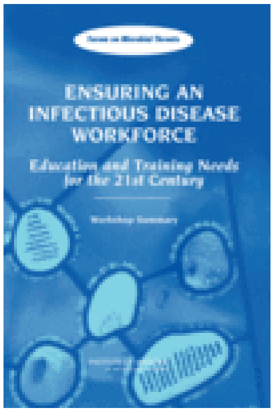

Ensuring an Infectious Disease Workforce: Education and Training Needs for the 21st Century - Workshop Summary

Stacey L. Knobler, Thomas Burroughs, Adel Mahmoud, Stanley M. Lemon, Editors, Forum on Microbial Threats

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Education and Training Needs for the 21st Century

Workshop Summary

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Editors

Forum on Microbial Threats
Board on Global Health
INSTITUTE OF MEDICINE
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This report is based on the proceedings of a workshop that was sponsored by the Forum on Microbial Threats. It is prepared in the form of a workshop summary by and in the name of the editors, with the assistance of staff and consultants, as an individually authored document. Sections of the workshop summary not specifically attributed to an individual reflect the views of the editors and not those of the Forum on Microbial Threats. The content of those sections is based on the presentations and the discussions that took place during the workshop.

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The serpent has been a symbol of long life, healing, and knowledge among almost all cultures and religions since the beginning of recorded history. The serpent adopted as a logotype by the Institute of Medicine is a relief carving from ancient Greece, now held by the Staatliche Museen in Berlin.

COVER: A detailed section of a stained glass window 21 × 56″ depicting the natural history of influenza viruses and zoonotic exchange in the emergence of new strains was used to design the front cover. Based on the work done at St. Jude Children's Research Hospital supported by American Lebanese Syrian Associated Charities (ALSAC) and the National Institute of Allergy and Infectious Diseases (NIAID). Artist: Jenny Hammond, Highgreenleycleugh, Northumberland, England.

"Knowing is not enough; we must apply.
Willing is not enough; we must do."
—Goethe

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All presenters at the workshop have reviewed and approved their respective sections of this report for accuracy. In addition, this workshop summary has been reviewed in draft form by independent reviewers 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 this independent review is to provide candid and critical comments that will assist the Institute of Medicine (IOM) in making the published workshop summary as sound as possible and to ensure that the workshop summary meets institutional standards. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process.

The Forum and the Institute of Medicine thank the following individuals for their participation in the review process:

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The review of this report was overseen by **Melvin Worth, M.D.,** Scholar-in-Residence, The National Academies. Appointed by the National

Research Council, he was responsible for making certain that an independent examination of this report 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 editors and the institution.

Preface

The Forum on Microbial Threats (previously named the Forum on Emerging Infections) was created in 1996 in response to a request from the Centers for Disease Control and Prevention (CDC) and the National Institutes of Health (NIH). The goal of the Forum is to provide structured opportunities for representatives from academia, industry, professional and interest groups, and government to examine and discuss scientific and policy issues that are of shared interest and that are specifically related to research and prevention, detection, and management of emerging infectious diseases. In accomplishing this task, the Forum provides the opportunity to foster the exchange of information and ideas, identify areas in need of greater attention, clarify policy issues by enhancing knowledge and identifying points of agreement, and inform decision makers about science and policy issues. The Forum seeks to illuminate issues rather than resolve them directly; hence, it does not provide advice or recommendations on any specific policy initiative pending before any agency or organization. Its strengths are the diversity of its membership and the contributions of individual members expressed throughout the activities of the Forum.

ABOUT THE WORKSHOP

Recent increased attention to both United States and international public health systems as well as the medical research and treatment infrastructure has revealed significant deficiencies in their capacity to respond to infectious diseases. Medical and public health professionals may be poorly equipped to detect, diagnose, and treat common infectious diseases as well as those diseases that pose an unexpected threat. The need for the development of domestic and international training programs in the expanding field of emerging and reemerging infectious diseases is well recognized. Well-trained infectious disease professionals form the basis of a strong national healthcare system. Increasing costs of care have prompted training in medicine and public health to focus on improving efficiency, cutting costs while maintaining gains in life expectancy and reducing morbidity. In the past decade, public health and medical schools have introduced new educational and communications technologies (Internet and health informatics), problem-based learning approaches, and partnerships and networking to encourage new areas of core competencies. However, there is an increasing need for programs that can improve the breadth and quality of training infectious disease professionals receive. Recent investments made to address the threat of biological weapons seem to be beneficial in strengthening the public health infrastructure but may or may not address the nation's most critical needs.

The workshop will review trends in research training programs and discuss the requirements for establishing successful educational initiatives and training programs to ensure a competent and prepared workforce for current and future challenges in infectious diseases. Some key disciplines to be explored as case-study examinations include infectious disease epidemiology, vaccinology, vector biology, and public health laboratorians.

The goals of the workshop were to:

1. Identify infectious disease training initiatives sponsored by government, foundations, academia, or industry that are or have been successful, and factors required for continued success.
2. Identify topics of public, private, or Congressional interest, such as food safety, vector-borne diseases, restrictions on foreign scientists, and public health preparedness where there may be a dearth of training initiatives or other barriers.
3. Discuss the role of the U.S. Agency for International Development, World Health Organization, and other international organizations in the training of foreign nationals and identify additional training needs (e.g., surveillance, epidemiology, and laboratory training) that would be beneficial in capacity-building and infrastructure development initiatives.
4. Discuss possible alterations in academic programs at the professional student, clinical training, and research training levels to increase awareness of and capacity to recognize and treat or prevent emerging infections.
5. Consider whether current government training programs at the CDC, NIH, and Department of Defense are adequately supported and

whether establishment of public/private partnerships to expand current initiatives would be of value.

The issues pertaining to the stated goals were addressed through invited presentations and subsequent discussions, which highlighted ongoing programs and actions taken, and also identified priority needs in these areas.

ACKNOWLEDGMENTS

The Forum on Microbial Threats and the Institute of Medicine (IOM) wish to express their warmest appreciation to the individuals and organizations who gave valuable time to provide information and advice to the Forum through their participation in the workshop. A full list of presenters can be found in Appendix B.

The Forum is indebted to the IOM staff who contributed during the course of the workshop and the production of this workshop summary. On behalf of the Forum, we gratefully acknowledge the efforts led by Stacey Knobler, director of the Forum; Marjan Najafi, research associate; Elizabeth Kitchens, research associate; and Katherine Oberholtzer, research associate, who dedicated much effort and time to developing this workshop's agenda, and thank them for their thoughtful and insightful approach and skill in translating the workshop proceedings and discussion into this workshop summary. We would also like to thank the following IOM staff and consultants for their valuable contributions to this activity: Patrick Kelley, Dianne Stare, Bronwyn Schrecker, Eileen Choffnes, and Kate Skoczdopole.

Finally, the Forum also thanks sponsors that supported this activity. Financial support for this project was provided by the U.S. Department of Health and Human Services' National Institutes of Health, Centers for Disease Control and Prevention, and Food and Drug Administration; U.S. Department of Defense; U.S. Department of State; U.S. Department of Veterans Affairs; U.S. Department of Agriculture; American Society for Microbiology; Aventis Pasteur; Burroughs Wellcome Fund; Pfizer; GlaxoSmithKline; and the Merck Company Foundation. The views presented in this workshop summary are those of the editors and workshop participants and are not necessarily those of the funding organizations.

Adel Mahmoud, *Chair*
Stanley M. Lemon, *Vice-Chair*

Contents

ENSURING AN INFECTIOUS DISEASE WORKFORCE

Summary and Assessment

Infectious diseases continue to threaten individuals and societies worldwide, in industrialized and developing countries alike. The threats take a variety of forms. New diseases emerge, often being passed from animals to humans. Previously unrecognized diseases become apparent. Endemic diseases stage a resurgence. Microbes that once were controllable with antibiotics evolve to become resistant to drugs. A number of chronic diseases are being found to have infectious etiologies. Biological agents may be used intentionally to cause harm. Thus, it is vital for the United States, along with other nations, to develop and support a workforce that is sufficiently large, well trained, and strongly motivated to meet current and future challenges in detecting, controlling, and preventing microbial threats.

The Institute of Medicine's (IOM) report *Microbial Threats to Health* (2003a) provides a detailed description of the challenges and recommends actions that will be necessary to meet them. Among its conclusions, the report stresses the need for a global approach (IOM, 2003a). The United States should seek to enhance the global capacity for responding to infectious disease threats, and it should take a leadership role in promoting the implementation of a comprehensive system of surveillance for infectious diseases wherever they arise. Attention should be focused, in particular, on improving response and detection capabilities in the developing world, where infectious diseases are most prevalent and opportunities for spread are considerable.

The report also makes clear the need to better understand the dynamic relationship between microbes and humans, rather than to focus simply on fighting individual microbes. The emergence and spread of microbial threats are driven by a complex set of factors. Ultimately, the emergence of such threats derives from the convergence of genetic and biological factors; physical and environmental factors; ecological factors; and social, political, and economic factors (IOM, 2003a). Clarifying and addressing these factors will be essential in developing and implementing effective prevention and control strategies.

In recognition of such complexities—both microbial and societal—the report emphasizes that mounting an effective response to infectious disease threats will require multidisciplinary efforts involving all sectors of the clinical medicine, public health, and veterinary medicine communities. Such a multidisciplinary approach must rest squarely on a well-prepared workforce within each of these communities. However, "the number of qualified individuals in the workforce required for microbial threat preparedness is dangerously low," the report concludes (IOM, 2003a). In addition, there must be open and active communications within and among these communities. Similarly, expanded communications—along with greater coordination and cooperation—should take place among the larger scientific, government, and industrial sectors. This synergy will prove vital in advancing basic knowledge of microbes, in developing and implementing new treatments for infectious diseases, and in fostering measures to control or prevent the spread of microbial threats.

The Forum on Emerging Infections (now renamed the Forum on Microbial Threats) convened a 2-day workshop discussion—the subject of this summary—to examine the education and training needs to ensure an adequate infectious diseases workforce. The workshop considered the workforce in the United States as well as in the developing world. Not only do developing nations deserve attention in their own right, but as people, animals, and goods move around the globe in shrinking amounts of time, infectious agents also have an increasingly easier time spreading around the globe.

EXPLORING THE CHARACTERISTICS OF THE WORKFORCE

Participants at the workshop explored a variety of issues relating to the strength and characteristics of the infectious diseases workforce.

Expanding the Research Workforce[1]

One key question discussed at the workshop focused on the types of scientists and other workers that will be needed in the research enterprise in

[1]For more information, see Victoria McGovern's paper in Appendix A, page 156.

order to meet the wide range of microbial threats. Of course, the nation—and the world—will continue to need people trained in fields, including microbiology and immunology, that traditionally have been associated with infectious diseases. But new needs are emerging as well, driven, in part, by the shift toward a more systemic view of infectious disease, in which microbes and humans are intricately entwined. For example, participants highlighted the need to attract more people in the physical, chemical, mathematical, and computational sciences to apply their expertise to biological questions. The field also needs to attract more people from ecology and evolutionary biology to help lay the groundwork for understanding the human–microbe interface, as well as people from the veterinary sciences to help in understanding the flow of diseases between animals and humans.

As the workforce grows more diverse, some practical hurdles likely will arise. How can we get people from various disciplines talking with one another, speaking a common language, visualizing common problems, and valuing each other's skills and ideas? In other words, how can we promote greater and more productive integration at the interfaces between and among often disparate disciplines? Workshop participants proposed a number of possible strategies.

Within universities, for example, departments can hold regular seminars that bring together researchers from a range of disciplines to share knowledge and generate new ideas. More fundamentally, universities can change their cultures to better foster collaborative, crosscutting research. Tenure systems can be restructured to reward faculty who participate in such research, often as part of a team, and resources can be made available when strong faculty want to move in new directions. Looking beyond academe, workshop participants suggested that local, regional, and national scientific meetings offer opportunities for promoting cross-pollination among a mix of scientists. Networks can be formed to "nucleate" individual researchers and groups around common problems. Foundations can play a particularly important role here by helping to build and support networks to advance a particular field, often by supporting promising young scientists who may lead the field as their careers unfold. Training courses or workshops can bring people together, provide them with shared knowledge, and help them frame new ways of thinking about that knowledge. Professional societies can give new ideas and new connections a boost by bringing people together around emerging issues, and their publishing operations can give a kind of validation that legitimizes, enhances, and encourages innovative but risky work that may yield significant scientific reward.

Participants also discussed potential problems with the educational pipeline that supplies scientists to the research enterprise. Of particular note, concerns were expressed that younger scientists pursuing careers at universities are facing increasing difficulty. Some participants suggested that the entering salaries of trained scientists are not competitive with other intellectually challenging careers. In addition, it is taking longer to get through the system. Thirty years ago, the average new Ph.D. in the life sciences received his or her degree in 6 years, while today it takes an average of 8 years (NRC, 1998). Some evidence suggests that the period spent in postdoctoral training is getting longer as well. As a result, the pool of young scientists positioned to compete for research funding—a gateway to academic success—is shrinking. Twenty years ago, for example, scientists under the age of 35 represented 20 percent of the pool applying for grants from the National Institutes of Health (NIH), the nation's major funder of research in the health sciences. Today, this age group comprises less than 5 percent of the pool—and the situation is worse in clinical research (Goldman and Marshall, 2002). Thus, the professorate is graying, with more research dollars going to older scientists, while younger researchers are being left in extended professional adolescence.

Science is bigger than academe, of course. Industry employs a great number of researchers and other technical workers. Workshop participants suggested some new routes for training people in the skills suited to industry's specific needs. For example, universities might create a "professional doctorate," akin to the way medical schools train a cadre of people ready to practice medicine. Such students would receive broad-based training across a number of disciplines, and they would participate extensively in team-oriented research. Most people in industry, however, will not need a Ph.D. degree. As an alternative approach, some universities are developing specialized 2-year master's degree programs that provide students with the educational groundwork and research experience necessary to meet the day-to-day needs of industrial laboratories. Early evaluations of these programs indicate that graduates are finding ready acceptance in the job market.

THE ROLE OF PHYSICIAN–SCIENTISTS

Physician–scientists play an important role in advancing medicine. Workshop participants explored how to take even greater advantage of this segment of the workforce in meeting current and emerging microbial threats (Ganem, 2003). Typically defined as persons who perform biomedical research and hold either an M.D. or M.D.–Ph.D. degree, physician–scientists work in a variety of areas, including basic research, disease-oriented research, and patient-oriented research. They are trained to ask clinically relevant questions that lead to the development of research projects linking basic and clinical research; they also are a vital force in transforming clinical observations into testable research hypotheses and translating research findings into medical advances. Workshop discussions focused heavily on physician–scientists trained to work in the laboratory. Among their activities, physician–scientists are especially well positioned for studying basic mechanisms of microbial replication and pathogenesis, working with high-level pathogens under strictly controlled conditions, developing new vaccines, and discovering new pathogens.

Several lines of evidence, however, suggest that shortages are developing in the overall supply of physician–scientists (Rosenberg, 1999). For example, a study by Ajit Varki and Leon E. Rosenberg found that in 1983 there were 18,535 physician–scientists in the United States, but by 1998 this number had fallen to 14,479—a 22 percent decline (Varki and Rosenberg, 2002). Workshop participants also reported anecdotal evidence that fewer physician–scientists are applying for fellowships in infectious diseases programs at numerous universities nationwide, and that fewer physician–scientists are reporting research results in professional journals serving the field.

Participants offered a variety of reasons for the declining number of physician–scientists. The list includes financial disincentives, including an increasing debt burden for medical school graduates, which tend to push the youngest members of the medical profession away from research (Rosenberg, 1999). (Some participants argued, however, that financial considerations may be less important than is sometimes suggested.) Other factors include a lack of senior physician–scientist role models engaged in research in infectious diseases, and changes in hospital practices. For example, the growth of managed care has imposed financial constraints on academic health centers, and many leaders of clinical departments now require that their faculty members see more patients, thus reducing the time they have available for research or to train upcoming physician–scientists (Rosenberg, 1999). Such changes mean that there is no reinforcing mechanism to encourage people to continue on the long pathway of clinical training while retaining an interest in laboratory science and pathophysiology.

A number of ways were suggested for recruiting more physician–scientists. For example, medical schools can seek out more students who are interested in and demonstrate an aptitude for research. In this way, promising students can be "bonded" to medicine even before they begin formal medical training. During their training, students can be encouraged to seek intensive research experiences early, and they should be rewarded for their efforts. Some participants suggested that cultivating M.D.–Ph.D. programs may provide an especially useful avenue for bonding students and enriching the pipeline for physician–scientists. Support also can be extended beyond medical school. Residency programs can be augmented—for example, through journal clubs and periodic dinners with senior physician–scientists—to help keep residents interested in continuing a career in research, and development programs can be conducted following residency to help smooth the transition of new physician–scientists as they enter their new careers.

The Role of Ph.D. Scientists[2]

In today's scientific environment, including work in infectious diseases, most Ph.D. scientists concentrate on a single specific discipline—and this system has yielded remarkable advances. But many observers suggest that this approach may be less effective in producing scientists who have the broad perspective and breadth of knowledge that will best equip them to address the complex challenges that lie ahead in handling microbial threats worldwide.

Workshop participants discussed several educational models for producing Ph.D. scientists who possess the palette of skills necessary to help in translating research into everyday clinical practice. Graduates of such programs will be "adaptive" experts who can respond rapidly to changing conditions in research and clinical medicine, and who can help to identify unmet needs in these areas.

One of the models described is represented by the Medical Engineering Medical Physics Ph.D. program conducted by the Harvard-MIT Division of Health Sciences and Technology (Abelman et al., 1997; Wilkerson and Abelman, 1993). This program is designed to educate graduate students at the interface of engineering, the physical sciences, and the biomedical sciences via a flexible structure that permits exploration of all the intersections of those disciplines. It is considered unique in providing students with clinical experience similar to that which second- or third-year medical students would have. Although this program is focused on engineering and the physical sciences, the model on which it is based is considered equally adaptable to trainees in the natural sciences. Other innovative Ph.D. programs are based on a "targeted exposure" model, in which students receive varying amounts of training in pathophysiology, pathobiology, or medical concepts in addition to their regular coursework. In one such program at Washington University, for example, students take a two-semester course in human pathology that focuses on the clinical and basic science aspects of important disease states, and the interactions initiated in the course are sustained via a clinical mentor program that continues through the graduate experience.

Both approaches have demonstrated success (Gray and Bonventre, 2002). Workshop participants noted that the programs attract exceptional candidates and are consistently oversubscribed. Many alumni have entered

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[2]For more information, see Martha L. Gray's paper in Appendix A, page 143.

top-ranked institutions, often obtaining positions of leadership, and they are proving successful in garnering grant support. Importantly, many of them are in positions where they can connect with the patient-care enterprise during the course of their research and thus have the potential to create vibrant links between the laboratory and clinic.

Based on their experiences with such training programs, workshop participants offered a number of lessons that can be used in designing new multidisciplinary Ph.D. programs in areas specifically related to infectious diseases. An institution should begin by firmly establishing the overarching goals of the training program. Students should take a strong core of courses in their chosen discipline, in order to learn one field thoroughly. Providing students with first-hand knowledge of human disease through direct interactions with patients is crucial. Although this can happen passively by bringing patients into classes, a more effective approach is to take students into the clinical setting. As any student making the transition from preclinical to clinical work can testify, there is a world of difference between learning in the classroom and implementation in the wards. Finally, institutions should commit to establishing a truly multiprofessional community and to "institutionalizing" programs that cut across classical organizational structures. Such organization greatly reduces the inevitable barriers that exist between departments or disciplines, and it helps both students and faculty to better understand the various underlying value systems and perspectives. It is this understanding that forms the foundation for the necessarily collaborative work that is required to bring the proverbial bench to the bedside.

Strengthening the Public Health Workforce[3]

By the very nature of their jobs, public health (PH) professionals will be instrumental in protecting society from microbial threats and in mounting effective responses to disease outbreaks, whether naturally occurring or intentional. PH professionals are defined as people educated in public health or a related discipline who are employed to improve health through a population focus. They receive education and training in a wide range of disciplines, come from a variety of professions, work in many types of settings, and engage in numerous kinds of activities.

As many observers have noted, however, the public health infrastructure at the local, state, and federal levels in the United States has suffered years of neglect. As one result of such systematic lack of financial and policy support, there has developed an overall shortage of qualified work-

[3]For more information, see Margaret A. Potter's paper in Appendix A, page 176.

ers prepared to prevent or respond to major outbreaks of infectious disease. In recognition of this situation, the IOM report *Microbial Threats to Health* called for immediate, broad-based efforts to ensure that the nation has an adequately trained and competent PH workforce that can respond quickly to emerging microbial threats and monitor infectious disease trends (IOM, 2003a).

Workshop participants suggested that efforts to buttress the PH system might best begin by obtaining a better understanding of the numbers, locations, and expertise of the various types of people comprising the workforce. In many cases, data are limited. One widely cited analysis found that for the year 2000, there were 448,254 workers in state and local health departments, schools of public health, and a few selected national voluntary organizations (Gebbie, 2003; Gebbie et al., 2000). This total amounts to 158 workers per 100,000 people in the general population—a decline from 219 workers for the same population in 1979, when the PH workforce was at its largest. The workforce is unequally distributed by region, with density differences thought to be related, in part, to state and local funding and policy decisions and to geographic conditions that influence the provision of services (Gebbie, 2003). Among the professionals in the workforce—who make up roughly 44 percent of the total—public health nurses comprise the largest group. Other groups identified, in descending order of size, include environmental professionals, officials and administrators, public health physicians, and public health educators (Gebbie, 2003). These statistics represent only rough counts at best, however, and workshop participants agreed that new national studies are needed to better characterize the workforce and to identify current and future needs.

Within the total PH workforce, two categories of professionals were identified by participants as being particularly relevant to meeting the challenges of emerging microbial infections: epidemiologists and infection control/disease investigators (see Potter in Appendix A). But both groups face significant shortages. In the analysis for the year 2000, these two classifications together contributed less than 0.47 percent of the total workforce (see Potter in Appendix A). This percentage may underrepresent or overcount the actual number of workers in the groups, for several reasons. Still, workshop participants expressed concern that these professionals, both central in the front-line defense against disease outbreaks, apparently are so lacking in the PH workforce. (See the section "Fields of Special Emphasis" for additional details.)

Participants also discussed efforts to assess and improve the core competencies of members of the workforce. At heart, competency is a measure of whether workers have the knowledge and skills to perform their assigned tasks. (A related issue is "capacity," which is a measure of whether an organization has sufficient resources for delivering to people the services it is supposed to deliver.) A number of organizations have compiled descriptions of core competencies for the overall PH workforce and for specific groups of PH professionals, such as public health nurses and environmental scientists.

One widely recognized set of recommendations is outlined in the IOM report *Who Will Keep the Public Healthy?* (2003b). It endorses the five core components of public health that have long been recognized—epidemiology, biostatistics, environmental health, health services administration, and social and behavioral science—but also adds eight more critical areas. The new areas encompass informatics, genomics, communication, cultural competence, community-based participatory research, policy and law, global health, and ethics (IOM, 2003b). In addition to serving as general guidelines for public health, these new competencies also will find application among professionals working specifically in the area of infectious disease.

Strengthening the PH workforce will require a range of efforts, and workshop participants identified schools of public health as having a particularly important role to play. There currently are 33 schools of public health in the United States that are accredited by the Association of Schools of Public Health (ASPH). In 2002, these schools graduated 5,665 people, with roughly two-thirds of them earning a master of public health (M.P.H.) degree, which is the field's core professional degree. There are an additional 37 accredited M.P.H. programs in community-health and preventive-medicine departments of medical schools, and 15 accredited M.P.H. programs in other types of schools (Council on Education for Public Health, 2003).

Workshop participants discussed the variety of ways that schools of public health can contribute to meeting the challenges of emerging infections. By definition, they can serve as a key link in improving the education of the PH workforce. As evidence of the need for expanded education, the federal Centers for Disease Control and Prevention (CDC) estimated in 2001 that 80 percent of PH workers lacked specific public health training and only 22 percent of chief executives of local health departments had graduate degrees in public health. In addition to training future members of the PH workforce, the schools can reach workers already in the field as well. Indeed, a number of schools already are conducting practical training programs to reach workers by distance-communication media (such as the Internet) and in special on-site programs. For example, two federal agencies, the CDC and the Health Resources and Services Administration (HRSA), now support practical education programs through nearly 50 schools of public health. The training through these centers covers crosscutting topics of relevance to public health practice, as well as specialized topics relevant to emerging infectious diseases.

Schools of public health also can advance research, as scientists pursue studies into communicable diseases, their vectors, their incidence and prevalence, their prevention, and their treatments. In addition, there is a strong need for expanded practice-oriented research. Such research is needed to help answer fundamental workforce questions—for example, how many professionals the PH system actually requires for optimum performance, and how many students should be trained to satisfy these requirements—and to assess the performance capacity of PH agencies. Without such information, schools cannot target education and training programs, state and local governments cannot develop effective standards for staffing public health agencies, and policy makers cannot allocate resources rationally.

Integrating Public Health and Health Care[4]

In tandem with strengthening the nation's public health workforce, it also will be important to better educate all students in the health professions in the basic concepts of public health (Colin-Thomè, 1999). Indeed, recent experiences with both the intentional release of anthrax spores and the natural spread of the West Nile virus serve to reinforce the importance of links between educated, alert health-care workers and a responsive PH system. Strengthening the relationship between public health and clinical medicine also will be important in developing plans to handle the surge of patients that might arise during a large-scale disease outbreak.

One way that workshop participants explored to integrate knowledge of public health concepts into the broader health context is to revise the curricula used in institutions that train health and scientific professionals, including those in the medical, nursing, veterinary, and laboratory sciences. It was suggested that curricula for educating non-specialists in the fundamentals of public health should be built around nine principle areas: evidence-based ethical practice, health-care needs assessment, cultural competency and awareness, epidemiologic transitions, partnership building, health policy analysis, management and leadership, health-care planning, and evaluation of the effectiveness of interventions.

In revising their curricula, institutions can begin by evaluating the strengths and weaknesses within their various departments. Among possible strengths are commitment to change within the overall institution; commitment of a critical mass of staff members to promoting public health education; available baseline information about public health content already in the curricula; and external contacts that some staff members have with national or international networks interested in public health. Weaknesses can include insufficient resources and time; staff members who are inadequately trained to teach or learn epidemiologic/population concepts or who feel un-

[4]For more information, see Walid El Ansari's first paper in Appendix A, page 76.

reasonably treated by management and are thus unwilling to cooperate with new initiatives in protest; and managers, especially at higher levels, who lack the responsibility to bring about proposed institutional policies.

Within most departments and institutions, committed leadership will be critical in setting change in motion and ushering it to successful conclusion. Thus, initiators of curricula reform might best begin by embracing a dynamic staff development program to explain both the necessity for and the benefits of introducing public health concepts into general study. Some resistance should be expected, and leaders would be wise to learn why such resistance is arising and how it might be reduced without engendering bitterness. Senior management will be required to empower staff members for broad-based action, in order to consolidate gains and ultimately to anchor the new approaches in the institutional culture.

FIELDS OF SPECIAL EMPHASIS

Complementing their explorations of some general issues facing the infectious diseases workforce, workshop participants also examined "case studies" of a number of professions and scientific areas of investigation that are more specific to the field.

Infectious Diseases Physicians[5]

Physicians specially trained in the area of infectious diseases (ID physicians) comprise an important part of the workforce that is charged with meeting current and future challenges in detecting, treating, and preventing microbial threats. There is a limited amount of data regarding the number and level of expertise of ID physicians in the United States or worldwide. Workshop participants suggested, however, that several lines of evidence indicate that programs to train ID physicians need to be strengthened.

For example, the number of infectious diseases training programs that participate in the U.S. national resident matching program decreased between 1994 and 2002 (from 120 to 105), and the total number of positions offered also declined (from 257 to 251) (see Gorby in Appendix A). Graduates filled a larger percentage of the available slots, however, and the total number of participants increased during this period (from 155 to 198). Still, more than 20 percent of training slots went unfilled in 2002, despite an increased demand for ID specialists. Of interest, the percentage of slots filled with U.S. graduates rose from 34.6 percent to 51 percent. From the U.S. position this trend might be considered positive, as more ID physicians

[5]For more information, see Gary L. Gorby's paper in Appendix A, page 129.

are being trained who are likely to remain in this country. But from the international perspective the trend may seem less positive, as fewer experts are being trained who may return to their native countries, where emerging infectious diseases often pose even greater problems. As another indication of the need for strengthening training programs, a survey of recent ID graduates found that only 51 percent of respondents felt that their training in infection control was adequate (Joiner et al., 2001). The answer, all participants agreed, is to strengthen training programs to boost the number and skill level of ID physicians from both the United States and other countries, especially in the developing world.

Participants identified a number of factors that may deter physicians from entering careers in infectious diseases and public health. There are monetary drawbacks, as ID physicians and PH physicians rank on the lower end of the income scale when compared with other medical specialties. In addition, few students are exposed at an early stage in their training to career options in infectious diseases or public health. Many physicians who enter these fields also report that they encounter a less than desirable working environment, often marked by understaffing, limited resources, and a frequent turnover of key personnel (including, in state agencies, the chief medical officers who are appointed politically).

Among efforts to strengthen the ID physician workforce, a first step would be to gain a better understanding of the landscape. In the aftermath of the terrorist attacks on the United States on September 11, 2001, there has been a significant increase in funding, especially to states, to improve bioterrorism preparedness and the capacity of hospitals to respond to infectious diseases. Two of the largest funding sources have been the Health Resources and Services Administration and the Centers for Disease Control and Prevention. The HRSA provided $918 million in 2002 and budgeted $542 million in 2003; the CDC provided $918 million in 2002 and $870 million in 2003. It must yet be determined, however, whether this funding has increased the number of physicians working in the areas of infectious diseases or public health. In addition, although such increased funding is welcome, it remains possible that future funding will be reduced if the threat of bioterrorism is perceived to decrease.

Participants also suggested that ID training programs need to ensure that formal didactic training in public health, epidemiology, and infection control practices is included in every fellowship experience. This could be accomplished in a number of ways, including participation in formal month-long rotations or accessing an Internet-based training course. Such a course might best be developed jointly by the Infectious Disease Society of America and others, including the CDC, the Society for Healthcare Epidemiology of America, and the Association for Professionals in Infection Control and Epidemiology (Joiner et al., 2001).

Closer links need to be cultivated between ID physicians in private practice and the relatively small group of ID physicians who work full time in an infection control/public health capacity. Participants suggested that these links should be grown primarily at the local level (and to a lesser degree at the state/territorial health department level) to strengthen the necessary "nuts and bolts" local response network. This may require exploring novel technologies for on-demand interactive training, such as a natural language engine paired with a text-to-speech software application or animated virtual teaching assistant. Such technologies would enable conversation-like interactions by many users simultaneously.

Incentives to encourage students to pursue ID/PH careers must be developed. Marketing of such careers should take place relatively early in the educational process, and certainly prior to the accumulation of a large educational debt. An unusual but possible approach to raise awareness of ID/PH careers might employ "edutainment" venues analogous to recent television series about forensic pathology. As a result of such exposure, premed or high school students who were previously unaware of the career path might give some consideration to the option. In addition, forgiveness of educational loan debts for students who elect to undergo ID/PH training would remove a major deterrent to the pursuit of such careers. In exchange, these individuals would have to agree to work in an ID/PH capacity for several years after their training, and it would be hoped that many of these individuals would remain in the field even after their obligation was met.

Participants also suggested that consideration be given to developing a Public Health Medical Reserve Force analogous to military reservists. This force could be formally and selectively activated, thus ensuring an adequate and competent response team. Membership should carry an obligation for recurring ID training certification for which the reservist would be compensated. Physicians would be joined on this force by other health professionals, and together they would form a multidisciplinary national resource that stands ready to respond to any natural or intentional major disease outbreak.

Epidemiologists/Allied Health Professionals

As the science that studies how often diseases occur in different groups of people and why, epidemiology will play a key role in combating microbial threats, whether they arise naturally in a population or are introduced by terrorism (Perl, 2003; Srinivasin, 2003). Public health epidemiologists will be involved in the investigation and control of infectious diseases, the design and enhancement of surveillance systems to detect diseases, and the analysis and interpretation of surveillance and other data. They also will be central in interacting with physicians, nurses, hospitals, and laboratories.

Workshop participants reported, however, that the United States lacks a sufficient number of epidemiologists who are adequately trained and have enough resources to meet current and emerging microbial threats. The picture is even more bleak in the developing world.

Comprehensive data are lacking on how many epidemiologists the nation has and what their skill levels are—but several studies have pointed to major shortcomings. For example, a survey by the Council of State and Territorial Epidemiologists (CSTE), conducted from late 2001 to early 2002, found that the number of epidemiologists working in state and territorial health departments had declined during the past decade, from 1,700 full-time equivalent positions to less than 1,400 (CSTE, 2003). Approximately 42 percent of current epidemiologists lacked formal academic training in epidemiology. Moreover, most of the respondents thought that their operations had insufficient staff and resources. The lack of workforce growth has occurred despite the significant expansion in the scope of responsibilities for epidemiology during the same period. Another study following the terrorist attacks of September 2001 identified the need for at least 600 new epidemiologists in public health departments nationwide to meet the requirements for biopreparedness alone.

In the event of a disease outbreak, epidemiologists working in hospitals often find themselves at the center of efforts to identify the pathogen, treat patients when therapies are available, and control the spread of infection both within their own hospital and among the public. Thus, workshop participants saw a need for training more people to work in hospital epidemiology and infection control, and, in particular, to train future leaders in these areas. Some participants called for the National Institutes of Health to assume this role, just as it now supports training programs to prepare leaders in other areas related to infectious diseases, such as research on HIV/AIDS and tuberculosis. Schools of nursing also can be provided with sufficient funds to support training programs in these areas. Similar training in the area of hospital epidemiology and infection control is equally important within health-care settings in developing countries. Organizations active in training programs, such as CDC and the World Health Organization (WHO), should consider such elements for program design.

Participants identified additional needs as well. To complement efforts to train more people who specialize in hospital epidemiology, steps can be taken to provide all professionals who work in the area of infectious diseases (including physicians, nurses, and allied professionals) with at least the basic concepts of epidemiology and infection control. Schools of medicine and nursing can do more to incorporate this material into their curricula, and students pursuing fellowships in infectious diseases should certainly be exposed to this material. To support such efforts, accrediting organizations might require that training programs add some element of formal training in hospital epidemiology and infection control, and professional societies, such as the Infectious Diseases Society of America, can take leadership roles in emphasizing the importance of these issues.

Environmental Health Professionals

There is a clear tie between environmental health and infectious diseases: diseases spread by animals and insects, diseases linked to contaminated water or faulty sewer systems, and diseases that hold potential for being spread deliberately by terrorists. As workshop participants heard, however, the workforce of environmental health professionals is showing signs of weakness.

In 2000, local health departments nationwide employed approximately 19,400 environmental health specialists; this cohort represented roughly 10 percent of the total public health workforce. But even as needs for such specialists are increasing, the numbers of students and graduates in environmental health are declining. Twenty-five U.S. universities currently offer accredited undergraduate programs in environmental health. Between 1993 and 2002, these programs experienced a 42 percent drop in enrollment and a 58 percent drop in the number of students graduating. Compounding problems, increasing numbers of environmental health professionals, including many in upper management, are now retiring from local public health departments.

Workshop participants discussed several efforts under way to strengthen the field. For example, the Centers for Disease Control and Prevention, working with a number of other public and private groups, has been developing a comprehensive action plan. Called "A National Strategy to Revitalize Environmental Public Health Services," the plan sets out six major goals with related objectives and activities (CDC and National Center for Environmental Health, 2003). The goals include building program capacities at local, state, tribal, and territorial levels; supporting research to identify ways to enhance environmental health services; fostering strong leadership; expanding communications among agencies, communities, and other partners and improving the marketing of environmental health services to policy makers and the public; promoting the development of a competent and effective environmental health work-force; and creating strategic partnerships among agencies, organizations, and interests that influence environmental health services. Reaching these goals will require collaborative efforts and sustained commitment by all stakeholders.

To aid in workforce development, the CDC, working with the American Public Health Association, has developed a set of recommendations for core competencies for local environmental health professionals (CDC and APHA, 2001). The competencies represent a broad set of skills, including being able to assess and interpret data, manage programs, solve problems, evaluate programs, build collaborations, educate and train coworkers and others, and communicate information about environmental health to a range of audiences. According to workshop participants, a number of local public health agencies are now developing training programs to improve the skill levels of their workers, not only in terms of their technical competencies but also their leadership and management competencies.

Veterinary Public Health

Interactions among humans and animals can have a dramatic impact on public health (King, 2003). Approximately 70 percent of infectious diseases that have newly emerged or reemerged in recent decades were transmitted to humans from animals. Moreover, many of the infectious agents that might be used in bioterrorist attacks originate in animals (King and Khabbaz, 2003). Another potential health threat that arises from human–animal interactions is an increase in the resistance of pathogens to drugs as a result of misuse of antibiotics in animals raised commercially (King and Khabbaz, 2003). These and other concerns are heightened by increasing international movement of people, animals, and animal products; climate and other environmental changes, including those that affect wildlife populations; and issues of national and global security.

Clearly, veterinarians have an important role to play in protecting public health, and workshop participants explored a variety of ways to involve them more fully in this mission. One challenge will be to expand and diversify the core workforce—that is, veterinarians who hold full-time jobs in public health. Today, less than one half of 1 percent of veterinarians are so employed. Possible steps forward include increasing the number of veterinarians who take part in the Centers for Disease Control and Prevention's Epidemic Intelligence Service, which is a 2-year, hands-on comprehensive epidemiology and public health training program. This program also can serve as a model for developing regional programs in order to expand the number of veterinarians who can participate. In addition, veterinary schools and schools of public health can join together to develop and offer dual degree programs. On a larger scale, the veterinary community is exploring the possibility of developing a federally funded National Veterinary Service to help bring in recruits who will work in public health and related areas.

It also will be important to involve the thousands of veterinarians in private practice, who deal with public health issues with their clients on a regular basis, but often lack significant education or training in even basic public health concepts. Workshop participants offered a variety of suggestions on how veterinary education and training can be improved. As a foundation, veterinarians will need to develop a new portfolio of skills, knowledge, and aptitudes to meet contemporary problems. Veterinary schools will need to strengthen training in such areas as genomics, bioterrorism, population health, emerging diseases, information technology, risk communications, and cultural differences related to health. Schools also should make greater efforts to change behaviors, not only among their students but also internally. Emphasis should be placed on fostering interdependence, working in teams, and respecting other disciplines. In addition, schools can strive to expand the "professional value" of their graduates. Well-trained veterinarians will be needed to participate in such activities as disease and pathogen surveillance, epidemiology and investigation of infectious diseases, population health and medicine, monitoring antimicrobial resistance, wildlife epidemiology and management, and biomedical research in which they will work hand in hand with scientists from numerous other disciplines.

One key to success, participants agreed, will be to get more students interested in veterinary science—the earlier, the better. Public communication efforts can target younger people, who often have a natural interest in working with animals, and new scholarship and fellowship programs can be developed to provide motivated students with the resources necessary to fulfill their goals. Universities also can develop mentor programs to help students as they pass through their college years. Assistance also can be made available after graduation, through programs such as the proposed National Veterinary Service. As students learn more about the vital link between veterinary medicine and public health, they will be better equipped to handle emerging challenges, whether they are serving directly in public health, working in wildlife epidemiology and management, or serving clients in private practice.

Vector Biology/Entomology[6]

A number of vector-borne pathogens, including malaria and dengue, remain as major health burdens and as obstacles to economic development throughout much of the world's tropics. Diseases caused by vector-borne pathogens, including Lyme disease and West Nile fever, also continue to emerge in many temperate regions. However, the United States now lacks the capacity, including a sufficient workforce, to confront these agents, according to the IOM report *Microbial Threats to Health* (IOM, 2003a).

As a first step in addressing this issue, workshop participants explored some of the forces that have helped cause the workforce gap. Many of these

[6]For more information, see Andrew Spielman's paper in Appendix A, page 183.

forces revolve around the way that the nation funds research in the health sciences (see Spielman in Appendix A). For the most part, it is the research interests of faculty members at universities that largely determine the characteristics of the scientific workforce—and it is the ability of researchers to gain funding for their projects, typically from the National Institutes of Health, that makes it more or less attractive for universities to employ them. Thus, changes in the system that the NIH uses to review investigator-initiated proposals may help redirect health-related research on vectors into promising areas, such as vector microbiology and insect transgenesis. Such changes may come slowly, but participants agreed that they would be worthwhile in helping to rebuild and reshape the workforce.

One goal, in particular, will be to find ways to support research efforts that bring vector biologists into collaborative contact with researchers in a range of other fields, including parasitology, clinical medicine, and public health. Such collaborations might find natural homes in schools of public health or medicine, or in cross-departmental centers at universities. Although the NIH can play an important role in fostering multidisciplinary projects and other innovative research, foundations and private donors have so far proved most aggressive. Several groups, including the Bill & Melinda Gates Foundation, the Burroughs Wellcome Fund, and the MacArthur Foundation, support cutting-edge research and training programs to advance knowledge and increase the field's human capital.

Vaccinology[7]

Vaccines against infectious diseases are one of the major success stories of modern medical science. Yet in the United States and worldwide, many diseases remain for which vaccines either have not been developed or are not readily available. Thus, there is a critical need for more people in a range of disciplines to work in vaccinology, the field that comprises vaccine development as well as the use of vaccines and their effects on public health.

One factor that workshop participants identified as complicating vaccine development is the increasing scientific complexity of the process. For any disease now being studied, there may be four or five strategies, often quite different, being explored. As a result, development efforts typically require a much greater range of expertise than previously was the case. In addition, the targets for vaccination are expanding. Vaccination traditionally has been considered a pediatric task, and pediatricians have been in the forefront of promoting and developing vaccines. But target populations are now expanding to include adolescents and adults, and vaccines are being developed to fight a broader range of diseases, including some diseases, such as cancer and

[7]For more information, see Stanley Plotkin's paper in Appendix A, page 166.

Alzheimer's disease, that are linked to infectious agents. New vaccines also are being developed for therapeutic use against some chronic infections, an approach that previously was not considered possible.

This changing nature of vaccine development has led to a need for expanded education and training, and workshop participants identified a number of areas in which more physicians and scientists are needed. The areas include, among others, pathogenesis and the development of animal models that shed light on pathogenesis; immunology, which is needed to better understand a target disease so that appropriate antigens can be identified; and clinical trials, which can range from small to exceedingly large and which require a thorough knowledge of epidemiology to design and conduct. Safety assessments also have become increasingly important, and people with a broad understanding of diseases are needed to analyze immune reactions in studies performed in both laboratory and clinical settings.

Participants suggested that in order to help strengthen the workforce in vaccinology, medical schools can do more to teach their students about vaccinology and disease prevention via vaccines, so that they will consider this a realistic career path. Changing curricula to emphasize prevention rather than treatment may help bring this about. It also is vital that training programs be multidisciplinary and incorporate a range of core subjects, such as pathogenesis, microimmunology, safety regulations, scale-up technology, clinical development, and investigational new drug formulations.

The question then arises: who will teach these courses? Workshop participants proposed that one hitherto overlooked place to seek help is industry. Bringing skilled people from private companies into the early stages of training potential scientists and physicians may be a challenge—involving such issues as confidentiality—but at least some participants were confident that problems could be overcome. Moreover, they stressed that industry has a vested interest in finding innovative ways to improving education. When companies now look to hire people in vaccinology, they often have trouble finding sufficient numbers of qualified candidates. Indeed, some participants suggested that this is one of the reasons why the U.S. vaccine industry is relatively small. Industry also can help by developing and supporting training opportunities in the workplace, to ensure that more students are exposed to career paths in vaccinology.

Laboratorians[8]

As vividly demonstrated by efforts to contain West Nile virus in 1999, anthrax in 2001, and severe acute respiratory syndrome in 2003, public health laboratories play a lead role in the detection and response to infec-

[8]For more information, see Scott J. Becker's paper in Appendix A, page 56.

tious diseases. The laboratories also perform a number of other key services to support and improve testing programs and to manage laboratory data for effective disease surveillance (CDC, 2002). In order to perform at peak effectiveness, laboratories need a highly trained staff—but the nation now faces an ongoing shortage of skilled laboratorians. For example, a 2002 wage and vacancy survey taken by the American Society of Clinical Pathologists (ASCP) found that the average vacancy rate for staff-level medical technologists ranged from 6 to 10.2 percent, depending on geographic region (Ward-Cook, 2003). Of particular concern, laboratories are losing to retirement a significant cohort of senior staff, including laboratory leaders, often before they have a chance to recruit and train replacements.

Workshop participants explored some of the factors behind the workforce shortages. These factors include the need for laboratory scientists to master a large, and expanding, body of knowledge and skills; government hiring practices and legal hurdles that often make it difficult to fill positions; concern about biosafety risks; and relatively low pay compared to other sectors of health professionals. There also has been a drop in the number of students interested in laboratory science, which has led to closure of hundreds of accredited training programs, from roughly 1,000 in 1970 to about 500 today (Painter, 2000).

In order to recruit more laboratory scientists, steps will be needed to increase awareness of laboratory careers among students, beginning even before high school and continuing through the college years. Laboratory skills also should be incorporated in larger measure into the curricula of medical schools and schools of public health. State laboratories can help drive this effort by working with schools. Some state laboratories, for example, now offer rotations to medical students and to other students pursuing degrees in relevant sciences. Steps will be needed as well to make careers in laboratory science more attractive: better wages; improved opportunities for training and advancement for practicing laboratorians; added measures to address biosafety risks; relocation assistance; and, importantly, increased public recognition for laboratory technicians and scientists.

Faced with such challenges, a number of organizations have launched innovative programs to help fill workforce needs. Among the examples described at the workshop is the Emerging Infectious Disease (EID) Fellowship program, conducted jointly by the Association of Public Health Laboratories (APHL) and the Centers for Disease Control and Prevention (see Becker in Appendix A). Begun in the mid-1990s, the program enables college graduates at the bachelor's, master's, and doctoral levels to spend 1 to 2 years working in public health laboratories. More than 200 fellows from the United States and abroad have been placed in local, state, and federal laboratories nationwide. Following their training, many fellows accept positions in public health laboratories or continue their education and pursue careers in medicine or other health-related fields. The APHL also recently established the National Center for Public Health Laboratory Leadership. In the past, laboratorians have lacked any mechanism beyond on-the-job training to gain the managerial, public policy, communications, and other skills essential to oversee the complex workings of a public health laboratory. The new center is identifying and disseminating the knowledge needed for effective decisionmaking in public health laboratories, and it is providing technical assistance—such as workshops in grant writing, media relations, and the regulatory inspection process—to support laboratory leaders.

Efforts also are being expanded to improve the knowledge and skills of current laboratory workers. The National Laboratory Training Network, conducted jointly by the APHL and the CDC, offers a variety of courses and workshops. Since its inception in 1989, the network has delivered more than 3,200 workshops and training activities—including courses in bioterrorism, tuberculosis, virology, and molecular laboratory methods—to more than 100,000 laboratorians. This type of targeted training is not available from any other source.

Collaborative Research

The complex problems involved in controlling infectious diseases—from emergence and detection to treatment and prevention—will require the involvement of experts from a broad range of disciplines and health sectors. Furthermore, an interdisciplinary, collaborate approach can facilitate the training of the workforce needed to meet these challenges (Cassatt, 2003). As many workshop participants reported, however, the present structure of most academic and public health institutions forces individuals, disciplines, and even entire sectors to operate independently of each other. Thus, opportunities for collaboration—and the synergy that springs from such cooperative efforts—are often lost.

In order to explore ways in which collaborative research might be fostered, participants discussed some current trends within the National Institutes of Health, the nation's single largest supporter of health-related research. In 2003, the agency issued what is called the NIH Roadmap for Biomedical Research. Intended to guide research over the next decade, the roadmap describes major opportunities and gaps that no single institute at the NIH could tackle alone but that the agency as a whole must address in order to make the biggest impact on the progress of medical research. Within this broad framework, the plan identifies three main areas that offer the most compelling opportunities: new pathways to discovery, research teams of the future, and re-engineering the clinical research enterprise (Zerhouni, 2003).

Within each of these areas, it is clear that life and medical scientists will need to work collaboratively with researchers in a number of other fields, including chemistry, computer science, information science, mathematics, and physics, to name but a few. It also is clear that improving crosscutting research will rest solidly on training more researchers, not only in their individual disciplines but also in how to work creatively across disciplines, often in large, multidisciplinary teams. Workshop participants described this as breaking out of the "silos" that now characterize the structure of the research enterprise. At the NIH, the silos are the individual institutes that focus on targeted areas of research; at universities, they are the departments that focus on individual disciplines. Silos also exist, of course, in other organizations at all levels of government, as well as in many organizations in the health and scientific communities.

