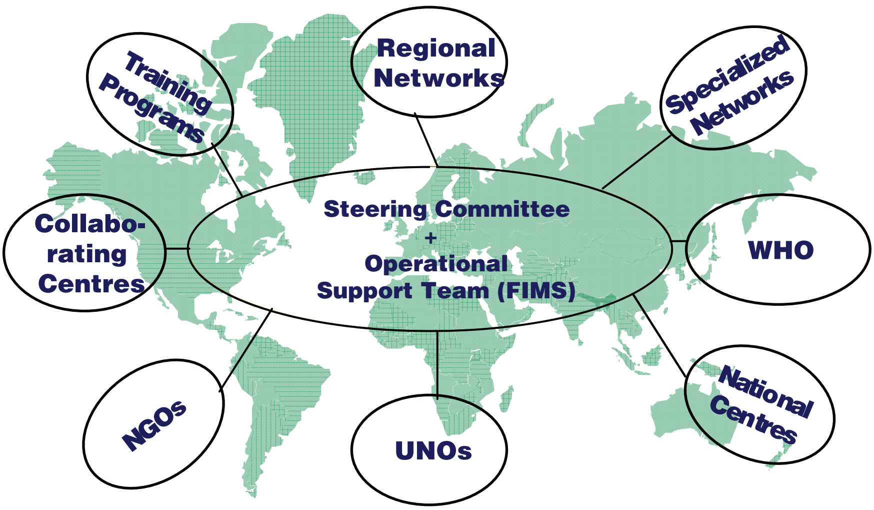

FIGURE 4-1 Structure of the Global Outbreak Alert and Response Network.
SOURCE: Libel (2008).

outside of the country's official Ministry of Health to ensure facilitation of dialogue to contribute to the verification process of an outbreak in a timely manner. This allowance has been of significant value, especially from regions in which governments have sometimes been cautious about releasing formal public health reports. This is an important change, Libel noted, that allows for necessary communication among countries and a thorough verification process. Libel identified other specific benefits of GOARN activities and efforts that fall under some of the larger areas bulleted above. Specific benefits include: enhancing dialogue with country governments and other international stakeholders to build trust; strengthening credibility and transparency; alleviating costs to mobilize or best use resources and providing surge capacity; and providing access to information exchange, best practices and technology transfers, and equitable and appropriate participation in field missions. All of these factors may contribute to the incentive of a country to respond to or control a disease outbreak with the best scientific advice and evidence to protect their human and animal populations. GOARN has become a trusted "operational arm of the International Health Regulations" and has been welcomed around the world, Libel said.

PROGRAM FOR MONITORING EMERGING DISEASES (PROMED-MAIL)

Another system that tracks information about disease outbreaks around the world was described by Peter Cowen, of North Carolina State University. ProMED-mail, or the Program for Monitoring Emerging Diseases, is a project of the International Society for Infectious Diseases set up in 1994 to provide a means of quickly disseminating information about infectious disease outbreaks. This free service has more than 40,000 subscribers in 160 countries. The subscribers are the source of the information handled by the system. Subscriptions are available in multiple languages including English, Russian (ProMED-RUS), Spanish (ProMED-ESP), Portuguese (ProMED-Port), and French (ProMED-FRA). There are also pages dedicated to translations in Chinese and Japanese. ProMED-MBDS is a special service of ProMED mail (in English) for the Mekong Basin Disease Surveillance (MBDS) group of countries. Volunteer rapporteurs and moderators with expertise in 22 areas are the backbone of the system. Spending as much as 3 to 6 hours a day on the effort, rapporteurs search the Internet for information, including official WHO reports, about emerging diseases and verify that information. Information is passed on to volunteer subject-matter experts, such as Cowen, a veterinarian who serves as an animal and zoonotic disease moderator. Based on the expert moderator's analysis, the information may then be posted to the group via ProMED-mail.

The map presented in Figure 4-2 shows the number of pathogens reported by region, and, Cowen explained, reveals the gaps in the system. He is particularly concerned that much of Africa and the Middle East, as well as areas of Southeast Asia, are not well covered by the system. Figure 4-3 shows the representation of the disease for which ProMED has disseminated information in 2007–2008.

Cowen pointed out advantages, gaps, and challenges of the system. The system archives every posting, and most postings contain a comment to put the data in context. Therefore, a researcher interested in tracking how a particular outbreak developed and was identified would find the archive a valuable resource. The archives also show the communication among moderators that led to the decisions about whether to post the data.

One significant challenge is the cost of running ProMED-mail, which Cowen said is a nonprofit operating "on a shoestring" and is almost entirely reliant on volunteers. Similar to other web-based systems, they are challenged to deal with the volume of daily postings. Not only do they need to determine the importance of the data, but they need to project whether those data have the potential to overload the technical system. But personal communication is key to success, he said in closing: "If we are ever going to do real monitoring for emerging diseases, I think it is important that we develop collegial relationships, we get to know each other. These things are always done person to person, and certainly one of the reasons ProMED-mail works is that we know each other very well and we trust each other." From the vantage point of an animal health professional, he

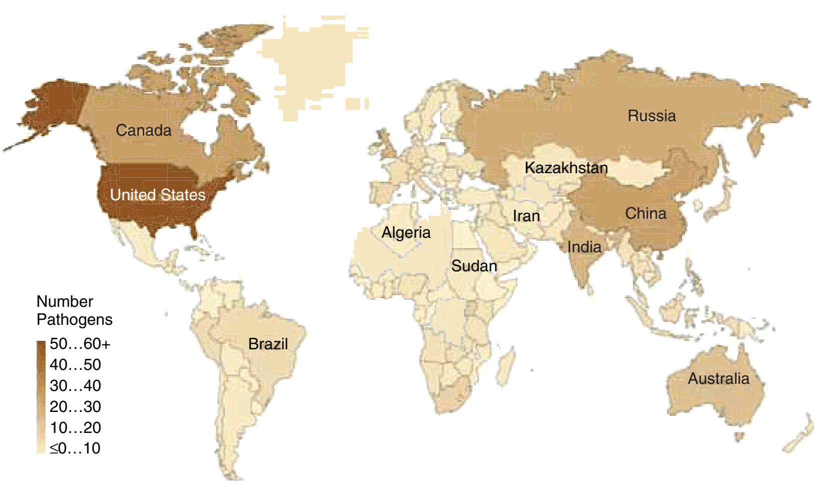

FIGURE 4-2 Pathogens reported by global location via ProMED.
SOURCE: Reprinted with permission from John Brownstein.

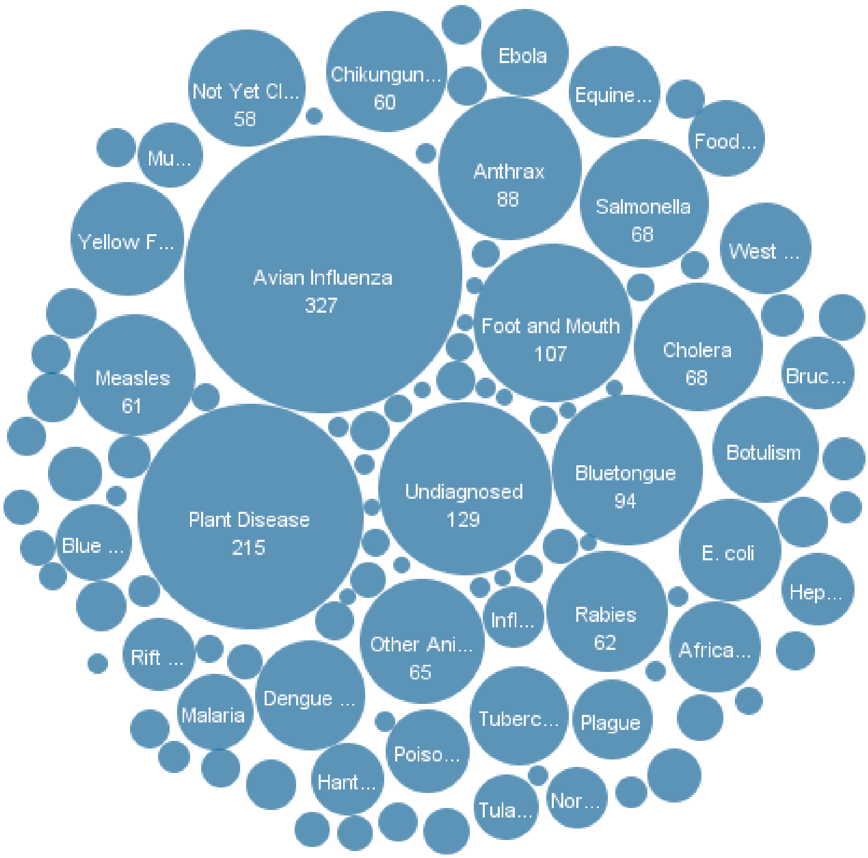

FIGURE 4-3 ProMED-mail disease report summary, 2007–2008.
SOURCE: Reprinted with permission from John Brownstein.

stated his hopes for greater integration among systems developed within different fields.

DEPARTMENT OF DEFENSE GLOBAL EMERGING INFECTIONS SURVEILLANCE AND RESPONSE

Another disease surveillance system was developed by the U.S. Department of Defense (DoD) to monitor and respond to infectious diseases that are a threat to military personnel or their families, that reduce medical readiness, or that present a risk to national security (DoD-GEIS, 2008). Tracy DuVernoy of the DoD, explained that the Global Emerging Infections

Surveillance and Response system (GEIS) was established by a Presidential directive in 1996, in response to growing recognition of the potential threat that infectious diseases pose to the health of U.S. military. GEIS collaborates with partners both within the DoD and in other federal agencies, universities, and elsewhere. Its goals are:

- Disease surveillance and detection;
- Response and readiness;
- Integration and innovation; and
- Cooperation and capacity building.

GEIS has established five priorities, DuVernoy explained: respiratory illnesses (particularly influenza), febrile illnesses (particularly malaria and dengue fever), enteric (acute diarrheal) disease, antimicrobial resistance, and sexually transmitted infections. The GEIS network includes partners and laboratory facilities in many parts of the world (see Figure 4-4).

To illustrate how the system operates, DuVernoy described GEIS's global influenza surveillance system, which has three elements. First, the

FIGURE 4-4 Overview of Department of Defense Global Emerging Infections Surveillance and Response System (DoD-GEIS).
SOURCE: DuVernoy (2008).

sentinel surveillance component has 71 surveillance sites around the world. Second, population surveillance monitors DoD personnel in all service branches, as well as civilian populations at four clinics located near the California–Mexico border. Third, the international surveillance system consists of Department of Defense medical research laboratories in five locations overseas, with approximately 850 staff. These laboratories conduct surveillance of influenza and other diseases in their regions.

DuVernoy described three other DoD disease surveillance efforts that have been funded by GEIS: the Early Warning Outbreak Recognition System (EWORS), Alerta, and the Electronic Surveillance System for the Early Notification of Community-based Epidemics (ESSENCE). EWORS is a computer-based system through which hospitals can serve as sentinels, as hospitals collect and monitor data about emerging diseases. The multilingual network was first operational in Indonesia and has expanded. Alerta is a surveillance system that was developed for the Peruvian Navy, and later expanded to include the Army. DuVernoy also noted that DoD is now funding new integrated surveillance activities in Peru in its recognition of the growing importance of the interaction between human and animal health. In this effort, they are attempting to pilot the Alerta system to incorporate not only human surveillance, but also animal disease information by working with both the ministries of agriculture and of public health. ESSENCE, which was developed in the 1990s, but expanded after September 2001, is a secure system for collecting and analyzing near real-time data in the Washington, DC, area to provide early warning of bioterrorism and other disease threats.

DuVernoy closed with the observation that the global coverage provided through these systems has been "an incredible asset" and that the systems can be very flexible. Collaboration with ministries of health and agriculture in other countries, with CDC, and with many other organizations and universities has greatly enhanced the potential for the system. On the other hand DuVernoy added that their "efforts are still not well integrated on the animal side" because the primary mission is to protect the active-duty forces. Another gap is that population coverage is not always consistent. Children are not well represented in the surveillance programs, nor are people who live in remote areas. At the same time, the system may be too sensitive within other populations, she said, yielding too many alerts for events that pose little risk.

ARBONET

The national surveillance system for arboviral diseases,[2] ArboNET, was described by Marc Fischer of CDC. The system was developed in 1999 in response to the emergence of West Nile virus in the United States, was expanded to cover other arboviral diseases in 2003, and is maintained by CDC's Division of Vector-borne Infectious Diseases. Diseases covered in this system are listed in Box 4-1.

ArboNET has four primary objectives, which are to:

- Monitor the epidemiology, incidence, and geographic spread of West Nile virus and other arboviruses;
- Provide timely information regarding arboviral disease to public health officials, government leaders, researchers, clinicians, and the public;
- Support prevention and control efforts and stimulate research on arboviral diseases; and
- Evaluate funding needs.

ArboNET collects several types of data: human disease cases, screening of donated blood, veterinary data, and data on wild birds, sentinel chickens, and mosquitoes. Sources include health care providers, veterinarians, and commercial laboratories who report information to a state or local health department. ArboNET staff collect a variety of information on human patients and blood donors, including demographic information, details of illness, and outcome. They are working to collect additional information on medical risk factors, underlying conditions, any immunosuppressive medications the individual has taken, and details of any laboratory testing. Data collected on animals include species, location, types of virus, and dates of symptoms and collection.

Because arboviral diseases are nationally notifiable[3] diseases in the

[2]Arthropod-borne viruses or "arboviruses" are a diverse array of agents that share the unique characteristic of transmission by blood-feeding arthropods, including ticks, mosquitoes, sand flies, and biting midges. More than 100 arboviruses are known to infect humans and over 40 to infect domestic animals. Infection can result in a wide range of disease syndromes, including systemic febrile illnesses, encephalitides, and hemorrhagic fevers. Examples of important human pathogens include the four dengue viruses, West Nile virus, yellow fever virus, and Japanese encephalitis virus. Rift Valley fever, Nairobi sheep disease, Venezuelan equine encephalitis, and Bluetongue are examples of veterinary diseases caused by infection with arboviruses (Miller et al., 2008).

[3]A notifiable disease is one for which regular, frequent, timely information on individual cases is considered necessary to prevent and control that disease. Each year a list of nationally notifiable diseases is agreed on and maintained by the Council of State and Territorial Epidemiologist and CDC. Diseases that are considered nationally notifiable may or may not be designated by a given state as notifiable (reportable) in the state. States may use the national notifiable diseases list as well as other information, such as state-specific health priorities, to

BOX 4-1
Examples of Arboviruses Tracked in ArboNET

Cache Valley
California serogroup
Chikungunya
Colorado tick fever
Dengue
Eastern equine encephalitis
Jamestown Canyon
Japanese encephalitis
LaCrosse
Powassan
St. Louis encephalitis
Venezuelan equine encephalitis
West Nile
Western equine encephalitis

SOURCE: Fischer (2008).

United States, the state, local, and district health departments (including those in commonwealths of the United States) enter any disease surveillance data they receive into an electronic database that is uploaded weekly to CDC. CDC analyzes the data and disseminates it regularly. Dissemination includes weekly updates that are transmitted through listserves that go to health departments, to the USGS NWHC as weekly, monthly, and annual summary reports, and as publications in peer-reviewed journals. Fischer explained that there are some differences in the way data on neuroinvasive diseases and non-neuroinvasive diseases are reported. All arboviral diseases are legally reportable throughout the United States, but more complete data are available for those that are neuroinvasive (e.g., encephalitis or acute flaccid paralysis) than for those that are not. For the neuroinvasive disease, the data are used to calculate rates of disease, project the total number of cases and infections, and compare trends over time. Figure 4-5 shows the incidence of West Nile virus neuroinvasive disease in the United States in 2007.

guide their determination of which conditions/diseases to make notifiable in their state. Thus, the list of state-specific notifiable diseases may vary across states and in a given state; the list may vary over time as well. Disease reporting is currently mandated by legislation or regulation only at the local or state level (CDC, 2001).

