The Economic and Social Impact of Emerging Infectious Disease:
Mitigation through Detection, Research, and Response
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Executive Summary

New advances in science and medicine help us gain ground against certain infectious diseases, yet even in the twenty-first century other infectious diseases continue to emerge at a rapid pace—and frequently with significant human and financial costs. Emerging infectious disease (EID) comprises those infectious diseases whose incidence in humans has increased in the past two decades and threatens to increase in the near future.¹ EID includes new or unrecognized diseases, those that are spreading to new geographic areas and hosts, as well as those that are re-emerging. One recent example is Severe Acute Respiratory Syndrome (SARS), which claimed nearly 800 lives and imposed a devastating $50 billion in global losses.

¹ WHO (SEARO). Combating Emerging Infectious Diseases. New Delhi, 2005, pg. 1. “Emerging infectious diseases are diseases of infectious origin whose incidence in humans has increased within the recent past or threatens to increase in the near future. These also include those infections that appear in new geographic areas or increase abruptly. The new infectious diseases and those which are re-emerging after a period of quiescence are also grouped under emerging infectious diseases.”
Executive Summary

EID poses major risks to the health and welfare of global human and animal populations. Human populations are directly at risk from infection and indirectly at risk through the impact on their food supply. The risks associated with food supply include economic losses related to the culling of animals and the unavailability of food due to real or suspected contamination. These risks have the potential to severely disrupt global supply chains and further harm human health and welfare.

The life sciences, food and agriculture, and health care industries face the greatest risk from the impact of EID, but are also uniquely positioned to mitigate human and financial losses. A global increase of investment in mitigation strategies is not enough without cooperation among these three industries, as well as between governments and global organizations.

Individually and in conjunction with each other, these industries, governmental bodies, and international organizations should focus on the following key activities to mitigate EID:

- Early detection of high-consequence pathogens responsible for epidemic or pandemic-prone diseases, or that otherwise pose a threat to world populations or economies;
- Timely and accurate verification of the presence or absence of these pathogens using diagnostic methods in the field, in laboratories, and in health care settings; and
- Comprehensive and rapid response to care for infected patients and reduce exposure of the wider population to contaminated food, infectious humans and animals, and the accidental and/or deliberate release of high-consequence pathogens.

Vigorous, cooperative pursuit of these key activities can serve as a bulwark against the threats that EID poses to humans and animals and to the operational resilience of businesses, governments, and institutions.

Moreover, living in close proximity to animals can increase the likelihood of zoonotic infection when animals become infected.
I. Introduction and Background

- Severe economic and social disruption or disaster can result from epidemic or pandemic-prone infectious diseases for which there are limited or no therapeutic interventions or when existing therapeutic interventions are not used.

- EID is not fully preventable, however mitigating its impact on the operational integrity of critical national infrastructure, private industry, and global trade is possible. Mitigation requires social, political, and economic commitment across governments and industries, as well as through unique public-private partnerships.

- If planning, surveillance, research, and response at the local level are lacking or inadequate, EID can result in far reaching and severe global consequences.

- Three industries—life sciences, food and agriculture, and health care—are at the forefront of exposure to epidemic-prone pathogens. They are also uniquely positioned to mitigate the impact of EID on society through enhanced detection, verification, and response capabilities.
Introduction

New or emerging infectious diseases with the potential to cause severe epidemics or pandemics are increasingly prevalent. What previously passed for acceptable planning and response has been re-evaluated in light of the recent SARS experience and in anticipation of an avian influenza pandemic or other infectious disease event. Preventing EID from gaining a foothold in new environments is a formidable challenge, but measures to mitigate its impact on human and animal populations are possible.

EID is largely a product of societal-based decisions and demographic changes that are generally considered to be a ‘hidden cost’ of human economic development. Social, political, and economic factors force a continual stream of decisions upon governments and relevant non-governmental authorities. Regardless of whether the need for decisions is adequately addressed or ignored, unintended consequences can promote the emergence of infectious diseases, some of which are referenced in Table 1. The threat of naturally occurring EID is compounded by other factors including the increased mobility of humans, the increased import and export of food products, and the potential deliberate use of pathogenic micro-organisms or toxins for hostile purposes. These factors have short, medium, and long-term impacts on populations and economies around the globe.

Infectious disease epidemics may last a few weeks or a few months and can overwhelm the everyday course of society. For this reason, planning to manage the numerous, complex, and connected impacts of an infectious disease disruption or disaster has motivated multidisciplinary strategies across sectors, professions, and functional roles. These multidisciplinary strategies, when supported by information technology, bioinformatics, and communications technology, assist in reducing the lag time between detection of high-consequence pathogens, laboratory verification, and response.

Such strategies were implemented more widely at the turn of the twenty-first century with regard to the handling, storing, and transporting of high-consequence pathogens for research and development. These steps were taken to preserve the safety and security of researchers and the general public and to ensure the integrity of the surrounding environment. Where implemented, multidisciplinary strategies have increased the effectiveness of biosafety and biosecurity best practices.

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Effective preparedness and response also hinges on establishing cooperative relationships prior to an event, regardless of the origin or type of the potential infectious disease threat. Unique alliances and public-private partnerships are becoming more common, and help mitigate the multi-faceted impact of a severe epidemic or pandemic. As evidenced in the past, outbreaks begin as local events and go on

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4 While infectious diseases can emerge as a consequence of a host of convergent factors, we have chosen to define those diseases that occur accidentally as arising directly from unintentional events, including negligence.