In an effort to dismantle such silos, the NIH has launched a number of projects to stimulate new ways of combining skills and disciplines in both the physical and biological sciences. For example, the agency is funding several so-called "glue grants," which are large grants (providing about $5 million annually for direct costs) to enable interdisciplinary teams to attack in a coordinated manner fundamental biological issues. In addition to their role in advancing science, the grants will serve as experiments to help determine whether such team efforts can, as believed, provide greater returns than can individual scientists operating independently—and if the answer is positive, how such advantages can be maximized. Lessons learned from these grants should help inform how research is funded and conducted not only by the NIH but across other government agencies and in academe.

It should be noted, too, that lessons about collaborative research might be gained by looking to industry. As workshop participants reported, interdisciplinary research is literally the order of the day at pharmaceutical and other health-related companies. Biologists, computer scientists, drug metabolism scientists, medicinal chemists, synthetic chemists, pharmacologists, pharmaceutical scientists, and many other specialists all work together toward a common goal, with little room for squabbles over turf.

The NIH also is exploring innovative ways to train researchers to meet emerging interdisciplinary challenges. Workshop participants described, for example, some efforts under way in the area of biomedical computing, including the creation, in 2001, of the Center for Bioinformatics and Computational Biology. Increasingly, researchers spend less time in their "wet labs" gathering data and more time on computation. As a consequence, more researchers find themselves working in teams to harness the new technologies. A broad segment of the biomedical research community perceives a shortfall of suitably educated people who are competent to support those teams. The problem is not just a shortage of computationally sophisticated associates, however; there also is a need for a higher level of competence in mathematics and computer science among biologists themselves. The center will train scientists in these fields by having them "learn while doing," while at the same time generating such new developments as mathematical models of biological networks, modeling and simulation tools, and methods for analyzing and storing data.

In addition to the practical challenges to be met in training new generations of scientists to tackle complex biomedical issues, there is a philosophical question as well. It is a matter of breadth versus depth. Is it better to assemble teams of people, each with a deep understanding of an individual discipline, to attack a specific problem? Or better to have people with very broad knowledge who can work across a number of disciplines, but who may not have detailed knowledge in any single discipline? No best answer emerged, but workshop participants generally agreed that for the present, some combination of both approaches, adjusted to the scientific issues being addressed, may prove most practical.

Behavioral Scientists

Human behavior, both individual and collective, plays a critical role in disease emergence (Tawfik, 2003). At the same time, programs aimed at influencing human behavior have long proved important in protecting or improving individual and public health. The permutations are varied. People can be encouraged to give up risky behaviors or to adopt new behaviors that promote health. Groups of people can be persuaded to take particular actions or to work with other groups to achieve health goals. Even governments are amenable to change brought about by changing people's knowledge, perceptions, and attitudes. Although changes in human behavior can be difficult to achieve and maintain, this approach often offers the only way to achieve lasting desired outcomes. In promoting public health, then, behavioral scientists can make important contributions.

As an example of some of the challenges involved in promoting behavioral change, workshop participants discussed a project under way to improve the outcomes of infectious disease control in selected developing countries. The 5-year effort is hosted by the Johns Hopkins University School of Public Health, in partnership with a number of other organizations, and is supported by the U.S. Agency for International Development. The project's mandate is to use strategic communication to create "health competent" societies in which mothers and children are better protected from a variety of infectious diseases, particularly HIV/AIDS, tuberculosis, and malaria.

Within each of the countries, project staff members work together with local health professionals, who often are employed in health ministries or schools of public health. The first step is to help these professionals become better able to communicate public health concepts and to advocate for programs designed to improve public health. Working in tandem, project members and local health professionals then target three main audiences.

One audience comprises national policy makers, such as presidents and health ministers, who can directly influence nationwide health policies. The advocacy teams strive, for example, to get policy makers to add more money to national health budgets, to increase allocations for controlling infectious diseases, to adopt policies that will most effectively address health needs, to fill vacant positions in the health workforce, and to take action to reduce the stigma often associated with some of these diseases. The second audience includes health service providers. Much of this effort focuses on equipping them with knowledge and skills that will help them provide better treatment, offer more informed counseling, ensure that their patients adhere to treatment regimens, and participate in surveillance activities to detect disease outbreaks and notify higher-level authorities. The third audience comprises the individuals in local communities. A key component of this effort is to form partnerships with groups of people who are affected, directly or indirectly, by a given disease. This might include, for example, groups of youth who have HIV/AIDS, groups of mothers with sick children, or groups of adults who are sick or know someone who is sick. Engaging communities in this manner will help not only in improving treatment of individuals but also in disease surveillance.

Workshop participants agreed that lessons learned from this and similar programs may well build on each other and help inform future efforts to influence human behavior for the betterment of health—and that more skilled and experienced behavioral scientists will be needed to bring such efforts to fruition.

Bioethics and Genomics[9]

Recent years have seen remarkable scientific and technological advances, and progress has been especially notable in fields that directly or indirectly touch human health. Biotechnology is yielding new ways to develop drugs and vaccines. The genetic codes of major pathogenic organisms are being unraveled. Perhaps most important, researchers have sequenced nearly the entire human genome. Many observers have commented on the impact that such advances will have on human health. Less attention has been paid, however, to how the nations and peoples of the world will share in this newfound intellectual wealth.

[9]For more information, see Tara Acharya et al. in Appendix A, page 67.

Workshop participants identified some of the ways that genomics and biotechnology can be harnessed to improve health in the developing world, and they explored some of the factors that may slow such efforts. Today, most research in these areas is concerned with the priorities of industrialized nations. But some projects suggest that genomics and biotechnology can make a huge contribution to public health in developing nations within the next 5 to 10 years (Daar et al., 2002). Some participants even suggested that over the longer term, these fields could well have greater impact in the developing world than in the industrialized world, due, in part, to the huge health inequities that exist among nations.

Participants provided a list of the "top ten" biotechnologies for improving health in developing countries. It includes molecular diagnostics, recombinant vaccines, drug and vaccine delivery systems, bioremediation, sequencing pathogen genomes, methods that enable females to protect themselves against sexually transmitted infections, bioinformatics, enriched genetically modified crops, recombinant drugs, and combinatorial chemistry.

A key question, of course, is: how to get from here to there? Who will energize the efforts needed to put these or other promising technologies into action globally? Participants discussed a model that may catalyze action. The Bill & Melinda Gates Foundation has pledged $200 million to the Grand Challenges in Global Health initiative, which is administered by the Foundation for the National Institutes of Health. The intent of the initiative is to engage creative minds from across the world and the breadth of scientific and technology communities, including those who have not traditionally engaged in global health research, to partner in developing solutions to critical scientific and technological problems that, if solved, could lead to important advances against diseases of the developing world. By directing substantial and carefully targeted resources toward key health-related research questions pertinent to developing countries, the initiative is intended to attract talented investigators to address these issues and significantly accelerate the development of affordable, practical solutions.

Workshop participants noted that not only is there a moral and social argument for industrialized nations to move aggressively in sharing emerging scientific knowledge and tools, but there is also an argument based on enlightened self-interest. Since infectious diseases often emerge first in the developing world, controlling them on that "front line" might prevent or at least slow their spread globally. Collective action will be needed by developed nations in many areas—including efforts to build research infrastructure and to improve education and training—to provide developing countries with sufficient capabilities to capitalize on the latest advances. These steps will require a financial commitment by the governments of industrialized countries, along with the sharing of relevant intellectual property, a thorny issue that will demand extensive discussion. Some participants agreed with the suggestion for a global genomics initiative (Dowdeswell et al., 2003), in partnership with developing countries, to provide a forum to discuss and develop these issues.

ASSESSING DOMESTIC AND INTERNATIONAL TRAINING PROGRAMS AND EDUCATIONAL NEEDS

The need to develop new domestic and international education and training programs to support a workforce capable of dealing with emerging and reemerging infectious diseases, and to continue and expand ongoing training programs that are proving effective, is well recognized. Workshop participants explored a variety of issues related to U.S. and global needs for such programs and examined a number of examples of current efforts.

Public Health Leadership

Public health professionals play key roles in protecting society from microbial threats and in mounting effective responses to disease outbreaks. As numerous reports have observed, however, the PH system at the local, state, and federal levels in the United States has suffered years of neglect and needs to be rebuilt. At the workshop, participants noted that an important step in strengthening the system will be to enhance the leadership capacities of senior public health officials, as these people are well positioned to lead change within organizations and across the broad sweep of the public health community (Woltring, 2003). As added importance, it is expected that 40 percent to 50 percent of the managers and administrators in local, county, and state PH departments will retire in less than a decade.

Meeting this workforce challenge is the goal of the Centers for Disease Control and Prevention/University of California Public Health Leadership Institute (PHLI). Established in 1991 and funded by the CDC, the PHLI's key objectives are to provide participants (called scholars) with knowledge, skills, and experiences that enhance their commitment and ability to provide leadership; to support scholars in exercising leadership in a variety of contexts, including within their agencies or jurisdictions and within professional organizations and schools of public health; and to strengthen their abilities to form collaborations that contribute to the development of healthy communities. Further aims include developing a nationwide network of senior PH leaders and stimulating leadership development efforts at state and local levels.

The PHLI is a year-long program that offers a variety of coordinated activities, including independent reading, teleconferences and electronic seminars, on-site retreats, personal leadership assessment, and peer consultation, among others. The curriculum focuses on improving skills in personal leadership, leading organizational change, community building and collaborative leadership, and leadership in training others. Woven throughout are efforts to improve communications skills, to enable scholars to better communicate personally and within and among teams and organizations, and to participate effectively in such broader efforts as media advocacy and social marketing.

More than 500 scholars have graduated from the PHLI. They have come from nearly every state, and they have been drawn from government PH agencies (local, state, and federal), academic PH organizations, national health organizations, and other health-related systems. The question, of course, is: does it work? Interim evaluations suggested that the PHLI program was meeting its objectives and having an important impact on scholars' leadership skills. At the workshop, participants discussed results of the latest, and most comprehensive, evaluation, which covered scholars who took part through 1999. Conducted with help from outside consultants, the evaluation included a survey of scholars (which had a 67 percent response rate) and a set of 18 in-depth interviews of individuals in four groups, including PHLI management and faculty, respected public health leaders who did not participate in the program, CDC staff, and PHLI scholars (for elaboration of survey responses).

The evaluation demonstrated that the PHLI had a measurable, positive impact on scholars' leadership effectiveness (Woltring et al., 2003). Among key results, respondents reported great or moderate impact on personal leadership effectiveness by expanding their view of their role as a public health leader (82 percent) and by enabling them to use new approaches and ways of doing things (77 percent). Regarding organizational leadership, respondents reported great or moderate improvement in assessing the need for organizational change (69 percent) and improving their organizations' performance in accomplishing core functions (67 percent). As to community leadership, respondents reported great or moderate impact in developing coalitions or collaborations (68 percent) and enhancing the capacity of community-based organizations (55 percent).

From a broader perspective, scholars underscored the importance of the relationships and networks they developed as a result of their participation (Woltring et al., 2003). Ninety-four percent of respondents described these relationships as meaningful, and 57 percent reported that the relationships increased their effectiveness as public health leaders. Moreover, the evaluation revealed that scholars have made significant contributions to the public health enterprise. Scholars reported a high degree of involvement in such activities as teaching/mentoring colleagues in the field (65 percent), providing leadership to national professional organizations (55 percent), and participating in the development of state or regional PH leadership groups. Outside public health leaders interviewed during the evaluation also commented on the impact that the alumni are having on advancing workforce development for the field, as well as on their enhanced leadership of professional PH organizations and their growing ability to influence the national public health agenda.

For example, PHLI alumni have joined together to form the Public Health Leadership Society. Among its activities, the society recently developed a Code of Ethics for public health and is working to help schools of public health incorporate ethics competencies into their curricula. Alumni also have played critical roles in forming and developing state and regional public health leadership institutes. As of April 2002, seven state and seven regional institutes were serving 38 states, and five additional state or regional institutes were under development, to add 5 more states to the total being served.

Beyond providing insight into the performance of the PHLI, the evaluation has forged new ground in applying a solid design and methodology to the difficult task of retrospectively assessing leadership training programs, and it offers an approach from which others may learn. The greater hope is that current and potential funders will be inspired by the evaluation's positive results to continue—and even expand—their support for leadership training, both nationally and internationally.

The CDC continues to support leadership training. In 2000, the agency launched the National Public Health Leadership Institute, through a partnership headed by the University of North Carolina at Chapel Hill School of Public Health and the Kenan-Flagler Business School. The target audience is mid- and senior-level public health managers in state and local governments. Two to six staff members take part as a team in the nearly year-long program, working together to develop a public health business plan. Teams also are encouraged to include key stakeholders in their community who do not work directly in public health but have an interest in seeing the plan come to fruition. Evaluation efforts to date indicate that the program is succeeding in giving participants needed management skills and improving their job performance. The CDC also conducts a variety of other complementary programs in such areas as mentoring, coaching, and program development and planning.

Applied Epidemiology

The workforce necessary to improve U.S. and international capacity to respond to microbial threats must be supported with strong training programs in the applied epidemiology of infectious disease prevention and control. According to the IOM report *Microbial Threats to Health* (IOM, 2003a), the Centers for Disease Control and Prevention, the National Institutes of Health, and the Department of Defense (DoD) should expand current and develop new intramural and extramural programs that train health professionals in applied epidemiology and field-based research in the United States and abroad. The agencies should develop these programs in close collaboration with academic centers or other potential training organizations or facilities. In addition, the knowledge and skills needed to confront microbial threats must be better integrated into the training of all health professionals.

One of the largest current efforts in this area is the CDC's Epidemic Intelligence Service (EIS), which is a 2-year postgraduate training and service program that provides health professionals with an opportunity to "learn while doing"—that is, to play hands-on roles in active epidemiology projects in the United States and abroad. The program enrolls about 70 participants, called "officers," each year. Most participants are U.S. residents, but recent years have seen increasing numbers of participants from other countries. A typical class comprises primarily physicians, but it also might include nurses, veterinarians, dentists, and doctoral graduates in epidemiology and the social and behavioral sciences. The majority of EIS officers train at CDC headquarters, where they work in specialized disease- or problem-specific areas; some officers go to either a state or large local health department, where they receive broad training in a front-line public health experience. During their training, each officer is required to complete a set of core activities, including the conduct of field investigations, the analysis of large databases, and the evaluation of public health surveillance systems. They also are trained in communications skills and are required to respond to public inquiries.

Since the program's inception in 1951, more than 2,500 professionals have participated. In recent years, most graduating officers (nearly 90 percent) embark on careers in public health at the local, state, federal, or international level. The majority of foreign officers either return to their country of citizenship or to another international setting, where they typically work in some area of public health.

The EIS's success has helped foster the development of similar training programs in more than 25 other countries, with EIS graduates and CDC staff often aiding in their development. Two common types of programs currently under way are Field Epidemiology Training Programs (FETPs) and Public Health Schools Without Walls (PHSWOWs). FETPs are typically organized within a country's ministry of health, while PHSWOWs usually are partnerships between ministries of health and university schools of public health (or departments or institutes of public health within a university). Both models emphasize competency-based field epidemiology, with the PHSWOWs generally providing broader training in management and social sciences than do the other programs (Mock, 2003).

The goal of FETPs is to provide service to the sponsoring government or health ministry while also training public health workers in epidemiology and disease outbreak investigation. During training, staff members, trainers, and trainees (fellows) seek to provide and enhance core public health functions, including disease control and prevention, surveillance, and supplying information needed to inform government policies and legislation. FETPs have produced more than 900 graduates, and more than 400 more are currently in training. Many observers have concluded that these programs have contributed significantly to improving their nations' efforts in infectious disease control and prevention.

The Public Health Schools Without Walls program, which began in the early 1990s with support and leadership from the Rockefeller Foundation, aims at helping developing nations increase their capacity to train graduates with technical, managerial, and leadership competencies who will respond to practical health problems and direct health systems that are becoming increasingly decentralized (CDC, 2004a). PHSWOWs seek to break the barriers that often exist between teachers and students, between researchers and communities and government policy makers, between health-care providers and patients, and between traditional public health education and other health and related disciplines. Programs target health professionals in entry- or mid-level positions, and training typically culminates in their receiving a Masters of Public Health degree or some other type of postgraduate certification.

PHSWOWs combine the strengths of rigorous training conducted at the participating academic organizations with extensive supervised practical experience that stresses solving immediate local health needs as much as memorizing knowledge. In addition to gaining technical knowledge and skills, the trainees develop competencies in investigating and evaluating local health problems; designing, managing, and evaluating health programs; assessing and controlling environmental hazards, including those that might arise from bioterrorism; and communicating effectively with colleagues, communities, and government officials.

Workshop participants discussed the performance of some of the first PHSWOWs developed: in Ghana (CDC, 2004b), Uganda (CDC 2004c), Zimbabwe (CDC, 2004d), and Vietnam (CDC, 2004e). Evaluations show that the programs have produced several hundred graduates, and almost all of them are now involved in the management of health services, mostly at the district level. For example, in Uganda, which has a mid-sized program, more than 50 participants have graduated. Some of them have taken managerial positions in the nation's ministry of health, some have remained at the participating academic institute, and some have assumed managerial positions in various health programs at national and regional levels. Additional training programs have been started or are being developed in a number of other countries in Africa and Asia.

Despite their successes, however, PHSWOWs remain vulnerable. Each of the programs depends heavily on external funds to support its activities, and a limited number of faculty members are responsible for teaching participants. Recommendations for future efforts include expanding faculty development and institutional infrastructure for research; developing more flexible learning tools and making increased use of continuing education; expanding the number and type of professionals served; and incorporating a regional strategy for institutional development, including promoting specialization within public health education systems. Indeed, institutional development is a key issue. Universities and other academic and professional organizations may have an important role to play in this regard, and this role might best be served by their committing to "institutional mentoring" efforts that will be significant in scope and long lasting in duration.

Partnerships[10]

Strategies to improve public health, including efforts to expand the workforce and to combat infectious diseases, increasingly highlight the need and value of forming partnerships. Partnerships can operate at local (Findley et al., 2003), national (Morse, 2003), and international levels (Haroon, 2003; Steenbergen and El Ansari, 2003), and they can comprise a range of participants, including people and groups from government agencies, academic and medical institutions, industry, private philanthropies and non-governmental organizations, and local communities, to name but a few.

A growing body of literature suggests that many partnerships and other types of collaborative projects appear to meet their stated goals, and hence such efforts are widely deemed to be "good." This may well be the case. But workshop participants observed that much more can be done to evaluate their actual effectiveness and to identify factors that significantly affect their outcomes, and they discussed several studies intended to inform such questions. The studies focused primarily on five academic–community partnerships in South Africa (see El Ansari in Appendix A). Funded by the W. K. Kellogg Foundation, the partnerships are intended to improve health care in the communities by reforming the way that medical, nursing, and health professionals are trained. The projects are joint ventures between local and regional academic institutions and health service providers, on the one hand, and the beneficiary communities and their civic organizations, on the other hand. Their goal is to train health professionals in an interdiscipli-

[10]For more information, see Walid El Ansari's "Stakeholders' Perceptions" paper in Appendix A, page 89.

nary, community-oriented, and community-based fashion, and then to develop or expand networks and other mechanisms by which these providers can interact with people and groups in the communities to provide needed services.

Some of the studies described at the workshop offered ideas on how evaluations of community partnerships might best be conducted, while others described how well the partnerships are performing and how they might be improved. A key lesson is that it is important for parties on all sides to respect each others skills, abilities, and contributions. One study, for example, examined how the health professionals as a group and community members as a group viewed each other's expertise in five areas: educational competencies, partnership fostering skills, community involvement expertise, change agents proficiencies, and strategic and management capacities. It turned out that community members have a positive view of the capabilities of the professionals, particularly their abilities in such areas as budget management, policy formulation, and the introduction and management of change. The professionals, however, had limited appreciation of the capabilities of community members in every aspect of expertise examined. According to the study team, these findings suggest that if joint working is to survive, then professionals will need to increase their valuation of the indigenous proficiencies inherent in their community partners. It is a matter of moving away from a "them and us" mentality toward a sense of "we" that will help foster a partnership of mutual benefit.

Workshop participants also examined ways that distance-learning is being employed to form "virtual partnerships" that foster international education in health-related areas. One project, for example, involves the Emerging Infections Network, a Web-based training tool, operated by the Asia Pacific Economic Cooperative, which links public health professionals in 21 countries that border the Pacific Rim. The network provides up-to-date information about emerging infectious diseases of international importance, and it seeks to encourage timely and effective notification and control of disease outbreaks.

In order to enhance the network's value, researchers from the University of Washington School of Public Health recently developed and tested a new set of instructor-led learning materials and placed them on the Web site, supplementing a viewer-guided page of electronic links to library resource materials. Access to the site increased substantially after the new training materials were launched, especially among public health workers in Asia. The researchers concluded that expanding this and other such outreach efforts can help overcome the lack of accurate information and the difficulty in establishing real-time communications among international health workers and agencies, problems that often encumber global disease surveillance efforts. As electronic linkages mature, there will be an accompanying increase in the speed of interaction and flexibility necessary to respond efficiently to infectious diseases wherever they occur.

ADDRESSING THE WORKFORCE CRISIS IN THE DEVELOPING WORLD[11]

Infectious diseases are a global problem and therefore require a global response (Culpepper, 2003; Hrynkow, 2003; Duale, 2003). As the IOM report *Microbial Threats to Health* observed, nations must be concerned not only with diseases that afflict their own citizens, but also with diseases occurring elsewhere (IOM, 2003a). Particular attention needs to be paid to the developing world, where the burden of infectious diseases is greatest. A number of forces at work in developing countries—population growth, urbanization, poverty, malnutrition, climate change, and political instability, among others—have created conditions that can promote the emergence and reemergence of diseases. It is estimated that one of every two people in developing nations will die from an infectious disease.

It is vital to combat infectious diseases in developing countries for the sake of their populations; this mandate should not be minimized. The steady push toward globalization also has catalyzed the speedy long-distance transport of people and animals—prime carriers of infectious microbes—and thus a pathogen emerging in a developing country is only a plane ride or boat ride away from the United States or any other part of the developed world.

It is therefore vital that the United States, along with other developed nations, help developing nations improve their capacity to monitor and address microbial threats as they arise. The IOM report recommended that U.S. investments should include financial and technical assistance, operational research, enhanced surveillance, and efforts to share both knowledge and best public health practices (IOM, 2003a). It also will be important for the United States to coordinate its efforts with key international agencies, such as the WHO. A number of federal agencies, including the Centers for Disease Control and Prevention, the National Institutes of Health, the Department of Defense, the Agency for International Development (USAID), and the Department of Agriculture (USDA), can play central roles. These agencies should communicate amongst themselves and coordinate their programs, and they should collaborate actively with private organizations and foundations. There is an absence of any ongoing investigations into the variable needs within developing countries in infectious disease, and these agencies

[11]For more information, see A. Edward Elmendorf's paper in Appendix A, page 127.

need to support and develop a needs assessment. It was suggested that these agencies convene an international forum in the near future to examine infectious disease education and training needs in developing countries.

During the workshop, participants made clear that an important part of helping developing nations improve their capacity to handle microbial threats will be to help them to improve their scientific and medical workforces charged with controlling infectious diseases.

Framing the Issue

Data regarding health workforces in developing nations are limited and largely anecdotal, but participants generally agreed that the apparent shortcomings constitute a crisis. By way of illustration, they noted that the United States spends just over $2.20 per capita per year on domestic programs directed solely to infectious disease epidemiology, while numerous developing countries, such as Bangladesh, spend about that amount per capita per year overall for health (see Elmendorf in Appendix A).

As the United States and other developed nations work with developing nations on workforce problems, care should be taken to involve a range of participants from the countries and to respect cultural and social issues (Starling, 2001). Directors of government ministries of health, along with other officials directly responsible for health policies, must be involved. Also to be included are top officials in ministries of education and senior academic administrators in higher education, because of their responsibility for universities and schools of medicine and public health, and leading officials responsible for civil service operations and employment practices, because such a large share of the health workforce in most developing nations is employed in the public sector. High-level representatives of the health professions should be invited as well; they may seem obvious participants, but in fact this group has frequently been ignored in government policy deliberations.

Various international organizations also should help in addressing workforce issues, perhaps in collaborative ventures. Given its mission, the WHO should have a key role. Other key participants might be the World Trade Organization (because of its growing interest in trade in services, which inevitably will include services provided by health professionals), the World Bank and the International Monetary Fund (because of their involvement with developing country macroeconomic issues), and the Organisation for Economic Co-operation and Development (because of its role as a forum for discussing and coordinating economic and social policies). Bringing together these parties—along with their domestic counterparts in various countries—in a targeted international effort will likely be a formidable task, but workshop participants called it a challenge that the global community cannot afford to let pass.

Lessons from Africa

As one way to help illuminate the health challenges in the developing world, participants discussed needs and activities in Africa.

The needs, of course, are great. Some 300 million to 500 million new cases of malaria are diagnosed worldwide each year, and between 1 million and 2 million people die from the disease. Up to 90 percent of the cases and 90 percent of the deaths occur in Africa, primarily among young children. Other diseases, such as AIDS and trypanosomiasis, also are prevalent. In response, numerous international organizations have mounted a variety of health initiatives, often aimed at specific diseases. Although these programs are valuable in their own right, they will perform best if they rest on robust public health systems within each developing country. This will require increasing the size of the workforces, enhancing the skills of health professionals and allied workers, and strengthening motivations for countries to invest in workforce development and for professionals to choose public health as a career (El Ansari and Phillips, 2001).

Again, the needs are clear. Ten countries in Africa have only one doctor per 30,000 citizens—and that doctor nearly always lacks formal training in public health. Twenty-seven countries do not have a school of public health and often do not offer any formal PH training at all. Even in nations that have schools of public health, links are generally lacking among academic training, research, and the everyday practice of public health. Links also are frequently poor between institutions in developing countries and organizations in the developed world that work in public health training and health research.

In light of such needs, some participants offered several recommendations from AfriHealth, a relatively new organization that is working to mount a pan-African effort to improve public health. The group has called for international donors to join together in making a major investment in public health in Africa. Investments should total perhaps 5 to 10 times the amount now being spent, and commitments should cover perhaps 25 to 50 years. New and expanded programs should focus not only on improving the skills of individual PH professionals, but also on improving the infrastructures of PH schools and other institutions that will train professionals, conduct needed research, and generally support the field.

Education and Training Programs

Not to be overlooked, of course, are the workforce education and training efforts, both publicly and privately supported, now under way in the developing world (Breman and LeDuc, 2001). These programs can serve as a foundation on which to build stronger health systems. Workshop participants explored some of these programs, examining their successes and their continuing needs. For example, the National Institutes of Health's Fogarty International Center (FIC), whose mission is to promote and support scientific training internationally to reduce disparities in global health, conducts more than two dozen programs. The center's core concept is to build training on top of research. Its primary, and oldest, effort is the AIDS International Training and Research Program (AITRP). Started in 1988, the program brings foreign scientists and allied health professionals (from the masters level to the postdoctoral level) to the United States for advanced training either at the NIH or at schools of public health or medicine. The AITRP is intended to establish critical biomedical and behavioral science expertise in developing countries affected by HIV/AIDS and the related tuberculosis (TB) epidemic, facilitate new prevention research efforts that supplement or complement NIH and other U.S. research on these diseases, establish long-term cooperative relationships between U.S. and foreign research groups, and support cooperation between U.S. academic research centers and foreign scientists.

The AITRP has trained more than 2,000 scientists from some 60 countries. Complementing its in-depth training, the center also offers short courses on a variety of topics, both in the United States and in developing countries, and more than 50,000 students and health professionals have taken part. Evaluations show that a great majority (80 percent) of the foreign scientists trained in the United States return to their home countries, and many of them ultimately assume leadership positions in government and academic health organizations.

The FIC also conducts the International Training and Research Program in Emerging Infectious Diseases, which was started in 1995 and operates in partnership with several institutes within the NIH. Modeled on the AIDS program, it offers foreign scientists advanced training opportunities at the NIH or U.S. universities (in such areas as epidemiology, basic laboratory practices, and selected social sciences), and conducts short courses in the field, which attract a range of health workers whose jobs involve diagnosis, patient management, and the control and prevention of infectious diseases. The relatively young program already has trained more than 200 scientists who have returned to their countries of origin. As another measure of its success, roughly 10 percent of all presentations at a recent world congress on tuberculosis were authored or coauthored by program graduates.

Indeed, the FIC places high priority on encouraging foreign scientists to return home, and has developed a program tailored to this goal. The Global Health Research Initiative Program, supported by 13 partners across the NIH, provides financial and other types of assistance to help ensure that scientists who complete their training in the United States will be able to continue their research at their home institutions.

Programs such as this may help avoid a "brain drain" from the developing to the developed world (Hilary, 2002). Some workshop participants suggested that a brain drain already is well under way. In Africa, for example, is it estimated that some 23,000 qualified academic professionals emigrate annually. Information from South African medical schools suggests that a third to a half of its graduates immigrate to the developed world. This trend, according to some observers, is worsening the already depleted scientific and healthcare workforces in many developing nations. Some workshop participants noted, however, that the movement of health professionals, though deserving of vigilant scrutiny, may not be all bad, and may even offer some benefits to developing nations. Many of the professionals move to positions in international health organizations, such as the WHO, where they can participate in decisions that affect global health policies. In addition, migrating health scientists can promote research activities relevant to their home countries, thereby helping to improve the allocation of health research funding in these areas.

Another FIC program addresses the recognized need to join together a host of disciplines to understand and control infectious diseases. The Ecology of Infectious Diseases program spans several institutes at the NIH and involves a number of outside agencies, such as the CDC, the USDA, the National Science Foundation, the National Institute for Environmental Health Sciences, and the U.S. Geological Survey. It provides grants to multidisciplinary teams of researchers, in both foreign countries and the United States, who will collect data on a range of topics, with the goal of improving current ability to predict the outbreak of infectious diseases.

The FIC also is stepping up efforts to foster the development of "centers of excellence" in the developing world. The idea is to have scientists in those countries take the lead as principle investigators in research and training programs. Several programs, in such areas as brain disorders and bioethics, already are under way. The latest effort is the International Clinical, Operational, and Health Services Research and Training Award for AIDS and Tuberculosis. Involving numerous partners from within and beyond the NIH, the program is intended to integrate research aimed at improving care and treatment across a range of conditions related to HIV/AIDS and TB. Planning grants have been made to a dozen countries, and plans call for making full awards in 2004.

Encouraging more young U.S. scientists to study in developing nations offers another route to workforce development. Whether they remain in those countries or return to the United States to share their experiences, these scientists can make important contributions. The FIC, with support from the Ellison Foundation, recently launched a fellowship program that will enable advanced students in medicine, dentistry, and nursing, as well as doctoral candidates in public health, to study at institutions in the developing world. The students will spend a year in mentored clinical research training.

The Department of Defense also supports efforts to improve laboratories, health and scientific workforces, and disease response capabilities in the developing world. Many of these programs are components of the DoD's Global Emerging Infections Surveillance and Response System (GEIS). Established in 1997, the system is intended to improve the United States' ability to protect the health of its military and civilian populations, as well as global health interests, through systematic laboratory-based surveillance, research, disease response, training, and capacity building. As part of this effort, the DoD supports infectious disease research laboratories in five developing nations: Egypt, Indonesia, Kenya, Peru, and Thailand. The laboratories have long been in place as basic research facilities, but many of their activities have now been woven into the operations of the GEIS.

These laboratories support disease surveillance and outbreak response in the host countries. But they do more, too, by serving as training facilities. Training takes several forms. For example, lab personnel train scientists and other technical workers from the host countries in the latest diagnostic methods and other bench techniques. The goal is to raise the quality of local laboratories to a uniformly high level. When this happens, the DoD labs redirect their efforts to helping the local laboratories develop quality control programs, to ensure that the high standards are maintained. The DoD labs also hold workshops devoted to outbreak response. Professionals from ministries of public health and workers from local and regional health departments attend the workshops, which may last 2 to 3 weeks, to gain skills that will help them better detect emerging infectious diseases on their own. As an indication of the popularity of these workshops, the laboratories regularly receive more requests to attend than there are spaces available. In other training efforts, the DoD provides funding for some host national laboratory employees and others to attend academic institutions in the United States for advanced degree training, which they can put to work when they return to their home institutions.

The DoD also sends U.S. scientists and physicians to the laboratories to receive advanced training in infectious diseases and other scientific areas, and to experience what it is like to work in public health. Participants in such efforts may spend several weeks to several months in the laboratories, and evidence suggests that they often emerge with heightened interests in pursuing research or public health careers, either in the United States or in the developing world.

IMPLICATIONS OF VISAS AND SELECT AGENT RESEARCH RESTRICTIONS[12]

As the United States works to improve its abilities and the abilities of other countries to combat microbial threats, it also will be necessary to keep the nation safe from other threats that have emerged in recent years. The terrorist attacks of September 11, 2001, along with the purposeful distribution of anthrax spores through the mail that followed, have raised national concerns about security. In response, the government has initiated a series of measures—and is planning more. Many of these measures directly affect the scientific and health communities.

Workshop participants universally agreed that the nation must be kept safe, but many of them expressed concern that some of the new security measures may unduly interfere with how research and scientific training are conducted, both in the United States and internationally. Most of the discussions focused on two issues: the system that controls how visas are issued to foreign scientists and students wanting to enter the United States; and the system that controls who may work with certain biological agents and toxins that pose a severe threat to public health and safety ("select agents"), what procedures must be followed when working with them, and how the materials may be transferred among laboratory facilities within the United States and internationally (see Atlas in Appendix A) (Flagg, 2003; Barrett; 2003).

Visas

In short, the U.S. scientific and health communities have long depended heavily on foreign-born scientists and physicians, including those already accomplished in their fields and those still pursuing their education. A host of reports have documented their numbers, as well as their contributions. The occasional bad apple cropped up. But the government's visa system was, in general, considered adequate (if sometimes slow) in handling the stream of applications, while prohibiting entry of individuals who posed serious security risks. The terrorist attacks changed everything. Many people, including many in government, became convinced of the need to scrutinize everyone—including, and maybe particularly, scientists and students—who wanted to enter the country. The government put new visa regulations and application procedures in place, and consular officers who decide an application's fate began taking more time in rendering their decisions, rejecting more applicants or referring them back to the start of the application process. Safety was spelled conservatism.

[12]For more information, see Ron M. Atlas' paper in Appendix A, page 51.

As workshop participants reported, problems arose almost overnight. Many scientists and students found themselves facing long delays in obtaining their visas, with some of them being prohibited entirely, sometimes with little explanation (White and Peterson, 2003). Individuals from certain countries, including those in the Middle East where tensions and threats of terrorism were judged by some observers as high, seemed to come under sharpest review. As a result, academic institutions found themselves short of faculty and staff, graduate and postdoctoral fellowships went unfilled, research collaborations were put on hold, and major scientific meetings were canceled or went without key speakers or participants, among other problems (Powell, 2002; Alberts et al., 2002). (Similarly, many medical and high-tech industries found themselves short of workers.) Some observers began to suggest that if such shortages were to continue, they might translate into fewer people being trained in science and medicine, fewer research advances being made, and fewer new therapies being transferred into practice (Shouse, 2002). In addition, if fewer students come for training, then there ultimately would be fewer professionals to return to their home countries and enter their scientific and medical workforces.

Foreign scientists and students already in the United States on visas sometimes faced problems as well. In some cases, if a person were to leave the country even briefly—perhaps to attend a scientific conference or to go home for a visit—then he or she would have to obtain a new visa and possibly be subject to the same delays that new applicants faced.

At the time of the workshop, the federal government was reexamining its visa policies and trying to identify and implement steps to speed up the application and approval process. Given that state of flux, participants noted that the scientific community should carefully monitor events and work to ensure that constructive policies and mechanisms are adopted. One important task will be to gather systemic data to document any current and continuing problems. Participants also discussed a series of recommendations developed by the American Society for Microbiology for how the visa processing system should be changed. The overarching principle is that screening procedures should result in a minimum of disruption of educational and research endeavors. Among specific suggestions, the government should ensure that the visa system has sufficient personnel and other resources so that all applications can be processed in a timely manner, and it should explore and possibly develop procedures that expedite, on the basis of objective criteria, the processing of applications from individuals who are least likely to pose a threat. In addition, the process for readmitting trainees who leave the country for brief periods should be simplified, and the requirement that such individuals be re-interviewed should be eliminated.

Participants noted that the scientific community has an important communications role to play as well. Scientists and scientific institutions and organizations can explain to policy makers and the public that the best defenses against the threat of bioterrorism are advancing the research agenda to produce new vaccines, diagnostic tools, and therapeutic agents, and building a large and well-trained workforce ready to combat any microbial threats that arise, either naturally or as a result of hostile actions. Scientists also can make clear that biomedical research is an international endeavor, and that efforts to control and prevent infectious diseases must of necessity be global. Moreover, the scientific community can promote the underlying principal of the universality of science, and explain to all quarters that this principle requires freedom of association, movement, and communication as well as access to data and information in connection with international scientific activities. These freedoms must obtain without discrimination on the basis of such factors as citizenship, religion, creed, political stance, ethnic origin, or race.

Of course, communications is a two-way street, and some participants called on the scientific community to talk more openly with the national security community in order to better understand the dangers of today's world. The idea is that with such knowledge, scientists will be better prepared to engage in activities—some of which are likely to involve new constraints and adherence to new regulatory mandates—that will reduce the threat that terrorists might misuse life and medical sciences in tragic ways.

Communications has a thoroughly utilitarian side as well. The scientific community needs to stay informed about visa policies, and scientists (and managers) who are involved in programs that bring foreign scientists and students to the United States need to provide them with up-to-date information about the visa application process. When organizing meetings, staff appointments, collaborative research ventures, or fellowship programs that involve foreign scientists and students, U.S. scientists and managers should build in more lead time, and they should be prepared for delays in the processing of visas and for the possible need to provide more information to consular officers. Above all, they should remember that it is the scientists' or students' responsibility to obtain travel documents, and not the government's responsibility to issue visas without due consideration.

Select Agent Research Restrictions

At the time of the workshop, considerable controversy swirled around the government's regulations—and proposed regulations—regarding select agents. The Centers for Disease Control and Prevention devised the list of select agents and regulates their possession by government agencies, universities, research institutions, and industry. The Department of Agriculture also assumes some oversight responsibility of select agents. Some scientists were calling for the government to remove all restrictions and allow the scientific community to determine how best to control research with such agents. Other scientists, perhaps the majority, agreed that restrictions were needed—but even within this group there were differences of opinion about what form such restrictions should take and what their ultimate impact on research likely would be. Workshop discussions reflected these varying views.

Complicating matters is the fact that many of the select agents are not commonly found in the United States, and hence there is a lack of U.S. scientists experienced in working with them. A common custom had been for U.S. laboratories to recruit foreign scientists who have such experience. But following the 2001 terrorist attacks, the government passed the USA Patriot Act, which placed added restrictions on who could have access to select agents within U.S. laboratories. Specifically, the act denies access to people from countries that the United States designates as supporting terrorism. These restrictions subsequently were incorporated into the Biopreparedness Act, and thus into the CDC's regulatory schemes.

Under the new restrictions, debate continued about their effects on scientific research in academe and industry. Some workshop participants suggested that negative effects would be dramatic, with biotechnology being especially hard hit; other participants saw less of a threat. But there were general agreements that the scientific community should carefully monitor events as they unfold. If problems arise, scientists can bring them to the attention of the relevant government agencies and departments and insist that they be responsive.

One particular challenge will be for the scientific community to develop working relationships with the national security and law enforcement communities (Schatz, 2002). The Biopreparedness Act requires that the Department of Justice clear individuals before they are granted access to select agents, and this responsibility has been assigned to the Federal Bureau of Investigation (FBI). Workshop participants expressed concern about how the FBI will carry out this job. Will it provide appropriate security oversight without interfering with the legitimate pursuit of science, especially as the magnitude of biodefense research increases? The scientific community can watch to see if the FBI proves reluctant to grant clearances to foreign scientists, and whether backlogs arise in granting clearances.

Beyond their concerns about regulations imposed by the Biopreparedness Act, participants also worried that some government agencies—including the Department of Defense, the Department of Health and Human Services, and the Department of Agriculture—might further restrict foreign nationals from entering their laboratories. Participants noted that there may be some areas where classified research is conducted and where restricted access to foreign nationals may be appropriate, but that broad restrictions of international scientists is neither appropriate nor called for by the select agents regulations. To help ensure that such actions do not happen, the scientific community can highlight for policy makers and the public the value of international scientific exchanges for global health and national security.

IDENTIFYING PRIORITIES FOR THE FUTURE

Workshop participants pointed to a number of priority areas, both large and small (Bond, 2003; Carroll, 2003; Jackson, 2003; Boulton, 2003; Gotuzzo, 2003).

As an overarching principle, they stressed that infectious diseases are a global problem and therefore require a global response. Thus, as the United States and other developed nations work to strengthen their capacities to meet current and new microbial threats, they also must look outward. Special attention should be paid to the developing world, where infectious diseases are most prevalent and opportunities for spread are considerable. Of course, an important part of helping developing nations improve their capacities to meet microbial threats will be to help them strengthen their scientific and medical workforces charged with controlling infectious diseases. Additional U.S. help should include financial and technical assistance, operational research, enhanced disease surveillance, and efforts to share both knowledge and best public health practices.

The United States would be well advised to seek—even catalyze—international assistance in this task. Given its mission, the World Health Organization can play a major role. Help also can come from the World Trade Organization, the World Bank, the International Monetary Fund, and the Organisation for Economic Co-operation and Development. The magnitude of the problems facing developing nations deserves no lesser response from the world community.

In assisting developing countries, developed nations should take care to respect local cultural and social values. To the fullest extent possible, they also should actively involve a range of local stakeholders—national and community government officials, teachers and administrators at academic institutions, health professionals, and members of the public—in order to gain "buy in" and improve the prospects of success.

As another guiding principle, participants emphasized that mounting an effective response to infectious disease threats, in the United States and elsewhere, will require leadership and multidisciplinary efforts involving all sectors of the public health, clinical medicine, basic science, and veterinary communities. Thus, strong workforces need to be developed and sustained in each of these areas. In addition, these communities must expand communications amongst themselves, which too often is lacking today. Similarly, greater cooperation and coordination is needed among the larger scientific, government, and industrial sectors. Such synergy will help in advancing fundamental knowledge about microbes, in developing and implementing new treatments for diseases, and in improving current abilities to predict disease outbreaks and prevent or control their spread.

In discussing the various components of the U.S. workforce involved in combating microbial threats, it became clear that comprehensive data are lacking. Even fewer data are available for the developing world. Studies have produced at least rough estimates of the U.S. workforce—but participants agreed that compiling an up-to-date, thorough picture of the landscape will be essential to guide future capacity development efforts. Moreover, such data will be needed to underpin efforts to gain more financial support for workforce development. Both governments and private foundations—potential sources for expanded funding—will be most likely to respond positively in the face of convincing data.

As participants explored specific segments of the workforce, a number of trends and needs emerged. For example, the scientific community is adopting a more systemic view of infectious disease, in which microbes and humans are intricately entwined, and this shift is increasing the need to recruit people from previously overlooked disciplines into the biological arena. Physicists and chemists, mathematicians and computer scientists, evolutionary biologists and ecologists—all are joining with traditional microbiologists and immunologists to answer complex questions that once were difficult if not impossible to address. The challenge is for universities and other academic institutions, from departments on up, to develop ways to foster such collaborative research, often conducted by large teams. How can institutions break down their disciplinary "silos" and promote cross-fertilization? How can they encourage people from disparate fields to talk with one another, to speak a common language, to visualize common problems, and to value each other's skills and ideas? Numerous approaches are being tried and likely more will be needed in order to learn what works and then build on those successes.

Participants also stressed the need to redouble efforts to increase the supply of physician–scientists. Among many roles, physician–scientists are a vital force in translating laboratory research into practical medical advances. But their numbers have dropped significantly in recent years. This decline has been due, in part, to the growth of managed care, which has forced many academic health centers to cut the amount of time that physician–scientists have available for research or to train upcoming physician–scientists. A number of ways were proposed to help grow this population. For example, medical school graduates who pursue careers in research can be forgiven at least part of their accumulated educational debts, and medical schools can seek out undergraduate students who show an aptitude for research and "bond" them to medicine even before they begin formal training.

Literally by definition, public health professionals will be instrumental in efforts to protect society from microbial threats, whether naturally occurring or arising from terrorist actions. But as numerous reports have observed, the nation's PH system, including its infrastructure of human resources, has fallen into disarray and must be rebuilt. The challenge will be to rebuild as efficiently as possible. This marks one of the areas where workshop participants saw a pressing need for more data, and they called for new national studies to better characterize the PH workforce in terms of numbers, locations, and levels of expertise.

Even as such national studies proceed, however, steps can begin now to strengthen the PH workforce. As participants noted, for example, efforts are needed to boost the supply of physicians who specialize in infectious diseases. ID physicians are and will remain instrumental in meeting microbial threats, but evidence suggests that their numbers are seriously lacking. One approach is to grab students' interest in such a career early—perhaps during middle school or high school, but certainly before they begin medical training. Enticement also might come from programs to forgive the educational debts of medical graduates who pursue training in infectious diseases and enter the field of public health, especially as ID physicians often earn less than their counterparts in other medical specialties. In addition, participants highlighted the need to attract and train more epidemiologists to work both in hospitals and in the field. The federal government can help in this effort by expanding current programs and developing new programs, both intramural and extramural, to train health professionals in applied epidemiology and field-based research in the United States and abroad. Also important to assuring a strong public health workforce in the future will be investment in leadership development within organizations in the United States and around the world. One speaker suggested the potential benefit of building a network of global leaders for public health.

In tandem with strengthening the PH workforce, it will be important to better educate all students in the health professions in the basic concepts of public health. As experience has amply demonstrated, health workers outside of the formal PH community are often the first to encounter infectious diseases. Forging tighter links between public health and other health professions will help increase the nation's "surge capacity" to handle the numbers of people who might be stricken in large-scale disease outbreaks. Thus, workshop participants called on institutions that train health professionals—including medical schools, nursing schools, and veterinary schools—to revise their curricula accordingly. Institutional leadership will be critical in setting such change in motion and seeing it to fruition. Leaders will need to explain convincingly the necessity for and the benefits of introducing PH concepts into general studies, and they will need to empower staff members to take actions that ultimately will anchor the new approaches in the institutional culture.

A major goal across all diseases, of course, is prevention—and when it comes to infectious diseases, the record already is strong, with vaccines available to ward off many microbial threats. But many diseases remain for which new or better vaccines are needed, and workshop participants noted that more people are critically needed in a range of disciplines to work in vaccinology. Toward this end, medical schools can do more to teach students about vaccines and vaccinology—information often relegated mainly to pediatrics—so they might consider this area as a career path. Training would best be multidisciplinary and incorporate a range of core subjects, such as pathogenesis, microimmunology, safety regulations, and clinical development. Since medical schools now offer so few courses related to vaccinology, they may need to look to industry for teachers. Industry can help in other ways as well, such as by developing and supporting training opportunities in the workplace, to ensure that more students are exposed to career paths in vaccinology.

Similarly, disease prevention is the ultimate goal of vector biologists and entomologists. Many of the world's most dangerous microbial pathogens are passed to humans by insects or other vectors, and achieving a better understanding of the details of transmission could well help in devising methods to slow or stop the process completely. Here, as in most other areas of research related to infectious diseases, collaboration may hold the key. Thus, workshop participants cited the need for expanding efforts to bring vector biologists and entomologists together with researchers in a number of other fields, including parasitology, clinical medicine, and public health. Both the government (through the National Institutes of Health, among other agencies) and private foundations can play important roles in fostering such multidisciplinary projects.

One major challenge that the nation already faces—and will continue to face—as it strives to strengthen the infectious diseases workforce arises not from science or the microbial world, but rather from the government's own policies. As a result of the terrorist attacks of 2001, the government has launched a series of security measures that directly affect how science operates. Of particular note are policies that affect how visas are issued to foreign scientists and students who want to enter the United States, and policies that control who may work with a select group of biological agents and toxins that the government deems to be a severe threat to public health and safety. Many members of the scientific community have expressed concern that these and other policies being developed will significantly limit the free and open conduct of science in a variety of ways, not the least by preventing foreign scientists and students from studying or working in the United States.

Many workshop participants expressed similar concerns. They also noted, however, that the policies were new and their consequences not yet fully known. Thus, it will be important for the scientific community to monitor events carefully as they unfold, document any problems, and then work with the government and other stakeholders to ensure that constructive policies are in place. One suggested guideline is that the best policies will be those that result in a minimum of disruption of educational and research endeavors.

Participants also noted that scientists have an important communications responsibility. They can explain to policy makers and the public that an active research effort and a well-trained health workforce are ultimately the best defenses against the threat of bioterrorism, and that the strength of medical science—indeed, of science itself—rests soundly on the principle of universality. But at the same time, scientists have a responsibility to listen respectfully to the concerns of other groups. This will mean, for example, talking openly with the national security community. The goal of such dialogue will be to arrive at a consistent set of government policies that will protect the nation's safety while enabling science to perform at peak efficiency and deliver fully on its promises for improving human health and well-being.

