Infectious Disease Surveillance
We acknowledge with appreciation the public health practitioners who conduct surveillance activities, the first critical step in protecting communities from infectious diseases. For his commitment to epidemiologic science, diligence in communicating the role of surveillance, and his readiness to serve, we dedicate this volume to Dr. Stephen B. Thacker, a champion of science and surveillance throughout his career at the Centers for Disease Control and Prevention.
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Long-standing, fundamental barriers to effective prevention and control of infectious diseases remain with us—poverty, war, politics, cultural differences, and ethics challenges. Moreover, the recent financial crisis has resulted in substantial budget cuts throughout the USA and Europe, and decreases in salaries and reductions in staff require public health authorities to re-evaluate such core activities as disease surveillance. In this context of diminished resources, surveillance continues to be the cornerstone of public health practice, the primary tool for triggering interventions to prevent and control infectious diseases. Consequently, cost-effective surveillance is needed to tackle the challenges that infectious diseases still pose. Meanwhile, opportunities exist to enhance surveillance practice through increased global collaboration, dramatic advances in information science and technology, and development of new biologic science (e.g., genomics).

In this second edition of Infectious Disease Surveillance, a new chapter on the history of infectious disease surveillance provides the reader a context of both continuity and change. Two other new chapters on disease eradication build on the lessons learned from the Smallpox Eradication Program. A fourth new chapter on monitoring antibiotic usage and infections with antibiotic-resistant pathogens demonstrates the value of surveillance in formulating strategies to promote antibiotic stewardship to reduce emergence of antibiotic-resistant pathogens.

The epidemiologic pattern of infectious diseases has evolved since the book’s first edition. New bacterial strains (e.g., the carbapenemase-producing Enterobacteriaceae) continually emerge, and previously recognized viruses are spreading outside of their original area of endemicity. Arboviruses (e.g., chikungunya and dengue) are becoming pandemic with the spread of the Aedes albopictus mosquito. The introduction of chikungunya in Italy in 2007 resulted in a proficient community transmission that caused over 200 cases. Recently, autochthonous cases of chikungunya virus infections have been documented in France. Dengue virus autochthonous transmission has been documented in both France and Croatia, as well as in Florida (USA). In addition to the updates to chapters from the first edition to reflect such changes as these, chapters have been added on surveillance for infections related to transfusion and transplantation, antibiotic resistance, and human immunodeficiency virus/acquired immunodeficiency syndrome in countries undergoing transition. Other new chapters address infection control during international travel and among border populations. As addressed in another new chapter, surveillance during mass gatherings has become critical, especially with increased concerns regarding terrorism.

Emergence in 2009 of an influenza pandemic strain highlighted multiple challenges for infectious disease surveillance. While global event-based surveillance focused on emergence of avian influenza (H5N1) in Asia, resulting in early detection of clusters and timely investigation to assess human-to-human transmission, a new pandemic strain of swine origin emerged in the Americas. It was identified only after it had resulted in widespread community transmission, had spread to neighboring countries, and probably had been exported to Europe. Surveillance for the pandemic highlighted the difficulty in monitoring its spread worldwide and, in particular, to characterize its severity. The challenge of adjusting surveillance for pandemic influenza, from the detection of imported cases to the monitoring of its spread throughout communities, was enormous. A chapter on what was learned from this experience is also included.

Re-emergence of wild poliomyelitis in 2011 resulted in hundreds of cases, indicating that surveillance efforts failed to detect its re-emergence at a stage that would have allowed timely disease prevention and control. Similarly, elimination of measles in Europe remains a challenge partly because endemic and imported cases are not recognized in a timely manner. High-quality surveillance systems can play a crucial role in monitoring and preventing spread of diseases (e.g., poliomyelitis and measles), and robust systems support other vital public health interventions.
The revised International Health Regulations now in place provide a framework for a global approach to infectious disease surveillance and control. These regulations required national health jurisdictions to assess and strengthen their capacity to conduct surveillance for infectious diseases by June 2012. However, despite a long tradition of infectious disease surveillance, the majority of advanced countries still have gaps in their ability to detect and respond to infectious diseases, especially among hard-to-reach communities.