6 Biosecurity has multiple connotations, and outside of arms control and non-proliferation, biosecurity often refers to food security in terms of access to food, food free from GMOs, and freedom from disease in the food chain. Biosecurity can also refer to preventive and protective measures taken against the deliberate acquisition of high consequence pathogenic micro-organisms and toxins for intentional misuse, and can also broadly include control and response. Trapp, Ralf. Implementing biosafety and biosecurity – who, what, why & how: Biological and Toxin Weapons Convention, 2008. http://www.bwpp.org/MX2008Training/documents/TrappMX2008Implementingbiosafetyandbiosecurity.pdf


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### Table 1: Origin of Infectious Disease Threats

<table>
<thead>
<tr>
<th>Origin of Infectious Disease Threats</th>
<th>Naturally Occurring Diseases</th>
<th>Accidentally Occurring Diseases</th>
<th>Deliberately Occurring Diseases</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Can be endemic (the persistent presence of a pathogen in a host in a particular geography)</td>
<td>• Can emerge as a consequence of negligence ⁴ (opportunistic pathogens, such as MRSA) or poor infection control</td>
<td>• Anti-personnel or anti-food and agriculture (livestock or crops) biological and toxin weapons have an extensive history</td>
<td></td>
</tr>
<tr>
<td>• Can be emerging (the presence of a pathogen in a new host or new geography)</td>
<td>• Can emerge as a consequence of ineffective or non-existent biosafety ⁵ practices and/or biosecurity practices ⁶; ⁷</td>
<td>• Are banned by an international treaty (Biological and Toxin Weapons Convention)</td>
<td></td>
</tr>
<tr>
<td>• Can be new (pathogen previously unknown)</td>
<td>• Can emerge as a consequence of poor quality control in food handling and production</td>
<td>• Can be sophisticated (weaponized) or simplistic (homemade)</td>
<td></td>
</tr>
<tr>
<td>• Can be re-emerging (the presence of a pathogen in hosts or geographies, previously responsive to preventive or therapeutic interventions, previously eradicated, but has re-emerged in response to drug, insecticide, or pesticide resistance)</td>
<td>• Can emerge as a consequence of accidents arising from transporting pathogenic micro-organisms and toxins</td>
<td>• Can be engineered to withstand known preventive or therapeutic interventions</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Can mimic naturally occurring disease outbreaks</td>
<td></td>
</tr>
</tbody>
</table>
to have global consequences if they are not stopped. To improve the ability to detect and respond quickly, national programs for detection, verification, and response can be supplemented and complemented by private industry.

Three industries at the forefront of exposure to high-risk, epidemic-prone pathogens are life sciences, food and agriculture, and health care. These industries are also best equipped to mitigate the social and economic impacts associated with the spread of infectious diseases. Experts have urged greater cooperation and coordination of preparedness and response efforts across these industries to prevent or mitigate high-consequence pathogen exposures.

Gaps in current planning and response capabilities pose a challenge for effective EID prevention and recovery. These gaps include unequal geographic distribution of research and development capacity and funding, excessive lag times between the detection of new pathogens and the creation of therapeutic interventions, inadequate supply of prophylaxis or countermeasures, and an incomplete understanding of pathogenesis for EID, particularly zoonotic pathogens. Additionally, there are gaps in the use of effective isolation and infection control measures in health care and a lack of surge capacity to adequately respond to events.

Background

In the first decade of the twenty-first century, the dynamic and often unpredictable relationship of host-pathogen interactions continues to challenge researchers and health care professionals. The infectious disease paradigm is shifting as our understanding of the relationship between host, infection-causing pathogens, and chronic diseases becomes more nuanced and complex. Simultaneously, human encroachment upon previously uninhabited environments, and the rate at which people, animals, and cargo traverse the world, has reduced the time it takes for a highly infectious disease to spread.

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8 WHO. “A zoonosis is any disease or infection that is naturally transmissible from vertebrate animals to humans. 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”. http://www.who.int/topics/zoonoses/en/


Factors Behind Emerging Infectious Disease

EID is the result of a convergence of social, political, and economic factors, whether the diseases are new, re-emerging, or becoming endemic.

Societal decisions and actions, or lack thereof, can have unintended consequences that cause EID to flourish, harming local populations and potentially the global community.

**Social factors** include behavioral activities such as increased trade and travel, sexual practices, food consumption patterns, new medical practices, mass migrations of people, human conflict, and the deliberate use of pathogens for hostile purposes.

**Political factors** govern public health access and allocation of resources, including access to prevention programs, prophylaxis, and post-exposure treatment interventions. Additionally, international political factors can have an impact, including limited or non-existent educational programs to support detection, identification and verification, and response, as well as limited or non-existent information technology and telecommunications infrastructure to establish surveillance links with high-risk areas of the globe.

**Economic factors** arise from insufficient financial investment in research and development to produce interventions, procedures, processes, technology, and training. Additionally, economic factors include insufficient support for a large number of beneficial programs including public-private partnerships, market incentives to develop interventions for “neglected” diseases such as malaria, research into disease pathogenesis, notification of outbreaks, infection control programs and technology, and training of health care professionals and laboratory and field researchers.