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Appendix A

Authored Papers

IMPLICATIONS OF RESTRICTIONS ON FOREIGN STUDENTS AND SCIENTISTS FOR INFECTIOUS DISEASE RESEARCH

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It is clear that after September 11, 2001, we live in a new era, an era of fear—fear of foreigners who could be terrorists and fear of scientific information that could be misused by terrorists. The consequence is that we in the scientific and academic communities are now subject to new levels of public scrutiny that are manifest in the regulations governing visas for foreign students and visiting scientists and in the security clearance requirements for those with access to microorganisms and toxins (select agents) that are considered high-risk biothreats that might be used by terrorists. As graduate dean at the University of Louisville, dealing with foreign graduate students and visa issues being implemented under a post-9/11 regulatory framework, as a scientist involved in biodefense, and as a past president of the American Society for Microbiology (ASM), which has certainly been on the forefront of the debate on the select agent rules and the legislation that was passed after the anthrax attacks of Fall 2001 to reduce the threat of bioterrorism, I have found myself balancing divergent norms of science and society and communicating across boundaries of national security, science, policy, and public concerns—trading the world of a laboratory scientist for a bully pulpit before journalists to reach the public, congressional hearing rooms to reach policy makers, and forums like this to reach fellow scientists.

We in the scientific community have an obligation to provide an educational forum that reaches far and wide, within the scientific community about the new legislation and regulations, and about how we need to comply to be good citizens of the world. Additionally, we need to educate the broader public as to the importance of international exchange in the scientific arena so as to ensure that regulations are constructed in ways that permit the advancement of biomedical research. We have a need to explain to the public and policy makers that the best defense against the threat of bioterrorism is to advance the research agenda against infectious diseases so that we have the vaccines, therapeutics, and diagnostics needed to combat emerging and reemerging infectious diseases as well as "plagues" that may be introduced by terrorists. We need to make clear that biomedical research is an international endeavor and that the battle against infectious diseases must be global. We also have an obligation to engage in a dialog with the national security community so that we understand the threats and vulnerabilities of our new world and can engage in activities—some of which will involve constraint and adherence to the new regulatory mandates—that will reduce the threat of the misuse of the life sciences by terrorists.

When the USA Patriot Act was first proposed, it would have banned all foreigners from entering a U.S. laboratory where a select agent was present. The ASM explained to the Congress that biomedical research is international in nature. We brought a clear message to the debate: infectious disease is a global health issue that requires international exchange and cooperation. Half of the manuscripts submitted to ASM journals come from outside the United States. If we curtail international collaborations, then we put the health of this and other nations at risk. If we cannot combat infectious diseases regardless of where they occur in the world, we put U.S. national security at risk as well. The Congress listened. When the Patriot Act was passed, such proposed global restrictions on foreigners were removed.

Having said that, we in the scientific community also made compromises concerning who could have access to select agents and the regulatory system overseeing possession of those agents. In my view, the compromises were critical for demonstrating that the scientific community was responsive to public concerns about bioterrorism and for achieving public support for biomedical research needed to advance biodefense capabilities.

I recognize that some people would accuse me of having entered into a Faustian deal for having agreed that we should restrict certain individuals from having access to select agents within U.S. laboratories, namely, aliens from countries that the United States designates as supporting terrorism and those individuals who are not permitted to purchase handguns. When the ASM looked at the impact of restricting individuals from the few nations that are designated by the United States as supporting terrorism, and only restricting them in the laboratories where a limited number of select agents were present, we found that there were very few scientists and very few exchanges that were being affected in the United States. We agreed to accept that provision, which became a restriction in the Patriot Act and which was subsequently incorporated into the Biopreparedness Act, and thus, into the regulatory scheme of the Centers for Disease Control and Prevention and the U.S. Department of Agriculture oversight of select agents.

George Poste, who has been very outspoken about the hubris of the scientific community placing the United States in danger by not fully recognizing the potential for misuse of science, had made the claim that the Patriot Act and the implementation of the select agent rule are major impediments to industry that is multinational, and that the biotech industry would not fare well under the Patriot Act. The restriction imposed by the Patriot Act and subsequently incorporated into the Biopreparedness Act stated that individuals from nations that support terrorism may not have access to select agents in U.S. laboratories. Thus, it should have minimal impact on multinational corporations. It is true that implementation of the select agent rules involves a site-specific registration and clearance process. An individual cleared to work with certain agents in one laboratory who goes to work in another laboratory requires a new clearance. Additionally, the owners of each private laboratory in possession of select agents must be cleared. Potentially that can impact the ability to collaborate and to move personnel from laboratory to laboratory. We are still in the early phases of implementing the new select agent possession regulations and need to wait and watch carefully for real impacts. If we detect negative impacts, then we need to bring them to the attention of the relevant departments and agencies and insist that they be responsive. We also need to recognize that we have new responsibilities in the era of terrorism. Unfortunately, the days of a graduate student working alone in a laboratory with dangerous pathogens in the middle of the night are probably gone. But maybe this is for the good of all, as appropriate biosecurity measures should enhance biosafety.

Perhaps the greatest challenge for the scientific community will be developing a working relationship with the national security and law enforcement communities. The Biopreparedness Act requires that the Department of Justice clear individuals who have access to select agents. This responsibility has been given to the Federal Bureau of Investigation (FBI). This is a new system, and there is legitimate concern over how it will work. Can it provide appropriate security oversight without interfering with the legitimate pursuit of science, especially as the magnitude of biodefense research increases exponentially? At this point, we do not have any data that suggest that the system is not going to work—but there is considerable concern.

Beyond the regulations and clearances imposed by the Biopreparedness Act, there is concern that some government laboratories, for example, Department of Defense laboratories, Department of Agriculture laboratories, and potentially other laboratories within the Department of Health and Human Services, will further restrict foreign nationals from entering those laboratories. The select agent regulations do not provide for such broad restrictions of international scientists. While there may be some areas where classified research is conducted and where restricted access for foreign nationals may be appropriate, it is important for the scientific and biomedical communities to highlight the value of international scientific exchanges for global health and national security.

Turning to the issue of visas for students and visiting scientists, the implementation of new regulations aimed at reducing the risk of terrorism is raising concerns in the academic and scientific communities. Resources are needed to ensure appropriate implementation of the new tracking and interview systems. Within the academic and scientific communities, we need to gather systemic data to document problems. The major educational organizations, including the American Association of Universities and the Council of Graduate Schools, requested that the requirement for interviews to obtain visas be implemented only if there were sufficient resources to prevent undue delays that would interrupt the flow of foreign students into the United States. The State Department promised to be responsive and quickly instructed the consular services to give preference to students for interviews so that educational exchanges are not inhibited.

The ASM asked the State Department to develop procedures and allocate resources necessary to assure prompt and appropriate action on visa requests for students and researchers seeking to study within the United States. The ASM pointed out that educational exchanges and training of students, researchers, and clinicians in microbiology and other scientific disciplines from countries around the world are critical for the advancement of biomedical science and public health. If we limit our ability to exchange scientific information and train scientists, then we will severely limit our ability to fight infectious diseases—and infectious diseases do not respect any political borders. The ASM therefore urged the State Department to eliminate the adverse impact of visa policies on the continued education and training of foreign students in the United States. Given that the ASM has supported appropriate measures to reduce the risk of terrorism, it did not urge laxness in processing visas. Rather, the ASM urged that screening processes be undertaken with a minimum of disruption of educational and research endeavors, urging observance of the following principles in designing and implementing screening procedures:

1. Screening procedures must be developed, planned, and implemented in a manner and on a schedule that ensures that interviews or other processes do not interfere with legitimate scientific training.
2. The United States must devote the necessary resources to ensure that prudent procedures do not fail as a result of a lack of adequately trained personnel to implement the procedures in a timely manner.
3. Microbiology and other sciences must not be singled out as an area of concern or in a manner that admission of students for science education and training is impeded.
4. In light of inevitable limitations upon resources, procedures must be developed that expedite, on the basis of objective criteria, the processing of visas least likely to pose a threat so the overall system permits the timely admission of all qualified individuals legitimately interested in advancing their education or advisory role to U.S. governmental agencies.
5. The process for reentry of trainees who have been granted visas for training in the United States should be simplified, eliminating the requirement for reentry interviews for students who have been out of the United States only for a brief period.

In response, the State Department reiterated its commitment to protect international exchanges of students and researchers.

Thus, in many ways we are at a critical crossroads. We face a new regulatory environment—one crafted out of fear of terrorism. We face a critical need to advance biomedical science to combat the threat of bioterrorism as well as the emergence and reemergence of deadly infectious diseases. We must find the right balance between openness and security—between restrictions and free exchange impacting foreign students, visiting scientists, and international collaboration. This will require continuing dialogue among the scientific community, the national security community, policy makers, and the public. We must be ready to confront the challenges of infectious diseases in this new era of regulatory oversight of research and educational exchange.

TRAINING AND SUSTAINING THE PUBLIC HEALTH LABORATORY WORKFORCE—OUR FIRST LINE OF DEFENSE AGAINST INFECTIOUS DISEASE

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Public health laboratories play a lead role in the detection and response to infectious disease. That role cannot be performed without a sound laboratory infrastructure—including highly trained staff and linkages with private-sector laboratorians—that must be in place well in advance of a crisis. However, an ongoing shortage of skilled laboratorians compromises the nation's laboratory system and reduces our vigilance for infectious microbes. To remedy this situation and avert the consequences of more dire workforce deficiencies, public and private employers, trade groups, and relevant government agencies must find new ways to attract and retain the nation's next generation of laboratory technicians and scientists.

Public Health Laboratories and Microbial Threats to Health

As vividly demonstrated by efforts to contain West Nile virus in 1999, anthrax in 2001, and severe acute respiratory syndrome (SARS) in winter 2003, public health laboratories play a crucial role in identifying and analyzing infectious organisms in support of public health disease investigations. Infectious disease testing is, in fact, one of the core functions of public health laboratories and encompasses a range of vital activities (CDC, 2002). These activities include:

- Isolating and identifying causative agents—including emerging or reemerging pathogens—that are present in clinical specimens (e.g., blood, urine, saliva) or in unusual specimen matrices such as food and environmental samples.
- Determining the source of infections by identifying human carriers and environmental sources of disease.
- Providing specialized tests for low-incidence, high-risk diseases, such as tuberculosis (TB), rabies, botulism, and plague.
- Confirming atypical laboratory test results and providing reference diagnostic testing to private-sector laboratories that may not have the ability to fully identify disease agents of public health significance.

In addition to hands-on testing to characterize infectious agents, public health laboratories perform a number of services to support and improve testing programs and to manage laboratory data for effective disease surveillance (CDC, 2002). These services include:

- Conducting research to develop and validate diagnostic tests for emerging infectious diseases and to improve existing infectious disease tests (for example, by developing rapid test methods).
- Providing advice to private-sector laboratories regarding newly marketed tests.
- Developing and overseeing quality assurance programs for private clinical laboratories through training, consultation, certification, and proficiency testing to assure the reliability of laboratory data used for communicable disease control.
- Ensuring the ability to accumulate, synthesize, and communicate test results and other laboratory information essential for public health analysis and decision-making.
- Providing a statewide disease reporting network.
- Participating in national database systems for surveillance of diseases of national and global concern.

State public health laboratories are the critical link between the nation's many private-sector clinical laboratories—which, by virtue of their primary diagnostic function, are often the first to report unusual laboratory results—and the public health establishment. They maintain strong ties with national laboratories at the Centers for Disease Control and Prevention (CDC) and other federal agencies, and with state health officers, state epidemiologists, and directors of state programs in sexually transmitted disease, tuberculosis control, maternal and child health, and environmental health.

It is easy to recognize that infectious disease outbreak investigations and disease prevention and control efforts depend on sound and timely laboratory data. It is similarly clear that all of these activities will be adversely affected by deficiencies in either public health laboratory *capabilities* (specific services performed) or *capacity* (volume of services that can be performed within a defined time period). Workforce limitations affect both.

Public Health Laboratory Workforce Shortage

The current shortage of skilled public health laboratorians is not a sudden phenomenon. Rather, it has been ongoing for some years. Public health laboratories, like other parts of the public health system, have suffered chronic underfunding. An October 2000 report concludes that long-term reductions in public health laboratory staffing and training have impaired the ability of state and local authorities to identify biological agents

(Smithson and Levy, 2000). More recently, a 2002 Institute of Medicine (IOM) report refers to the nation's "antiquated laboratory capacity" that leaves Americans vulnerable to exotic infectious organisms as well as more mundane microbes (Committee on Assuring the Health of the Public in the 21st Century, 2003).

Unpublished data from a "straw poll" conducted in spring 2003 by the Association of Public Health Laboratories (APHL) show an average vacancy rate for state laboratory testing personnel of 8.6 percent. These data are comparable to data from the American Society of Clinical Pathologists' (ASCP) 2002 wage and vacancy survey, which found that the average vacancy rate for staff-level medical technologists ranged from 6 to 10.2 percent, depending on geographic region (Ward-Cook et al., 2003). But some states greatly exceed the average. Tennessee is one. The state public health laboratory has been struggling since late 2001 to fill fully a third of its clinical microbiology positions (personal communication, J. Gibson, Director of Microbiology Laboratory, Laboratory Services, Tennessee Department of Health, August 11, 2003).

However, although these figures represent significant understaffing, they may be deceptively low. The number of staff positions authorized by states generally does not keep pace with the laboratory workload. That is, any vacancies likely represent a true reduction in laboratory capacity. In Kentucky, for example, the state laboratory is recruiting for two positions in 2003, including the laboratory director's post, which had been vacant since December 2002. However, the state completely eliminated ten laboratory positions due to budget constraints, and these positions do not get counted as vacancies (Isaacs, 2003). There also is evidence that public health laboratories and other employers have increased the use of temporary staff and broadened the selection criteria for permanent positions, thereby filling vacancies with less qualified individuals (a medical laboratory technician in place of a medical technologist, for example) (ASCP, 2003).

The lack of adequate laboratory capacity was driven home during the bioterrorism incident that occurred in fall 2001, when many public health laboratories required overtime hours and halted much routine work because key personnel were diverted to testing for *B. anthracis* or to related support activities, such as sample log-in and screening. The Connecticut state lab brought in a team of volunteer microbiologists and the New York City lab arranged to borrow staff from the city's private clinical labs to augment beleaguered public health laboratory workers (APHL, 2002; APHL, 2003a). Even the relatively mild SARS outbreak in the United States in winter 2003 strained laboratory capacity (APHL, 2003b). If two moderate infectious disease outbreaks were to coincide, the nation's public health laboratories would be overwhelmed.

Where Have All the Lab Workers Gone?

The growing shortage of laboratory workers stems from three root causes: the ongoing retirement of a significant cohort of senior staff, including laboratory leaders; government hiring practices; and a shrinking pool of future laboratory professionals that impacts both the public and private infectious disease workforce. In many cases, public health laboratories are losing their most skilled personnel before they have a chance to recruit and train replacements. One northeastern state saw 20 percent of its laboratory staff—19 individuals—retire in June 2003. Ohio's state laboratory director writes in *Focus* magazine, "What laboratory can replace the knowledge (and value) that a senior technologist with 29 years experience immersed in molds and fungi brings with them to work every day? How about trying to replace your senior chemists, bacteriologists, virologists, or immunologists?" (Becker, 2003).

Of particular concern, an APHL study anticipates an average of 13 vacancies in state public health laboratory director positions by 2006, with a candidate pool that more than two-thirds of current directors describe as either "not adequate" or "only marginally adequate" in size to meet future needs (Schoenfeld et al., 2002). In addition to scientific and technical expertise, public health laboratory directors must have management, public policy, and communication skills, making this position especially difficult to fill, but also especially important, since it is the directors who provide leadership in times of crisis and who advocate for the needs of the laboratories.

From one vantage point, the public health laboratory workforce shortage can be seen as part of an overall shortage of state government employees—one that is likely to get worse. According to a 2002 report by the Council of State Governments (CSG) and the National Association of State Personnel Executives (NASPE), both the pending retirement of current state employees (whose average age is 44.5 years) and mandatory state hiring freezes or other hiring limitations (in effect in 27 states) contribute to the declining number of state workers (Carroll and Moss, 2002). On average, the current vacancy rate of state government positions is just over 11 percent, but more than half of states report vacancy rates above the national average, including Alaska at 21.6 percent. The CSG/NASPE report predicts that state governments could lose more than 30 percent of their workforce by 2006 due to the twin problems of an aging workforce and continuing state budget shortfalls (Carroll and Moss, 2002).

From a second vantage point, the public health laboratory workforce shortage can be seen as part of a serious labor problem plaguing public health and private clinical laboratories throughout the nation. The U.S. Bureau of Labor Statistics projects that 122,000 new medical technologists and medical laboratory technicians will be needed between 2000 and

2010—or roughly 12,200 new clinical laboratorians each year—to replace retiring workers and meet the rising demand for laboratory tests (Hecker, 2001). Yet in recent years, on average fewer than 5,000 individuals have graduated from accredited training programs annually (U.S. Department of Labor, 2002; Painter, 2000). In 1999, the ASCP certified fewer medical technologists than it did in 1959 (2,216 and 2,349, respectively) (Painter, 2000).

A drop in the number of students interested in laboratory science has led to the closure of hundreds of training programs approved by the National Accrediting Agency for Clinical Laboratory Sciences (NAACLS), a fact that does not bode well for the future. There were about 1,000 NAACLS-approved programs in 1970, compared to about 500 today (Painter, 2000; NAACLS, 2003). California, the most populous state, had only eight clinical laboratory science programs in the 2003–2004 academic year, with a combined class capacity of just 89 students (AMA, 2003). And not all programs are necessarily filled to capacity. Lack of knowledge about professional laboratory careers (a byproduct of low recognition for current workers) and higher-paying job options in the science and allied health fields are the chief reasons cited for declining enrollments (Beckering and Brunner, 2003; CHP 2001).

In fact, public health laboratories are suffering from the combined effects of government workforce problems *and* adverse trends within the field of laboratory science.

Recruitment Issues

Recruiting laboratory scientists for any position is difficult in the current job market since qualified workers are scarce. But there are additional challenges. The field of laboratory science is evolving much more rapidly than ever before, and new entrants to the field must be prepared to constantly update their skills. Yet, despite the degree of technical expertise required, laboratorians receive little recognition for work that is largely unseen by the public. Moreover, many laboratory positions are in rural areas and inner cities—locations that tend to be less desirable. Potential public health laboratory recruits also face government hiring constraints, limited career mobility, and generally lower salaries and greater on-the-job learning curves than in the private sector.

The 2001 terror attacks and recent SARS outbreak afforded laboratorians some measure of public appreciation for their work, but also raised fears of extraordinary biosafety risks for all infectious disease laboratorians. In addition, the terror attacks spawned new federal legislation that complicates the hiring process for some laboratories, including all state public health laboratories and many university-based research facilities.

Challenges to recruitment include:

Rapidly Changing Technology

Ten years ago, infectious disease laboratorians were expected to be proficient in classic methodologies to identify infectious organisms: microscopy, culture techniques, and serology. Those methods are still used. But today they exist alongside an ever-changing and increasingly complex set of newer methods that staff members in more advanced laboratories must know or be prepared to learn quickly: commercial nucleic acid amplification tests (used for tuberculosis and sexually transmitted diseases), conventional polymerase chain reaction (PCR), real-time PCR (used for emerging infectious diseases and agents of bioterrorism), pulse field gel electrophoresis (a molecular "fingerprinting" technique used for outbreak investigations), and the latest methods—spoligotyping and variable number tandem repeat analysis. In addition to mastering these techniques, laboratorians must also possess above-average computer software skills to track specimens, analyze data, and communicate test results to relevant parties (e.g., specimen submitters, state health officials, national disease databases).

Unique Public Health Skill Sets

In order to work in a public health setting, a laboratory scientist must have an added skill set above and beyond the technical expertise described above. The average university-trained molecular microbiologist, for example, lacks a working knowledge of infectious disease outbreak management, quality control practices, the principles of population-based disease surveillance, Biosafety Level 3 work practices, and the role of the state epidemiologist and other state and national health officials with whom the laboratory must interface on a regular basis.

Ultimately, to work well within a public health laboratory, technical staff must understand the public health relevance of clinical testing. Whereas a private-sector laboratorian will test a sputum sample to determine whether a specific patient is positive for tuberculosis, public health laboratorians will sometimes process the same sample, but to other ends. The public health scientist wants to identify the exact strain of TB infecting the patient and to compare it to TB isolates from other individuals. Is the same strain responsible for multiple TB cases within the state? Do current cases represent the leading edge of a larger infectious disease outbreak? The public health laboratorian may also conduct susceptibility testing to gauge the pathogen's resistance to a host of antimicrobial agents and work with epidemiologists to forward this information to infection control practitioners and clinical laboratories throughout the state.

New public health laboratory recruits must be willing to learn public health principles and to acquire the additional technical and communication skills needed to make them effective partners within the larger health system.

Government Employment Practices

By definition, public health laboratories are embedded within government agencies and are therefore subject to the vagaries of government employment practices, which are shaped by fiscal and political considerations, as well as plain bureaucratic inertia. In many states, even after a new position has been authorized and fully funded, it can take up to a year to process paperwork, advertise the post, interview applicants, and finally fill the vacancy. In the meantime, existing staff must cope with any extra workload. Once the new recruit is on the job, his or her position may not be secure. Some state public health laboratory personnel work under collective bargaining agreements forged by unions, and, when layoffs occur they affect those employees with least tenure. Moreover, positions that are funded through federal grants or fee-for-service programs are only as secure as the revenue stream. Finally, junior laboratory personnel have limited opportunities for advancement, since there tends to be low turnover among senior public health laboratorians. When senior positions do become vacant, they typically must be filled through a competitive hiring process that may or may not favor in-house applicants.

Legal Hurdles

Even before prospective employees can be considered for laboratory work, a slew of government laws and regulations narrow the applicant pool. The Clinical Laboratory Improvement Amendment (enacted by the federal government in 1967 and updated several times since) requires directors of all laboratories that test human specimens to hold either an M.D. or Ph.D. with board certification, thus excluding otherwise qualified candidates, including individuals who have been mentored under current directors but lack an appropriate advanced degree.

The USA Patriot Act, which became law after the 2001 terror attacks, raises a number of legal hurdles for employees in all laboratories that work with so-called *select agents*—high-consequence organisms such as anthrax, ebola, and *Yersinia pestis*. In practice, most of the diagnostic laboratories affected by the legislation are public health laboratories. These facilities are barred from hiring nationals of countries of concern, as designated by the Act. In addition, they must screen all current and prospective workers, who, as a condition of employment, are required to sign a Federal Bureau of Investigation information release form and undergo background checks and fingerprinting that some employees have found intrusive.

Finally, some states have their own licensure requirements for public- and private-sector laboratorians.

Where Do We Go from Here?

The preface to the IOM's recent report on microbial threats to health states, "We must trumpet the message of urgency and concern, but our more demanding task is . . . to consider what further investments of fiscal and political capital are needed if we are to keep pace with our microbial competitors" (IOM, 2003). Certainly, one area in need of further investment is the nation's infectious disease workforce, and, in particular, the clinical laboratory scientists who come face-to-face with the microbes themselves.

If a severe shortage of laboratory scientists is to be averted, steps must be taken to increase awareness of laboratory careers and to make those careers more attractive: better wages, improved opportunities for training and advancement for practicing laboratorians, measures to address biosafety risks, relocation assistance, and—importantly—increased recognition for laboratory technicians and scientists. Indeed, the scarcity of qualified laboratorians has already begun to place an upward pressure on salaries, which are rising just ahead of inflation (at least in the private sector) (Ward-Cook et al., 2003).

But while hospitals and other private clinical labs are able to institute sign-on bonuses and offer flexible schedules and other work incentives, public health laboratories are generally constrained by government employment rules, forcing them to consider innovative solutions. In the wake of the anthrax scare, the Alaska state laboratory pressed for a separate job classification for public health microbiologists to permit greater salary increases. The New Hampshire state laboratory attempted to use an international employment agency to expand its search for traditionally trained microbiologists, but found that none exists. (In any case, the Patriot Act now restricts the hiring of foreign-born nationals.)

Other state laboratories have offered laboratory rotations to medical students and those pursuing degrees in relevant sciences and enlisted senior laboratorians as adjunct faculty to local universities in an effort to improve awareness of laboratory careers. Efforts to incorporate laboratory courses in public health curricula and public health courses in curricula for medical technologists are also under way.

The Tennessee public health laboratory, in an attempt to fill long-standing vacancies, has established two programs to help potential employees obtain the national certification and state licensure required to work in state laboratories. The first is an affiliation with a local university. Students spend 6 months in traditional on-campus courses, followed by a 6-month paid internship at the Tennessee state laboratory. The second program, geared for students who have already fulfilled academic requirements, is a 1-year paid internship comprising clinical laboratory lectures and practice rotations at the state laboratory.

The APHL Emerging Infectious Disease (EID) Fellowship program was begun in the mid-1990s to introduce recent college graduates at the bachelor's, master's, and doctoral levels to the practice of public health laboratory science. To date, more than 200 fellows have been placed in local, state, and federal public health laboratories throughout the United States and abroad. Domestic and international EID fellows have participated in nearly 40 outbreak investigations and contributed to over 200 publications in peer-reviewed journals. Following their training, many fellows accept positions in public health laboratories or continue their education and pursue careers in other health-related fields. Applications for the 2004 class of fellows were up 40 percent over the previous year, possibly reflecting an increased awareness in the lay population about infectious disease threats.

The APHL is also working to expand continuing education opportunities for current public health laboratorians through its National Laboratory Training Network (NLTN) and newly established National Center for Public Health Laboratory Leadership (NCPHLL). The NLTN (www.nltn.org) is a collaborative program between the APHL and the CDC. Since its inception in 1989, it has delivered more than 3,200 wet workshops and training activities reaching over 100,000 laboratorians. This type of targeted training—including courses in rabies, bioterrorism, tuberculosis, virology, investigation of food-borne outbreaks, molecular laboratory methods, and more—is not available from any other source.

The NCPHLL was established to address the growing leadership vacuum in public health laboratories. Other than through the center's activities and on-the-job experience, current laboratorians have almost no mechanism to acquire the managerial, public policy, communications, and other leadership skills essential to oversee the complex workings of a public health laboratory. The center is identifying and disseminating the knowledge needed for effective decision-making in public health laboratories and also providing technical assistance—such as workshops in grant writing, media relations, and the regulatory inspection process—to support current laboratory leaders.

All of these efforts are helpful in building the strong national laboratory system that must undergird any serious effort to curb microbial threats to health. Yet more must be done. The Medical Laboratory Personnel Shortage Act of 2001 (HR 1948) is in legislative limbo. If enacted, this bill would expand the National Health Service Corps scholarship and loan repayment program to medical technologists and increase funding for the

Allied Health Project Grants Program, which helps attract laboratory professionals to the field (especially in rural and underserved communities).

The IOM has recommended that the CDC, the Department of Defense, and the National Institutes of Health develop new programs and expand current programs to train the infectious disease workforce, incorporating hands-on experience at public health agencies whenever possible (IOM, 2003). Stints in public health laboratories should be a prominent part of these programs.

Of pressing concern, more must be done to interest younger students—at the middle school and high school levels—in laboratory science. The Coordinating Council on the Clinical Laboratory Workforce and the American Society for Clinical Laboratory Sciences are developing a recruitment "tool kit" to suggest ways that high school science teachers and counselors can attract students to laboratory science careers. This project is a promising start.

A lot is riding on our collective efforts to assure a robust network of private and public health laboratories. Without qualified personnel to process routine diagnostic tests, to support national disease surveillance, and to identify the next novel microbe, the health of Americans will surely suffer.

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WHO WILL LIVE IN THE "HOUSE OF GENOMICS"?

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INTRODUCTION

Francis Collins' vision of the future of genomics research is likened to a house founded on the Human Genome Project with three levels of research projects: genomics to biology, genomics to health, and genomics to society (Collins et al., 2003). But who will occupy this house, and which societies stand to gain from the genomics revolution? Will the beneficiaries be only the privileged in the developed world? Of the 15 challenges framed by Collins et al., only one relates explicitly to the health of 5 billion people in developing countries. In this future, exciting though it is, it is difficult to imagine the benefits of the Human Genome Project reaching the people in developing countries who need them the most. Here we show that, contrary to common perception, genomics and related biotechnologies are relevant to and should be harnessed for purposes of global development and health, and we point to strategies to help make this happen. This is particularly relevant for the "infectious diseases workforce of the twenty-first century," the subject of this symposium, for we must understand the context in which that workforce will be functioning and the technologies that will be utilized to address the diseases. Only then can we plan for the education and training needs of that workforce.

Science and Technology Must Be Harnessed for Developing Countries

In the face of growing global health disparities, the potential of science and technology to improve global health cannot be ignored. To improve the health of millions of people in developing countries, we need to reap the benefits from our vast expansion in scientific knowledge and from the multitude of technologies we have developed. This is a plea policy makers,

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advocacy groups, scholars, and other concerned people have recited for many years but sadly still needs to be repeated. Most health resources and 90 percent of all medical research are targeted at problems affecting only 10 percent of the world's population (Global Forum for Health Research, 2002). United Nations Secretary-General Kofi Annan stresses that the benefits of sciences should be for humankind as a whole: "This unbalanced distribution of scientific activity generates serious problems not only for the scientific community in the developing countries, but for development itself. It accelerates the disparity between advanced and developing countries, creating social and economic difficulties at both national and international levels" (Annan, 2003).

With new advances in genomics technology,[1] there is now tremendous potential to address health and development issues in developing countries. The World Health Organization (WHO) declared genomics to be a promising tool to improve global health, even though it warned that changing medical practices based on new technologies takes time and are not likely to happen overnight. The then Director-General of the World Health Organization, Dr. Gro Harlem Brundtland, stated in this report that it is: "clear that the science of genomics holds tremendous potential for improving health globally. . . . The specific challenge is how we can harness this knowledge and have it contribute to health equity, especially among developing nations" (Advisory Committee on Health Research, 2002).

The central premise for health equity is global solidarity (Benatar et al., 2003). Global solidarity can achieve health equity through (1) respect for the dignity of human life; (2) addressing the relationship between human rights, responsibilities, and needs; (3) ensuring freedom of choice; (4) democratic principles of accountability, representation, cooperation, and good governance; (5) and recognizing the importance of the environment and sustainability for the future. These concepts are intertwined with the promotion of enlightened self-interest. For instance, promoting global health equity is in the interest of the developed world: healthy developing world populations not only represent expanded market opportunities for products from industrialized countries, but the control of infectious diseases is becoming a major security issue for countries like the United States. As Martin Luther King said, "It really boils down to this: that all life is interrelated. We are caught in an inescapable network of mutuality, tied into a single garment of destiny. Whatever affects one directly, affects all indirectly" (King, 1968).

[1]In this paper, the term "genomics" is used to refer to the powerful new wave of health-related life sciences energized by the human genome project and the knowledge and tools it is spawning.

Genomics Has the Potential to Improve Health in Developing Countries

That genomics will revolutionize biological research is undeniable (Collins et al., 2003, p. 837). With regard to the impact of genomics on health, however, there is still a misconception in the global health community that genomics and related biotechnologies are not relevant to developing countries. We argue here that genomics has tremendous potential to alleviate health problems the world over, not just in developed countries. Take for example the case of malaria. Genomics and bioinformatics, in the hands of innovative researchers, resurrected the little-used drug fosmidomycin off the shelf and brought it into clinical trials as a novel anti-malarial drug in less than 2 years (Jomaa et al., 1999). The team successfully searched the *Plasmodium falciparum* genome for the gene of an enzyme targeted by fosmidomycin, an antibiotic developed and manufactured by a Japanese pharmaceutical company. In vitro studies have indicated that fosmidomycin inhibits the growth of multi-resistant strains of *P. falciparum*. When administered to adults in Gabon with malaria, fosmidomycin was found to be a safe and effective method of treatment (Missinou et al., 2002). Using a drug that has already been developed reduces the cost of the treatment, thereby making it a realistic opportunity for developing countries.

Genomics and related health biotechnologies do have the potential to improve health of people in developing countries, but considering that resources in developing countries are limited there is an urgent need to prioritize the most promising technologies. In order to identify these technologies, the University of Toronto Joint Centre for Bioethics carried out a technology foresight exercise where an international group of eminent scientists with expertise in global health issues were asked to identify and prioritize the top 10 biotechnologies for improving health in developing countries within the next 5 to 10 years (Daar et al., 2002). The results are presented in Table A-1 and highlight the relevance of genomics and related biotechnologies to health needs in developing countries.

The top 10 list includes technologies and technology platforms to address a range of developing world problems including infectious diseases, non-communicable diseases, malnutrition, and environmental contamination. These include:

- Simple hand-held devices using molecular-based diagnostics to conduct rapid, low-cost testing for a variety of infectious diseases, such as HIV and malaria. Researchers have made breakthroughs already with these technologies in Latin America in the diagnosis of leishmaniasis and dengue fever (Balmaseda et al., 1999; Harris et al., 1998);
- Genetically-engineered vaccines that are cheaper, safer, and more effective than current vaccines, and which hold new promise in fighting

TABLE A-1 Top 10 biotechnologies to improve health in developing countries

1. Molecular diagnostics
2. Recombinant vaccines
3. Vaccine delivery systems
4. Bioremediation
5. Sequencing pathogen genomes
6. Female-controlled protection against sexually transmitted infections (STI)
7. Bioinformatics
8. Nutritionally-enhanced genetically modified (GM) crops
9. Recombinant therapeutic proteins
10. Combinatorial chemistry

HIV/AIDS, malaria, and tuberculosis. For example: using DNA technology to design an AIDS vaccine candidate specifically for Africa; or plant-made vaccines incorporated into potatoes and other vegetables and fruits to protect against hepatitis B, cholera, measles, and other ailments

- Alternatives to needle injections (e.g., inhalable drugs, powdered vaccines) that could make vaccine and drug delivery safer, easier to administer, and potentially less expensive
- Genetically modified bacteria and plants that can clean up contaminated air, water and soil
- Vaccines and vaginal microbicides that empower women to protect themselves from sexually transmitted infections and achieve contraception without needing consent from male partners
- Computer-based tools to mine data on human and nonhuman gene sequences for clues on preventing and treating infectious and non-communicable diseases
- Genetically modified staple foods such as rice, potatoes, corn, and cassava with enhanced nutritional value

Even though we highlight the potential of biotechnologies for improving health in developing countries we are not dismissing the value of conventional ways to improve health in developing countries—such as water sanitation, or access to mosquito bed-nets. We suggest instead that there should be an appropriate balance between the use of new technology and more conventional public health strategies. There is a common perception in the global health community that the health needs of developing countries are best addressed by existing public health interventions at the exclusion of new technologies, but clearly this is a false dichotomy. For example, vaccines are biotechnology products that over the years have become indispensable public health tools. Malaria control needs better water drainage systems, widespread public acceptance, and use of bed-nets, but also new effective drugs and vaccines and "smart" insecticides based on molecular recognition.

Genomics Has Definite Global Public Goods Characteristics

Clearly, genomics and other health biotechnologies encompass important scientific knowledge that is relevant not just for the health of the developed world but also for developing countries. However, due to the enormous inequities in global health and global health research discussed above, knowledge—including genomics knowledge—is not optimally developed or utilized for improving the health of people in developing countries. In a closely interconnected world, localized sub-optimal utilization of scientific knowledge to alleviate misery and protect against diseases such as HIV/AIDS can have global repercussions. The global public goods characteristics of genomics provide justification for collective action to harness genomics for public health.

"Goods" can be defined along a spectrum from pure "private" goods to pure "public" goods. An apple is a private good since its consumption can be withheld until a price is paid (i.e., it is excludable), and once eaten by someone, it cannot then be eaten by someone else (i.e., it is rivalrous in consumption). In contrast, the benefits of public goods are enjoyed by all (non-excludable), and consumption by one individual does not deplete the good and does not restrict its consumption by others (non-rivalrous) (Sandler, 1997). For example, the Internet is typically open to all (i.e., is non-excludable), and downloading information from the Internet does not deplete the information (i.e., it is non-rivalrous). *Global* public goods possess properties of "publicness" across national boundaries (Kaul et al., 1999). Many goods are not easily classified, often falling somewhere along the spectrum between public and private categories (Woodward and Smith, 2003).

Genomics has significant global public goods characteristics that are expressed in diverse ways (Thorsteinsdóttir et al., 2003). For example, genomics is based on a worldwide resource, the human genome, that has a strong public nature. In a symbolic sense, the human genome has been declared to be a common global heritage of humanity (UNESCO, 1997). The very input to genomics is thus the non-excludable, non-rivalrous, genome. Genomics knowledge, like other types of knowledge, can also be considered the archetypal public good (Stiglitz, 1999). Genomics knowledge, especially sequence data, is typically open to anyone able to acquire it (non-excludable) and in general, made public via genomics databases on the Internet and journal publication. Because knowledge is non-rivalrous in consumption (i.e., it is not depleted by use) it is possible for many individuals to use the same knowledge for various purposes.

Although genomics knowledge has global public goods characteristics, the application of genomics knowledge may be open to exclusion or rivalry. At the individual level therapeutics based on genomics are, for example, private goods as they are both rivalrous and excludable when consumed by an individual. For example, more than one individual cannot consume a tuberculosis drug, and a diagnostic test is usually good for only one use. Nonetheless, the externality effects of rapid diagnosis and accurate treatment (i.e., controlling the spread of infection) point to potential benefits for an entire community, much like herd immunity conferred by vaccination programs.

But genomics as a global public good is not only born; it is also made. In other words, genomics has certain innate characteristics reviewed above that make it a global public good, but the social and political organization of initial genomics research has enhanced its global public goods characteristics. The way the Human Genome Project was funded and undertaken, and the emphasis on placing the resulting knowledge in the public domain where it can be freely shared are factors that strengthen the global public goods characteristics of genomics. If the field had developed without extensive international collaboration and without the strong emphasis on disseminating the resulting knowledge so rapidly in the public domain, then that would have diminished the global public goods characteristics of genomics. Ensuring that this knowledge remains accessible to people from all countries will help leverage it for development needs rather than restrict it and its potential benefits for the developed world.

Developing Countries Need to Build Local Capacity to Be Active Participants in Genomics

Although knowledge is theoretically free to be disseminated, in practice constraints are often put on its use. In order to absorb and make use of scientific knowledge, considerable investment is required (Pavitt, 2001). For example, education and training, physical access to journals or the Internet, research infrastructure, and the ability to establish the necessary production processes to turn genomic knowledge into a useful product are necessary access goods for genomics, and all challenge the ability to make *practical* use of genomics knowledge. Genomics is, in this sense, only a "public" good to those countries that have the capacity to exploit genomics knowledge and to conduct genomics research, which regrettably leaves out most developing countries. The challenge of taking genomics to society goes far beyond issues of privacy, medical insurance, and employment, which often are emphasized in developed countries and are singled out by Collins et al. in their paper (Collins et al., 2003). While it is important to regulate the potential misuse of genomics, it is at least as important to ensure that the benefits of genomics reach all societies. In order for this to happen, there is a need to optimize the global public goods characteristics of genomics worldwide, with a special focus on developing countries that are currently lagging behind.

Some developing countries have started to build up their own capacity in genomics and other health biotechnologies. They include countries such as China, Cuba, India, and South Africa. They have followed different approaches where, for example, South Africa places emphasis on utilizing its biodiversity and traditional knowledge resources, but Cuba's niche has been to develop vaccines to meet the health needs of its population, a demand that is accentuated by the United States trade embargo with Cuba. Genomics development requires a complex system of innovation, where diverse actors and policies are required for encouraging the production of innovative knowledge. A recent research project at the University of Toronto Joint Centre for Bioethics examining the factors and conditions that have encouraged capacity building and health innovation in developing countries may help to identify best practices that can be used by other developing countries in the fields of genomics and related biotechnologies (Thorsteinsdóttir et al., 2004). Building such capacity in developing countries not only encourages these countries to produce appropriate health products for their populations but can also generate extra income opportunities, which ultimately can improve the economic conditions in these countries.

International Collective Action Is Needed to Strengthen Genomics in Developing Countries

International collective action is also needed to mobilize genomics for global health and help bring genomics to society. Such action can drive efforts to improve research infrastructure, education, and training to provide developing countries with the "access goods" they need. Effective north–south and south–south partnerships are an important strategy to promote capacity-building. As Pang has suggested, "At the beginning of the new millennium, it is apparent that developing countries should participate in managing their own futures and thus be invited to work together in equal partnership toward a healthier world" (Pang, 2003). Political and financial commitment on the part of governments of both industrialized and developing countries is needed, as highlighted in the report from the Commission on Macroeconomics and Health (Commission on Macroeconomics and Health, 2001). Public–private partnerships such as the Malaria Vaccine Initiative, Global Aids Vaccine Initiative, Médicins Sans Frontières' Drugs for Neglected Diseases Initiative, and most recently, the Bill & Melinda Gates Foundation's Grand Challenges in Global Health initiative are very important efforts that seek to leverage scientific discovery and international research efforts for developing country needs.

To spur the use of genomics as a global public good, we further propose a Global Genomics Initiative (Dowdeswell et al., 2003; Acharya et al., 2004). This global network should be loosely structured and should have the speed and agility to address the multi-faceted and rapidly evolving features of genomics and related biotechnologies. It should involve partners from multiple sectors to face the challenging complexities of biotechnology: academia, private sector, national governments, public-interest groups, nongovernmental organizations, and media. Its inclusive nature could facilitate collaborative decision-making and help to minimize risks associated with new technologies (restricting new technologies to a "club" potentially encourages dangerous misuse by those who are excluded). And it should encourage participation and leadership from developing countries rather than only from the developed world. A focused, collaborative initiative—such as the Global Genomics Initiative—that aims to promote genomics as a global public good could reinforce these efforts and channel them towards one of the most pressing issues of our time—improving global health.

Genomics and related biotechnologies are relevant to and should be harnessed for purposes of global development and health so the benefits of the Human Genome Project will reach the 5 billion people who need them the most—not just the privileged 600 million in the developed world. It will increase the likelihood that the inhabitants of Collins' genomics house will come from all over the world.

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PUBLIC HEALTH FOR ALL: WORKFORCE DEVELOPMENT THROUGH AN INTEGRATED APPROACH TO HEALTH CARE CURRICULA

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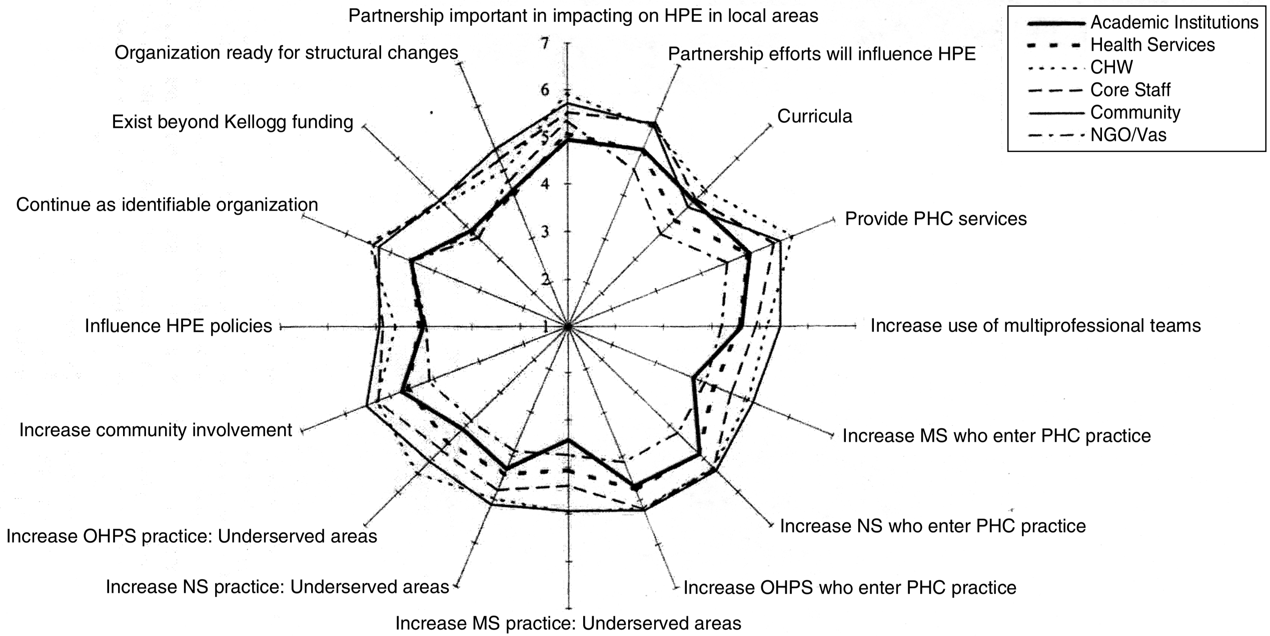
There have been calls for a worldwide change in the education of health professions to ensure that the actions of graduates will contribute to the improved health status of populations. The new investments in workforce development are unprecedented (Potter, 2001), triggered by the increasing costs of care. This has prompted the training in the health professions generally and public health (PH) particularly to focus on improving efficiency and cutting costs, while maintaining gains in life expectancy and morbidity reduction. More and more evidence suggests that for the broader socio-health needs to be tackled, a more coherent community-based PH mind-set will be required (Ewles and Simnett, 1999; El Ansari and Phillips, 2001; El Ansari et al., 2004).

In the face of such sentiments, however, a wide range of health professionals are poorly equipped to think in terms of and deal with population-based health principles and philosophies. Thus, there is an increasing need for educational programs that can improve the breadth, awareness, and training of a wide variety of health professionals on PH concepts and thinking, as well as on epidemiologic approaches and methodologies. Different health problems will require PH responses mounted at various local, regional, state, or international levels (Veenema, 2001). This fact highlights the greater need for PH competencies within primary care (Colin-Thomè, 1999). Well-trained PH-oriented health professionals can form the basis of a strong national health care system. Hence, different groups, including clinicians, policy makers, academics, and educators, could promote the PH perspective, providing that they are better educated in epidemiology, health service evaluation, and health promotion (Dalziel, 2000). Consequently, incorporating public health threads and concepts into the health professions' curricula offers a way forward (El Ansari et al., 2003a).

As illustrated in Figure A-1, the workforce necessary to accomplish the needed improvement in the population's health must be supported with strong training programs that bring to attention a variety of health education and health promotion roles, while providing an increased understanding and awareness of the wider PH context in which health professionals practice (Latter and Westwood, 2001). In order to ensure a prompt and



MS, medical students; NS, nursing students; OHPS, other health professions students; HPE, health professions education; PHC, primary health care
Note: All comparisons significant at $p < 0.001$ level.

FIGURE A-1 An integrated view of the public health workforce.
SOURCE: El Ansari, W. 2003. "Educational Partnerships for Health: Do Stakeholders Perceive Similar Outcomes?" *Journal of Public Health Management and Practice* 9(2): 136-156, Figure 2. Reprinted with permission.

effective response to overarching population problems, the knowledge and skills required for the promotion of community health (Bollag et al., 1982) need to be better integrated into the training of all health professionals. To accomplish this, it will be necessary to weave together the various skills, knowledge, attitudes, and worldviews of the multiple professions. When public heath workers are all those responsible for providing the essential services of public health regardless of the organization in which they work (DHSS, 1994), the importance of the "general" workforce contribution to an effective public health infrastructure comes to the fore. The vision is to broaden knowledge about health and disease by an inclusive designation of a primary care-oriented, disease-oriented, patient-oriented, population-oriented, and prevention-oriented PH education. As such, widening the PH infrastructure will have to take into consideration both the clinical affiliations of students and graduates and their PH credentials (Rowitz, 1999).

There are many published reports on the range of public health competencies required in primary care (Carlson and El Ansari, 2000; El Ansari, 2004) and the training of "specialist" PH professionals (Carlson and El Ansari, 2001). Likewise, the development of both postgraduate PH programs (El Ansari et al., 2003b) and health protection programs (El Ansari and Privett, 2005) for the advancement of a "dedicated" PH workforce (Potter, 2001) have also been described. What emerges is that the literature on the widening of the PH human infrastructure, the "broader" PH workforce that could be capitalized on, is sparse. For instance, the introduction of PH concepts into a wider range of health care curricula seems to have received less attention (El Ansari et al., 2003a). These considerations form the underpinning of this report.

Aim and Methods

The aim of this report is to emphasize some of the issues that require attention in developing a strategy for the establishment and development of appropriate team concepts in heath care curricula. The insights reported represent the initial "brainstorming" sessions that were held separately by the author with each of five staff members of the Department of Public and Community Health at the School of Health and Social Care, Oxford Brookes University, Oxford, United Kingdom. The purpose of the sessions was to explore the members' perceptions of the way forward so that PH principles could be incorporated into the school's wider health care curricula. After the initial brainstorming, SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis sessions were undertaken, and the author grouped the emerging themes and concerns into categories. The focus was fourfold: to highlight the areas of strengths that are already present, to capitalize on the potential opportunities that could be anticipated, to draw attention to the aspects that represent weaknesses to the endeavor, and to identify possible threats that could affect the effort. Originally, the SWOT analysis generated a long list of topics. The Delphi technique was then used to condense the list by employing several rounds of refinements (Yuen et al., 2002). The five participants were asked to highlight the issues they felt were pertinent. Three rounds of refinements were undertaken, and after each round of fine-tuning topics were eliminated from or added to the list. Thus, the more pertinent issues were progressively distilled and focused on, while the less influential ones were gradually withdrawn. The main findings of this exercise are depicted below.