Advances in information technology are inducing paradigm shifts in public health practice. The backbone of infectious disease surveillance remains the traditional notification of cases of diseases and analysis of trends and clustering (indicator-based surveillance). Implementation of Internet-based notification in certain areas has improved timeliness of reporting dramatically because notifications are conveyed to a central database where they can be analyzed. Health information exchanges in the USA have improved both reporting timeliness and completeness. In addition, event-based surveillance (e.g., implementation of a mobile-based disease surveillance system during the 2009 hajj in Saudi Arabia) has emerged as a complementary approach to infectious disease surveillance. Although initial efforts focused on comprehensively scanning the epidemiologic horizon, recent approaches emphasize information integration. Chapters on electronic sentinel surveillance and wireless applications highlight these modern surveillance tools.

Surveillance science continues to evolve. Chapters on statistical modeling and use of spatial analysis with geographic information systems highlight the importance of integrating statistical and epidemiologic sciences with surveillance practice. With the emergence of social networks, we are confronted with yet another challenge for surveillance science and practice. Similarly, the monitoring of search terms related to influenza in Google® (Google, Inc., Mountain View, CA) has proven to be highly correlated with influenza outbreak trends (http://www.google.org/flutrends). However, understanding the role of new technologies in surveillance for emergent situations will require additional studies to, for example, distinguish useful information from meaningless “epidemiologic noise.” More than ever before, communities are playing an active role in infectious disease surveillance and control. Social networks are being used to monitor specific emerging events, but in the future they might play a substantial role in disease surveillance.

Public health surveillance of infectious diseases remains a synthesis of art and science, requiring an optimal balance of ingredients. Experienced public health practitioners from around the world, by contributing to this book, provide the reader essential knowledge about infectious disease surveillance as well as practical tools that can be translated into successful public health practice.

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A compendium of infectious disease surveillance must confront both the inevitable and the impossible. As long as the human host and microbial agents occupy the same environment, it is inevitable that infectious diseases will continue to occur and pose real challenges to public health programs and the populations they serve. Unlike classical surveillance for vital statistics, which tracks those constants of the human condition—birth and death—surveillance for infectious diseases tackles the impossibly diverse spectrum of illness that an evolving microbial world sets loose on the human population. In recent years, infectious disease surveillance is increasingly bridging the gap between human and animal worlds in order to track infections in the vectors that play important roles in the emergence and spread of new infectious diseases. Our surveillance systems are now tasked to extend to multiple host species in order to better monitor infectious threats to humans. Additionally, in recent years, authorities are interested in surveillance systems that can anticipate what has not yet happened: identify new infectious agents before they emerge, detect signals of exposure or prodromal symptoms before a disease has become manifest in large numbers of the population. Fortunately, the seemingly impossible scope and standards to which practitioners of surveillance for infectious disease must strive is often matched by innovation and execution equal to these challenges.

This new textbook on infectious disease surveillance features selected best practices and model surveillance programs that are being carried out on a local, state, national, or global scale, to address the infectious disease challenges of the twenty-first century. The book also contains lessons learned from surveillance of the past—in particular, the experience of surveillance targeted against the only infectious disease ever eradicated globally, smallpox. Public health practitioners and students approach infectious disease surveillance from a variety of backgrounds, and must assume a range of responsibilities in carrying out their mandates. For example, today every public health practitioner has by necessity become a leader in their own community’s efforts to prepare for future pandemics of influenza. This textbook can provide a strong grounding in infectious disease surveillance that is vital to these efforts.