EID Events Are Dominated By Zoonoses

More than 60 percent of EID has zoonotic origins, as shown in Figure 1. Yet scientists acknowledge a deficit in high-consequence zoonotic pathogen research and a misallocation of surveillance resources.\(^{12}\) Taken together, these factors demonstrate an increased potential for negative social and economic impacts of EID.

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\(^{11}\) Pathogenesis comprises the origin of a disease and its progression in a host.

Introduction and Background

Figure 1: Convergent Factors Contributing to Emerging Infectious Pathogens With a Focus on Zoonoses

Factors associated with the disease-causing agent:
- adaptation to new vectors and hosts
- mutation and recombination/reassortment in humans and other animals after exposure to multiple pathogens (e.g. food borne viruses, influenza viruses)
- development of increased virulence or drug resistance

Increasing demand for animal protein, leading to changes in:
- farming practices (e.g. large "open" poultry production units in Asia)
- animal markets
- bush meat consumption
- global trade
- natural animal habitats (e.g. encroachment on forests)

Human behavioral changes, including changes in:
- extent of ownership and movement of pets
- extent of ecotourism, boating, camping, etc.
- food preferences (e.g. wild animals and raw milk)
- demographics (e.g. producing older, more susceptible populations)
- level of compliance with recommended prevention measures

Shortfalls in public health infrastructures and policy, resulting from the lack of:
- integration with animal health surveillance
- funding to the public health sector
- sustained funding of scientific studies to answer public health questions and build expertise

New analysis of socio-economic influences and environmental conditions identify emerging ‘disease hotspots’ in lower latitudes, including tropical Africa, Latin America, and Asia. The location of these hotspots reveals a need for a geographical re-allocation of surveillance resources, investment in further surveillance, verification, and response capabilities, and continued vigilance given the ever-increasing mobility of people and goods.

Zoonotic pathogens pose a compounded risk in many locations around the world where humans and animals live in close proximity. In these instances, the threat of acquiring a zoonotic infectious disease is compounded by the direct economic threat associated with the culling of infected animals or healthy animals suspected of being infected. Such events can destroy the livelihood of a population and impact its food supply, which makes zoonosis an imperative risk for all governments and several key industries, especially life sciences, food and agriculture, and health care.

**Characterizing the Infectious Disease Risk**

Infectious disease-causing pathogens pose varying degrees of risk to humans and animals. In many countries, infectious agents are categorized into four risk groups. Pathogens included in the highest risk group are those that are easy to transmit and that have no effective treatment or cure, while those in the lowest risk group are unlikely to cause disease in humans or animals.

While pathogen risk groups are generally accepted to be universal, which pathogens belong to a particular group can vary by geographic location. International and national health agencies, such as the World Health Organization (WHO) and the U.S. Centers for Disease Control and Prevention (CDC), maintain and publish these risk group classifications. Of most significance to this paper are the disease-causing pathogens in groups 3 and 4 as characterized in Table 2.
## Table 2: Pathogen Risk Groups\textsuperscript{15,16}

<table>
<thead>
<tr>
<th><strong>Risk Group 1</strong>: A micro-organism that is unlikely to cause human disease or animal disease.</th>
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</thead>
<tbody>
<tr>
<td><strong>Risk Group 2</strong>: A pathogen that can cause human or animal disease, but is unlikely to be a serious hazard to laboratory workers, the community, or the environment.</td>
</tr>
<tr>
<td><strong>Risk Group 3</strong>: A pathogen that usually causes serious human or animal diseases, but does not ordinarily spread from one infected individual to another. Effective treatment and preventive measures are available.</td>
</tr>
<tr>
<td><strong>Risk Group 4</strong>: A pathogen that usually causes serious human or animal disease and that can be readily transmitted from one individual to another, directly or indirectly. Effective treatment and preventive measures are not usually available.</td>
</tr>
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Qualitative and Quantitative Cost of Epidemic-Prone and Zoonotic Emerging Infectious Disease

II. Qualitative and Quantitative Cost of Epidemic-Prone and Zoonotic Emerging Infectious Disease

- Up-front costs associated with preparing for and responding to epidemic-prone infectious diseases must be factored into planning. Ignoring epidemic-prone infectious diseases or failing to adequately prepare and respond carries other costs.

- The majority of EID is the consequence of zoonotic pathogens. The impact of zoonotic epidemics from 1995 to 2008, many of them preventable, exceeded $120 billion globally.

- The economic consequences of EID are experienced by many areas of industry including employment, trade, travel, tourism, transport, social gatherings, and health care.

The Broad-Based Economic Impact of Zoonotic and Infectious Disease in Humans and in Animals for Consumption

Independent of its origin, EID has many costs related to prevention and response. There is also significant—and likely greater—cost associated with failing to develop and implement prevention and response capabilities. Even when plans and capabilities exist, the more insidious...
costs of failure to follow known prevention methods may be incurred in research facilities, food production and processing, and health care facilities. The former increases the likelihood of contamination from handling, storing, and transporting high-risk pathogens. The latter manifests as hospital acquired infection (HAI). Across all of these industries, the potential impact on operational, financial, and reputational integrity can be extremely severe. In addition, negligence in high-containment laboratory settings can compromise public confidence, potentially delaying development of the therapeutic interventions and countermeasures needed to prevent or mitigate the effects of severe epidemics or pandemics.