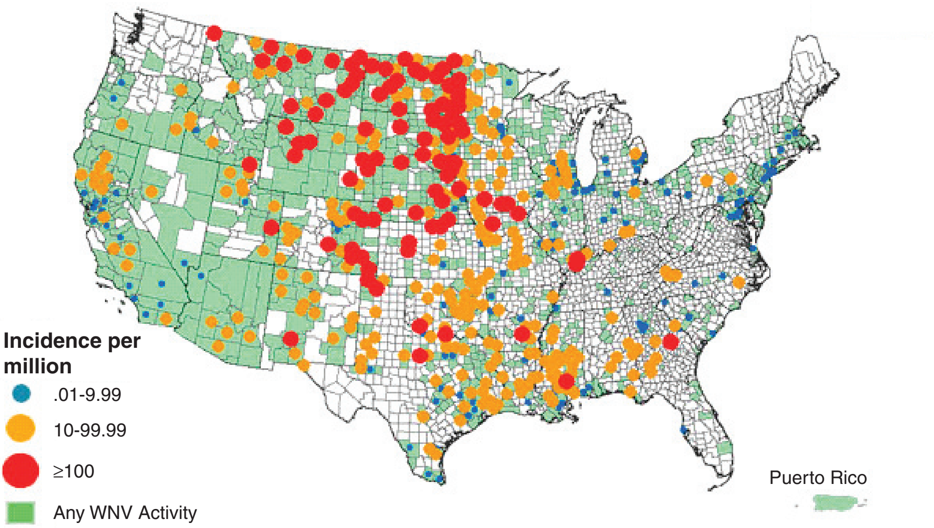

FIGURE 4-5 Incidence of West Nile Virus Human Neuroinvasive Disease in the United States, 2007.
SOURCE: Fischer (2008).

Animal data are not reportable, but are just as important as the human data. Fischer noted that collection and verification of these data vary by jurisdiction. He noted that slightly more than 500 animals (primarily horses) were identified and tested positive for West Nile virus in 2007. More than 1,800 birds tested positive; over half were American crows. The presence of virus in mosquito populations is not reportable, but many health departments use traps to monitor the presence of West Nile—nearly 8,100 mosquito pools tested positive for the virus in 2007.

The strengths of ArboNET are that it is a comprehensive system that collects human, animal, and ecological data, and that it can provide detailed data down to the county level, Fischer said. ArboNET also provides incidence and geographic temporal trend data for neuroinvasive diseases, as well as a broad picture of arboviral transmission activity and migration. With these data it is possible to see where disease reservoirs and vectors are occurring. Collaborations among CDC, state and local health departments, and blood services agencies, as well as rapid turnaround, allow for quick response.

However, Fischer also pointed out that ArboNET is a passive surveillance system and that it provides only minimal clinical and laboratory data.

Thus it is not possible to confirm that patients meet case definitions. Moreover, potentially long delays between the time cases occur and the time they are reported are beyond the network's control. Some of the data (human fever cases, animal and ecological data) are not reportable or notifiable by law; the results are variable and may not be representative. Finally, this system works differently than those used for other notifiable disease, which limits the potential for coordination. Fischer closed with a few questions about how the system might be improved:

- Would human fever data provide a more complete picture of where human disease is occurring?
- Do animal and ecological data help predict human disease and provide timely warning of local outbreaks?
- Can the data be used to develop predictive models for arboviral disease risk factors or trends?
- Can the data be used to help perform clinical trials or postmarketing surveillance for a West Nile virus vaccine?
- Can the system help detect the introduction or emergence of a new domestic arbovirus (e.g., dengue fever, Chikungunya, Japanese encephalitis, or Zika)?

EMERGING INFECTIONS NETWORK

The final system presented was the Emerging Infections Network (EIN), which was described by Phil Polgreen of the University of Iowa. A project of the Infectious Diseases Society of America (and funded by CDC), EIN is a network of infectious disease specialists who contribute clinical data to assist CDC in identifying emerging diseases. In essence, Polgreen explained, EIN began with the goal of establishing a permanent system to allow rapid communication about symptoms that clinicians were seeing, how they were responding, and so forth—both among clinicians and with CDC. The goal was not to replicate systems already in place, but to fill in gaps.

EIN now has approximately 1,200 members who are pediatricians or internists throughout the United States, as well as approximately 130 public health officials. At any given time, Polgreen explained, four or five conversations may be underway on the listserve about symptoms that physicians are concerned about, many of which are not necessarily about emerging infectious diseases, but rather day-to-day clinical challenges. For example, he noted that the moderated listserve discussions addressed community-associated *Methicillin-resistant Staphylococcus aureus* (MRSA) and multidrug-resistant *Clostridium difficile* before official reports were available, based on novel, difficult-to-treat symptoms that were reported at the time.

EIN also conducts periodic surveys (73 have been done since 1997) as urgent issues emerge. These may be about drug shortages or toxicities, but also diseases such as Hantavirus Pulmonary Syndrome or West Nile. The surveys help establish the scope of a problem, common treatment responses, and other information to support CDC in determining what steps it needs to take.

In Polgreen's view, the system would be even more useful if it were expanded to include electronic communities in other countries and veterinary providers, and if more communications among members were facilitated. Part of the solution would be technological. The current volume of e-mails and surveys is already high, but certain tools could be used to link groups and databases and thus help to focus, aggregate, and disseminate information more effectively. Polgreen observed that work is being done on electronic networks in other contexts that could provide useful ideas.

DISCUSSION

The session closed with a panel discussion of early warning systems. Presenters were asked to reflect on whether the current ad hoc arrangement is adequate, to identify any gaps they see, and to suggest pathways to improving disease surveillance.

An Ad Hoc System

The presentations made clear that, as a participant observed, "there are a lot of networks out there. There are a lot of listserves doing a lot of things." On the other hand, though, there is some overlap and redundancy, and in many cases critical communication and coordination that would make these networks of greater value is lacking. The discussion began with a question to the representatives of the disease surveillance systems that were presented in this session: "do you all interact with one another?" The panelists responded that they do sometimes, but not in any regular, coordinated way.

The panelists acknowledged the complexity involved with conducting surveillance all over the world and coordinating findings and responses. One panelist noted that "most of these surveillance systems have arisen because of opportunity." Participants noted that redundancies may exist, and the result may not be ideal, but whether some kind of "global design" would be preferable is not completely clear. The current arrangement "has certain attributes, which, if you designed it top-down, you might not be able to design in." It may not be possible to develop a system that "fits all the needs out there," another panelist, "nor will there be buy-in from everybody on a global system."

Even within a single country, there are a range of preferences and needs, so different systems have been developed to meet them. Many countries have complicated approaches to collecting public health data, and it is important that disease surveillance efforts and programs provide countries and officials with a strong, positive incentive to participate. A neutral, credible, scientifically-technical agency can substantiate response and control efforts by country officials, and help them in their preparedness efforts. Even under the best-case scenario when country officials have responded appropriately and in a timely manner, some ministers of health have lost their jobs because there was a disease outbreak in the first place. On the other hand, it may be more difficult for a single entity or structure to sustain that trust in every part of the world.

Contemplating these complexities, several participants made the point that "our efforts might be better directed at trying to understand what the data are telling us rather than getting different forms of data."

Gaps

On the other hand, a number of participants commented on important gaps in the current system. Looking broadly, participants noted that in terms of the widely shared goal of "looking at humans and animals and plants together, we are not really doing that enough. We are just beginning to do this." One aspect of that challenge is that the national notifiable disease system, at least in the United States, addresses only part of the surveillance challenge. Adding or linking to diseases in animal populations to the broader picture will require additional effort.

The other major gap relates to geography and resources. The basic problem of "developing countries not being able to pay for" disease surveillance efforts translates into a range of problems, noted one participant. Another pointed out that developing countries may lack "sufficient funds for computers, a reliable working electrical system, and access to the Internet." Thus communications are a challenge, data are not collected and reported, and information about evidence of disease or health practices is difficult to disseminate. Developing countries frequently lack personnel capacity to carry out surveillance to detect outbreaks, to conduct disease outbreak investigations, and to respond once an outbreak is identified, and international groups may face additional challenges in "quickly identifying the best people" on the ground to participate in a rapid response. Consequently, some regions are poorly represented in surveillance systems, which are often hotspot regions with a high likelihood of emerging diseases where surveillance is most needed. In short, participants agreed that is critical to build capacity for sustainable, long-term disease surveillance and response.

Discussants noted several creative responses to resource challenges, including the use of cell phones to improve communication in remote areas as more countries invest in cell phone technology. By applying such innovative solutions to known obstacles, existing disease surveillance systems have the virtue of some flexibility. On the other hand, though, many seemed to agree that "we have to go beyond just sending out alerts and receiving signals and learn how to put people in touch with each other." New technologies and Internet tools may make significant improvements possible, but "what we really need is information, usable information." In the end, one participant noted that it will be key to identify the critical priorities. The existing networks prove that disease surveillance is clearly achievable if it becomes a priority within the broader context of disease prevention, response, and control.

5

Laboratory and Epidemiological Capacity

The workshop focused on issues related to laboratory and epidemiological capacity because countries depend on diagnostic systems to detect human and animal diseases and to conduct disease surveillance. Presentations addressed the following topics: laboratory capacity in resource-constrained countries, the activities of OIE Reference Laboratories, personnel training, and the standardization of assays worldwide. Finally, two case studies focused on the experience and challenges in establishing a sustained operation of laboratories in Tanzania, and on clinical laboratory and epidemiological field training in Southeast Asia.

VETERINARY AND AGRICULTURAL LABORATORY CAPACITY IN RESOURCE-CONSTRAINED COUNTRIES

James Pearson, former director of the National Veterinary Services Laboratory and senior staff member of the World Organization for Animal Health (OIE), provided an update on veterinary and agricultural laboratories in resource-constrained countries. He began by describing the laboratory biosafety standards that have been established to protect humans, animals, and the environment. Both the World Health Organization (WHO) and the U.S. government have published laboratory standards for humans and the environment, he noted, while OIE has developed standards for protecting animals and the environment (OIE, 2004; WHO, 2004; PHS/CDC/NIH, 2007). These standards overlap significantly. Pearson provided an overview of four containment levels[1] spelled out in these standards.

Pearson explained that the key laboratory capacity issue is that many procedures for higher levels of biosafety are difficult for resource-constrained countries to establish or maintain. Specifically, he explained, biosafety level 2 (BSL-2) laboratories are widely used and available, but, as far as he is aware, few if any laboratories meet all the requirements for BSL-3 in resource-constrained countries. If true, this means that many countries lack the capacity to isolate viruses such as avian influenza. The few BSL-3 laboratories that do exist in underresourced regions—Morocco, South Africa, and Thailand each have a BSL-3 laboratory—may provide support to other countries as well. In general, the high cost of some of the equipment, such as animal inoculation cages, is a principal impediment to setting up a laboratory that meets higher biosafety level requirements.

Pearson also noted that few postmortem facilities in resource-challenged countries are meeting even BSL-1 standards, so that personnel may be exposed to significant risks. The alternative to using facilities that lack sufficient protection is for personnel to conduct testing in the field, wear HAZMAT suits, and bury the animal. This approach, however, may not provide adequate protection. The skill and training of staff are critical, he added. Upgrading training (e.g., training that covers clinical signs, diagnostic tests, optimal response, and disease reporting and control) may be a higher priority, in many cases, than establishing laboratories that meet higher levels. In Pearson's view, resource-constrained countries in general have conscientious laboratory workers who have received excellent training and have much of the equipment and supplies they need. On the other hand many resources are in short supply, such as facilities with capacity above BSL-1, specialized equipment (e.g., biosafety cabinets), and electric generators. Field forces are small, many personnel need more sophisticated training, and surveillance systems are not providing sufficient samples from the field. He summarized the situation by observing that BSL-2 laboratories are widely used and available in many countries. Although access may not

[1]These recommended containment or biosafety levels (BSL) describe safe methods for managing infectious materials in the laboratory environment where they are being handled or maintained. There are four BSLs, with BSL-1 representing a basic level of containment relying on standard microbiological practices and BSL-4 representing the most advanced containment when working with dangerous and exotic agents that pose a high individual risk of life-threatening disease (which may be transmitted via the aerosol route and for which no vaccine or therapy is available). The increasing numbers correspond to the increasing levels of protection for personnel and the environment. The purpose is to reduce or eliminate exposure of laboratory workers, other persons, and the outside environment to potentially hazardous agents. Each combination is specifically appropriate for the operations performed, the documented or suspected routes of transmission of the infectious agents, and the laboratory function or activity (PHS/CDC/NIH, 1999, 2007).

always be controlled in these labs, "the personnel with excellent training are doing a lot of good, accurate diagnostic work" despite inadequate equipment, lack of reagents, and supply- or cold-chain management challenges. He also noted that few countries have BSL-3 or BSL-4 laboratories. A few of the BSL-2 laboratories incorporate some BSL-3 precautions, and many receive other support from OIE Reference Laboratories (discussed below), but limited resources and poor infrastructure have restricted disease surveillance and laboratory response in some countries.

THE REFERENCE LABORATORY PERSPECTIVE—THE GLOBAL H5N1 CRISIS

Ilaria Capua, of OIE, used the example of the highly pathogenic avian influenza (H5N1) crisis to illustrate the role that the OIE Reference Laboratories—one or more laboratories designated as centers of expertise on one of the animal or human diseases OIE monitors—play in disease surveillance and response. Altogether, OIE has established a network of more than 160 Reference Laboratories in 32 countries, covering 95 diseases. Capua listed the principal responsibilities of those laboratories:

- Assist countries in diagnosis of index cases;
- Confirm laboratory results;
- Provide training on avian influenza diagnostic techniques;
- Produce and supply reference reagents; and
- Provide advice and support for the management and control of the disease.

Capua set the stage with a quick description of the H5N1 virus, noting that it is "the most aggressive virus in the animal kingdom—[inducing] a devastating disease, capable of killing birds within 48 hours of infection." Once considered a rare disease, it is now capable of infecting approximately 50 bird species and 10 mammal species, she noted, and is endemic in poultry on at least three continents. For every human infected, at least 1 million animals are infected. Thus, the disease is a threat to food security for developing countries, and also presents a unique threat compared to past disease because it is the first highly pathogenic one to become endemic in such a vast area. In short, it is "an enemy that we don't really know very well."

The current epizootic of avian influenza reached Africa in January 2006. Africa was not prepared, Capua explained, though the OIE Reference Laboratory community quickly realized that the virus would spread and "there would be no way to stop it." Africa had not previously experienced a highly pathogenic avian influenza epizootic, and most African countries lacked an early warning system in their poultry populations.

Veterinary diagnostic services were completely unprepared to detect and diagnose highly pathogenic avian influenza (H5N1), and few understood the relationship between wild bird ecology, husbandry practices, and the spread of the disease. Moreover, birds succumb to many lethal infections on the African continent, so the spread of highly pathogenic avian influenza (H5N1) was not immediately seen as a priority. As a result, significant delays in notification occurred—15 to 34 days elapsed between the initial event and notification to OIE in the countries first affected.

Since the highly pathogenic avian influenza (H5N1) crisis began, however, OIE has increased the number of veterinary laboratories diagnosing avian influenza, implemented training and networking in a number of countries, and increased funding for disease surveillance of wild and domestic birds.

That example illustrated both the gaps in the system and its capacity to respond. But Capua also considered the question of sustainability. She presented data from a 2007 Food and Agriculture Organization of the United Nations (FAO) survey of 20 western and central African countries that showed most of those countries have adequate laboratory infrastructures, though "the quality of the facilities and the diagnostic performance is heterogeneous—from zero to 10." Laboratory staff are present and have received basic training. Equipment is available, though in some cases no personnel are available to maintain it. On the other hand, two of the countries surveyed have no facilities, and an additional three had facilities that were not functioning at the time of the survey. Many laboratories need renovation or upgrades, and many staff need customized training on specific issues. Laboratories surveyed also lacked reagents because of cost, lack of local suppliers, or rapid deterioration in extreme environmental conditions. Most important, Capua explained, is that in most laboratories diagnostic activity is limited by a lack of samples to be tested, perhaps because funds for surveillance and monitoring are limited. In response to these deficiencies, Capua explained, OIE has focused on involving veterinary services in international research projects and developing other strategies to build international connections.