Pathogens: Many infectious diseases caused by the major pathogens of the past century are now well controlled in several regions of the world and progress is being made in others—thanks to the advent of effective vaccines, sanitation, infection control, and improvements in food hygiene and nutrition. Surveillance for vaccine-preventable diseases and enteric pathogens highlights some of these success stories and guards against the complacency that can precede resurgences. However, an astounding number of new infectious diseases have emerged in the past 30 years, and some agents of the past such as tuberculosis have reemerged with more severe, multidrug-resistant forms that challenge traditional control programs. Each of these poses some unexpected challenges to surveillance approaches. The emergence of West Nile virus into new regions of the world brought surveillance in insects, birds, and horses into the mainstream of state and local public health efforts. The emergence of drug resistance among bacteria, parasites, and more recently viruses, and the recent diffusion of a new hypervirulent strain of *Clostridium difficile* in hospitals of North America and Europe are just a few timely examples of infectious disease surveillance needs that showcase the interdependence and synergy that occurs when laboratory characterization of strains is linked with epidemiologic analysis of disease patterns. Preparedness for pandemic influenza requires facile and flexible laboratory-based surveillance systems that can span the globe and detect new variants. The number of pathogens of interest to infectious disease surveillance programs is expanding, and the availability and usefulness of detailed pathogen information down to the genetic code has also increased.

People: In addition to the dynamic nature of the microbial world, infectious disease surveillance must address a changing human population. Globalization, increased life expectancy, major expansion of populations suffering from immune suppression (from pathogens like HIV, and from treatments for
FOREWORD TO THE FIRST EDITION

conditions such as cancer and organ transplantation) have resulted in larger numbers of susceptible people who have ample opportunities to encounter microbes that can do them harm. Add to these forces the often-surprising types of human behavior, and one finds surveillance requirements that may encompass what is personal, private, or at times political. Inclusion of sociological, ethical, and legal aspects of surveillance in a core infectious disease surveillance textbook is clear recognition of the reality that in the twenty-first century the term “surveillance” has taken on increasingly nuanced connotations.

Places: The evolving environment and its interaction with infectious agents, animals, and people play an increasingly recognized role in disease transmission and emerging infections. The places in which people live, travel, work, and recreate encompass very diverse conditions that influence how surveillance should be implemented at various levels. Monitoring the impact on infectious disease of climate change, extension of the range of several vectors of infectious disease such as dengue, West Nile virus, or Chickungunya virus, are among the many new environmental challenges for surveillance and public health response. The healthcare environment continues to serve as a hot bed for infectious disease transmission and requires attention in all countries, including those with limited resources. The 2003 epidemic of severe acute respiratory syndrome (SARS) was characterized by major amplification of the newly recognized SARS coronavirus in the healthcare environment. Sensitive and timely surveillance was vital to the global control of SARS, permitting the effective targeted use of traditional strategies such as infection control, quarantine, and social distancing in order to interrupt transmission.

Processing information: Confronting the need for information that is faster, more granular, and increasingly complex, a huge growth area for innovations in surveillance relates to the technologic processes required to share public health information. From pony express to the information highway, from telegraph to text messaging, technology has the potential to transform infectious disease surveillance. However, the promise is often frustratingly greater than our current realities can deliver. Much of the world’s population now lives in a “24/7” media cycle where surveillance data may become dated before they are even issued. Assuring both scientific accuracy and public health relevance in this evolving social environment has always been important to infectious disease surveillance and shall remain so, but increasingly high expectations may become more and more difficult for local, state, or national public health authorities to meet. Despite the opportunities that technological advances have provided to enhance infectious disease surveillance, there have often been political constraints to information sharing of public health data that is construed to threaten tourism, economic, or political interests. However, major changes in the legal framework that underpins communicating urgent public health information to the World Health Organization (WHO) and among nations result from the new WHO International Health Regulations (2005) endorsed by 192 countries at the World Health Assembly in 2005 and scheduled to be implemented in June 2007. These regulations emphasize the need for transparency and timeliness in communicating selected public health events around the world and offer a new global standard for sharing critical surveillance information. This new standard implies, however, that each country develops a critical level of public health surveillance and response capacity to meet the challenges of the new regulations.