Animals removed from the food supply through infection or suspected infection can significantly damage the global economy. The recent Foot and Mouth Disease (FMD), Bovine Spongiform Encephalopathy (BSE) and avian influenza outbreaks are striking examples of the cost of these outbreaks. These diseases have generated billions of dollars in losses globally in the past decade, as illustrated in Figures 2-6. Based on the enormous financial, trade, and social impact of these types of events, research and development into preventive and therapeutic interventions have become an essential strategy.

Figure 2: Economic Impact of Recent Epidemics (Zoonotic)

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The economic impact of zoonotic disease can be extensive—reaching from the local farmers’ market to global trade agreements. Understanding these impacts is the first step in designing plans for preventing the spread of EID as well as the resumption of trade and the continued operation of services after an outbreak.

While exposure to naturally occurring, highly transmissible infectious diseases poses a global risk, certain industries have higher susceptibility to infectious diseases exposure and therefore may be more vigilant about planning to mitigate the social and economic outcomes. On the front line are life sciences, food and agriculture, and health care. Certain other industries may indirectly suffer severe economic losses due to a decrease in public gatherings, travel, and tourism. These industries include retail, wholesale, consumer packaged goods, aviation, hospitality, gaming, sports, media, entertainment, financial institutions, professional services, transportation, and logistics.

**Impact on Employment**
EID can affect global employment in several ways. Companies may experience reduced attendance due to infection, fear of infection, or absenteeism of workers caring for their families. Broader economic problems caused by reduced workforces may then initiate economic downturn and further unemployment.

**Impact on Economy and Global Trade**
Disease outbreaks among livestock are a major risk for the farming sector. Previous crises or fear associated with perceived contamination of the food supply have reduced consumer confidence, causing sudden and drastic cuts in consumption of the affected products and reductions in its price. In addition, losses can result from culling of infected livestock, reduced animal value due to control measures such as compulsory emergency vaccination, and business interruption costs.

The loss of access to regional and international markets tends to have much more important economic implications than local production losses alone. The extent of the economic damage is contingent upon the volume of exports from the affected area. Naturally, the impact can be severe for those areas that had an important and established export market before the outbreak.
Impact on Transport, Travel, Tourism, and Social Gatherings
With modern communications, news of even a small outbreak in a country can spread rapidly throughout the global community. Travelers intending to visit that country may perceive a threat and have concern for their personal safety. Economies in the affected countries can be severely impacted as commuters and vacationers cancel trips or immediately leave the affected country. Social gatherings such as symposia or conventions may be cancelled for public health reasons.

Impact on Delivery of Health Care
Concern continues to mount that a pandemic, or serious epidemic like SARS, will have an enormous and potentially incapacitating impact on the health care industry. Health care providers are considering and planning for how to deal with unprecedented numbers of patients in emergency rooms and hospitals, while coping with severe supply constraints. Quality of health care might further be compromised as employees on the front line of infectious exposure must deal with large numbers of patients and uninfected people seeking medical reassurance. These same workers must also bear the mental burden of the risk they may pose in spreading the disease to their families. Furthermore, if fears of contamination drive health care professionals, staff, and elective patients away from health care facilities, for-profit ones in particular which rely on patient flow and professional delivery of services on a daily basis, may find themselves unable to maintain operations.

These planning and response considerations raise a host of ethical, legal, commercial, and policy questions as to how to balance the duty of care with the occupational health and safety of employees and the financial needs of facilities. If unanswered prior to the occurrence of EID, the social and economic impacts could be catastrophic.
Figure 3: Economic Impact of Infectious Disease in South East Asia

19 Avian Flu Diary: The Return Of The Nipah Virus EMERGING DISEASES: Malaysian Researchers Trace Nipah Virus. www.sciencemag.org/cgi/content/full/sci;289/5479/518

Avian flu in Hong Kong: The avian influenza outbreak in 1997 cost hundreds of millions of dollars in lost poultry production, commerce, and tourism. Airport arrivals in November of that year alone were down by 22 percent from the preceding year.

Nipah (zoonotic disease) in Malaysia: In 1999, the Nipah virus caused the shutdown of over half of the country’s pig farms and an embargo against pork exports.

Plague in India: The 1994 plague outbreak in Surat, India and resulting panic brought about a sudden exodus of 0.5 million people from the region and led to abrupt shutdowns of entire industries, including aviation and tourism. Several countries froze trade, banned travel from India, and sent some Indian migrants home. The WHO estimated the outbreak cost India some $2 billion.
Qualitative and Quantitative Cost of Epidemic-Prone and Zoonotic Emerging Infectious Disease

Figure 4: Economic Impact of Infectious Disease in the Americas

1. Pandemic flu in the US (projected):
The estimated economic impact of Pandemic Influenza would be US$71.3 to $166.5 billion, excluding disruptions to commerce and society.

2. Cholera in Peru:
The outbreak of cholera in 1991 cost the Peruvian fishing industry an estimated $775 million in lost tourism and trade because of a temporary ban on seafood exports.

3. SARS in Canada:
Research suggests a loss in national economic activity in 2003 of roughly $1.5 billion, representing 0.15 percent of Canada’s real GDP. Real GDP in the City of Toronto itself was lowered by $950 million, or 0.5 percent, with about $570 million of this total concentrated in the travel and tourism sector.