Capua closed her remarks with a discussion of the vital importance of sharing information. Information sharing is vital because it is very likely that "whatever viruses are predominant in animals will be the cause of human infection," she explained, and because it is primarily veterinarians who possess the isolates that will be the key to preparing for a pandemic. She continued by mentioning that "interpreting information available from evolving animal viruses on a permanent basis" is the way to prepare, yet there are often significant delays between the isolation of particular viruses and publication of papers documenting such findings. OIE has made the sharing of this type of information a formal goal. Capua expressed hope that in the future, the global influenza programs that identify which mutations are dangerous and which regions are particularly at risk will work together with OIE, which has sequence and epidemiological information, to develop a common research and policy agenda to maximize the benefits of their work.

THE APPLICATION OF NAHLN PRINCIPLES TO INTERNATIONAL ANIMAL HEALTH EFFORTS

Within the United States, laboratories that provide veterinary diagnostic laboratory capacity for foreign animal disease surveillance are coordinated through the National Animal Health Laboratory Network (NAHLN). This network, created in response to a Department of Homeland Security directive, is designed to coordinate laboratory capacity at the state and federal levels for early disease detection, rapid response, and appropriate recovery to animal health emergencies. Barbara Martin, the network's coordinator, explained that NAHLN is a partnership of the Cooperative State Research, Education, and Extension Service (CSREES) of the U.S. Department of Agriculture (USDA), and the American Association of Veterinary Laboratory Diagnosticians. According to the NAHLN website, the network includes 58 laboratories (including 2 national laboratories) in 45 states. Martin also noted their collaborative, international training activities with universities, the USDA's Animal and Plant Health Inspection Service, Agricultural Research Service, and Foreign Agricultural Service; the Department of Defense; and the United States Agency for International Development (USAID).

The three purposes of this network are early detection, rapid response, and appropriate recovery. The network focuses on:

- Standardized, rapid diagnostic techniques;
- Trained personnel and modern equipment;
- Quality standards and proficiency testing;
- Secure communication and rapid reporting systems;
- Adequate biosafety and biosecurity measures; and
- Scenario testing.

Based on the coordinated approach NAHLN has established, Martin explained, the infrastructure and expertise of the nation's veterinary diagnostic laboratories are deployed in an efficient, strategic manner. An important part of their coordinated approach is to "get rid of the black-box syndrome," that is, to help animal health officials to better understand what the laboratories do and what constraints they face. Through drills and simulations, they have worked to involve as many people as possible in preparation for a range of scenarios. "Partnerships are key to everything that we do," Martin explained. Through strategic combinations of state and federal resources, they have supported standardized surveillance for high-priority diseases.

NAHLN has also provided training for avian influenza viruses, foot-and-mouth disease (FMD), and brucellosis to laboratory scientists in 60 countries as part of a long-term goal of developing diagnostic expertise worldwide. The training, which has focused on resource-challenged countries, has addressed proficiency in conducting assays, maintaining biosafety and biosecurity standards, and developing country reference standards, as well as training for individuals who can then serve as trainers at home. The network has found success with this effort, particularly in building communication networks in other countries. However, because international training is not part of the network's core mission, finding funds to sustain this training is challenging. As discussed earlier, laboratories in resource-challenged countries often lack adequate resources, so it is difficult for them to sustain the testing standards and procedures in which they were trained. Despite these challenges, Martin believes the NAHLN approach is a "practical stepwise approach to building capacity" internationally. The key question is "where would the commitment and resources come from?"

LABORATORIES IN TANZANIA

Tanzania is a resource-constrained country that faces challenges in establishing and sustaining laboratories, as described by Mmeta Yongolo of Tanzania's Central Veterinary Laboratory. Yongolo suggested that Tanzania is a critical country from an integrated human and animal health perspective. One third of the country is national park land, and there is "great diversity from the snow-capped mountain to organized animal preserves," as well as extensive interaction among livestock, wildlife, and humans.

Tanzania has a long tradition of collaborative laboratories, dating back to the country's early colonial era. However, economic fluctuations and changing levels of funding from the World Bank have resulted in significant cutbacks to the laboratory system. Today, Tanzania's new central laboratory has the capacity to deal with many emerging viruses (the country also has existing laboratories with traditional veterinary capacity). The Central Veterinary Laboratory can diagnose diseases using serology, DNA-based techniques, and embryonated chicken eggs (ECE) and mice virus isolation techniques. The range of diseases include, but are not limited to Rift Valley fever (RVF), FMD, highly pathogenic avian influenza (H5N1), African swine fever, Newcastle disease, rabies, rinderpest, and contagious bovine pleuropneumonia. Its staff is supplemented with medical and veterinary experts supplied by FAO, the University of Minnesota, USAID, OIE, and the United Nations Children's Fund (UNICEF).

Nevertheless, Tanzania faces significant challenges. The central laboratory does not have the capacity to deal with all of the human and animal disease threats in the region, which include Ebola, Marburg, yellow fever, dengue fever, RVF, and West Nile fever. Their prevalence is not known and they are not well mapped, the host populations have not been well studied, and other factors associated with them have not been studied. Several other potential zoonotic diseases are suspected to be present in the region—Bunyamwera, Pongola, Babanki, Semliki, and Sinbis viruses—yet their distribution and prevalence are not well documented, and further research is needed on their biology and ecology.

Tanzania's laboratories also lack sufficient equipment, reagents, and trained personnel, and have not been able to fully comply with biosecurity and biosafety guidelines. All of these problems could be addressed with greater resources, but Yongolo explained that the national government has had only a limited appreciation for the urgency of the problem. Tanzania's government must address hunger, widespread poverty, educational deficits, and other challenges in a constrained economic climate. And even given the importance of animals and animal health to not only the macro economy (e.g., eco-tourism in national parks which cover 1/3 of the country) but also to individual livelihoods, the laboratories are very dependent on foreign donors.

Collaboration with a number of international partners has also been a very important asset for Tanzania's public health system. Current partners include the Muguga Laboratory in Kenya; the Botswana Vaccine Institute; Veterinary Laboratory Agencies in the United Kingdom; the National Veterinary Services Laboratory in Ames, Iowa; and the University of Minnesota. Through these collaborations, the central laboratory has been able to handle or process many more samples than it could on its own, to reduce handling risks, and to confirm results. Yongolo suggested that a much greater degree of international collaboration would be the best way to improve disease detection, identification, and monitoring. He believes "the way forward is to establish a disease and virus survey" to better map diseases. "All of this can be done if we have long-term programs, not short-term programs."

BUILDING EPIDEMIOLOGICAL CAPACITY TO ADDRESS EMERGING INFECTIONS IN AFRICA

The Centers for Disease Control and Prevention (CDC) have focused significant attention on building laboratory and epidemiological capacity in strategic global locations that can serve regions with high threats and low resources. As part of a global strategy to monitor and respond to emerging infectious threats at the local, regional, and global levels, Robert Breiman of CDC-KEMRI[2] in Nairobi, Kenya, explained, that CDC has established the International Emerging Infections Program (IEIP). IEIP has five laboratories located in China, Egypt, Guatemala, Kenya, and Thailand. Breiman focused on his laboratory in Nairobi, the Kenya Medical Research Institute (KEMRI).

Although Kenya's IEIP laboratory was designed to establish diagnostic and epidemiological capacity, it also conducts public health research and contributes to intervention strategies for high-impact diseases. The cornerstones of the program are disease surveillance, rapid response to outbreaks, training and building local capacity, and applied research. When the laboratory opened in 2004, it was immediately faced with an outbreak of aflatoxicosis, but has also been deeply involved with cholera, typhoid, brucellosis, Chikungunya, and RVF.

The RVF outbreak, Breiman explained, highlighted the weaknesses of the veterinary surveillance and response system in the region—as well as the importance of establishing a center that would address human and animal health issues together. It also highlighted the importance of laboratory capacity, and the KEMRI has created two small BSL-3 labs that process specimens from throughout the region. KEMRI also has a partnership with the International Livestock Research Institute, and they are hoping to build capacity for veterinary surveillance through that partnership.

KEMRI is involved in several types of disease surveillance. Their primary surveillance objectives are to identify and characterize new or emerging pathogens for human and select animal diseases, establish public health priorities in rural and urban settings, and provide a platform for evaluating the impact of interventions that have targeted high-priority diseases.

KEMRI's strategies include population-based surveillance in one rural and one urban site, which entails surveying the target populations (totaling 55,000 people) every 2 weeks for respiratory and febrile illnesses and diarrheal disease. KEMRI sees 600 to 900 cases per 100,000 children each year. Free clinic care is available and specimens are collected, and the surveillance uncovers a range of problems. Perhaps most severe is bacteremic typhoid fever.

KEMRI has a national reporting system that uses integrated disease surveillance and response and conducts sentinel surveillance in hospitals and refugee camps. To work around the lack of computer capacity in remote regions, KEMRI has also been promoting the use of cell phones

[2]CDC's Kenya International Emerging Infections Program through the Kenya Medical Research Institute began in 2004 to establish diagnostic and epidemiological capacity in Kenya to address diseases of epidemic potential. The program is contributing to the development and widespread use of interventions to address high-impact diseases while conducting public health research of local, national, regional, and global importance (Breiman, 2008).

and text messaging to find out about disease rumors that need investigation. Through its surveillance program, Breiman explained, KEMRI hopes to understand the incidence and prevalence of zoonotic and epizootic diseases in coexisting human and animal populations, the risk factors for humans and animals, and the potential of animal sentinels to provide early warning.

Breiman noted what he calls one of KEMRI's "most valuable contributions" to the epidemiological capacity-building efforts: the Field Epidemiology and Laboratory Training Program (FELTP), an M.S. degree-granting public health program in applied epidemiology or laboratory management for Ministry of Health staff. The program is training its fifth cohort of students, which includes 20 residents from several countries. Thirteen graduates of the program, which is being expanded to include veterinarians as well as medical personnel, are now employed in the Kenya Ministry of Health, which previously lacked staff with significant epidemiological training. Some are holding leadership positions for integrated surveillance efforts, some are working in the reference laboratory system in Kenya, and some are serving as provincial medical officers and medical epidemiologists. KEMRI's new effort to include veterinarians in the cohorts is significant, as is their outreach to the Ministry of Agriculture to bring a concerted focus to disease surveillance issues that affect the intrinsic connection of human and animal health.

LABORATORY AND FIELD TRAINING IN SOUTHEAST ASIA

Another region with high population density, low resources, and high incidence of infectious disease is Asia. Jeremy Farrar of the Hospital for Tropical Diseases in Ho Chi Minh City, Vietnam, described conditions in that region. With half of the world's human population and more than three-quarters of the world's poultry living in South Asia, policies that work across political borders are of paramount importance in containing diseases. The sheer population density in India and China, he explained, places a tremendous burden on their public health systems, and public health for that region is important to the whole world.

Echoing some of the earlier discussions, Farrar pointed out that Asia is a disease hotspot because it is particularly fertile ground for zoonotic pathogens to emerge from wildlife and domesticated animals, and for drug resistance to develop. He views drug resistance as "the world's most important emerging health problem." Farrar reported that infectious disease accounted for 25 percent of all deaths in the patient population of the Hospital for Tropical Diseases in Ho Chi Minh City, Vietnam—a facility with 600 beds dedicated to infectious disease patients, with more than 1,000 patients annually, and serving a population of nearly 40 million Vietnamese.

He also noted that as many as 90 percent of infectious diseases worldwide are generally not diagnosed. Other lethal pathogens include severe respiratory infection, diarrhea, malaria, severe dengue fever, and typhoid. “For all of these, Asia is the champion of the World Series,” he suggested, because of the burden of existing endemic disease, drug resistance, and the frequent emergence of new pathogens.

Looking forward, Farrar believes the most promising approach to sustainable global disease surveillance and response is international collaboration, but he was careful to say that large, international organizations are only part of the answer, and that “sustainable collaborative work must be based close to where the problems are.” Clinical and scientific capacity that is locally rooted is critical, which means that “we have to bridge that biotechnological divide, and bring that knowledge base to where things are that matter.” He illustrated the point with the example of the international response to the highly pathogenic avian influenza (H5N1) outbreak in Hong Kong in 1997. Experts flew to Hong Kong from around the world, and he observed that: “you almost could not get a flight.” Farrar explained that the efforts of CDC, WHO, the academic research community, and others were clearly valuable in that crisis, but expressed his personal view that the local response was most critical. Thus, he suggested, the challenge is to develop a new model. First, training should move from the academic centers in the West to where the problems are. A BSL-3 laboratory is only as strong as the individuals who staff it, and it would be far easier to train adequate numbers of expert personnel in high-need countries if more educational opportunities were made available where the need is greatest. Second, structures need to be developed to build collaboration and trust across institutions. This means sharing of data and samples and linking together various research centers. It also means linking the fields of public health, clinical science, and animal health, which have been “existing in parallel” for too long.

DISCUSSION

The committee was eager to focus on opportunities and challenges for strengthening surveillance capacity to prevent, detect, and respond to emerging infectious diseases around the world. Thus, they structured the discussion around themes that emerged from this section’s presentations, but focused on a few big questions. First, many speakers advocated integrating resources that are currently dedicated to human health, agricultural safety, and animal health, and urged that resource integration be done at every level, from local field-based activities, through laboratory and reporting systems, and up to the highest policy levels. Yet questions remained about the feasibility of making this degree of integration a reality, and the group was asked to reflect on the challenges.

No one questioned the value of greater integration, and numerous examples of specific collaborations were offered, but the challenge is clearly great. A participant observed that even within the United States, government agencies "don't always talk to each other," and that looking internationally, "getting them to work and think collectively before a crisis is key." Participants also identified more practical challenges: for example, combining resources seems particularly logical in resource-challenged countries, but setting up and running a laboratory that meets international biosafety standards and protocols for both human and veterinary laboratory testing procedures could be a significant challenge.

Others noted the cultural divide between the human and veterinary health communities. Because they have different cultures and generally train and work separately, the two groups often lack mutual respect and trust. Specific structures for developing communication and opportunities for collaboration are therefore clearly needed. The prevailing sentiment seemed to be that greater integration is a widely shared goal and that it will come with time, but only when they focus their attention on maximizing the currently available funding streams.

The rest of the discussion focused on the challenge of achieving long-term sustainable capacity around the world. Participants identified models of success that potentially could be replicated. The International Center for Diarrheal Disease and Research in Bangladesh, for example, has attracted international funding and provided competitive salaries, while providing opportunities for Bangladesh citizens to move up within the system and operate on an international level. At the same time, however, others suggested it is misguided to "see this through the prism of insisting that in a defined period of time these things will be [able to] stand alone without international funding and without international input." It is important to understand that disease surveillance and response in high-risk regions of the world are critical for protecting everyone's health. Moreover, it was suggested, the United States should be the first to recognize the benefits it has received from the international focus of its scientific work—"it [the U.S.] attracts some of the best people from around the world to come and work here, and America benefits from that."

Nevertheless, international grant funding tends to come in 3- to 5-year tranches and "the ministries know that at the end of 3 years it is gone." Thus, policy planning is organized around these short time frames. But, it was suggested, "We need to encourage cooperation in the long term—not just when Washington or London is worried about H5N1." Developing human capacity will require longer timelines: "You are not just talking about 3 years to train somebody or a week in a training program," and the reality is that "you can't build infrastructure and you can't develop people without having the financial resources." Participants pointed to creative strategies, such as developing funding packages that could only be used for projects that involve collaboration across sectors. Industry and the private sector were also cited as a relatively untapped resource.

Technology offers potential solutions to many of the challenges of coordination, remote field work, and rapid response, and a large technology company such as Google has the potential to offer valuable support with data management, software, and related resources. The question was raised, in that context, whether technology—hand-held devices, mobile diagnostics—could actually make it possible to bypass some of the current challenges facing central laboratories. Without a doubt, new technologies have already proven to be valuable in many contexts, but participants agreed that reference laboratories are still necessary, and that a true technological replacement remains "a long way off."

6

Concluding Participant Discussions on Facilitating Communication and Developing a Globally Sustainable Surveillance System

The committee used the closing discussion session to pull together the most important themes that emerged from the presentations and discussions. The conversation covered a range of issues and is organized in this chapter with a focus on some primary observations.

The goal of improving communication and information exchange is widely shared, and significant progress has been made.