Findings

It was not straightforward to categorize the different factors that emerged from the sessions into strengths or weaknesses (or alternatively, as opportunities or threats), as according to the specific circumstances of each institution, a particular factor could sometimes represent a potential strength or alternatively a possible weakness. This SWOT categorization (see below) also needs to take into account the time frame of operation of any factor in question: a particular weakness today could, if acted on, be rendered a formidable strength tomorrow. The fluid nature of the factors exhibited below meant that they are subject to a range of country- and institution-specific aspects: for instance, the overall political situation, the prevailing health policy directives, the vision of the institution's senior management, and funding arrangements, as well as professional requirements and legislation, can all determine whether a factor is seen to be a strength or a weakness. In order to highlight the factors and their subdivisions, they have been italicized.

Strengths

Policy

At the national level, the questions will have to address the presence or absence of government policies and the national climate in favor of PH. At the institution or the school levels, a parallel political commitment of the institution's senior management is necessary. The presence of *market forces* pointing to a need for health professionals with PH knowledge and background, and the availability of a local and national market niche for multidisciplinary PH, are favorable points. The *commitment and motivation* of a critical mass of the institution's staff to PH and their motivation in taking the PH agenda forward is another positive aspect. However, *resources* need to be considered in terms of the availability of a fair amount of dispersed PH knowledge and expertise within the institution, or whether some PH concepts already present in a number of areas of the school's curricula provide a modest starting foundation to build on. Here, baseline *information* about the available quality and quantity of PH in the curricula or whether any curriculum audit or mapping exercise had been undertaken would be useful. Finally, *external contacts*, such as local influential organizations, deaneries, PH resource agencies, or other local/regional universities, are seen as definite strengths. Similarly, other assets include any national links that some of the PH-enthusiastic members of the institution are already engaged with or international networks to which they contribute.

Weaknesses

Resistance and Anxiety

The reasons for any resistance to the move toward introducing PH principles within the broader health care curricula will need to be understood. For instance, is there poor *staff understanding* about where PH could fit in their curricula? At times, resistance could be partly attributable to the patchy nature of PH and health promotional activity within the national health system and *health policy atmosphere* of the country. As a response, health students might perceive that this topic relates little to their everyday practice world. The *internal politics* of the institution may also play a role: are some staff unwilling to cooperate with PH initiatives as a reaction to negative foregone situations? On the other hand, with too many initiatives going on, some staff could be suffering from *change fatigue*. Similarly, anxiety about PH could be generated due to insufficient *background training* of staff to teach or learn epidemiologic and population concepts or due to the complexities of the highly contextualized PH problems where the social and psychological domains are important. Such problems might represent challenges to the more "traditional" work of the institution.

Commitment and Resources

Low commitment to PH in some sectors of the institution represents one weakness. Already over-stretched time and other resources represent another. The pressures on course leaders to respond to many stakeholders' wishes for programs to incorporate current national and local policy priorities might affect their commitment to exploring the introduction of PH elements in their curricula.

Operationalization and Empowerment

In order to operationalize the PH concept, there needs to be a good fit between the agreed-upon school policy and the operationalization of such policy at a senior level. Hence, the lead department introducing the strategic changes should not be isolated from other departments within the school. This could be further complicated if the school is multi-sited and is dispersed on several campuses, as such geographical fragmentation might affect the way that strategic change takes place. A related point has to do with empowerment: are staff members who are responsible for policy implementation and operationalization of the initiative empowered by the institution to actually "make the change happen"?

Control and Reactivity

At times, staff might believe that nursing is a "mystical" thing, and that the PH agenda being set by the government is increasingly radical. So a question to address is whether there exists a general domination in the school by certain professional groups that may not always be conducive to the acceptance of the PH agenda. An associated aspect is whether there is a lack of PH interest in some areas of the school with whom members of the lead department do not have regular and strong links. It frequently proves beneficial to an institution to be proactively responding to the health policy directives rather than being reactive as the directives become imperatives.

Opportunities

Political Drive and Advocacy

Opportunities for more PH-oriented health care curricula present themselves when there is a political drive for a PH focus both in higher education and health service provision. Similarly, a prevailing atmosphere of national advocacy and local policies in favor of PH is conducive to the initiation and maintenance of change.

Interest, Debate, and Resources

A good sign at the policy level is any provisional interest in PH indicated by the institution's senior management. The presence of debates and deliberations on the appropriate mechanisms for bringing PH into the health care curricula at pre-registration and post-qualifying levels is seen as an opportunity window. At the financial and human resource allocation levels, any incoming research funds of the lead department instigating the change can contribute to enhancing its reputation and may offer opportunities for recruiting more PH-skilled teaching support for the needs of the wider school.

Joint Working and Partnerships

Some of the questions to address in this domain include whether there is any interest in linking up with other partners (e.g., PH resources of the Department of Health and other regional universities) in order to develop a fellowship of PH education providers. Furthermore, any already established links with other PH institutions in the area that have a research focus could be capitalized on.

Reforms and Restructuring

In academic institutions, there are often strategic reforms of one sort or another being planned or implemented. Any current reorganization or restructuring of the school and/or university could serve as opportunity for initiating the required change to PH-oriented curricula. An interconnected aspect is whether the institution has already begun to make changes that indicate that PH "has to happen."

Collaborative Links

Such connections focus on the possibilities for linking with other PH-related initiatives and programs within the institution. These links need to adopt a two-pronged approach. *Around the university*, the prospects include whether there are various PH strands within the institution, even if they have no specific focus, which could be linked into. Hence, networking with other departments that already are examining PH or primary care issues or linking with PH-orientated initiatives that the institution subscribes to (such as the Healthy Universities Initiative or Environmental Management Programs) are all important assets. The vision is to attempt to create a PH "critical mass" by way of forging connections between such initiatives, suitable schemes and parallel programs, and the lead departments. The second approach, *within the school*, focuses on teaching programs that already include a fair amount of PH that could act as a preparatory or initial platform for dissemination of the epidemiologic and population concepts. However, the vocabulary and terminology used by such programs will need to indicate and ascertain its PH content. When feasible, it could be useful to compare the lead department's PH educational outcomes vis-à-vis other programs and modify where necessary. Capitalizing on school-wide change is also good practice: are there other areas of change that need to take place across the school curricula (such as inclusion and diversity), and could these be taken forward simultaneously?

Threats

The Department Leading the Change

A group of factors has to do with the lead department's credibility, influence, and expertise. The lack of external or internal credibility of the lead department for the greater integration of PH across programs and other scholarly activity could act as a threat to the initiative. Some of the factors to address include whether the lead department is convincing and influential within the institution, and whether there are some members of the lead department with a high level of PH expertise and credibility. Is the size of the lead department and its academic team conducive to supporting the proposed changes? Does the lead department have sufficient resources in terms of funding and time to take this initiative forward across the whole school? Is there competition of the lead department with other established programs of international reputation?

Priorities, Competition, and Resources

The institutional priorities may sometimes override other efforts. For instance, there frequently are other initiatives that are being simultaneously implemented that could compete for institutional resources (for example, in the United Kingdom, the National Service Frameworks with Clinical Governance initiatives). In such cases, there will be a need to consider whether all the initiatives can be accommodated simultaneously within the institution. More common these days are funding cuts or impending threats, where staff are increasingly pressured to demonstrate more value for money.

Vision and Directives

This is critical. Required is a vision from the institution about where it should place itself within the local/national PH community. Sufficient, clear, and unambiguous directives from the senior management in relation to such issues are imperative; otherwise, PH could be viewed as another political "fad" that might just pass. Hence, any lack of senior staff conviction to invest speculatively in this area must be addressed.

Uncertainty

This presents a definite threat. When there are high levels of strategic change across the school and university, there usually are uncertainties about how and where the new policies and structures involving the institution's or school's reorganization and restructuring are going to settle.

This could be further complicated by uncertainties about sympathetic program leaders who could be leaving the institution, resulting in less support for the initiative.

Resistance and Barriers

Administrators and educators will have to identify what resistance to PH is encountered in which parts of the school. What are the origins of the barriers to incorporating PH concepts in the wider health care curricula? The factors that could contribute to resistance are varied and include the lack of staff members' knowledge about PH concepts/skills, barriers of time and effort to be invested in the teaching of PH principles, barriers of ignorance, lack of awareness of potential solutions, and change anxiety, as well as personality clashes and low motivation. Similarly, beliefs that PH is "everybody's responsibility but nobody's business," or little faith that the PH approach might improve the population's health, are important threats to look out for.

Generalists or Specialists?

For 30 years medical educators, health professions students, and physicians in training have been hearing from the general public that health professionals should think more about primary care and less about specialization (Rosenberg, 1999). The generalist–specialist debate needs to be considered: is there evidence that specialization in some areas of health care squeezes out the PH agenda from the curricula, particularly where the specialization is in the form of technical procedures, technological measures, and other roles that are currently "falling off of the doctor's table"?

Discussion

In the United Kingdom, public health skills deficits in qualified nurses have been identified through skills audits and training needs analysis (Latter and Westwood, 2001), and schools of health care and of medicine are increasingly aware of the need for developing competencies in public heath (Ibrahim et al., 1995). Similarly, in the United States concerns regarding the ability of the PH workforce to meet the changing needs of the American people have been voiced (DHSS, 1997), where the health of communities depends on the competence of 500,000 physicians, nurses, environmental health scientists, health educators, epidemiologists, and mangers working at the front lines of PH (Lichtveld et al., 2001). The vision becomes: how can a narrow base of frontline PH specialist workers be complemented with a "second line" of PH-oriented health professionals? To ensure the general improvement in the health of the population, it will be necessary for those who are not PH specialists to understand the underlying principles of population health constructs and values (Dalziel, 2000). To these ends, this report has provided a melange of factors that will need to be considered in order to piece together the puzzle that academic and teaching institutions are likely to face when incorporating and consolidating PH principles in their health and social care curricula.

Until recently, the vast majority of state health agencies were led by individuals without PH education or experience (Association of State and Territorial Health Officials, 1997). But at the heart of all successful PH activities are the PH workers, who with their focus on populations and communities take their own work beyond their individual professional and technical skills. On the one hand, PH agencies are providing more population-focused services to entire communities and fewer personal services to individuals (Gebbie, 1999). But on the other hand, there also is a need to include in the new PH movement the vast majority of heath professionals who are providing more patient-focused interventions. If the PH infrastructure is to be widened, then the skills and abilities of the different health profession groups must be challenged with up-to-date knowledge and skills to deliver essential PH service effectively. Since PH is an interdisciplinary field, no effort to improve the skill of the workforce can succeed by concentrating on a single profession (Gebbie, 1999). Only by focusing on *all* the health professions, and within a collective and preventive population-oriented context, will health and social workers be able to address the real determinants of disease and infirmity while promoting health.

Such aspirations are attainable only if PH notions are integrated into the education of the different health professions, preferably at the undergraduate level. But the delivery of quality PH concepts and training to non-specialist health professionals working in the field is also a challenging endeavor. Nevertheless, well developed and appropriately timed training, focused on the main PH competencies that a non-specialist PH worker would require, could play a key role in widening the competency base necessary to meeting the challenge of a narrow and constricted PH infrastructure.

Making the change toward more PH-oriented curricula is neither a straightforward effort nor an easy undertaking. For this reason, committed leadership will be critical to setting the change process in motion. Leading the change in organizations is an incremental process (Kotter, 1996). Thus, the initiators of the effort will need to exhibit leadership focused on overcoming barriers. Therefore, their first step would be the motivation of other departments/staff members to consider both the necessity and benefits of introducing PH notions into the curricula. The initiators could also establish a sense of urgency, garner support, and aid in the development of a vision and strategy. Because old practices do not change overnight, and resistance to changing established practices is a predictable human response (Lorsch, 1986), senior management will be required to empower the staff for broad-based action, to consolidate the gains, and ultimately to anchor the new approaches in the organization's culture (Kotter, 1996).

It is only realistic to expect resistance. Therefore, it will be necessary to be prepared to cope with resistance by understanding what causes it. Silence is the toughest form of resistance and should never be taken for implicit consent to the change. To keep the initiation of change momentum, an understanding, rather than agreement, needs to be the goal. Hence, lead departments need to understand the relevant internal and external actors' behavior, intentions, interrelations, agendas, and interests that could influence decision making (Blair et al., 1990). Undertaking a force field analysis (Ewles and Simnett, 1999) could help identify the helping and hindering forces. Here, the lead department will need to reflect on some questions regarding the range of stakeholders, their attitudes and power, and their criteria for agreeing to the change. If shifting the "traditional" health care curriculum to a more "innovative" public health-oriented one is to be successful, then PH and primary care need to be in free love rather than in an arranged marriage (Sim and Mackie, 2002).

Conclusion

If health professions graduates are to contribute to the improved health status of the population, then there is a pressing need for a change in their education. The aspects that necessitate consideration in such educational efforts span the macro, meso, and micro levels. They include such potential strengths as the prevailing policy, market forces, commitment and motivation to the effort, and the availability of resources, information, and external contacts. Features such as political drive and advocacy, interest in the education debate, collaborative links through joint working and partnerships, and ongoing internal reforms and restructuring could all act as opportunities. However, resistance and anxiety are stumbling blocks, the operationalization of the effort and empowerment of those leading it need to be considered, and issues of control and interests are critical. The presence of conflicting priorities and competition, the lack of vision and directives, and/or uncertainty about change could act as threats and barriers to the effort.

Within primary care, widening the foundation of health professionals with PH competencies suggests that higher education bodies will need to adapt their curricula to an approach that highlights population-based health principles, preventive philosophy, and PH concepts and methods. However, a way forward would need to embrace a multi-pronged approach.

National/local data on the composition and distribution of PH-oriented teachers and health professionals is important. A dynamic staff development program that discusses PH on an individual, group, and community level could prove useful. Similarly, curricular modification might require to be placed as a separate item on the agendas of program boards, and program leaders and directors could be invited to discuss how the national PH agenda is reflected in their curricula. A parallel approach would be to ensure that the school's programs are set within an educational trajectory that is strategically linked to the continuing professional development within the various service providers with whom the school "contracts." PH concepts could also be included in mentor preparation sessions and in discussions by link lecturers with mentors and practitioners. Monitoring the changes locally within the institution could be accomplished by including PH as a specific category in the annual review process of the programs. Nationally, the Faculty of Public Health, the Nursing and Midwifery Council, and/or the Workforce Development Confederations could scrutinize the PH program content through course validation and approval processes. The instigation of standards for the PH learning objectives is an asset, and a national framework for certifying/credentialing of the PH content of curricula would also be an advantage. Hence, a coherent policy framework as well as a national agenda on workforce development will need to be in place. However, research will be required to verify that "learning PH concepts" actually leads to the use of such population elements by health professionals in their later everyday practice. If shifting the traditional health care curriculum to a more innovative PH-oriented one is to be a success, then administrators of educational change will need to take into account a mélange of factors and stakeholders involved in a gradual and incremental process.

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STAKEHOLDERS' PERCEPTIONS OF OUTCOMES IN PUBLIC HEALTH EDUCATIONAL PARTNERSHIPS

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Partnership building has been considered an imperative for the new millennium. Partnerships have emerged as widespread components of public health strategies on a wide range of issues and platforms. At the local level, partnership building has been recognized as a strategy for the reduction of immunization disparities (Findley et al., 2003) and the decrease of ethnic discrepancies in the utilization of community services and the improvement of preventive care in vulnerable populations (Crist and Escandon-Dominguez, 2003). At the national level, partnerships have been used in diverse public health policy perspectives, from public health preparedness in the United States (Morse, 2003) to improving the coordination of health and social care in the United Kingdom (Department of Health, 1992). At the international level, the World Health Organization (WHO) and the International Labor Organization are strengthening the concept of public–private partnerships (Haroon, 2003), the Stop TB partnership initiative of the WHO advocates national partnerships for tuberculosis control (Steenbergen and El Ansari, 2003), and global public–private partnerships (Buse and Walt, 2000) and community-health services partnering for HIV/AIDS prevention (Goede and El Ansari, 2003) are becoming increasingly common. Whether the partnership is at the local (micro), national (meso), or international (macro) level, strategic planning has given way to strategic partnering, and the notion of competitive advantage has been transformed into the idea of collaborative advantage (Shannon, 1998). This report will focus on partnerships of the micro order: the local level where health providers, nursing teaching institutions, and community organizations and agencies come together.

Effective partnerships among government agencies, community-based organizations, and academic and medical institutions are advancing public health in the United States (Northridge, 2003) and South Africa (El Ansari et al., 2002). As the journey to tackling the long-standing health challenges progresses, there is a recognition that solutions lie within a broader framework than any individual efforts. Hence, there has been an expansion of the notion of partnerships to embrace those within and outside the health sector who can work collaboratively toward eliminating health disparities and other inequalities (Northridge, 2003). Collaboration involves working jointly with others on a project, where the participating agencies take on specified tasks within the project and share responsibility for its ultimate success (Michigan State University, 1996).

El Ansari et al. (2001) reported that although the literature makes distinctions among the terms "collaboration," "partnership," and "joint-working," they are used interchangeably to describe collective actions by individuals or their organizations for a more shared communal benefit than each could accomplish as an individual player. However, as there are many factors that could sustain or frustrate collaborative efforts (El Ansari and Phillips, 2001a), it is reasonable to expect that some arrangements for collaboration are more effective than others (Levin et al., 2002). By the same token, the many dimensions that are associated with partnership effectiveness indicate that such alliances will need continuous and ongoing attention and fostering if they are not to be fragile entities (Waddock and Bannister, 1991).

A central concern for public health partnerships is the accomplishment of the outcomes they set out to attain (El Ansari, 2003). On the one hand, the parties participating in partnership efforts might perceive a variety of challenges to collaborating because the outcomes are uncertain. On the other hand, the outcomes of collaboration have, in many instances, far exceeded the expectations of all the parties (Gray, 1989). Furthermore, short-term successes need not be mistaken for ultimate solutions to chronic problems and endemic concerns. While short-term effects are the immediate results of a program, long-term effects often extend from short-term effects (Linney and Wandersman, 1991) to encompass system changes in service delivery, system reform, cross referrals among agencies, and new community linkages (Kagan, 1991).

The achievement of the outcomes of partnerships is a critical variable to include in studies of partnership behavior (Murnighan, 1978). Nevertheless, any measurement/s pertaining to the attainment of the desired expectations will need to consider whether the "gaze" and scope of the evaluation is on macro- or micro-level outcomes, individual or social impacts, and the utility of employing proximal or distal indicators (El Ansari et al., 2001). Such dichotomies must take into account the different types and sources of data to be accessed, the variety of criteria to be available for purposes of assessment, and a judgment about the potential tradeoffs between them (Phillips et al., 1994). When all of these points have been deliberated, a question then arises: do stakeholders with different value systems and diverse cultural backgrounds actually perceive similar outcomes of their partnership efforts? These considerations formed the underpinning of this report.

Aims and Methods

The aims of this report are to:

1. Describe five South African community partnerships for health professions education and a range of their anticipated outcomes.
2. Test the appropriateness of employing "generic" stakeholder groups in partnership research. This is accomplished by examining whether certainty levels about outcomes would differ when the two generic stakeholder factions were broken down into six tightly defined "specific" partner groups.
3. Explore whether those groups out of the six specific partners who perceived greater certainty about the outcomes would also experience higher ratings on other related partnership functioning contentment parameters.

In fulfilling these aims, the concepts that are presented are premised on the findings of a research study that was undertaken by the author with the participation of five community partnerships in various locations in South Africa. The research tools employed in the study comprised self-administered questionnaires (N = 668) (El Ansari, 1999; El Ansari and Phillips, 2001b) and interviews (N = 46) (El Ansari and Phillips, 2001c), both of which have been detailed elsewhere and are beyond the scope of this report.

The W. K. Kellogg Foundation Initiative

The Kellogg Foundation launched its programs in Africa in 1986. Within 5 years, the foundation was to support the development of a major initiative: Community Partnerships for Health Professions Education (Henry, 1996a). This initiative was patterned along the lines of similar efforts begun in the United States in 1990 and in Latin America in 1992. The main purpose of this enterprise was to improve health care for communities by reorienting the education of health personnel through a partnership between health professionals and communities in order to reach a broad understanding of health issues within a specific social context. Hence, the essential strategy for these initiatives was the sharing of models of academic–community partnerships, and the focus was on population groups and individual persons, while also taking into account the health needs of the communities concerned (WHO, 1987).

Starting as early as 1992, a number of South African community partnerships (CPs) for health professions education (HPE) were created as linkages between communities and educational institutions. The aim of these partnerships was to address the reform of the way medical, nursing, and allied health professions were trained. Engineered as joint ventures between the local and regional health service providers and the academic medical and nursing training institutions, on the one hand, and the beneficiary communities and their civic organizations, on the other hand, the CPs were intended to train health professionals in an interdisciplinary, community-oriented, and community-based fashion. Such sentiments were appropriate for the young democracy that was evolving in South Africa. Within this context, a broad range of health personnel were required to address the overwhelming needs of the majority of people who were previously excluded from quality health care (El Ansari, 2002). These responses were clearly demonstrated by the emphasis on program activities of each of the partnerships. In the section below, the partnerships are made anonymous for reasons of confidentiality.

Partnership No. 1

This partnership comprised a consortium of the health services development unit of the university in the region, the local health service providers at two local hospitals, and four local communities. As such, the partnership had a solid foundation in the community and in the institutions in the area. The project's focus was on the development of a community college. It was envisioned that the college would serve to bridge the gap between secondary and tertiary education as well as including adult literacy training and programs for health workers. The partnership activities included bridging programs, vocational training, and health worker programs. The communities involved had been politically active and represented a strong stakeholder group. Through local civic and traditional/tribal systems, the partnership has been able to set up successful management systems that link the community with the health services. Stronger links with the university and other medical and nursing educational institutions were on their way to being established.

Partnership No. 2

In this partnership, the university had committed to initiate affirmative action in student selection and to develop support systems for disadvantaged students at the university. The vision was to promote more effective community-oriented health professions training as well as the development of relevant training for community health workers. With wide community support, and a decision to approach governmental and nongovernmental sources for funding, a multipurpose community center was strategically set up within the beneficiary community, as such a center was beyond the resources of the local government. The center provided a primary health care (PHC) service component, a PHC development unit for income generating activities, and also served as a community resource center. In parallel, the local health service (the provincial administration of the region) had pledged funds toward the development of part of the community center. By a process of consultation and networking with the existing health services that were provided by the municipality, the partnership aimed to improve the primary level health services of the people.

In view of the disadvantaged nature of the community, it was not possible to engage the community in a project that only addresses primary health care. The community perceived its urgent needs to be wider and of a higher priority than health care. It was envisaged that the community health center would serve as a focus for members of the community to move to deal with their priorities themselves. Outside the field of health care, the university was a valuable source of expertise. Activities at the center would facilitate the transfer of skills to the community.

In this partnership, all three of the partners were fully committed to the initiative, and they were highly respectful of each other. Since the initiative, there has been an increase in the number of "Black" students admitted to this once Whites-only regional university. Students now had a choice of receiving instruction in either Afrikaans or English, an option that did not exist before. Similarly, first-language Afrikaans faculty members were taking English courses, and the number of "Blacks" on the university faculty was increasing.

Partnership No. 3

The region where this partnership was set has a predominantly native African population. It was 95 percent rural and lacking in such infrastructure as water, sanitation, roads, and health facilities, due to the previous apartheid regime. The partnership comprised the university as the academic institution partner, the Department of Health and the municipality as service providers, and four local communities. The university was established in 1985, and from its inception, unlike the traditional medical schools in South Africa, it had been mandated to implement a community-based curriculum for medical training.

The partnership enabled the university to expand its vision to include a wide cross-section of health professionals. Thus, in addition to medical students, nursing and health education students and community health workers were trained. The main focus of the partnership was on appropriate training of health personnel and community health development, through initiating water, sanitation, and other projects.

Partnership activities included the development of academic community-based centers. Through the initiative, there was a move toward developing comprehensive health services, which were not previously available in this region. The stakeholders felt that the health service component was strong in this partnership, and that there was a great need for the university to strengthen its professional teaching staff by way of development of their capacities. Other activities included the establishment of the Department of Health Professions Education at the university, whose role included the whole medical school program in addition to the activities of the partnership, as these were inseparable. There was also a host of community development and social activities.

Partnership No. 4

This partnership comprised the two local nursing colleges and the nursing science department of the regional university as the academic partners. The health service providers were individually approached, and consisted of the provincial administration health services, which ran the heath care center in the locality, together with the regional Department of Health and the Department of National Health. The beneficiary communities in the region were approached through their residents' association/s. The objectives were to prepare the partners for participation and, through developmental workshops, to strengthen the partnership's management by enlisting 50 percent of the members from the community stakeholders. Other goals were to choose one community for the development of a PHC Teaching and Research Center, and to become involved in the training of community-based health workers.

The development of the PHC Training Center was accepted by the community and a steering committee was formed. The health service partners in the area were individually approached for their involvement. They responded by appointing representatives to serve on the partnership's steering committee. Two of the training institutions in the area sent their students for community-based experiences at the beneficiary community where the health center was initiated. Lecturers from these educational institutions were on the partnership's management committee.

Partnership No. 5

This partnership had as its goal the promotion of improved health care and health status of their disadvantaged communities through developing a model of HPE that is community-based. This was to be achieved through a partnership among the communities, the academic institutions, and the health service providers.

Three communities participated in this partnership. These communities were the most disadvantaged communities in the area. They were isolated, underdeveloped, lacked infrastructure, and had high levels of poverty and unemployment. The academic partner consisted of a wide array of training institutions: the health sector at the local university encompassed community health sciences, nursing, social work, psychology, physiotherapy, occupational therapy, child guidance, dietetics, human ecology, student counseling, and dentistry. Another participating educational institution was a local technikon, with its department of public health, department of paramedical services, and department of dental services. The health services partners included the regional services council and the provincial administration. The service providers at all levels had been very supportive of the partnership. For instance, frontline workers had been actively involved in managing the partnership, in training and supervising students in the field, and in research (planning and implementation of community surveys), as well as in teaching at the university.

The partnership recognized and accepted the idea that different models of community-based education would be developed at different sites, and in turn identified appropriate entry points into their target communities. The Community Health Center was employed as an entry point into one of the partnership's beneficiary communities. Then there was a process of engaging the structures in the community sites with the goal of community-based interdisciplinary learning. Several academic departments were already active in the area, and it was envisaged that the local community health center could be transformed into an academic PHC center.

Common Challenges

The partnerships initially faced many common challenges. While some of the challenges had to do with the South African setting and context, others had to do with the principles and notions of partnership working. For instance, poverty in South Africa was and continues to be a primary cause of many health problems (UNICEF, 1989). Despite the fact that South Africa ranks as an upper-middle income country, the majority of its citizens live in poverty (Carter and May, 1999; Zimmerman, 2000). Combined with the lack of education about health, the people who were most in need of public health services often did not receive it. Furthermore, the South African health care system was divided according to race, geographic area, the public sector (further divided into local, provincial, and central health authorities), and the private sector. Today, the right of access to health care services is guaranteed by the South African Constitution (Ngwena, 2000).

There were no similar models of partnership initiatives in Africa from which to learn and benefit. For inspiration and models of partnership practice and fostering, stakeholders and partners had to look to the West. In addition, some institutional leaders were convinced that the community-based focus of these educational efforts would lead to a "lowering of standards." An added aspect was that the leadership in some of the partnerships comprised people from cultural backgrounds different from that of the community/ies involved in the same partnership. In parallel, at the beginning of the efforts, the students who were undergoing the training in most of the institutions that participated in the partnerships were not from the communities that were partners in the initiative, nor did they come from the same cultural backgrounds. This was complicated by the fact that, because of the legacy of apartheid, there were inherent initial inequalities in these initiatives, where the communities were a "disadvantaged partner." Finally, several of the partnerships had lost many of their leaders to jobs in government institutions and in the nongovernmental organizations sector.

Outcomes

As the partnerships aimed to achieve educational reforms for health professionals, the definition of success for the partnerships had critical implications. A number of ambitious outcomes were aspired to. These included HPE impact, curricular, and services outcomes, as well as student, community, policy, sustainability, and structural change outcomes.

Health professions education impact outcomes. One anticipated outcome of the community partnerships was to improve health professions education by way of creating alternative settings for the education of health professions.

Curricular outcomes. Another desired product was to modify the HPE curricula so that they revolve around responsiveness to community health needs, to become more community-based and to enable students' participation. This was to be accomplished by changing the setting where learning takes place and linking with the communities by a process that included redesigning the curricula.

Services outcomes. The aim of the CPs was to provide an appropriate mix of quality primary care services that meet the needs of the community. Such a task needed to take into account issues surrounding teamwork activities between health and social care professionals.

Student outcomes. Another goal was to stimulate an increase in the number of qualified health and allied professionals who would appreciate the "community," be responsive to the community, choose and enter primary health care practice as a career, and serve in underprivileged areas once they finish their training.

Community outcomes. Community involvement in health care reforms is a treasured outcome of the partnerships. The participation of local people, the development of citizen-driven community action structures, and the empowerment of the community to participate as an active partner are all important to both the success and sustainability of the partnerships. The opportunities included offering the community partners specific active roles in the educational courses of the partnerships as well as improved community understanding of the university.

Policy outcomes. The CPs were promoting a primary care-oriented and community-based approach to health professions education. For such reasons, policy changes through the mobilization of a collective power base represented prized outcomes for the partnerships. The differing cultures, structures, and dynamics of community and academe come into play in the policy arena as they do elsewhere (Richards, 1996).

Sustainability outcomes. Long-term viability of CPs is associated with relationship building and group ownership (El Ansari, 2000a). Success in partnership work can be measured in terms of longevity (Staggenborg, 1986), where a more enduring effort is more likely to have impact (Kumpfer et al., 1993). Consequently, for extended survival, a variety of personnel, organizational, structural, financial, operational, and human factors and barriers need consideration (El Ansari and Phillips, 2001a).

Structural change outcomes. These outcomes embrace capacity building and social planning as well as system changes in service delivery, system reform, and new community linkages (Kagan, 1991). Accordingly, the extent to which the partnership efforts produce permanent changes for the participating professional institutions (Henry, 1996) and community lay organizations (El Ansari, 2000b; El Ansari and Phillips, 2001b) needed to be monitored.

Findings

The data collected from the five partnerships were pooled together, and the entire sample ($N = 668$) was initially categorized into two intuitive "generic" groups according to the organizations that the participants represented. The "professional" side of the partnerships ($N = 301$) comprised the health services providers, academic training institutions, and partnerships' core staff (full-time, paid employees of the partnerships). Alternatively, the "community" side ($N = 367$) included the lay community, community health workers, and nongovernmental and community-based organizations and voluntary agencies. The levels of certainty of the two groups in relation to the accomplishment of 16 different anticipated partnership outcomes (clustered under the eight categories described above) were then compared.

The two generic groups had similar levels of certainty in 45 percent of the 16 outcomes under investigation. For the remainder of outcomes, the professionals were more conservative in their perceptions that such outcomes would be accomplished. This was particularly true in relation to the policy outcomes (that the partnerships would influence the policies governing HPE), the sustainability outcomes (that the partnerships would continue as identifiable organizations or exist beyond Kellogg funding), and the structural change outcomes (that participating organizations were ready to implement structural changes to support the partnership). Similarly, for the student outcomes, the professionals were wary about whether the partnerships would affect the specializations that the medical students would choose to dedicate themselves to and the localities where they would serve once they completed their training. However, for all the outcomes, the range of responses of the groups indicated a moderate to good level of certainty that their partnerships would achieve the aims that they set out to attain.

Next, the two generic stakeholder groups were broken down into six different and more precise specific partners: the academic training institutions ($N = 130$), the health and other government services personnel ($N = 111$), community health workers ($N = 70$), core staff ($N = 60$), lay community ($N = 166$), and nongovernmental and community-based organizations and voluntary agencies ($N = 131$). Once more, the certainty levels of the six groups in relation to the accomplishment of the 16 anticipated partnership outcomes under study were compared.

A different picture emerged. When the partners were broken down into their specific groups, their responses indicated remarkable and significant differences in the levels of certainty in relation to the partnerships' anticipated outcomes. First, for all the outcomes, the range of responses of the six partner groups indicated a fair to good level of certainty that their partnerships would achieve the activities that they set out to attain. Second, the emerging pattern was that the community members, the community health workers, and the partnerships' core staff perceived more certainty about the outcomes. On the other hand, the academic institutions, the health service providers, and, especially, the representatives of nongovernmental organizations and voluntary agencies were more cautious about whether the intended outcomes would be achieved. There seemed to be a "certainty" gap between these two polar partner groups. This certainty gap was wide and distinct for some of the anticipated services, sustainability, and community outcomes, and conversely the gap was narrow and hazy in relation to the health professions education impact outcomes as well as structural change outcomes.

Third, there was an "onion skin" appearance in the levels of each group's certainty. Each of the stakeholder groups frequently had a "harmonious" level of certainty about most of the outcomes related to their partnerships. Each partner group exhibited an "orbit" of assertion where most of their responses were located. Different stakeholders orbited had dissimilar levels of confidence in the accomplishment of outcomes. At most times, each group was more or less confined to its orbit. However, for certain outcomes, groups momentarily departed from their established certainty levels (orbit) to other higher or lower ones. Hence, the term "orbital" hypothesis was employed to refer to the onion-skin appearance of the relatively distinct, multiple, successive, and incremental levels of certainty that different specific stakeholders and partners exhibited in relation to their partnerships' outcomes.

In order to verify further whether such an orbital hypothesis held true not only for the partnership outcomes but also for other partnership variables, the study went on to explore whether the six specific partners who perceived greater certainty about the outcomes would also experience higher ratings on other related partnership parameters. Hence, the groups' perceptions as regards another 15 partnership "feel-good" (contentment) variables, inspired from the literature as being critical to the effective fostering of collaborative efforts (El Ansari and Phillips, 2001a), were measured. These contentment variables addressed a wide range of fulfillment and approval issues: for example, satisfaction with the partnerships' operations, sense of ownership for the partnerships' accomplishments, and commitment in terms of endorsing or adopting the partnerships' missions. They also focused on partnership and member participation: for example, the partnerships' involvement in the educational activities of the targeted beneficiary localities, and members' personal contribution and involvement in their partnerships. The feel-good dimensions similarly included whether there were formalized rules and procedures, adequate operational understanding of the partnerships' operations, good quality flow of information, and appropriate leadership skills. Several authors (Gottlieb et al., 1993; Herman et al., 1993; Rogers et al., 1993) have highlighted the importance of these parameters.

The stakeholder perceptions of the feel-good variables that are critical to partnership fostering suggested that, with some exceptions, the three partner groups who scored the highest certainty levels in relation to the anticipated outcomes of the CPs were the same groups that scored highest on the other feel-good variables. These findings provide direct supportive evidence for the certainty gap referred to above. For instance, the community health workers, the partnerships' core staff, and the community members exhibited significantly higher levels of sense of ownership, commitment, and contentment with the flow of information in their partnerships. Similarly, significantly more participants from these groups indicated high involvement levels in their partnerships, had more belief that their partnerships had long-range plans, and knew the organizational structure and staffing of their partnerships and what their roles in the partnerships were. In addition, more of them reported contentment with the information they receive from their partnerships' leaderships. These findings lent additional support for the orbital hypothesis: stakeholder groups' perceptions of the multiple facets of their partnerships are usually harmonious, forming rather discrete orbits of opinions and experiences for each partner, which are at times departed from, but usually returned to.

Such findings have direct and important implications in relation to the research and evaluation challenges that pose themselves when measuring stakeholder satisfaction to the multiple facets of partnership fostering. If the orbital hypothesis is verified by further research in a range of partnership contexts and settings, then its applications could be staggering. Researchers and partnership administrators could finally be able to measure a mere handful of aspects of the stakeholders' perceptions of their partnerships' functioning, and the findings could then provide fairly factual information to the researchers (as well as donors) about a multitude of other aspects of the partnerships, without having to measure them. This would offer critical savings in terms of time, resources, and effort, and would lead to less work disruption, when undertaking partnership research, because collaborative ventures usually exhibit multiple facets, display a wide range of perspectives, and include multiple stakeholders, each with a special interest in a particular aspect of the evaluation (El Ansari et al., 2004).

Discussion

Partners working together in a collaborative mode need not be considered homogenous entities. The groups come from different backgrounds, organizations, and cultures. They view the benefits and costs of participating in their partnerships differently (El Ansari and Phillips, 2004), and as the findings of this report have suggested, their opinions about the certainty that their partnerships' outcomes will be accomplished also vary to different degrees.

Hence, the complexity of each partner needs be recognized, as each generic partner is far from representing a homogenous unit. The partners may not be able to agree quickly on a common course of action (within the entity) necessary for their partnership. Many of them may not even see the partnership as defined in the initiative as a priority. Furthermore, partners in joint working arrangements value miscellaneous and diverse aspects of the partnerships in which they participate.

The first aim of this report was to describe five South African community partnerships for health professions education and a range of their anticipated outcomes. To this end, an overview was provided of each of the partnerships, as well as the collective challenges they faced and their anticipated outcomes. The findings suggested that the two generic stakeholder groups had similar levels of certainty in 45 percent of the outcomes under investigation. Other studies (Rogers et al., 1993) also found no statistically significant differences in outcomes efficacy between the staff and members of 61 partnerships in the United States. However, for this investigation, as regards the remaining outcomes, the professionals were significantly more cautious in their perceptions that such outcomes would be accomplished.

The second aim was to test the appropriateness of employing generic stakeholder groups in partnership research as opposed to tightly defined specific partner groups. Utilizing more specific stakeholder groups reflected a more precise depiction of the events, which might be concealed by generic grouping analyses. Furthermore, each specific group exhibited an orbit of assertion where the majority of their responses were located. This confirms that partner groups are not homogeneous (El Ansari and Phillips, 2001b), and neither are the individuals who volunteer to participate (Merrell, 2000); rather, they comprise diverse and resourceful member organizations. Hence, methodological issues become important as researchers get involved in the operational tasks of measuring (Gelmon et al., 1998) and the analytical tasks of comparing performance (Mays and Halverson, 2000; El Ansari et al., 2001).

The third aim was to explore whether those groups out of the six specific partners who perceived greater certainty about the outcomes would also experience higher ratings on other related partnership functioning contentment parameters. The findings suggested that the answer to the question is a qualified "yes." If a particular stakeholder is confident that the anticipated outcomes would be accomplished, then that stakeholder is more likely to be also satisfied with the partnership, committed to its work, feel a sense of ownership, and exhibit high participation and involvement in the partnerships' activities.

Conclusion

This investigation has confirmed that in partnership settings, employing generic groups could, at times, be more feasible—and indeed might offer its own set of usefulness in drawing an empirical portrait. However, employing tightly defined stakeholder groups holds more promise for a more precise depiction of events. The general impression is that each partner is unique. Hence, the attitude to be created in collaborative interventions is one of a clear understanding that embraces the different origins and aspirations of the stakeholders and recognizes their mutual roles, responsibilities, resources, and limits. Only by paying due attention to their individual value systems and weaving those beliefs into a common vision can the partnership process be advanced.

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HEALTH PROTECTION: COMMUNICABLE DISEASE, PUBLIC HEALTH AND INFECTION CONTROL EDUCATIONAL PROGRAMMES—A CASE STUDY FROM THE UK

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Summary

The health protection (HP) landscape is changing. Issues related to infectious diseases in the context of global health are receiving the attention of world leaders and policy makers. In the UK, the national health policies resonate with such transformations, presenting a range of opportunities and challenges. The opportunities include the formation of a new national organisation dedicated to protecting the people's health and reducing the impact of infectious disease, the Health Protection Agency. The opportunities also include the opening of non-medical specialists's pathways in public health. The challenges represent the limited number of centres offering infection control education; the hospital focus and bias of the courses; new, resurgent and emerging infections; globalisation and travel; bacterial resistance; vaccine safety and coverage; bioterrorism; global response capacity; and visa restrictions. Within this context, this paper presents a case study of an HP educational programme at a British university in the south of England. It outlines the course design and philosophy, participants, recruitment, aims, descriptions and learning outcomes. A range of teething problems associated with the initiation and running of such programmes is considered. These include aspects related to the university, features associated with the modules, characteristics of the students, and other interconnected larger scale international issues. Some suggestions for the way forward are presented. Collectively, attention to the suggested measures can ensure that

the processes that teaching programmes embrace to refine their content and delivery will equip tomorrow's professionals with the requisite HP knowledge and skills.

Introduction

Infectious diseases are a major threat to mankind's survival, health, wellbeing, prosperity, social stability and security (Chief Medical Officer, 2002). They account for 41% of global disease and are responsible for millions of deaths each year (Chief Medical Officer, 2002). Recent events have put microbial threats and public health into the forefront: "SARS has emphasized that infectious diseases can come out of nowhere" (Lovinger, 2003). Such realities highlight the importance of public health and health protection (HP). Globally, as well as nationally in the UK, there have been emerging opportunities as well as growing challenges on several fronts with regard to HP. Although HP includes communicable disease (CD) control, protection against non-communicable environmental hazards, and emergency planning and response (Regan, 1999), this paper will focus on the first of these: the CD function.

Health Protection: Opportunities

Two major positive developments stand out. First is the publication of a HP strategy for England and the formation of the Health Protection Agency (HPA). The HPA is to deal with the health threats from infectious diseases, chemicals, toxins and radiation hazards. As infectious diseases pose an everchanging risk because the problem is never static, HP is in the premier division of health priorities (Chief Medical Officer, 2002). However, this presents a number of challenges in relation to the development and training of the workforce (Nicoll and Murray, 2002). Second, a medical qualification is no longer a requirement for directors of public health. Non-medical public health specialists' pathways have been accepted by the UK Faculty of Public Health (Somerville and Cornish, 2001). In the past, there were fewer training opportunities for non-medically qualified workers from many disciplines and professions wishing to work in specialist public health (El Ansari et al, 2003a). As a result of these changes, the preparation for a new cadre of public health professionals is underway. Many students undertaking postgraduate education as an initial component of public health training require instructional courses in recognition, prevention and control of CDs.

Health Protection: Challenges

The range of challenges to HP is broad. Table A-2 depicts some contributory factors that underline the need for HP, considering lifestyle and environmental influences. Health threats include infections transmitted through animals, insects, and food and water, as well as illnesses resulting from environmental toxins, misuse of antibiotics and bioterrorism (King and Khabbaz, 2003).

CDs and infection control have had a low profile in the UK with limited educational opportunities (Pratt et al, 2002). Such training had a strong hospital focus and less regard to the wider community impact (Pratt et al, 2002), despite the fact that care is increasingly provided in the community (McGarry, 2003). Protecting patients with indwelling devices or receiving enteral nutrition, and protecting carers from infections has extended the interest in microbial threats to out-of-hospital care settings (Friedman, 1999).

New and emerging infections have come to the fore. Since the 1970s, about 30 previously unidentified infectious diseases have become important (Chief Medical Officer, 2002; Pennington, 2003), emphasizing the necessity to strengthen the infection control infrastructure. Similarly, the re-appearance of old adversaries such as tuberculosis and syphilis (Public Health Laboratory Service, 2001), as well as opportunistic infections, requires coordinated responses. Likewise, malaria is reappearing, and the influenza pandemic is long overdue.

The effect of globalisation underscores the need for HP. Rapid travel of people, food and other products conveys many infectious agents (Lovinger, 2003). Travellers need to know how to avoid illness, and health professionals need to be able to assess those who return with an illness (Spira, 2003). In parallel, the threats associated with health care are increasing as bacterial resistance to antibiotics continues and hospital-acquired infection remains a concern (Croxson et al, 2003).

Vaccine safety and public expectations emphasise the need for HP (Nicoll and Murray, 2002). Pertussis has re-emerged due to poor efficacy vaccines (Canada, Sweden) (Skrowronski et al, 2002). In the UK, parental confidence in childhood immunization was dented after adverse publicity (Begg et al, 1998). Low vaccination coverage also poses threats (Communicable Disease Report Weekly, 1999), and suggests that measles can be severe and fatal in industrialised countries (Ciofi Degli Atti, 2003). BCG (Dobson, 2002) and Measles Mumps and Rubella (MMR) (Blackwell et al, 2002) vaccination rates among UK asylum seekers were found to be below that required to provide adequate population immunity. Even with high coverage, the threat is not totally avoided. Resurgence of whooping cough was reported in countries with high vaccination coverage (Crowcroft, 2002).

TABLE A-2 The need for health protection: lifestyle and environmental influences

Issue	Example
Travel	Malaria infections when travelling in warm countries
Trade	Incidents of food poisoning from imported food (e.g., coconut)
Increasing antibiotic resistance	MRSA. Vancomycin-resistant Enterococci
Increasing elderly population	In the UK from 1901 to late 1990s, the population over 65 years of age quadrupled. This is likely to impact on future care as the elderly are more prone to infection
Increasing immature neonates surviving	Survival of premature/low-birthweight babies has improved. The increase of babies needing invasive devices to provide life support increases the risk of infection
Immunosuppression due to chemotherapy or transplant	Patients with leukaemia and other immunosuppressive diseases are at higher risk of microbial infections
Immunodeficiency states	HIV/AIDS
Deforestation and animal movement	Exposure of workers (arthropods); loss of protective wildlife (predators) who kill rodents. Ebola haemorrhagic fever is believed to have first infected a forest worker clearing trees when bitten by an infected monkey
Global warming	Has brought floods and droughts. Heavy rain provides breeding sites for malaria and causes flooding, which contaminates clean water supplies
Health care associated infections	In 1999, it was estimated that healthcare-associated infections cost the NHS almost £1 billion per year
Fear of bioterrorism	Anthrax scare in the United States and fear of smallpox release
Changes in animal husbandry	vCJD speculated to be caused by eating beef from cattle with bovine spongiform encephalopathy, believed to be due to feeding animals with animal byproducts
Vaccination	Meningitis C and Hib vaccinations led to a decrease in numbers of infected individuals
Media hype	MMR vaccine safety scare (UK) could have contributed to decrease in vaccination take up, increase in infected individuals and concern about outbreaks
Lifestyle changes	Legionella pnemophila colonises air conditioning systems, inhalation of contaminated aerosols leads to infection

MRSA, methicllin-resistant Staphylococcus aureus; vCJD, new variant Creutzfelt-Jacob disease; Hib, Haemophilus influenza serotype B; MMR, measles, mumps and rubella; HIV, human immunodeficiency virus, AIDS, acquired immunodeficiency syndrome; NHS, National Health Service

Bioterrorism and the release of biological agents necessitate HP. Release of anthrax (United States) as a biological weapon, or the deliberate contamination of restaurants with Salmonella can cause widespread illnesses (Torok, 1997). Such threats are considered to be low in the UK (Lightfoot, 2001), but ricin has been found in London (Mayor, 2003).

Education for CD and infection control has been underdeveloped with no single pattern of provision (Public Health Laboratory Service, 2002). Globally, there are calls to address the deficiencies in this area (Ronald and Memish, 2001). What emerges from the literature and state of affairs is the need for a competent workforce able to respond to microbial threats. A capable workforce must be underpinned by CD prevention and control training programmes (IOM, 2003). Hence knowledge (education) and skills (training) to confront microbial threats will need to be integrated into the preparation of a wide range of health care professionals (El Ansari et al, 2003b) for effective responses to a variety of infections (El Ansari et al, 2003b). Such a task is challenging when, "there is no global definition of 'infectious diseases' physicians and cover competency"(Ronald and Memish, 2001: 50). Collectively, these ideas formed the basis for the HP educational courses ("CD and public health" and "Infection control in practice" modules) described here, where the focus is on the CD function (Regan, 1999) of HP.

Aim of the Paper

This paper is a study of HP educational developments at the postgraduate programme in Public Health, Oxford Brookes University, UK. The aims of this paper are:

- to highlight some emergent opportunities as well as growing challenges in relation to HP;
- to describe an HP educational programme at a British university;
- to identify the teething problems associated with the initiation and running of such a programme and suggestions for the way forward.

Case Study: Background

This paper employed a case study approach (Yin, 1994). The case is the HP educational programme addressing CD and infection control modules at Oxford Brookes University, UK. The case was selected as it was initiated at the time when HP was receiving international attention and the HPA was being instigated nationally. Hence, there was an opportunity to incorporate the latest recommendations regarding CD, infection control practice and workforce developments for microbial threats into the modules design.

Figure A-2 depicts HP as a triad of international concern, national responsibility and local commitment. It illustrates the temporal interrelationships between these three dimensions in relation to the HP modules described in this paper.

In recognition of the need for HP education, the university sought to develop a training course for health care professionals and infection control nurses. The university was already providing two modules for infection control practitioners. The first, infection control in practice, focused on acute hospital care, and the second is an introduction to clinical microbiology. Recognising the provision of more community-oriented services and the global challenges of microbial threats, it was felt that another new module was required to encompass CD and the problem of infection control in the community.