22. A wicked strain: the projected number of U.S. deaths as a result of an influenza pandemic is more than 1.7 million over an 18-month period. Nearly half of those victims will be between the ages of 15 and 44. The Centers for Disease Control and Prevention estimate the economic impact to the United States at $71.3 billion to $166.5 billion. Osterholm, Michael Tand Erik Rasmussen, The Centers for Disease Control and Prevention estimate the economic impact to the United States at $71.3 billion to $166.5 billion. Risk & Insurance, April 15, 2005. http://findarticles.com/p/articles/mi_m0BJK/is_5_16/ai_n1365057
Figure 5: Economic Impact of Infectious Disease in the United Kingdom\textsuperscript{24} and Sub-Saharan Africa\textsuperscript{25}

\textbf{Bovine spongiform encephalopathy (BSE) in Britain:} The outbreak of BSE disease in the United Kingdom in 1995 resulted in a mass slaughter of cattle, drastically cut beef consumption, and led to the imposition of an EU embargo against British beef of several years duration. The losses to the British economy were estimated by the WHO at $5.75 billion, including $2 billion in lost beef exports.

\textbf{TB and Multi-drug resistant TB (projected globally):} Recent Sub-Saharan Africa data indicates that there were approximately 8.8 million new cases and 1.6 million deaths were attributed to the disease in 2005. The economic cost of TB-related deaths (including HIV co-infection) in this region from 2006 to 2015 is projected to be US $519 billion when there is no effective TB treatment.


Economic Impact of Recent Epidemics

The following section provides greater details on costs attributed to real and projected epidemics caused by pathogens belonging to Risk Groups 3 and 4 as characterized in Table 2.

**The Impact of Severe Acute Respiratory Syndrome (SARS)**

In 2002 and 2003, SARS—a novel virus that causes acute respiratory disorder—is believed to have emerged in China where it is assumed to have made a zoonotic leap. Within months, this communicable disease spread around the world, from Asia to North and South America and Europe. Before it was finally contained, SARS infected 8,098 people, nearly 800 of whom died.

Many more around the world felt the deep financial impact of SARS. It measurably lowered the GDP of Asian countries and Canada. The total worldwide impact of $50 billion in losses, as shown in Figure 2, was largely from industries such as tourism, retail, and trade, as people cancelled trips and business deals due to the fear and uncertainty about transmissibility of this previously unknown pathogen. Health care also suffered immense panic and concern about a disease that had no known cure. A significant number of those infected were health care workers, causing high levels of distress amongst hospital staff, a situation that raises legal and ethical issues about the obligation of health care workers to perform their duties and the protection they are provided during such an event.

**The Projected Impact of Pandemic Influenza**

No other anticipated global EID scenario is causing as much concern as pandemic influenza. In 1918, pandemic influenza was responsible for an estimated 50 million deaths worldwide.

A new influenza pandemic is expected when the virus mutates to a form that is readily transmitted among humans. The projected losses to

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29 Darby, Paul. The Economic Impact of SARS. The Conference Board of Canada, May 2003
31 Maunder et al. Factors Associated With the Psychological Impact of Severe Acute Respiratory Syndrome on Nurses and Other Hospital Workers in Toronto. Journal of Psychosomatic Research, Volume 66, pgs. 936-942, 2004
Qualitative and Quantitative Cost of Epidemic-Prone and Zoonotic Emerging Infectious Disease

global economies could top $1.25 trillion, and the pandemic could kill as many as 150 million people worldwide.\(^{33,34}\)

To date, current strains of avian influenza—the anticipated source of pandemic influenza—have killed tens of millions of domestic birds (poultry) and wild birds worldwide.\(^{35}\) This has amounted to billions of dollars in losses for economies in Asia, which have been hit the hardest.\(^{36}\) As avian flu spreads throughout the world’s poultry food supply, it is causing import/export bans as it did in France in 2006 and in the U.S. in 2008.\(^{37}\)

Once the virus becomes capable of efficient human-to-human transmission, the potential disruption to industry, services, and government is anticipated to be enormous. Stockpiling of vaccines and antiviral medication is happening on a global basis and massive planning efforts are underway to mitigate the effects of the pandemic.\(^{38}\) The sufficiency of these measures is currently being evaluated. Access to the existing standard of care, however, will remain a concern when a pandemic strikes.\(^{39}\)

**Bovine Spongiform Encephalopathy (BSE)**

BSE, a zoonotic neurodegenerative disease found in cattle also known as “mad cow disease”, can be transmitted to humans through the consumption of infected cattle products. In humans, it is known as “Variant Creutzfeldt-Jakob disease” (vCJD), a long incubation disease that is fatal and has killed 204 people.\(^{40}\)

By far, the greatest impact of BSE has been economic. In the UK, more than 4.4 million head of cattle were destroyed to stop the spread of a BSE outbreak. The combined effects of a fall in consumer confidence throughout the UK and Europe, and the subsequent bans and

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36 Ibid
38 CDC chief says that avian flu is the biggest threat, (CIDRAP News, Center for Infectious Disease Research and Policy, February 2005), http://www.cidrapsummit.org/cidrap/content/influenza/avi
restrictions on beef trade, caused the British cattle and beef market to collapse, costing nearly $6 billion. In Canada, a single cow infected with BSE led to the ban of Canadian beef imports in the United States, costing an estimated $5 billion.