A number of systems and mechanisms for detection and reporting are in place, and in general, working well. As previously suggested, there is overlap, and sometimes the missions of the entities involved are in conflict, or at least not well synchronized. Nevertheless, "there [is] an ever-increasing amount and varying levels of quality of data coming in." Networks have been established that facilitate communication on the local level and build the trust necessary to facilitate data sharing and reporting, and the number of these networks are increasing.

One suggestion was that the human health community is "much better prepared to deal with risk communication—preparing the right message with the right language for the right audiences" than the veterinary community has been, but that the veterinary community is catching up. Participants remarked that one lesson from the H5N1 avian influenza crisis was the value of making sure that "when WHO speaks, when OIE speaks, when FAO speaks, the message is the same," referring to the World Health Organization (WHO), the World Organization for Animal Health (OIE), and the Food and Agriculture Organization of the United Nations (FAO). The crisis was an opportunity for the human and animal-concerned communities to work together and to better integrate the challenge of communicating with governments and the public while they responded to a crisis.

At the same time, however, another participant noted, "We have told the world a pandemic is coming, a pandemic is coming, and it hasn't happened." Public attention has waned, and this illustrates the importance of "thinking carefully about addressing people's concerns, especially nonscientific concerns." Public and political attention generally flows to a crisis.

The challenge of communication is not simply a matter of public relations, as several participants noted. It is the primary tool for tackling major objectives, such as changing behaviors to reduce public health risks. Understanding the needs and characteristics of a community can be critical to communicating effectively about human and animal health risks, and progress is being made in this area. A participant cited the example of WHO, which uses expertise from anthropology and risk communications to go into the field and explain the measures that need to be taken.

A variety of factors complicate the pursuit of the goal of improved communication and information exchange.

Many disease surveillance and reporting systems are in place, but the sheer volume of effort required to keep up with the flow of information can sometimes be dauting. As one participant observed, "Sometimes when you are in the field you just want to work, and you don't want to send a report every night, and you don't want to have 20 calls or e-mails coming in on your phone. This is something that we have to manage."

Intellectual property issues are another significant challenge to improved information sharing. Competition among disciplinary fields, as well as the pressure individual researchers and research teams may feel to publish their own results, are counter-pressures to the benefits of sharing samples and data that others could use. With regard to reporting and sharing information, however, one participant suggested that there are really two separate questions. The first is whether epidemiological information that is collected should be submitted to a national or an international entity. The second is whether the data that are collected in the course of an outbreak will be shared with other researchers or organizations.

The sharing of agents, resources, and data is another gap related to the "upstream research agenda" and can be important not just for responding to an immediate crisis, but also for ensuring that longer term research challenges are met. An example from activities of the World Bank illustrates this challenge. The Bank's program for making "advance market commitments" involved the private sector to make sure that a necessary drug or diagnostic test can be developed without undue risk to the drug companies.

This approach also helped to avoid complications related to competition for information and data. But the issues around intellectual property are of particular importance when countries, for example, provide viral strains that are used to manufacture globally used vaccines. WHO has convened an interdisciplinary working group to address the issue of sharing influenza virus and sequencing data that would be based on mutual trust and transparency, but they have not yet achieved an agreement. "The issue is still the benefits. What benefits will be attached to this commitment of sharing the viruses?"

The presentations demonstrate the large number of research communities that have an interest in some aspect of zoonotic disease in humans and have insights to offer, which further complicates integration and communication. The wildlife biology community, for example, is rarely represented in public health discussions, and "a lot of wildlife biologists don't think disease is an issue in wildlife population ecology." Yet ecology—the way organisms interact with each other in a changing environment—is "an organizing principle" for understanding both epizootic and zoonotic diseases, and this integration is very important. Another participant described the potential contributions that could come from building on the Smithsonian Institution's Global Earth Observatories—a network of 29 existing and 2 planned global long-term ecological monitoring sites that have been monitored for up to 25 years—to contribute to the development of a systematic, long-term global emerging disease wildlife surveillance research program. The benefit of this public–private partnership could offer an unprecedented opportunity to look at disease in wildlife populations and the impact of human disturbance and climate change on disease dynamics.

Questions were raised about the incentives for sharing information and the potential benefits and risks of sharing. Governments or ministers with responsibility for public health may take into account the risk of severe economic disruption, unrest, or other consequences when an animal or human disease outbreak is announced. One participant offered the example of West Nile virus reporting in the United States to illustrate the power of incentives. For a time, any U.S. county that submitted a positive report of West Nile would receive federal funds to cover half of their cost of control measures. This created a competitive race to identify West Nile early in the season to secure the funds early. Indeed, the program was so successful it became too expensive and had to be discontinued for lack of funding.

The value of an integrated, sustainable global disease surveillance system needs to be made clear to human and animal health communities.

The issue of making the benefits clear goes beyond the challenges of sharing information among scientists and public health agencies. The question is, "If the main benefit is at the global level, why are we asking each country to invest in surveillance—what is the benefit for them?" In many cases, the short-term risks of identifying and reporting disease outbreaks may seem to outweigh any long-term benefits. Trade may be significantly disrupted even by the rumor of some disease, such as foot-and-mouth disease (FMD).[1] "This means that there are punitive sanctions for reporting, rather than punitive sanctions for not reporting," one participant noted. Moreover, many countries believe they may have the internal capacity to control an outbreak within their borders. Even if they do, this sets the precedent for other countries not to report an outbreak.

One proposal is to make the incentives clearer and more specific. As one participant explained, "We need to further define this 'global public good,' because whatever mechanisms are agreed on have high transaction costs." For example, if the international surveillance system were sufficiently recognized and trusted, a country could earn an official seal of approval for its internal surveillance system and standards that would be a trusted badge of good practice and safety. That benefit, in turn, could serve as an incentive for further cooperation. For example, a country could build confidence among trading partners that it can adequately detect and control animal disease, which may lead to its ability to geographically limit trade restrictions where regulatory frameworks permit.

Another proposed strategy is to better link sustainable disease surveillance to the broader notion of the environmental commons, which is gaining traction in the world of international finance, aid, and trade. The discussion of the interacting factors that contribute to the development of zoonotic diseases in humans demonstrated that emerging infectious diseases are an integral aspect of larger environmental concerns such as global climate. Yet, there has not been complete buy-in from the international community, and disease surveillance is too easily viewed as a kind of "old-fashioned," smaller scale activity by governments and other potential funders of surveillance efforts. One risk of this semi-marginal status is that funding and attention come in the midst of a crisis, not in time for adequate planning and preparation. As one workshop participant observed, "When you see people dying, you are already very late in the epidemic."

A participant also questioned whether we are "missing the ball" on biosecurity because "[disease] surveillance is a critical biosecurity tool."

[1]A false FMD rumor from a Kansas sale yard ran rapid through the market place in 2001, causing the cattle futures to drop dramatically and major companies relying on beef to lose valuable shareholder equity. The next-day market indicators of several major companies impacted by the false scare: Tyson Foods, Inc., down 2.6%; Smithfield Foods down $0.26; ConAgra shares down 1%; Outback Steakhouse, Inc. down 3.1%; Wendy's International down $0.07 (see http://www.newsratings.com/analyst_news/article_463143.html, "Meat Stocks Tumble," Wachovia Securities, 2004).

He cited the example of FMD to explain his point. The disease became a problem in the United Kingdom and in neighboring countries because of the lack of early detection and a delayed governmental response (NRC, 2005). As a lesson learned, strict international standards regarding the trade of animals and animal products are now in place and many countries that have invested considerable resources to eradicating the disease are now disease-free. The participant further observed "Those countries need to sustain their surveillance efforts or they will surely be re-infected." The countries that have already tackled their problems effectively are investing in "an insurance policy," stated participants, by helping countries that still have the disease work on monitoring and eradication.

The compelling message is that sustained global disease surveillance is a basic public health necessity because ongoing interactions among humans, animals, and the environment will inevitably lead to disease emergence or re-emergence and the impact of disease reverberates throughout national and global social, economic, and trade systems.

One participant suggested canine-rabies as an example that well illustrates the case that needs to be made. Canine-rabies is a fatal disease that is a significant problem in many parts of the world, and is both underreported and underestimated in terms of the harm it causes. Canine-rabies regularly travels from wildlife to domestic animals and humans, and thus is a good example of the interactions under discussion. More important, perhaps, is that when canine-rabies emerges it is an indicator that something has changed in a particular area—human or animal behaviors have changed in a way that allows the disease to take hold. It could never be truly eradicated, but it is relatively easy to control with vaccines and other measures.

The resource challenge cannot be ignored.

Canine-rabies is just one of many diseases that could be controlled, but is not controlled in many regions because resources are inadequate. All of the goals or ideas mentioned throughout the workshop are not without cost. Most of the presenters alluded to the challenges of sustaining funding for worthwhile programs and many highlighted problems in extremely poor parts of the world. These countries may lack vehicles, adequate roads, equipment, laboratory capability, and adequately trained personnel. The conditions of buildings and the varying academic rigor of medical and veterinary schools in many developing countries were cited as a significant obstacle. Others pointed out that "sustainability is not just training people once—it is a long-term investment in keeping people updated," providing them with opportunities to learn and work with each other, with career development opportunities, and so much more.

However, several participants commented that the human and animal health communities have not done a good job at demonstrating the return on investments for disease surveillance. It was noted that "Eventually the resource people are going to say, 'What am I going to get out of this and what is at risk if I don't do this?'" Demonstrating or documenting the benefits is complex and therefore is a challenge because the benefits are so complex. However, both the human and animal health communities need to make the case that the benefits of sustainable disease surveillance do not rest just in "a dollar return on investment, but in social, economic, and political stability." Participants suggested that the justifications for funding must be framed carefully: "Say you had prevented SARS, how would you prove it? Even if you made a good case, somebody else would say you didn't, that it would never have taken off and it was all a false alarm." Other discussants agreed, noting that if the case for disease surveillance efforts were made on the basis of a single pathogen, for example, "You are in for a line item removal when [the disease] doesn't happen." The stronger argument is that an investment has made the country better prepared for a range of ongoing, unpredictable risks.

Gerald Keusch, one of the workshop convening co-chairs, closed the meeting with a few final observations:

- Setting priorities for the expenditure of effort and resources is very important, but very difficult to do. In the case of HIV, for example, "the investments at the beginning were not consistent with the threat it actually became, but we weren't smart enough to know when to push."
- "Gaming the system is a fact of life" when it comes to scrambling for resources, "but is it the best or only way to proceed?"
- "With the exception of short-term threats from specific pathogens that are emerging, we have yet to figure out how to make a case for ongoing [disease] surveillance."

On behalf of the committee, Keusch ended the meeting by thanking the workshop presenters and participants, noting that a wide range of pertinent and interesting information had been shared with the committee and guests to address this challenging human and animal health issue.

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Appendix A

Committee Biographies

Gerald T. Keusch, M.D. (*Co-Chair*), is associate provost for global health at Boston University, and associate dean for global health at Boston University School of Public Health. Prior to this appointment, Dr. Keusch served as director of the Fogarty International Center at the National Institutes of Health (NIH) and associate director for international research in the office of the NIH Director. A graduate of Columbia College and Harvard Medical School, he is board certified in internal medicine and infectious diseases. He has been involved in clinical medicine, teaching, and research for his entire career, most recently as professor of medicine at Tufts University School of Medicine and senior attending physician and chief of the Division of Geographic Medicine and Infectious Diseases at the New England Medical Center in Boston, MA. His research has ranged from the molecular pathogenesis of tropical infectious diseases to field research in nutrition, immunology, host susceptibility, and the treatment of tropical infectious diseases and HIV/AIDS. He was a faculty associate at Harvard Institute for International Development in the Health Office. Dr. Keusch is the author of more than 300 original publications, reviews, and book chapters, and he is the editor of 8 scientific books. He is the recipient of the Squibb, Finland, and Bristol awards for research excellence from the Infectious Diseases Society of America, and has delivered numerous named lectures on topics of science and global health at leading institutions around the world. He is currently involved in international health research and policy with the NIH, the United Nations, and the World Health Organization (WHO). He has been a member of several Institute of Medicine (IOM) consensus committees, and is currently a member of the Board on Global Health and the Forum on Microbial Threats.

Marguerite Pappaioanou, D.V.M., M.P.V.M., Ph.D., Dip ACVPM (*Co-Chair*), is the executive director of the Association of American Veterinary Medical Colleges (AAVMC) in Washington, DC. Prior to joining the AAVMC, Dr. Pappaioanou held a joint appointment as professor of infectious disease epidemiology in the School of Public Health and College of Veterinary Medicine at the University of Minnesota. She also held numerous positions at the Centers for Disease Control and Prevention (CDC), most recently as acting deputy director in the Office of Global Health in 2004, and associate director for science and policy from 1999 to 2004. She co-coordinated the CDC's international response to the Severe Acute Respiratory Syndrome (SARS) and avian flu outbreaks in 2003, and served as the point of contact at CDC for Department of Health and Human Services (HHS) activities in Afghanistan and Iraq. As chief of Surveillance and Evaluation—Special Projects, AIDS Program, and as assistant chief for science, she led studies on AIDS and HIV infection, and survey design for a national system of HIV surveillance in 39 U.S. cities. She received the Charles C. Shepard Science Award for coauthorship of the scientific paper *Prevalence of HIV Infection in Childbearing Women in the United States*. Dr. Pappaioanou has received numerous awards, including the U.S. Public Health Service Commendation and Outstanding Service Medals; Award of Recognition, Association of Teachers of Public Health and Preventive Medicine; and the Robert Dyar Labrador Memorial Lectureship, University of California, Davis, 2002. She is a Diplomate of the American College of Veterinary Preventive Medicine and an honorary Diplomate of the American Veterinary Epidemiology Society for her contributions to progress in public health. She recently served on the National Research Council's (NRC's) Committee on Methodological Improvements to the Department of Homeland Security's Biological Agent Risk Analysis. Dr. Pappaioanou received her Ph.D. in comparative pathology and M.P.V.M. from the University of California, Davis, and her D.V.M. and B.Sc. from Michigan State University.

Corrie Brown, D.V.M., Ph.D., is the Josiah Meigs Distinguished Teaching Professor at the College of Veterinary Medicine, University of Georgia. Her research interests include pathogenesis of infectious disease in food-producing animals through the use of immunohistochemistry and in situ hybridization. She is active in the fields of emerging diseases and international veterinary medicine and currently serves as coordinator of activities for the College of Veterinary Medicine. Prior to joining University of Georgia in 1996, she worked at the U.S. Department of Agriculture (USDA) Plum Island Foreign Animal Disease Center for 10 years, conducting pathogenesis and control studies on many foreign animal diseases. Her bench research interests at University of Georgia have been focused on poultry diseases, and she works closely with the USDA facility in Athens that is dedicated to foreign diseases of poultry. In educational research, she has several grants to help promote awareness of foreign animal diseases and global issues in veterinary curricula and beyond. Dr. Brown is a Diplomate of the American College of Veterinary Pathologists. She also trained veterinarians in Afghanistan to perform animal autopsies to help prevent the spread of bird flu. She has published or presented more than 250 scientific papers and has testified to Congress on issues involving agroterrorism. Dr. Brown has served on many industrial and federal panels, and has been a technical consultant to numerous foreign governments on issues involving infectious diseases and animal health infrastructure. She has served on several NRC committees, including the Committee on Assessing the Nation's Framework for Addressing Animal Diseases and the Committee on Genomics Databases for Bioterrorism Threat Agents: Striking a Balance for Information Sharing. Dr. Brown received her Ph.D. in veterinary pathology with a specialization in infectious diseases from the University of California, Davis, and her D.V.M. from the University of Guelph in Ontario, Canada.