This view was subsequently supported.

With careful planning, the new module could augment the existing infection control training. However, it would have to meet the needs of both the infection control practitioners (study at Level 3 after qualifying) and those working in public health (usually postgraduate study, Level 4). To satisfy both these learner groups, the new module (CD and public health) was designed to be taken at either Level 3 or 4. Both cohorts attend the same lectures but assessment is different to reflect study at postgraduate level. Students specialising in infection control are encouraged to undertake the set of four modules outlined in Figure A-2. Planning commenced in 1999 and the new module was established as the Chief Medical Officer's (CMO's) report was published in January 2002 (Chief Medical Officer, 2002). The report supported the local view that there was a need for "stronger professional education and training programmes" (Chief Medical Officer, 2002:15). This amalgamation of national responsibility and local commitment acted as the driver of the initiative.

Course Design and Philosophy

Modular programmes at the university generally run for 1 day a week for 8 weeks. Two features characterise this HP programme. Firstly, it runs as an intensive 1-week block module (Monday–Friday, 9.00 am–5.30 pm). The rationale was that students would be totally away from their workplace, focusing exclusively on the course, the course work and the required assessments. Students would attend the lectures and would be able to network over break times. Such "block" delivery would enable participants living away from Oxford, and unable to commute each week for 8 weeks, to stay in Oxford for the module's duration. The second feature is that as collaborative approaches are required to control outbreaks rapidly and efficiently, this is reflected in the variety of university staff and non-

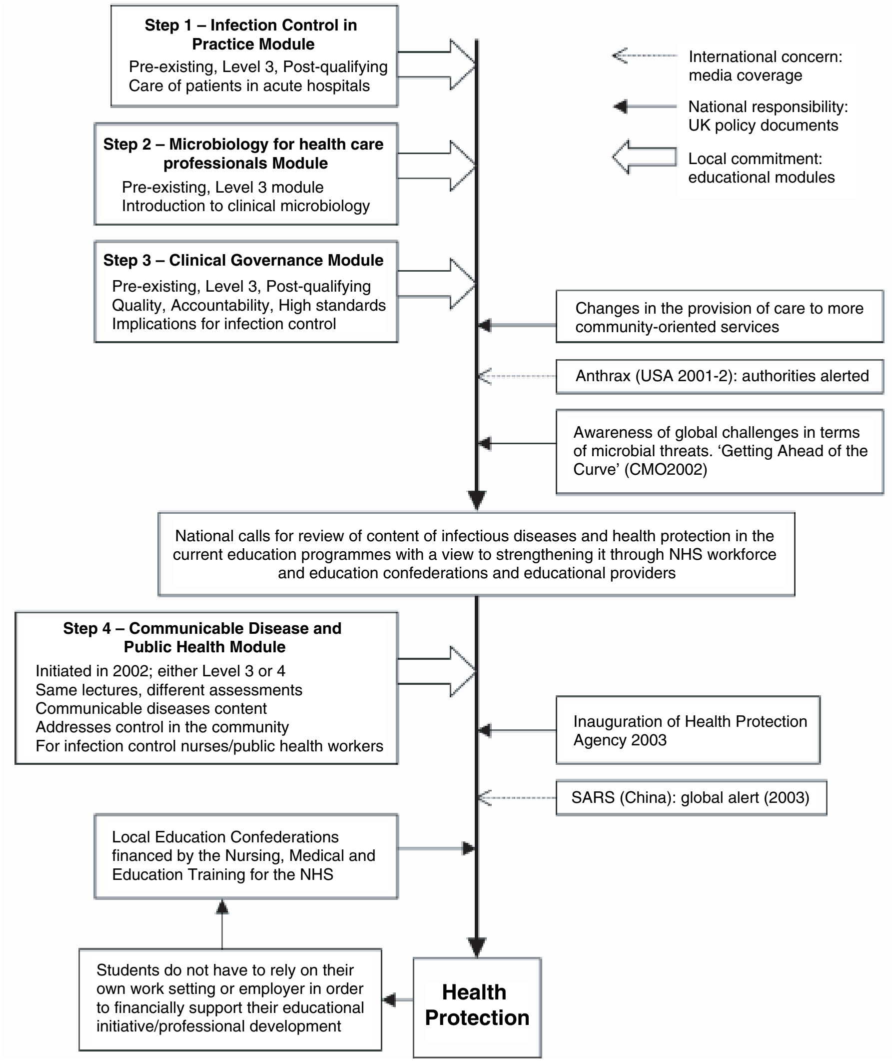

FIGURE A-2 Health protection: temporal relationships between international concerns, national responsibilities and local commitments. *Chief Medical Officer. Getting Ahead of the Curve, a Strategy for Combating Infectious Diseases (including Other Aspects of Health Protection). London: Department of Health, 2002.

university contributors who are involved in the teaching. In practice, CD and infection control cannot be dealt with by one individual, and involving external speakers enhances the student's appreciation of the roles and responsibilities of others with whom they need to collaborate.

The course philosophy is premised on increasing the student's knowledge about pertinent topics of CD and infection control. Through planned sessions, participants learn about a range of issues and disease agents, sources of information and risks of exposure, data on safe practices, public safety agencies and avenues for advice. The course also maintains the flexibility to respond to identified individual learning needs. At the start of each module, students are asked to review the programme and identify particular topics that they need to learn about but which are not already included. If it is deemed an appropriate addition, the module team then does its utmost to include such topics in the content. The course is also mindful of relevant incidents and responds by bringing the participants "up to speed" with current global and national events. As anthrax and Severe Acute Respiratory Syndrome (SARS) became international concerns, both were swiftly added to the course content in their respective years.

By using learning sets, the module stimulates students to exchange ideas, share challenges, network and 'bond' within the duration of the course. This involves a great deal of interaction between students and presenters. Students work together to plan how they would collaboratively manage incidents such as a food poisoning outbreak or public water supply contamination. Infection control and CD control are ideally suited to this since no single health care professional group has all the responsibility. Management improves when everyone involved acknowledges their duties and recognises the significance of working together. A classroom where the students are removed from their work responsibilities provides an ideal non-threatening forum to debate the multifactorial influences. Such shared learning contributes to establishing future sources of contact, support and expertise between the participants. These connections and relationships could assist the students in identifying and managing future incidents, liaising with experts and working as teams.

Course Participants: Recruitment and Professional Profiles

Recruitment has been good although the university had not advertised this module and its reputation relied entirely on "word of mouth." In spite of this, at the time of the writing of this paper, it had run three times in 14 months. The first run was immediately after the validation of the module; due to the short notice, there were seven students. With the spread of the news, the number of students quadrupled in each of the subsequent two runs. Interest in the module is high, based on the number of queries that are received. If such demand is sustained, it might be necessary to run the module twice in the academic year 2003/2004. The students come from a range of backgrounds and disciplines representing many professions. Table A-3 shows the student numbers that attended each of the three "runs" of the course, the range of their professions, the student's geographical distribution indicating the distance each had to travel in order to attend the course, and some of their feedback as regards their teaching and learning experiences at the university. The diversity of the students' professional profiles poses challenges to the teaching and learning strategies.

Course Aims, Descriptions and Learning Outcomes

Whilst the course organisers acknowledge that there is no substitute for "hands-on" experience, the modules are designed to enhance knowledge and skills in dealing with microbial threats. In the time available for the modules, the programme does not assume to produce expert practitioners. The modules do, however, inform the learners of frequently encountered pitfalls and provides them with knowledge of how to deal with microbial threats, who to contact and how to utilise the available resources. Upon completion of the modules, students are not expected to be "experts," but should be safe and informed practitioners with a wealth of information and useful networks of contacts. "The control and prevention of infectious diseases is a responsibility of all healthcare professionals—not just the specialists" (Chief Medical Officer, 2002:142).

The course aims to understanding the methods of spread of infection and implementation of safe practice. Hence, the relationships between the methods of disease spread and the behavioural aspects that influence the outcomes are explored. There is emphasis on communication and collaborative working for productive relationships between the different professional groups. The infection control in practice module focuses on principles of infection control incorporating infectious diseases and epidemiology, both in hospital and community settings. The CD and public health module has a broad public health perspective, and examines the disease epidemiology, trends of emerging infections, surveillance, screening, vaccination, and legal and ethical aspects.

Table A-4 depicts the learning outcomes and session outlines of the HP modules. The two modules examine the systems required to prevent, investigate and control the threat of infectious diseases. In addition to the emphasis on collaboration, they also explore how socioeconomic and cultural factors influence the outcomes of CD control practices. They aim at good surveillance, early assessment and prompt action.

TABLE A-3 Recruitment: student numbers, professions, distance traveled and feedback

Professions	Locations	Some feedback
First run—seven students		
3 infection control nurses	All within 50 miles	Good venue
2 acute hospital nurses		Wonderful speakers
1 community nurse working with the homeless		Interesting topics covered
1 MPH student	International student	Handbook very helpful
Second run—22 students		
1 acute hospital nurse	Local	Overall feedback was good; problem solving gives the opportunity to see what you know in practical situations—good learning exercise
1 health visitor	Local	
1 deputy director of PH	Local	
1 director of PH	30 miles	
1 nursing in general practice hours	40 miles	This was an "extra run" put on at the beginning of term-the library were limited which the students did not like
1 nursing officer (PH)	50 miles	
1 policy analyst	120 miles	
Remaining students either on fast-track PH training or studying for MPH	Local and international	[Wanted] more information on the newly emerging HPA; [Wanted] an early finish on the last day
Third run—26 students		
15 students (Infection Control Award)	45 miles	Excellent, lots of information, very interesting; intense, compact; brilliant, lots of information gained, stimulating; thought provoking; high standard of lecturer input, consistently good handouts
2 students taking as a stand-alone module	Local	
1 environmental health officer	35 miles	Too long; mentally exhausting; very busy, not enough time to absorb information
1 health development manager	Local	
3 PH specialists; 1 PH manager; 1 PH nurse; 1 assistant director of PH	Local to 120 miles	Much better understanding of community health groups and how issues are dealt with

PH, public health; MPH, Master's of Public Health; HPA, Health Protection Agency

TABLE A-4 Health protection modules: some learning outcomes and session outlines

	Infection control in practice	Communicable disease and public health
Learning outcomes[a]	Micro-organisms: spread and interactions	Biological, socio-economic and environmental factors
	Practices and policies of IC	Prevention and control measures
	IC for individual clients and the workplace	Legal and ethical issues
	Environmental audit and risk management	Information analysis
	Evidence-based change	Disease surveillance
Session outlines	Introduction; history of IC control	Introduction; history of CD
	Handwashing; waste disposal and ward cleaning; sterile supplies department (visit)	Organisation of the NHS; key workers in CD control; epidemiology; morbidity and mortality; surveillance
	Specimen collection; disposal of equipment antibiotic resistance; infection control audit	Groupwork: working in teams; identification of individual learning needs; transmission; decontamination
	The ventilated patient; untoward incidents; catheter/invasive-devices-related infections; blood-borne infections; managing infection	Basic microbiology; Public Health Laboratory Services; basic immunology; combating infectious diseases; environmental influences; outbreak investigation
	Surveillance; meningitis; caring for the deceased Busby box: practical exercises clinical governance; implementing change	Legal, organisational and ethical aspects of CD control; groupwork; immunity and immunisation; Busby box: preventing/ controlling infectious diseases

[a]Adapted from Oxford Brookes University, 2001, 2002.
IC, infection control; CD, communicable diseases; NHS, National Health Service

Teething Problems: Considerations for Course Design

The programme team encountered some teething problems during the initiation and running of the HP modules. These included university issues such as the delivery format, classroom accommodation, staffing and administration; module features such as flexibility, and teaching and learning methods; characteristics connected to the students such as the interprofessional background of students, workplace demands and practice links; and international large-scale issues such as the global response capacity and visa restrictions.

Delivery Format

The delivery of a 1-week intensive module meant that students required workplace release for the entire week. Although this can be difficult, the advantages could outweigh the problems. The rationale was that although a week's release could be more difficult to obtain, the students are able to focus their undivided attention on the course.

Classroom Accommodation

The module delivery is a daily 1-week block rather than the standard format (8 weeks). Securing suitable accommodation when running modules that do not fit the usual university configuration could be tricky. Utilising the same room for the whole delivery week is desirable, as students have considerable workloads, and seeking different rooms each day on an unfamiliar campus is unpleasant. The team found that obtaining the same room for a week was not always simple and early communication with room-booking systems is imperative. It is also important to have conveniently located "breakout" rooms for the groupwork. Running the module outside of the university's normal timetable meant that the library hours were restricted as were other support services, such as the refectory.

Staffing and Human Resources

A full-time lecturer with CD/public health experience participated in the planning, but had other administrative responsibilities. A part-time lecturer with infection control/CD experience was employed to develop, validate and lead the module, but also had other responsibilities. As the first lecturer left the university, one person remained to run the module. In such circumstances, the quality of the delivery might suffer. However, with the support of colleagues, staff members, and external speakers, the validity of the module has not been compromised (confirmed by stakeholders'/students' feedback). This highlights the importance of planning for adequate/stable staffing and for having sufficient external support.

Administration

Running the module at two different academic levels represents a difficult enrollment process. It is important to ensure that the students are registered for the correct level. Likewise, admission requirements are difficult to standardise due to the diversity of student's backgrounds and experiences.

Flexibility

The everchanging nature of microbial threats means that the inclusion of topical issues is critical. The team have kept abreast in identifying relevant national and international microbial incidents and swiftly included them into the curriculum, e.g., foot and mouth disease (UK), SARS (Hong Kong and China) and anthrax (USA). Ongoing "surveillance" of occurrences that represent rich material for discussions and "real-life" platforms for debates is important. Such flexibility has been favourably received by the students.

Teaching and Learning Methods

The team has implemented several strategies to facilitate learning. Students attend lectures and seminars, engage in problem-solving activities, reflect on both their own experience and that of peers, and engage in discussions and debates on a range of issues. Employing such a multipronged approach to learning is a useful tool in maintaining the student's attention. It has been important to recognise that students come from widely varying professional and educational backgrounds and to provide support and encouragement, ensuring that all views are considered.

Interprofessional Learning

Satisfying the diversity of the student's backgrounds, and quantity and quality of their professional experience is challenging. However, this diversity is a richness to be capitalised upon, as it is useful in forming networks and appreciation of others' work and duties. Student learning comes not only from the lecturers, but also from each other's experiences. For instance, one request was to explore the practical problems of infection control in resource-limited developing countries. A group discussion was greatly enhanced with a presentation by a student with first-hand experience of working in such settings.

Workplace Demands

Some students requested deferral of the dates for submission of their written assignments due to their individual workloads. However, this is challenging since acceptance of work outside of the agreed timetable affects equal opportunity, and disrupts the validation of results and their approval by the external examiner.

Practice Links

The team ensured the involvement of current practitioners from practice areas relevant to both the students and the curriculum. This ensured relevancy to current practice and policy.

Global Response Capacity

Infectious diseases are a global threat requiring global responses, and this needs to be reflected in the curricula. As permeable international borders have replaced the geographic isolation that used to contain disease outbreaks, the curriculum needed to focus on the global burden of disease. Developing countries carry the greatest burden. The team had to make choices about the inclusion of topics that were not very prevalent in the UK but had global relevance. Curricula should develop capacity to monitor/address microbial threats as they arise.

Visa Restrictions

Foreign scientists and academics can encounter problems in gaining access into a country where courses/conferences are running. No such problems have been encountered with the courses described here.

Discussion

In the 1960s, a U.S. Surgeon General, impressed with the rapid progress of antibiotics and vaccines, announced, ‘The time has come to close the book on infectious disease.” As with many predictions of the future, that standpoint was premature (Pennington, 2003). On the other side of the Atlantic, the postwar development of drugs to treat infection led to a view in the 1960s and 1970s that infectious diseases might be conquered (Chief Medical Officer, 2002). Such optimism was also unfounded.

Infectious disease is ubiquitous and persistent with new, emerging and re-emerging infections. Much infection goes unreported or is undernotified, so routine surveillance portrays an incomplete picture of the magnitude and nature of the threat (Chief Medical Officer, 2002). Prevalence and incidence pyramids are important in infectious diseases; those identified engage only the tips of the pyramids, and surveillance figures are likely to underestimate the real burden (Pennington, 2003).

In the UK, these facts have been realised and responded to by the establishment of the HPA in 2003. The HPA represents a new national organisation, dedicated to protecting health and reducing the impact of infectious disease and other hazards. The prospects now exist for England to have the best HP in the world in 5 years (Nicoll and Murray, 2002). However, accepting that specialised training is not often undertaken (Nicoll and Murray, 2002), the HPA aims to improve knowledge about HP through development, education and training. Consequently, there are calls for a focused educational strategy on CDs and to "review the content of infectious diseases and HP in the current education programmes with a view to strengthening it through NHS workforce and education confederations and educational providers"(Chief Medical Officer, 2002:142).

In response to these calls, this paper focused on the learning and training needs for HP, with attention on infectious diseases. In undertaking this task, the paper employed a holistic, singular case study approach. However, there are many subsections (e.g., philosophy, course organisation, structure, teaching methods, educational and learning outcomes, challenges) that comprise complex domains (Lincoln and Guba, 1985). Hence the contextual details have been outlined in order that readers can judge the relevance of the findings. The paper has detailed the HP educational courses as a component of the postgraduate programme in public health at Oxford Brookes University. Such a "home" for the modules within postgraduate public health is natural given that HP is seen as an integral subspeciality of public health, and basic public health skills (Carlson and El Ansari, 2000) are essential to its delivery (Nicoll and Murray, 2002).

The first aim of the paper was to highlight some emerging opportunities as well as growing challenges in HP. To this end, the paper has discussed some recent advancements that represent opportunities for the HP agenda in the UK. A competent workforce is critical; without it, a public health agency is as useless as a new hospital with no health care workers (Gebbie et al, 2002).

The paper has also shed light on a range of challenges that underline the need for developments in HP. These include the scarcity of infection-control-trained personnel and programmes; traditional hospital focus of infection control educational courses; new, emerging and resurging infections; globalisation and increasing travel; threats associated with health care; vaccine safety and public expectations; and bioterrorism.

These challenges are important as they invite detailed planning, staffing and budgets, as well as integration and implementation. The human resources for the discipline of infectious diseases are inadequate in many countries (Ronald and Memish, 2001) . Strengthening the infrastructure and resources required to address the challenges posed by disease outbreaks is critical (IOM, 2003), but the CMO's report does not provide detailed implementation strategies (Nicoll and Murray, 2002). While a 2001 survey found "great deficiencies at local level where staffing was surprisingly variable" (Communicable Disease Surveillance Centre, unpublished data), greater use is now being made of non-medical specialists by opening up the opportunities for full membership of the Faculty of Public Health (Frankel, 2003). However, with limited funding, the local level becomes a priority for HP investment (Nicoll and Murray, 2002). Although there is no integrated approach to encompass the aspects of HP from national, to regional, to local level (Nicoll and Murray, 2002), a vision for the future has been proposed.

The second aim of the paper was to describe a HP educational programme that addresses CD and public health and infection control in practice modules. The paper has highlighted the rationale of the modules, their design, recruitment, philosophy and aims, and descriptions of learning outcomes and session outlines. The course philosophy responds to a "seamless service" and collaboration between agencies involved in planning and delivering community services (Glen and Leiba, 2002). Incorporated within the modules is the ability to react quickly to developments and to acknowledge he individual needs of students. In the UK, a recent document reported that the current education provision is failing to meet the needs of practitioners as regards infection prevention in the community (Pratt et al, 2002). This echoes the previous shortcomings and the proposed actions for stronger education and training programmes (Chief Medical Officer, 2002). The necessity of educating and training a microbial threat workforce has been acknowledged (IOM, 2003).

However, the published literature describing infection control and CD education is sparse. In the past, few courses existed in the UK. Hence, this paper did not find much literature with which to contrast its findings or to highlight similarities. However, an important point is that the number of infection control and CD courses around the UK is increasing. For instance, the HPA implements an introductory course in epidemiology and surveillance of infectious diseases, but it is more suitable for public health medicine trainees (Anonymous, 2003). Some institutions provide community/infection control study at Master of Science (MSc), Diploma, or Certificate levels (University of Essex, 2003; UHI Millennium Institute, 2003) which are longer and more demanding levels of study. Similarly, other programmes consist of four modules delivered over four 1-week study blocks (University of Leeds, 2003). Other universities (University of Hertfordshire, 2003) run similar courses but depict very limited information on their websites, are more focused on the control of infections in hospitals (London School of Hygiene and Tropical Medicine, 2004), or represent courses that seem to be aimed at qualified nurses (London South Bank University, 2004). Yet others incorporate chemical and radioactive hazards (University of Bristol, 2003) or are part of Master's of Public Health Degrees (Northumbria University, 2004). The courses highlighted here do not represent an exhaustive list of all the courses in the UK.

The range of threats to health is broad and includes international movement, complex food systems, environmental changes, and the wildlife population (King and Khabbaz, 2003). Meeting these challenges and facilitating training of the workforce (IOM, 2003) requires interdisciplinary and collaborative links between human and animal health clinicians, researchers, laboratorians and public health officials (King and Khabbaz, 2003).

As the HPA brings together the expertise of health and scientific professionals working in public health, CDs, emergency planning, infection control and laboratories, so do the modules. The teaching teams include inputs from a range of "external" contributors (former and current consultants in CD control, professor of microbiology, HPA senior member, consultant microbiologist and environmental health officer) and "internal" contributors (the course organiser, a former infection control practitioner and the programme leader, a reader in public health). Such a knowledge matrix is hoped to alert students to the need for partnerships that respect contributions and successful collaborative efforts that span organisational lines (El Ansari, 2003) and professional boundaries (El Ansari, 2001). This concurs with the complexity of infectious disease that requires many disciplines and sectors. Opportunities for synergism are enhanced when disciplines collaborate to discuss the problem, avoid lost opportunities and reduce effort and expense redundancies (IOM, 2003). Recent events highlight the role of partnerships (El Ansari, 2001; El Ansari, 2004) and multi-agency responses (Chief Medical Officer, 2002), as public health prevents disease and promotes health through a growing circle of partners (Steenbergen and El Ansari, 2003; Goede and El Ansari, 2002).

The third aim of the paper was to identify the teething problems associated with the initiation and running of such a programme and to suggest some potential solutions. The paper has reported some factors that could act as threats. These include university- or module-associated issues such as the module's delivery format and its implications for full-time employed mature students, classroom accommodation, module staffing, and the teaching and learning methods. In education, such issues have received attention (El Ansari et al, 2003; El Ansari, 2002; El Ansari, Pearson, and Davis, 2002).

Another group of challenges involves the student's characteristics. With diverse backgrounds, experiences and cultures of students, the University views interprofessional learning as important. Encouraging collaborative learning among culturally diverse students is both advocated and practiced. It is important for the class to move from a cluster of individuals to a working group. Hence students need to have shared understanding of each other's values, cultures, differences, skills and expertise. Through discussions and deliberations, the module's designs address the relationship of professional groups to develop appropriate attitudes and motivations for working with others and competencies to practice collaboratively (Glen and Leiba, 2002). Such a weaving of world views of the various professions is desirable (Gebbie et al, 2002), and could contribute to increasing the interaction between professionals of different disciplines. These are important advantages of collaborative education.

A challenge to workforce development is the resources allowing official health agencies to partner the wider circle of public health workers. The courses maintain many links with practice through the invited speakers, planned visits and group debates. Such practice linkages between academic public health and HP agencies, with exchange of faculty and agency professionals, gives students the opportunity to learn from hands-on practitioners (El Ansari et al, 2003a).

Additional challenges represent international large-scale issues such as the global response capacity. Infectious diseases are a leading cause of death and disability in developing countries and are re-emerging as a serious health problem in developed nations. They require global responses (Chief Medical Officer, 2002; IOM, 2003) spanning both the industrialised and developing nations. To an unprecedented extent, infectious diseases in the context of global health are on the agendas of world leaders and health policy makers (Fauci, 2001). For instance, the European Union has plans for its own centre for disease prevention and control (Weiss, 2003).

However, the burden of infectious disease occurs within developing countries where an estimated one in every two people dies from such a disease. Such sentiments will need to be reflected in the curriculum. Global actions from national governments and non-governmental organizations, as well as the professions as regards public health measures, are critical. These could focus on poverty reduction or stepping up immunisation programmes, and on lessening the chances of introducing new diseases

to the dissemination of preventive knowledge and the monitoring of disease outbreaks. Simultaneously, the strengthening of infection control precautions, legislative responses and institution of surveillance all contribute.

In a parallel vein, in the United States, the potentially negative impact of visa restrictions on scientific enterprise has been recognized (Gebbie et al, 2002; White and Peterson, 2003), suggesting that ongoing research (or educational) collaborations have been hampered (Alberts, Wulf, and Fineberg, 2003). Hence, foreign workers with unique skill sets that are not available in the existing labour pool in a country might require consideration. Although the application of stringent geographical criteria that delay visa clearance of "foreign" scientists are for rigorous applicant screening rather than policies to exclude, the outcomes and impact on research remain unaltered.

Conclusions

Many infectious diseases could be prevented or cured with known public health measures. As part of a wider public health movement, the founding of the HPA was a significant step to addressing microbial-related threats. The World Health Organisation recommendations propose that, in the face of terrorism and emerging infections, a country's best defence is a high-quality public health service (Gates, 2003). There is an immense need for national and international societies to embrace this specialty. There is also a need to address the deficiencies in this discipline by motivating funding agencies and training institutions to redirect resources to strengthen the health professional's capacity to deal with infectious diseases adequately throughout the world (Carlson and El Ansari, 2000). It is hoped that the courses described in this paper are a step forward to accomplishing these aims.

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ADDRESSING THE HEALTH WORKFORCE CRISIS IN THE DEVELOPING WORLD

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Data are limited and largely anecdotal on the health workforce crisis in the developing world.[3] In considering this issue, it is important to bear in mind the limits of international and developing countries financial and institutional capacity. For example, while the World Bank is the largest external financier of health, nutrition, and population programs in the developing countries, its annual commitments for health in developing countries amount to only around $1 billion, and its work on health involves employment of only about 250 professional staff in Washington, D.C., and around the world. According to one estimate, the United States spends $2.22 per capita per annum on infectious disease epidemiology alone—a figure that may be contrasted with the fact that a number of low-income developing countries, such as Bangladesh, spend about this amount per capita per annum overall on health.

It was proposed at the Institute of Medicine (IOM) Forum that emphasis should be placed on a global perspective in addressing health workforce issues, rather than one of international health. A global perspective might, for example, call for financing of U.S. participation in the fight against polio from U.S. domestic resources devoted to polio prevention and control, rather than from development "assistance" funds. The Millennium Development Goals should be seen as a commitment of the global community, rather than solely as an aspiration. The Severe Acute Respiratory Syndrome (SARS) outbreak made it abundantly clear—if proof still were needed after September 11, 2001—that there are no more walls. A global perspective would see American engagement in health human resources issues of other countries less in terms of our defining the problem and sending American personnel into poor countries to deliver services than in terms of a collaborative effort to solve jointly defined problems. Such a joint problem definition might result in temporary use of American health workers in particular poor countries, but that use would be decided jointly in the context of a collaborative long-term program, involving a wide range of domestic and external stakeholders, for resolution of the country's human resources for health problems.

[3]For a recent synthesis of available evidence, see Lincoln Chen et al., *Human Resources for Health: Overcoming the Crisis* (2005), Harvard University Press, available on the web at www.globalhealthtrust.org/Report.html.

The IOM Forum was warned against the risks of pursuing a parochial, non-global health workforce agenda. The ease with which one could lose a global perspective was illustrated in the case of the American Public Health Association (APHA). While the APHA has assigned itself a global concern, its executive director publicly endorsed a proposal to ease U.S. visa restrictions for foreign medical graduates willing to be deployed in underserved areas of the United States. There seemed to have been no consideration of the impact of such incentives for foreign medical graduates to remain in the United States, from the standpoint of their participation in the foreign and U.S. labor markets. In effect, this reduction of visa restrictions constituted an incentive for developing country health care providers needed critically in their own countries to emigrate to the United States.

Solutions to health workforce issues, whether in developing countries or in the United States, need to take into account the full complexity of the issues and the many stakeholders concerned. Parties that need to be brought to the table include not only ministries of health and others directly responsible for health policies. Also to be included must be ministries and senior academic administrators responsible for higher education (because of their responsibility for universities and medical schools) and for civil service and public employment policies and practices (because such a large share of the health workforce is employed in the public sector), as well as the organized health professions (who have frequently been ignored in developing country policy making). Finally, ministries of finance and treasuries, which hold the purse of public spending, need to be brought into the dialogue.

Internationally, it should not be expected that the World Health Organization alone can handle health workforce issues in their much-needed global context. The World Trade Organization should be involved because of its growing concern with trade in services, which inevitably will include the services of health care personnel. International financial institutions, such as the World Bank and the International Monetary Fund, should be involved because of their engagement with developing country macroeconomic and sectoral policies. The Organisation for Economic Co-operation and Development should have a role because it is deeply involved as a forum for coordination and cooperation on industrial country economic and social policies, including health and labor policies. Bringing all of these actors together internationally, along with their many domestic counterparts, constitutes a formidable challenge. Finally, the work of the Global Commission on International Migration should be brought to bear.[4]

[4]The Commission presented its report, Migration in an interconnected world: New directions for action, to the UN Secretary-General, UN member states, and other stakeholders on October 5, 2005. Additional information is available at its website: www.gcim.org/en/.

ENSURING AN ADEQUATE INFECTIOUS DISEASES PHYSICIAN RESPONSE TO EMERGING INFECTIONS

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There is a limited amount of quality data regarding the number of infectious diseases (ID) physicians in the United States or worldwide. So, this report subscribes to the goal of the Health Resources and Services Administration (HRSA) Public Health Work Force Enumeration of 2000 (Gebbie, 2000), which was to arrive at a current best estimate: "the perfect was not allowed to become the enemy of the good."

Infectious Diseases Physician Training Programs/Status

Table A-5 displays the demographic changes in infectious diseases training programs between 1994 and 2002 (Joiner et al., 1998; Personal communication, A.C. Mucha, Director of Organizational Affairs, Infectious Diseases Society of America, June 2, 2003). During this period, there has been a slight reduction in the number of programs that participate in the national resident matching program, but the overall number of positions offered is about the same now as it was in 1994. The number of filled positions has risen from 60 percent to around 80 percent, and the percentage of positions filled with U.S. graduates has risen from 34.6 percent to 51 percent. Evaluating this latter statistic is somewhat like evaluating a new software product. Viewed from one perspective (national), the trend could be considered a feature, as we are training more ID experts who are United States citizens and likely to remain in this country. However, viewed from another perspective (international), the trend could be considered a "bug." Emerging infectious disease challenges may appear anywhere on the globe, and a smaller proportion of experts may enter the global community if the trend continues.

Adequacy of Infectious Diseases Training

Within the past decade, there have been two published surveys that addressed the adequacy of ID fellowship training (Slama et al., 2000; Joiner et al., 2001). In 1998, an informal Infectious Disease Society of America (IDSA) survey of all members determined that over 85 percent of ID spe-

TABLE A-5 Infectious diseases fellowships 1994–2002

	1994	1995	1996	1997	2001	2002
Program #	120	124	117	107	104	105
Applicant #	178	196	160	189		
# positions offered	257	260	237	217	255	251
# filled (% offered)	155 (60.3)	163 (62.7)	145 (61.2)	156 (71.9)	204 (80)	198 (79)
% filled U.S. grads	34.6	38.8	36.7	46.9	51	51

Note: 1994-1997 data are from Joiner et al., 1998; 2001-2002 data are from personal communication with A.C. Mucha, Director of Organizational Affairs, IDSA, June 2, 2003.

cialists felt their research, basic science, clinical microbiology, HIV, and clinical infectious disease training was adequate (Slama et al., 2000). However, only 35 percent of them felt that their training in public health was adequate, and less than 31 percent felt that their infection control training was adequate. A more formal survey was done of recent ID fellowship graduates who had passed their infectious diseases board certification between 1992 and 1999 (Joiner et al., 2001). Around 80 percent of the respondents were IDSA members. Findings were similar to the IDSA membership survey in the sense that similar areas of training were felt to be inadequate. For example, only 51 percent of respondents felt that their training in infection control was adequate. Interestingly, 52 percent were providing infection control services in their practice, and about half of these individuals indicated that they were compensated for this activity. Those who were actually providing these infection control services were more confident of their training, as two-thirds of them believed that their fellowship provided them with sufficient skills with which to conduct such work. Ninety-one percent felt that didactic teaching of infection control was a necessary component of fellowship programs. The authors concluded that a Web site-based training program for infection control should be jointly developed by the Infectious Disease Society of America and others, including the Society for Healthcare Epidemiology of America (SHEA), the Association for Professionals in Infection Control and Epidemiology (APIC), and the Centers for Disease Control and Prevention (CDC).

Demographics of IDSA Members

To ensure an adequate infectious diseases workforce, one must first know the nature of existing ID expertise and how their professional effort is distributed. Assuming that roughly four out of five recent fellowship graduates are IDSA members (Joiner et al., 2001), the society's member demographics hold some validity in estimating these parameters. More than 83 percent of its members belong to the categories of Adult or Pediatric Infectious Diseases, with Internal Medicine being the next most common specialty (see Table A-6). Over 50 percent of members listed patient care as their primary professional activity, and another 22 percent identified with clinical or basic research (see Table A-7). Only a little over 4 percent listed public health or hospital epidemiology as their primary activity (Personal communication, A.C. Mucha, Director of Organizational Affairs, Infectious Diseases Society of America, June 2, 2003). Thus, only a small minority of ID specialists are responsible for formally responding to an emerging infectious disease agent within their jurisdiction or hospital.

TABLE A-6 IDSA Members by Specialty (2003)

Specialty	Percent
Adult ID	71.55
Pediatric ID	12.62
Internal Medicine	7.50
Other	6.62
Family Practice	1.31
Ob/Gyn	.39

TABLE A-7 IDSA Members by Professional Activity (2003)

Activity	Percent
Patient Care	50.30
Clinical Research	13.97
Basic Research	8.88
Administration	8.50
Teaching/Educ.	7.35
Public Health	4.18
Hospital Epi.	2.77
Clinical Micro.	2.54
Other	1.51

Infectious Diseases Job Market

Two studies have examined the infectious diseases job market by evaluating advertisements in widely circulated journals covering internal medicine. Preheim found that the number of advertisements for ID jobs in the *New England Journal of Medicine* declined significantly from 1990 to 1995. Only a small, and decreasing, minority of positions listed hospital epidemiology or infection control as a major component of the position (Preheim, 1998). A second study by Tice et al. confirmed the earlier study, but found that job opportunities increased 140 percent from 1995 to 2002 (Tice et al., 2002). Most of the increase was in private practice opportunities. This study did not enumerate epidemiology or public health jobs, presumably because they made up a small proportion of the total. The authors also commented that many medical communities do not have a specialist trained in infectious diseases and do not advertise for one. This is an unstudied need. In addition, there is no information on which to rely regarding changes to the job market since the terrorist events of 2001. In general, it seems reasonable to assume that overall job opportunities in the ID private-practice sector have been increasing.

Infectious Diseases/Public Health Physicians

A survey study by the Council of State and Territorial Epidemiologists conducted in 2001–2002 identified a significant deficiency in infectious disease and all other areas of epidemiology (CSTE, 2003). In 1992, there were about 1,700 "full-time equivalent" positions in epidemiology surveillance. By the time the survey was conducted, this number had decreased to less than 1,400. Of these professionals, 152 were physicians. Ninety-nine of these worked in an infectious disease or bioterrorism (BT) capacity. Most state/territorial epidemiologists reported a shortage of staff and resources. The study concluded that increased capacity was urgently needed. The study argued for increased federal funding in the face of shrinking state budgets, despite the fact that about 60 percent of the funding for epidemiology and surveillance already came from the federal government.

It is even more difficult to measure the job market for public health (PH) physicians. In epidemiology circles, a popular monthly newsletter entitled "Epi Monitor" is the "best resource" for identifying epidemiology jobs (personal communication, A. Mardis, Medical Epidemiologist, Nebraska Health and Human Services System, May 29, 2003). Although they had done no formal enumeration, the newsletter publishers reported a general sense that the number of available jobs had increased. They noted that many positions were being advertised due to turnover and that many recent positions had been reposted because of a lack of qualified applicants.

Resources to Develop Infectious Diseases/ Public Health Physician Expertise

Funding sources to develop ID/PH expertise are diverse, with ID fellowships traditionally financed through hospitals, medical schools, and some research training grants. New funding sources to augment ID/PH expertise mainly fall under the guise of bioterrorism preparedness. Two of the largest BT financial resources are the Health Resources and Services Administration and the Centers for Disease Control and Prevention. The HRSA provided $275 million in 2002 and budgeted $542 million in 2003. The CDC provided $918 million in 2002 and $870 million in 2003. In 2000, the CDC established a national system of Centers for Public Health Preparedness, with the purpose of improving the capacity of frontline public health and health care workers to respond to bioterrorism, other infectious diseases outbreaks, and other PH threats and emergencies, primarily through education and training. There are three types of centers: academic, specialty, and advanced practice sites. Academic centers link schools of public health with state, local, and regional needs. Specialty centers, which are established in colleges or universities, may address unique content, discipline-specific, or technology needs. Advanced practice sites, which have been established in local public health departments, focus on operational readiness, communications, and/or information technology and training applications. Although these resources broadly target ID/PH expertise, they are not specifically designed to increase the ID or PH physician workforce. While the influx of funds for bioterrorism preparedness is welcome, one must recognize that these funds are at risk if the threat of BT is perceived to decrease. As shown by the outbreak of severe acute respiratory syndrome (SARS) and the recent outbreak of monkeypox, Mother Nature can masquerade as a terrorist. So, the enhancement of ID/PH physician expertise is essential regardless of the relative threat of bioterrorism.

Nebraska: An Example of Demand and Change

Nebraska has 93 counties. On September 11, 2001, there were 72 counties that were not covered by local health departments (see Figure A-3). At the time there were 16 health departments that covered the remaining 21 counties. By using tobacco settlement dollars through The Healthcare Funding Act (LB692), Nebraska funded 16 new health districts. To receive the funds, districts had to identify a region that served at least 30,000 individuals. Only one county currently is not part of a local health district (see Figure A-4). Sixteen new districts were formed, and new health directors were hired. A minority of these directors had preexisting public health backgrounds or training, and they were not physicians. Local health district boards have physician membership, but in general they are not trained in infectious diseases or public health (Personal Communication, A. Mardis, Medical Epidemiologist, Nebraska Health and Human Services System, June 6, 2003). Nebraska's need and response to improve its public health infrastructure anecdotally supports the notion that there is a growing need for ID/PH expertise in the country that has been recognized since September 11, 2001.

Large Private–Public Partnership

As discussed above, there is a relatively small cadre of physicians whose primary function lies in the public health or infection control fields, and there are many other physicians and health care workers whom we rely on to activate a public health or infection control response in the event of an infectious disease outbreak, through passive reporting of unusual events.

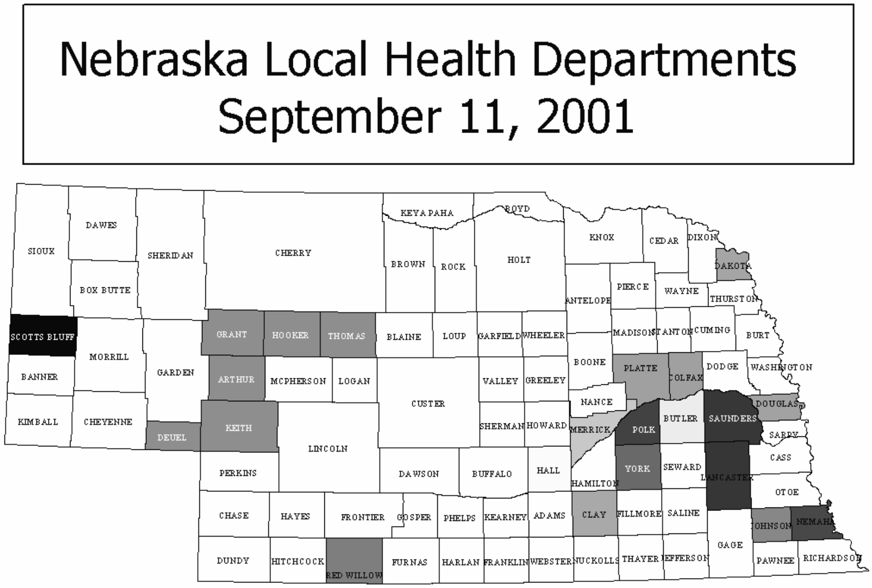

FIGURE A-3 Shaded regions indicate local health department coverage pre-9/11/01.

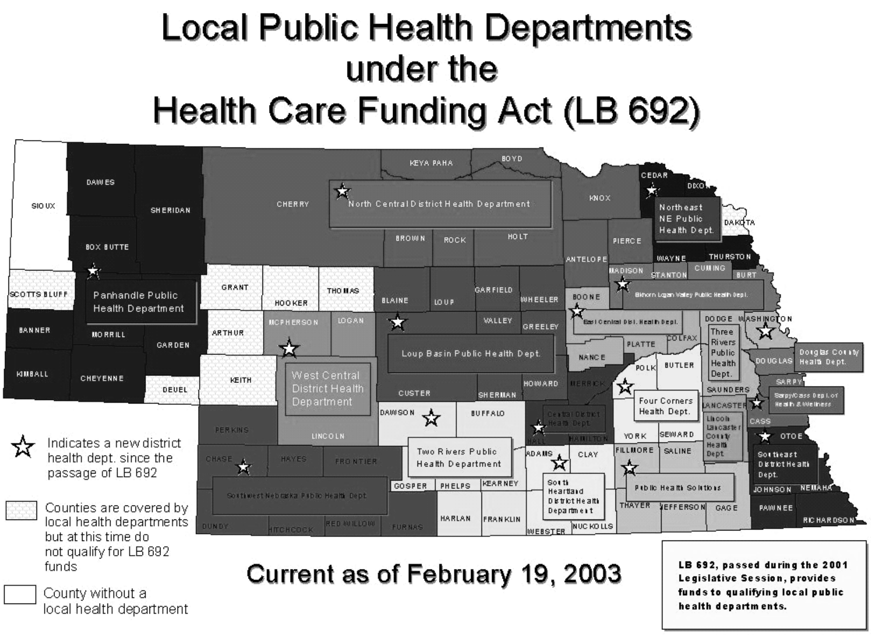

FIGURE A-4 Shaded regions indicate local health department coverage 2003.

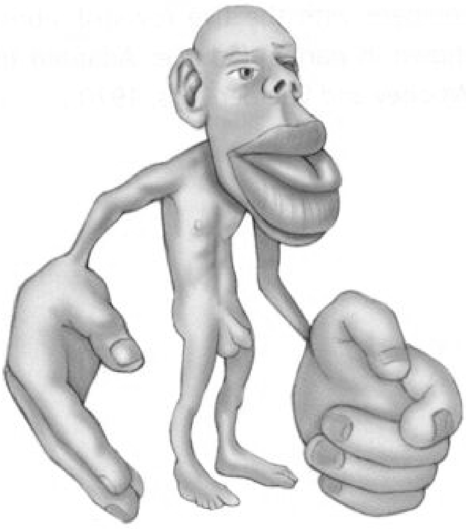

FIGURE A-5 Homunculus illustrating the "small body" of full-time ID/PH physicians.

The situation is somewhat analogous to the concept of a homunculus, which is a man with body parts in proportion to the relative amount of brain substance devoted to innervating each part (see Figure A-5). In this analogy, "official" public health/infection control physicians make up the very small torso of the public health homunculus, while a larger "unofficial" group fulfills the disproportionately large part of the peripheral nervous system of public health functionality as the oversized eyes, ears, nose, hands, etc. These physicians are largely in private practice and are not necessarily ID specialists. Some of them may serve on their local health district boards, yet lack adequate training and knowledge about public health, epidemiology, and infectious diseases. This is not surprising, because even among infectious disease specialists, there is a relative lack of confidence in their own infectious disease epidemiology and infection control training. Together, these unofficial providers are the disproportionately large private part of this critical private–public partnership that makes up the sum total of the nation's public health response pool. Members of this large private portion have a keen interest in the intended function, but often lack knowledge of public health as a discipline. To function optimally they are in need of formal, practical training.

Deterrents to Infectious Diseases/Public Health Physician Careers

Why don't more physicians enter careers in infectious diseases and public health? One reason is the significant financial disincentive. The average medical student graduates with a debt of about $100,000 (AAMC Databook, 2002), and public health physicians fall into the low-earner category. According to an American Medical Association (AMA) Physician Marketplace Report from 1996, low earners were those who earned less than the 25th percentile, or $120,000 (AMA, 1997). In 2000, the median net income for general internists was $144,000. According to the IDSA Web site, in 1998 the median salary for ID private practice was $151,000, but starting salaries in academia were around $109,000 (IDSA, 2000). The Council of State and Territorial Epidemiologists (CSTE) survey, which was published 6 years after the AMA study that defined the low earners' salary mark as $120,000, identified the median salary scale for PH physicians at $87,190 to $120,000 (CSTE, 2003). Clearly, one would find it difficult to choose a career path that would involve additional training for lower wages following the accumulation of a sizeable educational debt. In addition, few students are exposed to an ID/PH career path prior to the accrual of this debt. In general, medical students and residents have a lack of familiarity with PH career options. According to a 1998 Institute of Medicine report, only 56 out of 125 medical schools required courses on public health, epidemiology, or biostatistics. Lastly, the job environment may be a deterrent. Understaffing, limited resources, and relatively frequent turnover of political appointee state chief medical officers may detract from job satisfaction (CSTE, 2003; personal communication, R. Raymond, Chief Medical Officer, Nebraska Health and Human Services System, May 21, 2003). The average term of office for state chief medical officers is about 2.5 years, and only 12 of the current officers have held that position for more than 4 years (personal communication, R. Raymond, Chief Medical Officer, Nebraska Health and Human Services System, May 21, 2003).

Models for Enhanced ID/PH Physician Capacity

There are numerous ways to address the need for enhanced ID/PH physician competence and capacity. Some of the lessons learned from the recent efforts at bolstering bioterrorism preparedness should be applied to the problem of ensuring an adequate infectious diseases workforce both in quantity and quality. As an anecdotal example, the diagram in Figure A-6 depicts the initiatives of the Center for Biopreparedness Education (CBE, 2003). This is a consortium with over 30 members, including codirection by faculty members from both medical schools in Nebraska. It is supported by CDC and HRSA funds provided through the state of Nebraska. The center's initiatives grew out of a needs and resource assessment, which

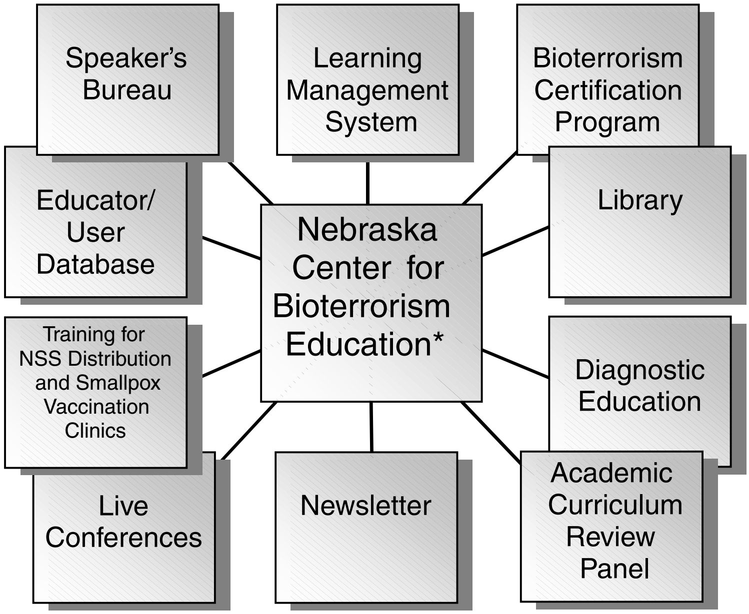

FIGURE A-6 Schematic organization of BT Education Consortium. *Renamed Center for Biopreparedness Education 1/02/2005. NSS, National Strategic Stockpile.

enabled the development of an educator database, in addition to identifying educational needs. A notable feature is the center's participation in a learning management system. Through this system, users will be able to access distance education courses from any one of the more than 20 participating states. The system will maintain individual user educational profiles while tracking their participation in live on-site conferences or on-line instructional modules. A certification program has been conceived. This certification is not like board certification of medical specialties, but is more analogous to Basic Cardiac Life Support that crosses disciplines. Among the live conferences, the center cosponsors the military-derived Medical Management of Chemical and Biological Casualties Course (Chemcare) and the Medical Effects of Ionizing Radiation Course (MEIR) in a unique joint effort with the Collaborative Training Center at Offut Air Force Base. Participants receive training certificates upon completion of the course. This joint approach enables the development of a database of expertise that can be called on should the need arise, and enables effective integration of civilian and military expertise in an actual event because of similar preparative training. A bioterrorism library with full-time librarian has been established. From this resource, providers across the state can request BT-related publications in a variety of formats (e.g., hardcopy, video, CD-ROM, electronic document). In addition, a teledermatology system is being implemented to enable distant evaluation of unique visual signs of illness, and academic curriculum review panels are being organized to aid health sciences professional schools to develop appropriate BT curricula. While this consortium is designed for BT education, a similar model could be adapted to enhance the training of the infectious diseases workforce.