**Quantification of Economic Impact of Bioterrorism**

As with naturally occurring zoonotic EID, bio-terrorism is a threat to human health and to our food supplies and supply chain. Following the deliberate use of anthrax in the United States in 2001, there was a substantial increase in funding to counter the threat of bioterrorism against national assets at home and abroad. Other nations have committed to the G8’s Global Partnership Against the Spread of Weapons of Mass Destruction (which includes bio-terrorism agents), including: Canada ($730 million); Sweden ($12 million); France ($910 million); Germany ($1.8 billion); Italy ($1.2 billion); Norway ($121 million); Japan ($200 million); UK ($750 million); EU ($1.2 billion); Switzerland ($13 million); Netherlands ($29 million); Czech Republic ($75,000); Finland ($12 million); and Russia ($2 billion). The U.S. government alone has budgeted nearly $50 billion between FY2001 and FY2009.

While many countries have constructed models for identifying the social and economic impact of anti-personnel and anti-livestock bioterrorist scenarios, the frequency of such attacks remains exceedingly low. The small-scale 2001 anthrax attack in the United States resulted in a cost of over $200 million to decontaminate anthrax-infected facilities. This raises the question of the economic ramifications of a large-scale bioterrorist attack. A study by the CDC estimates that the economic impact of a bioterrorist attack could range from an estimated $477.7 million per 100,000 persons exposed (brucellosis scenario) to $26.2 billion per 100,000 persons exposed (anthrax scenario).

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45 Since the 2001 terrorist attacks on the United States, the U.S. government has spent or allocated nearly $50 billion among 11 federal departments and agencies to address the threat of biological weapons. For Fiscal Year 2009 (FY2009), the Bush Administration proposes an additional $9 billion in bioweapons-related spending, approximately $2.5 billion (39%) more than the amount that Congress appropriated for FY2008. The Center for Arms Control and Non-Proliferation. “Federal Funding for Biological Weapons Prevention and Defense, Fiscal Years 2001 to 2009” Brief published on 15 April 2008. http://www.armscontrolcenter.org/media/09_budget.pdf.
III. Global Preparedness and Response Capabilities

- Three key industries—life sciences, food and agriculture, and health care—are crucial to managing EID and its negative social and economic impacts.

- Detection, identification and verification, and response to severe epidemic or pandemic prone disease causing pathogens hinge on cooperation and coordination, necessitating further investment and increased capacity.

- Cooperation among industries and organizations is necessary because activities carried out in isolation often have unforeseen consequences. Examples of these consequences include the accidental fostering of drug resistance in pathogens, continued emergence of infectious diseases, as well as other opportunities for disruption and long-term costs.

The life sciences, food and agriculture, and health care industries play an important role in detection, identification and verification, and response, which are the key pillars of effective infectious diseases management. These industries are at the forefront of exposure to high risk and epidemic-prone pathogens and, if properly prepared, are also in a strategic position to prevent or mitigate the spread of infectious diseases.
Pillars of Infectious Disease Management

Detection
Effective disease detection includes ongoing surveillance, reporting, and analysis of a given population over time.

Disease surveillance is the gathering and generation of data on disease incidence and prevalence within a population, and is the cornerstone of effective response.\(^47\) It is used to assist in prioritizing decisions with respect to human, zoonotic, and animal infectious disease prevention and control methods. Activities developed to detect high-consequence pathogens leverage technical and organizational processes and skills, as shown in Table 3.

**Table 3: Overview of Cross-Sector Industry Roles in Detection**

<table>
<thead>
<tr>
<th>Life Sciences</th>
<th>Food and Agriculture</th>
<th>Health Care</th>
</tr>
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<tbody>
<tr>
<td>Microbiological laboratory tools, technologies, equipment, and materials (e.g., reagents, cell culture, etc.)</td>
<td>Networked communication within local and regional geographies for sharing disease intelligence</td>
<td>Trained health care professionals and technologists</td>
</tr>
<tr>
<td>Trained technicians and scientists</td>
<td>Training of livestock owners</td>
<td>In-house laboratory</td>
</tr>
<tr>
<td>Pathogen reference databases/bioinformatics</td>
<td>Use of rapid hand-held diagnostics</td>
<td>Infection control sampling</td>
</tr>
<tr>
<td>Development of diagnostic tools for the field and clinical settings</td>
<td>Implementing and integrating quality assurance and sampling into food manufacturing and distribution</td>
<td>Pathology</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Use of diagnostic and clinical tools and equipment (e.g. microbiology, medical imaging)</td>
</tr>
</tbody>
</table>

The presence of robust and sensitive detection capabilities across life sciences, food and agriculture, and health care are mutually reinforcing. Early detection of infectious disease in animals is vital for prevention of the disease in humans. It is also critical for fast development of prevention and control interventions. Further, if adequate surveillance capabilities are not in place, the downstream public health prevention efforts will be less effective. Sharing disease intelligence is also beneficial for preventing or rapidly controlling infectious disease emergencies of international concern and can contribute to the early warning of potentially significant outbreaks.

The implications for trade and travel can be significant if pathogen or disease presence is detected. Consequently, verification plays a crucial role in the management of infectious diseases.

**Identification/Verification**

*Effective identification and verification of the presence or absence of pathogens using field, laboratory, and clinical diagnostic tools and equipment.*

Following the detection of a pathogen, confirmatory tests are needed to demonstrate the presence or absence of disease during an outbreak. This requires access to diagnostic equipment and professionals trained to use and interpret the results of these diagnostic tests. These tests include rapid hand-held diagnostic tools, such as those used in the field or in clinical settings on the host suspected of being infected, confirmatory microbiological laboratory tests, and accepted clinical procedures that help confirm the presence of a disease (e.g., medical imaging, laboratory-based tests).