John S. Brownstein, Ph.D., is an assistant professor of pediatrics at Harvard Medical School, and has joint appointments in the Children's Hospital Boston Informatics Program at the Harvard-Massachusetts Institute of Technology Division of Health Sciences and Technology and the Division of Emergency Medicine. Dr. Brownstein was trained as an epidemiologist at Yale University, where he received his Ph.D. His research is dedicated to statistical and informatics approaches aimed at improving public health surveillance and practice. This research has focused on a variety of infectious diseases, including malaria, dengue, HIV, West Nile virus, Lyme disease, respiratory syncytial virus and influenza. He is also leading the development of several novel disease surveillance systems, including HealthMap.org, an Internet-based global infectious disease intelligence system. Dr. Brownstein has advised the IOM, HHS, and the White House on real-time public health surveillance. He has used this experience in his role as a board member of the International Society for Disease Surveillance. He has authored more than 30 articles in the area of disease surveillance. This work has been reported on widely, including pieces in *Science*, *Nature*, *The New York Times*, *The Wall Street Journal*, CNN, National Public Radio, and the BBC.

Peter Daszak, Ph.D., is the executive director of the Consortium for Conservation Medicine, a partnership among two schools of public health (Johns Hopkins, Pittsburgh), a veterinary school (Tufts), a school of environmental science (Wisconsin's Sustainability and the Global Environment), a federal wildlife health institution (United States Geological Survey's National Wildlife Health Center), and an international conservation non-governmental organization (Wildlife Trust). His research addresses the links among anthropogenic environmental change, wildlife diseases, public health, and conservation. He is especially involved in research on emerging diseases, in trying to understand their ecology and the factors that drive emergence. Dr. Daszak investigates anthropogenic environmental changes linked to disease emergence and how they influence host–parasite population dynamics. Current projects include studying the ecology of West Nile virus, Nipah virus (a disease that emerged from fruit bats to kill more than 100 humans in Malaysia recently), SARS, H5N1 avian influenza, and other diseases that cross the wildlife–human boundary. Dr. Daszak also works on wildlife emerging diseases that have conservation significance (e.g., amphibian chytridiomycosis, Partula snail microsporidiosis, testing hypothesized examples of extinction by infection). Dr. Daszak has a number of research projects investigating the role of trade in the spread of wildlife and human pathogens and the impact of this on public health and conservation. He recently served on the NRC's Committee on National Needs for Research in Veterinary Science. He is originally from Great Britain, where he earned a Ph.D. in parasitology and a B.Sc. in zoology.

Cornelis de Haan graduated with a degree in animal science from Wageningen University in the Netherlands in 1966. From 1966 to 1967, he worked in dairy research and development in Ecuador and in small-holder agriculture in Peru. He then moved to Africa, where until 1983 he occupied the posts of senior scientist and later deputy director general (research) of the International Livestock Center for Africa in Addis Ababa. He joined The World Bank in Washington, DC, in 1983, initially as senior livestock specialist for West Africa and later for Eastern Europe and the Middle East. From 1992 until 2001, he occupied the post of senior advisor for livestock development, responsible for the livestock development policies of The World Bank. Mr. de Haan is now retired, but still works as consultant on animal agriculture for The World Bank. His main interests are institutional aspects of livestock development, livestock and the environment, food safety issues and livestock and poverty reduction. He is part of a joint World Bank-United Nations System Influenza Coordinator task force called Beyond HPAI (highly pathogenic avian influenza), which will recommend institutional and funding mechanisms for a more permanent control of pandemics and other zoonotic diseases.

Christl Donnelly, Sc.D., M.Sc., is a professor of statistical epidemiology at Imperial College, London. Previously, she was head of the Statistics Unit at the University of Oxford Wellcome Trust Centre for Infectious Disease Epidemiology (1995–2000) and a lecturer in statistics at the University of Edinburgh (1992–1995). Her research focuses on the synthesis of methods combining sound statistical principles and insights from biomathematical models of disease transmission. She has considerable experience with SARS, bovine tuberculosis (TB), and avian influenza. Dr. Donnelly has been a member of the Bill & Melinda Gates Foundation's Schistosomiasis Control Initiative Technical Committee since 2002. She was the deputy chairman of the Independent Scientific Group on Cattle TB from 1998 to 2007, and contributed to the Office of Science and Innovation's project *Foresight—Infectious Diseases: Preparing for the Future* from 2004 to 2006. She was an advisor to the Spongiform Encephalopathy Advisory Committee from 1996 to 2003, and Bovine Spongiform Encephalopathy (BSE) and Sheep Subgroup member from 1998 to 1999. Dr. Donnelly was also a member of the Foot and Mouth Disease Official Science Group and the Joint Royal Society/Academy of Medical Sciences Working Group on the Science of TSEs in 2001. She was awarded the Distinguished Alum Award by the Harvard School of Public Health's Department of Biostatistics in 2005 and the Franco-British prize by the Académie des Sciences in Paris in 2002. Dr. Donnelly received her Sc.D. and M.Sc. in biostatistics from Harvard University and her B.A. in mathematics from Oberlin College.

David P. Fidler, J.D., M.Phil., B.C.L., is the James Louis Calamaras Professor of Law at Indiana University School of Law and is director of the Indiana University Center on American and Global Security. Professor Fidler is one of the world's leading experts on international law and public health, with an emphasis on infectious diseases. His books in this area include *International Law and Infectious Diseases* (Clarendon Press, 1999), *International Law and Public Health* (Transnational Publishers, 2000), *SARS, Governance, and the Globalization of Disease* (Palgrave Macmillan, 2004), and *Biosecurity in the Global Age: Biological Weapons, Public Health, and the Rule of Law* (Stanford University Press, 2008, with Lawrence O. Gostin). Professor Fidler has acted as an international legal consultant to WHO, the World Bank, CDC, the U.S. Department of Defense, and various nongovernmental organizations involved with global health or arms control issues.

Kenneth H. Hill, Ph.D., is a Professor at the Department of Global Health and Population at the Harvard School of Public Health. His research interests have been in the development of demographic measurement methods (particularly for demographic outcomes that are hard to measure, such as child and adult mortality, unmet need for family planning, undocumented migration); the measurement of child mortality (with particular emphasis on tracking national trends and linking them to other changes). They also include the exploration of links between demographic parameters and economic crisis; the impact of policy and programs on demographic change; the role of gender preferences on child health behaviors and fertility; the demography of sub-Saharan Africa; the role of development, particularly child mortality change, on fertility decline; the measurement of demographic parameters for populations undergoing complex emergencies; and measurement of adult mortality in the developing world: Africa, Asia, Latin America, and Middle East. Dr. Hill has also served on several NRC committees or panels, and has chaired both the Panel on the Population Dynamics of sub-Saharan Africa and the Working Group on Demographic Effects of Economic and Social Reversals.

Ann Marie Kimball,[1] **M.D., M.P.H., F.A.C.P.,** is professor of epidemiology and health services and an adjunct in medicine and biomedical and health informatics at the University of Washington. She also serves as the director of the Asia Pacific Economic Cooperation Emerging Infections Networks and the director of the Amauata Global Informatics research and training program. Dr. Kimball has devoted her career to studying health issues and has worked in numerous positions in the United States and abroad. Her research interests are primarily in international health, trade, HIV/AIDS, emerging infections, maternal and child health, and health informatics. In 2006, she published *Risky Trade: Infectious Disease in an Era of Global Trade* (Ashgate). Previously, she served as a member of the IOM's Forum on Emerging Infections, as a member of the Department of Health and Human Services' Emerging and Reemerging Diseases Strategic Planning Task Force, as regional advisor for the Pan American Health Organization in HIV/AIDS, and as the chair of the National Alliance of State and Territorial AIDS Directors in the United States. She has served as a U.S. delegate to the American Pacific Economic Council Health Working Group. Dr. Kimball received her M.D. and M.P.H. from the University of Washington, and her B.S. in biology and humanities from Stanford University.

Ramanan Laxminarayan,[2] **Ph.D., M.P.H.,** is senior fellow at Resources for the Future in Washington, DC. His research examines the integration of epidemiological models of infectious disease transmission and acquisition of bacterial and parasite resistance into the economic analysis of public health problems. His interest in "resistance economics" is focused on improving the analytical framework to study problems such as bacterial resistance to antibiotics and pest resistance to genetically modified crops. His research

[1]Appointed in September 2008.
[2]Appointed in September 2008.

activities relevant to this study focus on incentives for surveillance and reporting of infectious disease outbreaks. He has worked with WHO on evaluating malaria treatment policy in Africa, and has served on the IOM review panels for several reports, including *Malaria Control: A Reconsideration of the Role of DDT* and *Assessment of the Role of Intermittent Preventive Treatment for Malaria in Infants*. Dr. Laxminarayan received his undergraduate degree in engineering from the Birla Institute of Technology and Science in Pilani, India, and both his master's in public health and doctorate in economics from the University of Washington, Seattle.

Terry F. McElwain, D.V.M., Ph.D., is the executive director of the Washington Animal Disease Diagnostic Laboratory and director of the Animal Health Research Center in the College of Veterinary Medicine at Washington State University. He is past president of the American Association of Veterinary Laboratory Diagnosticians, and serves on the Board of Directors of the World Association of Veterinary Laboratory Diagnosticians. Dr. McElwain has been a key architect in the creation and development of the National Animal Health Laboratory Network, and has been closely involved in the development of the new School for Global Animal Health at Washington State University. He interacts with CDC, and is also a member of the governor's emergency preparedness task force in the state of Washington. He recently served on the NRC's Committee on Assessing the Nation's Framework for Addressing Animal Diseases. Dr. McElwain has a long, established research record in the field of veterinary infectious diseases, especially those of agricultural animals. He received his D.V.M. from the College of Veterinary Medicine, Kansas State University, and his Ph.D. from Washington State University.

Mark Nichter, M.P.H., Ph.D., is Regents Professor of Anthropology at the University of Arizona, holding joint appointments in the Departments of Family Medicine and Public Health. He has pioneered the use of ethnographic methods in the fields of medicine, ethnomedicine, and public health. Professor Nichter has conducted extensive research in developing countries as well as in the United States, and his research and writing has shaped the field of medical anthropology and addressed issues such as child survival, infectious and vector-borne disease, women's health, pharmaceutical use and drug resistance, and emerging diseases. At the University of Arizona, he has built a doctoral program in medical anthropology, and has chaired the work of more than 30 Ph.D. students. He has also helped train health social scientists and medical and public health researchers in India, Sri Lanka, Thailand, and the Philippines. He also played a pivotal role in developing an international clinical epidemiology network that operates in more than 41 countries. Professor Nichter has received some of the most prestigious awards in his discipline, including the Radcliffe-Brown Award from the Royal Anthropological Society and the Margaret Mead Award from the American Anthropological Association. The Society for Medical Anthropology awarded him the Virchow Award and most recently its Career Mentorship Award. Professor Nichter served as president for the Society of Medical Anthropology, and has most recently served as a member of the IOM Committee on the Use of Complementary and Alternative Medicine by the American Public.

Mo Salman, B.V.M.S., M.P.V.M., Ph.D., is professor of veterinary epidemiology in the Animal Population Health Institute of the College of Veterinary Medicine and Biomedical Sciences at Colorado State University. He holds appointments in the Department of Clinical Science and Department of Environmental Health and Radiological Sciences. His educational background is in veterinary medicine, preventive veterinary medicine, and comparative pathology. He received his veterinary medical degree from the University of Baghdad, Iraq, and a Master's in Preventive Veterinary Medicine and a Ph.D. from the University of California, Davis. He is a Diplomate in the American College of Veterinary Preventive Medicine and Fellow of the American College of Epidemiology. Dr. Salman is the author of more than 200 refereed papers in scientific journals and has participated in numerous conferences and national and international meetings in more than 25 years as a faculty member. He has served on the board of two scientific journals, *Journal of Preventive Veterinary Medicine* and *American Journal of Veterinary Research*. He is the section editor for the epidemiology section of *Animal Health Review* and serves on several national and international professional and scientific committees in the animal health sectors. He was the chair of the U.S. Animal Health Association Committee on Foreign and Emerging Diseases. Dr. Salman is engaged in research and outreach projects in more than 15 countries around the world. He participated in the peer review of the European Union scientific review for the geographical assessment for BSE and was elected to be on the European Food Safety Agency's Panel for Animal Health and Welfare. He is chair of the Continuing Education Committee of the Association for Veterinary Epidemiology and Preventive Medicine. He is the recipient of the 2007 American Veterinary Medical Association's XII International Veterinary Congress Prize for his contributions to international understanding of veterinary medicine. Dr. Salman's research interests are in the methodology of surveillance and survey for animal diseases, with emphasis on infectious diseases.

Oyewale Tomori, D.V.M., Ph.D., is vice chancellor of Redeemer's University in Nigeria. Dr. Tomori is also a Fellow of the College of Veterinary

Surgeons of Nigeria. Dr. Tomori worked as a regional virologist in Africa with WHO for many years and is a virologist of international repute. Within the past 30 years, he has carried out meaningful research studies on a wide range of human viruses and zoonotic and veterinary viruses, which are of immense public health importance in Nigeria and in Africa as a whole. The studies involve epidemiological and serological surveys for viral infections, the control of viral epidemics, the development of diagnostic tests for viral infections, the immunology of viruses, the pathology and pathogenesis of viruses, the development of viral vaccines, and characterization and ecology of viruses. Prominent among the viruses he has studied are the yellow fever virus, the Lassa fever virus, the poliomyelitis virus, the measles virus, the Ebola virus and a hitherto unknown virus, the Orungo virus, which he elucidated the properties of and registered with the International Committee of Virus Taxonomy. This discovery is considered an outstanding contribution to the discipline of virology. Professor Tomori is recognized as one of Africa's front-line Lassa fever researchers. He has developed a unique diagnostic virus neutralization test for the Lassa fever. His major contribution on yellow fever is the development of a technique for forecasting impending outbreaks of the disease, which has helped to put the country in a state of preparedness to combat the epidemic. Professor Tomori received his D.V.M. from the Ahmadu Bello University, Zaria, and his Ph.D. in virology of the University of Ibadan. He is a Fellow of the Royal College of Pathologists of the United Kingdom and a Fellow of the Academy of Science in Nigeria.

Kevin D. Walker, M.S., Ph.D., is a professor with the National Food Safety and Toxicology Center at Michigan State University and international advisor with the USDA Animal and Plant Health Inspection Service (APHIS). His current focus is the design and implementation of strategic initiatives where animal health, public health, and the environment intersect at the national and global levels. Dr. Walker's areas of expertise include animal diseases, economics, food safety, international trade standards and agreements, leadership, and policy. He previously spent 8 years as the director of agricultural health and food safety within the Inter-American Institute for Cooperation in Agriculture, based in Costa Rica, where he worked with national governments in the 34 countries in the Americas to enhance public infrastructure, leadership development, emerging issues assessments, and implementation of international trade standards and agreements. Prior to working overseas, he was the director of the Centers for Emerging Issues within APHIS/Veterinary Services. During this time the Centers carried out a variety of national risk analyses for emerging issues, including BSE, *E. coli* O157:H7, avian influenza, and tuberculosis. Dr. Walker has collaborated and worked with a large number of organizations, including the World

Trade Organization, the World Organization for Animal Health, the Food and Agricultural Organization of the United Nations, the International Plant Protection Convention, and the Codex Alimentarius. He recently served on the NRC Committee on Assessing the Nation's Framework for Addressing Animal Diseases. He is also a Fellow with the Kellogg Foundation.

Mark Woolhouse, Ph.D., is a professor of infectious disease epidemiology at the University of Edinburgh in Scotland. He held research posts at the University of Zimbabwe, Imperial College London Medical Research Council Training Fellowship), the University of Oxford (Beit Memorial Fellowship and Royal Society University Research Fellowship), and now Edinburgh (initially in the School of Veterinary Studies). He has worked on a variety of infectious disease systems: human schistosomiasis, involving extensive field work in rural Zimbabwe; verocytotoxigenic *E. coli* in cattle in rural Scotland; the epidemiology and transmission biology of foot-and-mouth disease (FMD) in livestock; trypanosomiasis in humans, cattle, and tsetse in East and Southern Africa; and transmissible spongiform encephalopathies in cattle (BSE) and sheep (scrapie). He has published more than 150 scientific papers on these and other topics. He advises the United Kingdom government on both animal and human health, and his work during the UK 2001 FMD epidemic led to an Officer of the British Empire award in 2002. Dr. Woolhouse is a Fellow of the Royal Society of Edinburgh. He trained as a population biologist with a B.A. from Oxford University, an M.Sc. from the University of York, and a Ph.D. from Queen's University before turning to epidemiology.