Assessment and Recommendations

There clearly is a current demand for more infectious diseases expertise both in the private sector and in an official public health capacity, yet the number of ID fellowship training slots is slightly lower than in 1994. However, the number of slots filled has increased from 60 percent up to 79 percent, with an increasing number of U.S. medical school graduates. If one examines these data from the opposite point of view, more than 20 percent of training slots remain unfilled, despite the increased demand for ID specialists. Clearly, market demand is not having a maximal input on funneling trainees into fellowships. Student awareness of the demand for ID expertise must be raised, and deterrents to an ID/PH career must be eliminated to better utilize existing slots to meet the increased need. Moreover, the ability of experts to respond adequately to emerging infectious disease threats must be augmented through changes in educational curricula and organized response infrastructure. The following challenges must be met to accomplish these goals:

- About half of ID physicians feel their training provides an inadequate skill set to respond to intentional or natural emerging microbial threats.
- A very small minority of ID physicians serve in an official capacity in positions whose purpose is to identify and control infectious disease outbreaks.
- In the past decade, job opportunities for ID physicians have been increasing primarily in the private sector. More recently, positions in the public health sector may have been increasing as well, but the evidence for this is not as well documented.
- There is an identified need for enhanced infectious disease expertise in state and territorial health departments, but there is high job turnover and a lack of qualified applicants.
- Major recent funding pools for developing ID/PH physician expertise, which have been in the guise of bioterrorism preparedness and have helped bolster public health infrastructure, also show how the nation's ID response capacity could be at risk should the perceived risk of bioterrorism diminish.

- There are significant deterrents to choosing an ID/PH career path, including financial disincentives, inadequate marketing of opportunities to potential trainees, and limited resources within the PH job environment.
- The current public health system is reliant on the large private portion of the public–private partnership for activating and providing surge capacity for the public health response to emerging infections.
- The lack of uniform standards for PH certification competency has resulted in a wide variation in the level of public health and private-sector preparedness for emerging infections.

What are some potential solutions to these challenges?

ID training programs need to ensure that formal didactic training in public health, epidemiology, and infection control practices is included in every fellowship experience. This could be accomplished through formal month-long rotations, participation in the SHEA epidemiology course, or participation in a website-based course. For the latter, Joiner et al. suggested that such a program should be jointly developed by IDSA, CDC, SHEA, and APIC. Both basic and advanced components should be included in a modular design (Joiner et al., 2001; Note: since this document was drafted, the IDSA began development on a web-based infection control/epidemiology course). Medical schools also must do a better job of including these topics in their curriculums.

Closer links need to be cultivated between private practice ID physicians and the relatively small group of ID physicians who work full time in an infection control/public health capacity. These links should be grown primarily at the local level and to a lesser degree at the state/territorial health department level to strengthen the necessary "nuts and bolts" local response network. Mechanisms for rapidly educating existing local ID/PH resources need to be developed. Even with best efforts at continuing education, sudden demands for training may arise in unforeseen outbreaks of emerging infectious diseases. The large unofficial private part of the public health workforce needs to be targeted through multimodal training. Novel technologies for on-demand interactive training should be explored. An example of this would be a natural language engine paired with a text-to-speech software application or animated virtual teaching assistant. This type of solution would enable conversation-like interactions of users with a relatively low bandwidth educational website that could be accessed simultaneously by many users (VTA, 2003).

A more formal updated assessment of the recently changed ID/PH job landscape is in order to determine how significant the lack of qualified individuals may be. It is possible that the ID job market in the public health/infection control arena has opened up significantly following the large influx of funds in 2002 to states and territories for bioterrorism preparedness and the increased importance of hospital response capacity. However, documentation of this is lacking. Moreover, the documented increase in ID private practice opportunities may be siphoning even more ID physicians away from PH careers. It is important to determine how many new positions are being supported by these funds to find out how much of the PH infectious disease response capacity is at risk if this funding were to decrease in the future.

Incentives to encourage individuals to pursue infectious diseases training and careers in public health/infection control activities must be developed. Marketing of PH careers should take place prior to the accumulation of a large educational debt while students are still in an "undifferentiated" career state, because large economic pressures clearly play a role in career choices. An unusual but possible approach to raise public awareness of ID/PH careers might employ "edutainment" venues analogous to recent television series about forensic pathology. However, in this case the programming would be slanted toward the detective work of the epidemiologist. Premed or high school students who were previously unaware of the career path might give some consideration to the option. Forgiveness of educational loan debts for individuals who elect to undergo infectious diseases/public health training would remove a major deterrent to the pursuit of an ID or PH career. In exchange, these individuals would have to agree to work in a PH capacity for several years after their training. One would expect that many of these individuals would remain in the public health field even after their obligation was met.

Consideration should be given to the development of multilevel PH competence certification and the development of a Public Health Medical Reserve Force analogous to military reservists. Such a program would significantly bolster the surge capacity now provided by the large private part of the largely informal public–private partnership that currently exists. The need for this was crystallized by the recent SARS experience in Canada, and the point was driven home by an e-mail sent on June 5, 2003, by W. Michael Scheld, M.D., the president of IDSA. In this message, he solicited the membership on behalf of the Ontario Ministry of Health and Long Term Care to try to find ID physicians who were willing to go to Toronto to help, because the resources of the ID physicians in that city had been stretched to the limit. While well-intentioned people often say they would be willing to help in an emergency, it is extremely important that potential respondents have the right expertise for the problem being encountered and that they actually show up when called on. A Medical Reserve Force that could be formally and selectively activated would have an obligation to respond, thus ensuring an adequate and competent response team. Membership on the Medical Reserve Force should carry an obligation for recurring training certification for which the reservist would be compensated. As of April 2005, some cities have community-based Medical Reserve Corp (MRC) units that function as a specialized component of Citizen Corps, a national network of volunteers that are organized under the President's USA Freedom Corps. While this is a step in the right direction, the existing volunteer MRC falls below the level of formal training and mandated obligation to deploy that this document is advocating. Because a serious natural or intentional emerging ID threat would likely involve a response by private, public health, and military medical personnel, it would be wise to develop any PH certification program (and BT certification as well) in concert with the military. This would facilitate effective integration of civilian and military medical responses, because both groups would be operating under the same knowledge base and with the same vocabulary. Levels of certification should be tiered from basic to advanced. Although this solution has been raised in the context of the ID physician, a Public Health Medical Reserve Force and public health certification should not be limited to physician participation only.

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ADDRESSING THE MICROBIAL THREAT TO HEALTH: TRAINING Ph.D. SCIENTISTS TO HELP LEAD THE WAY

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"The United States has shown leadership in the past by strengthening its own and others' capacities to deal with infectious diseases, but the present reality nevertheless is that public health and medical communities are inadequately prepared. We must do more to improve our ability to prevent, detect, and control emerging—as well as resurging—microbial threats to health," notes a 2003 Institute of Medicine report (IOM, 2003). The report goes on to outline the multiple factors, illustrated in Figure A-7, that account for new or enhanced emergence of microbial threats, emphasizing that it is the convergence of one or more of these factors that poses the greatest risks and challenges.

Recognizing the magnitude of the challenge and the fact that dealing with infectious disease threats is going to be an ongoing, evolving challenge for many generations to come, a key issue relates to how we educate the next generation to grapple effectively with the complex social, scientific, environmental, and human factors that conspire to promote the emergence and spread of disease.

Generally speaking, the present educational paradigms provide outstanding grounding in relevant, highly specialized disciplines. And, generally speaking, our nation's approach to infectious disease has apportioned work and responsibility accordingly to these specialized disciplines, with the physicians serving the primary role of translating and delivering advances in science and technology to the care of patients and to the shaping of public health policies. While these educational strategies should be credited for the dramatic advances in our ability to detect, control, and prevent infectious disease, it is also apparent that they do not presently train individuals to have the broad perspective and context consistent with the complex challenges attendant to the global infectious disease challenges that lay ahead.

In short, the premise here is two-fold: (1) there is a critical need to establish a multidisciplinary, multiprofessional model for graduate training in the area of infectious diseases, and (2) appropriately trained Ph.D. scientists can have a direct role in translating science and technology to advancing our ability to deal with microbial threats to health. Experience with

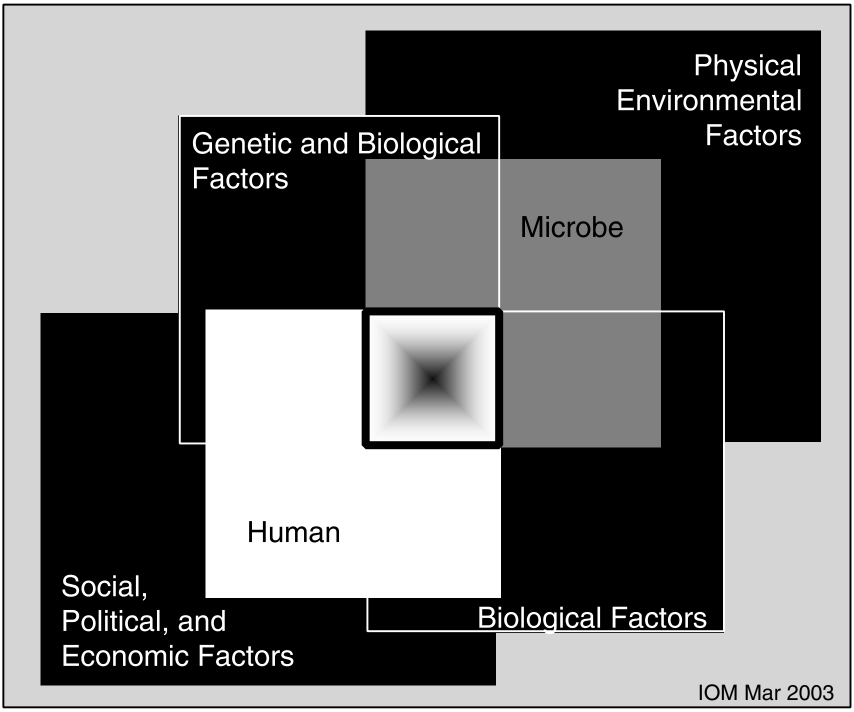

FIGURE A-7 The Convergence Model, illustrating that the microbe-host interaction is influenced by determinants from multiple domains. Each box represents a domain. The center box represents the convergence of factors that could result in a particularly high-risk situation. From the standpoint of education, this convergence model suggests that these multiple domains should be represented (from IOM, 2003).

multidisciplinary, multiprofessional Ph.D. training programs in different biomedical areas clearly illustrates that such training paradigms can be enormously successful and attract exceptional students. The formulation of these training modules recognizes the complex, multidisciplinary factors associated with unmet medical needs (see Figure A-8). Much of this report is therefore devoted to describing these educational models. As one might surmise from the similarity of Figures A-7 and A-8, it should be straightforward, in principle, to adapt these models to establish the kind of training suggested by the complex multifactorial nature of the infectious disease threat.

The notion of multidisciplinary education (or research) in the biomedical arena is one that can generate passionate responses—for and against. Those people opposed typically cite one of two objections: (1) that the

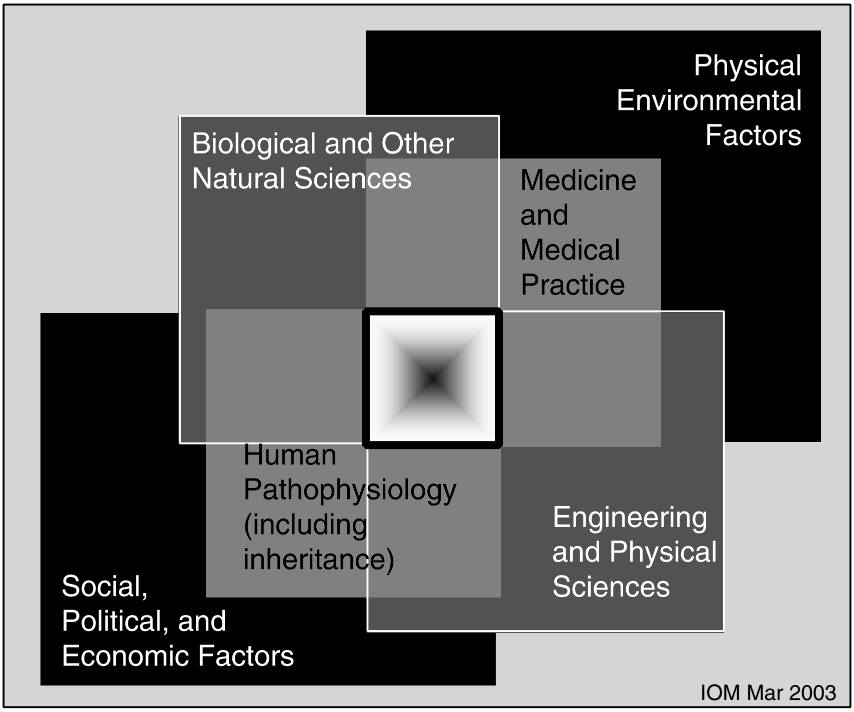

FIGURE A-8 Adapted from the concept of Figure A-7, this diagram illustrates the multiple domains intrinsic to most unmet medical needs. Each box represents a broad domain. The center box represents the convergence of factors that play a role in a health or medical problem, and presumably would play a role in developing a solution. The educational models described here are designed to provide the student with the context and, in some cases, experience, represented by this diagram.

increased breadth incurs an unacceptable loss of depth, and/or (2) why mess with success, as our institutions are very well honed and have a good track record in handing off new biomedical science and technology to the industries that can translate and deliver them to the benefit of humans and human health. The outcome data from the training models described below largely refute those two objections. The argument in favor of multidisciplinary, multiprofessional training in biomedically related areas (including infectious disease) focuses on the following realities:

- Identifying areas of unmet need requires understanding the multiple associated contexts.
- Solutions require contributions from multiple disciplines and professions.

- Solutions are rarely typified by a clean sequence of compartmentalized progress.
- Organizational structures (and educational programs) are normally unidisciplinary and highly focused on a single facet of an area or problem.

Is it possible to train Ph.D. scientists to increase the likelihood of their impacting infectious disease medicine and public health? And if so, how? Would such training attract the very best scientists? To our knowledge, there is no direct evidence in the specific area of infectious disease. There is, however, increasing evidence from programs that seek to train Ph.D.'s broadly to be at the forefront of advancing clinical medicine. The overarching philosophy of these programs is essentially the same as that for M.D.–Ph.D. training programs; that is, if someone is going to be in a position to translate bench research to the bedside, then that person needs to have substantial training in both domains.

We focus particularly here on two prototypical training models established over the past 15–25 years—models that could be suitably adapted to focus on infectious disease in accordance with the 2003 IOM report (IOM, 2003). We presume here that we have well-established and effective training models for basic biological research, so the issue becomes the mechanism and degree to which we augment that training in light of the realities enumerated above and suggested by Figure A-8. We also include comments about the nature of the training environment, something that we feel to be as important to a successful outcome as the specific curricular components of training.

HST-MEMP Model: In-depth Pathophysiology and Clinical Training for Ph.D. Students

The Harvard–MIT Division of Health Sciences and Technology (HST) was established in 1970 as a joint effort between the Massachusetts Institute of Technology and Harvard University to bring engineering and the physical sciences to biology and medicine. The first academic program that HST offered was a unique M.D. program, steeped in basic science and geared to the education of physician–scientists (Abelmann et al., 1997; Wilkerson and Abelmann, 1993). In 1978, the Medical Engineering Medical Physics (MEMP) Ph.D. program was launched. This program was designed specifically to equip graduate students at the interdisciplinary foci of engineering and the physical sciences and biology and medicine so that the students would be prepared to solve critical problems in medicine. This program was, and remains, unique in providing a clinical experience that is very similar to one that a second- or third-year medical student would have. Central to the mission of this program is the training of Ph.D. scientists both in their chosen subspecialty of engineering and the physical sciences and in the fundamentals of clinical medicine so that they can identify unmet medical needs and ultimately make contributions that will impact health care. Although MEMP has an engineering and physical science focus, the model is equally applicable to trainees who might have a natural science focus. We describe it in some detail here so that the differences from more traditional Ph.D. training can be appreciated and to aid those who wish to adapt this model to focus on other multidisciplinary educational goals, such as is needed for infectious disease.

The MEMP Ph.D. program carries out its multidisciplinary mission via a flexible structure that permits exploration of all the intersections of those disciplines. Students are jointly admitted by HST and a collaborating department selected from any of the "traditional" engineering or physical science departments at MIT or Harvard. Presently, we accept about 10 percent of applicants, yielding a class of approximately 18–22 students each year (the number has varied from 10 to 22, depending on available fellowship funding). The program accepts students with quantitative backgrounds (usually with undergraduate degrees in engineering or physics) who want to solve problems in human health. We attract people who are very comfortable in multidisciplinary environments and who are eager to have full access to the rich environments of Harvard and MIT (including the teaching hospitals) in deciding on mentors, collaborators, and courses. The applicants also are attracted to the concept of learning and working alongside medical students. The most compelling evidence we have that this program attracts the very best students (beyond the high selectivity) is that HST-MEMP is generally the first choice of our applicants, with more than 75 percent of admitted students selecting this program over others at MIT, Harvard, and other top-ranked institutions.

Depending on their interests and career goals, students follow diverse curricular paths. With guidance from HST and collaborating department faculty, the student begins with an intensive grounding in a subdiscipline of engineering or physical science at MIT or Harvard. The student then passes a doctoral qualifying examination in the collaborating department. At that point, HST becomes the student's primary institutional association. In addition to their thesis research, students are required to complete seven preclinical courses in one of two tracks: a systems physiology track or a cellular/molecular track. Ph.D. students take these courses with the HST M.D. and M.D.–Ph.D. students, thus providing a rich environment for cross-fertilization between the Ph.D. students and physician–scientist trainees. It should be noted that the content in these courses is structured much like a graduate school subject to include basic science foundations, cutting-edge science, and clinical correlates in recognition of the goals of the students, whether they are pursuing an M.D. or Ph.D. degree, to ultimately have research as an important part of their career. It should also be noted that most students do not segment their training into the "engineering/physical sciences" piece followed by the medical piece; rather, they integrate some medical subjects early in their training, and may take a few engineering subjects later in their training. Indeed, the semester format of the medical courses permits this kind of integration with regular graduate courses by all HST students (M.D., Ph.D., or M.D.–Ph.D.).

After completing the set of preclinical courses, students then complete a three-part clinical experience over a total of 4 months. This opportunity to participate in clinical training, through coursework with medical students and hands-on experience, is a distinctive hallmark of the MEMP program. The first 6-week period is an intensive introduction to clinical medicine. Students develop skills in patient interviewing and physical examination, become proficient in the organization and communication of clinical information, and work on correlations of clinical issues with basic pathophysiology. Finally, the students become familiar with the multiple components of clinical decision making and the broad economic, ethical, and sociological factors that impact this decision-making process.

In the second 6 weeks, they enhance their clinical skills by working with a hospital ward team in the same manner as would be expected for a third-year medical student. They are directly involved in acute and longitudinal patient care, participate in patient management decisions with the house staff and attending staff, and attend regularly scheduled teaching conferences. Students take call in turn with their fellow students, including night call. They are involved in the assessment and medical management of many common diseases seen on a medical ward, such as chronic obstructive lung disease, atherosclerosis, congestive heart failure, renal failure, and hepatitis, and in this way they are exposed to what is largely adult medicine.

This frontline clinical experience has a profound influence on the student, who comes away from it with an insight into the health care system and how physicians make decisions. Students witness the successes and failures of modern medicine's diagnostic and therapeutic approaches and often formulate their goals for how their future research can impact individual patient care. Attending physicians often comment that the performance of the Ph.D. students is indistinguishable from third-year M.D. candidates.

A third bout of clinical experience comes later in the Ph.D. training. At this point, the student constructs, with faculty advice, a 1-month preceptorship that is conducted in a clinical environment. In some cases, students use this preceptorship to design or launch a pilot clinical study; in others, they seek to understand the medical management of a particular class of diseases; in still others, they seek to define how an emerging science or technology might impact clinical medicine. The experience involves patient contact, and a term paper is required.

Record of Success

The program works. As described in more detail elsewhere (Gray and Bonventre, 2002; Mark, 2002), outcomes of this HST model for Ph.D. training are very similar to outcomes from M.D.–Ph.D. programs. The total time from matriculation to awarding of the Ph.D. degree has been a mean of 6.1 years—a duration similar to the time-to-degree for most Ph.D. training programs in engineering and physical sciences.

In terms of career choices, of those students who had completed training as of summer 2001, 98 percent have remained in biomedically related careers, with 67 percent in academic positions and 26 percent in business positions. Virtually all of the academic positions are in top-ranked institutions, and they are about evenly split between engineering/physical science departments in a university-based setting and clinical departments in a medical-center setting. Notably, a substantial fraction (36 percent) of graduates in the 1981–1995 cohort are already in influential leadership positions.

Those graduates in academia have been successful in garnering grant support. In a study done in 2001, we found that of our graduates in U.S. academic institutions, 60 percent of those who had graduated before 1990 had currently active grants from the National Institutes of Health (NIH). This compares very favorably to graduates of Medical Scientist Training Program (MSTP)-funded M.D.–Ph.D. programs, where approximately 50 percent of those who received their Ph.D. roughly 10 years prior to the study had ever held an NIH grant (NIGMS Medical Scientist Training Program, 1998). Although we do not have direct comparative data, one would expect only a very small proportion of graduates from engineering programs (e.g., graduates of the departments that collaborate with MEMP) to be supported by the NIH.

The scope of research of our graduates encompasses the spectrum from basic science to clinical research, as reflected by their publications. Although we do not have complete data from all of our alumni, we have ample evidence that MEMP alumni publish in leading basic and clinical journals, with the top 20 including more general publications such as *Nature Medicine*, *Proceedings of the National Academy of Sciences*, and *Science*, as well as specialty publications, such as *Circulation* and *J. Orthopaedic Research*, and basic science publications, such as *Biophysical Journal* (Gray and Bonventre, 2002).

Thus, while MEMP is still a relatively young program, its graduates have been very successful in careers that reflect their training at the boundaries of science, engineering, and clinical medicine. The impact that MEMP grads have had on medicine is more difficult to assess quantitatively. The success in NIH funding tells part of the story. The publication record tells another part. The final part of the story lies in direct evidence of translation. We do know that at least 17 of the 59 alumni (26 percent) with known positions in the 1981–1995 cohort are directly involved in moving their scientific accomplishments to clinical-level investigation and implementation. This is likely a marked underestimate of the numbers involved in translation. These data clearly support the notion that investigators who do not have an M.D. can, nevertheless, become actively and integrally involved in bringing their discoveries to the bedside. More generally, these data indicate an ability of MEMP graduates to navigate and adapt to changes in biology, engineering, and medicine, identifying and making primary contributions to critical unmet needs. Interestingly, in describing their own successes, MEMP alumni consistently credit the in-depth biomedical and clinical experiences and the multiprofessional community of HST as the most important factors (Mark, 2002).

Targeted Exposure Model: Pathophysiology/Pathobiology Training for Ph.D. Students

An alternative to the HST-type model with in-depth biomedical training model is a targeted exposure model where pathophysiology, pathobiology, or medical concepts are offered to graduate students. This alternative has been used in a variety of training programs for decades. Since their inception in the early 1960s, most formal biomedical engineering (BME) doctoral programs have embraced (patho)physiology as a core requirement. In some cases, such as the program at Johns Hopkins University and the joint program at the University of California, San Francisco, and the University of California, Davis, the required or optional courses are taken together with medical students. However, in many cases the courses are specifically created for BME students and do not include medical students. (A reasonable summary of these curricula can be gleaned from the Whitaker Foundation Web site [www.whitaker.org].) Although most BME programs use a targeted exposure model to provide a medical perspective, to our knowledge the new BME program at Purdue University (where students have a summer clinical internship) is the only one other than HST-MEMP to require both substantial coursework and an extended in-depth clinical experience. It is interesting to note that with the rapid growth in the number of bioengineering programs, some of them are expanding the medical science opportunities while others are moving away from the notion of embracing medical science, in favor of refining (or defining) the discipline of bioengineering—as distinct from the application of engineering to medical problems—and these curricula do not include courses like pathophysiology or pathobiology.

In a somewhat similar but independent trend, several Ph.D. programs in the biological sciences have introduced targeted medically relevant material into their curriculum. To our knowledge, the most long-standing of these is the program introduced in 1983 by Irwin Arias at Tufts University, in which selected Ph.D. students take a one-semester subject in pathobiology, in which they interact with patients, handle pathological specimens, and see major diagnostic and therapeutic facilities, as a basis for delving into pathobiological mechanisms (Arias, 1989). Washington University launched a similar program in 1992 in which students have a two-semester experience in human pathology that focuses on the clinical and basic science aspects of important disease states. In addition, the interactions initiated in the course are sustained through a clinical mentor program that continues throughout the graduate experience. We are aware of a number of other relatively brief efforts to address this need and the substantial student interest in biomedical training; many of these efforts were abandoned due to lack of funds. At Harvard Medical School, in the late 1970s Morris Karnovsky offered a pathobiology course that served roughly 50 Boston-area graduate students. In 1992, this effort was renewed in a more extended format. Sixteen students each year were selected after admission to the Division of Medical Sciences. These students took a number of preclinical courses with the Harvard medical students, and they had regular visits to hospitals where they would meet with investigators doing research at the interface of basic science and clinical medicine, talk with patients, and see clinical procedures (Bunn and Casey, 1995). Eight programs were funded between 1992 and 1996 by the Markey Charitable Trust to enhance the knowledge of clinical medicine of Ph.D. students through one or more additional courses (NRC, 2004). Each of these programs appears to be viewed as extremely attractive and successful by their students, but the only program for which outcome data are known to be available is the one at Tufts University (Arias, 2002), where, in particular, career decisions were appreciably influenced, with substantially more participants selecting academic positions, especially in medical centers, compared with the otherwise-similar graduate cohort reported in the MSTP study (NIGMS Medical Scientist Training Program, 1998).

Application to Future Ph.D. Training in Infectious Disease

Several key conclusions can be drawn from these graduate programs with experiences in medical science. These programs attract exceptional candidates and are consistently oversubscribed. Although outcome data are incomplete, alumni of these programs are overwhelmingly retained and are successful in biomedical careers, and many are in positions where they can connect with the patient-care enterprise during the course of their research and thus have the potential to create a vibrant link between the clinic and basic research. That is, they appear to be bridging the traditional gap between basic science (and engineering) and medicine, an objective that attracted them to these special training programs and a success for which alumni credit their training program as having laid the foundation. Anecdotally, what draws these exceptional students to these programs is an excitement about the problem domain—problems that are challenging, important to the human endeavor, and for which solutions have enormous implications. Certainly the problem domain encompassed by the global infectious disease challenge shares all of those attributes, and so, if framed in the large context typified by Figure A-7, could be expected to attract exceptional talent.

In framing the training program as typified by Figure A-7 (or Figure A-8), it is worth emphasizing the fundamental difference between these training approaches and the more classical approaches. What in particular has distinguished the HST graduate (and medical) training programs is that there is adequate flexibility for students to establish a broad and deep background in their field of interest, and, in addition, to have substantial experiences in both research and clinical practice within a multiprofessional training community where they develop knowledge and social networks. Consequently, students come to understand and appreciate the domain knowledge, the culture, and the value systems of both biomedical discovery and medicine. By getting the "best of both worlds" (without getting separate degrees in both), graduates are well positioned to create scientific and technological innovation, since they can more easily identify the important needs and establish the path for translation from concept to implementation. The contrast between this approach and the more traditional approaches is considerable. Generally speaking, the more traditional training programs exist in uniprofessional communities, have highly specified core curricula, and have limited multidisciplinary experiences. Although these traditional training programs have been undeniably successful in many respects, they satisfy only part of the training need suggested by Figures A-7 and A-8.

In applying the principles underlying the HST-type training model (or the targeted exposure model) to a focus on infectious disease, we offer the following guide:

1. Establish the overarching goal of the training effort.
2. Begin with the best elements of traditional programs.
3. Splice those elements together by establishing a few multidisciplinary courses or experiences.
4. Ensure trainees have an opportunity for hands-on, real-world learning outside the core areas of expertise.
5. Absolutely ensure students become part of a vibrant multidisciplinary/multiprofessional community.

This implementation strategy is one that can create an informed workforce now and can evolve naturally and appropriately over time.

The principle implementation challenges relate to establishing a truly multiprofessional community and to "institutionalizing" a program that cuts across the classical organizational structures. As an aid to overcoming those challenges, we offer here several important "lessons learned" that are not obvious and that we have learned, in part, through trial and error.

First, exposing students to human disease through direct interactions with patients is extremely important. This can happen in a more passive fashion, such as by bringing patients into classes in graduate courses, or more actively by bringing students to the clinical setting. Such experiences lack the power of a period of total immersion in the clinical milieu, but in our experience certainly have had positive effects in decreasing the gulf between the bench and the bedside.

Second, having both M.D. and Ph.D. students together in the same course helps all students to better appreciate the vastly different cultures encompassing the practice of medicine and the practice of science.

Third, there are benefits to teaching graduate students clinical medicine and medical science in the same way that one teaches medical students. In other words, it is not necessary (and is, in fact, not desirable) to ask instructors to modify what and how they teach to accommodate the fact that these students are not medical students.

Fourth, as any student making the transition from preclinical to clinical work will attest, there is a world of difference between learning something in the classroom and having to implement it on the wards. The opportunities, limitations, and constraints of the clinical environment are far more difficult to appreciate by students who have not had to function in that environment.

Finally, one of the most important lessons has come through our organizational structure. We have had the benefit of training M.D.'s, Ph.D.'s, and M.D.–Ph.D.'s—with about 120 of each enrolled at any given time—under the auspices of a single academic unit. By contrast, M.D. and Ph.D. students are usually in wholly separate departments and even institutions, and there are many pressures to maintain that segregation. This multidisciplinary, multiprofessional organization greatly reduces the inevitable barriers that exist between departments and institutions and helps students and faculty to better understand the value system, perspectives, and key questions of each other—and it is this understanding that forms the foundation for the necessarily collaborative work that is required to bring the proverbial bench to the bedside. Furthermore, by electing not to create a virtual construct, but instead by formally establishing a multidisciplinary, multiprofessional organization comprised of students, faculty, and administrative infrastructure, it becomes easier to resist the inevitable pulls and pushes that aim to make these programs "fit" and seek to elevate one domain in favor of another domain.

The value in undertaking the considerable effort involved in establishing and maintaining such training programs and the associated organizational structure lies in the significant impact that graduates are likely to have on infectious disease. The documented success of both the HST-type in-depth model and the targeted model supports our contention that such training could have comparable success in the infectious disease domain. Furthermore, there is increasing evidence that part of the scientific and technological innovation process requires a sharing and translation of knowledge from one domain to another (Grant, 1996; Hanson, 2002; Hargadon and Sutton, 1997; Sole and Edmondson, 2002). It is not clear how individuals learn to build such communities and to identify and access needed domain knowledge, but it is reasonable to assume that there are advantages to training programs that explicitly place the students in such multidisciplinary, multiprofessional communities.

In summary, outcome data from the in-depth HST-type and targeted exposure training models provide compelling evidence that Ph.D. scientists can play a huge role in advancing clinical medicine. Given the similar complexity of the infectious disease problem domain, it is reasonable to believe that such training models can be and should be implemented to train the infectious disease workforce of the future. The magnitude of the infectious disease problem requires a renewed commitment to education (IOM, 2003). The multidisciplinary, multiprofessional training models described here offer a principled approach to creating training programs in infectious diseases to build a cadre of individuals who have a deep appreciation of the complex multifactorial (multidisciplinary and multiprofessional) issues that conspire to make infectious disease a continuing burden around the world. Furthermore, these training models create "adaptive experts" who can lead change by adapting to the myriad advances and changes in science, technology, and the world.

Thus, in view of the importance of the infectious disease threat, and the reality that addressing the infectious disease threat will involve multiple disciplines and professions, coupled with compelling data indicating that multidisciplinary, multiprofessional educational approaches can be very successful and tend to attract the very best people, it is time for a deep commitment to train the next generation of infectious disease specialists positioned to take the lead in improving our ability to prevent and control microbial threats to health.

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WHAT KINDS OF SCIENTISTS DO WE NEED TO TRAIN, AND HOW?

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We are moving into a future that incorporates a more systematic view of infectious disease—a future in which, as Joshua Lederberg has said, we consider the life and times of the microbiome, the system of organisms that live within and upon us, rather than focusing on any "war" between "us" and "them." This shift already is changing, and will continue to change, who infectious disease researchers work with at the bench, who they talk to, and who they train. Now is the time for considering what kinds of thinkers we need to be attracting to this field, and about how we invite and integrate new people into our research culture.

Doing this brings us to the intersection of two large issues: how the scientific boundaries of the infectious diseases are changing, and how the workforce is changing. This report will first share some insights from a recent Banbury Conference that asked, how can we move toward a more unified understanding of infectious disease? Who do we need at the table? How can we lower barriers that keep fields apart? How can we bring critical fields together in hopes that we can move ahead, farther and faster, toward understanding the bones of the problem of how the creatures in, among, and around us live, and harm us, and help us. After laying out those ideas, this report will switch gears to talk not about who does research but about how we train those people. Is the Ph.D. degree the best model? For some scientific work, yes, but for many of the tasks at hand, no.

Bringing new approaches into the infectious diseases will require:

- Bringing people (and ideas) together better.
- Valuing emerging fields.
- Protecting the time and promotability of the people who do it.

Anthony Fauci's early 2001 "roadmap" paper discussed the need to bring new kinds of expertise into the study of infectious disease. He highlighted the need for expertise in genomics and proteomics, which will have many applications in our field. Synthetic chemistry and mathematical modeling need to be brought in, especially for drug design. Epidemiological approaches, both at the molecular and macro levels, will be more and more important. Also, there is a need to draw in people with skills for developing robotics and high-throughput approaches. And we need experts in informa-

TABLE A-8 Science base for infectious diseases research in 21st century

Field	Research applications
Genomics and proteomics	Host immunity Diagnostics New drug targets Vaccines Drug resistance Pathogenesis
Synthetic chemistry/robotics	Drug design High-throughput screening
Computer/mathematical modeling	Drug design Predictive models of transmission
Molecular epidemiology	Pathogen virulence Transmission patterns
Genetic epidemiology	Host susceptibility
Information technology	All encompassing

tion technology—people whose skills are in demand not only across the life sciences but across the whole of the economic and intellectual spectrum (see Table A-8).

Physical, computational, and mathematical approaches to life science research are only going to become more important as the field turns rich new data toward application. As a field, we need to be recruiting people with appropriately numerate backgrounds, not only from other kinds of attractive life science areas, but also from the many areas outside of human health where they could turn their attention. At the same time, we need to do a better job of pulling people in from other traditional life science disciplines if we are going to understand how we and our microbes interact, and especially if we are to understand how, why, and when a given bug becomes a "pathogen," causing disease, rather than living quietly near us, a microbial face in the crowd.

Infectious disease research needs to attract immunology back into its microbiology roots. The field needs insights, language, and people from ecology, evolution, and development to lay the groundwork for understanding the human–microbe interface. And the researchers focusing on human diseases need to look, closer and more often, at plant biology, at the infectious diseases of plants, and at that rich literature of those fields, as well as at veterinary science.

TABLE A-9 Mechanisms to promote more productive interactions at the interfaces between fields

Mechanism	Advantages
Convening Activities	Enhance local collaboration and help build nearby peer connections; advance integrated approaches; provide opportunities for cross-talk among pathogen systems, scientific approaches, or fields.
Training and Retraining: Courses, Sabbaticals, and Level-Peer Mentoring	Bring groups of scientists to a common level of competency in a field or approach; help spread new ideas and competencies.
Network Development	Provide mechanism for focusing on defined problems; attract targeted expertise to the field.
Support of "No points" Science	Encourage more directed development of critical tools; provide a safety net for those opening new systems.

There are so many ways of doing science that would be remarkable additions to the field: pages could be spent on listing them. The hurdle is not pointing at the science that needs to be brought in to the infectious diseases, but the practical matter of doing it. How can we promote greater and more productive interactions at the interfaces between fields (see Table A-9)?

Locally, there are seminars, and series of them. Researchers could interact better in their own backyards by using these venues to bring a department or mixed group up to a common speed on new approaches. Crossing departments or crossing colleges—bringing together researchers from medicine, engineering, or agricultural schools within a university—would certainly stir in new ideas. There are plenty of ways to use meetings to reach the goal of finding more unified ways of looking at disease. The Midwest Microbial Pathogenesis meeting is an excellent example of how to do it. This is an excellent but regional meeting that mixes researchers—and, importantly, mixes many young scientists, from across the spectrum of disease. Keystone meetings, the American Society of Microbiology small meetings office's conferences, and other existing venues are places where there are straightforward ways to build excellent small meetings in the kind of intimate conditions where new perspectives can be mixed together and let to stew.

From these kinds of events, which nucleate researchers around problems, you can start to build networks, and when funders get involved in building and supporting networks, as the MacArthur Foundation has in vector biology, the effects can be dramatic. That kind of problem-focus can do great things. Another approach is to try to identify the people who will be leading the field in a decade or two, and to build networks to bring them along faster, an approach that the Burroughs Wellcome Fund, the Life Sciences Research Foundation, the Searle Scholars program, and others have taken.

While we are on funders, there is what Nina Agabian has called "no points" science—the thankless scientific exploration that opens fields. Too often, funders do not have the right mechanisms in place to encourage the high-effort, low-yield work needed to break a system open. Researchers work on critical tool development with support and time cribbed here and there, and proposals for discovery science, the critical early steps into new directions, are devalued as "fishing expeditions." Funders need to fix this. We need to encourage risk and to reward skilled and serious pioneers. We should demonstrate clearly to the communities we serve—especially the academic world—that this kind of work is important and should be graded high in both the research and service categories at tenure time.

We need to encourage the spread and cross-pollination of knowledge. Training courses and workshops work. They bring a cadre of people together, inoculate them with a shared knowledge, frame new ways of thinking about that knowledge, and then turn them loose on the world to spread it. Courses are aimed, usually, at young researchers—students and postdocs. Sabbaticals and lateral mentoring can spread ideas across the more senior population. But in both course and sabbatical support there is a funding gap that needs to be addressed.

The professional societies concerned with infectious diseases—the American Society of Microbiology, the Infectious Disease Society of America, and several others—are important parts of the field's infrastructure and have roles to play in bringing in new approaches. Their oldest and most central roles are convening researchers and publishing journals. Societies can give new ideas and new connections a boost by playing a part in bringing people together around emerging issues. More importantly, through their publishing operations they help define the field. Their publishing choices can give a kind of imprimatur that legitimizes, enhances, and encourages nascent approaches to the scientific problems that hold their organizations together.

Finally, universities need to prepare themselves for the coming wave of more connected, more collaborative science. They have to value good work, even when that work is team driven. The tenure system is a huge barrier to young scientists' reaching out. Universities should value this kind of work and actively support it by protecting time for it and making resources available when strong faculty want to move in new directions.

Looking at a related issue, the scientific workforce, in general, and how it is trained, we need to understand what kind of workers are needed at the bench and how we can best train them. An obvious place to start is to ask, "Is there a problem, or are we already doing what we should?"

The RAND Corporation recently released a report titled "Is There a Shortage of Scientists and Engineers? How Would We Know?" The answer to the first question depends, according to the report, on what "shortage" means. When we ask if there is a scientist shortage, we could be asking any of a number of questions: Are we making fewer scientists than before? Are our competitors getting more of their scientists into the marketplace? Do the producers of scientists want to make more scientists? Are we under-supplying the nation's needs? Is the lack of production driving up the cost of hiring scientists?

The first four problems—if they are, indeed, problems—can be addressed by changing the number of scientists produced and put into the system. But the fifth is self-solving: "if you pay them, they will come" is a principle that has been demonstrated over and over again in labor markets. The salaries expected by our finishing graduate students are not skyrocketing. Although postdoctoral salaries are increasing, they are rising because of changes imposed by funding agencies, such as the National Institutes of Health (NIH), and they are increasing to levels that stem despair. The entering salaries of trained scientists are not rising to levels that will encourage our best and brightest 18-year-olds to focus on research as a career rather than choose other, higher paying, intellectually challenging professions.

There is more to life than money, of course, but early career scientists, those in training, in graduate school, and postdoctoral positions, defer more than earning while they train. They put off building other important stabilizers of happiness, health, and wealth, such as starting families, buying homes, and saving for retirement. It is taking longer and longer to get through the system. A 6-year Ph.D. was the norm 30 years ago, turning out new Ph.D.'s at an average age of 29.5 years. Now, the average new Ph.D.'s are 32 years old, finishing up their degrees in 8 years (see Figure A-9). This is very discouraging to people entering the system. And on top of this, the period spent in postdoctoral work is getting longer as well, but that is not as easy to quantitate because postdocs are not as well tracked as graduate students.

A 35-year-old should have his or her career well launched. In most of the fields that compete with science for bright young people, a 35-year-old is professionally mature. But if we look at NIH grant dollars, it is clear this is not true in health science research (see Figure A-10). Twenty years ago, young people comprised 20 percent of the grant pool. Today, they com-

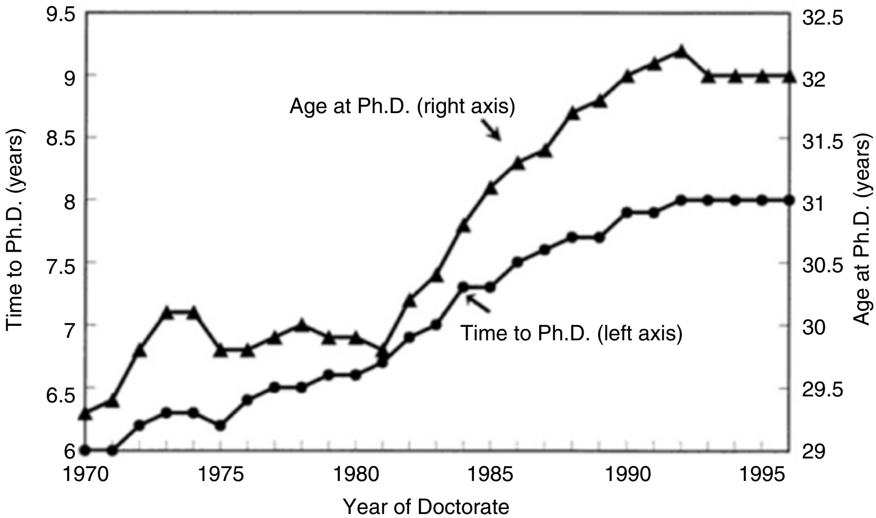

FIGURE A-9 Ph.D. time to degree is increasing.
SOURCE: *Trends in the Early Careers of Life Scientists*.

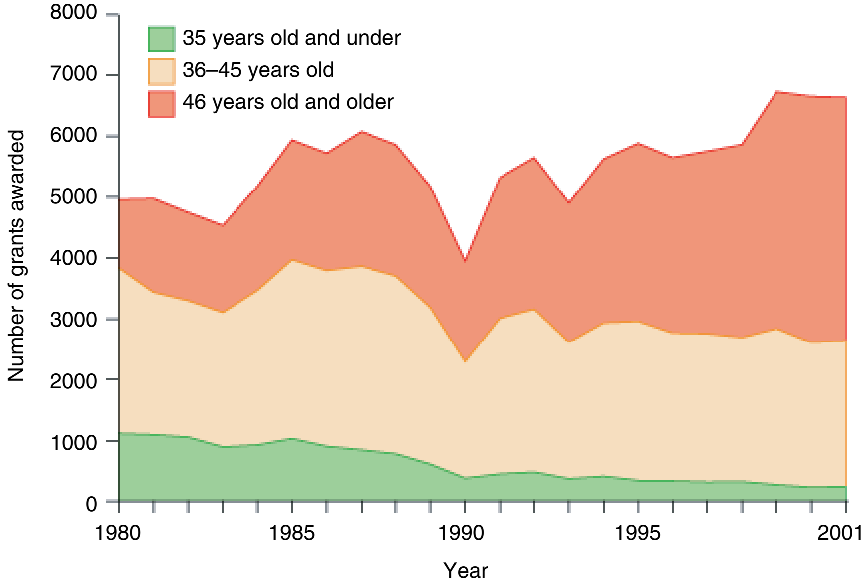

FIGURE A-10 Young researchers awarded fewer grants.
SOURCE: Goldman and Marshall, *Science* 298:40–41, 2002.

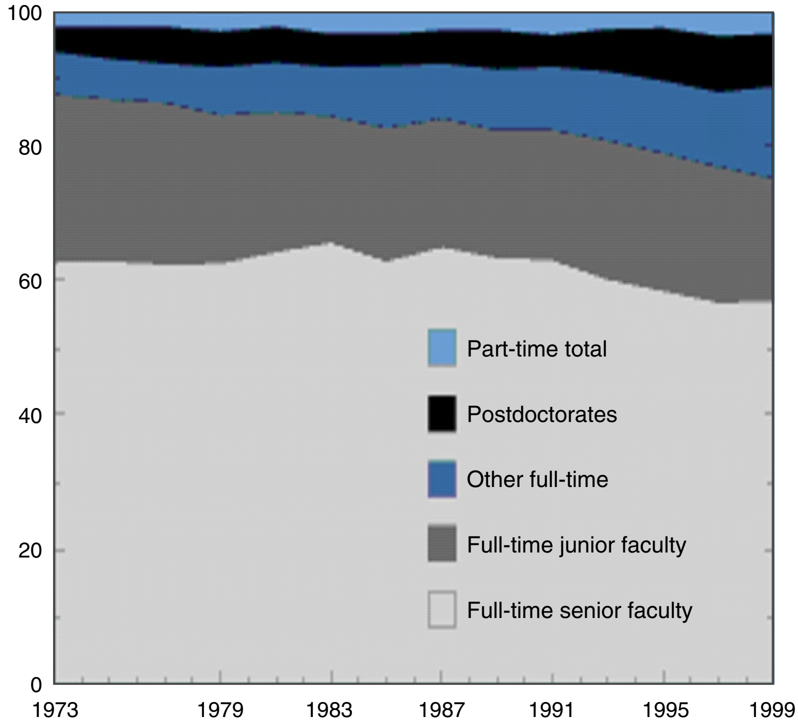

FIGURE A-11 More researchers are in non-faculty academic jobs.
SOURCE: Derived from *Science and Engineering Indicators 2002*.

prise less than 5 percent—and worse in clinical research. Why? It is not that we discriminate against the young. The bigger factor is that they are just not in the pool of researchers in a position to submit grants. So we are getting top-heavy, with more of our dollars in older people, while our "new blood," our young researchers, are left in an extended professional adolescence.

Thirty years ago, about 10 percent of the people in the system were postdocs or in other positions where they were fully trained but not yet stable (see Figure A-11). That population had more than doubled by the end of the century, largely because of growth in non-postdoctoral, non-tenure-track, non-stable research-track positions. As the young crowd into these unstable positions, the professoriate is graying. Reaping the intellectual and material rewards of independent science is less and less a young person's game.

The numbers are discouraging to us, the people already in the system.

But how much more discouraging they are to the 15-year-old who has just caught the excitement that brought us into this field, or to the 19-year-old premed who is driven toward a career bridging the bench and the clinic. These numbers are not hidden from students. Increasingly, American students vote with their feet. They are lost to us.

But we need them. And science is bigger than academe. Industry needs people. And there may be problems coming if we cannot get enough scientific workers abroad, as we have been able to do so far.

Industry does not necessarily need the same things as academe. In academic science, innovation is the big thing, and producing one's first important, innovative work is the centerpiece of the Ph.D. Industry needs innovation. But companies also need praxis. Industry is driven by people who go in and get the job done. Companies need team players with multivalent skills.

RAND suggests, then, creating a "professional doctorate," akin to the way medical schools train a cadre of people to readiness for practicing medicine. In this case, graduates would be ready for industry and would be fed into jobs. But are doctorates what are needed?

Most people degreed in the life sciences do not even work in science and engineering. How can we better tap into this pool of people, who are clearly interested, in some level, in the life sciences? If we look at who stays in, it is primarily those individuals with Ph.D. and master's degrees. How can we catch more of those students who receive bachelor's degrees before they go into other things?

If we look outside academe, it is not a Ph.D. life sciences workforce. In fact, more than 70 percent of the workforce does not have an advanced degree (see Figure A-12). Many of those people have specific, practical education. Practical education, preparation for real day-to-day work, matters.

How can we attract people into the practical, professional jobs industry needs to fill? In 1997, the Sloan Foundation began one experimental approach, the Professional Science Masters program (www.sciencemasters.com). The foundation is supporting 30 programs, developed by academe in concert with industry, to produce professional skilled people in 2 years. These programs aim to deepen student knowledge; fuse and integrate fields; and integrate science with law, management, and other professional bodies of knowledge.