Principles: Given the dynamic nature of the pathogens, people, places, and processes associated with infectious disease surveillance, assembling a textbook on this broad subject might be considered an impossible task. Fortunately, the principles underlying surveillance for infectious diseases are surprisingly stable. The common threads woven through the chapters of this book should display to the reader the key principles of why, how, when, and where to employ infectious disease surveillance programs. These principles will serve the public health practitioner well for the foreseeable future. The diverse public health workforce engaged at local, state, national, and international levels in infectious disease surveillance activities can look to this textbook to emphasize the basics for those new to the field and expand horizons for those who have spent careers engaged in one or more aspect of this work.

Anne Schuchat and Jean-Claude Desenclos
July 2007
Preface to Second Edition

High quality national surveillance is the cornerstone of infectious disease prevention and control.

Advances in biomedical sciences have enabled substantial gains in the prevention and control of infectious diseases including the ability to detect, track, treat, and immunize against some diseases. However, infectious pathogens continue to evolve and adapt. Recently, the global community has experienced a resurgence of measles in Western Europe, introduction of cholera in Haiti, and the emergence of New Delhi metallo-β-lactamase 1-producing Klebsiella pneumoniae. The World Health Organization’s International Health Regulations (2005) called for strengthening of capacity to conduct surveillance in every Member State. In 2009, the first major test of these regulations occurred during the H1N1 influenza pandemic.

In recent years, infrastructures to conduct surveillance benefited from innovations in information technology including powerful mobile devices and widespread use of the Internet. The ongoing transformation of the healthcare information systems, especially increased use of electronic medical records, offers additional opportunities for complementary surveillance systems. Implementation of Internet-based systems and large datasets, however, has resulted in a complexity that requires development of new skills among public health professionals. This requires close collaboration with information technology specialists and biostatisticians. It is also prudent to assess the legal and ethical dimensions related to the use of these technologies for core surveillance activities, which, for epidemiologic reasons, include collection of private personal information.

Advances in laboratory and epidemiologic methods, including molecular diagnostic tests for organism identification, have expanded the surveillance toolset and knowledge base of public health practitioners. Further progress in healthcare technology has enabled life-saving procedures including blood transfusion and solid organ transplantation. These positive changes pose inherent risk of transmission of pathogens from donors to recipients. Thus, an understanding of these new frontiers is a prerequisite for robust surveillance systems.

Inspired by a shared vision to support global surveillance efforts, we have collaborated with over 120 authors in writing the second edition of Infectious Disease Surveillance. Its 46 chapters primarily represent surveillance systems from North America and Europe. However, the principles and approaches can be applied in other settings.

We have organized the chapters into six sections based on major themes. Section one begins with an introductory chapter that highlights the critical role surveillance plays in public health and offers an overview of the rest of the book. Subsequent chapters offer historical perspectives including lessons learned in the 1970s from the smallpox eradication campaign. The rest of the chapters address the International Health Regulations and supranational surveillance in the European Union.

Section two describes program-specific surveillance systems, such as population-based surveillance for bacterial pathogens, vector-borne, and transplantation-related infections. Section three explores the use of information technology to advance infectious disease surveillance. Chapters in this section discuss use of the Internet to facilitate disease reporting, dissemination of findings, electronic transfer of surveillance data from laboratories, and data management. In addition, novel surveillance systems that use emerging mobile technologies are covered, as are automated algorithms to assist in detection of cases in electronic laboratory data or to detect temporal and spatial clustering. Section four presents topics in surveillance methodology, including molecular epidemiology, data analyses, geographic information systems, and evaluation of surveillance systems.

Section five addresses broad topics important in the conduct of public health surveillance for infectious diseases. Two chapters discuss ethical and legal considerations in the conduct of surveillance. Additional chapters cover communication with mass media and
examples of surveillance-related training opportunities. Lastly, section six provides a rationale for and examples of public–private partnerships in surveillance programs, and lessons learned from the 2009 influenza pandemic.