Appendix B

Workshop Agenda

DAY 1: JUNE 25, 2008

9:30–10:15 a.m.	**Registration and Check-in** All participants must check in at the security desk.

SESSION I: CHARGE AND STATEMENT OF THE PROBLEM

10:15–10:25 a.m.	**Welcome and Opening Remarks** *Marguerite Pappaioanou, Committee co-chair* *Gerald Keusch, Committee co-chair*
10:25–10:45 a.m.	**Charge to the Committee from the Sponsor** *Dennis Carroll and Murray Trostle, USAID*
10:45–11:15 a.m.	**Keynote Presentation: Convergence of forces behind emerging and reemerging zoonoses, and future trends in zoonoses** *Tracee Treadwell, CDC*
11:15 a.m.–12:00 p.m.	**Panel Discussion: The need for a global and sustainable surveillance system for zoonoses, and roles of various international organizations** *Moderator: Gerald Keusch, Committee co-chair*

Panelists
Nancy Cox, CDC
Stéphane de La Rocque, FAO
Marlo Libel, Pan American Health Organization, on behalf of David Heymann, WHO
Alejandro Thiermann, OIE
Tracee Treadwell, CDC

12:00–1:00 p.m. **Lunch on your own**
(speakers will have meal vouchers, committee to meet in closed session)

SESSION II: ACTIVE SURVEILLANCE SYSTEMS FOR DETECTING ZOONOSES
(Moderator: Mark Woolhouse, committee member)

Animal Health Surveillance Systems
This panel will discuss the varying methodologies used to conduct surveillance in different animal populations, including: poultry and livestock (for consumption), wildlife and exotic animals, marine mammals, and bushmeat. The presenters should:

- Briefly describe the surveillance activities/methodologies and current funding levels, special challenges to conducting surveillance in these different populations;
- Discuss the reliability/validity (including sensitivity and specificity) of data obtained from these surveillance systems, timeliness, access to data—how the data are shared/disseminated, what it would take to achieve sustainability over many years; and
- Highlight the major gaps and challenges.

The session will focus on international surveillance initiatives, rather than U.S.-focused programs.

1:00–1:15 p.m. **Global Early Warning System (GLEWS) and transboundary disease surveillance program**
Stéphane de La Rocque, FAO

1:15–1:30 p.m. **OIE standards for identifying/diagnosing diseases, diagnostic confirmation, data collection and reporting from countries, network of reference laboratories, relationships with Chief Veterinary Officers—committee work, food safety (Codex Alimentarius)**
Alejandro Thiermann, OIE

1:30–2:00 p.m.	**Surveillance and outbreak investigation of wildlife—terrestrial and marine animals, birds, Wildlife Disease Information Node** • Wildlife Disease Information Node—*Joshua Dein (on NBII), USGS National Wildlife Health Center* • Outbreak investigation—*Scott Wright, USGS National Wildlife Health Center*
2:00–2:15 p.m.	**Ebola surveillance in nonhuman primates** *Pierre Rollin, CDC*
2:15–2:30 p.m.	**Surveillance of bats** *Peter Daszak (for Jon Epstein), Consortium for Conservation Medicine*
2:30–2:45 p.m.	**Surveillance of bushmeat and exotic animal consumption and GAINS** *William Karesh, Wildlife Conservation Society*
2:45–3:00 p.m.	**Surveillance of infectious diseases in companion animals** *Larry Glickman, University of North Carolina, Chapel Hill*
3:00–3:45 p.m.	**Panel Discussion: Active surveillance systems, with presenters from Session II**
3:45–4:00 p.m.	**Break**

SESSION III: EARLY WARNING SYSTEMS FOR ZOONOTIC DISEASES IN HUMANS

(Moderator: Mo Salman, committee member)

4:00–5:00 p.m.	**Panelists will provide a brief description of the early warning system, discuss what works well in their systems, and more importantly, identify the gaps and challenges.** • Global Public Health Intelligence Network (GPHIN) *Marlo Libel, PAHO*

- Global Outbreak Awareness and Response Network (GOARN)
  Marlo Libel, PAHO
- ProMED-Mail
  Peter Cowen, North Carolina State University
- U.S. Department of Defense, Global Emerging Infections Surveillance and Response System (DoD-GEIS)
  Tracy DuVernoy, U.S. Department of Defense
- ArboNET
  Marc Fischer, CDC (via teleconference)
- Emerging Infections Network (IDSA)
  Philip Polgreen, University of Iowa

5:00–6:00 p.m. **Panel Discussion: Early warning systems, with presenters from Session III**

6:00 p.m. **Adjourn for the Day**

6:30–8:30 p.m. **Committee Working Dinner (closed session)**

DAY 2: JUNE 26, 2008

8:00–8:30 a.m. **Registration and Check-in**
All participants must check in at the security desk.

8:30–8:45 a.m. **Recap of Day 1 and Overview of Day 2 of the Workshop**
Gerald Keusch and Marguerite Pappaioanou, Committee co-chairs

SESSION IV: LABORATORY AND EPIDEMIOLOGICAL CAPACITY
(Moderator: Terry McElwain, committee member)

Panel members will have 15 minutes each to discuss the successes and challenges in developing laboratory and epidemiological capacity in resource-constrained countries.

8:45–9:00 a.m. **Broad view of veterinary/agricultural laboratory capacity in resource-constrained countries (clinical and field training, BSL-3 labs, biosecurity issues)**
James Pearson, former director of National Veterinary Services Lab (retired)

9:00–9:15 a.m.	**Reference lab perspective—experience serving as an OIE reference laboratory and providing technical assistance and training to countries in Africa on avian influenza; international policies for sharing specimens and resources and lab data** *Ilaria Capua, OIE*
9:15–9:30 a.m.	**Training and deployment of assays in other countries and standardization of assays worldwide** *Barbara Martin, coordinator for the U.S. National Animal Health Laboratory Network*
9:30–10:00 a.m.	**Experience and challenges in establishing and sustaining operation of laboratories in Tanzania with high-quality assurance** *Mmeta Grasford Yongolo, Virology Department of the Animal Diseases Research Institute*
10:00–10:15 a.m.	**Integrated emerging infectious disease surveillance in Nairobi, Kenya** *Robert Breiman, CDC International Emerging Infectious Diseases Program*
10:15–10:30 a.m.	**Clinical laboratory and epidemiological field training in Southeast Asia** *Jeremy Farrar, Oxford University Clinical Research Unit*
10:30–11:00 a.m.	**Break**
11:00 a.m.–12:00 p.m.	**Panel Discussion: Laboratory and epidemiological capacity, with presenters from Session IV**
12:00–1:15 p.m.	**Lunch on your own** (speakers will have meal vouchers, committee to meet in closed session)

SESSION V: FACILITATING INFORMATION EXCHANGE, IMPROVING COMMUNICATION, AND IMPROVING POLICIES

1:15–2:30 p.m. **Moderated Panel Discussion (20 minutes):**
Panelists: Ilaria Capua, OIE; Stéphane de La Rocque, FAO; Marlo Libel, WHO/PAHO; Sylvia Robles, The World Bank; Alejandro Thiermann, OIE (Gerald Keusch, moderator)

- International policies for sharing specimens and resources as well as laboratory and epidemiological data (speakers from WHO/PAHO and OIE); Indonesia incident
- Communication and interaction in outbreak investigations (speakers from WHO/PAHO, OIE, FAO)
- Economic and political constraints (OIE, The World Bank)
- Others?

General Open Discussion (25 minutes)

2:30–3:00 p.m. **Break**

SESSION VI: DEVELOPING A GLOBAL AND SUSTAINABLE SURVEILLANCE SYSTEM

3:00–5:15 p.m. **Moderated General Discussion: Developing global sustainable surveillance and response to emerging zoonoses**
(Gerald Keusch and Marguerite Pappaioanou, moderators)
Methodology, resources, interconnectedness, politics

- Sustainable versus surge
- Disease-specific sentinel surveillance versus Comprehensive and integrative surveillance
- Integration of tools for ongoing sentinel surveillance
- What's working, what's not?
- Where do we go from here?

5:15–5:30 p.m. **Closing Remarks**
Gerald Keusch and Marguerite Pappaioanou, Committee co-chairs

5:30 p.m. **Adjourn**

Appendix C

List of Workshop Participants

Mark Abdy, U.S. Department of Health and Human Services
Sam Adeniyi-Jones, U.S. Department of Health and Human Services
Shafiq Ahmed, George Washington University, School of Public Health and Health Services
Karen Becker, U.S. Agency for International Development
Brian G. Bedard, The World Bank
Rebecca Blank, U.S. Environmental Protection Agency
Douglas Boenning, Office of Science and Data Policy
Robert Breiman, Centers for Disease Control and Prevention–Kenya
Camille Brewer, U.S. Food and Drug Administration
Patti Bright, U.S. Geological Survey
Ilaria Capua, Istituto Zooprofilattico Sperimentale delle Venezie
Dennis Carroll, U.S. Agency for International Development
Michelle Cooper, Government Accountability Office
Tierra Copeland, U.S. Department of State
Peter Cowen, North Carolina State University
Nancy Cox, U.S. Centers for Disease Control and Prevention
Stephen Cunnion, Potomac Institute for Policy Studies
Stéphane de La Rocque, Food and Agriculture Organization of the United Nations
Josh Dein, U.S. Geological Survey, National Wildlife Health Center
Mary Denigan-Macauley, Government Accountability Office
Thais dos Santos, Pan American Health Organization
Cindy Driscoll, Maryland Department of Natural Resources
Joseph Dudley, Science Applications International Corporation

Jane Durch, Institute of Medicine
Tracy DuVernoy, U.S. Department of Defense-Global Emerging Infections Surveillance and Response System (DoD-GEIS)
Francois Elvinger, Virginia Polytechnic Institute and State University
Jeremy Farrar, University of Oxford
Julie Fischer, Henry L. Stimson Center
Mark Fischer, U.S. Centers for Disease Control and Prevention
Jeffrey Fox, Microbe
Alan Franklin, U.S. Department of Agriculture, National Wildlife Research Center
Harry Gedney, National Park Service
Zivile Gedrimaite, European Commission
Larry Glickman, University of North Carolina at Chapel Hill
A. Chevelle Glymph, District of Columbia Department of Health
Jennifer Gregory, U.S. Government Accountability Office
Louise Gresham, Global Health and Security Initiative
Stephen Guptill, Guptill Geoscience
Carole Heilman, U.S. National Institutes of Health
Lisa Hensley, U.S. Army, Medical Research Institute of Infectious Diseases
William Karesh, Wildlife Conservation Society
Janet Kim, American Association for the Advancement of Science
Patrice Klein, U.S. Department of Agriculture, Animal and Plant Health Inspection Service
Joseph Kowalski, U.S. Department of State
Eric Kuchner, Johns Hopkins University
Theresa Lawrence, U.S. Department of Health and Human Services
Marlo Libel, Pan American Health Organization
Barbara Martin, U.S. Department of Agriculture, Animal and Plant Health Inspection Service
James Matthews, Sanofi Pasteur
Tom McGinn, U.S. Department of Homeland Security
Michael Michalski, Stanford University
Joshua Michaud, Johns Hopkins University
Mark Miller, U.S. National Institutes of Health
Kellie Moss, Congressional Research Service
Terry Nipp, Department of Health and Human Services, National Center for Foreign Animal and Zoonotic Diseases
Donald Noah, U.S. Department of Homeland Security
Eunchung Park, U.S. National Institutes of Health
Jim Pearson, World Organization for Animal Health
Katey Pelican, University of Minnesota
Dana Perkins, U.S. Department of Health and Human Services
Robert Pinner, U.S. Centers for Disease Control and Prevention

Phil Polgreen, University of Iowa, Department of Internal Medicine
Diane Post, U.S. National Institutes of Health
Gerardo Ramirez, U.S. Food and Drug Administration
Sylvia Robles, The World Bank
Claudinne Roe, Office of the Director of National Intelligence, United States
Amira Roess, Westat
Pierre Rollin, U.S. Centers for Disease Control and Prevention
Joshua Rosenthal, National Institutes of Health, Fogarty International Center
Terri Rowles, U.S. National Oceanic and Atmospheric Association
Tiaji Salaam-Blyther, Congressional Research Service
Julie Schafer, U.S. Department of Health and Human Services, Biomedical Advanced Research and Development Agency
Steven Schutzer, University of Medicine and Dentistry of New Jersey
Julie Sinclair, U.S. Department of Health and Human Services, U.S. Public Health Service
Nicholas Studzinski, U.S. Agency for International Development
Katharine Sturm-Ramirez, National Institutes of Health, Fogarty International Center
Hollis Summers, U.S. Department of State, Avian Influenza Action Group
Alejandro Thiermann, World Organization for Animal Health/U.S. Department of Agriculture
Tracee Treadwell, U.S. Centers for Disease Control and Prevention
Murray Trostle, U.S. Agency for International Development
Gary Vroegindewey, U.S. Department of Defense, Veterinary Service Activity
Mary Elizabeth Wilson, Harvard University
Clara Witt, U.S. Department of Defense-Global Emerging Infections Surveillance and Response System (DoD-GEIS)
Scott Wright, U.S. Geological Survey, National Wildlife Health Center
Mmeta Yongolo, Support Programme to Integrated National Action Plans for Avian and Human Influenza (SPINAP-AHI) Project, Tanzania

Appendix D

Speaker Biographies

Robert F. Breiman, M.D., is currently head of the U.S. Centers for Disease Control and Prevention's (CDC's) Global Disease Detection Division and director of the International Emerging Infections Program in Nairobi, Kenya. He oversees population-based surveillance for infectious disease syndromes, which includes a component to study veterinary–human health interfaces, and has led investigations of outbreaks of Rift Valley fever in Kenya, avian influenza in Nigeria, and Chikungunya virus in Lamu, Kenya, and Comoros Islands. Dr. Breiman is the principal investigator on a GAVI-funded investigation of the efficacy of a rotavirus vaccine for prevention of severe diarrhea in infants in western Kenya and a project funded by The Bill and Melinda Gates foundation on the burden of diarrheal disease in children. Before moving to Kenya, Dr. Breiman worked in Dhaka, Bangladesh at the International Centre for Diarrhoeal Disease Research, Bangladesh (ICDDR,B), where he led prospective investigations on pneumonia, tuberculosis, cholera, typhoid, shigella, rotavirus and other enteric diseases, and encephalitis. Dr. Breiman was the team leader for World Health Organization (WHO) teams investigating Severe Acute Respiratory Syndrome (SARS) in China (2003). He also led investigations of outbreaks of Nipah encephalitis in Bangladesh. He also worked on field studies of vaccines to prevent influenza, rotavirus, and cholera. Dr. Breiman served as director of the U.S. National Vaccine Program Office (1995–2000) and is a former chief of the Epidemiology Section of the Respiratory Diseases Branch at CDC, where he led work on the epidemiology of a variety of causes of pneumonia, with particular focus on pneumococcal and Legionnaires' disease. He served as the team leader of the investigation of Hantavirus Pulmonary Syndrome in the southwestern United States (1993).

Ilaria Capua, D.V.M., Ph.D., is currently head of the Virology Department at Istituto Zooprofilattico Sperimentale delle Venezie, Padova, Italy, and head of the National, United Nations Food and Agriculture Organization (FAO), and World Organization for Animal Health (OIE) Reference Laboratories for avian influenza (AI) and Newcastle disease. She has been involved in managing several AI outbreaks on a global scale, and in particular, her group has supported African and Middle Eastern countries affected by the H5N1 crisis. She is currently coordinating two European Union– (EU–) funded projects. She is a partner in an additional four EU-funded projects and is a Work Package leader in the EU Network of Excellence for Epizootic Disease Diagnosis and Control, EPIZONE. Dr. Capua is currently the chair of OFFLU, the joint OIE-FAO veterinary network of expertise on avian influenza. In 2006, she ignited an international debate on sharing genetic information and launched the Global Initiative on Sharing Avian Influenza Data, endorsed by 70 medical and veterinary virologists and 6 Nobel laureates. In 2008, Dr. Capua was among the winners of the *Scientific American 50* prize for leadership in policy for promoting sharing of information at an international level.