One example of such a program is the Master's in Microbial Biotechnology at North Carolina State University, which is one of the three "corner" universities for which the Research Triangle is named. North Carolina's Research Triangle Park is the largest research park, or area set aside for scientific and technical innovation and development, in the United States. The area's needs for a well-trained high-tech workforce are considerable.

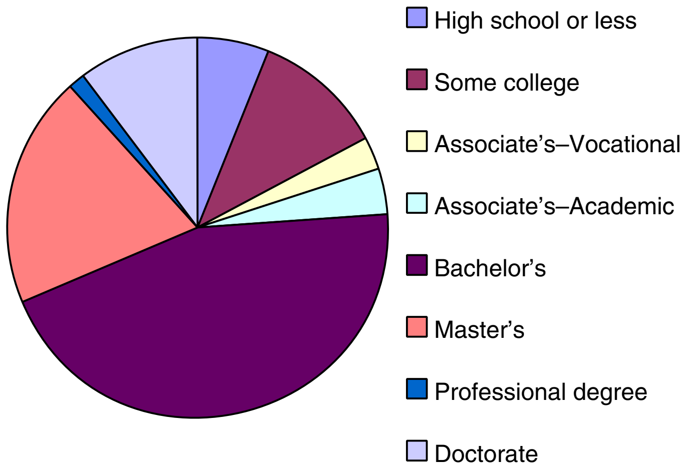

FIGURE A-12 Education levels of science and engineering (S&E) employees outside academe.
SOURCE: Derived from *Science and Engineering Indicators 2002*.

The N.C. State Microbial Biotechnology program mixes training in microbiology, business, and process biotechnology. Along with laying the educational groundwork and providing research experience, the program prepares its students for careers, including by actively creating professional networks that the students can step into. A dedicated 22-year-old entering a program like this emerges with a real job, a professional job, 2 years later. This is a real draw.

Evaluations of these programs are only now coming in, but one program has looked at how its graduates are doing in the job market. The average master's holder makes about $33,000 a year. Two thirds of the graduates of the Professional Science Master's programs are earning more than $50,000 a year, and a good number of them start out making more than $70,000. For most of these graduates, their compensation also includes additional incentives, such as signing bonuses, stock options, and tuition benefits. So their compensation compares well enough with the 2002 lawyerly average of $60,000 across specialties, since students know that law, itself, has many jobs that leave law school graduates underpaid and deep in debt. Clarifying and popularizing the track to professional master's level jobs could, potentially, let smart, ambitious 18-year-olds see a future for themselves in science again. Some of the students who choose to go this route will find themselves more interested in the long view of research and will move off the master's track and toward a Ph.D. But for these students, advanced study will be a real choice, not the default it is for so many doctoral students today. Some students who enter science thinking of a good payday, or simply a stable future, will find themselves wrapped up in the excitement and joy of basic science, and they will be excellent Ph.D. students—the kind we would all like to see more of. When those students come to us, we can do great things for them, and look to them for our future.

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VACCINES IN THE 21ST CENTURY

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University of Pennsylvania and Aventis Pasteur Vaccines

Vaccines are an essential element in the success of modern medical science, and they have played a central role in providing people around the world with longer and better lives. Indeed, it is difficult to exaggerate the impact of vaccination on the world's population. With the exception of providing safe water, no other modality, not even antibiotics, has had such a large effect on mortality reduction and population growth. However, despite the remarkable advances that have been made in basic knowledge of immunology and microbiology, proportional translation of these findings into new vaccines has not occurred, and many diseases that need to be controlled by vaccines remain throughout all regions of the globe (see Table A-10). The evolution of a new field of microbiology and immunology—called "vaccinology," and comprising not only vaccine development but also the use of vaccines and their effects on public health (Bendelac and Medzhitov, 2002; Plotkin, 2003)—has led to the lack of an adequately trained workforce to develop vaccines. The need for people to work on vaccines to control these pathogens is critical. An increased commitment to research and to the recruitment and training of more scientists in the field is necessary to ensure the development of vaccines for the numerous infectious diseases that threaten the world's human population.

TABLE A-10 Some Major Infectious Diseases Uncontrolled by Vaccination

Chlamydia	Influenza
Cytomegalovirus	Parainfluenza
Dengue	Malaria
EBV	Meningococcus B
E. coli 0157	Nosocomial (Staph, enterococcus)
Helicobacter pylori	Shigella
Hepatitis C	Strep, GpA + B
Herpes simplex	Tuberculosis
HIV	Urinary tract infection
Human papillomavirus	Zoster

Changing Vaccine Development Strategies

The technical complexity of vaccine development has increased over the years. In the past, attenuation and inactivation have been the primary paths to vaccine development (Plotkin and Plotkin, 1999). Only recently have additional methods come into play, including live recombinants, alpha virus replicons, reverse genetics, and prime-boost strategies, to name a few. So, what might have been characterized as relatively straightforward, technical work in the past has now become extremely complex, requiring a great range of expertise. For any agent of interest these days, at least four or five strategies, all different, are being explored. These strategies include:

Attenuation

Heat, oxygenation, chemical agents, and aging were the first methods of attenuation used, notably by Pasteur for rabies and anthrax vaccines. Passage in animal hosts, such as the embryonated hen's egg, was the next method, as practiced by Theiler for yellow fever vaccine. After the development of cell culture in the 1940s, attenuation in vitro was accomplished by a variety of means, including selection of chance mutants, adaptation to growth at low temperatures, chemical mutation to induce inability to grow at high temperature (temperature sensitivity), or induction to auxotrophy in bacteria.

Inactivation

The second set of strategies is the inactivated organism or subunit path. In the late 19th century, Theobald Smith in the United States and Pasteur's colleagues independently showed that whole organisms could be killed without losing immunogenicity, and this approach soon became the basis of vaccines for typhoid and cholera, and later for pertussis, influenza, and hepatitis A. In the 1920s, the exotoxins of *Corynebacterium diphtheriae* and *Clostridium tetani* were inactivated by formalin to provide antigens for immunization against diphtheria and tetanus. Later, influenza vaccine progressed from viral soup to the extracted proteins that are used today in acellular vaccines.

Reassortment

For viruses with segmented genomes, such as influenza virus and rotavirus, reassortment has been used to combine genetic material coding for protective antigens of pathogens with genes coding for attenuated behavior in the host. The resultant reassortants can immunize without causing illness. Reassortants have been fundamental to the preparation of both killed and live virus influenza vaccines.

Peptides

Extracted native polysaccharides from the capsules of *Haemophilus influenzae* type b, pneumococci, meningococci, and typhoid bacilli proved useful in immunizing older children and adults, and, more recently, the conjugation of these polysaccharides with proteins has provided us with immunogens that generate T cell memory and are effective even in young infants. Although peptide subunits of proteins have not thus far been successful against infectious diseases, they do offer hope for vaccines against melanoma and other cancers, and both lipidated and multiepitope peptides show greater immunogenicity against microbes (BenMohamed et al., 2002; Meloen et al., 2001).

Live Recombinants

To develop live recombinants, genes from heterotypic viruses can be inserted into an attenuated virus. As examples, the envelope genes from three dengue virus serotypes have been inserted into a fourth attenuated serotype to produce a candidate dengue vaccine. Dengue virus genes have also been inserted into the attenuated 17D yellow fever virus as a carrier; a candidate West Nile virus vaccine is also based on this carrier (Guirakhoo et al., 2002; Monath, 2001).

Alphavirus Replicons

Splitting cDNA copies of alpha virus RNA genomes makes it possible to insert a gene for a foreign protein into a segment that also codes for replicase enzymes, whereas the genes for the viral structural proteins are contained in another helper construct from which the packaging signal for RNA is deleted. Co-transfection enables the replicon to be incorporated into an alpha virus particle that can enter cells, in which the foreign gene is then expressed. The particle is immunogenic but unable to replicate (Liljestrom and Garoff, 1991; Rayner et al., 2002).

Reverse Genetics

Reverse genetics, the technique of inducing specific genetic lesions and then observing the phenotypic changes, is being applied to several viruses, particularly to negative stranded RNA respiratory viruses such as influenza virus, parainfluenza virus, and respiratory syncytial virus (Murphy and

Collins, 2002; Neumann et al., 1999; Fodor et al., 1999; Palese and Garcia-Sastre, 2002). This technique depends on inducing mutations at specific sites in cDNA and reconstituting a new virus by furnishing nonstructural enzymes, in a co-transfection with the modified genome segments. This rescued virus can then be examined for its phenotypic qualities.

Prime-Boost Strategies

Although immune responses and protection afforded by DNA vaccines or vectors alone are often insufficient, the combination of modalities in a prime-boost configuration is more promising (Excler and Plotkin, 1997). The prime-boost approach works both for generating antibodies and for generating cell-mediated immunity. For example, one of the earliest trials of the prime-boost concept involved priming with canarypox vectors containing human immunodeficiency virus (HIV) genes and boosting with injections of the envelope glycoprotein 120 of the virus (Pialoux et al., 1995). This approach may work for other diseases as well; in fact, clinical trials of a malaria vaccine that uses DNA priming followed by boosting with modified vaccinia Ankara (MVA) are now in progress (Moorthy and Hill, 2002).

Expanding Targets of Vaccination

Targets for vaccination are expanding (see Table A-11). Vaccination has traditionally been considered a pediatric task, aimed at improving the health of children, and pediatricians have been in the forefront of promoting and developing vaccines. As vaccine development progresses, the target diseases and populations are broadening to include adults in specific risk groups (e.g., hospitalized patients) and adults in general (e.g., for pertussis). Noninfectious diseases also will become targets of immunization strategies (Frenkel and Solomon, 2001). Cancer prevention is already provided by hepatitis B vaccine, which is reducing the incidence of hepatic neoplasms, and the recent preliminary success of a human papillomavirus vaccine in preventing infection and dysplasia is promising for cervical cancer. In addition, the isolation of antigens specific for transformed cells allows for the possible development of vaccine prevention and therapy for cancer. Immunization may also be useful in situations in which infection plays no role, such as to prevent conception or to neutralize drugs in the bloodstream to treat addiction (Singh et al., 1998; Kantak et al., 2000).

The application of vaccines to pregnant women has been inhibited by medicolegal concerns. The primary goal of vaccination in pregnancy is to either protect the newborn (e.g., group B streptococcal disease) or to protect the woman herself (e.g., influenza). Candidate vaccines that might be used late in pregnancy to protect the neonate during the early months of life

TABLE A-11 New Targets for Vaccination

Targets	Examples
Adolescents	Human papillomavirus, cytomegalovirus, pertussis
Adults	*Herpes simplex* virus, zoster, pertussis
Hospital patients	Staphylococcus, pseudomonas, Candida
Pregnant women	Group B streptococcus, respiratory syncytial virus, parainfluenza virus 3, *H. influenzae* type b, pneumococcal polysaccharide, pertussis
Bioterror threats	New smallpox, anthrax, plague
Noninfectious diseases	Cancer, diabetes, Alzheimer dementia

include those against respiratory syncytial virus, pertussis, pneumococcal polysaccharide, and group B streptococcus.

Vaccines for herpes simplex and zoster are being developed for adults. Nosocomial infections are now being targeted as well, and a staphylococcal vaccine is far advanced in development. Extending vaccination of pregnant women beyond tetanus and influenza to other diseases is being seriously considered, and efforts are being blocked only by the large legal establishment in this country. Most importantly, immunology is being extended to noninfectious diseases, to include immunization against so-called cancer antigens, antigens on neoplastic cells, diabetes, and even against amyloid for Alzheimer's disease.

Not only is vaccinology moving ahead in those areas, but it is also moving toward therapeutic vaccination, something that has not been considered largely before (Vandepapeliere, 2002). Therapeutic vaccination against chronic infections is an entirely new field of vaccinology. Therapeutic immunization protocols are currently being tested in at least four viral diseases—hepatitis B, HIV, herpes simplex, and papilloma—based on the idea that whereas in chronic infection the host is unable to mount an effective immune response, external administration of antigens may induce cellular responses that suppress viral replication (Peters, 2001). Therapeutic immunization may also be useful in chronic bacterial infections, such as that due to *Helicobacter pylori*.

Workforce Issues

The new strategies and expanding targets of vaccines have led to a demand for more scientists trained to conduct research and develop vaccines. The changing nature of vaccine development has led to a need for expanded training and education of scientists in the field. Students must be educated on vaccines, vaccination, and vaccinology in medical school, so that they will consider this a realistic career path. Currently, little time and attention is spent on the study of vaccines, and more should be done to integrate this into the current medical school curriculum.

A number of areas exist in which physicians and scientists are needed. These areas include pathogenesis and the development of animal models that shed light on pathogenesis; choice of antigens, which in turn depends on understanding of immunology of the disease; and the large area of clinical trials, which range from small trials to very large and complex trials that require a tremendous amount of preparation and knowledge of epidemiology. Safety assessments also have become important in this climate, particularly in developed countries, and people with a broad understanding of diseases are needed so analysis of an immune reaction can be performed in both the clinical and laboratory settings. Postlicensure studies on safety, effectiveness, risk groups, and persistence are necessary as well.

The study of pathogenesis is critical to vaccine development, and more young investigators are needed in this field. Molecular biology permits us to construct just about any antigen; however, there have been relatively few vaccines brought to market as a result of efforts in the area, primarily because too little is known about pathogenesis, and as a result, the target antigen remains unknown. For example, the genomic sequence is known for cytomegalovirus (CMV), but a major issue that has recently developed is that many immunoevasive genes exist in the virus. To develop a live vaccine, these genes may need to be deleted.

Education and Training

The need for scientists in vaccinology is considerable. When companies look to hire people in this area, they are having problems finding qualified candidates who have the right education and background in the sciences. This is one of the reasons why the vaccine industry is small—there are not enough people who are properly trained in the science of vaccines to comprise an adequate and well-trained workforce. Although it would be a good idea to have more than the four major companies that now currently manufacture vaccines, expanding the field is difficult, because each new company will be competing with the larger companies to hire the few trained personnel that exist. It is vital that on-the-job training opportunities, especially for students, be further developed to ensure that professionals are exposed to career paths in vaccinology. Training programs in vaccinology are critical for the development of a strong workforce.

Another problem is the trivial amount of time in medical school that is devoted to disease prevention via vaccines. A practical solution to this would be to change the curricula to emphasize prevention rather than treatment. Currently, some postgraduate vaccinology courses and programs are in place both domestically and internationally. These programs may provide a solid foundation on which present programs can be expanded and future epidemiology training programs modeled.

Since 2000, the Marcel Merieux Foundation, headquartered in France, has offered an annual course in advanced vaccinology, which aims to introduce participants to the different aspects of vaccinology, and, in particular, the development of vaccines, the conduct of clinical trials, and the safety issues involved in the administration of vaccines. This course, delivered in English, is intended for scientists of both the public and private sectors who are responsible for vaccine development, the implementation of vaccine strategies, or the introduction of new vaccines in public health programs. The course also covers selecting appropriate vaccination strategies, integrating new vaccines into public health programs, the side effects of vaccines, perfecting new vaccines, and therapeutic vaccines. This course is open to people from all over the world, and developing countries have shown great interest. Surprisingly, few Americans apply for the course, even though there is scholarship money available to pay their expenses. This is astonishing, but there is not a large pool of people in training who are interested in vaccine development. So, academia and the vaccine industry should partner to discuss and develop such a program. While the 2-week course in France is exactly this type of program, there is a paucity of other courses (Fondation Marcel Merieux, 2003).

Infectious diseases are complex, a fact that has led to a focus on multidisciplinary and multicultural training. This is true for the vaccine industry as well. It is very clear that a microbiologist can work in the laboratory and move into the world of vaccinology by trial and tribulation. However, to encourage more people to go into this field, it would be useful to develop a multidisciplinary program that includes training in a number of core areas, including microbial immunology, safety regulations, scale-up technology, clinical development, and investigational new drug formulations. A multidisciplinary approach in education would enable students to learn about vaccine development, and much could be gained by this approach. The question that then arises is who will teach these courses? The majority of qualified people are in industry. Trials often cannot be done too many times if they are not done correctly the first time; there are not too many second chances when it comes to clinical trials. It is also possible to learn from academics who have been through clinical trials, but again, most of the people with such experience are in industry.

People who have conducted phase III trials outside of industry do in fact exist, but there is no formal training available in that type of complex operation—and the complexity of such trials is ever increasing as regulations increase. So, those people who have mastered the necessary skills are rare, and they are solicited for their expertise. Although these skills are specialized, it is possible to teach them. For example, a vaccinology fellow

Box A-1
University of Maryland Vaccinology Training Grant

The National Institutes of Health funds a training grant in vaccinology at the University of Maryland Center for Vaccine Development. This program enables individuals with M.D. or Ph.D. degrees to be prepared specifically for careers in vaccinology, either to pursue basic vaccine development research or to conduct investigative clinical trials. The program offers all trainees a broad exposure to both the laboratory and clinical trial phases of vaccinology, but is set up as two tracks so that trainees can select whether to concentrate in either the laboratory or the clinical aspects of vaccinology. The laboratory track provides for training basic scientists and physician–scientists in vaccine development laboratory research, particularly in the use of recombinant DNA technology to prepare new vaccine candidates and the use of modern immunological techniques to study the human humoral and cellular immune response to different vaccines. The clinical track trains clinicians (internists or pediatricians) in clinical trial design, protocol preparation, procurement of administrative and ethical clearances, and performance of clinical trials and analysis of data. The ultimate goal of this program is to provide a well-trained cadre of individuals who can fully exploit the unprecedented opportunities now available in vaccine development.

SOURCE: University of Maryland School of Medicine, 2003.

from a university participating in the development of a phase III trial would learn from this experience. A number of formal courses in vaccinology are taught in schools of public health throughout the United States and abroad. For example, courses are offered at the University of Maryland, Johns Hopkins University, the University of Geneva, and the University of Texas at Galveston. The University of Maryland Center for Vaccine Development provides formal training in all aspects of vaccinology, through a training grant from the National Institutes of Health (see Box A-1).

Getting skilled people in industry engaged at the level of training scientists when they are in their predoctoral and early postdoctoral period is a challenge that needs to be addressed—but solutions should be possible. Confidentiality issues may be involved, but they could be worked out. Other issues to be addressed extend beyond the science underlying development and the practical aspects of development to marketing issues and to the policy issues related to utilization and acceptance.

The development of vaccines is a delicate fabric. The makeup of this fabric consists of academia and biotechnology companies developing ideas and passing them to industry, which then develops the products. The government then comes in, developing and enforcing regulations and making recommendations, and then academe again becomes involved in testing the vaccines. This process is working fairly well at the moment, but vaccine shortages have recently become apparent. In order to expand on what we have now, shortages of people will be encountered along the way.

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SCHOOLS OF PUBLIC HEALTH: MEETING THE WORKFORCE CHALLENGE OF EMERGING INFECTIONS

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Schools of public health contribute to meeting the challenge of emerging infections. Faculties at these schools conduct research and teach current and future working professionals. However, for a number of reasons, measuring the need for and the impact of these contributions is problematic. We have reliable estimates on the current supply of professionals trained in epidemiology and disease investigation, but we lack standards and methods for determining demand, that is, the appropriate number needed for optimal surveillance, detection, and response. Nor do we yet know how well the schools are meeting the task of educating those in the workforce, since performance capacity studies are lacking.

The experience with anthrax-contaminated mail in the fall of 2001 and winter of 2002 raised concern about the lack of good information and illustrated the fact that state and local public health agencies could quickly become overwhelmed by the intentional dispersion of an infectious agent. The federal Government Accounting Office estimated that authorities had received 70,000 samples containing white powder suspected of being anthrax during that 3-month period; and it identified gaps in disease surveillance systems, inadequate laboratory facilities, and workforce shortages (Heinrich, 2003).

This report presents a summary of recent and ongoing efforts within and outside of public health schools to address some of the demand and supply issues concerning public health professionals. It begins with an overview of workforce information that is specific to the infectious disease challenge, examines some of the current and future contributions by the schools to meeting the demand, and concludes with recommendations for research and education focused on assuring that schools contribute optimally to the task of protecting the public from emerging infections.

Current Supply of Public Health Infectious-Disease Workers

Gebbie et al. (Gebbie et al., 2000) have recently reported a job-classified enumeration of the approximately 448,254 individuals who constitute the nation's paid public health workforce. The classifications most relevant to meeting the challenge of emerging infections are "epidemiologist" and "infection control/disease investigator." Together, these two classifications contribute less than 0.47 percent of the total enumerated workforce. This percentage may underrepresent or overcount the actual number of relevant workers, for several reasons. First, not all epidemiologists work on infectious diseases for all or most of their time; some of them, for example, work on chronic diseases and injuries. Second, workers who function in these job classifications might hold otherwise-titled positions or might work in agencies not included in the count (e.g., state environmental health departments). Third, some professional classifications (e.g., physicians and nurses) that are included in the enumeration might function as infectious disease specialists, but the enumeration data failed to capture the functional roles of individual workers. Fourth, since the year-2000 enumeration, staffing for the detection and containment of infectious diseases in state and local health departments has probably increased due to federal bioterrorism funding. Despite these limitations, given that epidemiology is the core science of infectious disease monitoring and that infection control/investigation is the front-line defense against outbreaks, the fact that these positions comprise such a low percentage of the public health workforce is startling.

The "Demand" Side: Currently Employed Infectious-Disease Workers

There is no good information about how large a professional workforce is needed to combat emerging infections, how specifically to educate people for this work, or what the rate of turnover in the relevant positions might be. These are quite clearly important questions for educators and policy makers. Systematic studies of public health capacity—particularly research on the number, types, and distribution of professionals needed to confront emerging infections—do not exist. Without such information, schools cannot target education and training programs, state and local governments lack standards for staffing of public agencies, and policy makers cannot rationally allocate resources for achieving this important public health function.

At least one professional collaboration attempted to quantify public health workforce needs for its own strategic planning purposes, using the professional judgment and experience of a committee comprised of local and state health officials and legislative staff. This committee estimated that minimum staffing should include 1.1 full-time-equivalent (FTE) epidemiologists and 0.55 FTE disease investigators per 50,000 people (Libbey, 1998). As fully acknowledged by its contributors, this method was subjective and not validated by systematic performance-capacity research. The staffing numbers projected by these FTE-to-population ratios are limited by the fact that actual staffing patterns must adapt to available resources and be suited to jurisdictional size, population, political organization, population-specific health risks, and other factors. Nevertheless, if projected to the entire U.S. population (more than 280 million) and compared with the workforce enumeration data, then this method suggests that there are fewer than 20 percent of epidemiologists and about 30 percent of disease investigators actually on the job, as compared with the need. The disparity between projected need and current actual staffing patterns would vary widely among regions of the country, between neighboring states, and even among areas within states. Even if the "correct" FTE projections for any jurisdiction were half of those cited here, then the conclusion would remain that the functions of epidemiology and disease control/investigation should probably be staffed with more professionals than are currently in place.

The "Supply" Side: Research and Teaching

Schools of public health contribute to the supply of infectious disease specialists in the public health workforce by conducting research that informs professional judgment and programming and by educating the workforce both current and future. Both sets of functions have been undergoing significant change within these schools over the past decade, and continued developments are foreseeable.

Research

Practice-oriented research is needed to answer the questions about how many students and workers are needed to meet the challenges of emerging infectious diseases, and schools of public health have a special role here. Scientists in these schools contribute to the pursuit of research into communicable diseases, their vectors, their incidence and prevalence, their prevention, and their treatments, along with scientists in other schools as well as with those in public-sector agencies and private-sector institutions. The foci of this research span a continuum from basic, laboratory-based studies and clinical trials on the one end all the way to experiential, practice-based studies at the opposite end. Academic scientists in public health, like their counterparts in other schools, often have greater support and incentives to work on problems at the basic science/clinical end of the research continuum. But public health schools have special reasons to encourage the attention of their faculties to topics at the practice end of the research continuum. Two sequential reports by the Institute of Medicine concerning the future of public health, one in 1988 (IOM, 1988) and the other in 2003 (IOM, 2003), pointedly recommended that schools of public health should conduct research on improving the capacities and performance of public health agencies and on the health of groups, communities, and populations.

Since 1993, accreditation criteria for these schools have included specific encouragement for practice-oriented research (CEPH, 2002).[5]

Recent developments provide further incentives for practice-oriented public health research by drawing attention to the scholarly importance of this field. In 2002, Academy Health (a national organization of scientists focusing on health research and policy) authorized the formation of a Public Health Systems Research Affiliate, and in 2003 the organization added public health as a major session within the agenda for its annual research meeting. The Council on Linkages Between Public Health Practice and Academia, whose leaders and membership include academicians in public health and preventive medicine, is developing an agenda and soliciting funding commitments for public health systems research. While the topics on this agenda (workforce, infrastructure, and performance standards) are not restricted to infectious disease alone, they are highly relevant to the capacities and effectiveness of public health systems to face the challenge of emerging infections.The Association of Schools of Public Health (ASPH), the membership organization of fully accredited institutions in the United States, has provided leadership for the development of practice-oriented research. In 2000, the ASPH Council of Public Health Practice Coordinators (faculty and administrators appointed by their deans to advise and to manage academic-practice programs) issued a white paper that articulated a comprehensive rationale for practice-oriented scholarship, including research (ASPH, 2000). Planning to further this work, the council in September 2003 convened a 2-day workshop to initiate the writing of another white paper that will examine, among other issues, the academic policies that affect faculty members' incentives to conduct practice-based research.[6]

Teaching

There are currently 36 accredited schools of public health, with the number of schools increasing by six during the past decade. The schools' accreditation criteria mandate that they sponsor degree programs in five core disciplines, including epidemiology (CEPH, 2002b).

In 2002, ASPH-member schools produced more than 1,000 graduates in epidemiology (ASPH, 2003), but this number has limited relevance to the

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[5]Criterion VI states: "The school shall pursue an active research program, consistent with its mission through which its faculty and students contribute to the knowledge base of the public health disciplines, including research directed at improving the practice of public health."

[6]This author is a member of the ASPH Practice Council who participated in the practice-research meeting, held in Phoenix, AZ, on September 11–12, 2003; and is co-chairing a work group of the Council that is writing an ASPH white paper on practice-based research.

actual supply of epidemiologists who enter the public health workforce. Little is known about the specific educational backgrounds of public health workers, except that formal training for such careers is unusual rather than typical (Public Health Functions Project, 1995). According to the federal Health Resources and Services Administration (HRSA), in 1989 only 44 percent of the then-estimated 500,000 public health workers had any formal, academic training in public health, and those with graduate public health degrees were an even smaller fraction (HRSA, 1991). Even less is known about career paths among graduates of public health degree programs. The educational requirements for employment in epidemiology positions (e.g., master's versus doctor's degree) differ among state and local jurisdictions. Not all individuals who hold the title "epidemiologist" necessarily have formal education specific to their work, and many who do attain such education do not go to work in public health agencies. Furthermore, some institutions that are not public health schools also contribute to the supply of these workers. There are currently 41 accredited Master of Public Health (MPH) programs in community-health and preventive-medicine departments of medical schools, and there are 16 accredited MPH programs in other schools (CEPH, 2005).

Given that most public health workers are not formally educated in this particular field, the schools are directing practical training programs to them in their work sites, by distance-communication media, and in special on-campus programs. Two federal training programs are currently administered through cooperative agreement grants available exclusively to ASPH-member schools of public health. The Health Resources and Services Administration launched its Public Health Training Centers in 2000 and now funds 14 of these centers in schools of public health (U.S. Health Resources and Services Administration). The federal Centers for Disease Control and Prevention (CDC) created Centers for Public Health Preparedness in 2001 and now sponsors 22 such centers in the schools (CDC, 2003). The training provided through these centers includes crosscutting topics of relevance to public health practice as well as specialized topics relevant to emerging infectious diseases.

However, the continued effectiveness and commitment of schools to train working professionals depends in part on funding from the public sector. Since public health as a discipline does not have credentialing or continuing-education requirements (as do some related disciplines such as medicine, health education, and nursing), its workers have little reason for, and no expectation of, paying out-of-pocket for post-degree training. Currently, grant programs of the CDC and HRSA heavily subsidize the cost of training to the agencies that employ these professionals, and the school-based centers function as nonprofit organizations under the terms of their cooperative agreement contracts. Without this funding mechanism, professionals employed in state and local health departments would lack both incentives and resources to pursue training.

Recommendations

The foregoing overview of demand and supply issues for the nation's infectious disease workforce brings into sharp relief several major concerns that call for attention.

First, the numbers, actual jobs, characteristics, and qualifications for members of the public health and infectious disease workforce are not sufficiently well documented. The year-2000 enumeration study was a very important and well-executed effort to begin this documentation, and it should be repeated on a regular basis over time. However, a limitation of that study was the lack of correspondence between its standardized set of universal job classifications (as recommended by a national blue-ribbon panel (Public Health Functions Project, 1995)) and the position descriptions actually used by the states and local health agencies whose workers were counted. For the future, a better approach might be to base workforce enumeration on the essential public health services or on important cross-cutting functions. The staffing of work needed to carry out surveillance, detection, and response to emerging infections is indeed one of those functions. Future studies of the public health workforce should also include demographics and educational backgrounds, information that will help to guide both educators in designing programs and students in selecting them. Schools of public health should systematically track the career paths of their graduates and assess the incentives that draw some of them into public service. This information will help to inform hiring and compensation decisions among public agencies and policy makers.

Second, there is an inadequate base of evidence on which to guide policy making for targeting education and training programs, for specifying qualifications and numbers of public agency staffs, and for allocating resources for workforce development. Public health systems research is needed to assess the performance capacity of public health agencies. The training of workers should be planned and directed to achieve strategic improvements in the worker competencies needed to assure infectious-disease surveillance, detection, and response. Schools should consider the review of academic policies that create disincentives for faculty members to contribute to this research.

Third, research and education to assure an effective infectious disease workforce cannot be sustained without federal and state funding commitments. Practice-oriented research, including public health systems research, lacks current earmarks in the major federal health-research budgets of the National Institutes of Health and the Centers for Disease Control and

Prevention. The authorizing legislation for both the CDC and the HRSA workforce training programs will soon expire. For the HRSA training centers, appropriations have been eliminated from federal administration budgets in each fiscal year since they were first authorized, making their ongoing operations repeatedly subject to special action by Congress during each of the past 3 years.

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U.S. CAPACITY TO CONFRONT EMERGING VECTOR-BORNE PATHOGENS

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The discipline of public health entomology began to assume its present form during the 1960s with the development of the concept of vectorial capacity and the abandonment of hope that malaria could be eradicated. The National Institutes of Health (NIH) system of funding investigator-initiated grant proposals soon became the main source of support for research in tropical medicine and parasitology (TMP) in the United States. Insect physiology came to be considered relevant to tropical medicine and parasitology following a Woods Hole Conference in 1978. Within 4 years, so many proposals of this kind were received that a separate ad hoc study section was formed to consider entomological proposals. Insect transgenesis came to be considered relevant to TMP following a Keystone Symposium in 1993. In 1994, the four main U.S. societies dealing with vector-borne pathogens passed resolutions requesting a narrower definition of TMP. The broadened definition held, however, and the ad hoc study section was divided once again in 2003 such that proposals containing a field component were excluded. Vector biology, thereafter, would be removed from TMP and considered in an epidemiological context. A Coolfont Symposium in 1982 distinguished public health entomology as taught in health-related institutions from that taught in departments of entomology in land-grant institutions and enumerated the faculty engaged in this work. Another survey, conducted in 2002, indicated that about half of these programs had been discontinued. An Institute of Medicine (IOM) conference in 2003 recommended that the U.S. "human resource capacity" in vector biology should be "rebuilt." Although the NIH system of investigator-initiated grants largely determines the characteristics of the faculty employed in health-related institutions, private donors and foundations may also influence hiring practices. The reemerging discipline of public health entomology should rest heavily on vector ecology, epidemiology, and microbiology. (This report summarizes a more detailed account published in the *Journal of Experimental Biology* [Spielman, 2003].)

Introduction

Malaria and dengue remain as major health burdens and as obstacles to economic development throughout much of the world's tropics, while Lyme disease and West Nile fever continue to emerge in many temperate regions. The growing level of annoyance caused by many diverse insects and ticks, of course, adds to the need for effective entomological interventions. The research activities that are appropriate for dealing with these problems focus primarily on vector ecology, but they also include epidemiology and population genetics, as well as aspects of insect physiology. Vector transgenics may, in the future, provide useful modalities. The research interests of the faculty serving in U.S. universities largely determine the characteristics of our scientific workforce, and the discussion that follows is designed to identify the forces that influence hiring practices for faculty engaged in public health entomology.

Discussion

Source of U.S. Research Funding

In teaching institutions in the United States, health-related positions for junior faculty are allocated largely on the basis of external funding. Such "soft" funding less critically defines faculty profiles in universities whose appointees receive their salaries from the various states. During the second half of the 20th century, therefore, the administrations of schools of public health and of medicine increasingly designed their faculties around the "investigator-initiated" system of research grants awarded by the National Institutes of Health, and the "RO1" system of grants served largely as the engine of faculty growth. Today, job descriptions continue to be composed mainly around this perception. Before 1982, proposals relating to vector-associated disease were reviewed by the members of the Tropical Medicine and Parasitology Study Section of the National Institute of Allergy and Infectious Disease (NIAID). The entire gamut of relevant disciplines was considered by this group of experts in entomology, microbiology, vaccinology, and other disciplines.

Developments Following the Woods Hole Conference of 1978

Entomological review was separated from the regular TMP Study Section in 1982, in the wake of the development of the first hormonomimetic insecticides and the landmark meeting of this committee in 1978 in Woods Hole, MA. The meeting was inspired by the research accomplishments of the noted insect physiologist Carroll Williams, who spoke of the "third generation of insecticides" that was then being developed. The sense of this meeting held that although funding for insect physiology had previously derived largely from the National Science Foundation, any research effort pertaining to the physiology of insects should now be considered relevant to tropical medicine or parasitology. The NIAID accepted this recommendation and agreed to consider such proposals. Many proposals subsequently were submitted, and they were reviewed by the TMP Study Section as a whole. Some of the proposals in insect physiology were funded, and this encouraged additional submissions, which, in turn, required the assignment of reviewers who specialized in insect physiology. Within 4 years, so many basic physiological proposals were submitted that a new ad hoc committee was formed to evaluate all proposals requiring entomological attention. Epidemiological and parasitological applications of entomology, as well as certain arbovirological proposals, were thereupon separated from the health-related sciences and placed in a context that included basic insect physiology. The composition of this standing committee thereafter evolved to match the proposals that were submitted, a situation that would necessarily tend to favor subjects familiar to the members of the committee.

By 1994, the effect of this separation of entomology from health was such that the community of public health entomologists in the United States became alarmed. Led by George Craig, the various societies that were most directly concerned with tropical health addressed resolutions to the NIH director, requesting corrective action. These societies included the American Society of Tropical Medicine and Hygiene, the Entomological Society of America, the Society of Vector Ecology, and the American Mosquito Control Association. The societies pointed out that 93 percent of the 56 grants in vector biology that were funded in 1993 dealt with fundamental insect physiology or molecular genetics, and that their principle investigators mainly were associated with experimental research rather than with tropical medicine or medical entomology. Within a decade after this ad hoc study section became a separate unit, virtually all NIAID-funded work on vector-associated disease would then have been conducted entirely at the bench. No analysis of previous funding patterns was provided.

Developments Following the Keystone Conference of 1998

American scientists concerned with vector-associated infections began to employ molecular techniques during the late 1980s; the first symposium on that subject was held at the annual meeting of the American Society of Tropical Medicine and Hygiene in 1986. It examined the idea that the pathogen competence of a vector population might be reduced by releasing transposon-favored, transgenically incompetent mosquitoes. None of the speakers were, themselves, engaged in work on vector arthropods. That situation soon changed. Numerous vector-related projects soon focused largely on molecular genetics. Indeed, 22 of the 53 titles that comprised the 1998 Keystone Symposium on transgenesis, titled "Toward the Genetic Manipulation of Insects," dealt with mosquitoes or kissing bugs (James et al., 1998). The expertise of three of the five conference organizers derived largely from their research accomplishments with mosquitoes. This influential symposium was the second in a continuing series of such events that were funded by the John D. and Catherine T. MacArthur Foundation and attended by members of various granting agencies. The sequencing of the genomes of *Plasmodium falciparum* (Gardner et al., 2002) and *Anopheles gambiae* (Holt et al., 2002) and the ongoing NIAID-funded effort to sequence that of *Aedes aegypti* have greatly facilitated such work. The creation of an insect that might be released in nature and that would transmit particular useful genes to a disproportionate fraction of its offspring became the goal of many research efforts.

The self-generating dynamic that followed the acceptance of insect physiology by the TMP Study Section in 1978 operated once again in 1998. The many proposals relating to molecular genetics that were submitted to the ad hoc medical entomology panel, soon designated as an "Ad Hoc Special Emphasis Panel," required appropriate reviewers' expertise. Members of a review panel would naturally tend to favor proposals in their own discipline. Such a shift in membership encouraged the submission of more proposals of this nature, and the more molecular proposals that were submitted and funded, the more the membership shifted. In a session held in 2002, for example, 17 of the 20 members were themselves engaged exclusively in experimental research performed in the laboratory. This process accelerated into 2003 when the Ad Hoc Special Emphasis Panel was divided, much as the original Tropical Medicine and Parasitology Study Section was divided in 1982. All entomological proposals that included a field component were thereupon removed to an epidemiological study section, then operating within the NIAID.

Sources of Research Funding

The NIAID program of investigator-initiated grants in tropical medicine and parasitology was augmented in 1980 by a system of tropical disease research units that originally was designed to support overseas work on the five parasitoses selected by the World Health Organization (WHO) and expanded in 1995. These "program grants" include several discrete "projects," and they generally are based in a tropical site. Although few in number, these university-based programs continue to provide first-rate employment and training opportunities for people engaged in research on vector-borne infections.

Supplemental funding opportunities have been provided since 1982 by the Small Business Innovation Research Program (SBIR), which is designed to encourage small U.S. businesses to develop innovative products in conjunction with the academic scientific community. Various governmental agencies contributed more than $1 billion during 2002 to this program. A complementary program, known as the Small Business Technology Transfer Program (STTR), expanded support for these academic–entrepreneurial links, and contributed nearly $100 million more during 2002. Although health expenditures would have comprised only a fraction of these totals, the financial incentives would be considerable. Except for efforts devoted to bioterrorism, it seems unlikely that these programs would be sufficiently reliable to serve as stimuli for the creation of academic appointments.

The NIH's system of training grants has long provided crucial support to many generations of students interested in vector-associated disease. The NIAID program is designated mainly for U.S. nationals, and the program conducted by the Fogarty International Institute is mainly for foreign scientists. Although both programs support students, neither provides faculty salaries. The federal Centers for Disease Control and Prevention (CDC) recently initiated a system of training grant awards in public health entomology, and it now awards research contracts in response to particular emerging infections. These training programs and occasional research efforts do little to stimulate faculty hiring.

The United States military was an important source of extramural funding for research in vector-associated disease during the 1970s. The military-funded, investigator-initiated proposals, much as those considered under NIH's RO1 system, supplied funds according to the opinions of an Ad Hoc Study Group on Medical Entomology of the Walter Reed Army Institute of Research. This panel operated in the pattern of an NIH study section. That program, however, was too small to influence staffing patterns in the U.S. university system, and it ended during the middle 1980s. Particular projects on such vector-borne "select agents" as those responsible for tularemia and eastern equine encephalitis have been funded by the Defense Advanced Research Projects Agency. But this source of funding, too, is small and potentially short-lived and may not influence university hiring practices. The various Naval Medical Research Units also maintain overseas laboratories that conduct research projects devoted to vector-borne infection. Grants from the National Oceanic and Atmospheric Administration support faculty engaged in research on the distribution of these infections.

The U.S. Agency for International Development (USAID) became a major granting agency in 1963, in the wake of the failure of the worldwide effort to eradicate malaria. Although malariological research was discouraged during the eradication effort, 5 percent of all operational funds were designated for research after the effort was abandoned. An audit of the program, conducted in 1983, described a $125 million general research fund that had been awarded since 1963 (GAO, 1982). Of this, the $26.5 million that had been spent was devoted mainly to academic research on drug and vaccine development. Robert Desowitz's book *Malaria Capers* (1993), however, described the sadly disappointing nature of this research effort. USAID's subsequent program of "environmental impact evaluation" provided opportunity for numerous university faculty to gain important experience in the epidemiology of infectious disease, but provided little salary support. Such "nonacademic" units as Harvard University's Institute for International Development once devoted important resources to the central administration of that institution, but generated few new teaching faculty. The personnel were recently transferred to Boston University. The National Science Foundation also awards relevant funds. Although certain of the non-health-related U.S. governmental agencies provide some support for university faculty, their impact on university hiring practices seems slight.

Funds from the U.S. Department of Agriculture (USDA) largely shape the faculties of U.S. land-grant institutions. Faculty at these state universities draw their salaries as a line item in each state's budget, and many of them also acquire research funding from federal "Hatch" funds. Until recently, these universities produced many of the medical entomologists employed by public health agencies and universities. The entomological orientation of the land-grant programs has been uniquely strong, and the departments of entomology in the United States tend to be located in such institutions. This element of financial permanence largely insulates the faculties of land-grant colleges from peer-generated pressures on their faculty profiles. Although NIAID funding supplements their basic agriculture-oriented sources, the faculty profiles of the land-grant schools tend to respond less directly to public health requirements than do those of schools of medicine or of public health.

Various foundations have long played an important part in funding research efforts relevant to vector-borne infection. The Rockefeller Foundation, of course, contributed much fundamental knowledge during the early part of the 20th century. The MacArthur Foundation's program has focused narrowly on molecular biology, as has the program of the Burroughs Wellcome Fund. The Bill & Melinda Gates Foundation has entered this field of endeavor with a system of unusually large donations. A multimillion-dollar gift to the London School of Tropical Medicine has permitted that institution to transform its malaria activities with a multifaceted program of research. An even larger gift to the Johns Hopkins Bloomberg School of Public Health, from another anonymous source, permitted that school to expand its malaria program. New faculty members appear to have been recruited in response to both of these gifts. The Gates Foundation has recently requested suggestions for a grand malariological challenge, and we await the result. This effort, too, seems likely to increase the number of scientists engaged in research on vector-borne infection. Although foundation support now tends to be directed toward narrow "cutting-edge" goals, such funds have been sufficiently generous and sustained since the early 1990s to influence faculty hiring patterns.

Antimalaria interventions recommended by the Roll Back Malaria program of the WHO and its partner agencies seek to halve the burden of malaria during the first decade of the millennium, and to halve it once again by 2015, by "scaling up" the application of these techniques. Only limited operational research is conducted, and progress has not yet been reported. The United Nations recently launched a Millennium Development Goals program for reducing poverty in the developing world, and one component of this program is concerned with developing antimalaria strategies. The role of research in this developing strategic formulation is yet to be defined.

Changes in Vector-Related Activities in U.S. Universities

A comprehensive review of the status of training and research in public health entomology was conducted in 1982 as part of the Coolfont Symposium, which was organized by the National Research Council and included participants from various universities, diverse laboratories, the military, federal and multilateral granting agencies, and various foundations. Questionnaires were submitted to 28 schools of medicine, schools of public health, departments of biology, and departments of entomology that were identified as potential sources of training in disciplines that pertained to the transmission of vector-associated disease. The 24 institutions that responded listed 63 relevant faculty, and about half of the respondents had only 1 faculty member. Of those responding, 17 had teaching programs that included some field-related component; but only 7 had overseas components.

Characteristics of the different programs that were identified are instructive. Because faculty in the seven land-grant institutions draw their salaries from their state coffers, they tend to design their research and teaching programs around local needs. The training programs of these institutions focused on the biology of the vectors themselves, and none included course work in epidemiology or pathogenesis. A few programs included virological components. Conversely, the seven health-oriented institutions emphasized course work pertinent to the burden of human disease while downplaying entomological subjects. The salaries of these health-related faculty were then, as now, notoriously soft, deriving mainly from external sources, a fact that induces the faculty to cast a broad net in their search for grant support. Overseas activities play a large part in their endeavors. The three responding departments of biology were housed in private institutions. Their programs and research orientation differed. One department, at Notre Dame University, trained a large fraction of the medical entomologists of the time and focused on the biology and genetics of mosquitoes. Some seven doctoral-level vector biologists had been graduating from these diverse U.S. institutions each year. In general, the respondents suggested that the growth of their programs was less dynamic than in the recent past.

A smaller but comparable survey of U.S. training opportunities in public health entomology was conducted in 2002 by Walter Tabachnick at the request of the American Mosquito Control Association (personal communication). He found that 12 universities had active doctoral-level programs in the subject and that they employed 33 relevant faculty. These instructors had been producing some nine doctoral graduates in vector biology per year since 1998. A simple comparison of the Coolfont and Tabachnick surveys suggests that nearly half of the relevant programs may have been discontinued during the past 2 decades, and that the extant programs employed only half as many faculty as in 1982. Surprisingly, no diminution in doctoral graduates was evident.

Transgenesis came to dominate vector-oriented studies beginning in 1993, when a series of notable research findings was published (Aldhous, 1993). As practiced, these research efforts generally include no field component. The Special Program for Research and Training in Tropical Diseases (jointly supported by the United Nations and several other international organizations), the MacArthur Foundation, and the Burroughs Wellcome Fund, modified their funding policies in 1993 such that future grants in this discipline would be devoted to attempts to create transgenic vector insects. Although the public health usefulness of such a mosquito was then controversial (Spielman, 1994) and still remains in doubt, an aura of excitement has increasingly come to surround vector transgenesis. The proportion of the faculty that Tabachnick surveyed who were engaged in this narrowly focused aspect of the study of vector-associated disease may be quite large. In general, then, fewer university faculty in the United States appear to be prepared to investigate the transmission of vector-borne pathogens than in the recent past. The magnitude of the investment in research in vector transgenics will affect this trend.

Conclusions

A panel recently convened by the Institute of Medicine recognized that the United States now lacks the capacity to confront the health threats posed by vector-borne pathogens (Institute of Medicine, 2003). The panel concluded that the Centers for Disease Control and Prevention, the Department of Defense (DOD), the National Institutes of Health, and the

Department of Agriculture "should work with academia, private organizations, and foundations to support efforts at rebuilding the human resource capacity at both academic centers and public health agencies in the relevant sciences—such as medical entomology, vector and reservoir biology, vector and reservoir ecology, and zoonoses—necessary to control vector-borne and zoonotic diseases."

These diverse federal agencies differ in their faculty-enhancing policies. In the past, only the NIH had sufficient resources and a commitment to investigator-initiated research to affect staffing decisions at health-related and private U.S. institutions. The influence of the USDA mainly affects land-grant institutions, and staffing decisions there respond largely to the interests of their respective state legislatures. The departments of entomology in these institutions, therefore, tend to be shaped by local interests. Funding by the CDC and the DOD has been much lower than that of the NIH, and their funds have been directed toward narrowly defined goals that have changed as the perceived need has changed. The National Science Foundation, which was not included in the IOM recommendation, at least until recently, has tended to fund basic rather than health-related research. The CDC, the DOD, and the USDA employ vector-related health scientists, but without stimulating the faculty appointments that result in their production. Therefore, the human resource capacity at U.S. universities that might be capable of dealing with vector-related issues in health would depend largely on the system of generous investigator-initiated research that resides at the NIH.

The IOM recommendation cited above omits reference to the contribution of private foundations to the human resource capacity of U.S. academe. The Gates Foundation and the Burroughs Wellcome Fund seem likely to play an important role in this dynamic. The funding policies that they pursue in the immediate future may encourage faculty to engage in insect transgenesis, insect physiology, or research relating to transmission of pathogens.

Changes in the NIH system of proposal review may impose novel constraints on health-related research on vectors conducted by the faculty of U.S. universities in the immediate future. Investigator-initiated proposals might be evaluated at the NIH in an epidemiological context in place of the biological milieu that pertained in the recent past, and the research tradition of at least some of the authors of these proposals will differ fundamentally from that of their reviewers. Faculty working in land-grant institutions, in particular, may not readily be able to address reviewers whose research tradition focuses on numerical rather than experimental applications. In addition, many of the reviewers of proposals dealing with vector transgenics will, themselves, be practitioners of that discipline. Authors of research proposals that pursue aspects of insect physiology may also find themselves at a disadvantage. These developments seem likely to increase the numbers of funded research proposals that approach vector biology from the tradition of molecular biology. The administrators of U.S. schools of public health and of medicine, therefore, would feel constrained to plan their staffing policies accordingly.

A cohort of scientists is required who can usefully produce the next generation of public health entomologists and whose research activities will promote that goal. Their programs will strike some balance between the three entomological interests that have vied for support during the past half century—vector biology, insect physiology, and molecular biology—and their work should incorporate strong epidemiological features. Because faculty-hiring priorities are determined so strongly by the NIH system of investigator-initiated grants, a major responsibility in this regard falls on that federal agency. Participation by foundations and private donors may contribute powerfully to the outcome of this process. The characteristics of the evolving discipline of public health entomology remain to be defined.