It is our hope that this book will serve as a practical guide for surveillance practitioners and key partners; it provides not just conceptual theories but also practical pearls from other practitioners who have been involved in implementation of public health programs. Illustrative examples are provided and referenced for further reading. This book can also serve as a textbook for public health students and for trainees in applied epidemiology and preventive medicine. Lastly, the book may also be of interest to academic and industry researchers in infectious diseases and medical informatics.

Finally, we acknowledge with gratitude many individuals who made this book possible through their encouragement and support. In particular, we are indebted to the generosity of the contributors and external reviewers, and the patience and understanding of our families and friends. We are encouraged by the hope that this book, which grew out of the dedication and expertise of many collaborators, will strengthen current efforts to enhance infectious disease surveillance.

Nkuchia M. M’ikanatha  
Ruth Lynfield  
Chris A. Van Beneden  
Henriette de Valk  
May 2013

About the cover
The cover uses two sets of images to represent surveillance for endemic diseases (seasonal influenza) and use of DNA fingerprinting technology to investigate an emerging infectious disease (a new strain of Escherichia coli associated with a large outbreak in Germany and other European countries in 2011). Images: one set is a pulsed-field gel electrophoresis profile of the E. coli O104:H4 isolates involved in 2011 in Germany on a background of a scanning electron micrograph of E. coli. The other is a figure based on weekly surveillance for seasonal influenza in the USA on a background of an electron micrograph for influenza H1N1 virus. Cover artwork suggestions: Sameh Boktor and Carol Sandt; conceptual design Nkuchia M’ikanatha.
High quality national surveillance is the cornerstone of infectious disease prevention and control.
—World Health Organization, 2004

Major challenges to global and national public health systems during the past 30 years arising from both emerging and established pathogens demonstrate the need for reassessment of the commitment to infectious disease surveillance. The critical need for better surveillance became more urgent during the past decade with the threat of bioterrorism and the recognition of the potential for an influenza pandemic. Concurrently, changes in public health information infrastructure, especially the widespread use of computers and Internet-based systems, resulted in ongoing improvements in the conduct of surveillance. In addition, advances in laboratory and epidemiologic methods, including molecular diagnostic tests for organism identification, have expanded the surveillance toolset and knowledge base.

Inspired to support local and national public health efforts in infectious disease surveillance, we have collaborated to create a readily accessible resource inclusive of recent developments in the field. It contains 40 chapters drawn from experiences of over 100 authors involved in implementation of surveillance systems. We acknowledge the disproportionate representation of surveillance systems from North America and Europe, but when possible, we sought to include considerations for surveillance as it may be applied around the world.

We have organized the subjects into four sections based on major themes. Section I begins with an introductory chapter that highlights the critical role surveillance plays in public health and offers an overview of the rest of the book. The second chapter introduces the International Health Regulations (IHR 2005) and its emphasis on international reporting and strengthening surveillance capacities worldwide. The other chapters in the first section describe disease-specific or program-specific surveillance systems, such as foodborne and vector-borne disease surveillance.

Section II explores the use of information technology to advance infectious disease surveillance. The chapters discuss use of the Internet to facilitate disease reporting and dissemination of findings, electronic transfer of surveillance data from laboratories, and data management. Also, novel surveillance systems that use algorithms to assist in detection of cases in electronic laboratory data or use automated analyses to detect temporal and spatial clustering are introduced. Section III presents topics in surveillance methodology, including molecular epidemiology, data analyses, communication with the media and the public, and evaluation of surveillance systems.

Section IV addresses broad topics important in the conduct of public health surveillance for infectious diseases. Chapters discuss ethical considerations, the legal basis for conducting surveillance, and the legal considerations for isolation and quarantine. In addition, examples of surveillance-related training opportunities and partnerships in the private sector are presented. Lastly, Section V concludes with a review of historical lessons learned from application of surveillance in disease control—in the 1970s, smallpox, and more recently in 2003, the severe acute respiratory syndrome or SARS.