Laboratory capability to verify pathogens is essential to execute a response during an outbreak. Characterization of novel and emerging infectious diseases is also essential to better recognize, detect, and achieve verification in the event of a future outbreak. In this way, detection can be improved through the identification and verification process. For example, laboratory identification of new pathogens can help to develop more sensitive detection tools for use in field and clinical environments.

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Table 4: Overview of Cross-Sector Industry Roles in Identification/Verification

<table>
<thead>
<tr>
<th>Life Sciences</th>
<th>Food and Agriculture</th>
</tr>
</thead>
<tbody>
<tr>
<td>■ Development of field kits to rapidly determine presence of pathogen</td>
<td>■ Pre-production random laboratory-based verification of detection samples in livestock, feed, soil, and ground water</td>
</tr>
<tr>
<td>■ Designate high-containment reference facilities to rapidly test dangerous samples to evaluate presence of pathogens in large numbers of possible patients for human and zoonotic pathogens</td>
<td></td>
</tr>
<tr>
<td></td>
<td>■ Random sampling built into food production processes</td>
</tr>
<tr>
<td></td>
<td>■ Trained personnel to read samples and determine safety</td>
</tr>
<tr>
<td></td>
<td>■ Use of microbiology laboratory (on site or shared outsourced facility) to confirm presence or absence of pathogens on equipment, employees, or in products</td>
</tr>
<tr>
<td></td>
<td>Health Care</td>
</tr>
<tr>
<td>■ Detection of infectious disease in patients</td>
<td></td>
</tr>
</tbody>
</table>

Response

Effective measures to mitigate or prevent spread of a disease in the field using a mixture of practices including patient isolation, quarantine, therapeutic interventions, prophylaxis, culling of animals, and food recall practices.

While it is not possible to fully anticipate infectious disease incidents of international public health concern, it is possible to prepare for response and recovery, whatever the origin of the outbreak. Initial efforts taken to control the spread of infectious diseases, prior to pathogen verification, will follow a similar set of practices aimed at isolation, quarantine, and travel controls.\(^4^9\)

If an event is determined to be an act of bioterrorism or sabotage, there are particular implications for which agency (e.g. law enforcement,

public health, etc.) will assume the lead in the disease investigation. Regardless of origin, the ultimate goal—controlling the spread of disease—remains the same. In the event that prior intelligence or prior verification was received, appropriate prophylaxis can be provided to prevent further exposure of employees and the general public. Preparing to recover from an infectious biological event necessitates that preparedness and response procedures are tested and evaluated for their applicability and potential efficacy. No singular set of characteristics exists for an infectious biological incident or contamination. Managers may use a combination of pathogen-specific plans as well as more flexible approaches for isolation and quarantine in the case of unidentified or unverified diseases. Planning for prevention and planning for response are parallel efforts.

### Table 5: Overview of Cross-Sector Industry Roles in Response

<table>
<thead>
<tr>
<th>Life Sciences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Principally responsible for developing therapeutic interventions for EID</td>
</tr>
<tr>
<td>Drive laboratory research and findings into clinical applications and interventions (translational research)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Food and Agriculture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Culling of infected animals or animals suspected to be infected</td>
</tr>
<tr>
<td>Product recall of suspected or known contaminated food products and animal by-products</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Health Care</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provide care in hospitals or alternate locations</td>
</tr>
<tr>
<td>Administer preventive or post-exposure interventions</td>
</tr>
<tr>
<td>Provide preventive or post-exposure public health solutions such as isolation and quarantine</td>
</tr>
</tbody>
</table>

**Managing the Infectious Disease Risk: Research Facilities**

Because modern epidemic-prone infectious diseases can be novel (e.g. SARS) or constantly evolving (e.g. seasonal influenza), research...
facilities are essential for understanding pathogenesis and developing therapeutic interventions. To counter a potential epidemic, research on infectious diseases must be conducted years in advance. Efforts aimed at shortening this development cycle include translational research methods, which encourage the use of technologies enabling bench-to-bedside solutions. Once interventions have been developed, production can begin for stockpiling in preparation for an epidemic or a pandemic. The devastating potential of an epidemic resulting from EID, in conjunction with the paucity of facilities dedicated to this research, has spurred an increase of labs, with the majority in the United States.

Lab-based infectious disease research inevitably entails the handling of pathogens and carries parallel requirements to ensure safety and security. It is imperative that research laboratories employ appropriate and effective security measures and equipment, upgrading both as needed, in order to prevent release of pathogens and to ensure the occupational health and safety of researchers as well as the integrity of the surrounding environment. In order to reduce the exposure to and mitigate the spread of highly pathogenic micro-organisms and toxins in the laboratory environment, new and unique engineering and equipment solutions are being developed to preserve operational integrity of laboratories, preserve occupational health and safety, and to expedite development of countermeasures.

Dedicated biomedical research facilities are designed to handle high risk pathogens and infected specimens and animals. Health care facilities, however, due to their open, care-oriented design, face greater challenges in reducing exposure to pathogens, whether through person-to-person contact or through exposure to the hospital environment.

Managing the Infectious Disease Risk: Health Care Facilities
Health care facilities are an integral component in the immediate response to a spreading infectious disease.