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Appendix B

Workshop Agenda

FORUM ON EMERGING INFECTIONS

Institute of Medicine, Board on Global Health
The National Academies

ENSURING AN INFECTIOUS DISEASE WORKFORCE: EDUCATION AND TRAINING NEEDS FOR THE 21ST CENTURY

June 12–13, 2003
NAS Lecture Room
2101 Constitution Ave, NW
Washington, DC

Thursday, June 12, 2003

8:30 AM **Continental Breakfast**

9:00 AM **Welcome and Opening Remarks**
Adel Mahmoud, Forum Chair

9:15 AM **Responding to the 2003 IOM Report:**
Microbial Threats to Health in the 21st Century
Joshua Lederberg, Professor Emeritus and Sackler Foundation Scholar, The Rockefeller University
Gail Cassell, Vice President, Scientific Affairs and Distinguished Lilly Research Scholar in Infectious Diseases, Eli Lilly and Company
Adel Mahmoud, President, Merck Vaccines
Frederick Sparling, Professor, Medicine & Microbiology & Immunology, University of North Carolina

10:15 AM **Break**

Session I: Exploring the Spectrum of the Research Workforce

Moderator: Joshua Lederberg, Rockefeller University

10:30 AM **Bridge Building between Medicine and Basic Science: The Role of the Physician–Scientist**
Donald Ganem (videoconference), Department of Microbiology and Immunology, University of California, San Francisco

11:00 AM **What Kinds of Scientists Do We Need to Train, and How?: Workforce Issues for Infectious Disease Research**
Victoria McGovern, Burroughs-Wellcome Fund

11:45 AM **Training Ph.D.s to Translate Science to Clinical Medicine**
Martha Gray, Division of Health Sciences and Technology, Massachusetts Institute of Technology

12:30 PM **Lunch**

Session II: Panel Discussion—The Implications of VISA and Select Agent Research Restrictions

Moderator: Stanley Lemon, University of Texas Medical Branch, Galveston

1:30 PM **Melissa Flagg,** Office of the Science and Technology Adviser to the Secretary, U.S. Department of State
Alan Barrett, University of Texas Medical Branch, Galveston
Ronald Atlas, University of Louisville, and President, American Society of Microbiology

2:30 PM **Break**

Session III: Panel Discussion—Fields of Special Emphasis

Moderator: Carole Heilman, National Institute of Allergy and Infectious Diseases, NIH

2:45 PM **Vaccinology,** Stanley Plotkin, Aventis Pasteur
Cross-disciplinary Research, James Cassatt, NIGMS, NIH
Vector Biology/Entomology, Andrew Spielman, Harvard SPH and Frank Collins, University of Notre Dame
Veterinary Public Health, Lonnie King, College of Veterinary Medicine, Michigan State University

5:00 PM **Adjourn/ Reception** (Garden Terrace)

Friday, June 13, 2003

8:30 AM **Continental Breakfast**

9:00 AM **Opening Remarks: Stanley Lemon,** Forum Vice-Chair

Session IV: Exploring the Spectrum of the Public Health Workforce

9:15 AM **The Public Health Workforce**
Kristine Gebbie, Center for Health Policy, Columbia University

9:45 AM **Reuniting Schools of Public Health and Public Health Practice**
Margaret Potter, Graduate School of Public Health, University of Pittsburgh

10:15 AM **New Skills for a New Age: Leading the Introduction of Public Health Concepts in Healthcare Curricula**
Walid El Ansari (videoconference), School of Health and Social Care, Oxford Brookes University, UK

Session V: Panel Discussion, Fields of Special Emphasis

Moderator: **Stephen Morse,** Mailman School of Public Health, Columbia University

10:45 AM **The ID Doc,** Gary Gorby, Omaha VA Medical Center
ID Epidemiologists/Training Allied Health Professionals, Trish Perl and Arjun Srinivasin, Johns Hopkins University Hospital
Training and Sustaining Laboratorians, Scott Becker, Association Public Health Laboratories and Janet Nicholson, National Center for Infectious Diseases, CDC

	Behavioral Scientists and Public Health, Youssef Tawfik, Johns Hopkins University, Center for Communication Programs **Bioethics, Genomics, and Public Health,** Abdullah Daar, University of Toronto
12:30 PM	**Lunch**

Session VI: Assessing Domestic and International Training Programs and Educational Needs

1:30 PM	**Does Leadership Training Make a Difference: The CDC/UC Public Health Leadership Institute** **Carol Woltring,** Center for Health Leadership & Practice, Public Health Institute, Oakland, CA
2:00 PM	**Educational Partnerships for Public Health: Do Stakeholders Perceive Similar Outcomes?** **Walid El Ansari** (videoconference), School of Health and Social Care, Oxford Brookes University, UK
2:30 PM	**Public Health Schools Without Walls** **Nancy Mock,** Tulane School of Public Health and Tropical Medicine, New Orleans, LA
3:00 PM	**Break**

Session VII: Panel Discussion—Addressing the Workforce Crisis in the Developing World

Moderator: Fred Sparling, University of North Carolina, Chapel Hill

3:15 PM	**Edward Elmendorf,** World Bank **Sharon Hrynkow,** Fogarty International Center, NIH **Sambe Duale,** Tulane School of Public Health and Tropical Medicine **Randall Culpepper,** DOD/GEIS, Walter Reed Army Institute of Research

Session VIII: Panel Discussion—Identifying Priorities for the Future

Moderator: Stanley Lemon, University of Texas Medical Branch, Galveston

4:15 PM **Queta Bond,** Burroughs Wellcome Fund
Richard Jackson, National Center Environmental Health, CDC
Matthew Boulton, State Epidemiologist, Michigan/University of Michigan
Eduardo Gotuzzo, Universidad Peruana Cayetano Heredia
Dennis Carroll, U.S. Agency for International Development

5:15 PM **Closing Remarks, Stanley Lemon**

Meeting Adjourns

Appendix C

Forum Member Biographies

STANLEY M. LEMON, M.D. (*Chair*), is the John Sealy Distinguished University Chair and Director of the Institute for Human Infections and Immunity at the University of Texas Medical Branch (UTMB) at Galveston. He received his undergraduate A.B. degree in biochemical sciences from Princeton University *summa cum laude*, and his M.D. with honor from the University of Rochester. He completed postgraduate training in internal medicine and infectious diseases at the University of North Carolina at Chapel Hill, and is board certified in both. From 1977 to 1983, he served with the U.S. Army Medical Research and Development Command, followed by a 14-year period on the faculty of the University of North Carolina School of Medicine. He moved to UTMB in 1997, serving first as Chair of the Department of Microbiology and Immunology, then as dean of the School of Medicine from 1999 to 2004. Dr. Lemon's research interests relate to the molecular virology and pathogenesis of positive-strand RNA viruses responsible for hepatitis. He has had a longstanding interest in antiviral and vaccine development, and has served previously as Chair of the Anti-Infective Drugs Advisory Committee and the Vaccines and Related Biologics Advisory Committee, of the U.S. Food and Drug Administration. He is the past Chair of the Steering Committee on Hepatitis and Poliomyelitis of the World Health Organization Programme on Vaccine Development. He presently serves as a member of the U.S. Delegation of the U.S.-Japan Cooperative Medical Sciences Program, and chairs the Board of Scientific Councilors of the National Center for Infectious Diseases of the Centers for Disease Control and Prevention. He is currently [2005] Co-chair of the Committee on Advances in Technology and the Prevention of their Application to Next Generation Biowarfare Threats for the National Academy of Sciences and recently chaired an Institute of Medicine study committee related to vaccines for the protection of the military against naturally occurring infectious disease threats.

P. FREDERICK SPARLING, M.D. (*Vice-Chair*), is J. Herbert Bate Professor Emeritus of Medicine, Microbiology and Immunology at the University of North Carolina (UNC) at Chapel Hill, and is Director of the North Carolina Sexually Transmitted Infections Research Center. Previously, he served as chair of the Department of Medicine and chair of the Department of Microbiology and Immunology at UNC. He was president of the Infectious Disease Society of America in 1996–1997. He was also a member of the Institute of Medicine's Committee on Microbial Threats to Health (1991–1992). Dr. Sparling's laboratory research is in the molecular biology of bacterial outer membrane proteins involved in pathogenesis, with a major emphasis on gonococci and meningococci. His current studies focus on the biochemistry and genetics of iron-scavenging mechanisms used by gonococci and meningococci and the structure and function of the gonococcal porin proteins. He is pursuing the goal of a vaccine for gonorrhea.

MARGARET A. HAMBURG, M.D. (*Vice-Chair*), is Vice President for Biological Programs at Nuclear Threat Initiative (NTI), a charitable organization working to reduce the global threat from nuclear, biological, and chemical weapons. Dr. Hamburg is in charge of the biological program area. Before taking on her current position, Dr. Hamburg was the Assistant Secretary for Planning and Evaluation, U.S. Department of Health and Human Services, serving as a principal policy advisor to the Secretary of Health and Human Services with responsibilities including policy formulation and analysis, the development and review of regulations and/or legislation, budget analysis, strategic planning, and the conduct and coordination of policy research and program evaluation. Prior to this, she served for almost six years as the Commissioner of Health for the City of New York. As chief health officer in the nation's largest city, Dr. Hamburg's many accomplishments included the design and implementation of an internationally recognized tuberculosis control program that produced dramatic declines in tuberculosis cases; the development of initiatives that raised childhood immunization rates to record levels; and the creation of the first public health bioterrorism preparedness program in the nation. She completed her internship and residency in Internal Medicine at the New York Hospital/Cornell University Medical Center and is certified by the American Board of Internal Medicine. Dr. Hamburg is a graduate of Harvard College and Harvard Medical School. She currently serves on the Harvard University Board of Overseers. She has been elected to membership in the

Institute of Medicine, the New York Academy of Medicine, and the Council on Foreign Relations, and is a Fellow of the American Association for the Advancement of Science and the American College of Physicians.

DAVID ACHESON, M.D., is Chief Medical Officer at the Center for Food Safety and Applied Nutrition, U.S. Food and Drug Administration (FDA). He received his medical degree at the University of London. After completing internships in general surgery and medicine, he continued his post-doctoral training in Manchester, England, as a Wellcome Trust Research Fellow. He subsequently was a Wellcome Trust Training Fellow in Infectious Diseases at the New England Medical Center and at the Wellcome Research Unit in Vellore, India. Dr. Acheson was Associate Professor of Medicine, Division of Geographic Medicine and Infectious Diseases, New England Medical Center until 2001. He then joined the faculties of the Department of Epidemiology and Preventive Medicine and Department of Microbiology and Immunology at the University of Maryland Medical School. Currently at the FDA, his research concentration is on foodborne pathogens and encompasses a mixture of molecular pathogenesis, cell biology, and epidemiology. Specifically, his research focuses on Shiga toxin-producing *E. coli* and understanding toxin interaction with intestinal epithelial cells using tissue culture models. His laboratory has also undertaken a study to examine Shiga toxin-producing *E. coli* in food animals in relation to virulence factors and antimicrobial resistance patterns. More recently, Dr. Acheson initiated a project to understand the molecular pathogenesis of *Campylobacter jejuni*. Other studies have undertaken surveillance of diarrheal disease in the community to determine causes, outcomes, and risk factors of unexplained diarrhea. Dr. Acheson has authored/co-authored over 72 journal articles, and 42 book chapters and reviews, and is coauthor of the book *Safe Eating* (Dell Health, 1998). He is reviewer of more than 10 journals and is on the editorial board of *Infection and Immunity* and *Clinical Infectious Diseases*. Dr. Acheson is a Fellow of the Royal College of Physicians, a Fellow of the Infectious Diseases Society of America, and holds several patents.

RUTH L. BERKELMAN, M.D., is the Rollins Professor and Director of the Center for Public Health Preparedness and Research at the Rollins School of Public Health, Emory University in Atlanta. She received her A.B. from Princeton University and her M.D. from Harvard Medical School. Board-certified in pediatrics and internal medicine, she began her career at the Centers for Disease Control and Prevention (CDC) in 1980, and later became Deputy Director of the National Center for Infectious Diseases. She also served as a Senior Advisor to the Director, CDC and Assistant Surgeon General in the U.S. Public Health Service. In 2001, she came to her current position at Emory University, directing a center focused on emerging infectious disease and other urgent threats to health, including terrorism. She has also consulted with the biologic program of the Nuclear Threat Initiative and is most recognized for her work in infectious diseases and disease surveillance. She was elected to the Institute of Medicine (IOM) in 2004. Currently a member of the IOM's Forum on Emerging Infections and the Board of Life Sciences of the National Academy of Science, she also chairs the Board of Public and Scientific Affairs at the American Society of Microbiology.

ENRIQUETA C. BOND, Ph.D., is President of the Burroughs Wellcome Fund. Dr. Bond received her undergraduate degree from Wellesley College, her M.A. from the University of Virginia, and her Ph.D. in molecular biology and biochemical genetics from Georgetown University. She is a member of the Institute of Medicine, the American Association for the Advancement of Science, the American Society for Microbiology, and the American Public Health Association. Dr. Bond serves on the Council of the Institute of Medicine as its vice-chair; she chairs the Board of Scientific Counselors for the National Center for Infectious Diseases at the Centers for Disease Control and Prevention; and she chairs the Institute of Medicine's Clinical Research Roundtable. She serves on the Board and Executive Committee of the Research Triangle Park Foundation, and on the Board of the Medicines for Malaria Venture. Prior to being named President of the Burroughs Wellcome Fund in 1994, Dr. Bond served on the staff of the Institute of Medicine since 1979, becoming the Institute's Executive Officer in 1989.

STEVEN J. BRICKNER, Ph.D., is Research Advisor, Antibacterials Chemistry, at Pfizer Global Research and Development. He received his Ph.D. in organic chemistry from Cornell University and was a National Institutes of Health NIH Postdoctoral Research Fellow at the University of Wisconsin-Madison. Dr. Brickner is a medicinal chemist with nearly 20 years of research experience in the pharmaceutical industry, all focused on the discovery and development of novel antibacterial agents. He is an inventor/co-inventor on 21 U.S. patents, and has published numerous scientific papers, primarily within the area of the oxazolidinones. Prior to joining Pfizer in 1996, he led a team at Pharmacia and Upjohn that discovered and developed linezolid, the first member of a new class of antibiotics to be approved in the last 35 years.

JOSEPH BRYAN, M.D., graduated from Oklahoma Christian College in 1974 and from the University of Oklahoma College of Medicine in 1979. After completing a residency in Internal Medicine at the Alton Ochsner Medical Foundation in New Orleans in 1982, he participated in clinical trials in Salvador, Brazil. He completed a research fellowship in central nervous system infections at the University of Virginia in July 1984. Dr. Bryan became an officer in the medical corps of the U.S. Navy in October 1984 and completed a fellowship in infectious diseases at the National Naval Medical Center in Bethesda, MD, in November 1986. Dr. Bryan served at the Uniformed Services University of the Health Sciences, conducting clinical trials and epidemiologic studies in Pakistan, Zambia, and Belize. In 1997, he became the Course Director for Military Tropical Medicine and participated in other tropical and preventive medicine courses through the Naval School of Health Sciences in Bethesda. In July 2000, Dr. Bryan joined the Office of Medical Services of the Department of State as a consultant in infectious diseases and tropical and travel medicine. He has been elected a Fellow in the American College of Physicians and Infectious Disease Society of America. He has published 39 peer-reviewed papers, nine invited articles, and one book chapter. He serves as an adjunct Professor at the Uniformed Services University.

NANCY CARTER-FOSTER, M.S.T.M., is Senior Advisor for Health Affairs for the U.S. Department of State, Assistant Secretary for Science and Health and the Secretary's Representative on HIV/AIDS. She is responsible for identifying emerging health issues and making policy recommendations for United States Government (USG) foreign policy concerns regarding international health, and coordinates the Department's interactions with the non-governmental community. She is a member of the Institute of Medicine's Forum on Infectious Diseases, the Infectious Diseases Society of America (IDSA), and the American Association of the Advancement of Science (AAAS). She has helped bring focus to global health issues in U.S. foreign policy and brought a national security focus to global health. In prior positions as Director for Congressional and Legislative Affairs for the Economic and Business Affairs Bureau of the U.S. Department of State, Foreign Policy Advisory to the Majority WHIP U.S. House of Representatives, Trade Specialist Advisor to the House of Representatives Ways and Means Trade Subcommittee, and consultant to the World Bank, Asia Technical Environment Division, Ms. Carter-Foster has worked on a wide variety of health, trade and, environmental issues, amassing in-depth knowledge and experience in policy development and program implementation.

GAIL H. CASSELL, Ph.D., is Vice President, Scientific Affairs, Distinguished Lilly Research Scholar for Infectious Diseases, Eli Lilly & Company. Previously, she was the Charles H. McCauley Professor and (since 1987) Chair, Department of Microbiology, University of Alabama Schools of Medicine and Dentistry at Birmingham, a department which, under her leadership, has ranked first in research funding from the National Institutes of Health since 1989. She is a member of the Director's Advisory Committee of the Centers for Disease Control and Prevention. Dr. Cassell is the past President of the American Society for Microbiology (ASM) and is serving her third three-year term as Chairman of the Public and Scientific Affairs Board of ASM. She is a former member of the National Institutes of Health Director's Advisory Committee and a former member of the Advisory Council of the National Institute of Allergy and Infectious Diseases. She has also served as an advisor on infectious diseases and indirect costs of research to the White House Office on Science and Technology and was previously Chair of the Board of Scientific Counselors of the National Center for Infectious Diseases, Centers for Disease Control and Prevention. Dr. Cassell served eight years on the Bacteriology-Mycology-II Study Section and served as its Chair for three years. She serves on the editorial boards of several prestigious scientific journals and has authored over 275 articles and book chapters. She has been intimately involved in the establishment of science policy and legislation related to biomedical research and public health. Dr. Cassell has received several national and international awards and an honorary degree for her research on infectious diseases.

MARK FEINBERG, M.D., Ph.D., is Vice President for Policy, Public Health and Medical Affairs in the Merck Vaccine Division of Merck & Co., Inc. He received a bachelor's degree magna cum laude from the University of Pennsylvania in 1978, and his M.D. and Ph.D. degrees from Stanford University School of Medicine in 1987. From 1985–1986, Dr. Feinberg served as a Project Officer for the Committee on a National Strategy for AIDS of the Institute of Medicine and the National Academy of Sciences. Following receipt of his M.D. and Ph.D. degrees, Dr. Feinberg pursued postgraduate residency training in Internal Medicine at the Brigham and Women's Hospital of Harvard Medical School and postdoctoral fellowship research in the laboratory of Dr. David Baltimore at the Whitehead Institute for Biomedical Research. From 1991–1995, Dr. Feinberg was an Assistant Professor of Medicine and Microbiology and Immunology at the University of California, San Francisco (UCSF), where he also served as an Attending Physician in the AIDS/Oncology Division and as Director of the Virology Research Laboratory at San Francisco General Hospital. From 1995–1997, Dr. Feinberg was a Medical Officer in the Office of AIDS Research in the Office of the Director of the National Institutes of Health, and Chair of the NIH Coordinating Committee on AIDS Etiology and Pathogenesis Research. During this period, he also served as Executive Secretary of the NIH Panel to Define Principles of Therapy of HIV Infection. Prior to joining Merck in 2004, Dr. Feinberg served as Professor of Medicine and Microbiology and Immunology at the Emory University School of Medicine, and as an Investigator at the Emory Vaccine Center. Dr. Feinberg also founded and served as the Medical Director of the Hope Clinic—a clinical research facility devoted to the clinical evaluation of novel vaccines and to translational research studies of human immune system biology. At UCSF and Emory, Dr. Feinberg and colleagues were engaged in the preclinical development and evaluation of novel vaccines for HIV and other infectious diseases, and in basic research studies focused on revealing fundamental aspects of host-virus relationships that underlie the pathogenesis of HIV and simian immunodeficiency virus (SIV) infections. In addition to his other professional roles, Dr. Feinberg has also served as a consultant to, and member of, several committees of the Institutes of Medicine and the National Academy of Sciences.

J. PATRICK FITCH, Ph.D., is Program Leader for Chemical and Biological National Security (CBNP) at the University of California, Lawrence Livermore National Laboratory (LLNL). CBNP is a $54M program (FY02) at LLNL with over 140 staff. CBNP activities include basic pathogen biology and materials sciences through to deployed operational systems for counter terrorism support. Previous to CBNP, Dr. Fitch led several different LLNL divisions including genomics, bioengineering, and engineering research. His research interests include bioinstrumentation, computer modeling of pathogen biology and host response, and medical devices. In addition to journal, conference and patent publications, Dr. Fitch has authored several books and book chapters including *An Engineering Introduction to Biotechnology* (SPIE Press, 2002). Dr. Fitch received a Ph.D. degree in Electrical Engineering from Purdue University in 1984 and B.S. degrees in Physics and in Engineering Science from Loyola College in 1981. Dr. Fitch is a Senior Member of the Institute of Electrical and Electronic Engineers (IEEE), Fellow of the American Society for Laser Medicine and Surgery, Member of the International Society for Optical Engineering (SPIE), Editorial Board Member of *Biomolecular Engineering,* Advisory Board Member for the College of Engineering at Colorado State University, and former Board Member of the California State Breast Cancer Research Program. He received an IEEE Best Paper Award for nonlinear digital signal processing in 1988, national Federal Laboratory Consortium for Technology Transfer (FLC) awards for medical devices in both 1998 and 1999, and the 2002 LLNL Science and Technology Award. Dr. Fitch also successfully developed and marketed a medical device business strategy to venture investors.

S. ELIZABETH GEORGE, Ph.D., is Deputy Director, Biological Countermeasures Portfolio Science & Technology Directorate, Department of Homeland Security. Dr. George serves as the Deputy Director of Biological Countermeasures in the Department of Homeland Security. Until merging into the new Department on March 1, 2003, Dr. George was the Program

Manager of the Chemical & Biological National Security Program in the Department of Energy's National Nuclear Security Administration's Office of Nonproliferation Research & Engineering. Significant accomplishments include the design and deployment of BioWatch, the nation's first civilian biological threat agent monitoring system and PROTECT, the first civilian operational chemical detection and response capability deployed in the Washington subway system. Previously she spent 16 years at the U.S. Environmental Protection Agency (EPA), Office of Research and Development, National Health and Ecological Effects Research Laboratory, Environmental Carcinogenesis Division, where she was Branch Chief of the Molecular and Cellular Toxicology Branch. She received her B.S. in Biology (1977) from Virginia Polytechnic Institute and State University and M.S. and Ph.D. in Microbiology (1979 and 1984) from North Carolina State University. She was a National Research Council Research Fellow (1984–1986) in the laboratory of Dr. Larry Claxton at the U.S. EPA. Dr. George is the 2005 Chair of the Chemical and Biological Terrorism Defense Gordon Research Conference. She has served as Councilor for the Environmental Mutagen Society and President and Secretary of the Genotoxicity and Environmental Mutagen Society. She holds memberships in the American Society for Microbiology and the American Association for the Advancement of Science and is an adjunct faculty member in the School of Rural Public Health, Texas A&M University. Dr. George is the recipient of the U.S. EPA Bronze Medal and Scientific and Technological Achievement Awards and Department of Homeland Security (DHS) Under Secretary's Award for Science and Technology. She is author on numerous journal articles and has presented her research at national and international meetings.

JESSE L. GOODMAN, M.D., M.P.H., was Professor of Medicine and Chief of Infectious Diseases at the University of Minnesota, and is now serving as Deputy Director for the U.S. Food and Drug Administration's (FDA) Center for Biologics Evaluation and Research, where he is active in a broad range of scientific, public health, and policy issues. After joining the FDA commissioner's office, he has worked closely with several centers and helped coordinate FDA's response to the antimicrobial resistance problem. He was Co-chair of a recently formed federal interagency task force which developed the national Public Health Action Plan on antimicrobial resistance. He graduated from Harvard College and attended the Albert Einstein College of Medicine followed by internal medicine, hematology, oncology, and infectious diseases training at the University of Pennsylvania and University of California, Los Angeles, where he was also chief medical resident. He received his master's of public health from the University of Minnesota. He has been active in community public health activities, including creating an environmental health partnership in St. Paul, Minnesota. In recent years, his laboratory's research has focused on the molecular pathogenesis of tickborne diseases. His laboratory isolated the etiological intracellular agent of the emerging tickborne infection, human granulocytic ehrlichiosis, and identified its leukocyte receptor. He has also been an active clinician and teacher and has directed or participated in major multi-center clinical studies. He is a Fellow of the Infectious Diseases Society of America and, among several honors, has been elected to the American Society for Clinical Investigation.

EDUARDO GOTUZZO, M.D., is Principal Professor and Director at the Instituto de Medicina Tropical "Alexander von Humbolt," Universidad Peruana Cayetan Heredia (UPCH), in Lima, Peru, as well as Chief of the Department of Infectious and Tropical Diseases at the Cayetano Heredia Hospital and Adjunct Professor of Medicine at the University of Alabama at Birmingham School of Medicine. Dr. Gotuzzo has proven to be an active member in numerous international societies such as President of the Latin America Society of Tropical Disease (2000–2003), Member of the Scientific Program of Infectious Diseases Society of America (2000–2003), Member of the International Organizing Committee of the International Congress of Infectious Diseases (1994–Present), President Elect of the International Society for Infectious Diseases (1996–1998), and President of the Peruvian Society of Internal Medicine (1991–1992). He has published over 230 articles and chapters, as well as six manuals and one book. Recent honors and awards include being named an Honorary Member of the American Society of Tropical Medicine and Hygiene (since 2002), Associated Member of the National Academy of Medicine (since 2002), Honorary Member of the Society of Internal Medicine (since 2000), Distinguished Visitor, Faculty of Medical Sciences, University of Cordoba, Argentina (since 1999), and the Golden Medal for "Outstanding Contribution in the Field of Infectious Diseases," awarded by the Trnava University, Slovakia (1998), among many others.

CAROLE A. HEILMAN, Ph.D., is Director of the Division of Microbiology and Infectious Diseases (DMID) of the National Institute of Allergy and Infectious Diseases (NIAID). Dr. Heilman received her bachelor's degree in biology from Boston University in 1972, and earned her master's degree and doctorate in microbiology from Rutgers University in 1976 and 1979, respectively. Dr. Heilman began her career at the National Institutes of Health as a postdoctoral research associate with the National Cancer Institute where she carried out research on the regulation of gene expression during cancer development. In 1986, she came to NIAID as the Influenza and Viral Respiratory Diseases Program Officer in DMID and, in 1988, she was appointed Chief of the Respiratory Diseases Branch where she coordinated the development of acellular pertussis vaccines. She joined the Division of AIDS as Deputy Director in 1997 and was responsible for developing the Innovation Grant Program for Approaches in HIV Vaccine Research. She is the recipient of several notable awards for outstanding achievement. Throughout her extramural career, Dr. Heilman has contributed articles on vaccine design and development to many scientific journals and has served as a consultant to the World Bank and WHO in this area. She is also a member of several professional societies, including the Infectious Diseases Society of America, the American Society for Microbiology, and the American Society of Virology.

DAVID L. HEYMANN, M.D., is currently the Executive Director of the World Health Organization (WHO) Communicable Diseases Cluster. From October 1995 to July 1998 he was Director of the WHO Programme on Emerging and Other Communicable Diseases Surveillance and Control. Prior to becoming director of this program, he was the Chief of Research Activities in the Global Programme on AIDS. From 1976 to 1989, prior to joining WHO, Dr. Heymann spent 13 years working as a medical epidemiologist in sub-Saharan Africa (Cameroon, Ivory Coast, the former Zaire, and Malawi) on assignment from the CDC in CDC-supported activities aimed at strengthening capacity in surveillance of infectious diseases and their control, with special emphasis on the childhood immunizable diseases, African hemorrhagic fevers, pox viruses, and malaria. While based in Africa, Dr. Heymann participated in the investigation of the first outbreak of Ebola in Yambuku (former Zaire) in 1976, then again investigated the second outbreak of Ebola in 1977 in Tandala, and in 1995 directed the international response to the Ebola outbreak in Kikwit. Prior to 1976, Dr. Heymann spent two years in India as a medical officer in the WHO Smallpox Eradication Programme. Dr. Heymann holds a B.A. from the Pennsylvania State University, an M.D. from Wake Forest University, and a Diploma in Tropical Medicine and Hygiene from the London School of Hygiene and Tropical Medicine, and completed practical epidemiology training in the Epidemic Intelligence Service (EIS) training program of the CDC. He has published 131 scientific articles on infectious diseases in peer-reviewed medical and scientific journals.

PHIL HOSBACH, Ph.D., is Vice President of New Products and Immunization Policy at Sanofi Pasteur. The departments under his supervision are new product marketing, state and federal government policy, business intelligence, bids and contracts, medical communications, public health sales, and public health marketing. His current responsibilities include oversight of immunization policy development. Mr. Hosbach acts as Sanofi Pasteur's principle liaison with CDC. Mr. Hosbach graduated from Lafayette College in 1984 with a degree in Biology. He has 20 years of pharmaceutical industry experience, including the last 17 years focused solely on vaccines. He began his career at American Home Products in Clinical Research in 1984. He joined Aventis Pasteur (then Connaught Labs) in 1987 as Clinical Research Coordinator and has held research and development positions of increasing responsibility, including Clinical Research Manager and Director of Clinical Operations. Mr. Hosbach also served as Project Manager for the development and licensure of Tripedia, the first diphtheria, tetanus, and acellular pertussis (DTaP) vaccine approved by FDA for use in U.S. infants. During his clinical research career at Aventis Pasteur, he contributed to the development and licensure of seven vaccines and has authored or co-authored several clinical research articles. From 2000 through 2002, Mr. Hosbach served on the Board of Directors for Pocono Medical Center, in East Stroudsburg, PA. Since 2003 he has actively served on the Board of Directors of Pocono Health Systems, which includes Pocono Medical Center.

JAMES M. HUGHES, M.D., received his B.A. in 1966 and M.D. in 1971 from Stanford University. He completed a residency in internal medicine at the University of Washington and a fellowship in infectious diseases at the University of Virginia. He is board-certified in internal medicine, infectious diseases, and preventive medicine. He first joined CDC as an Epidemic Intelligence Service officer in 1973. During his CDC career, he has worked primarily in the areas of foodborne disease and infection control in health care settings. He became Director of the National Center for Infectious Diseases in 1992. The center is currently working to address domestic and global challenges posed by emerging infectious diseases and the threat of bioterrorism. He is a member of the Institute of Medicine and a fellow of the American College of Physicians, the Infectious Diseases Society of America, and the American Association for the Advancement of Science. He is an Assistant Surgeon General in the Public Health Service.

STEPHEN JOHNSTON, Ph.D., is a Professor and Director at the University of Texas Southwestern Medical Center. A major focus of Dr. Johnston's lab has been technology development. His interest of late has been especially in the area of vaccine development. He was co-inventor with Dr. John Sanford of the hand-held, helium gene gun, and he and Dr. Sanford used the gene gun to first demonstrate gene (DNA) immunization. Genetic vaccines have revolutionized approaches to delivering and developing vaccines. In this regard, Johnston's group first published on a method, Expression Library Immunization, that offers a systematic approach to searching genomic information for new vaccines. His group has also developed techniques for discovering peptides that target specific cells and is employing this to create more effective, targeted vaccines. Through the Center for Biomedical Inventions, his group with collaborators in immunology, instrumentation, genomics, and chemistry is attempting to forge a fully integrated approach to developing the best methods for delivery and discovering vaccines.

GERALD T. KEUSCH, M.D., is Provost and Dean for Global Health at Boston University (BU) and BU School of Public Health. He is a graduate of Columbia College (1958) and Harvard Medical School (1963). After completing a residency in internal medicine, fellowship training in infectious diseases, and two years as an NIH Research Associate at the SEATO Medical Research Laboratory in Bangkok, Thailand, Dr. Keusch joined the faculty of Mt. Sinai School of Medicine in 1970, where he established a laboratory to study the pathogenesis of bacillary dysentery and the biology and biochemistry of Shiga toxin. In 1979, he moved to Tufts Medical School and New England Medical Center in Boston, to found the Division of Geographic Medicine, which focused on the molecular and cellular biology of tropical infectious diseases. In 1986, he integrated the clinical infectious diseases program into the Division of Geographic Medicine and Infectious Diseases, continuing as Division Chief until 1998. He has worked in the laboratory and in the field in Latin America, Africa, and Asia on basic and clinical infectious diseases and HIV/AIDS research. From 1998 to 2003 he was Associate Director for International Research and Director of the Fogarty International Center at the NIH. Dr. Keusch is a member of the American Society for Clinical Investigation, the Association of American Physicians, the American Society for Microbiology and the Infectious Diseases Society of America (IDSA). He is the recipient of the Squibb (1981), Finland (1997), and Bristol (2002) Awards of the IDSA. In 2002 he was elected to the Institute of Medicine of the National Academies.

LONNIE KING, D.V.M., is Dean of the College of Veterinary Medicine, Michigan State University. Dr. King's previous positions include both Associate Administrator and Administrator of the USDA Animal and Plant Health Inspection Service (APHIS) and Deputy Administrator for USDA/APHIS/Veterinary Services. Before his government career, Dr. King was in private practice. He also has experience as a field veterinary medical officer, station epidemiologist, and staff assignments involving Emergency Programs and Animal Health Information. Dr. King has also directed the American Veterinary Medical Association's Office of Governmental Relations, and is certified in the American College of Veterinary Preventive Medicine. He has served as President of the Association of American Veterinary Medicine Colleges, and currently serves as Co-Chair of the National Commission on Veterinary Economic Issues, Lead Dean at Michigan State University for food safety with responsibility for the National Food Safety and Toxicology Center, the Institute for Environmental Toxicology, and the Center for Emerging Infectious Diseases. He is also co-developer and course leader for Science, Politics, and Animal Health Policy. Dr. King received his B.S. and D.V.M. degrees from The Ohio State University, and his M.S. degree in epidemiology from the University of Minnesota. He has also completed the Senior Executive Program at Harvard University, and received a M.P.A. from American University. Dr. King previously served on the Committee for Opportunities in Agriculture, the Steering Committee for a Workshop on the Control and Prevention of Animal Diseases, and the Committee to Ensure Safe Food from Production to Consumption.

GEORGE KORCH, Ph.D., attended Boston University and earned a B.S. in biology in 1974, followed by post-graduate study in mammalian ecology at the University of Kansas from 1975–1978. He earned his Ph.D. from the Johns Hopkins School of Hygiene and Public Health in Immunology and Infectious Diseases in 1985, followed by post-doctoral experience at Johns Hopkins from 1985–1986. His area of training and specialty is the study of the epidemiology of zoonotic viral pathogens and in medical entomology. For the past 15 years, he has also engaged in research and program management for medical defense against biological pathogens used in terrorism or warfare.

JOSHUA LEDERBERG, Ph.D., is Professor Emeritus of Molecular Genetics and Informatics and Sackler Foundation Scholar at The Rockefeller University, New York, New York. His lifelong research, for which he received the Nobel Prize in 1958, has been in genetic structure and function in microorganisms. He has a keen interest in international health and was co-chair of a previous Institute of Medicine Committee on Emerging Microbial Threats to Health (1990–1992) and currently is co-chair of the Committee on Emerging Microbial Threats to Health in the 21st Century. He has been a member of the National Academy of Sciences since 1957 and is a charter member of the Institute of Medicine.

JOSEPH MALONE, M.D., the director of the Department of Defense Global Emerging Infection System (DoD-GEIS), completed the Centers for Disease Control and Prevention's Epidemic Intelligence Service (EIS) program in June, 2003. He graduated from Boston University School of Medicine in 1980, and trained in internal medicine and infectious diseases at Naval Hospitals in San Diego, and Bethesda, MD, leading to board certification. He was a staff physician at the Naval Hospitals in San Diego, CA, and Bethesda, MD. He deployed to Guantanamo Bay, Cuba, in support of Operation Safe Harbor and was attached to Surgical Team 1 during Operation Desert Shield. He later directed the Infectious Disease Division and HIV unit at the Naval Medical Center at Portsmouth, VA, from 1996–1996. In 1999 he worked for the Disease Surveillance Program (in affiliation with DoD-GEIS) at the U.S. Naval Medical Research Unit No. 3 in Cairo, Egypt. While at CDC's EIS program he was deployed to New York City to assist in the emergency public health response after the September 11, 2001, attacks, assisted in the public health response to documented anthrax contamination in Kansas City, and was the acting state epidemiologist for the State of Missouri from February–June 2003. CAPT Malone has several military awards, including the Department of Health and Human Services (HHS)/ U.S. Public Health Service (USPHS) Crisis Response Service Award. He is an Associate Professor at the Uniformed Services University of Health Sciences and holds the Certificate of Knowledge in Travelers' Health and Tropical Medicine from the American Society of Tropical Medicine and Hygiene. He has over 20 publications.

LYNN MARKS, M.D., is board-certified in internal medicine and infectious diseases. He was on faculty at the University of South Alabama College of Medicine in the Infectious Diseases department focusing on patient care, teaching, and research. His academic research interest was on the molecular genetics of bacterial pathogenicity. He subsequently joined SmithKline Beecham's (now GlaxoSmithKline) anti-infectives clinical group and later progressed to Global Head of the Consumer Healthcare division of the Medical and Regulatory group. He then returned to pharmaceutical research and development as Global Head of the Infectious Diseases Therapeutic Area Strategy Team for GlaxoSmithKline.

STEPHEN S. MORSE, Ph.D., is Director of the Center for Public Health Preparedness at the Mailman School of Public Health of Columbia University, and a faculty member in the Epidemiology Department. Dr. Morse recently returned to Columbia from four years in government service as Program Manager at the Defense Advanced Research Projects Agency (DARPA), where he co-directed the Pathogen Countermeasures program and subsequently directed the Advanced Diagnostics program. Before coming to Columbia, he was Assistant Professor (Virology) at The Rockefeller University in New York, where he remains an adjunct faculty member. Dr. Morse is the editor of two books, *Emerging Viruses* (Oxford University Press, 1993; paperback, 1996) (selected by *American Scientist* for its list of "100 Top Science Books of the 20th Century"), and *The Evolutionary Biology of Viruses* (Raven Press, 1994). He currently serves as a Section Editor of the CDC journal *Emerging Infectious Diseases* and was formerly an Editor-in-Chief of the Pasteur Institute's journal *Research in Virology*. Dr. Morse was Chair and principal organizer of the 1989 NIAID/NIH Conference on Emerging Viruses (for which he originated the term and concept of emerging viruses/infections); served as a member of the IOM's Committee on Emerging Microbial Threats to Health (and chaired its Task

Force on Viruses), and was a contributor to its report, *Emerging Infections* (1992); was a member of the IOM's Committee on Xenograft Transplantation; currently serves on the Steering Committee of the IOM's Forum on Emerging Infections; and has served as an adviser to WHO, the Pan-American Health Organization (PAHO), FDA, the Defense Threat Reduction Agency (DTRA), and other agencies. He is a Fellow of the New York Academy of Sciences and a past Chair of its Microbiology Section. He was the founding Chair of ProMED (the nonprofit international Program to Monitor Emerging Diseases) and was one of the originators of ProMED-mail, an international network inaugurated by ProMED in 1994 for outbreak reporting and disease monitoring using the Internet. Dr. Morse received his Ph.D. from the University of Wisconsin-Madison.

MICHAEL T. OSTERHOLM, Ph.D., M.P.H., is Director of the Center for Infectious Disease Research and Policy at the University of Minnesota where he is also Professor at the School of Public Health. Previously, Dr. Osterholm was the state epidemiologist and Chief of the Acute Disease Epidemiology Section for the Minnesota Department of Health. He has received numerous research awards from the National Institute of Allergy and Infectious Diseases and the CDC. He served as principal investigator for the CDC-sponsored Emerging Infections Program in Minnesota. He has published more than 240 articles and abstracts on various emerging infectious disease problems and is the author of the best selling book*, Living Terrors: What America Needs to Know to Survive the Coming Bioterrorist Catastrophe*. He is past president of the Council of State and Territorial Epidemiologists. He currently serves on the IOM's Forum on Emerging Infections. He has also served on the IOM Committee on Food Safety, Production to Consumption and the IOM Committee on the Department of Defense Persian Gulf Syndrome Comprehensive Clinical Evaluation Program, and as a reviewer for the IOM report on chemical and biological terrorism.

GEORGE POSTE, Ph.D., D.V.M., is Director of the Arizona Biodesign Institute and Dell E. Webb Distinguished Professor of Biology at Arizona State University. From 1992 to 1999 he was Chief Science and Technology Officer and President, Research and Development of SmithKline Beecham (SB). During his tenure at SB he was associated with the successful registration of 29 drug, vaccine, and diagnostic products. He is Chairman of diaDexus and Structural GenomiX in California and Orchid Biosciences in Princeton. He serves on the Board of Directors of AdvancePCS and Monsanto. He is an advisor on biotechnology to several venture capital funds and investment banks. In May 2003 he was appointed as Director of the Arizona Biodesign Institute at Arizona State University. This is a major new initiative combining research groups in biotechnology, nanotechnology, materials science, advanced computing and neuromorphic engineering. He is a Fellow of Pembroke College Cambridge and Distinguished Fellow at the Hoover Institution and Stanford University. He is a member of the Defense Science Board of the U.S. Department of Defense and in this capacity he Chairs the Task Force on Bioterrorism. He is also a member of the National Academy of Sciences Working Group on Defense Against Bioweapons. Dr. Poste is a Board-Certified Pathologist, a Fellow of the Royal Society, and a Fellow of the Academy of Medical Sciences. He was awarded the rank of Commander of the British Empire by Queen Elizabeth II in 1999 for services to medicine and for the advancement of biotechnology. He has published over 350 scientific papers, co-edited 15 books on cancer, biotechnology, and infectious diseases, and serves on the Editorial Board of multiple technical journals. He is invited routinely to be the keynote speaker at a wide variety of academic, corporate, investment, and government meetings to discuss the impact of biotechnology and genetics on healthcare and the challenges posed by bioterrorism. Dr. Poste is married with three children. His personal interests are in military history, photography, automobile racing, and exploring the wilderness zones of the American West.

DAVID A. RELMAN, M.D., is an Associate Professor of Medicine (infectious diseases and geographic medicine) and of Microbiology and Immunology at Stanford University School of Medicine, Stanford, California, and chief of the Infectious Diseases Section at the Veterans Affairs Palo Alto Health Care System, Palo Alto, California. Dr. Relman received his B.S. in biology from Massachusetts Institute of Technology, Cambridge, Massachusetts, and his M.D. from Harvard Medical School. He completed his residency in internal medicine and a clinical fellowship in infectious diseases at Massachusetts General Hospital, Boston, after which he moved to Stanford as a research fellow and postdoctoral scholar. He joined the Stanford faculty in 1994. His major focus is laboratory research directed toward characterizing the human endogenous microbial flora, host-microbe interactions, and identifying previously-unrecognized microbial pathogens, using molecular and genomic approaches. He has described a number of new human microbial pathogens. Dr. Relman's lab (http://relman. stanford.edu) is currently exploring human oral and intestinal microbial ecology, sources of variation in host genome-wide expression responses to infection and during states of health, and how *Bordetella* species (including the agent of whooping cough) cause disease. He has published over 150 peer-reviewed articles, reviews, editorials, and book chapters on pathogen discovery and bacterial pathogenesis. Dr. Relman has served on scientific program committees for the American Society for Microbiology (ASM) and the Infectious Diseases Society of America, and advisory panels for National Institutes of Health (NIH), CDC, the Departments of Energy and Defense, and National Aeronautics and

Space Administration (NASA). He is currently (2005) co-chair of the Committee on Advances in Technology and the Prevention of their Application to Next Generation Biowarfare Threats for the U.S. National Academy of Sciences. He is a member of the Board of Directors of the IDSA and the Board of Scientific Counselors at National Institute of Dental and Craniofacial Research (NIDCR)/NIH. He received the Squibb Award from IDSA in 2001, the Senior Scholar Award in Global Infectious Diseases from the Ellison Medical Foundation in 2002, and is a Fellow of the American Academy of Microbiology.

GARY A. ROSELLE, M.D., received his M.D. from Ohio State University School of Medicine in 1973. He served his residency at Northwestern University School of Medicine and his Infectious Diseases fellowship at the University of Cincinnati School of Medicine. Dr. Roselle is the Program Director for Infectious Diseases for the Veterans Affairts (VA) Central Office in Washington, D.C., as well as the Chief of the Medical Service at the Cincinnati VA Medical Center. He is a Professor of Medicine in the Department of Internal Medicine, Division of Infectious Diseases at the University of Cincinnati College of Medicine. Dr. Roselle serves on several national advisory committees. In addition, he is currently heading the Emerging Pathogens Initiative for the Department of Veterans Affairs. Dr. Roselle has received commendations from the Cincinnati Medical Center Director, the Under Secretary for Health for the Department of Veterans Affairs, and the Secretary of Veterans Affairs for his work in the infectious diseases program for the Department of Veterans Affairs. He has been an invited speaker at several national and international meetings and has published over 80 papers and several book chapters.

ANNE SCHUCHAT, M.D., joined the Centers for Disease Control and Prevention in 1988 as an Epidemic Intelligence Service officer in the Meningitis and Special Pathogens Branch within the Division of Bacterial and Mycotic Diseases (DBMD), National Center for Infectious Diseases (NCID). She also served as the initial medical director of the Active Bacterial Core surveillance (ABCs)/Emerging Infections Program Network. She became Chief of the DBMD Respiratory Diseases Branch in 1988, where she remained until becoming Acting Director of the National Center for Infectious Diseases in 2005. She joined colleagues from across the agency during emergency response activities for the 2001 anthrax bioterrorism response and the 2003 SARS outbreak, where she headed the Beijing City epidemiology team for the World Health Organization (WHO) China Office. Dr. Schuchat has made critically important contributions to prevention of group B streptococcal disease, evaluation of foodborne listeriosis, evaluation of Neisseria meningitidis, Haemophilus influenzae, and Streptococcus pneumoniae vaccines. She has mentored dozens of EIS officers and others at CDC, and has worked closely with WHO, FDA, NIH, USAID, and IDSA on a number of infectious disease and prevention issues. Dr. Schuchat graduated with Highest Honors from Swarthmore College and with Honors from Dartmouth Medical School. She served as Resident and Chief Resident in Internal Medicine at New York University's Manhattan VA Hospital before beginning her public health career at the CDC.

JANET SHOEMAKER, is Director of the American Society for Microbiology's Public Affairs Office, a position she has held since 1989. She is responsible for managing the legislative and regulatory affairs of this 42,000-member organization, the largest single biological science society in the world. She has served as principal investigator for a project funded by the National Science Foundation (NSF) to collect and disseminate data on the job market for recent doctorates in microbiology and has played a key role in American Society for Microbiology projects, including the production of the ASM *Employment Outlook in the Microbiological Sciences* and *The Impact of Managed Care and Health System Change on Clinical Microbiology*. Previously, she held positions as Assistant Director of Public Affairs for ASM, as ASM coordinator of the U.S./U.S.S.R. Exchange Program in Microbiology, a program sponsored and coordinated by the National Science Foundation and the U.S. Department of State, and as a freelance editor and writer. She received her baccalaureate, cum laude, from the University of Massachusetts, and is a graduate of the George Washington University programs in public policy and in editing and publications. She has served as Commissioner to the Commission on Professionals in Science and Technology, and as the ASM representative to the ad hoc Group for Medical Research Funding, and is a member of Women in Government Relations, the American Society of Association Executives, and the American Association for the Advancement of Science. She has co-authored published articles on research funding, biotechnology, biological weapons control, and public policy issues related to microbiology.

TERENCE TAYLOR, is President and Executive Director of the International Institute for Strategic Studies-US (IISS-US). He is also Assistant Director of the IISS in London. He studies international security policy, risk analysis, scientific and technological developments and their impact on political and economic stability worldwide. He is one of the Institute's leading experts on issues associated with nuclear, biological, and chemical weapons and their means of delivery. He has a particular responsibility for IISS on all issues affecting public safety and security in relation to biological risks and advances in the life sciences. He was one of the Commissioners to the UN Special Commission on Iraq for which he also conducted missions as a Chief Inspector. He was a Research Fellow on the Science Program at the Center for International Security and Co-operation at Stanford University where he carried out, among other subjects, studies of the implications for government and industry of the weapons of mass destruction treaties and agreements. He has also carried out consultancy work for the International Committee of the Red Cross on the implementation and development of the laws of armed conflict and consultancy for private companies on political risk analysis (both regional and country-specific). He is chairman of the Permanent Monitoring Panel on Risk Analysis for the World Federation of Scientists. He served as a career officer in the British Army on operations in many parts of the world, including counter-terrorist operations and UN peacekeeping. His publications include monographs, book chapters and articles for, among others, Stanford University, the World Economic Forum, Stockholm International Peace Research Institute (SIPRI), the Crimes of War Project, I*nternational Herald Tribune*, *Wall Street Journal*, the *International Defence Review*, the *Independent* (London), *Tiempo* (Madrid), the *International and Comparative Law Quarterly*, *The Washington Quarterly,* and other scholarly journals including unsigned contributions to IISS publications.