Dennis Carroll, Ph.D., is currently director of the U.S. Agency for International Development's (USAID's) Avian and Pandemic Influenza Preparedness and Response Unit. Dr. Carroll was initially detailed to USAID from the U.S. CDC as a senior public health advisor in 1991. In 1995, he became the Agency's senior infectious diseases advisor and was responsible for the Agency's programs in malaria, tuberculosis, antimicrobial resistance, disease surveillance, and emerging infectious diseases. He officially left CDC and joined USAID in 2005, when he assumed responsibility as director of the API Unit. Dr. Carroll has a doctorate in Biomedical Research, with a special focus in Tropical Infectious Diseases, from the University of Massachusetts at Amherst. He was a research scientist at Cold Spring Harbor Laboratory in New York, where he studied the molecular mechanics of viral infection. Dr. Carroll has received a number of performance awards from both CDC and USAID, including the 2006 USAID Science and Technology Award for his work on malaria and avian influenza, and the 2008 Administrators' Management Innovation Award for his management of the Agency's API program.

Peter Cowen, D.V.M., Ph.D., has served in the North Carolina State University College of Veterinary Medicine's department of Population Health and Pathobiology as an assistant and associate professor of epidemiology/public health since 1985. He directed the school's WHO/Pan American Health Organization (PAHO) Veterinary Public Health Consulting Center for graduate and residency programs in veterinary public health from 1990 to 1997. He received a B.A. in Sociology from Beloit College. His interests later shifted to veterinary medicine, resulting in his decision to attend the University of Ibadan, Nigeria, for his D.V.M. With a growing appreciation for the international needs of the profession, he returned to the United States to obtain both an M.P.V.M. and Ph.D. from the University of California, Davis in 1980 and 1986 respectively, under the direction of Dr. Calvin W. Schwabe, former chair of the WHO's first expert council on veterinary public health and founder of the first postgraduate training program in epidemiology housed in a veterinary college. In 1998–1999 he worked as a visiting epidemiologist with the Office of Public Health and Science, Food Safety and Inspection Service, at the U.S. Department of Agriculture. A project of particular importance to Dr. Cowen since 1996 is his work as moderator for ProMED-mail, an Internet emerging disease surveillance system recognized globally as a major communication avenue for the public health profession. In 2007, Dr. Cowen was inducted as an honorary Diplomate of the American Veterinary Epidemiology Society.

Nancy Cox, Ph.D., is director of the U.S. CDC Influenza Division and director of the CDC's WHO Collaborating Center for Surveillance, Epidemiology and Control of Influenza. She received a Bachelor's degree in Bacteriology from Iowa State University. Dr. Cox was then awarded a Marshall Scholarship to study at the University of Cambridge, where she earned a doctoral degree in Virology, with a dissertation that focused on influenza virus/host interactions. Dr. Cox began her career as a postdoctoral fellow, first at the University of Maryland–Baltimore County and subsequently at the CDC, where she continued her work on influenza viruses. She was selected as the chief of the Molecular Genetics Section of the Influenza Branch in 1983, chief of the Influenza Branch in 1992, and director of the Influenza Division in 2006. She frequently serves as a WHO temporary advisor for vaccine strain selection and expansion of the WHO's global influenza network. Since 1988 she has served on the International Committee for Taxonomy of Viruses, Orthomyxovirus Subcommittee both as a member and chair (1993–1999). She also co-chaired the U.S. Interagency Group on Influenza Pandemic Preparedness from 1993 to 1995, which began the process of writing a national response plan for the next influenza pandemic. She has also served on the organizing committee for many international influenza meetings, including Options for the Control of Influenza III, IV, V. She chaired the organizing committee for Options for the Control of Influenza VI, which was held in 2007. In her capacity as WHO Collaborating Center director, she has organized and participated in numerous national and international training courses on influenza epidemiology, isolation, and identification. Dr. Cox is the recipient of many scientific and achievement awards, including recognition by *Time* and *Newsweek* magazines for The

Time 100: The People Who Shape Our World (2006) and Giving Back (2006) awards, respectively; the Secretary's Award for Distinguished Service (2006); and Federal Employee of the Year (2006). She was also coauthor of the *Lancet* Paper of the Year (2006). She is an editor for *Lancet Infectious Diseases* and is the author and coauthor of more than 195 research articles, reviews, and book chapters.

Stéphane de La Rocque, D.V.M., Ph.D., graduated from the veterinary school of Lyon, France. He has over 15 years of experience in the field of vector ecology, spatial epidemiology, and remote sensing. He started his study of the epidemiology of hemoparasites in the northern part of South America, then spent nearly 10 years in West Africa (Burkina Faso, Senegal) working primarily on tsetse flies and their control, then bluetongue, Rift Valley fever, and West Nile. During the outbreaks of bluetongue and West Nile in France, he was leading a research team on arboviruses for the French Agricultural Centre for International Development (CIRAD). Dr. de La Rocque was part of the team who initiated the so-called Emerging Diseases in a changing European Environment (EDEN) project, a project spanning 25 countries that was supported by the European Commission to study environmental changes and the emergence of diseases. He was the general coordinator of EDEN for 3 years before joining FAO in Rome in 2006. In the Animal Health Division of FAO, he heads the group in charge of the OIE-WHO-FAO Global Early Warning System (GLEWS) project. Dr. de La Rocque is a laureate of the French National Academy of Medicine, the French Entomological Society and the Society of Geomatics.

Joshua Dein, V.M.D., M.S., currently serves as the animal welfare officer and the captive wildlife specialist at the U.S. Geological Survey (USGS) National Wildlife Health Center in Madison, WI. He is also the principal investigator for the National Biological Information Infrastructure (NBII) Wildlife Disease Information Node, which includes development of a national wildlife disease database system. Dr. Dein has also been active in other informatics collaborations aimed at integrating multidisciplinary health data and information, such as the Canary Database and WildPro Multimedia. Dr. Dein holds a V.M.D. and M.S. in Pathology from the University of Pennsylvania and an M.S. in Ornithology/ Entomology from the University of Delaware. He is actively involved in a number of national and international projects involving wildlife disease informatics, development of disease surveillance systems, and integration of these systems with those for public and livestock health.

Tracy S. DuVernoy, D.V.M., M.P.H., Dipl. ACVPM, is chief of the Communications Center for the U.S. Department of Defense-Global Emerging

Infections Surveillance and Response System (DoD-GEIS), where she plans and directs activities related to the surveillance of various types of influenza, and develops and maintains lines of communication and coordination with other organizations and agencies also dealing with influenza. She is responsible for monitoring daily trends related to the global incidence and prevalence of influenza in addition to other emerging infectious diseases of military importance. She was a senior staff veterinarian with the Veterinary Services' Emergency Programs at the USDA's Animal and Plant Health Inspection Service (APHIS). Her duties included the development, evaluation, and improvement of programs and operational activities designed to prevent or eliminate threats to American agriculture from emerging or newly introduced animal diseases. Dr. DuVernoy was a private clinical practitioner for 8 years, focusing on small animal, avian, and exotic internal medicine and surgery. From 1997 to 2001, she investigated adverse vaccine events in children postimmunization while at the Food and Drug Administration (FDA) and disease outbreaks among military personnel while at the U.S. Army Center for Health Promotion and Preventive Medicine. She then spent 2½ years at the Maryland Department of Health and Mental Hygiene, Center for Veterinary Public Health, where she oversaw the rabies and West Nile virus programs and was the acting state public health veterinarian for 1½ years. She is board-certified by the American College of Veterinary Preventive Medicine. Dr. DuVernoy received her D.V.M. from the University of Florida, and an M.P.H. from the Uniformed Services University of the Health Sciences.

Jeremy Farrar, B.Sc., M.B.B.S., F.R.C.P., D.Phil, OBE, has been the section head of Oxford University's Neurological Disorders department since 2005. He is also director of Oxford University's Clinical Research Unit in Ho Chi Minh City, Vietnam. The Clinical Research Unit is dedicated to clinical and laboratory research on tropical infectious diseases, including dengue, malaria, typhoid, tetanus, and influenza, as well as infectious diseases affecting the brain. Dr. Farrar coordinates the South East Asia Influenza Clinical Research Network across Indonesia, Thailand, and Vietnam, with international partners from the National Institute of Allergy and Infectious Diseases, Oxford University, Wellcome Trust, and the WHO. His research interests include the interplay between infections and the immune system as well as the pathophysiology and treatment of bacterial meningitis, tuberculous meningitis, tetanus, malaria, dengue hemorrhagic fever, and Japanese B encephalitis. Dr. Farrar was recently awarded the Oon International Award for Preventative Medicine for his work on avian flu (H5N1). He is also an elected Fellow of the Royal College of Physicians and the Academy of Medical Sciences of the United Kingdom, and was awarded the Order of the British Empire (OBE) for this contribution to the scientific field. Dr. Farrar undertook his medical training at University College and the Westminster Hospital London and subsequently trained in Neurology in Edinburgh, Melbourne, San Francisco, and Oxford. He has a Ph.D. in Immunology from Oxford.

Marc Fischer, M.D., M.P.H., is an officer in the U.S. Public Health Service, and chief of the Surveillance and Epidemiology Activity in the Arboviral Diseases Branch at the U.S. CDC in Fort Collins, CO. He joined the CDC in 1994 as an Epidemic Intelligence Service officer in the Childhood and Vaccine Preventable Diseases Branch in the Division of Bacterial and Mycotic Diseases. From 1999 to 2005, Dr. Fischer served as director of the CDC Unexplained Deaths and Critical Illnesses Project (UNEX). He moved to the Division of Vector-Borne Infectious Diseases in 2005. Current activities and research interests include surveillance and epidemiology of Japanese encephalitis and West Nile viruses, and development and implementation of arboviral vaccines. Dr. Fischer received his bachelor's and medical degrees from Duke University, and his M.P.H. from the University of Washington in Seattle. He completed a residency in pediatrics and a fellowship in pediatric infectious diseases at Children's Hospital and Regional Medical Center in Seattle. Dr. Fischer is a Fellow of the American Academy of Pediatrics (AAP) and a member of the Pediatric Infectious Diseases Society. He is the CDC lead of the Advisory Committee on Immunization Practices Japanese encephalitis vaccine working group, the CDC liaison to the AAP Committee on Infectious Diseases (Red Book Committee), and an editor for *The Pediatric Infectious Disease Journal*.

Larry Glickman, V.M.D., Dr.P.H., M.P.H., is adjunct professor of clinical epidemiology in the Department of Emergency Medicine at the University of North Carolina at Chapel Hill School of Medicine and senior epidemiologist at OneEpi, a consulting firm. From 1978 to 2008, he was professor of epidemiology at veterinary and medical colleges at Cornell University, University of Pennsylvania, and Purdue University. Dr. Glickman obtained his V.M.D. from the University of Pennsylvania, and holds postdoctoral degrees in Physiology from the State University of New York at Binghamton, and Epidemiology and Public Health from the University of Pittsburgh. In 2004, with a $1.2 million U.S. CDC grant, he created the National Companion Animal Surveillance Program to detect acts of bioterrorism, monitor emerging and zoonotic diseases, and study the effects of toxic chemicals on companion animal health. Dr. Glickman is recognized for developing the field of veterinary pharmacoepidemiology through his vaccine and drug safety research using national veterinary medical databases. He has published more than 300 journal articles, book chapters, and monographs and he has received more than $10 million in grants and contracts from federal agencies, including the National Institutes of Health, CDC, FDA, USDA, and U.S. Department of Education, as well as private foundations and industry. Dr. Glickman's honors include the University of Pittsburgh Graduate School of Public Health award as one of 50 major contributors to public health in the past 50 years; an Alumni Award of Merit from the University of Pennsylvania School of Veterinary Medicine for Advancing Animal Health; the Pfizer Prize for Research Excellence; the American Kennel Club Award for Canine Research; The Merck Award for Creativity in Veterinary Education; and the Purdue University Inaugural Prize for Sustained Excellence in Animal Health Research. He served as chairperson of the National Academy of Sciences committee that authored *Animals as Sentinels of Environmental Health Hazards* in 1991.

William B. Karesh, D.V.M., leads the global health programs of the Wildlife Conservation Society. Dr. Karesh has pioneered initiatives focusing attention on problems raised by the interactions among wildlife, people, and their animals, and he leads a team of more than 100 health professionals working around the world on these issues. Programs cover terrain from Argentina to Zambia and range from efforts in the Congo Basin to reduce the impact of diseases such as Ebola, measles, and tuberculosis on endangered species such as gorillas and chimpanzees, as well as humans living in the region, to global surveillance systems for emerging disease. Dr. Karesh also chairs the International Union for the Conservation of Nature (IUCN) Wildlife Health Specialist Group, a network of more than 400 wildlife and health experts living and working in 55 countries. Dr. Karesh is currently chief of party for the Wild Bird Global Avian Influenza Network for Surveillance (GAINS) program. He also serves as president of the OIE Wildlife Working Group and co-chair of the IUCN Species Survival Commission–Wildlife Health Specialist Group. Dr. Karesh received his D.V.M. from the University of Georgia. He has been a speaker at a number of the Institute of Medicine's Forum on Microbial Threats workshops.

Marlo Libel, M.D., M.P.H., is a medical epidemiologist with PAHO's Control of Communicable Diseases Program in the Disease Prevention and Control Area. He is responsible for the implementation of the Regional Plan for Surveillance and Control of Emerging and Reemerging Diseases. He has worked as an epidemiologist within a variety of PAHO programs since he began working there in 1985, including the Health Situation Analysis Program, Health Situation and Trend Assessment Program, and Communicable Diseases Program. Previously, he worked in the Rio Grande do Sul State Health Department, Brazil. Dr. Libel earned his M.D. from Faculdade Católica de Medicina do Porto Alegre and his M.P.H. from the School of Public Health and Tropical Medicine at Tulane University. He has published in journals such as WHO and PAHO bulletins, *American Journal of Epidemiology*, and *Science*.

Barbara Martin, M.S., is the coordinator of the National Animal Health Laboratory Network (NAHLN) for the USDA's APHIS at the National Veterinary Services Laboratories. She is responsible for ensuring that the United States has the capacity and capability for early detection, rapid response, and recovery from foreign animal diseases. She has coordinated the implementation of national, standardized surveillance for high-priority diseases including classical swine fever and avian influenza, and is currently focusing efforts on preparedness, including table-top exercises in NAHLN laboratories throughout the United States. Prior to becoming NAHLN coordinator, she led USDA validation efforts for rapid diagnostic assays for diseases including foot and mouth and classical swine fever; was responsible for the production, evaluation, and distribution of reagents used in the USDA's brucellosis, tuberculosis, and Johne's disease programs; developed and implemented standardized training and proficiency testing processes for brucella serology; and was involved in the review of laboratories in other countries to assess diagnostic capabilities, make recommendations on diagnostic methodologies, and deploy new technologies.

James Pearson, D.V.M., M.S., is currently a consultant to the OIE. Formerly, he was head of OIE's Scientific and Technical Department. Dr. Pearson joined the OIE staff in 1999 and directed one of the three technical departments until 2002. He coordinated technical support activities, meetings, and publications of several OIE scientific groups that develop animal health Standards and Guidelines (e.g., disease diagnosis and surveillance, import/export, wildlife, research, vaccines). Dr. Pearson was elected vice president of the OIE Standards Commission in 1991 and served in this position until 2000. Since 2002, Dr. Pearson has continued to represent the OIE at national and international meetings and he is the consultant technical editor for the *OIE Manual of Diagnostic Tests and Vaccines for Terrestrial Animals*. Dr. Pearson is also veterinary consultant for Bechtel National Inc. and is helping to coordinate the program to establish veterinary diagnostic laboratories and animal health programs in Uzbekistan, Georgia, and Kazakhstan.

Philip M. Polgreen, M.D., M.P.H., is an assistant professor at the University of Iowa and the director of the Infectious Diseases Society of America's (IDSA's) Emerging Infections Network, a U.S. CDC-sponsored sentinel surveillance group. He is currently working with an interdisciplinary group of researchers to apply quantitative approaches (e.g., social networking, time series methods) to understand and solve problems in the field of infectious diseases. In addition to traditional hospital epidemiology, his research interests include developing new ways to aggregate information about infectious diseases (e.g., prediction markets) and applying quantitative methods to help prevent the spread of infections. Dr. Polgreen is a member of the IDSA and the Society for Healthcare Epidemiology of America. He received his M.D. from the University of Cincinnati.