It is our hope that this book will serve as a practical guide for surveillance practitioners and key partners; it provides not just conceptual theories, but practical pearls from other practitioners who have been involved in implementation of public health programs. Illustrative examples are provided and referenced for further reading. This book can also serve as a textbook for public health students and for trainees in applied epidemiology and preventive medicine. Lastly, the book may also be of interest to academic and industry researchers in infectious disease and medical informatics.
Finally, we acknowledge with gratitude many individuals who made this book possible through their encouragement and support. In particular, we are indebted to the generosity of the contributors and external reviewers, and the patience and understanding of our families and friends. We are encouraged by the hope that this book, which grew out of the dedication and expertise of many collaborators, will strengthen, even in a small way, current efforts to enhance infectious disease surveillance.

Nkuchia M. M’ikanatha
Ruth Lynfield
Chris Van Beneden
Henriette de Valk
July 2007
Acknowledgments

This book could not have taken shape without the shared vision and work of many people. Over 100 experts in public health put finger to keyboard at very late hours in order to share their expertise. We are truly grateful for their generosity.

In addition to the authors’ labors on their chapters, a number of people put significant effort into reviewing various components of the book. In particular, we thank Chris Carr, Lars Eisen, David Fleming, Jaclyn Fox, D.A. Henderson, Kathleen Julian, Denise Koo, Stephen Ostroff, Dale Rohn, Carol Sandt, Kay Smith, William K. Reisen, and David Welliver for reviewing chapters. We thank Hellen Shenk, Amanda Perry, and Deepa Saravana for assistance with document search and management. We are grateful to Sameh Boktor, who served as illustration consultant and finalized many of the illustrations in this book.

We recall with fondness Michael Blench, past Canada’s Global Public Health Intelligence Network (GPHIN) Technical Advisor and Project Coordinator, the position he held from 1997 until his untimely death in 2011. Michael embraced the vision for this book and he contributed to Chapter 31: The Public Health Intelligence Network, which we dedicate to his memory.

We are grateful to our colleagues at Wiley-Blackwell for their encouragement and assistance, in particular Maria Khan, Kate Newell, and Rebecca Huxley. We are grateful to Lindsey Williams for the invaluable help she provided during the production stage of this edition.

Finally, we extend our most sincere gratitude to each of our family members, co-workers, and friends who supported our commitment to this project, and enabled it to come to fruition.

Disclaimer

The findings and conclusions in chapters by authors from federal agencies (e.g., US Centers for Disease Control and Prevention, US Food and Drug Administration) are those of the authors and do not necessarily represent the views of the federal agencies.
“To count them all, demands a thousand tongues, a throat of brass, and adamantine lungs,” Homer said of the massive Greek armies gathered against the terrified Trojans in The Iliad. “As they marched, the gleam of their armor flashed up into the firmament of heaven,” the bard ventured, taking the metaphorical route. But still unable to describe their immensity, he settled for a sample. He devised a list naming only the captains and the ships and left the rest to the imagination. “Their names, their numbers, and their chiefs I sing.” In this poetic treatment of a mathematical puzzle, Homer managed to enumerate something that eluded his capacity for control and denomination.

Lists, such as the one Homer used in The Iliad and The Odyssey, abound in the literature of all ages. Eons after Homer, in crafting another Ulysses, James Joyce iterated his own legendary lists of things, from catalogs of books and daily budgets to the contents of Leopold Bloom’s kitchen drawer, which gave clues to his character. Among a host of items, “A Vere Foster’s handwriting copybook . . .: 2 fading photographs of queen Alexandra of England and of Maud Branscombe, actress and professional beauty: a Yuletide card, bearing on it a pictorial representation of a parasitic plant; the legend Mizpah . . .: a butt of red partly liquefied sealing wax, obtained from the stores department of Messrs Hely’s, Ltd., 89, 90 and 91 Dame street . . .”

The ancient Egyptians were master list-makers. Firm believers in an extension of life on earth, they devised religious texts or lists of spells for navigating the complexities of afterlife. “In the land of the night the ship of the sun is drawn by the grateful dead.”