Hospitals and clinics are prepared to care for infected patients, and they play a pivotal role in early warning and detection of an emerging epidemic. Because they are a locus for infected patients, however,

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they also provide an opportunistic location for a disease to spread. In the event that diagnostic tests confirm the presence of a highly transmissible disease, emergency operating procedures (EOPs) will be triggered to protect exposed health care professionals, other patients, and the public from further exposure. Infection control procedures are grouped by the mode of disease transmission. These procedures can range from timely contact tracing of cases and interactions, screening at ports of embarkation and departure, social distancing, expanded pre-hospital emergency preparedness and response, to the use of airborne infection isolation rooms within health care facilities.53

Developing the resilience needed to manage a disruptive infectious biological event includes advanced supply chain planning and the implementation of human capital plans to ensure the continued delivery of services within a health care setting. Operational resilience planning includes consideration of the use of hospital infrastructure in the delivery of care during a patient surge. Continuity of services relies upon coordinated plans for managing triage, patient admission, alternate care sites, and partnerships with community resources that can extend care to the less critically ill without over-burdening the hospital (e.g., mobile response capabilities). Moreover, stockpiling critical consumables (e.g., pharmaceuticals, blood products, sterilants, decontaminants and disinfectants) as well as respirators, personal protective equipment (PPE), and other equipment, sometimes procured using just-in-time inventory management, is also a key operational strategy.54

Managing the Infectious Disease Risk: Food Production Facilities

Rapid globalization of food production and trade has increased the likelihood of international incidents involving contaminated food. Well-established best practice standards exist within private industry. However, the degree to which programs are implemented and enforced globally remains inconsistent. To rectify these gaps, there has been a shift to more holistically integrate industry processes into national and international food safety programs.55

Government regulators are responsible for developing national policies and standards that support the implementation of risk-based production and control programs, monitoring and surveillance of these programs and enforcement of legal standards. Shifting some of

Global Preparedness and Response Capabilities

The responsibility onto industry participants, and assigning them a major role in secondary prevention indicates an increasing reliance on enhanced detection, verification, and recall capabilities. For example, food companies are best situated to deploy capabilities for rapidly detecting contaminated food products and preventing them from reaching consumer markets.

Zoonotic EID in livestock poses a risk to farmers and others in the agricultural production supply chain. Pushing the identification of risk up the supply chain to the source itself is becoming integral to managing zoonoses (e.g., avian influenza, BSE). Increased detection capabilities on the farm complement random sampling in food production facilities. The earlier pathogens are detected the sooner interventions can be made available. Many countries have begun to incentivize and endorse research to protect animals raised for consumption, thereby protecting their major exports related to livestock and food products. Additionally, some governments are compensating farmers for complying with guidelines and regulations related to the reporting of infectious outbreaks and the culling of herds.

Twenty-first century public and veterinary health have a sophisticated understanding of how to detect, identify and verify, and respond to most known infectious diseases, but the extent to which these capabilities are present across the globe varies. Individual efforts at the industry or national level are paramount to achieving global health security. Without cooperation, however, collective health security benefits will not be fully realized.

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IV. Conclusions and Recommendations

Through a convergence of social, political, and environmental factors, EID ‘hot spots’ are causing governments and industry to face the significant challenge of mitigating outbreaks while simultaneously attempting to plan for and prevent epidemics and pandemics. Global efforts to expand joint planning, information sharing, and financial support of a range of global efforts aimed at detection, verification, and response are increasingly important. Failure to jointly pursue these goals in a balanced approach will only contribute to new, re-emerging, and therapeutically resistant pathogens.

The life sciences, food and agriculture, and health care industries are at the forefront of exposure to highly infectious pathogens and are also uniquely positioned to mitigate their impact. They are involved in efforts to safeguard:

- human and animal populations through therapeutic and other interventions;
- the global food supply chain; and
- the operational resilience of the delivery of health care services.

“Failure to jointly pursue these goals in a balanced approach will only contribute to new, re-emerging, and therapeutically resistant pathogens.”
Gaps identified across geographies and competencies indicate a deficiency in prevention and response capabilities. In the area of EID research, these gaps underscore the need for improved tools and facilities for detection and verification, as well as the need to speed up development and production of interventions and therapeutics through translational research, which by its nature can contribute to faster clinical implementation of interventions.

In food production and trade, cooperation between government and industry is critical in preventing contaminated food products from reaching consumers. It is necessary to include producers in the effort to detect EID in farm products at the source, which speeds up response and lowers the cost of recovery.

In health care environments, there is an ongoing need for improved planning and investment in the capacity to manage disruptive infectious biological events. Hospitals can be both a site for healing and a locus for infection. Therefore, implementation of accepted infection control practices, isolation precautions—when indicated—and solutions that allow for the uninterrupted delivery of vital diagnostic and treatment services is required. Adherence to these practices, plus the creation of adequate surge capacity, will allow hospitals to carry out the mission of delivering care during an event without contributing to the spread of EID.

Fortunately, many sectors recognize that when it comes to upstream planning and prevention efforts, the benefits outweigh the costs. History has shown, however, that opportunistic pathogens can and do exploit gaps in these efforts. Timely development of interventions and therapeutics, improved coordination between participants, and increased vigilance in food safety and enhanced response capacity in health care delivery will improve our ability to successfully address the increasing threat from EID.
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