Sylvia Robles, M.D., M.Sc., is a senior public health specialist at The World Bank. Her current work focuses on public health policy. Dr. Robles has worked on program evaluation and research on disease prevention and control in middle- and low-income countries. She previously worked for the PAHO Division of Disease Prevention and Control, where she led the Noncommunicable Disease Program for the Region of the Americas. She holds an M.D. from the University of Costa Rica and a M.Sc. in Epidemiology from the University of Toronto.

Pierre Rollin, M.D., began his career at the Pasteur Institute, Paris, working on rabies and viral hemorrhagic fevers in conjunction with overseas Pasteur Institutes. After serving a National Research Council fellowship at the U.S. Army Medical Research Institute of Infectious Diseases, he joined the Special Pathogens Branch, Division of Viral and Rickettsial Diseases, CDC. He was directly involved in the discovery and characterization of public health responses to a number of new and emerging diseases (e.g., Ebola hemorrhagic fever, Lassa fever, Marburg hemorrhagic fever, Sabia virus infection, Hantavirus Pulmonary Syndrome, Rift Valley fever, Crimean-Congo hemorrhagic fever, Nipah encephalitis, and SARS), their diagnosis in the laboratory and development of diagnostic tests, the management of outbreaks in the field (public health response, patient management, safety, diagnosis in the field, epidemiology, reservoir search), and the pathogenesis of disease in human and animal models. His research interests concern emerging zoonotic and arthropod-borne infectious diseases, with an emphasis on viral hemorrhagic fevers. Dr. Rollin received his M.D. from Montpellier University in France.

Alejandro Thiermann, D.V.M., Ph.D., is president of the Standard Setting Committee for the OIE at its headquarters in Paris. He has been seconded to the OIE by USDA–APHIS to serve as the special advisor to the Director General of the OIE. During 1997–1999 he was twice elected chairman of the World Trade Organization (WTO), Sanitary and Phytosanitary Committee. In 1994 he was elected vice president of the Code Commission of the OIE. In 2000 he was elected, and in 2003 and 2006 reelected, president of this standard-setting committee. Dr. Thiermann was an active member of U.S.

delegations involved in the negotiation of the Uruguay Round of the WTO and the drafting of the new International Plant Protection Convention. He also served for 2 years as the U.S. Coordinator for the Codex Alimentarius. A native of Chile, Dr. Thiermann received his D.V.M. from the University of Chile at Santiago, and his Ph.D. in Microbiology and Immunology from the School of Medicine at Wayne State University in Michigan.

Tracee Treadwell, R.N., D.V.M., M.P.H., is associate director for Zoonotic Disease Science at the National Center for Zoonotic, Vectorborne and Enteric Diseases, Coordinating Center for Infectious Diseases, at the U.S. CDC. In this role Dr. Treadwell is the senior scientist for zoonoses, working with various experts and senior management both internal and external to the agency to determine the strategic vision and goal for zoonotic disease science. Dr. Treadwell also manages the CDC's OIE Collaborating Center for Emerging and Re-emerging Zoonoses and is responsible for managing the cross-agency issues surrounding pathogens that may have recently been identified as zoonotic or have the potential for zoonotic implications, such as *Methicillin-drug* Resistant *Staphylococcus Aureus* (MRSA) and *C. difficile*. Dr. Treadwell is also developing the surveillance system "node" for BioPhusion that will include animal and human information. In her most recent role, Dr. Treadwell had overall responsibility of 20 staff members who serve as the emergency responders for the National Center for Infectious Diseases for terrorism and other infectious disease emergencies. Dr. Treadwell is recognized as a leader in public health surveillance, especially for high-profile gatherings and terrorism and emerging infectious diseases. She has served as the CDC lead for surveillance and epidemiology at many high-profile events such as the World Trade Organization Ministerial in Seattle, 1999; Democratic and Republican National Conventions in Los Angeles and Philadelphia, 2000; Superbowl in Tampa, 2001; World Trade Center attacks, 2001; World Series, 2001; and Olympics in Greece, 2004. She has served as the lead developer for the "Drop in Surveillance" systems that have been used at these events and many more. Dr. Treadwell served as the co-team leader on the team that received initial information for triage of suspected anthrax patients during the anthrax events of 2001. Additionally, she served as a WHO consultant while employed by CDC for deployment to Nigeria for polio eradication and served as the WHO lead in Hong Kong SAR during the SARS outbreak in 2003. Dr. Treadwell serves as the lead epidemiologist for CDC working on the integration of animal data into human data for a better idea of the health of a population, and she serves as the lead CDC epidemiologist working with the Laboratory Response Network on the use of this system as a tool for surveillance for bioterrorism and other public health emergencies. Dr. Treadwell also serves as the CDC lead on the consequence management and public health response for the Biowatch program.

Scott Wright, Ph.D., M.S., has been intensely interested in and involved with wildlife and ultimately wildlife diseases throughout his academic training and professional career. Currently, he is the branch chief of the Disease Investigations Branch with the USGS National Wildlife Health Center, the only federal diagnostic and research laboratory focused exclusively on wildlife, in Madison, WI. Prior to that, Dr. Wright worked for the former Florida Marine Research Institute (now part of the Florida Fish and Wildlife Conservation Commission), where he established the Marine Mammal Pathobiology Laboratory which focused exclusively on diseases of marine mammals. Dr. Wright's undergraduate study at the University of South Florida and early graduate education at the University of Florida gave him the opportunity to learn the multiple ecosystems within the state. His first look at wildlife diseases as a component of ecosystems was his involvement in the raccoon rabies dynamics as they were established in southern Florida. He gained a formal appreciation of wildlife diseases as a fellow of the Northeastern Research Center for Wildlife Diseases housed within the Department of Pathobiology at the University of Connecticut. He completed his doctoral training in veterinary pathology with a focus on diseases of wildlife, looking at Lyme disease as a thesis topic. He returned to Florida to continue training as a postdoctoral fellow in the Department of Infectious Disease of the College of Veterinary Medicine at the University of Florida. As part of Dr. Wright's extra-professional activities, he has been active in many aspects of the Wildlife Disease Association (WDA) and is now president. The WDA is the only international professional association of scientists focused on wildlife diseases.

Mmeta Yongolo, M.V.Sc., M.V.M., Ph.D., is head of the Virology Department of the Central Veterinary Laboratory, Ministry of Livestock Development and Fisheries in Tanzania. He is a virologist focusing in molecular epidemiology of viral diseases. Since 1993, he has undertaken research and diagnosis of viral zoonotic and transboundary diseases, those spreading between countries, of economic impact to animal populations in Tanzania, namely Newcastle disease; avian influenza; Gumboro; Fowl pox; Lumpy skin disease; ephemeral fever; foot-and-mouth disease; Rift Valley fever; rabies; African Swine Fever; canine distemper; Parvovirus; and Nairobi sheep disease. Currently he is national coordinator for avian and human influenza in Tanzania. He also serves as secretary to the Tanzanian National Task Force on Avian and Human Influenza as well as to the Rift Valley fever technical committee. Dr. Yongolo is a member of the Eastern Africa Laboratory network, the principal investigator for an avian influenza USAID-University of Minnesota–funded project, and lead investigator of Rift Valley fever SACCO Savings and Credit Cooperative-funded projects. He has also served as an FAO avian influenza laboratory expert in Sudan.

Appendix E

Overview of Disease Surveillance Systems Presented in the Workshop by Order of Presentation

TABLE E-1 Overview of Disease Surveillance Systems Presented in the Workshop by Order of Presentation[a]

Systems **Elements**	GLEWS	WDIN	GAINS	NCASP	GPHIN	GOARN
Organizational Authority	OIE, FAO, and WHO	NWHC	WCS	Banfield and PU	PHAC	WHO
Date Initiated	2006		2006	2004	1998	2000
Data Source(s)	-OIE and FAO Disease Tracking Systems -UN (WHO and others) -EU -Media -web-based surveillance systems	Federal, state, and local government agencies; non-government organizations; private sector; and open source news reports	-Over 20 countries contribute wild bird data to GAINS.org with the support of FAO and WCS -Census data from more than 105 million bird observations	-Banfield® electronic medical records (PetWare® Proprietary Software)	-MoH official reports -Radio -TV -News (in Arabic, English, French, Farsi, Portuguese, Russian, Chinese, and Spanish)	Informal (ProMED, GPHIN), field data (case-based and aggregated data)
Data Verification	OIE's Information Verification System; FAO EMPRES; OIE Reference Laboratories and Collaborating Centers; WHO Regional Office or country representative	Information not available	Field surveillance for HPAI in participating countries with the support of WCS staff and other GAINS partners	Information not available	Information filtered through an automated process and analyzed by GPHIN officials; WHO also verifies information	-WHO verifies information with member countries

ProMED-mail	DOD-GEIS	EWORS	ALERTA	ESSENCE	ArboNET	IDSA-EIN
ISID	DoD	DoD-GEIS and NAMRU-2	DoD-GEIS and NMRCD	DoD-GEIS	CDC	IDSA
1994	1996	1999	2003	1999	2000	1995
Media, official reports, local observers, seen or received by ProMED-mail readers, and ProMED-mail staff review of websites and traditional media	-DoD beneficiaries at 71 sentinel and non-sentinel sites globally -DoD domestic and overseas laboratories	Urban hospital centers outpatient and acute care centers -Indonesia -Lao People's Democratic Republic -Cambodia -Vietnam -Peru	88 reporting units (Hospitals, clinics, health centers, nurseries in Peru) and 37 Peruvian Navy ships	Outpatient visit data across all military treatment facilities; captures every patient encounter in DOD	Health care providers, veterinarians and commercial laboratories report to state/local health department	Clinical data
Top moderator, expert subject matter moderators and sometimes outside experts review the information	Program specific	Country data sent to the EWORS central hub daily for analysis to identify increases in case counts for a particular syndrome	Central hub, which is located at NMRCD in Lima, Peru	Further investigate and/or validate the event through robust reporting, structured analysis, and ad hoc query mechanism	CDC performs regular analyses of the data usually weekly during the West Nile virus season	Information not available

Continued

TABLE E-1 Continued

Systems **Elements**	GLEWS	WDIN	GAINS	NCASP	GPHIN	GOARN
Dissemination of Data Analyses	-GLEWS Platform (web-based system)[b] -Electronic distribution list	-WISDOM -WDIN publications, listserve, and bulletin	GAINS.org	LAHVA	Alerts are emailed or posted to the GPHIN website daily	-GOARN secured website -WHO's response strategy and operations
Partners in Network	OIE, FAO, and WHO	22 (Government, educational, and non-governmental organizations)	23 (Government, educational, and non-governmental organizations)	Banfield hospitals (>640)	WHO and Public Health Agency of Canada	200
Human/Animal/ Integrated Disease	Animal	Animal	Animal	Animal	Human	Human
Funding Source(s)	Information not available	Information not available	Information not available	CDC	Government of Canada	NTI-WHO Global Emergency Response Fund
Fees	No	No	No	Information not available	Yes	No
Affiliated Database	OIE's WAHIS	WHMN HEDDS CWDDC SEANET	WISDOM	None	None	None

ProMED-mail	DOD-GEIS	EWORS	ALERTA	ESSENCE	ArboNET	IDSA-EIN
(1) ProMED-mail website and e-mails in English (2) ProMED-mail in Portuguese, Spanish, and in Russian; (3) ProMED-MBDS in English reports on countries bordering the Mekong river	Program specific	-EWORS is a multi-language software -translates data into graphic presentations (e.g., site-specific geographical mapping)	Central hub contact the armed forces for a potential response and follow-up	Web-based epidemic outbreak detection and response application across the military health system	-Weekly updates: EpiX, USGS maps, and CDC website -Monthly MMWR updates (July-November) -Annual MMWR summary -Journal articles	One to five e-mails or postings to members
Information not available	Five DoD overseas laboratories; military health system; and other U.S. and foreign agencies	DoD-GEIS and its partners	DoD-GEIS and its partners	DoD-GEIS and its partners	CDC	CDC and Infectious Disease Society of America (IDSA)
Human	Human	Human	Pilot integrated human and animal	Human	Human	Human
Charitable and user donations	DoD	DoD	DoD	DoD	CDC	Information not available
No	No	No	No	No	No	Contingent on fee-based membership to IDSA or PIDS
None	Information not available	Information not available	Information not available	Information not available	Information not available	N/A

Continued

TABLE E-1 Continued

Systems **Elements**	GLEWS	WDIN	GAINS	NCASP	GPHIN	GOARN
Number of members, users, or subscribers	Information not available	Information not available	Information not available	Information not available	Information not available	WHO member countries (193)
Composition of members, users, or subscribers	OIE, FAO, and WHO member countries	Information not available	Information not available	Information not available	-National/ EU/International agencies -Academic institutions -Non-profit -international non-governmental organizations	N/A

NOTES: While the primary source of the information for this table is the workshop presentations, efforts were made to gather missing information and to verify information from official websites and documents produced by the organizations. ALERTA = Alerta Surveillance System in Peru; ArboNET = National surveillance system for arboviral diseases in the United States; Banfield = Banfield®, The Pet Hospital; CDC = U.S. Centers for Disease Control and Prevention; CWDDC = Chronic Wasting Disease Data Clearinghouse; DoD = U.S. Department of Defense; DOD-GEIS = U.S. Department of Defense-Global Emerging Infections Surveillance and Response System; EMPRES = Emergency Prevention System; Epi-X = The Epidemic Information Exchange; ESSENCE = Electronic Surveillance System for the Early Notification of Community-based Epidemics; EU = European Union; EWORS = Early Warning Outbreak Recognition System; FAO = Food and Agriculture Organization of the United Nations; GAINS = Wild Bird Global Avian Influenza Network for Surveillance; GLEWS = Global Early Warning and Response System for Major Animal Diseases, including Zoonoses; GOARN = Global Outbreak Alert and Response Network; GPHIN = Global Public Health Intelligence Network; HEDDS = National HPAI Early Detection Data System; IDSA-EIN = Infectious Diseases Society of America Emerging Infections Network; ISID = International Society for Infectious Diseases; LAHVA = Linked Animal-Human Visual Analytics for Healthcare Surveillance, Management and Response; MBDS = Mekong Basin Disease Surveillance; MMWR = Morbidity and Mortality Weekly Report; MoH = Ministry of Health; NAMRU-2 = U.S. Naval

ProMED-mail	DOD-GEIS	EWORS	ALERTA	ESSENCE	ArboNET	IDSA-EIN
>40,000 subscribers in 160 countries	97 partners that receive funding either directly or indirectly or they provide surveillance samples	Information not available	Information not available	Information not available	Information not available	1252 members
-Military -Non-profit -Government -Academic institutions -Others	Information not available	Information not available	Information not available	Information not available	Information not available	Information not available

Medical Research Unit No.2; NCASP = National Companion Animal Surveillance Program; NMRCD = Naval Medical Research Center Detachment in Lima, Peru; NTI = The Nuclear Threat Initiative; NWHC = U.S. Geological Survey National Wildlife Health Center; OIE = World Organization for Animal Health; PHAC = Public Health Agency of Canada; PIDS = Pediatric Infectious Diseases Society; ProMED = Program for Monitoring Emerging Diseases; PU = Purdue University; SEANET = Seabird Ecological Assessment Network; UN = United Nations; USGS = U.S. Geological Survey; WAHIS = World Animal Health Information System; WCS = Wildlife Conservation Society; WDIN = National Biological Information Infrastructure (NBII) Wildlife Disease Information Node; WHMN = Wildlife Health Monitoring Network; WHO = World Health Organization; WISDOM = Wildlife Information System for Disease Observation and Monitoring.

[a]This matrix contains information about systems that were described in the workshop and not the many other surveillance activities or the organizations conducting them that may have been described during the presentations.

[b]A GLEWS platform is currently being developed, which will have a connection to the website with different level of confidentiality, and it will be based on the FAO EMPRES system.

SOURCES: Compiled from the speakers' presentations during the Workshop; DoD-GEIS, 2007; Center for Biosecurity, 2008; PHAC, 2008; WCS, 2008; WIDN, 2008.